DEPARTMENT OF THE INTERIOR.

SECOND REPORT

OF THE

UNITED STATES ENTOMOLOGICAL COMMISSION

FOR

THE YEARS 1878 AND 1879,

RELATING TO THE

ROCKY MOUNTAIN LOCUST,

AND THE

WESTERN CRICKET

AND TREATING OF

THE BEST MEANS OF SUBDUING THE LOCUST IN ITS PERMANENT BREEDING GROUNDS, WITH A VIEW OF PREVENTING ITS MIGRATIONS INTO THE MORE FERTILE PORTIONS OF THE TRANS-MISSISSIPPI COUNTRY, IN PURSUANCE OF APPROPRIATIONS MADE BY CONGRESS FOR THIS PURPOSE,

WITH

MAPS AND ILLUSTRATIONS.

JOHN Y. DETWILER,
PRES. FLORIDA FISH COMMISSION,
NEW SMYRNA, FLA.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1880.

A8.1:

FORTY-SIXTH CONGRESS, SECOND SESSION.

CONGRESS OF THE UNITED STATES.

In the House of Representatives, April 9, 1880.

The following resolution, originating in the House of Representatives, was this day concurred in by the Senate:

Resolved by the House of Representatives (*the Senate concurring*), That there be printed with necessary illustrations, at the Government Printing Office, ten thousand copies of the second report of the United States Entomological Commission on the Rocky Mountain locust and other injurious insects, five thousand copies for the use of the House, three thousand copies for the use of the Senate, and two thousand copies for the use of the commission.

Attest:

GEO. M. ADAMS, *Clerk*.

TABLE OF CONTENTS.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

APPENDIX I.

APPENDIX II.

APPENDIX III.

APPENDIX IV.

APPENDIX V.

APPENDIX VI.

APPENDIX VII.

APPENDIX VIII.

LETTER OF TRANSMITTAL.

OFFICE OF THE UNITED STATES ENTOMOLOGICAL COMMISSION,
1700 THIRTEENTH STREET, NORTHWEST,
Washington, D. C., November 15, 1879.

SIR: We have the honor herewith to transmit to you the Second Report of the United States Entomological Commission on the Rocky Mountain Locust, or grasshopper of the West. The report is the result of the labors of the Commission during the years 1878 and 1879. In transmitting our First Report we endeavored to show that it was practically exhaustive of one phase of the inquiry, viz, the subjection and destruction of the young or unwinged insects as they hatch out in the more fertile portions of the trans-Mississippi country. We at the same time laid stress on the fact that it was impossible in so short a time to properly study the second phase of the question, one most difficult and most important, in our judgment, viz, how to prevent this fertile country from being overrun by the disastrous winged swarms from the Northwest. This fact cannot be better set forth than in the following portions of our letter to Dr. Hayden, submitting that report:

The young insects as they occur in the more fertile States affected can be mastered, as the Report will, we hope, abundantly prove. We point out the way, also, which we have every reason to believe will prove feasible and practicable, to prevent future incursions of the winged swarms.

While it has been the object of the Commission to cover as much ground as possible, so as to make this annual report as full and reliable as the time would permit, there yet remain several important subjects that it has so far been impossible to properly and exhaustively study.

The territory affected is so vast, embracing about 2,000,000 square miles, that much of it was imperfectly explored, especially in the Northwest. Mr. Riley had to cut short his investigations in British America both for want of time and want of funds. For similar reasons, and on account of Indian troubles, Montana, Wyoming, and Dakota have been but superficially explored.

The year 1877 was an abnormal year, *i. e.*, the winged insects had the previous year overrun and laid eggs in a large section of country in which the species is not indigenous, and a numerous progeny hatched in such country the past spring. This was most fortunate for many reasons, as it enabled the Commission to carefully study the insects in this their unnatural condition, and to carry on experiments with a view of learning how best to control them. Much of the work of the Commission was with these young insects. The losses sustained through the devastations of the pest by a young and struggling frontier population, ill able to bear them, were immense, and there was so much discouragement that hundreds and thousands of persons were on the point of abandoning their new homes. At this juncture the Commission went into the field, and, by its encouraging predictions and recommendations, did much to inspire the people with hope and confidence, and greatly helped to draw westward again the emigration that had stopped.

All this work, however, interfered with needed investigation into the proper range and native home and breeding grounds, and some other important questions which can only be properly studied during a normal year, *i. e.*, one in which the insect is confined to its native or permanent breeding grounds. Such a year will be the present (1878), for from our investigations we are able to state with confidence that the people of the more fertile country west of the Mississippi, occasionally termed the border States, will not be troubled with the young insects next spring and summer, and probably not for several years to come.

It is therefore quite important that the investigations be continued until every question is settled that human investigation can settle.

Fully recognizing the importance and the magnitude of the work yet to be performed it was our object to ascertain, as far as possible: 1. The relative amount of plains and prairie land that is susceptible of burning over in the permanent breeding grounds of the insect, and, as far as possible, the proportion in square miles, and the particular locations. 2. The proportion of more arid land and other regions not susceptible of being burned over, but in which the insects may develop. 3. The probable cost of burning over such land as will permit of it, and the present facilities for, or difficulties in the way of, doing so. 4. The best means of destroying the insects in the less fertile areas that cannot be burned over. 5. The proportion of land that can be irrigated and settled, and the best method of bringing about, as far as possible, the settlement of the same. 6. Such meteorological data, especially the prevailing direction of the winds at different seasons, as bear on the migration of the locust. 7. The cheapest and best method of making observations on the egg deposits, the hatching of young and the movements of the winged insects, and how far the force already in government employ is available for the purpose.

In order to perform this labor we asked for an appropriation of $25,000. But $10,000 were granted by Congress, and this only toward the end of the fiscal year 1878. It was then too late in the season to satisfactorily accomplish, with such limited means, the work proposed—a work to be done in a region in which it is difficult and expensive to travel. In order, therefore, to accomplish as much as possible with the means afforded, Mr. Riley drew no salary and remained in Washington editing and superintending the printing of the First Report, while Messrs. Thomas and Packard devoted themselves to the task of exploration. These facts were set forth in our annual report to you for the year 1878, and an additional appropriation of $15,000 was asked for, being the balance of the amount originally estimated as necessary. This was granted by Congress, but in the bill making the appropriation the Commission was charged with the additional work of investigating and reporting on the Cotton Worm, and other insects injurious to the cotton plant and to agriculture. The operations of the Commission thus being enlarged during the third year of its labors, the work was divided, and it was decided that Mr. Riley should take charge of that in the Southern States relating to insects affecting cotton, while Messrs. Packard and Thomas should continue that in the Northwest relating to the Rocky Mountain Locust, and, in addition, prepare two bulletins, one by the former on the Hessian Fly, and one by the latter on the Chinch Bug, two insects of vast importance to the western farming community. These have been prepared, as also an elaborate one by Mr. Riley on the Cotton-worm, containing the results of his labors in the South. The present report deals more particularly with the second phase of the locust question, and in transmitting it we recommend to your consideration, and to that of Congress, our conclusions in the closing chapter and our recommendations in reference to encouraging settlement, the building of railroads, the advisability of broader schemes of irrigation, of judicious burning, of co-operation with the Dominion Government in its efforts in the same direction, and particularly of a permanent system of observations and warnings, to be carried on under the auspices of the Chief Signal Officer.

The interest felt in the work of the Commission has resulted in a constantly increasing number of letters asking information on the subjects with the study of which we are charged, and an extensive correspondence with parties in all parts of the country has consequently been carried on at headquarters, in addition to the more special work of the Commission.

We take this occasion to thank you for the cordial encouragement and assistance which you have given us in our labors.

With some pride in the knowledge that events have fully justified the conclusions and predictions we have been able to make from year to year—based as they were upon the comparatively limited observations which time and means have allowed—and with the conviction that the carrying out, so far as practicable, of the suggestions in this and our previous report on the subject, will tend to a material abatement of the national evil which we have been studying, we have the honor to remain,

Very respectfully, your obedient servants,

CHARLES V. RILEY,
A. S. PACKARD, Jr.,
CYRUS THOMAS.

Hon. CARL SCHURZ,
Secretary of the Interior.

PREFACE.

This Second Report of the Commission on the Rocky Mountain Locust is the result chiefly of the labors of Messrs. Packard and Thomas, in their efforts to solve a most difficult problem, namely, the permanent amelioration of the locust evil by preventing the excessive increase of the destructive insect in its native habitat, and its disastrous migrations therefrom.

During the year 1878 the labors of the Commission were seriously interfered with, first, by an inadequate appropriation unavailable till the 1st of July; second, by the time required of Mr. Riley in publishing our first report; third, by the warlike disposition of the Indians that year, which rendered travel unsafe and sometimes impossible in many parts of the country to be explored. Dr. Packard visited portions of Colorado, Wyoming, Utah, and Idaho, and also received information from others regarding the presence of locusts in these Territories, and especially in Montana and Eastern Oregon. He found that this was a normal year, and the locust was found to occur throughout all these Territories in greater or less numbers, but usually only in scattering swarms; still, damage of a serious nature was done to crops in portions of Montana and Utah. To particularize, in Colorado scattering individuals occurred all over the northern counties, both on the plains and on the mountain summits. Small swarms occurred in Estes Park, South Park, and among the mountains of Gilpin County, where eggs in large numbers were laid.

Wyoming, on the whole, was less infested than in 1877, though large swarms were observed on eclipse day at Como Station on the Union Pacific Railroad, and local swarms were observed on Gilbert's Peak and on Ham's Fork late in August. In Utah locusts were a severe scourge in Summit County, one-half the wheat crop having been destroyed by them. They were also abundant in Cache and Malade Valleys, which indicated danger in Northern Utah the ensuing year of 1879. None occurred south of San Pete, Utah. He found that in Eastern Idaho locusts were abundant from the Utah line to the Montana line, especially at Franklin and at Taylor's Bridge, and local swarms were observed about Shoshone Lake.

In Montana local swarms were destructive to farms on Stinking-Water River and Ryan's Cañon and about Bozeman and Sterling as well as

Deer Lodge. They were also abundant at Virginia City and on Sun River and on the Upper Missouri between Helena and Fort Benton. They were also observed locally in the region south of Yellowstone Park.

In Eastern Oregon swarms were observed between McDonnell's Ferry and Blue Mountains. He thus proved that the Rocky Mountain locust is indigenous over the immense region already mapped by the Commission as the permanent breeding ground, and that the prospect for 1879 was that local injuries would ensue in the Territories, but unless the spring and early summer were unusually favorable the Mississippi States would not be invaded.

Mr. Thomas visited Colorado and other parts of the West, his special object being to ascertain if *C. spretus* would be found localized in Colorado. He found this to be the case as far south as Colorado Springs, not only up in the cañons and on the hills and mountains, but on the plains. He found them in considerable numbers in one or two cañons, and showing a disposition to migrate. He found specimens on the very tops of the range, and on the very top of Pike's Peak.

In Nebraska, Eastern Dakota, Minnesota, Manitoba, and Kansas no specimens, with one or two exceptions, were to be found, and their entire absence showed how completely they had left the Temporary Region, and the wisdom of the Commission in so designating the fertile country which, in exceptional years, suffers so greatly.

There was one limited locality of a few acres in Southeast Nebraska where some hatched out. They were quite injurious around Bismarck, destroying the gardens, but they came in from the north. This eruption, which appeared late in July, was traced from British America to Kansas, and was confined to a narrow belt. It did not touch the western border of Manitoba, or reach to the middle or interior of Dakota; on the west it did not reach to Fort Benton, but was wholly east of that. It touched southern, but did not reach the extreme southeastern part of Dakota, passed south in the region of Ponca, Nebr., and thence south and southwest into Kansas.

His investigations this year showed a strong tendency to rapid change in character of those locusts which remain for a few generations in the Sub-permanent Region. A few very limited flights were observed over the southwestern part of Minnesota.

At the close of the year it was deemed unwise to publish a final report until further investigations had been pursued, and an appropriation of $15,000 for continuing them was therefore asked of Congress. The appropriation was granted, but with it the Commission was charged with increased duties, and during the year now closing Mr. Riley's attention has been given to the subject of insects affecting the cotton-plant, while Messrs. Packard and Thomas have continued the locust investigation. Mr. Packard, with four students and one interpreter, visited portions of New Mexico and ascertained the southern portion of the range of the species with a view of more accurately mapping out the southern limit of distribution, left incomplete in our former map. He obtained important data upon the habits of the locust in that section and found that they had flown in and about Santa Fé from the north during the years 1865, 1868, 1874, and 1877, and he also traced them into Eastern Arizona. Mr. Thomas during this year devoted his time more particularly to the meteorological facts bearing upon the increase and development of the locust. He was forced to the conclusion that the meteorological data hardly bore out the generally received opinion that heat and dryness are necessary to excessive increase, but that winter conditions have greater influence than has been suspected. While the data he obtained have comparatively little value, therefore, and the annual and monthly means were of no value whatever as throwing light on increase and development, the daily records proved most valuable in their bearing on flights.

In planning this report it was decided to introduce with the more practical chapters a few giving the results of some of the purely scientific work that has grown out of the inquiry.

In Chapter I, Messrs. Packard and Riley have added to the hitherto published chronological history of locust injury by giving data for the past and the present year.

In Chapter II, prepared by Mr. Thomas, the subject of the relation of the locust and its ravages to agriculture and the settlement of the Territories is discussed in all its different bearings. Different plans of inducing increase in the purely agricultural rather than the pastoral population, the difficulties in the way of successfully burning over the locust-infested area, and the non-feasibility of other plans are dwelt upon; and while utter extermination of the pest is out of the question, it is clearly shown that the evil may be materially modified, and that government action in the matter is warranted because the evil is essentially a national one.

In Chapter III, also by Mr. Thomas, a mass of information is brought together in regard to the laws governing the migrations of locusts in all countries. It is there shown that the essentially migrating habit is confined to about four species, all of them inhabiting and coming from treeless, arid, and elevated regions. In a few instances a species which is sedentary in one part of a continent becomes migratory in another. As in the case of our own species, there are no laws of periodicity governing destructive flights, these only occurring at irregular intervals. Nevertheless the history of the most noted locust years, both in this country and in Europe, shows a tendency to their recurrence about every eleven years. It is also shown that the European and Asiatic species have, like our own, areas where they permanently breed, and from which they swarm in exceptional years to extend over adjacent regions in which they are not found permanently.

Chapter IV, also by Mr. Thomas, treats of the habits and characters of locusts in different countries within their areas of permanent distribution, especially so far as such areas relate to their movements. The

Rocky Mountain locust is shown to be migratory within the limits of its permanent range, and the source of the invading swarms of our own species, and the differences, both in direction and character, of return swarms, are set forth. These return swarms do little or no injury, and the migratory locusts of other parts of the world appear to manifest the same disposition to return to the country whence their immediate parents came, as in the case of our own species. The distance to which swarms may migrate in the course of a season, the position of the insects in flight, the influence of the winds on the flights, the height of flight, and other questions in reference to the movements of winged locusts, whether in this country or abroad, are discussed, as also the causes, both remote and immediate, of migration.

Chapter V, also prepared by Mr. Thomas, deals with the influence of meteorological conditions on the development and migrations of locusts, as also on the development of the eggs.

Chapter VI, prepared by Mr. Packard, deals with the subject of the southern distribution of *Caloptenus spretus*, and gives the history of locust invasions in New Mexico.

In Chapter VII Mr. Packard gives a summary of locust flights during the years 1877, 1878, and 1879.

In Chapter VIII, also by Mr. Packard, an account is given of the western cricket, an insect that proves extremely destructive in the mountain regions of the West, and about which the Commission has had many inquiries. Its ravages, enemies, and parasites, breeding habits, and geographical distribution, are set forth, so that they can be compared with those of the Rocky Mountain locust. Remedies are suggested, and the chapter concludes with a study of the external and internal anatomy of this large cricket.

In chapter IX Mr. Packard treats of the air sacs of locusts, with a view of indicating their origin, and of showing their use in flight.

Chapter X, by Mr. Charles S. Minot, is the result of careful histological study of the locust, and of the cricket before mentioned.

Chapter XI, by Mr. Packard, on the brain of the locust, is the result of similar study of the nervous system and the brain of the locust.

Chapter XII, by Messrs. Riley and Thomas, treats of the destructive locust of California, and shows, that while the species is distinct from the Rocky Mountain locust, yet in size, habits, destructiveness, and even in natural enemies, the two strongly resemble each other.

Chapter XIII, by Mr. Riley, gives further facts about the natural enemies of locusts, and deals more particularly with the locust egg-feeding habit of the larvæ or the Bee-flies (*Bombyliidæ*), a large family of two-winged flies, quite abundant in the West, and the larval habits of which were not previously known.

In the closing chapter, XIV, Mr. Riley has endeavored to present more accurate data than had hitherto been given concerning the permanent breeding grounds, with a view of ascertaining what courses the government may pursue in the future toward ameliorating the locust evil. With the assistance of a large map (Map I) in six sections, so arranged that they may be put together on canvass or cloth and hung up in school-rooms or other public buildings, the surface characteristics of plains, mountains, plateaus, and basins are considered, especially from the point of view of the relative areas in which the vegetation is susceptible of being burned over. No one particular course is recommended or deemed sufficient, but it is shown that good results will flow from increased settlement of the Territories, the building of railroads, increased irrigation, the preservation of the timber, judicious burning, the perfection of a system of observations and warnings, and co-operation with the Dominion Government in these various measures.

In Appendix I will be found some further data and replies to our first circular. In Appendix II Mr. S. H. Scudder gives a list of the Orthoptera collected by Mr. Packard in his western trip made in 1877, and describes some new species. The list is interesting, as showing the number of forms closely allied to *spretus*, but with shorter wings, occurring in Washington Territory and Oregon. The report of Mr. John Marten (Appendix III) of observations made the present year in Iowa, Dakota, Minnesota, and Nebraska under Mr. Thomas's direction, gives a detailed statement of the locust conditions in those States. In Appendix IV a very full exposition of locust literature is given by Mr. B. P. Mann, supplemented by Mr. Thomas; while in Appendices V and VI additional data regarding the locust in Texas and regarding flights are brought together. In Appendix VII Mr. Packard gives some notes of his journey in 1878, and in Appendix VIII an account of Yersin's researches on the functions of the nervous system of articulates, as supplementary to Chapter XI on the brain of the locust.

The delay in printing the report which was not ordered printed by Congress till April, 1880, is to be regretted, but has permitted the including of some facts ascertained since it was submitted.

The commissioners take pleasure in here thanking the numerous correspondents who have replied to the circulars issued, and the managers of the following railroads for favors over their respective lines:

Lake Shore and Michigan Southern; Chicago, Rock Island and Pacific; Chicago, Milwaukee and Saint Paul; Western Union; Northern Pacific; Saint Paul and Sioux City; First Division Saint Paul and Pacific; Saint Paul and Pacific; Sioux City and Pacific; Chicago and Northwestern; Des Moines and Fort Dodge; Chicago, Burlington and Quincy; Central Railroad of Iowa; Kansas Pacific; Saint Joseph and Denver; Missouri, Kansas and Texas; Atchison, Topeka and Santa Fé; Burlington and Missouri River, in Nebraska; Denver and Rio Grande; Texas and Pacific; International and Great Northern; Illinois Central; Denver Pacific; Union Pacific; Atchison and Nebraska.

Their acknowledgements are due to a number of persons who have aided, but particularly to Mr. Henry Gannett, of Washington, Mr. S. H. Scudder and Mr. B. P. Mann, of Cambridge, Mass., Dr. C. S. Minot, of Roslindale, near Boston, Mr. J. G. Lemmon, of Sierra Valley, Cal., and Mr. John Marten of Carbondale, who have contributed to this report; to Mr. E. A. Schwarz, who has constantly assisted in office work, and to the late Albert J. Myer, who, as Chief Signal Officer, obligingly furnished meteorological data whenever required.

MAP OF A PORTION OF WESTERN NORTH AMERICA

SHOWING THE DISTRIBUTION OF VEGETATION WITH REFERENCE TO THE MULTIPLICATION OF AND MEANS OF SUBDUING THE ROCKY MOUNTAIN LOCUST.

Prepared under the direction of the U.S. Entomological Commission

By Henry Gannett E.M.

1879.

MAP I.
NORTH WESTERN SECTION

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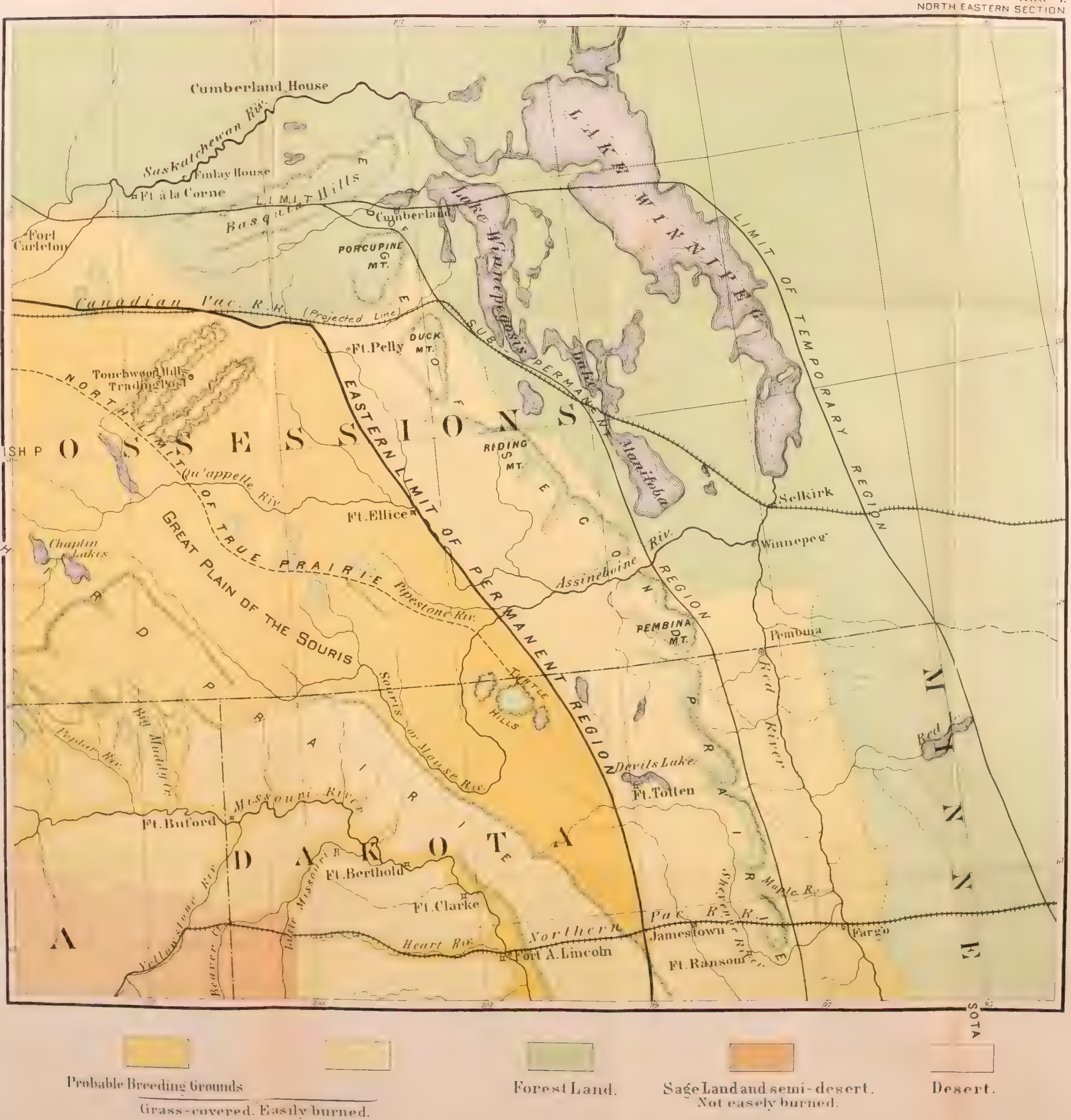
NORTH EASTERN SECTION



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MAP I

MIDDLE WESTERN SECTION

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MAP I.
SOUTH WESTERN SECTION

Probable Breeding Grounds: Grass covered; Easily burned.

Forest Land.

Sage Land and semi desert. Not easely burned.

Desert.

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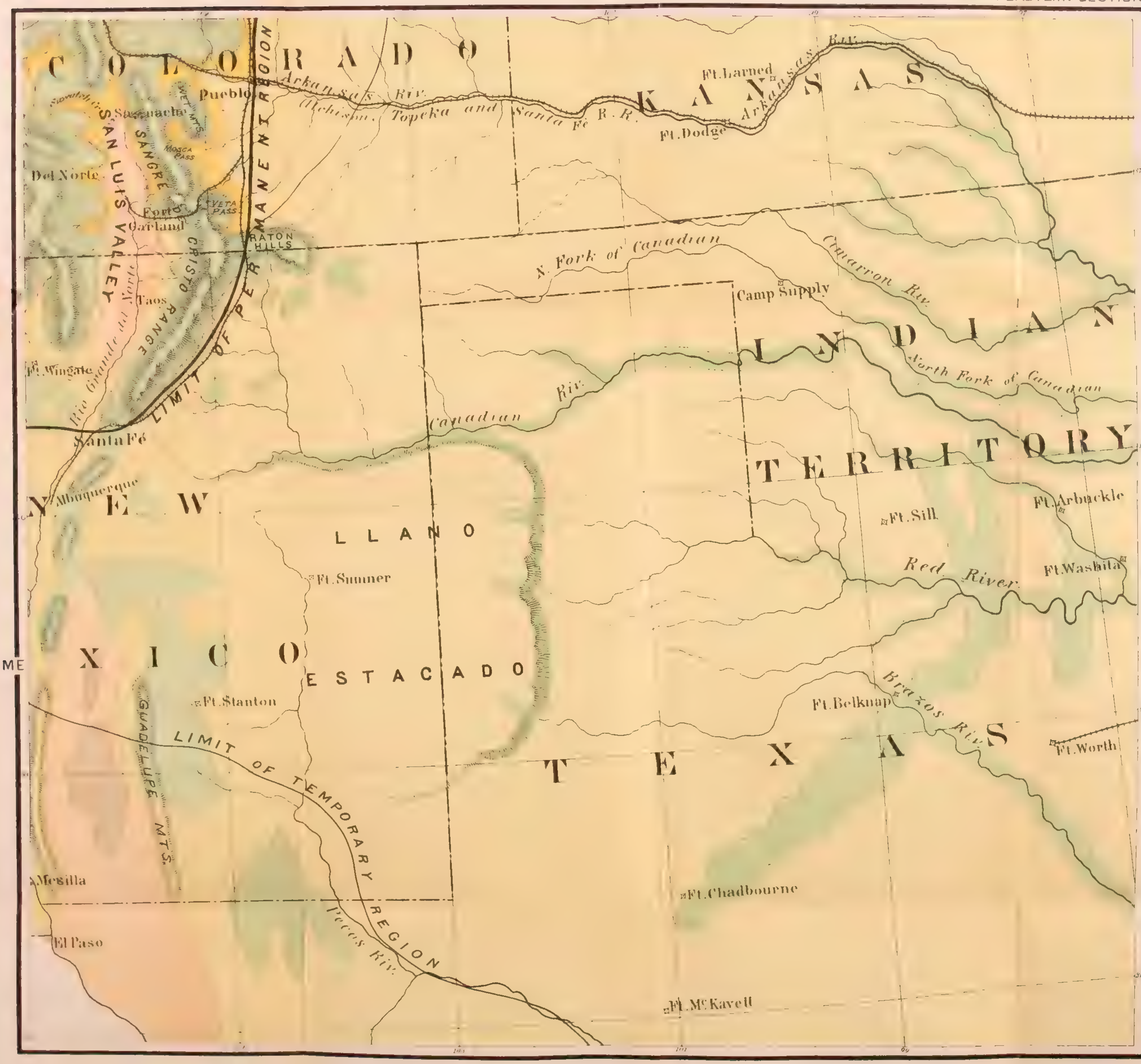
MAP I.
SOUTH EASTERN SECTION



Probable Breeding Grounds

Grass-covered Easily burned.

Forest Land.

Sage Land and semi-desert. Not easely burned.

Desert.

CHAPTER I.

ADDITIONS TO THE CHRONOLOGY OF LOCUST RAVAGES.

THE ROCKY MOUNTAIN LOCUST IN 1878.

THE LOCUST IN MINNESOTA IN 1878.

In a letter, dated August 26, Mr. A. Whitman, of Saint Paul, Minn., says:

I inclose a few more clippings on grasshoppers. I see by the papers that a swarm of them alighted at Mankato a few days ago. All these cases seem to be wandering squads that make short visits, and they seem to be as much scattered as they were at the end of last year.

The same correspondent writes, November 3, 1878:

There seems to have been a slight raid across the southwest corner of the State late in the summer. There was nothing to hurt then, and as it lasted but a few days I don't believe there are eggs enough to do any hurt.

The clippings sent by Mr. Whitman refer to the appearance of the Locust in Dakota, and only the following refer to Minnesota:

We understand that on Monday last, 12th, a pretty numerous swarm of grasshoppers settled down in the vicinity of Luverne, and still remained there on Thursday. They had not laid eggs at last accounts.—[*Mankato Review*, Rock County, August 20, 1878.

Reports from Rock County in this State, and the counties bordering in Dakota, are to the effect that the grasshoppers which recently settled down there are laying eggs. They occupy a pretty large district, chiefly a locality in which but little damage was done during their previous raid.—[*Mankato Review*, September 3, 1878.

'Hoppers were seen flying over Big Stone County last week.—[*Pioneer Press*, Minnesota, August 11, 1878.

A gentleman who was in Saint Paul yesterday, from Nobles County, reported the unusual prevalence of grasshoppers in that county. He says that they are consuming the corn and almost everything to be consumed, and doing a good deal of devastation. —[*Pioneer Press*, September 11. [Nothing to devastate.—A. W.]

THE LOCUST IN IOWA IN 1878.

The grasshoppers have hatched out in the vicinity of Red Oak, 20 miles east of here, in large numbers, but are doing no damage worth mentioning. They seem to be diseased and are only in a small locality about 20 miles square. They are the only ones that I have heard from in the Northwest this spring.—[W. K. Jollett, Malvern, Iowa.

FORT DODGE, IOWA, *September* 5.—A few days ago the people of Northwestern Iowa were somewhat alarmed by a report that the grasshoppers were again upon us. Upon inquiry we find the fact to be that they alighted one evening somewhere between Cherokee and Le Mars, densely covering a tract of country three or four miles wide. They took wing again early on the following day, and left without doing serious injury to anything, and without depositing any eggs. They came from the Northwest and went toward the Southwest.—[*Chicago Tribune*.

The *Rocky Mountain News*, of October 30, 1878, reports the locusts injuring fall wheat lately sown at Fort Madison, September 30.

THE LOCUST IN NEBRASKA IN 1878.

Mr. Clark Woodman, of Omaha, Nebr., communicates the following observation on September 17:

I have just returned from a trip on the Union Pacific Railroad. There are swarms of locusts at Schuyler, 76 miles west of Omaha, and beyond: none between Schuyler and Omaha. They are doing no damage, but are laying their eggs in great numbers. No one seems to be afraid of the results next spring.

Lieut. W. L. Carpenter writes from Omaha, Nebr., April 26, 1878:

A small brood of *C. spretus* is hatching out about 20 miles west of Lincoln, Nebr. There are none in this vicinity. I think the damage from spring broods will be trifling throughout the State.

The *Rocky Mountain News* of October 30, 1878, reports the locusts flying to the South at Genoa, Nebr., September 9.

Lieut. W. L. Carpenter communicates the following note, dated Omaha, Nebr., June 25, 1878:

A small flight of full-grown *C. spretus* appeared here June 16 and 17 from the south and southeast. Not large enough to do any damage. Could not learn that they were hatched in Nebraska.

THE LOCUST IN TEXAS IN 1878.

Mr. H. C. Overaker, of Plano, Tex., writes, December 8, 1878, that no grasshoppers had appeared this Fall.

THE LOCUST IN INDIAN TERRITORY IN 1878.

The *Rocky Mountain News* of October 30, 1878, reports from Fort Sill, Ind. T.:

September 23 quite a number of locusts coming from the north; September 24, remaining; 25, great numbers traveling south; 26, large swarms, great many alighting; 27, few remaining; 28, a few flying north and a great many on the ground; 29, a few flying north; 30, more numerous than at any time since their first appearance, depositing eggs.

THE LOCUST IN KANSAS IN 1878.

Mr. Day Graham, of Bazaar, Chase County, Kans., writes, September 14, as follows:

I suppose you know that the *spretus* is appearing in small numbers in Barton County. I understand they are not doing much damage yet. The people are expecting them almost any day.

On the other hand, Professor Thomas writes, November 7, that in Nebraska, Eastern Dakota, Minnesota, Manitoba, and Kansas no specimens (with one or two exceptions) were to be found.

The grasshoppers are very thick in Cowley, Sumner, Reno, and other counties, and have done much damage to wheat.—[*Salina Herald*, December 7, 1879.

The *Rocky Mountain News* of October 30, 1878, reports from Creswell, Kans., the locusts flying to the south on September 7, and on the 20th to the north; from Dodge City, Kans., September 6, swarms coming to the earth from the northeast with the wind; on the 7th, 10 a. m., "immense swarms, disappearing at 3 p. m., height of swarms 50 to 1,000 feet, flying from the northwest; September 10, 11 a. m., quite thick, swarms about 1,000 feet high, and flying west with the wind. Chinch Bugs at Creswell, Kans., September 26, eating young wheat.

Mr. Thomas Nixon, Argyle, Sumner County, Kans., writes, on October 4, 1878:

I have noticed the Rocky Mountain locust passing over here. For some time there were some flying north on the 18th and 19th days of September. They passed over once the 1st of this month very thick, going southeast, with wind quite strong southeast. Sky clear and fine. Some few have alighted and are depositing their eggs.

THE LOCUST IN DAKOTA IN 1878.

They have come and gone. They were evidently what was left from former years. They were hungry but not healthy. The swarm was about three miles wide and cleaned up nearly all the gardens, injured corn very much, and trimmed the potato vines. The wheat and oat crop was all harvested before they came. Corn had been more injured by the grub than it was by the grasshoppers The cabbage crop had also been injured by insects. Drouth had affected the gardens and the potato crop, but the wheat and oat crop was all that could be desired. The 'hoppers were coupling when here, and yet the ground in some localities was honeycombed with holes where they had tried to deposit their eggs; but one gentleman who was through the grasshopper troubles in Southern Minnesota, and his two boys, searched three hours, and, though they found thousands of holes, they discovered only four eggs. They found a deposit filling the egg-sacks, however, which, after lying a day or two, resembled red granulated sugar. The 'hoppers were also covered with red parasites, were generally smaller than the 'hoppers of former years, and many of them died from grief or other causes while here. The settlements west of Bismarck, on Hart River, and east of Apple Creek were not affected by them. They covered just a narrow strip about Bismarck.—[Quoted in *Farmers Union*, August 22, 1878.

A few grasshoppers were seen at Sioux Falls, Dakota, last week, but they appeared to be rising and had done but little damage to the unsecured crops.—[*Saint Paul Pioneer Press*, August 28, 1878.

BISMARCK, *June* 29, 1878.—The first genuine grasshoppers of the season appeared here yesterday. The wind in the forenoon was directly from the south, and about noon changed and came from the west. After the wind changed the 'hoppers were first noticed. They came from the south and lit when the wind changed, but not in any great numbers. They are not afflicted with the parasite of last summer. In 1873, the first grasshoppers appeared here during the first week in June, and came from the southwest and disappeared northeast, after leaving their eggs. In 1874, the young grasshoppers hatched out in great numbers in May and destroyed all the gardens around Bismarck. Afterward, during the same year, a great many swarms of grasshoppers passed over from northwest going southeast, and only lit when encountering an adverse wind. In 1875, grasshoppers also hatched here, and innumerable swarms passed over, the largest of which came from the south and passed directly north. They resembled clouds of smoke from prairie fires while passing over. This was in July, before the prairie grass was dry enough to burn. In 1876 and 1877 we were visited by grasshoppers, and great numbers flew over, mostly to the southeast, while a few swarms passed over to the north.

The only material damage done here to crops by grasshoppers since the settlement of this locality in 1872 was done by the grasshoppers that hatched here in May, 1874. We seem to occupy the middle ground. There is no doubt that the locusts hatch out in immense numbers to the north of our locality, and periodically move to the south and southeastward, and reach as far as Iowa and Kansas.—[*Pioneer Press.*

The Rocky Mountain News of October 30, 1878, reports from Bismarck, Dak., September 1 and 2, locusts flying southerly at great altitudes; on September 3, "on the ground and a few in the air, number decreasing rapidly;" on the 4th, very few on the ground, none in the air; September 5, 6, and 7, rapidly decreasing and many dying; September 9, disappeared.

The same newspaper, of the same date, reports from Yankton, Dak., locusts somewhat numerous until about September 12, and disappearing almost entirely after the cold weather of the 26th.

THE LOCUST IN COLORADO IN 1878.

The Rocky Mountain Locust during the summer of 1878 bred sparingly throughout the mountainous portion of the State. We found them not uncommon on the road to Gray's Peak, five or six miles from Georgetown, at an elevation of about 9,000 feet, August 20. On the extreme summit of Gray's Peak a few were seen flying by the workmen on the Summit House, then building, and I found several under stones, benumbed with the cold. At an elevation of about 12,000 feet they were common on the "alpes," or grassy slopes, leaping and flying when the sun was shining.

We were informed that a swarm was seen in South Park, August 14, flying east for an hour or two. It breeds annually in Snake and Bear River Valleys, but none had been seen the present summer in Snake River Valley.

We were also told that August 13 and 14 locusts were abundant in Estes Park; they were seen flying in the air in large numbers; and it was feared that they would lay their eggs, the ground being covered with them. We were also told that they bred this summer in small quantities in Gilpin County, especially on the Bear Mountains. At Summit, August 26, locusts were observed flying southwest with the wind. (United States Weather Signal Reports.) From these facts we judge that *Caloptenus spretus* bred sparingly in 1878 throughout the more elevated portions of Colorado, not existing in its normal numbers, and nowhere sufficiently abundant to gather into large, destructive, migratory swarms, though locally migratory. Later in the season we received the following information from Mr. William N. Byers:

September 10–13 I was in Northern Colorado. I found them abundant on White River, at White River Indian Agency, and extending up that river four miles (probably further) and down it an unknown distance; also, northward about forty miles, diminishing in numbers from south to north; also, a few along the Upper Bear River Valley. They were depositing eggs.

THE LOCUST IN WYOMING IN 1878.

Along the line of the Union Pacific Railroad the locust had not been seen this year, except in very limited numbers. Near Summit Station they had bred in the bottoms, but only in sufficient quantities for bait both this summer and in 1877. At Laramie City we were informed that some were seen between the 6th and 8th of August in the air, flying in a southeasterly course. At Rock Creek Station we were told by teamsters that there were no locusts seen this season between there and Fort Kinney, 200 miles north. On the whole, the Locust was more numerous in Wyoming this year than in 1877. On the day of the eclipse, July 29, Mr. William Carlin, at Como, saw a large swarm of locusts (*C. spretus*) passing over in a course a little south of east from about 10 a. m. to 4 p. m., the eclipse here not being total; they were also seen there three or four days after this date, flying in a northeasterly course. They were supposed to have bred in the Wind River and Big Horn region.*

Locusts were also observed by Mr. W. H. Reed in Freezeout Mountains, 35 miles northwest from Medicine Bow, flying to the east in considerable numbers, August 12. We saw a few on the ground September 5. Locusts were observed at Cheyenne, August 30, flying southeast. (United States Weather Signal Reports.)

From a letter of Mr. F. H. Williston, dated Como, Wyo., we take the following:

July 29, 1878, about 11 o'clock a. m., I first saw the Rocky Mountain Locust flying over Como Station on a southeasterly course, with wind about the rate of 15 miles per hour, the temperature 80° or 90°; continued to fly till about 3 or 4 p. m., and during the eclipse. A few of the locusts alighted, but none of any consequence.

THE LOCUST IN UTAH AND IDAHO IN 1878.

After passing through Wyoming and reaching Evanston, Wyo., the Rocky Mountain Locust was seen flying in the air in abundance in the bottoms, and continued to be seen as far west as Echo. They were also observed here by us September 2, on our return, at Evanston.

At Coalville, I was informed by Bishop Clough that during this season the young locusts had destroyed nearly one-half of the wheat crop in Summit County, and that when fledged they flew back (contrary to the general rule, as they usually keep on in a southeast course) in a northerly course to Morgan County, whence they came the previous autumn and laid their eggs; others flew towards the southeast. The invaders of the autumn of 1877 laid their eggs in the wheat fields, not in the hill-side as usual, so that the young when hatched in the succeeding spring could not be kept out of the wheat. At the Dairy, three miles south of Wahsatch, locusts were very thick August 24.

August 27 we noticed *C. spretus* frequently about the railroad station at Ogden, though they had not been specially abundant at this place the present year. At Logan they were abundant, flying 20 feet high, and at Smithfield and Richmond a few were to be seen.

At Richmond they came from the northeast over the mountains about the 1st of August, none having hatched out in the spring. They

* Mr. Carlin told us that in August, 1875, he saw at Creston an immense swarm of locusts flying in a southeast course from the northwest, probably from the Wind River Mountains. They were so abundant that they delayed the train, so that they had to sand the track, the men shoveling them away. In July and August, 1875, they were observed flying southeast at Rawlings, as also at the end of July, 1874, flying in the same direction, as well as in the summer of 1873.—[W. H. Reed.

destroyed this summer one-third of the oats and a third of all the garden produce. We saw them at this place August 27, flying in the air at an elevation of apparently about 500 feet; their course was down the valley, many taking a southwest course.

Flights of locusts entered Malad Valley late in August from Idaho, on the northeast. August 10, locusts were observed on the Snake River, at or near Taylor's Bridge.

At Franklin, Idaho, none hatched in the spring, but from the middle of July until the 30th flights arrived from the north, from the region of Market Lake and Port Neuf. I was informed that a large majority of those which hatched out last spring went, when fledged, in a northeast course (an exception to the ordinary rule, as they usually fly southwestward), and their progeny are supposed to have returned from their breeding-grounds to the northeast. I saw them in abundance August 27 and 28, at Franklin—a few in the air, most of them on the ground—when they were coupling, but not depositing eggs. They were seen eating the leaves of the willow, wild rose, and golden-rods.

Stage passengers from Montana noticed locusts all the way along the road from Pleasant Valley to Franklin. They were observed about the 18th of July in Gentile Valley, between Franklin and Soda Springs. They were seen by Mr. L. Bruner at Soda Springs August 18, but no eggs were deposited; about the 25th they flew in southeast and southwest directions.

A few locusts had recently passed over Salt Lake City, and we noticed them in the stubble of a recently harvested wheat field at Lake Point, 20 miles west of the city. According to the Weather Signal report, "vast numbers" flew over the city July 20, southward. They were reported to have extended this season to San Pete, where they had appeared late in August, while the settlements at the eastern portion of Wahsatch County were visited, about one-half of the wheat crop having been lost. Locusts were also seen by Mr. Bruner at York, 70 miles south of Salt Lake City, and also at Provo, September 1.

Flying swarms of grasshoppers have come here of late, and we are unable to learn from what direction they have come in every instance. However, they were too late to damage our small grain and do no great injury to other crops. They are depositing their eggs, and promise a crop for the coming season. These insects are subject to die in great numbers, which has often been the means of saving our crops. Even now they are dying off quite fast. There is a worm or insect attached to these creatures sometimes, that is fatal to their vitality.—[A. Christensen, Brigham City, Box Elder County, Utah, September 24, 1878.

From these statements it will be seen that a widely extended but not dense swarm, or several swarms, left the Pleasant Valley region on the Idaho line about the middle of July and traveled southward, reaching Salt Lake City and York by the end of the month. The movement was general, the advance guard reaching the southernmost limits of this area long before the main body arrived. The emigration beginning so early, the breeding-grounds must have been in Central Montana, directly north of Utah. The history of the invasion of Utah, slight as it was this year, is a repetition of that of former years, such as has been described in our First Annual Report (p. 156), the locusts originating in Central Montana, flying into Idaho one season, and their progeny invading Northern and Central Utah the next. The locusts seen this summer were the progeny of those which entered Central Montana in 1877. The season of 1878 in this basin region was very hot and rather dry.

THE LOCUST IN EASTERN OREGON IN 1878.

In the Lower Snake River region, in Eastern Oregon, we were told that locusts were seen this summer between McDowell's Ferry and the Blue Mountains, both flying and on the ground.

THE LOCUST IN NEVADA IN 1878.

This year, as well as 1877, was a locust year in this sparsely-settled territory. July 11 great numbers appeared at Winnemucca, and disappeared the 13th; on the 18th and 19th large swarms again appeared. (United States Weather Report.)

THE LOCUST IN MONTANA IN 1878.

From the statements of Mr. R. V. Sutherlin, editor of the *Rocky Mountain Husbandman*, we learn that this Territory was not seriously molested by invading locusts in 1878, as he writes:

> Those that hatched out in March, April, and May did some damage in a portion of Gallatin Valley and the Missouri and Prickly Pear Valleys, but when they took wings they were fortunately carried away from us, nearly all the swarms going beyond the Territorial boundary. Their course was towards the southwest. In the extreme southern part of the country that is cultivated (Upper Ruby Valley), a small farming district, a few swarms stopped just as the oat-fields were heading out, and did a great deal of damage. After getting a taste, they seemed to be contented to remain, and did so, depositing many eggs. In a portion of Gallatin Valley there were a few swarms that stopped and deposited eggs. Except the valleys above named, there have been no eggs deposited this year. Crops were generally good, and the yield of grain very large. A few farmers in the sections named above suffered, but after all the suffering was light compared with former years.

At Virginia City locusts were observed July 25 flying northwest; the 27th and 28th large numbers were seen, and they did some damage to gardens, leaving the 30th; August 1 small herds were seen flying northwest against the wind; on the 2d they flew northwest against the wind, some alighting; on the 3d they also flew in a northwest course, while on the 4th they disappeared. (United States Signal Bureau.) At Sterling a few eggs were deposited late in July. This region has been visited each summer from 1873 to 1878. Colonel Berthoud, engineer of the extension of the Utah Northern Railroad into Montana, made extensive surveys in Montana, and visited in person Deer Lodge, Madison, and Fire Hole Valley, the Geysers, Henry's Lake, &c., and reports to us that August 24 the locusts, *Caloptenus spretus*, were very abundant on Snake River, extending from Corbett's Station to three miles north of

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Taylor's Bridge, a distance of 22 miles; the direction of their flight was to the south and southeast. August 30 locusts were seen in abundance for a distance of one or two miles at Pleasant Valley Station (about 8,000 feet elevation; this is near the Idaho line). "At Deer Lodge I saw a few, but no damage was done by them. It was reported to me at Helena that on Sun River grasshoppers appeared in large numbers, as also near Clark's Fork, at Yellowstone River."

Immigrant grasshoppers have made their appearance on East Gallatin, and have already destroyed several crops. They are still coming, and it is feared they will do more damage than ever before. The 'hoppers that hatched out in the valley ate up a few crops entirely, and it looks now as though they will make a clean sweep, except under the mountains.—[*Rocky Mountain Husbandman*, August 8, 1878.

Grasshoppers in various localities are reported hatched and hatching in myriads. In the grain sections of Meagher County, in the Prickly Pear Valley, and elsewhere the pests have shown their destructive instincts, devouring the wheat and all kinds of young vegetation. Farmers are flooding their fields, and millions of the insects in this manner are swept away. Other methods are adopted to combat the encroaching insects, the most effective, perhaps, being that of scattering straw in the line of approach, setting fire to the same, and singing the 'hoppers to a helpless state, or burning them to a roast. Every product of the soil promises this year to find an active home demand, and it is to be hoped that the farmers will exhaust every means in their power to ward off an enemy active in dissipating the fruits of an important industry. —[Quoted by the *Denver News* of June 11, 1878, from the *Helena* (Montana) *Herald*.

Mr. James Fergus writes us from near Helena that in the spring of this year, particularly in the lowest valleys, the eggs and young locusts were destroyed by the cold, snowy, freezing weather. Late in the spring following—an early warm spring—locusts appeared on Smith River, doing, however, little or no harm. On the Upper Missouri River they did great damage to the late-sown wheat. On Middle Creek it is stated that fully one-fourth of the entire crop is destroyed by 'hoppers.

From the facts here presented it will be seen that the locusts which bred in the spring of 1878 in the Upper Missouri, Gallatin, Prickly Pear Valleys, and about Bozeman, constituted the swarms which from the middle of July to the end of August passed over the divide at Pleasant Valley into Eastern Idaho, and Cache and Malad Valleys of Utah, and passed south to the region about Salt Lake.

It thus appears that the locusts which bred in Central Montana in the spring of 1878 hatched from eggs laid in that region late in the summer of 1877 by swarms which came over the Belt Mountains from the Yellowstone and adjacent valleys lying to the north. (See First Report of the Commission, pp. 154 and 155.) The general course of the migration agrees with those of former years, as stated in our First Report.

Owing to the vigilance and activity of the farmers of Central Montana, the damage done was light. The following extracts from the *Rocky Mountain Husbandman* will show how the young unwinged locusts were met and vanquished:

Steven Howes, near Bozeman, has rigged up a machine to catch the grasshoppers in a bag. On Tuesday morning last, while the 'hoppers were numb and chilled, he ran the machine over eight acres of ground, and hauled in five bushels of them. He is quite elated over his success, and feels confident of being able to save his crop, which, only the day previous, he had been tempted to give up in despair.

The farmers of the Missouri Valley have been doing good execution during the past few weeks fighting grasshoppers. Thousands upon thousands have been destroyed. Of the many modes employed, that of burning dry manure and straw mixed is proving the most effective. The sides of the fields are protected by water ditches, and the manure and straw is scattered across one end in a narrow strip when the 'hoppers are on the move, and set on fire and is burned. The manure with a little straw mixed with it will burn for several hours. We are informed by those who have made the experiment that they have seen the 'hoppers march on until the burning heaps were a mass of grasshopper cinder.

As the season grows older the war upon the grasshoppers becomes more general all over the Territory. On the Missouri Valley the conflict has been long and fierce. The 'hoppers came out early, and are now almost ready to fly, and should none of the winged armies from other sections come in the crops will be good, notwithstanding great damage has been done. On the Gallatin it was thought there would but few hatch out. The spring there being cold and stormy, the eggs did not hatch; but late advices inform us that during the hot, sunny days of the past two weeks they have come forth in great numbers, and it is feared will yet destroy many crops. On other valleys they have not been so late in coming out, but have hatched at intervals; as fast as one army was vanquished by the industrious farmer, another was ready for action.

The modes of defense employed have been greatly diversified and numerous. Where the land has considerable grade and water is plenty, water is the only weapon needed; but if the land is level, then it is necessary to employ coal oil. The Gallatin and Prickly Pear farmers have tried the latter plan with great success. The 'hoppers, which are well grown, and would ferry a slow stream with ease, are instantly killed by coming in contact with the coal oil. The quantity of oil required is small. On the Missouri Valley, where water has been comparatively scarce, the burning of straw and manure has been the most successful.

The damage already done, taking the Territory throughout, will not reach a fourth of the acreage sown, and if the defense continues as successful, the remainder of the season, the harvest will be good. There seems to be no probability, however, that it will be so large as to produce a decline in prices. There was more than double the amount of grain raised on the Missouri Valley last year than there was the year previous, and we believe the same may be said of many other sections; yet grain bears a better price now than one year ago. This indicates that the demand is growing more rapidly than the production, and there is no question but the remuneration would be fair should the crop of the Territory exceed last year's production by half.

To sum up the situation of things in 1878, we may safely say that the Locust in its native home, as mapped out by the Commission in its First Report, comprising the Rocky Mountain plateau, and especially the Territories of Montana, Idaho, Utah, and Wyoming, with the State of Colorado, was much less abundant and destructive than in 1877. Everywhere the insect existed in nearly its usual normal numerical proportions, the swarms being local, and only occasionally doing local damage; the crops of grain being everywhere large and abundant. It will, however, be seen that even in "off" years the Locust is annually migratory, and even if the numbers are slight, they gather into swarms and travel hundreds of miles from their hatching-grounds.

THE ROCKY MOUNTAIN LOCUST IN 1879.

THE LOCUST IN NEBRASKA IN 1879.

From a communication dated June 14, from Mr. John Tannahill, Columbus, Platte County, Nebr., we learn that the young grasshoppers are doing some damage in the gardens: that they are still working farther north of Columbus, and that they extend into Madison County, where they destroyed large fields of grain.

NORFOLK, MADISON COUNTY, *June* 8.—In this valley, for a radius of six miles wide and twenty-five long, "the 'hoppers" are making a clean sweep of small grain. At present the wheat is half destroyed and going by degrees from the ravages of the grasshoppers. Oats are not damaged as much as wheat. Wheat ground is being plowed up and put into corn. "Crop prospects" growing beautifully less.

Mr. G. M. Dodge, of Glencoe, Nebr., writes, on May 19, as follows:

C. spretus has been hatching abundantly (in localities that were hard and bare last fall) from May 5 until date. Of course they do not yet appear to do much damage. I saw many young ones on the 18th on prairie land that was burned over on the 17th. The weather has been very dry all spring, with slight showers lately.

NORFOLK, MADISON COUNTY, *May* 23.—Young grasshoppers have made most fearful work in this region. Farmers are plowing up their wheat fields and planting corn. In some cases, wheat, rye, and barley all gone. They have not injured oats much, but are going for the early corn.—[Chicago *Tribune*.

CHICAGO, *June* 6.—Within the last three weeks I have seen spring-wheat ruined by grasshoppers in Nebraska and Dakota, and the ruined wheat plowed up. Such is the case west of Lincoln and Schuyler, in Nebraska. These facts are kept quiet in those States, for fear they will check immigration. No State newspapers have mentioned, or will mention, such casualties.—[Chicago *Tribune*.

THE LOCUST IN WASHINGTON TERRITORY IN 1879.

There are no *spretus* here, I think.—[H. K. Morrison, Kalama, Wash. T., May 13, 1879.

THE LOCUST IN DAKOTA IN 1879.

RIVERSIDE, CLAY COUNTY, *May* 16.—The drought has injured our wheat badly. Prospect for a crop very poor. The grasshoppers commenced hatching the 11th of April. The grain grows so slowly that they are eating off large areas of it. Grass just coming through the ground since the rains.—[Chicago *Tribune*.

SIOUX FALLS, MINNEHAHA COUNTY, *May* 18—Have had a splendid rain. Weather cool and prospect favorable for wheat. There are a few grasshoppers here; doing very little damage.—[Chicago *Tribune*.

VERMILLION, CLAY COUNTY, *May* 23.—The spring wheat is badly damaged by grasshoppers. The outlook now quite gloomy for all crops.—[Chicago *Tribune*.

THE LOCUST IN TEXAS IN 1879.

DALLAS, TEX., *May* 17.—Locusts are swarming two miles below here, on Trinity River.—[Chicago *Tribune*.

THE LOCUST IN COLORADO IN 1879.

Locusts were seen by us July 30 on Pike's Peak above timber line, in much the same situation and abundance as observed in 1878 on Gray's Peak. None, however, were seen, either this year or last, flying over the summit by the Weather Signal observers on Pike's Peak. No specimens were observed among the foot-hills at Manitou Springs.

A few small swarms flew over from the mountains to the plains, as will be seen by the following data communicated to us by Mr. J. S. Stanger, editor of the *Colorado Farmer*. The Locust appeared about the 15th of July in small flights on the Cache a la Poudre and Saint Vrain Rivers, in Laramie and Boulder Counties. July 23 a flight passed over Denver and alighted at Littleton, on the Platte River, but did not remain there an entire day, flying southward. They came from the Bear River Valley. It will be remembered that locusts were seen in abundance in White and Bear River Valleys early in September, 1878. The flights this year were evidently the progeny of these locusts.

The only other instance we could learn of was from Mr. J. B. Piper, who sent us a long-winged genuine male *C. spretus*, with the following note, dated August 1:

> Inclosed find a specimen picked up by me at dark this evening at West Las Animas, Bent County, Colo. They were in moderate numbers and flying north.

From this it will be seen that there were a less number of locusts in Colorado this year than even in 1878. The summer in Colorado was unusually dry, the rainfall of June, at Denver, being .32 inch. In May there was a slight excess of rain, as the United States Weather Signal observer informed us, and the spring was not unusually dry. The summer, however, was regarded as the driest since 1863, as it was throughout the Rocky Mountains.

> No need to be alarmed at the report about locusts hatching. Riley says a few hatch out every year in some places in Colorado.—[Colorado *Farmer*, June 12, 1879.

THE LOCUST IN WYOMING IN 1879.

In this Territory also locusts were still less frequent than in 1878. A few were seen the middle of July, at a height of 150 to 200 feet in the air, at Rock Creek Station, we were told by a person at this point. None were seen this season, so far as we could learn, between Sidney, Nebr., and the Black Hills.

The following data have been received since our return:

Lieut. C. A. H. McCauley, U. S. A., writes from Fort Steele, on the North Platte, July 3, 1879:

> A cloud of *Orthoptera*, as per sample, has been all day long passing through and over the post; numbers great, flight low, direction of arrival from the south and southwest chiefly; a strong, high wind from that direction prevailing all day. Temperature high, about 90° F. Alighting on ground; flights short when disturbed.

The same correspondent, in a letter dated Fort Steele, Wyo., August 12, 1879, continues as follows:

> It will probably be of interest to add that my survey extended to the southwest some 50 miles, during which I observed the extent of the *Orthoptera* observed here before starting out. The route was up the North Platte and tributaries in the east, farthest point a locality on Brush Creek; situation, long. 106° 30′ W., lat. 41° 23′ N., both approximate, and altitude some 1,200 feet above this (6,850 feet above the sea).

The ravages along Platte River were chiefly felt by ranchmen (farmers), whose crops of vegetables in the river bottom were greatly damaged.

C. spretus, in immense quantities, was noted on the road-crossing of Cedar Creek (an eastern tributary of the North Platte), a point some 10 miles northwest from the above-mentioned locality on Brush Creek, on July 26, none scarcely being there on our passing, July 18. The creek bottom is there limited—25 yards willow undergrowth adjoining water, and grassy area not over 100 to 150 yards from the creek's banks, upon either side. The *Orthoptera* did not go outside of the grassy area, beyond which, in every direction, extends sage-brush, the general vegetation of this part of the country, extending from the bottoms of creeks and rivers to the foot-hills, &c., of the mountains, whence they spring up to what is commonly called the lower timber line.

Mr. William Myers, hospital steward, U. S. A., referring to the locusts mentioned by Lieut. McCauley in his first communication, writes as follows from Fort Steele, Wyo., August 12, 1879:

The disappearance of the locusts toward the north was noticed on the 23d of July. The wind on that day was recorded: south, velocity 25 to 30 miles per hour: stragglers were observed for a week afterwards; the flight was low, the ravages committed in the vicinity slight, the vegetation consisting chiefly of sage-brush; the cotton-wood trees forming the groves on the banks of the Platte River were uninjured.

THE LOCUST IN UTAH IN 1879.

The summer in Utah was very dry, as was made evident by the fact that the Salt Lake has fallen two or three feet since last year, and early in August was falling daily. A few locusts hatched out on the benches about Salt Lake City, within a radius of 10 miles, but did little if any injury to the crops. May 14, and earlier, they appeared in considerable numbers in Provo Valley.

In Ogden Valley the young, May 21, were "exceedingly numerous," and even said by the newspapers to be "committing great ravages there," and to "have eaten the grain clear to the earth."

At Pleasant Grove, May 24, they were extremely abundant, and on the 23d were in force at Parowan and Cedar City, Iron County. May 25, they were abundant in and around American Fork. On the 22d of the same month they committed fearful ravages in grain crops at Eden. Weber Cañon was reported, June 7, to have been stripped, the fields and pastures being laid bare and even the sage-brush stripped of their leaves. June 19 the locusts were reported to have been destroyed in large numbers by the fly, probably the flesh-fly (*Sarcophaga carnaria*), which always abounds wherever the young of the locust exist in unusual numbers. Early in June the Utah southern train for Sandy was stopped by locusts. According to the Salt Lake *Herald*, "the insects accumulated on the rails so thickly that the train had to be cut in two parts going up the grade to Sandy."

Mr. John Lee reported, June 24, from Heber City, "that the ironclads are mowing everything down in that region. About eighteen or twenty farms were already cleaned out, and they are still at work."

Severe suffering resulted from the ravages of the young in Morgan County, particularly at Croydon. Mr. C. Bunting writes us:

This place was visited by the grasshoppers early in April last. The spring was very open, and all seeds were in and up, when they appeared in swarms so small as to appear as fine coal-dust, in patches of some six feet square. They grew, and for four months continued to hatch out fresh ones; it was late in the season before they left, and at this date there is no appearance of any for the next season. Not a green thing grew at this place; the wheat was up six inches high, but now all gone, as also oats; all trees and even sage-brush stripped. I have known the hoppers since they first came to Utah, but the continued hatching out for so long a time I never saw before. At the one and same time could be seen on the ground hoppers ready to fly, others just winged, and again others so small you could just see a place covered as with coal dust. I know of no place in Utah that has suffered so much as this this season. Settlements only two miles off raised some three parts of crop; others just across the Weber River, half crop. Fish died in the creek as it dried up, and this creek was known as Loss Creek, from the Indians years ago; but never since the settlement, now some seventeen years, has it answered to its name.

Mr. John Toone, of Croydon, also writes:

I have felt so disheartened at the loss of everything, not having raised the first green thing on which we can subsist either man or beast, that it has taxed all our physical energies endeavoring to find ourselves something to live upon.

In June, locusts were observed at Coalville, flying south and southeast, very high in the air.

At Lake Point some damage was done to grain in the spring, and a few small male *spretus* were observed there by us August 7.

August 5, a few locusts were seen flying in the air just east of Peterson, on the Union Pacific Railroad, but there was no migration southward from Montana such as took place last year in August; so that Northern Utah will in 1880 be, in all probability, comparatively free from young locusts, and probably from incoming swarms.

THE LOCUST IN MONTANA IN 1879.

The first grasshopper of the season was placed on our desk this week by Mr. F. F. Fridley, of the Upper Yellowstone. The specimen before us was several weeks old and seemed to belong to the hungry species. Mr. Fridley says large numbers have hatched out in the vicinity of his place.—[*Bozeman Courier*, April 10, 1879.

There are no grasshopper deposits this year to send forth a horde of destroyers upon the young crop. The only thing to be feared from this pest are the immigrants, and the earlier grain is put in the better chance it will have to escape.—[*Rocky Mountain Husbandman*, March 13, 1879.

This year the settled portions of Montana were entirely free from the locusts, either unfledged or summer immigrants, as will be seen by the following correspondence. Large numbers of locusts were reported by the *Rocky Mountain Husbandman* to have hatched out in the Upper Yellowstone River, but they were never heard from afterward.

Mr. O. C. Mortoon writes from Fort Benton that one very small scattering swarm of locusts arrived there July 21 from the southeast, the wind blowing gently from that quarter:

No eggs were deposited about Fort Benton this year, no swarms afterward appearing. There is no prospect now of this section suffering from the locust in 1880, unless by incoming swarms in July or August.

Mr. Chauncey Barbour, editor of the *Weekly Missoulian*, reports that there were no locusts in the Missoula Valley in 1877, or 1878, or 1879:

"I confidently predict that grasshoppers in destructive numbers will not visit Western Montana before 1885."

Mr. William F. Wheeler writes:

I have traveled all over Montana this year, and it gives me great pleasure to state that I have seen or heard of no migratory locusts or grasshoppers this year. Our crops have not been injured by them in the slightest degree. Some doubt about our having them next year, because there are no visible deposits of eggs.

Mr. W. C. Gillitte writes from Dearborn, Lewis and Clarke Counties:

I have been during the summer in that section of Montana lying between Helena and Sun River, and I have neither seen nor heard of any locust flying over or alighting in this region; in fact the native grasshoppers were very scarce compared with previous seasons. I have not heard of any damage caused by the locust in other parts of the Territory. My opinion is that we shall have several years of freedom from this plague. I have been in the Territory seventeen years, and judge by the past.

Mr. James Fergus writes from near Helena:

We have been entirely free from grasshoppers in this portion of Montana the past season—the first entire exemption in many years. As no eggs were laid, we shall expect no young to hatch and destroy our crops next spring.

J. S. Woolman, Territorial auditor, writes from Helena:

As this is the only year since 1872 that Montana has been exempt from injury from locust, it appears highly probable there will be another immigration here in 1880.

Mr. J. D. McCaman writes from Bozeman:

There were not many hatched in this county this season: some hatched on my farm and vicinity; they did not do any perceptible damage. The course the young hoppers travel is southwest; after they obtain their wings they rise and fly away from the location where they were hatched. The course is generally southwest. I was east during the summer: the men on my farm saw some swarms in the air. I presume they were the ones hatched and reared in the vicinity. We cannot reasonably expect any hoppers next season, as there were no eggs deposited in this vicinity and I have not learned of any being deposited in the Territory.

CHAPTER II.

THE RELATION OF THE LOCUST AND ITS RAVAGES TO AGRICULTURE AND THE SETTLEMENT OF THE TERRITORIES.

The whole of our first report and all of that part of the present which relates to the locusts might very properly be included under the above title; but our object in devoting a chapter to the subject named is to call attention more particularly to the effect of locust visitations on the agricultural condition and prospects of the newly-settled portions of the West, and also to what is likely to be their effect on the settlement of the Territories.

This topic if properly discussed will have to be considered in two divisions, one relating to the sections within the permanent and subpermanent areas, and the other relating to those lying in the temporary region.

The effect the locust question is likely to have on the agriculture of the temporary region east of the Rocky Mountains, the boundaries of which we have found no reason for changing in any essential particular from what was given in map No. 1 of our first report, depends very largely upon the solution of the problem so far as it relates to the permanent region. We shall therefore consider first this division of the subject.

First. *As to the Permanent Region.*

Since the publication of our first report the facts obtained have forced us to the conclusion that the boundaries of this region will have to be extended through more of the northern part of Nebraska and of Dakota than is included in our first map. The change we consider necessary is marked in the new map given in the present volume. The reader should bear in mind that by the term "permanent" we do not wish to convey the idea that the locusts are to be found breeding in all parts of this area each year, as we have stated in this and our former report that they are essentially migratory within this region, continuing in some sections for a year or two, and then changing to others, but that they are capable of continuing their race in any part of this region; that it differs in this respect from the temporary region. In the latter the climatic conditions are such that they do not appear to be capable of continuing their race, the progeny of invading swarms deteriorating and finally fading out unless they return to their native habitats. That the boundaries between these two regions cannot be marked with definite accuracy we admit, and hence in our former report mapped out an intermediate area to which we applied the term sub-permanent region, and, as will be seen by reference to the new map in this volume, we have still retained this region, though somewhat circumscribed. But the exact boundary is a matter of little importance practically; the two regions as such are very easily distinguished from each other by marked characteristics.

In the permanent region, which embraces the Rocky Mountain plateau and the bordering plains from the middle of Colorado northward, the rainfall is insufficient for agricultural purposes, and hence irrigation has to be resorted to; in the temporary region this is unnecessary; the plains and plateaus of the permanent region are to a large extent distinguished by the presence of *Artemesia*, Chenopodiaceous plants, and what is usually termed "bunch-grass;" in short by all the characteristics of a drier climate. One other peculiarity which should not be overlooked appears to mark roughly the southern boundary of the permanent home of the Rocky Mountain locust, and that is the isothermal curve or line of the 50° of mean annual temperature, which also corresponds very nearly with the isotheral curve or line of summer temperature of 70°. But this applies only to that portion of the region which extends upon the plains east of the mountains.

If any practical means of exterminating the locusts in this permanent region could be devised the whole locust problem could be solved, and nothing further would be necessary; but when we take into consideration the vast extent of this area, and the fact that a very large portion of it cannot be brought under cultivation without a material change in the climatic conditions, there appears but little hope that such a means of actual extermination will ever be devised, however much we may hope to check the injurious increase of the pest by the means recommended in the concluding chapter of this report. Our discussion of the future prospects of this region in reference to agriculture may as well therefore proceed on this basis. This may appear to be an abandonment of the hopes held out in our first report, but if the reader will examine that report carefully he will see that we there based these hopes upon the possibility of man being able, by the advancement in science and the knowledge of natural laws, to modify the climatic conditions of that region. At present we are proceeding upon the basis of the want of the knowledge as to how this desired end is to be accomplished.

It was thought that a plan for a general burning over the areas in which the locusts hatch, if done while they are in the larva state and properly carried out, would be one of the most effectual means of destroying them.

Theoretically the plan appears to be a good one, and although entailing considerable labor and expense, if it would prove as effectual practically as it appears theoretically, might be carried out under government authority and the expense justified.

But there are practical difficulties which decrease our hope of obtaining relief in this way, and we will present these in the strongest light here, as we shall recur to the subject in another chapter, and the experience of individual commissioners differs somewhat upon it.

First, the region over which the patches of egg deposits are scattered is so great, including an area of at least 500,000 square miles, that nothing short of an absolute certainty of forever exterminating this pest would justify the government in entering upon so formidable an undertaking. The actual area occupied in this region in any one year by egg deposits is, as a matter of course, but a small portion of this immense district, probably never amounting to more than 25,000 or 30,000 square miles, except in the years of greatest development. But supposing there was no other difficulty in the way than the labor and expense, it would still be a formidable undertaking, considering the widely scattered position of these areas of egg deposits; yet a certainty of accomplishing the desired end would justify the attempt by the general government.

As a very general rule, egg deposits, except in cultivated districts, are made where there is more or less grass, never being made in perfectly barren areas, and very seldom made in wood lands; this would appear to favor the theory.

But in order that burning may be effectual, it must be done after the locusts are hatched and before they have acquired wings, as burning the grass does not destroy the vitality of the eggs, and if delayed too long, the locusts would largely escape the danger by flight. It is necessary, therefore, to prevent the old grass from being burnt during the winter, as was attempted in parts of Iowa and Minnesota in 1876–'77. But it would be impossible to carry out a plan of this kind over the extensive area included in the bounds of the permanent regions. For in order to do this, it would be necessary, first, to know exactly where the egg deposits were made the autumn preceding the spring in which it was intended to put the plan into practice; next, it would be necessary to guard these areas carefully until the time for burning arrived to prevent them from being prematurely fired.

But there are other reasons why this plan, which appears so commendable in theory, fails to accomplish the expected result when put into practice.

First, the hatching is so uneven that it generally happens that some are acquiring wings by the time others are leaving the eggs. In the second place, there are few areas occupied by young locusts that the flames will sweep over without leaving gaps and unburned patches.

In all the prairies and plains except a few such "dead flats" as the valley of the Red River of the North, there are innumerable little "breaks" or barren spots where the surface declines; and these are the very spots the locusts select in which to deposit their eggs; on such spots the young locusts chiefly congregate, and these are points the fire fails to reach.

There are also numerous little depressions which the fire fails to reach, many little spots where the grass is too short or sparse to carry the flame, onward and thus breaks, and many points where the fire passes on so rapidly, simply burning the larger blades, that locusts are not killed. Thus, in various ways, a very large portion escapes, and the result, under what would appear to be most favorable conditions, falls far short of what is anticipated.

Mr. Whitman, in his paper published in the appendix to our first report, remarks, speaking of the large deposit of eggs in 1876, that—

> This impending danger aroused the farmers to unusual exertions during the fall of 1876. In counties where the trouble was an old one, conventions were held and measures taken to prevent the prairie grass from being burned before the hatching season of 1877. To preserve this grass and fire it just at the time when the locusts were hatching seemed to be one of the most feasible methods of general destruction, and one which in past years had commended itself to the citizens of the infested counties. It was carried into effect in the spring in such a way as not to do all the good of which it was capable, or to show that it was impossible to produce anything like wholesale destruction, on a date specified beforehand, by this means.

The writer of this chapter happened to pass through the southwestern part of Minnesota while the burning was going on. It was evident that the date chosen was too early, and hence the result in this case cannot fairly be cited as a test. In Northwestern Iowa the utmost precautions were taken by the authorities to give it a fair trial, but the undiminished hordes of young grasshoppers which ravaged the wheat fields afterwards gave clear evidence of the failure of success by this plan.

This method, if we may judge from the slight notice of it by Köppen both in his "*Heuschrecken in Südrussland*" and his paper on the "*Destruction des Sauterelles*," to the Exposition Internationale at Brussels in 1876, is considered of but little value in Southern Russia.

In a file of papers in the form of bulletins, published by the revenue department of the Government of Madras in 1878, in reference to the locusts that troubled that part of India that year, we find the following statement in reference to an attempt to destroy young locusts by burning them with straw:

> Here the ground was literally covered with them. I collected about 100 people and when I saw a large swarm (for they were just like bees) I first threw some straw over them (having carefully surrounded them) and set fire to it. Some perished, but they were but a few out of the millions and millions there. I worked for six hours at this work, and, though we did all we could, I do not suppose we effected much.*

This is not directly applicable to the point now under discussion, but it tends to show that the impression that all the locusts are killed where the fire passes over them is erroneous. We are, therefore, after a more thorough investigation of the subject, confirmed in the following opinion expressed in our first report:†

> Scarcely any eggs are laid in rank prairie, and the general impression that locusts are slaughtered by myriads in burning extensive areas is an erroneous one, at least in the temporary region.

We are inclined to think the same thing is to a great extent true in reference to the permanent region. There is some difference, it is true, in the character of the ground selected for egg deposits, and also in the grasses of the two regions, but not such as to render it probable that the result would be much more favorable in one section than the other.

Although we do not think this plan offers sufficient prospects of effectual destruction to justify the government in attempting to put it into operation, yet we think it may be used as one means of destroying the young in favorable localities by the farmers and others of those localities who are interested. But it is unnecessary except where it is certain the young locusts are in the grassy area, and should not be carried into effect until the locusts are nearly half grown, or, in other words, well advanced in the larva state.

If the plan for a general destruction by burning is abandoned as untenable, we must then confess we see no prospect at present of entirely exterminating them by artificial means.

The problem, then, is confined to a modification of the evil by lessening the numbers, or in some way counteracting them.

The various methods which may be adopted for destroying the unfledged locusts are fully explained in our first report. All these methods are fully as applicable in the permanent as in the temporary region,

* Proceedings of Board of Revenue of Madras, June 20, 1878, No. 1702. † Page 363.

and some, which depend upon the possibility of irrigation, are applicable on an extensive scale only in the permanent region, and may be used there with a very large degree of success.

A careful investigation of this subject for several years and repeated visits in person to this region have served to convince us that, with the advantages afforded by the system of irrigation necessarily adopted, there is no reason why the agricultural area lying along the east flank of the range should suffer any more from these pests than portions of the temporary regions. We do not think there is any likelihood of this section ever suffering from locust depredations to the same extent as Southern Russia, yet the peasants and agriculturists there manage to carry on operations and maintain themselves, although greatly deficient in that intelligence and education which is necessary to enable them to combat these pests to the best advantage. The superior intelligence and energy of our farmers will enable them to accomplish results of which the Russian peasants are wholly incapable.

But we refer to this simply as an illustration to show that this drawback will not of itself prevent the settling and cultivation of the arable areas of the permanent region. The agriculturist of those sections will become accustomed to these insects and acquire a thorough knowledge of their history and habits, and by this means—and, as we trust, largely through the work of this commission—learn how best to counteract them; and thus in the course of a few years the terror their invasions once caused will be no longer felt, and they will be ranked side by side with the chinch-bug, Hessian-fly, cotton-worm, and potato-beetle.

Although we confess we do not see any way of entirely preventing the incursions of invading swarms or of wholly avoiding injury by them, yet we think it possible and feasible to greatly modify the evil.

First, the means already suggested in our first report of destroying the young of the resulting broods, if carried out with energy, will not only save to a large extent the crops, but will destroy a very large number of the locusts; as the population increases the results will be more and more favorable; and year by year the methods of destroying them will be improved upon and probably new plans discovered. Aside from this direct favorable effect of the increase of the agricultural population of this section, there will be a secondary effect which will tend to modify the evil.

This agricultural belt, extending from Colorado into British America, is partly along the margin of and partly in the very heart of the permanent breeding-grounds where the swarms that invade the temporary region originate; it follows, then, as a natural consequence that just so far as the numbers are lessened by the operations in this section, just so far will the agriculturists of the temporary region be benefited, and, as we will hereafter see, like operations in the latter region will benefit those in the permanent region. We are fully aware of the fact that the part of this vast region which can be irrigated and cultivated is small in comparison with the whole area which forms the native home of the species, but fortunately in one respect this cultivated belt occupies in part, at least, the point of departure of the swarms which invade the temporary region. This fact, therefore, renders it more important that it be occupied by an agricultural population.

Although we have admitted that we are unable to present any plan of exterminating the locusts that holds out sufficient promise of success to justify the general government in undertaking it, it does not necessarily follow that there is no plan of modifying the evil which the government would be justified in undertaking. On the contrary, if the views we have advanced be correct, they suggest a means by which the general government might greatly aid in bringing about the desired result; and fortunately the result would be beneficial even should we be mistaken in the opinions advanced.

As will be seen by what has been stated, the great desideratum is to settle the cultivable belt alluded to as rapidly as possible with an agricultural population. Wherever valuable and permanent mines are discovered in the neighboring mountains, the arable areas in the vicinity will be taken up and cultivated to an extent at least sufficient to supply the demand for agricultural products, as in parts of Colorado. But there are large sections where no such influence will be brought to bear, and this is the case along that portion of the belt where the agricultural population is most needed for the purpose mentioned.

An examination of map No. 1, in our first report, will show that a comparatively limited belt in Central Montana, extending from the Big Horn Mountains northwest to the British line, a little west of Cypress Hill, forms the turning-point of the locust movements. Without now repeating the data which may be found in that report, we may summarize it by saying that from this region a large portion of the swarms come which visit Dakota, Minnesota, Nebraska, and Kansas; from this area also proceed a large portion of the swarms that move southwest into Idaho and Utah; this appears to be the point to which most of the returning swarms from the temporary region direct their flight.

That there are other areas in the permanent region which appear to be special breeding-grounds, as points of departure, is certainly true, but none to such an extent as this, and none affecting an agricultural area bearing any comparison with the area affected by the locust swarms originating in this belt.

Even should it be shown by subsequent investigations that as a rule the swarms falling on the temporary regions come from intermediate points, as Central and Southern Dakota and Northwestern Nebraska, the facts already ascertained warrant us in asserting that, as a very general rule, they originate in the belt mentioned.

It is evident, therefore, that if any method can be devised by which an agricultural (not pastoral) population can be thrown into this belt it will form one of the best possible means of modifying the evil. If they can be effectually distributed in this area the result will be of immense value to the agricultural interests of Dakota, Minnesota, Nebraska, Iowa, and Kansas, in fact of the entire temporary region. We do not pretend that it will wholly relieve this area from locust invasions, but it will very materially lessen their extent and injury.

In order to carry on agricultural operations to any great extent in this belt, an extensive system of irrigation will be absolutely necessary. It will have to be on a scale of greater magnitude than any that will be undertaken by a pioneer population. We doubt the propriety of the general government undertaking such a work directly, if it is possible to accomplish it in any other way. This, we think, may possibly be done by giving the land for this purpose. We are fully aware of the opposition at present to the government's donating any more of the public land, but the circumstances of this case bring it out of the general rule. If donating the entire body of public land in the belt described would suffice to settle it with an agricultural population, not only would the very purpose for which it is held be accomplished, but, if our views are correct, the result would be of immense benefit to the border States.

We therefore suggest the following as probably the most feasible plan of accomplishing the desired end: Let the United States donate a belt of fifty or sixty miles in width, running from the Black Hills west-northwest, so as to strike the Yellowstone River a short distance above the mouth of Big Horn River; from thence north-northwest by way of Fort Shaw, or the mouth of Sun River, in the direction of Fort Hamilton, in British America; this to be granted on condition that the company to which said land is granted shall, within a given time, construct a railroad from the Black Hills along the line designated, to the international boundary; shall undertake and carry out, to an extent to be designated, a system of irrigation, and shall equip and keep in operation said road for a certain number of years.

Whether such grant will be sufficient inducement for any competent company to undertake the work specified is probably the chief difficulty in the way of successfully carrying out this plan. On this point we do not feel qualified to express an opinion. That such a road, starting from the Black Hills, if once built would soon be connected southward and eastward with other roads cannot be doubted. That it would be the best possible means of bringing an agricultural population into this belt cannot be doubted. It would also be an important factor in settling the troublesome Indian problem in this section of the West.

If the plan should be adopted it might be well to colonize, if possible, with Russian peasants who are accustomed to fighting locusts.

The advantage to be derived from this plan consists chiefly in the fact that it is possible to destroy the young to a very large extent by the use of the proper means. If this is done in the very heart of their breeding-grounds, it greatly lessens the numbers that will migrate. Not only does it prevent the number destroyed from migrating, but for each one killed, so to speak, an entire family brood of the next or migrating generation is destroyed. In other words, the destruction of thousands there would be as effectual as destroying millions of the migrating swarms. The means of destroying the young, as before stated, can be made more effectual in the sections where irrigation is carried on than where it is not.

As shown in our first report the destruction of the young locusts bred in the temporary region from the invading hordes not only gives immediate relief but also tends to postpone future invasions by so lessening the numbers in the returning swarms that a longer time is required for development. With an agricultural population in the area designated the work of destruction would then be carried on at each end of their migratory route.

Here we may also remark that the present idea of making that section of our country peculiarly pastoral area, while doubtless profitable to the present and for two or three generations to come, will in the end entail hardships upon those to follow. It can no longer be doubted that while the destruction of forests was the chief agency, yet the pastoral habit of the people of Western Asia and other Oriental countries, once so fertile but now barren, was one important factor in producing the present dry and barren condition of those countries. No country in the interior of a continent, unless supplied with numerous lakes or numerous and permanent rivers, can remain permanently fertile and productive if given up largely to pasturage of sheep, goats, and cattle without cultivation. The rapid destruction of the mountain forests, and pasturing their slopes and bordering plains, will most certainly have a tendency to render that portion of our country more dry and barren.

Unless, therefore, our government adopts some policy by which an agricultural population can be thrown into that area the day will most assuredly come when it will be as barren and desolate as the plains of Arabia. The development of the locusts is but an incident of the change from a former condition of abundant moisture to the present dry one. But this branch of the subject we propose to omit at present.

It will be seen, therefore, by the foregoing that we think it is possible to modify to a very large extent the operations of the locusts so far as these relate to the area along the east flank of the mountains; and that the general government may, without any very great expense, very greatly assist in the work.

It is proper to state here, before leaving this part of our subject, that we have not suggested the building of a railroad along the belt designated without some knowledge of the difficulties in the way of such a scheme. Instead of following the valley of some stream it would have to cross alternately narrow valleys and broad elevated plateaus its entire length, but the difficulty in this respect would be no greater, and perhaps not as great, as that experienced in running the Northern Pacific across Eastern Dakota from the Red River to the Missouri. That but a comparatively small portion of the land along the line from Black Hills to the Yellowstone can be brought under cultivation we are fully aware, but fortunately for the object in view the locusts deposit their eggs and breed only, or at least chiefly, in these restricted areas.

Between the Yellowstone and the point where this railroad would cross the Missouri the country is rough and broken, but there are a number of fertile valleys and small areas that can be irrigated and cultivated. North of this it would run through as fine an agricultural region as there is in the Territory.

Another fact which is often overlooked should be borne in mind in discussing this scheme; that is, that the elevation of this region is much less than that of the plains along the east flank of the mountains in Wyoming and Colorado, which tends to very materially moderate the climate.

The following statistics from the meteorological records kept at Fort Shaw will furnish some data in reference to the climate of this region:

Monthly means of the temperature for two years.

January	21.28	August	67.15
February	30.39	September	54.04
March	36.58	October	49.12
April	46.51	November	39.92
May	56.04	December	26.75
June	64.98	Year	47.33
July	70.22		

This certainly shows a very moderate climate for this northern latitude. Wheat, oats, rye, and barley grow well, and Indian corn is also raised without difficulty and produces good crops. Such fruits as apples, plums, cherries, currants, raspberries, and gooseberries may be grown and matured here, the climate presenting no serious obstacle.

The amount of land that can be brought under cultivation depends wholly upon the amount of water that can be obtained for irrigation. If the plan for making reservoirs for preserving the winter supply should ever be adopted, the breadth of the agricultural belt would be very largely increased, and this would be doubly beneficial in assisting to destroy the locusts and tending to increase the moisture in the atmosphere by forming a larger evaporating surface. The growth of trees and shrubbery around these reservoirs would also be beneficial in the same direction.

But experience in the settlement of these mountain regions and Western Territories show that no such extensive works will, or in fact can be, undertaken by a pioneer agricultural population. Some efficient aid of some kind must be given if such a scheme is ever carried into effect, and if the land itself will do this, the government will act wisely in giving it for this purpose.

In reference to the bearing of the locust problem on the agricultural prospects of the inter-montane area, we have but few facts and few conclusions to present that we consider of special importance, and these relate almost entirely to Northern Utah and Eastern Idaho. The portion of this inter-montane section within the locust area consisting of Idaho, Western Wyoming, Western Colorado, Utah, and Nevada offers but little prospect of extension of agricultural operations within its bounds. It is not probable that of the 375,000 square miles contained in this area more than 25,000 to 30,000 square miles will be brought under cultivation for a century to come, its chief value being its mineral resources. The chief agricultural area at present, and the only one to which we shall call attention at this time, is the belt running north and south through the central part of Northern Utah and Southeastern Idaho.

As shown by our first report the region around Salt Lake is subject to repeated locust invasions from the north, apparently the resulting broods of the swarms that originate in that portion of Montana of which we have been speaking, and which pouring over the mountain pass at the head of Jefferson River, move down Snake River Valley.

If the scheme we have suggested should be carried out and should prove beneficial in reference to the eastern area, it would have, to some extent at least, a like effect as to this section. If it is possible to establish and maintain an agricultural population in the Upper Snake River Valley, this would have a strong tendency to modify the evil. But the present barren aspect of this region would seem to forbid any hopes of ever accomplishing this desired end. Still there appears to be one possible means of bringing this about, at least to a limited extent. The demand of trade will doubtless complete the railroad already started in that direction which is one step toward the desired end, but something more is required in this case.

Snake River affords a large body of water which if properly utilized would irrigate a large breadth of land, and notwithstanding the barren appearance of the soil it is really fertile when irrigated. It is possible, with a moderate expense, to throw dams across this stream at certain favorable spots, and by this means to spread the water over the adjoining plains. A work of this kind would of course have to be done by the general government. The feasibility of this project could easily be ascertained by an officer of the Engineer Corps of the Army; and as this is on the line of the chief inter-montane thoroughfare and also of the locust invasions of this region, the subject is certainly worthy of the attention of the government.

As will be seen by what we have presented on this subject, the philosophy of our plan for modifying the evil is to place an agricultural population in the very home of the species, which from necessity would be compelled to wage a constant warfare against them.

By stirring the soil their nests would be disturbed; by fighting the young their numbers would be diminished; and as irrigation would be necessary the effect of dry seasons on the crops would not be felt as in the temporary region. The possibility of inundating to a considerable extent their egg deposits by the winter supply of water would tend to diminish their numbers. The fact that their breeding-grounds are chiefly in the limited agricultural areas is also another argument in favor of the plan.

That large areas would be left where locusts breed, and pour down on the nearest cultivated areas, as in Western Colorado, is certainly true, but this does not lessen the value of the plan proposed, nor is it a reason why it should not be put into operation.

Other proposed schemes for destroying or preventing the multiplication of locusts in their native habitats.—Mr. Ellwood Cooper, of Santa Barbara, Cal., writing to the Commission in 1877, makes the following statement and suggestion:

> I have found on my ranch of 2,000 acres that these beds of (egg) deposit do not amount to more than five or six acres. I marked these places so that when the rainy season came I could plow the ground and thus destroy the eggs, and while grasshoppers were produced by the millions on adjoining ranches none were hatched on my place. The conclusion is, that it is not a question to be solved by meteorologists, scientists, or naturalists, but one for the plodding farmer, and that their total destruction is a matter easy, simple, and not expensive. It is a question of the plow—deep and thorough plowing of all the breeding-grounds. This will require a concert of action on the part of the Government of the United States and the governors of all the Western States. Let there be appointed for each Territory five commissioners and as many for each State where they have suffered from the ravages of this insect. The duties of these commissioners [to be] to solicit information during the coming summer, and wherever the locusts appear, to follow them and mark their breeding-spots; in the following spring have every spot well plowed; some kind of crop can be raised that will pay the expense. If this plan is vigorously followed up for a few years, the devastation and misery produced by these insects will be a history of the past.

While plowing is one most excellent method of destroying the eggs in thickly-settled districts where it can be practiced, the idea of carrying out the plan suggested over the vast area of the permanent breeding grounds in the mountain district is wholly impracticable. If, as we have shown, it would be impracticable to attempt to burn over the infested areas,the idea of plowing over these areas must be considered as utopian.

The introduction of foreign locust-eating birds has been suggested as one means of modifying the evil. That this plan has been adopted in certain islands with success is probably true, and we think it would be well to try the experiment in this country; but a more thorough examination of the subject and the result of the introduction of the English sparrow we must confess has greatly weakened our faith in the plan. We think it wise to protect by stringent laws our native insectivorous species, especially in the temporary region, as these have undoubtedly proved to be of great value in destroying the young locusts. But in the permanent region the birds have to a very large extent been left undisturbed in their native wilds; and as they have not, so far, increased to a degree sufficient to aid to any visible extent, there is no likelihood they will ever do so.

Other plans have been proposed (one or two will be mentioned further on under *General Remarks*), but as most of them are still less feasible and show a want of knowledge of the character of the breeding grounds and the difficulties to be overcome, it is unnecessary for us to consider them. The proposition for the government to burn over the areas of egg deposits after the young are hatched out offers some hope as a means of their destruction, but, as we have seen, appears to be impracticable with the limited population in the permanent region.

Collecting and destroying the eggs and young in the permanent breeding grounds, which is hereafter noticed, is worthy of careful consideration, as it is possible; but the immense expense it will entail has prevented us from mentioning it among the practicable remedies.

We are, therefore, of the opinion that the best plan to be followed is, first, to adopt measures to throw an agricultural population into the radiating points of the permanent breeding grounds, commencing with the portion of Montana designated; and, if possible, induce the Dominion Government to unite in this effort so far as relates to the region immediately north of the international boundary along the east flank of the Rocky Mountain range.

The plan proposed in our First Report of stationing a corps of observers connected with the Signal Service Bureau in the breeding areas of the Northwest for the purpose of gathering information in reference to the extent of egg deposits and numbers hatching, and to give notice of these facts and the departure of swarms, we think not only entirely feasible, but important, and one that would be of immense value in locust years to the sections the swarms from this region are in the habit of visiting.

Second. *As to the Temporary Region.*

What has been stated in the previous part of this chapter in reference to the probable effect of the settlement of the belt in Montana on the locust problem in its relation to this region need not be repeated here. As the relation of the locust problem to agriculture in the temporary region has already been discussed in our First Report, and as the chief objects we had in view in devoting a chapter to the general subject in this report were to consider the feasibility of the plan for destroying the locusts by burning over the grassy areas of the permanent region and to present the scheme herein mentioned, we do not design to enter at present into an extended discussion of this second division of the subject.

The experience of the farmers of this section in fighting the young locusts, a more thorough knowledge of their history and habits obtained through the work of the commission, the complete fulfillment of the predictions of the commission that 1877 would close the series of the invasion which had continued from 1874, and the conclusive proof of the theory advanced by the commission that this pest could not remain permanently in this region, have served to dispel the terror these insects once inspired, and should no other remedies than those already known ever be discovered, the locusts can never prevent the settlement of this section, or in fact of any other portion of the United States. This part of the problem, at least, is undoubtedly solved. That invading swarms will again come down on these border States and Territories is not doubted; that almost every year, in fact, a limited swarm drops down here and there, we know to be true; and that some loss is occasioned to some few farmers here and there is also true; but it is no more than occurs in almost every part of the Union. Every year limited areas in every State suffer from some kind of insects; in one it is the locust, in another the potato-beetle, in another the cotton-worm, in another the cabbage-worm, &c. We should not be surprised, if the coming spring and summer are dry, to see a limited invasion of the temporary region this year. We have no sufficient data on which to base a decided opinion, nor do we feel warranted in saying that even the probabilities lean in that direction, but there are a few slight indications, chiefly meteorological, which are sufficient to prevent us from asserting that there is no danger of an invasion the coming summer.

As heretofore stated, facts gathered during the last two years have forced upon us the conclusion that the northeast portion of Nebraska and the eastern part of Dakota should not be classed in the temporary region in the same sense as Western Iowa, Southern Nebraska, Kansas, and the regions southward; but that they really belong to what may truly be termed the subpermanent region. Even the extreme western part of Minnesota appears to fall into the same category. In this region the species appears to be able to maintain its existence for a longer time than in the southern section, though perhaps the former region is no more subject to the invasions of the great hordes than the latter. The area to which this statement appears to be particularly applicable is that which lies around the southern and western side of the Coteau of the Prairies. The elevated plateau is perhaps one cause of this. But the data we have obtained are not sufficient to enable us to decide this point with certainty.*

If the proposition of the Commissioner of Agriculture to cover this with trees could be carried out, it would most certainly have an ameliorating effect; but without any means of irrigating them, we have some doubt as to whether they could be made to live and grow. If any species can be found that will live without irrigation, the plan is most certainly a good one and would justify the government in undertaking it. A belt of timber along the Niobrara, which, within historic times, was a wooded stream, would also be beneficial to a limited extent. But to materially modify the locust injuries by this means would require a broad forest belt of a hundred miles or more in width, stretching from Big Sioux to the vicinity of the Black Hills. If the locusts sweep over mountains covered with forests, as we know is a fact often witnessed in Colorado, a narrow belt of timber along the line of their march

*NOTE.—Recent investigations strongly confirm this opinion.

is not likely to stop their progress; but if the Coteau of the Prairies is really a permanent breeding ground, which we are not yet fully prepared to affirm, clothing it with a forest growth would have a tendency to prevent them from using it for this purpose.

We are inclined to believe that, aside from the improved means of destroying the young, and a system of farming least liable to suffer injury from the invading swarms, the chief hope of amelioration lies in the increase of the agricultural population and its gradual extension into Dakota. The railroads which are now pushing their way into this section, especially those leading into Southern Dakota, will aid greatly in bringing about this result. With the increase of population the destruction of the young and of eggs will become more and more effectual.

As Minnesota is well supplied with lakes and the supply of moisture ample, it is more than probable that it would be a wise policy for the farmers of the southwestern portion and also of the extreme southeastern part of Dakota to devote their lands and attention largely to grazing of cattle and sheep. This industry, as has been shown in our First Report, is not liable to the same injury from the locusts as are the grain crops. But it is not likely this will be adopted to any considerable extent until the virgin freshness and strength of the soil is weakened by repeated wheat crops or wheat raising ceases from some cause to be remunerative. This State is well adapted to its production, and it is not only the most profitable crop at present, but is the money crop. The raising of wheat will, therefore, go on until it ceases to be as profitable as it is now, in spite of locust raids and grasshopper devastations.

We may repeat, therefore, in reference to the whole of the temporary region, that the "grasshopper scare" is over and past; the tide of immigration thither is greater than ever before, and those who go now, go with their eyes fully opened to the difficulties with which they have to contend, so far as the locusts are concerned, and hence will not be driven back by this cause. Year by year, as the population increases, the power to contend with this evil increases. The cultivation of the soil, the planting of trees, the introduction of stock, such as hogs, the increase in domestic fowls, and the improvement in the means of destroying the young, bring the evil more and more under control. There is, therefore, good reason for believing that the day is not far distant when the locust will be looked upon as no more injurious than the chinch-bug or cotton-worm, or perhaps as even less so.

The work of the Commission, therefore, so far as it relates to the locust in the temporary region, may be considered as about completed. The great point left for us to determine is that which is chiefly discussed in the present report: Is it possible to exterminate the locusts in their native breeding grounds? If not, how far and by what means is it possible so to diminish their numbers as to render the migrating swarms comparatively innoxious?

General remarks.—It is held by many citizens of the districts subject to locust ravages that it is the duty of the general government to offer bounties for the eggs and young locusts, as this would be one efficient means of destroying these pests. But it is difficult to convince members of Congress from Mississippi and Georgia that there is any better reason for paying the citizens of Minnesota and Nebraska for destroying insects injuring their wheat and corn than there is for paying the planters of Mississippi and Georgia for collecting the worms injuring their cotton. It is therefore not at all probable that any such plan will ever be adopted by Congress, at least in States which have power to adopt such measures for themselves. But there is another light in which this question may be considered which brings it out somewhat from under the principle stated. If it could be shown that there is a limited area within the bounds of our national territory from which the cotton-worm moths proceed and spread over the cotton States to deposit the eggs that produce the worm, and that by destroying the insects in this native home the spreading would be prevented, then the subject becomes a national one; just as the passing of lines of commerce over State boundaries renders them subjects of national control. If this native habitat should be in a territory, this fact of itself would bring it more exclusively under national control.

That all these supposed conditions do apply to the locust problem has been fully shown in our reports, and is well known to every one. The question then arises, Is not the general government under obligations to make a reasonable effort to prevent the hordes of locusts bred in the Territories from invading the States? The lands of Minnesota, Nebraska, Iowa, and Kansas have been sold to those who have them, or have been granted to them for the purpose of inducing them to settle upon and improve them. Now they find they are subject to the ravages of an insect which has its native home and breeding grounds beyond the bounds of their own States, and in Territories of the United States over which their State authorities have no control, and where they can take no measures for destroying the pests or preventing their invasions. These facts render the case peculiar, and different even from that of the Colorado potato-beetle. In the latter case, as in the case of many other injurious insects, it was an extension of the permanent home, thus bringing all possible remedies within the reach of the authority of any State or section invaded. But it is not so with the locusts; their migrations are not a spread of their native habitat, and do not bring within reach of the authority of the State invaded all possible remedies; in fact, the most effectual remedies are beyond the control of the States in the temporary region; they have no authority to take even the first step toward preventing the invasion of their territory, and hence are entirely helpless in this respect.

We hold, therefore, that this is an exceptional case, and that the general principle above mentioned does not apply to it; and we think it is the duty of the general government to make a reasonable effort to prevent swarms of devouring locusts from sweeping down upon the crops of the farmers of the temporary regions, who themselves and whose State authorities also are helpless in this matter.

While, therefore, Congress might feel that it would not be justified in offering bounties for locust eggs and young locusts collected in these States as a means of destroying these pests in the temporary region, it does not follow that it would be improper or even unadvisable to offer bounties for their collection in those sections of the Western Territories where the swarms that visit the temporary regions originate.

As heretofore stated, we have not presented this remedy as among the most important ones, because of the immense expense it is supposed it would require if carried out effectually. The plan was proposed in Minnesota in 1876, and the proper authority for carrying it into effect was granted by the legislature to the counties; but it was found that it would impose such onerous taxes upon the counties suffering most that it was abandoned.

Still, it is possible that the government may, by this means and with a moderate expenditure, do much to modify this evil. If the corps of observers suggested be established in Montana and Northwestern Dakota, notice could be obtained by this means of heavy egg deposits; with a law of Congress granting bounties for eggs and young, wherever the facts ascertained by this corps made it apparent that heavy invasions were likely to result notice could be given that the bounty would be paid for all collected in the areas designated. This plan, if it can be carried out, would undoubtedly prove very beneficial, and so far as it extended, certain. There are, however, two serious difficulties in the way: one is to induce persons to go so far away from inhabited sections for this purpose; the price necessary to bring this about would probably make the expense so great as to prevent the government from undertaking it.

The plan of burning, heretofore mentioned, might be combined with it, thus rendering it more effectual.

The possibilities would appear to justify the government in making one or two experiments in order to see the result, as in this way only can the feasibility and effectiveness of the plan be ascertained. In any case it is advisable to place a corps of observers in the section named, which should be connected with and under the control of the Signal Service Bureau, as it is essential to study carefully the climatic conditions under which the locusts increase most rapidly. Moreover, the value of the predictions in reference to their migrations will depend largely upon the forecast of the season and the knowledge of climatic influence on these insects. After a few years' observations, this corps would be able to inform Congress, through the Chief of the Signal Service Bureau, whether it would be advisable to attempt to burn over the infested areas or to offer bounties; and, in case the latter plan should be adopted, could act as agents of the government in measuring and paying.

As a plan of relief, propositions were brought forward some years ago in Southern Russia and Algiers to form companies that would insure against losses occasioned by locusts. M. Köppen, who discusses these propositions at some length, in his paper "On the destruction of the locusts," read before the "*Exposition Internationale et Congrès d'Hygiène et de Sauvetage*," at Brussels, in 1876, arrives at the conclusion that such a plan would be impracticable on account of the difficulty of assessing damages.

CHAPTER III.

FACTS CONCERNING AND LAWS GOVERNING THE MIGRATIONS OF LOCUSTS IN ALL COUNTRIES.

In our former report the facts relating to the migrations and "local flights" of the Rocky Mountain locust were given somewhat fully, and also discussed to some extent; but the time allotted to the preparation of that report and the space allowed did not permit us to properly arrange and give all the data collected, much less fully digest and discuss it. This part of our work has therefore been largely reserved for this, our Second Report.

As we have heretofore stated, there is nothing connected with the life-history and habits of the locust, no matter how trivial it may appear, but what is of some value in the solution of the problem for which the Commission was organized. The migratory habit constitutes, in fact, one of the chief characteristics of the migrating species, and adds very largely to their destructive powers.

That their migrations and flights are governed by certain laws will be admitted by all who believe that the forces of nature are governed by laws. To ascertain what these laws are has been one object of the investigations made by the Commission, and although we are fully aware that our work is not complete in this respect, as there are a number of points still shrouded in mystery, yet we believe sufficient data have been collected to enable us to point out some of these laws as positively ascertained, and to present more fully and satisfactorily than has been done heretofore the indications of others.

That, as a rule, the various kinds of *grasshoppers*, or species of *Acrididæ*, are not migratory, is a fact well known to all; in fact, out of the twelve or fifteen hundred species belonging to the family, less than a dozen are known to be truly migratory. That the migrating species are not limited to any one genus or group of the family was long ago ascertained.

Oedipodini and *Acridini* are two rather well marked groups, distinguished from each other by important characters, yet in each of these two do we find migrating species. It is evident, therefore, that the migratory instinct, or disposition, does not depend upon anatomical characteristics or differences of sufficient importance to mark the groups of the family. If we examine the species of the different restricted genera containing the more noted locusts, as *Pachytylus migratorius*, *Acridium peregrinum*, *Caloptenus italicus*, and *Caloptenus spretus*, not only do we find the same thing true in reference to them, but also that in some cases the most closely allied present the strange fact that one is truly migratory while the other is not; as, for example, *Caloptenus spretus* and *Caloptenus femur-rubrum* of our own country, and *Acridium peregrinum* of the eastern continent, which is scarcely distinguished from *Acridium americanum* of North America. It is therefore evident that we must look to something else than such anatomical differences as distinguish genera for the cause of the migratory disposition. Before entering upon the discussion of this peculiarity in habits, we will first discuss the facts, so far as known, in regard to their migrations, with reference chiefly to the Rocky Mountain locust of our own country, but referring to other species for illustration and to correct what we conceive to be erroneous opinions.

In our investigations of the migrations of the Rocky Mountain locust we have found it necessary to direct our attention to the following points as the ones of chief importance, and as forming the principal divisions of the subject:

1. Native breeding ground or point of departure, its position, boundaries, physical features, climate, &c.
2. Habits or characteristics of the species within this area of permanent distribution, so far as these relate to their movements; especially the question as to whether they are essentially nomadic or sedentary.
3. Their flights.
4. Climatic conditions.
5. Causes of migration.
6. The effect or consequences of these migrations.

The present chapter will be limited strictly to a consideration of the "philosophy of migrations," the last and all important topic—"consequences"—to which the attention of the Commission has been largely devoted, being treated of in other chapters.

I.—A BRIEF ACCOUNT OF LOCUST MOVEMENTS IN OTHER COUNTRIES.

As we shall have frequent occasion to refer to the migrations of locusts in other countries as well as our own, we will give a brief general review of locust movements in various parts of the world, limiting ourselves strictly to such facts as have a direct bearing upon the question under discussion. For the facts mentioned in this part of the chapter we are largely indebted to the following writers, but have endeavored, by a laborious consultation of the authorities quoted, so far as to be found in the Congressional and other libraries of our country, to verify these quotations:

K. Ritter.—"Die Heuschreckenplage der Länder der Alten Welt, nach ihrer geographischen Verbreitung." Ritter, Erdkunde, pt. 8, p. 789–815, 1843.

Adolph Keferstein.—"Ueber die schädlichen Heuschrecken." In Entomologische Zeitung, Stettin, 1843.

Fr. Th. Köppen.—"Ueber die Heuschrecken in Südrussland," St. Petersburg, 1866.

Numerous subsequent as well as older authorities not mentioned by these writers have been consulted.

The object in view in presenting the facts in relation to other species of locusts than our own is to draw therefrom conclusions in reference to the limits of their areas of permanent distribution; extent and directions of migrations; relations to faunal districts; powers and modes of flight; character of countries inhabited by them; effect of climatic influences; causes of migrations, &c.

It is now well ascertained that there are but two species of true migratory locusts (*Pachytylus migratorius* and *Caloptenus italicus*) that prove injurious in European countries,* hence it is fair to conclude that the older accounts of locust invasions and locust devastations in Europe apply to one or the other of these species. The locust literature relating to this part of the world is very voluminous and much of it of very little value in determining any of the more important questions in reference to the natural history, habits, or specific characters, being chiefly valuable in determining the regions visited and the chronology of locust migrations.

Among the earlier accounts of the locusts in Europe we notice the following:

Pausanias,[1] who says he personally knew that these insects three times perished upon Mount Sigylus, though not from the same causes; once the sudden visitation of a hurricane dispersed them; a second time the evaporation of a severe heat following upon a rain-storm destroyed them; and the third time they perished through a sudden cold.

Livy[2] states that in the year of Rome 579 (B. C. 75), the whole Pomptine district was covered with clouds of locusts.

Pliny[3] remarks that—

> There is another mode also in which these creatures perish; the winds carry them off in vast swarms, upon which they fall into the sea or standing waters, and not, as the ancients supposed, because their wings had been drenched by the dampness of the night. The same authors have also stated that they are unable to fly during the night in consequence of the cold, being ignorant of the fact that they travel over lengthened tracts of sea for many days together, a thing to be the more wondered at, as they have to endure hunger all the time as well, for this it is which causes them to be thus seeking pastures in other lands. * * * As they fly they appear to be larger than they really are, while they make such a loud noise with their wings that they might read-

*We are fully aware of what is said in reference to other species migrating, but we speak here of "true migratory species," and, notwithstanding numerous statements to the contrary effect, we are satisfied there are but two European species entitled to this designation.

[1] Attica, lib. i, cap. 24.

[2] Lib. 42, cap. 2.

[3] Nat. Hist., lib. 2, cap. 29, Bostock & Riley's English Transl., Bohn's ed. iii, p. 35.

ily be supposed to be winged creatures of quite another species. Their numbers, too, are so vast that they quite darken the sun. * * * Those from Africa are the ones which chiefly devastate Italy; and more than once the Roman people have been obliged to have recourse to the Sibylline Books to learn what remedies to employ under their apprehensions of impending danger.

This statement of their coming over from Africa has been so generally accepted as true by subsequent writers, without investigation as to its truth, that we shall hereafter call attention to it, in order to show its improbability.

Julius Obsequens[4] states that "Before the birth of Christ about 170 years the pastures of Italy were covered, as it were, with clouds of grasshoppers, and about Capua a hundred years thereafter."

According to Gregory, of Turin,[5] two armies of locusts appeared, which, passing through Arvernum, came together in Romaniae, where a great battle was fought between the hosts and many slain. No date is given, but it appears from the context to have been about 558. Purchas, who quotes the same incident, says that "the two armies passing by Clermont into the Romanaick Territory (a place in France) there fought together, where many of them were killed; when Clotarius was about to fight with his son Chrannus."

The year 593 A. D., following a very severe and general drought, was noted for a very general invasion of locusts.[6] The particular sections devastated we are unable to ascertain.

In 852 immense swarms from the eastern regions invaded the west, penetrating into Gaul, their daily marches being computed at twenty miles a day; and their flights, as stated, being regulated by leaders who flew first and settled on the spot which was to be visited at the same hour the next day by the whole legion. These marches were always undertaken at sunrise.[7]

Cuspinian mentions an invasion of Gaul in 874.[8]

In the reign of Basilius, the Emperor (according to Georgius Cedrenus) the eastern parts were consumed by grasshoppers to such an extent as to compel the inhabitants to sell their children and at last to pass into Thrace. But afterwards a vehement wind carried the locusts into the Hellespont, but they were thrown back on the sands and, reviving to a large extent, wasted the countries adjoining, and Thrace also, for three years.[9]

The following chronological account of their migrations in Europe, from 874 to 1092, is taken from Keferstein's article before mentioned:

They visited Italy in 864.[10] In 870 they showed themselves in France

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[4] As quoted by Purchas on Insects. The full title of this quaint old work is as follows: "A Theater of Politicall Flying Insects, wherein especially the Nature, the Worth, the Work, the Wonder and the Manner of Right-ordering of the Bee is Discovered and Described." London, 1657, p. 197, *et seq.*

[5] Historia Ecclesiastica Francorum, lib. 4, ch. 20.

[6] Shaw's "General Zoölogy," vi, p. 137, probably following Aldrovandus.

[7] Shaw, *l. c.*—Purchas on Insects, *l. c.*—probably quoted from Aldrovandus.

[8] Purchas on Insects.

[9] Purchas.

[10] Cantor, Geschichte der merkwürdigsten Naturbegebenheiten auf unserer Erde, Bd. 2 (1804), 104.

and destroyed all vegetation so that a famine ensued.[11] In 872 they were in Germany in such masses that they swept clean in one night 150 acres of land where they alighted.[12] In 873 they again destroyed in France the entire crops, and a strong wind drove them into the canal (?).[13] This is probably the same invasion alluded to by Cuspinian. In 885 they again appeared in Italy, especially near Rome, and Pope Stephen II exerted himself in vain to extirpate them.[14] In the year 1034 everything near Constantinople was devoured by them until a strong windstorm drove them into the sea.[15] Just as destructively they showed themselves here again in 1092.[16]

The first invasion of Russia of which we find any notice is that of 1008, of Kiev, mentioned by Karamsin.[17] Köppen also mentions the following invasions of that country in the eleventh, twelfth, and thirteenth centuries. In 1095 the locusts came the 28th of August and covered the earth. The movement was to the north.[18] The same author is quoted for invasions in 1103 and 1195, but without particulars. The chronicle of Nestor (quoted by Köppen) mentions another invasion in 1237. In 1271 all the cornfields of Milan were destroyed.[19]

From 1333 to 1336 great swarms of locusts committed frightful ravages; they migrated from Servia into Hungary, spread from there farther over Poland, Bohemia, and Austria, and divided here into two bodies, one of which visited Italy, the other France, Bavaria, Suabia, and Saxony.[20]

Again, in 1338, the neighborhood of Halle, on the Saale, was greatly devastated by them.[21] In May, 1350, an innumerable multitude of grasshoppers of an unwonted greatness, and uncertain origin, appeared in the province of Catania, in Sicily, which consumed corn, vineyards, woods, gardens, and trees, eating the bark to the roots in one day, and then by a sudden wind were carried into the Ionian Sea and drowned; but, being afterwards cast upon the Sicilian shore, "caused by their stink a cruel plague in July following."[22]

According to Otho Frisingensis,[23] grasshoppers came out of Africa into Italy, and also into France, in 1353 and also in 1374, causing such a famine and plague that the third part of the people perished. This old writer asserts that at last they were hurried by a violent wind into the British Ocean.

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[11] Cantor, 104.

[12] Cantor, 104.

[13] Cantor, 105.

[14] Rathleff, "Acridotheologie," i, 43.

[15] Rembold, "Tractat von Heuschrecken," 13.

[16] Rathleff, "Acridotheologie," 37.

[17] History of Russia, i, 438, quoted by Köppen. See also the French translation.

[18] Karamsin Hist., ii, 172.

[19] Shaw, Genl. Zoöl., vi. 137, from Aldrovandus.

[20] Cantor, 226; Keferstein, *l. c.*; Kronika Marcina Bielokiego, 1764, 189; Joannis Dlugossi, "Historia Polonica," T. i, lib. ix; Köppen, 111–112.

[21] Durhaupt, "Beschreibung des Saalkreises," Th. i, p. 645. 1749. Keferstein.

[22] Tazellus, quoted by Purchas.

[23] Purchas on Insects.

Rathleff[24] says that in 1354 they laid waste Italy and the fruitful provinces of Switzerland. This is probably the same invasion mentioned by Otho Frisingensis. Cantor[25] also mentions the invasion of 1374, adding that they again appeared in France in such masses that they reached even to England.

Shaw[26] (probably following Aldrovandus) states that in 1339 all the corn-fields of Lombardy were destroyed by the locusts.

In 1231 the locusts were so destructive in Puglia Daunia, a province of Naples (?) that the Emperor Frederick II promulgated a special law requiring every agriculturist, during their invasion, to collect every morning at sunrise four measures and present them to the magistrates, who were required to burn them.[27]

For a hundred years after the great invasion of 1374 Europe appears to have been comparatively free of these troublesome pests, at least the voluminous locust literature of this grand division is silent in reference to this long period.

In August, 1475, the insect storm proceeding from Hungary fell upon the oft devastated lands of Poland, Moravia, and Silesia. The swarms were so immense that they covered the sun like a thick cloud.[28]

Following this invasion there appears to have been another exemption of fifty years, the next appearance of note being in the year 1527, when they appeared again in Poland; and in 1536 in Hungary, traversing Lithuania and Poland to Schleswig.[29] Georgi says that in 1527 they came out of Turkey, and in 1536 from the Black Sea. Shaw gives 1541 as the date of another visitation to Poland; Georgi states that in 1542 a great swarm passed through Poland and Lithuania to Prussia and also visited Silesia. Rivero Pontano, as quoted by Lucretiis, says that "in the summer of 1541 a great army of locusts flew through Germany into Italy, towards our region. Wherever this swarm extended it devoured everything in its path, for the locusts were very large and numerous." Keferstein says also in reference to this invasion, that some passed forward over Silesia and Saxony, while others turned themselves toward Austria and Italy; and that again they were in Austria and Tyrol in 1544 and 1547. The invasion of Saxony is also mentioned by Ruyschet.[30]

In 1542 an immense multitude spread over a great part of Europe.[31]

John Exel, as quoted by Purchas, says that about Misnia in 1543 there were so many grasshoppers that they covered the ground about a cubit thick." We may remark here that our observations of the Rocky Mountain locusts have taught us not to treat all such statements as this

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[24] Acridotheologie, i, 47. Keferstein.

[25] 240—Keferstein.

[26] Gen'l Zoöl., 6, 137.

[27] Gaetano de Lucretiis, "On the Flight of Locusts." Atti del Real Instituto Sci. Nat. Napoli, 1811, 233 *et seq.*

[28] Cantor, 265—Kefferstein; Dlugoss, ii, 535-540—Köppen.

[29] Rathleff, i, 48—Kefferstein; Georgi "Geogr.-physik. Beschr. des Russ., 2058"—Köppen.

[30] "Wahrhaftige Zeitung, in Schlesien, geschehen, 1542."

[31] Paulus Draconus—from Purchas; Ruyschet, e. c.

as wholly imaginary. That locusts ever fell at any time or in any country a cubit thick over an extended area, we do not believe. But it not unfrequently happens that they are driven by a storm and lodged in a ravine, against a bank, fence, or other obstruction, to the depth of several inches, or even a foot or more. Purchas[32] remarks that "great droughts produce them, at least cause a prodigious increase of them; in 1553, after five years' drought, were great armies of them." In the tenth year of the Emperor Maurice, after a great drought, extending from January to September, there were infinite numbers of locusts in Italy, which caused a two years' famine.

Valleriola[33] notices an invasion of Arles in 1555. An invasion of Mailand in 1556 is also mentioned.[34]

For another hundred years from this time Russia appears to have been so little afflicted by the locust pest that Köppen fails to note a single invasion of that country. But after a rest of forty years they again appear in Italy, and Lucretiis[35] informs us that—

> So great were the injuries caused in 1571 in this country that the Vice Duke of Alcala, D. Parafante de Ribera, was obliged to put forth by the vote and advice of the royal council on the 8th of October, 1572, the first pragmatic decree *De Bruchis*, title 23, by which it was ordered that the communes should appoint experts and practical men to explore their territories and to search out all the places in which the locusts had deposited their eggs; and when found they were to dig trenches in the months of September and October through which operation the eggs might be destroyed. And in the month of April the swine are turned loose to devour the locusts, of which they are very gluttonous. The housewives also spread sheets or pieces of cloth at convenient times, long and large, upon which the locusts alighting are folded up and entrapped.

In 1613, in the month of May, a supposed new species of locust appeared in Provence which destroyed the entire crops.[36]

It appears from two papers, one by Bart. Xim. Paton[37] and the other by Juan de Quinones,[38] of which we have seen only the titles, that Spain was afflicted in 1618 or 1619, probably by *C. italicus*.

The account of the locust swarms seen in the Ukraine in 1645 and 1646 by Beauplan[39] is so interesting that we give it here:

> The grasshoppers, or locusts, which are there so numerous that they put me in mind of the scourge which God sent upon Egypt when he would punish Pharaoh. I have seen this plague for several years one after another, particularly in 1645 and 1646. These creatures do not only come in legions, but in whole clouds, five or six leagues in length and two or three in breadth, and generally come from towards Tartary; which happens in a dry spring; for Tartary and the countries east of it, as Circassia,

[32] *Loc. cit.*

[33] Curationes medicales, Lib. ii, Ob. 1.

[34] W. Strauch. "Naturliche Conterfeyhung des gewaltigen Fluges Heuschrecken." Hagen.

[35] *Loc cit.*

[36] Rembold "Von Heuschrecken," 45—Keferstein; A. Bersandier "Discours sur le dégât que les sauterelles firent en Provence, 1613–1614."

[37] "Discorso de la langosta, que en el tiempo presente aflige y para el venidero amenaza," 1619.

[38] Tratado de las langostas muy util y necessario, en que se tratan cosas de provecho y curiosidad para todos los que professan letras divinas y humanas y las mayores ciencias. Madrid, 1620.

[39] "A description of the Ukraine," in Churchill's Voyages, i, p. 541.

Bazza, Mingrelia, are seldom free from them. These vermin being drove by an east or southeast wind, come into Ukraine, where they do much mischief, eating up all sorts of grain and grass; so that wheresoever they come, in less than two hours they crop all they find, which causes great scarcity in provisions; and if the locusts remain there in autumn, and the month of October, which is the time when they die, after laying at least three hundred eggs apiece, which hatch next spring, then the country is three hundred times worse pestered. But if it rains when they begin to hatch they all die, and the country escapes that year unless they come from other parts. It is not easy to express their numbers for all the air is full and darkened; and I cannot better represent their flight to you than by comparing it to the flakes of snow in cloudy weather drove about by the wind. And when they alight upon the ground to feed, the plains are all covered, and they make a murmuring noise as they eat, where in less than two hours they devour all close to the ground. Then rising they suffer themselves to be carried away by the wind, and when they fly, though the sun shines never so bright, it is no lighter than when most cloudy.

In June, 1646, having staid two months in a new town, called Novogorod, where I was building a citadel, I was astonished to see so vast a multitude, for it was prodigious to behold them, because they were hatched there that spring, and being, as yet, scarce able to fly, the ground was all covered and the air so full of them that I could not eat in my chamber without a candle, all the houses being full of them even to the stables, barns, chambers, garrets, and cellars. I caused cannon powder and sulphur to be burnt to expel them, but all to no purpose: for when the door was opened an infinite number came in and the others went out fluttering about. And it was a troublesome thing when a man went abroad to be hit on the face by those creatures; sometimes on the nose, sometimes on the eyes, and sometimes on the cheek, so that there was no opening one's mouth but some would get in. Yet all this was nothing, for when we were to eat these creatures gave us no respite, and when we went to cut a bit of meat we cut a locust with it, and when a man opened his mouth to put in a morsel he was sure to chew one of them. * * * I have seen them at night, when they sit to rest them, that the roads were four inches thick of them one upon another, so that the horses would not trample over them but as they were put on with much lashing, pricking up their ears, snorting, and treading very fearfully. The wheels of our carts and the feet of our horses bruising those creatures, there came from them such a stink as not only offended the nose but the brain. I was not able to endure that stench, but was forced to wash my nose in vinegar and hold a handkerchief dipped in it continually to my nostrils.[40]

In 1650 Lithuania and Poland were again visited,[41] and in 1662 the province of Puglia Daunia.[42] In 1684 an immense number appeared in Hungary and Austria.[43] In the year following an immense swarm fell near Avignon.[44]

In 1689 another general invasion of Northern Europe began, striking first Lithuania and Poland[45] reaching Volhynia in Russia in 1690.[46] According to Rembold,[47] they were also abundant in Ukraine. In 1693 they swept in immense swarms through Hungary, Bohemia and Austria

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[40] Also "Gentleman's Magazine," 1748, August, p. 363.

[41] Köppen, 114.

[42] Lucretiis, *l. c.*

[43] Rembold, 325.

[44] H. Justell, Phil. Trans., 1686, vol. 16, p. 147.

[45] Jean Gallois, "Observations sur les sauterelles qui ont ravagé la Pologne et la Lithuanie in 1689"—Mem. Acad. Sci. Paris, *v.* 2, 88.

[46] Stoikoovitsch, "Uber die Heuschrecken und die Mittel ihrer Vertilgung," 1825, s. 8—Köppen; S. Ussans, "Particularités remarquables des Sauterelles qui sont venues en Russie," 1690.

[47] P. 18—Keferstein.

into Germany, destroying the crops in their pathway. Ludolf, who was an eye-witness of this invasion gives the following account of it:[48]

We had already entered upon the autumn of the year 1693, when the first intelligence was heard of the descent of locusts; they had come over on the 3d of August into Austria from Hungary, and farther eastward. From there they went into Bohemia, and apssed into Voigtland, and into the regions of Altenburg; then they flew across the Saal, and came finally within twenty days to Thuringia. There were so many millions of them that they showed thence like black clouds. In the daytime when it began to grow hot they raised themselves from the earth and sought new pasture ground, but by night they lay a hand (or even half a foot) deep on the ground and consumed everything that was green. Some mounted upon the trees, and in such multitudes that they bent the branches down to the ground. On the 18th of August they came through Jena, but these were only the forerunners; on the 20th of August at noon they flew over the city in indescribable multitudes. There were three bodies which followed at a certain distance from each other, and with such a noise as if a great stream were falling from a considerable height into the depths. A south wind struck them and drove them toward the north, on to the mountains lying nearest, where indeed they destroyed all the grass, but spared the vines and most of the trees. The day afterwards as on the third day about nine o'clock they mounted in a clear sunshine; by three o'clock in the afternoon they were all assembled together, and flew away as one army; only a few remained behind. They came to Weimar on the 20th of August about noon, and covered the ground two hands high about the city. All the locusts were yellow, but the males were smaller and brighter, females darker. Swans, ducks, and hens, as well as swine, eat of them greedily. There ensued a cold rain and frost so that they could go no farther, and so they perished at Naumburg and in other regions of the Saal after they had lived in those parts four weeks. The people feared for the next year, but nothing farther was observed of new locust swarms.

France, Italy, and the other parts of Southern Europe appear to have escaped the scourge at this time, but from a letter in the Philosophical Transactions (vol. 18, No. 208), it would appear that they reached Wales.[49]

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[48] App. 2 to Hist. Aethiop.

[49] This invasion gave rise to quite a number of papers, of which we note the following: *L. Ch. Crell*, "Dissertatio de Locustis non sine prodigio nuper in Germania conspectis." Lipsiæ, 1693.—*G. Wolf. Eberlin*, "Oratio de prodigioso locustarum agmine quod in diversis Pannoniæ et Germaniæ tractibus obumbravit solem, terrasque opperuit, an. 1693." Altdorf, 1693.—*G. E. Fesken*, "Gottes bedenkliches Heuschrekken-Heer, welches sich hin und wieder neulicher Zeit in ungewohnlicher Menge sehen lassen." Leipsig, 1693.—*Melissander Fichtelberger*, "Heu! Schrecken! Von Heuschrecken, So dieses Anno 1693." St. Annaberg, 1693.—*J. P. Hebenstreit*, "De locustis immenso agmine aerem nostrum implentibus, et quid portendere, &c." Jenæ, 1693.—*Same author*, "De remediis adversus locustas, imprimis Pontificiorum methodo expellendi eas per excommunicationem." Jenæ, 1693.—*Caspar Kirchmaier*, "De Locustis insolitis tergemino examine et portentoso numero e Thracia Daciaque in Pannoniam inferiorem perque Austriam in Germaniæ regionibus plures sese infundentibus, &c." Wittenberg, 1693.—*Ab. Klesel*, "Bericht von dem 1693 geschehenen Durchzuge der Heuschrecken." 1693.—*Christoph Loeber*, "Mit Gott! Eigentliche Beschreibung des entsetzlich grossen Heuschrecken-Heers welches in August—A 1693 bei und unweit Jena, &c." Jena, 1693.—*Also*, "Beschreibung des Heuschrecken-heeres." 1694.—*I. Ph. Freuner*, "Dissertatio phænomena locustarum præcipue nuperrimarum." Jena, 1693.—*G. A. Wollenhaupt*, "Dissertatio locustas et portentosam earum nubem, &c." Erfurt, 1693.—*Anon*, "Eine Heuschreckliche Schreckruthe so zu Plauen im Voigtlande am 15, und folgenden Tagen Augusti dieses laufenden Jahres 1693 sich merklich blicken gelassen, &c." Dresden, 1693.—*Anon*, "Heerzug der Heuschrecken." Leip, 1693.—*N. Hoepfner*, "Abhandlung über die Sturmwinde und Heuschrecken." Gera, 1694.—*Job Ludolf*, "Appendix secunda ad historiam Æthiopicam." 1694.—*E. Floyd*, "A letter giving an account of locusts lately observed in Wales." Phil. Trans, 1694, v. 18, No. 208.—*G. Owen*, "Extract from his history of Pembrokeshire," Phil. Trans, 1694, vol. 18, No. 208.—*Casper Neuman*, "Donnerwetter und Heuschrecken, beide im Jahr Christi 1693 zu Breslau gesehen." Breslau, 1694.—*Carl Rayger*, "De locustis volantibus," Ephem. Acad. Nat. Curios. 1694, Dec. 3, p. 29. Also, Rembold, 19; and Dreihaupt, 645, and accounts given in Ritter, Kefferstein, Fischer, Köppen, &c.

After the locusts had shown themselves repeatedly here and there in Germany until 1696 they disappeared.

In 1708 the numerous invasions of the eighteenth century commenced, culminating in the memorable irruption of 1747–'52, which spread over Europe from Turkey to Wales. We can do but little more than give dates of this busy locust century. In 1708 they came out of Wallachia and passed through Poland into Russia.[50] In 1710 a vast swarm for a time spread alarm through the army of Charles XII in Bessarabia.[51]

In 1712 they passed through Gallicia to Germany, and in this or the following year were very severe in Silesia. This invasion must have been much more severe than the brief notice given it by Ritter, Keflerstein, Fischer, and Köppen would indicate. It appears to have continued for three or four years and to have spread to Italy if we may judge from the following papers which appeared at that time.[52]

Italy was again visited in 1727, and parts of it severely ravaged. In 1730 to 1732 they visited Germany, penetrating to the vicinity of Berlin.[53]

In 1747–'48 the great locust swarm of the century, starting from Turkey,[54] spread through Wallachia, Moldavia, Transylvania, and Hungary, and from thence, in 1749, passed into Austria, Bavaria, and Germany, reaching Brandenburg in 1750. The Ukraine, Poland, and Silesia were also visited. Nor did the vast horde cease its onward course until it had penetrated into England and Scotland. In England they were especially destructive in Norfolk, Stafford, Cheshire, and Derbyshire.[55]

In 1759 they again visited Italy;[56] parts of Russia were invaded at intervals from 1783 to 1802, but no swarm entered Germany until 1803, and then only crossed the eastern border;[57] but in 1825, 1826, and 1827 various parts of this country were visited by them. From 1812 up to 1860, according to the record given by Köppen, some part of Southern

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[50] Georgi—in Koppen.

[51] Demole, Stoikoovitsch, Köppen, Keferstein, and Capellan.

[52] *J. Chistoph Ortlob*, "Dissertatio de præsagiis locustarum incertis et falsis." Lipsiæ, 1713.—*Paul Jetzen*, "Conjecturæ de ominosis locustis quæ æstate superiore Silesiam depopulatæ sunt, &c." Sedini, 1713.—*Same*, "Muthmaasungen von den wundersamen Heuschrecken welche im vorigen Sommer in Schlesien grossen Schaden gethan, &c."—Stettin, 1713.—*S. C. Loeber*, "Epistola de locustis." Ephem. Acad. Nat. Curios. 1715, cent iii, iv. app., 137.—*Guiseppe del Papa*, "Relazione delle diligenze usate con felice successo nell' anno 1716 per distruggere le cavallette, le quali avevano stranamente ingombrato una gran parte delle Maremme di Pisa, di Siena di Volterra, e tutte le campagne di Piombino, Scarlino e Sovvereto." Firenze, 1716.—*Tommaso Buonaventuri*, "Relazione delle devozioni ed opere di pieta che si son fatte nell' anno 1716 per ottenere da Dio la grazia di discacciare le cavallette che infestavano le Maromme di Pisa, di Siena e di Volterra. Firenze 1717.—*Francesco Scufoni*, "Osservazioni intorno alle cavallette." Romæ, 1718. We have seen only the titles of most of these papers, and notice them simply as indications of a more destructive invasion than generally supposed by European writers.

[53] *Keferstein.—J. L. Frisch*, "Beschreibung von allerley Insecten in Teutschland, &c.," T. 9, p. 6 See, also, C. H. Rappolt, "E generali contemplatione, &c." Berlin, 1730, and *Anon.*—"Edict wegen Vertilgung der Heuschrecken der Sprengsel; sub dato Berlin, 13 April, 24 Oct., 1731," in corpus. constitut. Marchic, 1740, v. 5, pt. 3.—*J. F. Wiedler*, "Narratio de erucarum et locustarum quæ agros Vittenburgæ vicinos aliquot abhinc annis vastarunt, interitu," Phil. Trans. 1734, v. 38, p. 294.

[54] Fischer Orthoptera Europea," 292.

[55] Keferstein, Fischer, *l. c.*—Ritter—Rathleff Acridotheologie in preface.—Köppen 115—Keunitz "Art Heuschrechen, in Ocon. Encyc."—Shaw Genl. Zool. 130.—Phil. Trans. v. 46. Gentleman's Mag., v. 18, p. 362. Also the various articles to which this invasion gave origin, too numerous to be mentioned here.

[56] Lucretiis.

[57] Keferstein.

Russia has suffered from them almost every year. As we shall have occasion hereafter to refer to such of these migrations as afford facts bearing upon the questions under discussion, we will omit further mention of them here.

According to Koerte[58] Germany has been visited in some part of its territory by the locusts the following years since the middle of the fifteenth century: 1475, 1527, 1636, 1686, 1693, 1696, 1712, 1714, 1715, 1719, 1727, 1728, 1729, 1730, 1731, 1734, 1746, 1747, 1748, 1749, 1750, 1752, 1753, 1754, 1759, 1763, 1803, 1825, 1826, 1827.

In Spain[59] the chronicles of locust visitations have distinguished the following years as the most noted: 1495, 1542, 1547, 1619, 1682, 1688, 1792.

An examination of Köppen's chronological record of locust migrations to European Russia and the adjoining provinces on the south shows the following dates of visitations to some one or other section of this area: 1008, 1092, 1094, 1095, 1103, 1195, 1237, 1333, 1334, 1335, 1336, 1475, 1527, 1536, 1542, 1650, 1689, 1690, 1693, 1708, 1710, 1712, 1747, 1748, 1749, 1750, 1756, 1757, 1783, 1793, 1799, 1800, 1801, 1802, 1803, 1805, 1806, 1812, 1813, 1814, 1815, 1816, 1820, 1821, 1822, 1823, 1824, 1825, 1828, 1829, 1830, 1831, 1832, 1834, 1835, 1836, 1843, 1844, 1845, 1846, 1847, 1848, 1850, 1851, 1853, 1856, 1859, 1860, 1861. Dates subsequent to 1861 are omitted from this list though given by that author.

In our notice of locust movements on other parts of the Eastern continent we shall not attempt to give the accounts in chronological order, or to pay any particular attention to dates, but to quote such facts as will assist in determining the areas visited, the direction of flight, the faunal districts to which the species appertain, &c.

Locusts in Asia and adjacent islands.—The monumental remains of Nineveh and Babylon reveal the fact of their presence, showing that they were used as food. They are also very distinctly figured on a cylinder, as mounted upon and feeding on some kind of shrub, the antennæ, long posterior legs, and abdominal segments being clearly shown[59a]. The accurate and striking description given by Joel is so exact that we think it evident the species was *Pachytylus migratorius;* but the remarkable fact which corroborates this opinion is the unusual direction of movement, as will hereafter be seen.

> But I will remove far off from you the *northern* army, and will drive him into a land barren and desolate, with his face toward the east sea and his hinder part toward the utmost sea[60].

Diodorus Siculus[61] says, speaking of the Acridophagi "over against Babylon," that—

> In these parts in the time of the spring, the south winds rise high and drive an infinite number of locusts out of the desert of an extraordinary bigness, furnished with

[58] "Die Strich—, Zug- oder Wanderheuschrecke." Berlin, 1828. p. 6.

[59] Ignot de Asso. "Oryctolog. et Zool. Arragoniæ," 1764, p. 113 in Ritter's Heuschreckenplage der Alten Welt," p. 11.

[59a] Rawlinson's Ancient Monarchies, ii., 493. The "buzzing insect" mentioned in the Zendavesta probably refers to the locust.

[60] Chap. ii, 20.

[61] Booth's Transl., i, p. 170.

most dirty and nasty colored wings; and these are plentiful food and provision for them all their days.

In the year 62 of the Christian era a plague of locusts spread over Upper Mesopotamia, and devoured vegetation to such an extent that the Parthian campaign was stopped for want of forage[61a].

Capt. Charles C. Frankland[62], July 26 and 27, at Smyrna—

At this period an immense flight of locusts (which indeed had for some days shown themselves in great numbers) passed over the city, falling upon the roofs of the houses where they lay two or three inches deep, and tumbled into the sea in such quantities that they could be traced in continuous streams for many leagues from the land, resembling in color and appearance so many millions of broiled shrimps. These insects being brought by the sea-breeze into the harbor, were thrown upon the shore and against the quays in such masses that their putrified carcasses infected the air in all directions. The passage of these animals lasted during many days, and at night as they crossed over the disk of the moon, by reflecting the light as they shot across the face of the planet, they resembled so many flakes of snow, or almost as many shooting stars. The heat of the weather at this period (87°) was so intense that during the night I was always obliged to sleep with my windows open, the consequence of which was that the locusts used to tumble into my room and upon my musquito curtains, and by hopping about the floor, and creeping into my bed, generally annoyed me considerably.

He observes further that there were two kinds, one more lubberly and less active than the other. M. Lefebvre[63] states that during one of his voyages, while in the vicinity of Smyrna, "the earth was covered in a short time to the depth of about two inches with a quantity of insects appertaining to the species *Œdipoda cruciata* Charp."

Corance[64] observed during many years residence in the island of Cyprus, that regularly inside of two years swarms of locusts were thrown upon the north coasts of the island by the north wind, from the shores of Carmania, which completely laid waste the country. Hasselquist[65] remarks that on his return from Cyprus to Smyrna they were becalmed for some days on the coast of Carmania, when they daily got some grasshoppers on board from the continent, and that he then was enabled to observe what miserable sailors these insects are. He observes that in the month of May and June a number of them were seen coming from the south, directing their course to the northern shore. "They darken the sky like a thick cloud, but scarcely have they quitted the shore before they, who have ravaged and ruined the country, cover the surface of the sea with their dead bodies." He says they come from the deserts of Arabia, take their course over through Palestine, Syria, Carmania, Natolia—go sometimes through Bithynia by Constantinople, and continue their journey through Poland, &c. An assumption we think in great part unwarranted.

It is somewhat singular that neither of the early travelers in Palestine—Arculf, Willibald, Bernard the Wise, Seawulf, Sigurd the Crusa-

61a Tacitus, Ann., xv, 5.—Rawlinson, Sixth Orient. Mon., 273.

62 "Travels to and from Constantinople in 1827-'28," vol. i, 264.

63 Annales Soc. Ent. France, 1833, ii, 338.

64 "Itinéraire," Paris 1816, p. 238.—Ritter.

65 "Voyages and Travels in the Levant, 1749-'52." Engl. transl., 444.

der, Benjamin of Tudela, Mandeville, Bertrandon de la Brocquiere, or Maundrell—makes any mention of the locusts. The same thing is true in reference to De Velde, to Rev. J. L. Porter, who resided for five years at Damascus; to Stevens, Stanley, and a host of other travelers in this part of Asia; which is strong negative evidence that there are numerous and considerable periods of rest from this plague in this part of Asia, where it is supposed to be so constantly found.

Olivier[66] relates that following the south wind, great clouds of locusts come up out of the interior of Arabia and the southwest regions of Persia, into Syria and Mesopotamia. He was twice an eye-witness of their invasions, the species being *A. peregrinum.* He observed this species in Egypt, Arabia, Mesopotamia, and Persia. The neighborhood of Aleppo is frequently ravaged by locusts.[67] In the year 1800, J. Morier observed their devastations in the region of Smyrna, and describes the perfect insects as 3½ inches long from the head to the end of the legs; of a red color. He states that they remained until July and August upon the fields, "driven now inland, now oceanwards by the winds."[68] R. R. Madden[69] states that in Smyrna he has seen the sky literally black with them; and that they appear always to travel in a straight meridional line, and thus all the line of country in their course is laid waste by them. Irby and Mangles[70] observed them at Shobek (near Mount Hor), and were told by their guide that they were on their way to Gaza, and that they pass almost annually. Chesney[71] says the fields of Asia Minor suffer comparatively little from locusts, but that they are not wanting in Syria. W. G. Palgrave[72] encountered the locusts on the Hasa plain, where he says they had alighted in their northerly wanderings from their birth-place in Dahna. He speaks of them as being reddish-brown and of large size.

M. Niebuhr, who was accompanied by Förskal in his travels through Arabia and other eastern countries, gives some important items of information in reference to the locusts of these regions. He says they did not find the numbers so great as they are commonly supposed to be in Europe. In Egypt he once only saw a cloud, which was brought by a south wind from the deserts of Lybia and fell in Cairo. In November, 1762, he observed a large cloud of them at Jidda, which was driven over the city by a west wind from the other side of the Arabic gulf. He adds, "Therefore, many of the insects must have been drowned in their passage." In July following he found a small quantity near Mount Sumara, which seemed to have spent the season in Arabia. "These swarms often cross the Red Sea a second time and return to Egypt, the upper part of which, adjoining the deserts of Lybia, seems to be the

[66] Travels in Syria, 2, 695.
[67] Russell's Aleppo, p. 407.
[68] "Second Journey," 99.—Ritter.
[69] Travels in Turkey, Egypt, Nubia, and Palestine, 1824-'27, ii. 30.
[70] Travels in Egypt and Nubia, Syria and the Holy Land. Murry's ed., 136.
[71] "Expedition to the Euphrates," vol. i, 362 and 537.
[72] "Narrative of a Year's Journey through Central and Eastern Arabia, 1862-'63," 2d ed., pp. 137-8.

cradle of these animals." He often saw clouds of them in Persia and Syria. The species found in Arabia was named by Mr. Förskal *Gryllus gregarius*, which, he thinks, is different from that named by Linnaeus *G. migratorius*.[73] "Jidda or Dsjidda," according to his map, is in Arabia, on the Red Sea, latitude 21° 28′, near Mecca.

Volney,[74] speaking of Syria, states that the inhabitants of Syria have remarked that the locusts are bred by mild winters, and that they always come from the deserts of Arabia. That the south and southeasterly winds drive with violence these clouds of locusts over the Mediterranean, where such quantities of them are drowned that when their carcasses are thrown on the shore they infect the air for several days, even to a great distance.

St. Jerome speaks of seeing the thickest swarms traversing Palestine and laying waste the land.[75]

While Olivier found the destructive locusts in a great part of Northern Persia, other travelers met with them along the southern borders of this country. Chardin saw near Bender Abassi, in the middle of March, 1674, so vast a cloud that the sky was completely darkened by them. They were red and very large.[76] J. Morier has, in his opinion, met with the same species (which Kefferstein correctly supposes cannot be *G. migratorius*) in the year 1811, at exactly the same season, near Abuschahr, during a southeast wind. The insects had legs three inches long, body and head a bright yellow.[77] He also observed them at Shiraz the 11th of July, driven by a southwest wind. Ousley[78] also observed locusts in the southern part of Persia. They also visit Kurdistan and Southern Media.[78a]

Burkhardt[79] asserts that Nedjed, or the central and elevated portion of Arabia, is especially subject to the ravages of the locusts. That when they have devoured the crops they enter the huts of the inhabitants, even into the innermost chambers, eating everything, even to the leather and water-bottles; and that they multiply rapidly and to fearful numbers by a three times repeated laying of eggs. He further states that when he visited the peninsula of Sinai in 1816 the locusts had already for five continuous years destroyed the harvests. The same writer[80] remarks as follows, in reference to the Syrian locusts:

> It was at Naeme (a place east of the Jordan) that I saw for the first time a swarm of locusts; they so completely covered the ground that my horse killed numbers of them at every step. This species is called in Syria *Djered Nedjdyat* or *Djerad Teyar*, that is, the flying locusts, being thus distinguished from the other species called *Djerad Dsahhaf* or devouring locusts. The former have a yellow body, a gray breast, and wings of a

[73] "Travels through Arabia and other Countries in the East." Heron's translation, ii, 324 *et seq.*

[74] "Travels through Syria and Egypt in the years 1773-'75." Translated into English, i, 305.

[75] Comment. on Joel, chap. 2.

[76] "Voyage," vol. ii, p. 221.—Ritter.

[77] "2d Journey," 43.—Ritter.

[78] "Travels," i, 195.

[78a] Rich. Kurdistan, 173; Kinneir, p. 43; Chardin, iii, 44.

[79] "Notes on the Bedouins and Wahabis," ii, 89.

[80] "Travels in Syria and the Holy Land," 238.

dirty white, with gray spots. The latter, I was told, have a whitish gray body and white wings.

He states that the former are much less dreaded than the latter.

Pallas[81] asserts that *Gryllus italicus* appears annually on the dry eminences in the arid southern regions from the European boundary as far as the Irtish and the mountains of Altai, but that it is only in particular years it multiplies in such numbers as to become pernicious. The larger species, *G. migratorius*, which is also common in this region, is also frequently observed mingled to a certain extent in the swarms of the former. Dr. Clark, who traveled over the steppes of Tartary, observed immense swarms of both species; but has confused the names of the species by designating the former (*C. italicus*) as *G. migratorius* and the latter (*P. migratorius*) as *G. tartaricus*. He says his guide informed him that instances had occurred of persons being suffocated by a fall of locusts on the steppes.[82]

In 1770, great swarms of *G. migratorius* appeared north of the Irtish in the Barbara Steppe.[83] On the west side of the Caspian Sea the locust plague appeared in Georgia and near the mouth of the Volga, almost always with the south wind, borne in great clouds out of Eriwan toward Georgia and Daghistan.[84]

The following, from a daily paper, applies to 1878 or 1879:

A plague of locusts.—A detachment of Russian troops, bound for General Lazeroff's expedition against the Turcomans, met with a curious misadventure near the Georgian town of Elizavetopol. At a few versts from the town the soldiers encountered the wing of an army of locusts, reputed to be twenty miles in length and broad in proportion. The officers in charge did not like to turn back, repelled by mere insects, and, pushing on, soon became surrounded by the locusts. These appeared to have mistaken the soldiers for trees, and swarmed by thousands around them, "crawling over their bodies, lodging themselves inside their helmets, penetrating their clothes and their knapsacks, filling the barrels of their rifles, and striving to force themselves into the unfortunate men's ears and noses." The commander gave the order for the troops to push on double-quick for Elizavetopol, but the road was so blocked with locusts that the soldiers grew frightened, and, after wavering a few minutes, a regular stampede took place.

Led by a non-commissioned officer of keen vision, who had observed a few huts a short distance from the road, the troops dashed across the fields, "slipping about over the crushed and greasy bodies of locusts as though they had been on ice." The huts were soon reached, and the officers rushed inside, but the refuge proved to be of little value, as the premises were already in the possession of the enemy. The peasants told the correspondent of the *Karkas* that for days they had been besieged by the vermin, the insects filling the wells and tainting the water, crowding into the ovens and spoiling the bread and preventing any food being cooked or stored. At intervals the villagers issued from their houses and made onslaughts on the locusts, killing them by thousands, and carting them away afterward to the fields for manure. The soldiers were detained prisoners by the insects for forty-eight hours, and on their march to Elizavetopol in the rear of the locust army they found every blade of grass and green leaf destroyed and the peasants reduced to beggary.

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[81] "Travels through the southern Provinces of the Russian Empire," Engl. transl., ii, 4, 22.

[82] "Travels in Russia, Tartary, and Turkey," 4th ed., i, 133.

[83] Georgi "Siberische Reise," pt. i, p. 28.—Ritter.

[84] Gamba "Voyage dans la Russie meridionale 1820–'24," ii, 226.

The locusts also often commit great ravages in China, and especially in the Province of Xensi.[85] In the year 104 B. C. a swarm arose in the east and flew through Turhoung, near Jumen—Thor at the entrance of the desert of Loj, in Western China—and the consequence was so great a famine that the campaign which the Emperor Wan Li was prosecuting had to be abandoned.[86] Navarette[87] says that in the reign of the Emperor Tai-Zung (about A. D. 636) immense swarms of locusts infested China, and that this noble Emperor, to stay the plague, took up a locust in the presence of the people and ate it, and immediately the locusts left his empire.

Ma-tuan-lin, in his grand encyclopedia entitled Wen-hein-tun-kao, registers year by year the locust devastations for a period of 1924 years, in which are recorded 173 visitations.[88]

John White[89] witnessed such flights of locusts in the island of Manila in 1819 that he was for hours protected from the rays of the sun by the passing swarms. "Fortunately," he adds, "this is not the case every year, and many years have elapsed without an invasion." He simply describes them as brown and resembling the large flying grasshopper. It had at the time he wrote not been satisfactorily ascertained from whence they came, whether from a distance or near at hand. Paul De la Gironiere[90] asserts that the locusts almost regularly every seven years leave the isles of the south in clouds and fall upon Luzon, bringing desolation and even famine. He describes their appearance in flight as a "fire cloud in the horizon." The figure given in his work is beyond question that of an *Acridium*. A more recent traveler to these islands, F. Jagor, confirms the statements of Gironiere as to the locust visitations, but adds in a note that the species is identified by Gerstäcker as *Oedipoda subfasciata* of Haan—*Acridium manilense* of Mayen.[91]

In the East Indies, according to Wahl,[92] there were found not only the destructive army locust (*G. migratorius*), but also a kind of yellow locust called Tscheddy, which often covers whole fields and darkens the air like a cloud.

Major Moore[93] was an eye-witness in Poonah how a swarm of locusts laid waste the country of Mahratta, and was supposed to have come out of Arabia. Their flight (or column) is supposed to have extended over five hundred miles.[94] The species is described as blood-red, and as different from *G. migratorius*. The Bombay *Courier*[95] states that a great

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[85] "Reise der Hollandischen Gesandtschaft nach China vom Jahre 1655-'57," p. 356.—Kefferstein.

[86] Ritter, p. 7.

[87] "An Account of the Empire of China," Churchill's Voyages, i, 95.

[88] Alfonso Andreozzi, "Sulle Cavallette," &c.—Noticed in Bulletino, Soc. Ent. Ital., ii, 1870, p. 77.

[89] "Voyages to the China Sea," 140.

[90] "Twenty Years in the Philippines," 229.

[91] "Travels in the Philippine Islands," 273.

[92] Erdbeschreibung von Ostindien, B. 2, 844.—Kefferstein.

[93] According to Kirby and Spence. Introduc. pt. 1, 239.

[94] As no statement of this kind is found in Maj. Moore's "Narrative of Captain Little's Detachment," we presume the communication was verbal or by letter.

[95] January 21, 1826, as quoted in the Asiatic Journal, vol. 23, pg. 90.

swarm of locusts, which for two months have been scattered over Guzurate, flew in a cloud over Baroda on the 23d of December, and occupied a space of ten English miles in reaching their destination.

G. Playfair[96] gives an account of the appearance of locusts in the Doab.

Salt[97] states that while he resided at Bombay numbers of the same species of locust (as that he saw at Amphila, on the coast of Abyssinia) were sent down to Mr. Duncan from the upper country for the purpose of pointing out the insect which had at that time laid waste several extensive tracts of land in the interior. He describes and figures the species, showing it to be an *Acridium* closely allied to *A. peregrinum*. In an article from the South Australian *Register*, of Adelaide, Australia, December 19, 1871, January 2, 1872,[98] in reference to the locust visitation of that region the following statement incidentally occurs:

Mr. Horne related some of his experiences concerning locusts in India, the species being probably *Acridium peregrinum*. They were in such numbers that they could be collected by tons, and they were fed upon by almost every description of animal.

In the article last quoted is a very full account of the locust ravages in Australia in the latter part of 1871. From this it appears that they take their origin in the north part of the country, and move southward. One correspondent quoted states that the locusts appear more or less every year in some part of the colony, though seldom so numerous as at this time. There appears to be but one migratory species, briefly described as "female dirty-brown, and male bright yellow." They usually come in November and December, seldom remaining after the 1st of January.

On the 17th of December, about sundown, there was an immense flight at Glendg from the seaward. They were in countless myriads, and flying about nine or ten feet high. They had every appearance of having crossed the Gulf; at least they were in full force at the end of the jetty, and appeared to be making their way against the wind towards the hills. One of the Glendg fishermen states that he has, on previous occasions, seen locusts crossing the Gulf, and that he has while out at sea found his boat covered with them. A few days afterwards (December 20) the locusts arrived in force at Glendg, traveling rapidly southward. The right wing of the army rested on the coast line, but did not go further westward than the green herbage of the sand hills. On the bare sands only a few stragglers were to be seen, and scarcely any within three or four yards of the water.

Another severe visitation to this section of Australia in 1824 is also mentioned.

It appears that New Zealand also occasionally suffers from locusts, but we have been unable to find any account of their movements or ravages in these islands.

On the Isle of France and Madagascar swarms of locusts appear, which darken the sun.[99]

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[96] Trans. Med. and Phys. Soc. Calcutta, i, 1825, p. 103.

[97] Voyage to Abyssinia in 1808 and 1810, App. lxi.

[98] Quoted in Trans. Ent. Soc. Lond., 1872, xii.

[99] Bory de St. Vincent, "Voyage a l'Ile de Bourbon," i, 226.—Mandelslo, Morgenlandische Reise, 1658. ii, 171.—Ritter.

Northern Africa has a locust history reaching back to the days of the Pharaohs:

And Moses stretched forth his rod over the land of Egypt, and the Lord brought an east wind upon the land all that day, and all that night; and when it was morning, the east wind brought the locusts.

And the Lord turned a mighty strong west wind, which took away the locusts and cast them into the Red Sea.[100]

The fact of their passing over the Red Sea from one side to the other, or rather of going from Arabia into Egypt and returning, is noted by modern travelers.

The statements of Paulus and Orosius,[101] Julius Obsequens,[102] and Eutropius, in reference to the vast hordes of locusts cast into the sea on the coast of Cyrene during the consulate of M. P. Hypsaenus and M. F. Flaccus, and producing a pestilence that destroyed 800,000 people, hosts of cattle, fowl, and wild beasts, has been so often repeated that it is only necessary to mention it here in order to add that it is scarcely worthy of belief. The fact of the locusts being cast into the sea is valuable as adding one to many incidents of this kind. Leo Africanus[103] speaks of immense swarms in Northern Africa, especially in Mauritania. Among other old works which speak of locust ravages in Northern Africa and Abyssinia, but contain little that is of any value in the present discussion, we may mention the following: Job Ludolph[104] gives an account of locust ravages in Abyssinia, also in other parts of Northern Africa. Joano dos Santos[105] describes the terrible famine brought on the inhabitants of Eastern Ethiopia by the locust ravages. Frances Alvarez[106] speaks of the incredible multitude of locusts that fall upon the earth, and that hide the sun by their swarms. Nicolaus Clenardus[107] makes mention of seeing immense swarms at Fezzan.

One of the fullest accounts of the locusts of Northern Africa preceding the later investigations of the French naturalists is by J. G. Jackson.[108] He says "they are produced from some unknown physical cause, and proceed from the desert, always coming from the South." He remarks that—

In traveling from Mogodor to Tangier, before the plague in 1799, the country was covered with them. A singular incident then occurred at El Araiche. The whole country, from the confines of the Sahara to that place, was ravaged by them; but after crossing the river El Kos, they were not to be seen, though there was nothing to prevent them from flying across it: moreover, they were all moving that way—that is, to the north; but when they reached the banks of the river they proceeded eastward, so that the gardens and fields north of El Araiche were full of vegetables, fruits, and grain. * * * In the year 1799 these destructive insects were carried away into the

[100] Exodus, x, 13, 19.

[101] Contra Paganos, l. 5, c. 11.

[102] Cap. 30.

[103] "Geographical Hist. Africa," Engl. Transl., 349.

[104] "History of Ethiopia." Latin Ed., Bk. 1. n. xcvi, 13 and Gents transl., p. 67.

[105] "Pinkerton's Voyages," vol. 16, p. 717.

[106] Itinerary to Ethiopia.

[107] Epist. L. 1 p. 73, quoted by Ludolph, Latin Edn.

[108] "An Account of Morocco, &c.," 2d edn., p. 103, &c.

Western Ocean by a violent hurricane, and the shores were covered with their dead bodies.

He says that when the locust is young it is green; as it grows it assumes a yellow hue, and lastly becomes brown. The figure given in this edition, plate 3, is very poor; but the thorax shows that it is an *Acridium*, and about three inches long.

According to Shaw the locusts in 1724 began to gather in Barbary after a south wind had been some time blowing. Toward the middle of April they had so multiplied that they formed immense clouds, darkening the sun. About the middle of May, when about to deposit their eggs, they began to move backwards into the plains of Metidja and other adjoining regions, and when the young were fully grown they became more ravenous and swifter in flight than before. Yet this condition lasted not long, when they scattered themselves and laid their eggs; as, moreover, their flight and progress came always from the north (?) so it is probable that they found their death in the sea.[109] Morocco and Taflete are often visited by locust swarms which come in great flocks from the south; they often appear two or three times in the course of the year, and their flights are frequently followed by famine, and this by pestilence.[110]

On the 23d of September, 1761, Förskal observed a swarm come down in Cairo. The swarm was composed of the species he termed *Gryllus gregarius* (undoubtedly *A. peregrinum*).[111] He saw them again in January, 1762, flying over the Libyan desert with the southwest wind; and in November, 1762, Niebuhr observed them (?) again on his journey from the Arabian Gulf to Djedda, where they came up with the wind out of the west, across the Gulf, and continued their flight toward the east.[112]

Browne observed them in Darfur.[113] Light met with them on the 11th of May, 1814, in destructive swarms at the entrance into Nubia, going up the Nile from Egypt, near the island of Phila.[114]

Burkhardt[115] mentions finding them at Tacazze, in Nubia, and also at the same time in Belad al Taka, in Lower Mareb, which he calls their peculiar brooding-place, from whence they issue in destructive migrating swarms and lay waste the fields and pastures of Nubia.

In 1813 they devoured everything in the country of the blacks from Besber up to Shendy. Burkhardt affirms that the locusts are at home in the whole district of the Nile from Egypt to Sennaar, and in all the Nubian desert; that all the swarms which he saw in Upper Egypt came from the north, and that the Nubians declared they came from Upper Egypt to them [116].

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[109] "Travels in Barbary and the Levant."—French Transl. of la Haye, i, 331.—Keferstein.

[110] Host, "Moroco," p. 300.—Ritter.

[111] "Descriptiones animalium quæ in itinere orientali Observata, Forscal" p. 81.

[112] Beschreibung von Arabien 168.—Kefferstein.

[113] Travels, 226.—Ritter.

[114] Light, Travels in Egypt, p. 56.

[115] Travels in Nubia, 391.

[116] Ritter Heuschreckenplage der Alten Welt, p. 19-23.—Keffenstein, l. c.

In this connection we may add that Diodorus Siculus says "the west, north, northwest, and east winds blow in Ethiopia as in other parts of the world; but the south winds never blow, nor are ever known in Ethiopia"[117].

The visitation of Algiers by these pests in 1866 was so severe that it drew a special official circular from Marshal Canrobert. They first appeared during the month of April, coming from the gorges of the mountains and the fertile valleys of the Littoral. They descended first on the plains of Mitidja and the Sahel of Algiers. Their mass at certain points intercepted the light of the sun, and produced an effect similar to that of the snow-storms which in the winter season fall in Europe and blot out even the nearest objects from the sight. They deposited eggs which soon gave life to innumerable larvæ, so that the first swarms were soon replaced and centupled by new generations. They not only destroyed all vegetation, but filled up the water-courses, the canals, and the rivulets, so that the troops had the greatest difficulty in preserving the water from infection. Almost at the same time the provinces of Oran and Constantine were invaded at Heman, where no locusts had appeared within the memory of the oldest inhabitants. At Sidi-bel-Abbis, at Sidi-Brahim, and at Mostaganen they attacked not only the tobacco plantations, the vines, and the fig trees, but also the olive trees, notwithstanding the bitterness of their leaves. At Relizabe and at Harba they invaded the cotton grounds. In the province of Constantine the locusts appeared simultaneously from the Sahara to the sea, and from Bongie to Calle[118].

M. Girard[119] gives a very interesting account of this invasion, in which he says the opinion most generally accredited in reference to Acridians (locusts) of Algiers is that they come from the equatorial regions of Africa, from Soudan. That the swarms hatching in the sands of these regions—a part of which move to the south, the others to the north—those moving northward arrive by steps in the Tell of Algiers. The specimens of this swarm which were sent to the society, in all stages of growth, when examined proved to be *A. perigrinum*.

Reference to the species which is found migratory in Algiers and other parts of Africa, and its specific characteristics, will be found in various works.[120]

The most complete account of the natural history and ravages of this species in Algiers is by M. G. Lallemant.[121] He says the two great invasions, that of 1864 and of 1866, arrived in the month of April. That these insects inhabit all the North of Africa, and a part of Asia; that

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[117] Booth's Trans., i, 189.

[118] Trans. Ent. Soc., Lond., 1866, vol. v, Proc., xxiii.

[119] In Ann. Soc. Ent. France, 4th Ser., 1864, vii, Bull., x-xiii.

[120] *Oliveer*, "Voyage dans l'emp., Othom." ii., p. 424.—*Serville*, "Orthop." 666.—*Shaw*, "Travels in Barbary and the Levant."—*Poiret*, Voyage en Barbarie, i, 306.—Compte-Rendu, Acad. des Sci., 1845, pp. 1041 and 1499.—*Lucas*, "Explor. Scient. Alg.," in Scien. Phys. Anim., art. iii, 29, and Bull. Soc. Ent. France, 1845, xxxii.

[121] In Ann. Soc. Ent. Blg., vol. 9.

he does not believe the swarms arise at once *en masse* (as though by a preconcerted signal), but, inhabiting this whole country, the isolated individuals join the group as it passes, thus augmenting it as it proceeds; hence, the longer the distances and the more the wind favors, the larger will be the swarm. He says they generally come into the French possessions of North Africa under the influence of a hot wind from the south, known in Algiers as the sirocco. This wind attains in Algiers a temperature of 51° (cent.), as he has ascertained by observation of many days in succession.

The three chief invasions of this section were in 1845, 1864, and 1866.

Bolivar's statements in reference to this species will be introduced hereafter, when we come to consider the question of passage across the Mediterranean Sea from Africa to Europe.

Rev. Samuel Gobat[122] makes the following statement in reference to an invasion he witnessed near Axum, in Abyssinia, in June, 1831:

> The air was teeming with locusts, by which the light of the sun was already greatly obscured. But this was only the advanced guard. On looking toward the north I perceived, about a league distant, several faint clouds, as it were, rising from the earth, which I at once took for locusts, having before seen this appearance of them near Cana of Galilee. Afterward this mist became so thick that it entirely hid the sky and neighboring mountains from our view, and the people of the country, though accustomed to seeing locusts, no longer believed these wonders to be occasioned by them; but the locusts soon arrived to convince us of the fact. The air was so darkened that we could scarcely discern the place of the sun; and the earth was so completely covered with these insects that we could see nothing else. Children running about the fields, at only a stone's throw, could scarcely be seen through the multitudes of locusts surrounding them. Every year there is a greater or less descent of locusts in Tigre, but they are much more numerous this year than usual.

He states that they are rarely found "beyond" (southwest of) the Tacazza River.

Henry Salt[123] says that during his stay in the bay of Amphila a large flight of these insects came over to one of the islands and in a few days destroyed nearly half of the vegetation. He describes, as before stated, a species seen at Bombay, which he asserts was the same as seen here. James Hamilton[124] mentions passing through a swarm in the latter part of April, 1854, on the Rahat, a branch of the Blue Nile, about N. lat. 14° 10′, E. long. 34° 10′.

Barth, in his Central Africa[125], remarks as follows: "I was here not a little surprised at the swarms of locusts which the wind drove into our faces and which certainly indicated our approach to more fertile regions." It was July, 1854, and he was then on the Niger about Gaben, N. lat. 16° 30′, E. long. 0° 20′, going south a little east. The southern limit of the desert he places at the latitude of Gao (or Gogo), N. lat. 17°.

The oft-quoted description of locust flights by Adanson[126] relates to

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[122] "Journals of a Residence in Abyssinia," p. 392.
[123] "Voyage to Abyssinia in 1809 and 1810," p. 172.
[124] "Sinai, the Hadjaz, and Soudan," p. 297.
[125] London Edition, V, p. 242.
[126] "A Voyage to Senegal." The isle of Goree, and the river Gambia. Engl. transl., p. 159.

migrations observed in February, 1750, during his voyage up the Gambia. In this case they were brought by a strong east wind, which he supposed would ultimately carry them into the sea. He describes them as being entirely brown, of the breadth and length of one's finger, and the wings much longer than those of any locust he had ever seen before. Barrow[127] encountered an immense swarm March 19, 1802, near the crossing of Orange River, S. lat. 29°, E. long. 23° 30′. From his language and judging by the direction he was moving we presume this was a swarm returning northward.

Moffat,[128] after giving a vivid description of their ravages in 1826, and the ineffectual efforts of the natives to stay their progress, remarks that—

> When a country is not extensive and is bounded by the sea, the scourge is soon over, the winds carrying them away like clouds to the watery waste, where they alight to rise no more. Thus the immense flights which pass to the south and east rarely return, but fresh supplies are always pouring down from the north. All human endeavors to diminish their numbers would appear like attempting to drain the ocean by a pump.

Richard Jobson's narrative[129], in which he speaks of the terrible suffering and famine brought on by locust devastations, relates to Eastern Africa—Barua and Dongali. Captain Clapperton[130] makes no mention of locusts, but his faithful servant, Richard Lander, in his journal, which is appended (p. 323), incidentally mentions them as an article of food in Yariba. Dr. Herman Krauss[131] gives an account of observations of the migrations and devastations of *A.* (*Schistocerca*) *peregrinum* in Senegal by Steindachner in the winter of 1864. In his enumeration of the Acridians of this region this is the only migratory species mentioned. He states that Steindachner observed a swarm, evidently of this species, flying at sea about 200 nautical miles from the African coast and distant from the Canary Islands. In connection with this well-authenticated evidence of flights at sea, we call attention to the remarkable statement of Sir Hans Sloane,[132] that Colonel Needham, who resided for some time in Teneriffe, informed him that in 1649 locusts destroyed all the products of that island; that they were seen to come off from the coast of Barbary, the wind blowing from thence; they flew as far as they could, then one alighted in the sea and another on it, so that, dropping one upon another, in this way they at length made a heap as big as the greatest ship above the water, and, as judged, almost as many under. Those above water, on the next day after being refreshed by the sun, took flight again and came in clouds to the island from whence they had perceived them in the air. They were troubled forty years be-

[127] "Travels"—"An account of a Journey in 1801 and 1802 to the Boshuna Nation, Southern Africa," p. 429.

[128] "Southern Africa," p. 298.

[129] "Voyage to Gambora, Africa," in Purchas' Pilgrims, II, 1046–7.

[130] "Journal of a Second Journey to the interior of Africa."

[131] "Orthoptera Von Senegal." Akad. Wissench. Wien., June and July, 1877, p. 33.

[132] Nat. Hist. Jamaica, I, Introd., LXXXI.

fore with a like calamity. He also states in another place[133] that while in latitude 14° 40′, and about 500 leagues from Barbadoes, a sailor took up a live grasshopper from the forecastle of the ship and brought it to him, assuring him it had fallen upon the vessel. This species he named *Locusta maxima cinereo purpurea, maculis brunnis.* He describes it as being two inches long to the end of the body, and two and a half to the tips of the wings (elytra), of an ash, inclining to a red or purple color, with many brown spots on them. He remarks that Vanderhagen noticed a similar occurrence in his voyage,[134] but without mentioning the distance from land. But this latter writer says that on his return to Helena he observed many red and whitish locusts swimming in the water and that some also flew upon the ship. He also quotes from Cadamosto a statement in reference to the abundance of locusts in Senegal.[135]

Andrew Sparrman[136] says that—

> Sometimes the locusts also afford a delicious treat to the more barbarous and remote tribes of the Hottentots, when, as at times happens after an interval of eight, ten, fifteen, or twenty years, they make their appearance in incredible numbers. At these times they come from the north, migrating to the southward, and do not suffer themselves to be hindered by any obstacles, but even if they happen to reach the sea, fly boldly on and are drowned in it.

The account of these as seen in the Canary Islands, quoted by Rev. T. H. Gallaudet[137] evidently commingles the statements of Sir Hans Sloane and Beauplan, relating to widely separated regions. Near the Cape of Good Hope, in Kaffir-land, swarms of locusts often destroy every green thing.[138]

Near Galam, in Senegal, in the year 1698, M. Brui encountered on his voyage an air-darkening swarm of locusts which was two full hours in passing, until the south wind began to blow, and drove them into the desert. Captain Stibbs had a similar experience near Barrahonda, on his voyage on the Zambia.[139]

As will be seen from the following brief notices, other parts of America, as well as the Western United States, have their locust pests, though not to the same extent as the Eastern Continent.

Edward Temple[140] speaks of the devastations of locusts about Buenos Ayres, where they devoured not only fruits and vegetables, but even large trees. He met with them at Cordova in immense numbers, but does not give direction of flight.[141] Speaking of the destruction of a field of tobacco-plants he compares the horde when spread over the field to a "brown mantle," indicating the color.

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[133] Vol. 1, p. 29.

[134] Excerpt. Clus-cur.

[135] See also the quotation from Sir Hans Sloane's account in Gentleman's Magazine, vol. 18, Aug., 1748, pp. 362, *et seq.*

[136] "Voyage to the Cape of Good Hope," Transl, I, p. 263.

[137] Scripture Biography for the Young.—Moses, vol. i, p. 114.

[138] Brace, Miscellen aus der neuesten auslandischen Literatur, 1834. Heft. 10, p. 107.—Keferstein.

[139] "Labat, Relat de l'Afrique Occidentale," II, p. 176.—Hugh Murray, Hist. Occ. of Africa, I, pp. 168 and 238.—Ritter.

[140] Travels in various parts of Peru, I, p. 104.

[141] See, also, Froreip, Notizen der Natur- und Heilkunde, vol. 28, p. 136.—Keferstein

Ringger,[142] in the month of October, 1820, observed for the first time in Paraguay a swarm of locusts which came over from the right coast of Paraguay. This was a species of *Acridium*. According to Molina,[143] Chili is much less infested with grasshoppers than Cujo and many other countries in America. Kefferstein quotes this writer incorrectly as saying they also show themselves here. According to Fannin,[144] they appear to be rare in this country.

Speaking of Uruguay, Fannin says these pests appear at intervals of five, six, or seven years, coming from the north in armies and depositing their eggs here.

Peter Schmidtmeyer observed them in May in immense numbers between San Luis and Mendoza.[145]

Darwin's account of the swarm he observed at Luxan, in March, 1825, has already been given in our First Report.[146] We need only to call attention to the fact that they came from the South and in mass, presenting a cloud of dark reddish-brown color. He erroneously supposed them to be identical with *P. migratorius*, as the species which is migratory in this part of South America, as has been ascertained by Burmeister, is *Acridium paranense*. A list of works relating to the history and migrations of this species will be found in our former Report (Appendix, p. 278). The Gilliss expedition observed them near San Luis; Padre Ovalle, between Mendoza and Buenos Ayres.[147]

For accounts of their migrations and operations in Central America and Mexico the reader is referred to our First Report.

REMARKS.

Having now taken a general but brief survey of the movements and operations of locusts in the various parts of the world, we desire, before entering upon the discussion of the various topics relating to migration, to call attention to certain facts which appear to be indicated by this survey.

The first is, that all the grand divisions of the earth and most of the larger faunal regions are more or less subject to ravages of locusts; but that the area of their most abundant development is to be found in Northern Africa, Western Asia, and Southern Europe, or in other words a vast semi-circular sweep around the eastern extremity of the Mediterranean Sea, reaching from Poland around the Caspian and southern end of Arabia to Senegal.

The second important conclusion to be drawn is that wherever they are largely and frequently developed, we find either extensive deserts

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142 Reise nach Paraguay, p. 420.—Kefferstein.

143 Geog., Nat., and Civil Hist. Chili, Transl., I, p. 146.

144 "Chili, Paraguay, Uruguay, and Buenos Ayres," In L'Univers, XXV, p. 6.

145 "Travels in Chili over the Andes in the years 1820 and 1821," p. 167.

146 P. 466.

147 First Report U. S. Entomological Commission, p. 466. The date of the publication of Ovalle's history of Chili as given in our report—1846—is probably a typographical error, it should be 1646.

or vast treeless areas, and an arid or dry climate. The desert character of that vast region of Northern Africa extending from Senegal to the Mediterranean, and from the Atlantic to the Red Sea, is well known, as is also the arid and desert character of a large part of Arabia, Syria, Persia, and Mesopotamia. The Ukraine, Crimea, and the regions around the north and east of the Caspian Sea, are characterized by those broad, treeless, and more or less elevated plains to which the name *steppes* has been applied. Extensive pampas and treeless plains form a marked feature of those sections of South America in which the locusts are found. The same we know also to be true in reference to the locust districts in North America. Keferstein remarks[148] that high chains of mountains covered with snow are the best natural barriers against the extension and migrations of the destructive locusts. That this may be true when applied to some species is not to be doubted, but that it is applicable to all is disputed by the history of our native species, *C. spretus.* Ritter assures us[149] that no traces of locusts are found in the cold climate of Thibet, in cool Cashmere, and that in the central interior of Asia, between the Himalaya and Altai mountain systems, and on the plains of Dekkan, in the south of Nerbudda, or in India beyond the Ganges, between the Brahmapootra and Irawaddy Rivers and Yangtse-Kiang, where a misty, rainy, maritime climate prevails, the locust plague is unknown.[150]

Judging from the silence of Stanley, Schweinfurt, and some other recent travelers in reference to locusts, there is a large region in Central Africa in which they do not prevail. The same appears to be true in regard to a large part of the northern portion of South America, where a rich and luxuriant growth of vegetation and a moist climate prevail. The freedom of Eastern North American from this pest is well known.

A third important conclusion to be drawn from our brief review is that locust migrations are not governed by any law of regular periodicity. If we divide the number of years given by the Chinese record (1,924) by the number of visitations (173) it gives an average of a little over 11 years. The time embraced in Kœrte's list of the 30 invasions of Germany also gives an average of a little over 11 years. Köppen's list of the visitations of Russia and adjoining regions[151] from 1008 to 1861 gives an average interim of something over 13 years. Although the average periods thus obtained by dividing the whole number of years by the number of visitations agree so nearly, yet by simply running the eye over the lists of years any one can see that this argument is purely accidental and will not hold good when applied to the various interims. In the earlier times less attention was paid not only to the study of natural history but to agriculture than at present, and only the

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[148] L. c.

[149] Heuschreckenplage der Alten Welt, p. 7.

[150] But see statement of Colonel Prejvalsky, Geog. Mag., May, 1878, quoted in our former Report, p. 477, that swarms of locusts were seen at an elevation of [illegible],000 feet in Altyn-Tag range, in Central Asia.

[151] "Heuschrecken in Südrussland," pp. 110-12.

more remarkable invasions were noted. It is also possible, and we are inclined to think more than probable, that, in most of the countries where locust visitations have long been observed, their invasions have become more frequent than formerly, but the records of visitation can not be relied upon for the determination of this question. Be this as it may, the facts we have presented are sufficient to show conclusively that their migrations are not governed by any regular periodicity, and hence depend upon some influence which is irregular in its operations, as, for example, climatic changes.

Yet, notwithstanding this conclusion, we cannot pass on without calling attention to the fact that if we take the years of the great general invasions of Central Europe, 1333, 1650, 1693, 1748, and 1825; of Spain, 1495, 1542, 1619, and 1682; of Algiers and adjoining regions, 1799, 1845, 1866, and the recent one of 1878; and the noted locust years in our own western country, to wit, 1820, 1855, 1866, and 1874–'76, the interim in each case is very nearly a multiple of 11 years.

II.—PERMANENT BREEDING GROUNDS OR AREAS OF PERMANENT DISTRIBUTION.

That migratory locusts occasionally extend their flights into sections where they are not found as permanent residents is too well known to require proof, and that they sometimes continue in these extralimital areas for two or three years by reproduction has been clearly demonstrated. As a proof of this assertion we have only to refer to the paper by Köppen already mentioned, and our former report. Therefore, in attempting to mark the boundaries of the distribution of these erratic insects, it has been found necessary to draw at least two lines, one to bound the inner or permanent area and another to designate the limits of fluctuation, or, to quote the words of M. Preudhomme de Borre:[152]

> In this study, so interesting, there is one point on which we should insist. It is this: that the observations of M. Köppen tend to confirm the principle of zoological geography, that the area of a species cannot be limited on the map by a simple curve, but between places where the species exist in a constant or normal manner and those where its absence is constant there is always a zone, often very broad, of temporary visitations, which is to the area properly so called what the penumbra is to the light, within the zone, of which the exterior limit is much more easily traced than the inner; this last is subject to continual oscillations with some undulatory movements dependent on the centrifugal or expansive tendency of the species and from the resistance which opposes it, and external circumstances, and evidently also the tendency of other species to spread out, with which it carries on a struggle for existence.

Köppen, in order to express fully the relation of *P. migratorius* to the regions in which it has been observed, found it necessary to trace upon the map three concentric lines, one marking the limit of its permanent distribution, corresponding to what we in our first report termed "permanent breeding-grounds"; a second, outside of this, marking the limits of its temporary existence in all its stages of development; and a third or

[152] See former Report, p. 475.

outer line, showing the utmost extent of its presence in the condition of bands of winged insects beyond the region where the species may live and propagate, or, in other words, the extreme boundary of its flights.

Our investigations, made independently of a knowledge of Köppen's conclusions, led to a somewhat similar result. We found it necessary, in order to express the relations of *C. spretus* to the various parts of the area over which it roams, to designate an inner or central region as its "permanent breeding-grounds," and an outer circumscribing belt as the "temporary region," corresponding with Köppen's first and second divisions. Its incapability of continuing its existence in this temporary region is so marked that we have attempted to designate an intermediate area showing the limits of the oscillations of the permanent breeding-grounds. But this, in the opinion of the writer of this chapter, is too indefinite to be of any real value, an opinion which it is proper for me to state is not fully concurred in by all the members of the Commission. Our investigations of this species have brought to light no facts to warrant us in designating an outer belt corresponding with Köppen's third area, as its flights do not extend into any sections, so far as ascertained, where it may not produce at least one resulting brood.

It is necessary for us to call attention here to the fact that this arrangement does not include all of the relations of migratory species to the regions they are found inhabiting. For example, a species may not be essentially migratory and hence may be found to possess this character in one district where the conditions are favorable while in another section it may be truly sedentary. Such appears to be the case with *A. americanum*, which in the southern half of the United States is sedentary, while in Yucatan and other parts of Central America it is said to be migratory. If *P. cinerascens* is ever truly migratory, of which we have some doubt notwithstanding the affirmative evidence on this point, then it forms a second example, as we are informed by Selys-Longchamps that it is sedentary in Belgium and other parts of Europe.[153] How far this characteristic applies to other locusts of the Eastern Continent we are unable to state, as the attention of European entomologists does not appear to have been specially directed to this point.

As will be seen hereafter, the evidence obtained by the Commission in reference to our Rocky Mountain locust shows it to be essentially migratory. The same also appears to be true of *A. peregrinum* and *P. migratorius*.

We may as well remark here, in order that our arguments and conclusions may be the better understood, that we do not include in the category of "migratory locusts" or of "locusts" in the true sense, those Acridians which occasionally, through the influence of climatic conditions, are greatly developed and even induced to migrate for short distances.

As the native home of an essentially migratory species must be a

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[153] Compt. Rend. Soc. Ent. Belg., 1871-2, xxiv.

more restricted area within the limits of their migrations, our first step in trying to fix the boundaries of this area for *C. spretus* was to determine as nearly as possible the outer limits of its geographical distribution. This was not difficult, except where the line runs through uninhabited sections from which no data could be obtained; as this limit, so far as this species is concerned, is determined not by straggling individuals, but by the utmost points to which flying swarms reach, for beyond these points stray individuals are seldom seen.

This outer limit of geographical distribution is found marked in map No. 1 of our former report, which is repeated in the present volume. The southern limit, which is supposed to pass through New Mexico and Arizona, has not been determined with satisfactory certainty, and it may be that, as mapped through Texas, it is slightly incorrect, as it is possible that the species extends its migrations into Eastern Mexico. It is even possible that the locust which occasionally devastates other parts of Mexico is *Caloptenus spretus*, but we think otherwise. We also know, from personal examination of specimens, that the species which occasionally overruns Honduras, the southern districts of Mexico, and Central America is quite distinct, and believe that the Rocky Mountain locust, with the exception of occasional visits to the southern side of the lower Rio Grande Valley, never goes south of the United States boundary.

Our reasons for this opinion may be briefly stated as follows: The *C. spretus* is evidently, as we have shown in our former report, a boreal insect. We cannot learn that any of the collections of insects made in Mexico contain this species, and we have been unable to obtain any evidence of its being found in that country. So far as it is possible to judge in reference to the species, in the accounts of locust ravages in Mexico and Central America, they appear to differ from *C. spretus*. In the account given by Gage, in his "New Survey of West Indies,"[154] it is stated "They were after the manner of our grasshoppers, but *somewhat bigger;*" also, that "where they lighted, either upon trees or standing corn, there nothing was expected but ruin," &c. The size indicated here is certainly larger than our Rocky Mountain locust; and, secondly, the allusion to their alighting on trees is more applicable to the habit of *Acridium americanum* and its congeners than to *C. spretus*. The locust alluded to by Squiers[155] is evidently too large for our species, measuring, according to his statement, "two and a half to four inches."

Those which have of recent years appeared in Yucatan are evidently species of *Acridium*. Some specimens were sent to Mr. S. H. Scudder, most of which proved to be *A. americanum*; a few specimens were observed of an unknown species allied to *A. flavofasciatum*[156]. Specimens received during the past season from the West Indies, which give indubitable evidence of having migrated, cannot be distinguished from *A. peregrinum*, the ultimate segment of the male abdomen distinguishing

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[154] See former Report, pp. 461–2.
[155] Quoted in our former Report, p. 460.
[156] See former Report, p. 462.

them from *A. americanum* and agreeing exactly with that of the former species.

Mr. E. Flint, in his letter of December 18, 1877, speaking of the migratory locusts that visit Nicaragua, says: "They resemble *Œdipoda* Say; these have spotted elytra wings, and are larger; last ventral segment notched, as in *spretus*."[157]

According to his letter specimens were sent to the Smithsonian Institution for determination, but we cannot learn that they were ever received.* We think it almost certain that the species does not belong to the genus *Œdipoda*, or to the group *Œdipodini*. It is most probably an *Acridium*, either *A. americanum* or a closely allied species; the "spotted elytra" and notch in the last ventral segment agree with this supposition, the prominent notch in the male of this species being readily observed. In addition to this we may say that large *Œdipodæ* appear to be very rare in Southern Mexico and Central America, while in this region and the northern part of South America *Acridium* reaches the maximum in development. A small collection made last summer in Central America by Professor Burrill contained but a single Œdipodean.

These reasons, we think, are sufficient to render it more than probable that the Rocky Mountain locust does not extend its incursions into Mexico or Central America.

The line on map No. 1, marking the outer limits of its distribution as given in our former report, may be considered as very nearly correct, requiring no change, perhaps, except at one point. Facts ascertained during the past and present season indicate a more southern extension in New Mexico, and possibly in Arizona. We have, then, an area extending east and west from the 93° to 119° of west longitude and north and south from 27° to 53° of north latitude; or 26° east and west and 26° north and south, which has as its strongly marked features an immense and highly elevated plateau from which shootup sharp ranges and lofty peaks. This elevated section is bordered by broad, treeless plains; the entire area is to a large extent free from forests, the chief exceptions being the higher mountain masses in Colorado and Wyoming, and the mountainous section in West Montana. Not only is this vast area, taken as a whole, comparatively treeless and barren, but the climate is dry, the average rainfall not exceeding twelve or fourteen inches per annum.

By comparing the area of distribution of this species with that of other species, we are enabled to deduce some important laws in reference to locust distribution, and the laws of migration which cannot be detected by studying one species alone.

The paper by Mr. F. T. Köppen in Petermann's "Mittheilungen aus Justus Perthes' Geographischer Anstalt," in regard to the distribution of *Pachytylus migratorius* has already been referred to in our former report, and M. Preudhomme de Borre's brief analysis of it is given there. According to this the northern limit of the permanent distribution of

[157] See former Report, p. 465.

* NOTE.—Specimens, possibly of this collection, sent us are closely allied to *A. peregrinum*.

this species begins on the coast of Portugal near the 40th parallel of north latitude, and extends from thence northeast through Spain, rising obliquely through France to Lake Geneva, and extending from there eastward, following approximately the 48th parallel, including Valois, Northern Italy, Carinthia, and Hungary, then passing into Southern Russia, where it reaches nearly to the 55th parallel. It continues from there across the middle of Siberia, passing north of the Chinese boundary, and terminates in Japan, leaving out the island of Niphon. From this point it proceeds southward to the islands of Fidochi to New Zealand and Australia, of which it embraces only the northern portion, and passes from thence to the island of Mauritius, and rising to the north crosses Africa up to Madeira. But the last part of the limits is more hypothetical from want of exact knowledge in reference to the existence of the species in the interior of Africa.

That the immense area embraced within these limits is permanently inhabited, even in the broadest sense, by *P. migratorius*, or that its migrations extend over it we do not believe can be shown. And if we judge by this author's paper on the "Destruction of the locusts in Central Russia," we do not understand him as really holding this view.

We will give some reasons for believing that the area over which this species roams is less extended than that designated by the boundary given.

That notices of specimens obtained from the extreme portions of this extensive area may be found in entomological works and papers we do not deny; but this we do not accept as sufficient to establish the fact that the species is to be found in these widely separated sections as migratory. That a species may be thus widely distributed we do not deny, for several instances of the kind have been clearly proved. But aside from the difficulty of distinguishing the migratory from the closely allied species of *Acridii* by single specimens, we are satisfied that the evidences in reference to the migratory species within this area contradict Köppen's conclusion as given by M. Borre. We doubt very much whether there is an entomologist in Europe who, without previous warning, would at once distinguish between *C. spretus* and *C. atlantis*. These differences can only be discovered by carefully studying the species in their native habitats. It is yet a matter of dispute in Europe whether *P. migratorius* and *P. cinerascens* are distinct; and the testimony in reference to the migratory character of the latter is so conflicting and uncertain that we are unable to come to any satisfactory conclusion on the point. Yet Köppen fails to state whether he considers the two as distinct or not.

Although the descriptions given by travelers are generally considered as worthless in determining species, yet we think a careful study of the numerous accounts and a proper application of the laws of insect distribution, if compared with the more accurate knowledge of these pests obtained in recent years, will lead to more correct results than by rely-ing upon the notices of isolated specimens obtained from various sections. The experience in this country bears us out in this opinion. Professor Haldeman, as late as 1853, supposes *Œ. corallipes* to be the species so destructive to vegetation in Utah;[158] and it was not until Walsh took the matter in hand in 1866 that the western locust was specifically determined; nor was the distinction between *spretus* and *atlantis* suspected until observed by Mr. Riley in 1874, when the invasion of that year caused him to enter upon the careful study of the species. What species the migratory locust of California is, in fact whether California has a truly migratory locust, are points not yet satisfactorily settled.

An incident showing the liability to error in determining a migratory species from specimens sent is mentioned in the Proceedings of the Entomological Society of London.[159] A copy of a dispatch from the English chargé d'affaires at Madrid was submitted to the society relative to the plague of locusts, together with a box of specimens. The insects sent were stated to be *Locusta migratoria*, when, on examination, they were ascertained to be *Decticus albifrons.*

The confusion in reference to *A. peregrinum* and the closely allied species is so great that no entomologist can decide in reference to a specimen satisfactorily without having recourse to a well-stocked cabinet. According to Stål,[160] *G. migratorius* var. *z* of Thunb., *G. rufescens* Thunb., and *A. flaviventre* Burm. are all synonyms of *A. peregrinum* Serv. He also gives as the localities where the specimens of this species which are in the Mus. Holm. were found as Buenos Ayres, Montevideo, Bahia, Madeira, Teneriffe, Algiers, Egypt, Nubia, and East Indies.

Walker[161] gives as localities from which specimens in the British Museum were taken, Syria, Egypt, Madeira, Teneriffe, South Africa, Ceylon, Nepaul, Hindostan, North Bengal, and "500 miles from land." Olivier mentions Egypt, Arabia, Mesopotamia, and Persia. Krauss and other authorities mention Senegal and the Canary Islands. In addition to these localities, it is stated that specimens have been found in Spain, Portugal, and England.

If we should accept these as true, and from them attempt to fix the area of distribution for this species, we should have to include all the territory bounded by a line running from the Ganges to the Aral Sea, thence to England, thence to the Argentine Republic, thence to the Cape of Good Hope, and back to the starting point. Could such a conclusion be accepted? We think not. Yet the extreme points depend upon the authority of Stål, one of the most thorough orthopterists of the present age. That the area over which this species roams is very extensive must be admitted. There are also some reasons for believing that it is found in the West Indies, but the species inhabiting the Argen-

[158] Stansbury's Report, p. 371.
[159] 1876—xxi, August 2.
[160] Recensio Orthopterorum, p. 65.
[161] Cat. Dermap. Salt., iii, p. 577.

tine Republic is distinct; nor can we find any reason for believing that it is found in South Africa.

We base our conclusions, therefore, on a careful study of all the evidence, making *the fact of migration* an essential requisite. Proceeding upon this basis, let us see what conclusion we shall reach in reference to the three chief locusts of the eastern continent—*P. migratorius*, *A. peregrinum*, and *C. italicus*.

To determine what is the permanent home of a migratory species we have to rely chiefly upon the following data: 1st. The fact that the species has been observed for a series of years inhabiting and reproducing itself in a given area, which is the best possible evidence. 2d. Where no such data have been obtained, the next best means of determining this point is to trace back the lines of migration to the point of departure. But in attempting to follow out the latter method caution is necessary lest we are led astray by exceptional cases. For illustration, in the great invasion of Europe in 1747–'50 it is asserted by the best authority that the locusts came from Turkey into Wallachia, Moldavia, Transylvania, and Hungary; that in 1749 they passed from thence into Austria and Bavaria, and in 1750 reached Brandenburg. The assumption that Austria and Bavaria were native habitats because the brood that proceeded to Brandenburg originated there would have been an error, as these localities were but stopping places in their western progress. Just as well might the people of Nebraska conclude the home of *spretus* is in the south because swarms were observed coming from that direction in 1875 and 1877, when, in fact, they were the resulting broods of the swarms of the preceding years which had passed southward. Kefferstein asserts that no existing observations would enable any one to follow any locust swarm back from Germany into Tartary, and consequently concluded that the hordes originated in the vicinity of the places where they were observed. Even those observed in England were believed by him to have originated in England. Schrank was also of this opinion.[162] Yet all the data which Kefferstein presents in reference to the history of their migrations in Europe, so far as *P. migratorius* is concerned, show that they proceeded from points eastward of the places visited.

That there is a large amount of testimony showing that *P. migratorius* is indiginous in a great part of Europe is true. But with the exception of one or two witnesses there is a failure to distinguish between this species and *P. cinerascens*. But without stopping to discuss this point, which is not essential to the object we have in view, we may add that Köppen's own conclusion, shown by the limits of permanent distribution he draws, contradicts the larger part of this testimony which relates to points north of his line. According to Köppen, great mountain chains are powerful obstacles to the diffusion of this species, and that it is rare in the southwest of Europe or northwest of Africa where it is almost completely replaced by other species, *i. e.*, *C. italicus* in Spain, Italy, and

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[162] Fauna Boica, Bd. 2, a. i, p. 35.

the middle of France, and *A. peregrinum* in Algiers. Bolivar, who is certainly well informed in reference to the Orthoptera of the Spanish peninsula asserts[162] that no data exist authorizing him to affirm the presence of this species in the peninsula, but that the citations doubtless refer to *P. cinerascens*. He does not admit *P. migratorius* in his list. For these reasons and others which might be adduced we conclude that the starting point of the boundary line should be placed much farther east than given by Köppen. Just where, we are unable to decide from our data, but it should not include Italy.

It is a significant fact that the great swarms entering Germany, Poland, Hungary, and even Bulgaria, as will be seen by reference to the preceding quotations, are always from the east, never from the west or south. As is evident from the facts presented in the foregoing review, and as shown by our observations of the movements of *C. spretus*, locust-swarms almost universally move in direct lines; hence it is fair to presume that the swarms which have swept over Central Europe for the past thousand years from the vicinity of the Black Sea to Poland, Germany, and Austria had their origin in some productive hive in the East, either around or beyond that sea. Nor should we omit the important fact that the swarms which can be identified with any reasonable probability as being of this species which have visited Italy or France, have proceeded from Hungary, or some point in that direction.

That this species is found in Southern Russia, and in the countries east of the Black Sea to the Irtish and the Chinese border, is a fact well known. How far east along this latitude it extends is a question of doubt which Köppen fails to remove. That China has been subject to locust invasions from time immemorial is shown by the records of that empire, but whether this species is the one committing the ravages in that country has not, so far as we are aware, been satisfactorily determined.

That this species should be found in India, we admit, is against the theory we are here advancing, yet the evidence to this effect is too strong to be disputed. It is somewhat strange that the data in reference to the Indian locusts are so meager, when we take into consideration the fact that so many scientific explorers have visited that country.

That *A. peregrinum* is the chief destructive locust of that section, we think is evident from the facts given below, but that *P. migratorius* is also found there, and often in great numbers, must be admitted. The most recent authority we have at hand on this point is a series of papers issued by the revenue department of the Government of Madras in 1878, in reference to the locust visitation of that year, which appears to have been very extensive.

We think it pretty evident that the locusts along this tropical belt are chiefly species of *Acridium*—*A. peregrinum*—and its varieties, or closely allied congeners. The swarms observed by Olivier in Central Arabia, Mesopotamia, and Persia, consisted of this species. The *Gryllus grega-*

[163] Synopsis Ortop. Esp. y Portug., p. 140.

rius of Förskal and Niebuhr seen in Arabia was evidently *A. peregrinum*, as were the locusts encountered by Palgrave on the Hasa plains. The species seen by Morier migrating in Southern Persia was not *P. migratorius*. The species seen by Salt at Bombay, which he asserts is the same as that observed on the coast of Abyssinia, is described as follows, and is certainly different from the *P. migratorius*:

The head and shoulders of the insect are armed with a thick shell or case; that of the head has a dull leaden gray color when alive, interrupted with red; the shoulder plate being of a reddish brown, spotted with white, smooth in front, and rough on the hinder part; the eye is bright yellow, with three black bars across it; feelers or horns black; the wings [elytra, we suppose] are of a yellowish-brown, lower part tinged with a fine purple, and the whole obscurely dotted with black. The legs are externally of a leaden gray color, the upper part shading off into black; the ribs also deep black, inside of second joint bright purple, and the thorns scarlet, tipped with black; the extremities being formed of triangular shells formed of two sharp claws and a knob in the center, smooth and round.

The figure in the plate is evidently a female *Acridium*; at least the thorax, wings, and abdomen would indicate this.

In a note to Mr. Thomas, Mr. S. H. Scudder suggests that it may be the *Acridium Ægyptium* of Linneaus; but this, according to Stål,[164] is synonomous with *Gryllus lineola*, Thunb[165] and *A. tartaricum* Fisch.[166] (not *G. tartaricus* Linn).

Fischer has doubtless included two or three species under his *A. tartaricum*.

Charpentier,[167] who separated *A. lineola* with some doubt, remarks, under the latter, that Germar informs him in letters that this species is found in the East Indies. It is also more than probable that it has been included by some authors under *A. succinctum* also, especially those examples from the East Indies. The remark in the *South Australian Register* also agrees with Salt's statement.

Wahl, it is true, affirms that swarms of *P. migratorius* are seen in India, but also adds that another species, a kind of yellow locusts, called Tscheddy, often covers whole fields and darkens the air like a cloud. Major Moor asserts that the destructive species of this country is "blood-red" and not the *P. migratorius*. That the locust infesting the Philippine Islands is not the latter species is clear from the statements of Gironiere and Jagor and the figure given by the former traveler; whether it is an *Acridium* or an *Œdipoda* is a matter of doubt.

These facts, together with our knowledge of the general laws that govern Acridian life, lead us to the conclusion that although *P. migratorius* is found in this part of tropical Asia, yet that *A. peregrinum* is really the prevailing migratory species.

Is it found in Africa as a migratory species? Judging from all the data we have been able to obtain, we are convinced it is not.

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[164] "Recensio Orthopterorum," I, 63.
[165] Mem. Acad. Pet., 5, p. 247, 1815.
[166] Orthop. Europe., 388.
[167] Horae Entomologicae, 131.

The universal testimony of those who have witnessed the locust migrations in Algiers, Morocco, and other portions of Northern Africa along the Mediterranean shore (exclusive of Egypt) is that they always come from the south. As proof of this, we have only to refer the reader to the accounts we have given relating to this section.

In addition to this, the testimony of the French naturalists and recent authorities show beyond dispute that the locust of this region is *A. peregrinum.* What species are found on the plains of Australia and Southern Africa is yet a matter of doubt, but the facts given are sufficient to show that the great intermediate tropical belt is not infested by *P. migratorius* as a migratory species.

Before proceeding further in the discussion of this subject, let us see if our conclusions will accord more nearly with the laws of geographical zoology than the theory attributed to Köppen. If so, then it is fair to presume that we are nearer the correct solution of this question than he is.

If the reader will take the trouble to examine Wallace's map of his Nearctic Region [168] and compare the Rocky Mountain subregion (No. 2) with the line marking the permanent distribution of *C. spretus* on our map he cannot fail to observe the almost exact coincidence of the boundaries of the two, the only difference worthy of notice being the southern extension, which, in reference to *C. spretus*, is yet an open question. Is this purely accidental; or is it in accordance with the laws of animal distribution which have enabled the talented author of that work thus to map the boundaries of the faunal region?

Let him now turn to the map of the Palearctic Region, [169]. Although he will fail to find such exact coincidence between the limits of locust distribution and the boundaries of the faunal districts as marked by the author, yet a careful examination will show that each migratory locust is, after all, confined, as far as its area of permanent distribution is concerned, to its own faunal district. The reader will observe that in the southeast part of subregion 1 (European) and the southwest of No. 3 (Siberian) there is an immense area marked as pasture-land, which extends east and west from Hungary to China, embracing within its bounds all that section to which the name Tartary, or Tahtary, was applied by the early writers and travelers. The northern boundary of this area, as mapped by Wallace, corresponds almost exactly with the line of permanent distribution of *P. migratorius* as given by Köppen; and we are inclined to believe that, with the exception of the debatable ground of Asia Minor and Syria (or Asiatic Turkey), the southern and eastern limits represent approximately the southern and eastern boundary of permanent distribution of this species.

From these broad, grassy plains, or steppes, carried by easterly winds, they sweep over Southern and Central Europe, usually along the northern shore of the Black Sea, but occasionally from Asia Minor; the Ukraine and the region of the Crimea, occupying the straits or narrows of this

[168] Geographical Distribution of Animals, I, p. 115. [169] Vol. L., p. 181.

westward extension, suffer most. It is from this direction instead of from Africa that the hordes come which visit Italy and occasionally penetrate to Sicily.

We may remark here that some of Wallace's boundary lines in this region appear to have been somewhat arbitrarily drawn, and in one case he appears to have been guided too much by the distribution of a single class of animals. If his line between 1 and 3, instead of following the Ural Range as it does on his map, had been traced along the valley of the Irtish, which he gives as the more correct eastern boundary of the European subregion, it would then correspond almost exactly with the eastern boundary of the pasture area described.

While there are some strong reasons for uniting the northern and southern shores of the Mediterranean into one faunal district, there are equally good reasons for considering the two parts as representing two faunal areas, less distinct, it is true, than his subregions, but not so homogeneous as the parts of most of the other subregions. In fact, it is still a matter of doubt whether it would not have been better to consider these two parts as separate subregions. If this be done, we will then find the locust distribution corresponding almost exactly with the faunal subregions, or that their permanent distribution is limited by the boundaries of their respective faunal areas. The European subregion, if extended as indicated, and as suggested by Wallace in his text, will embrace what we are inclined to think is really the home of *P. migratorius*. This is the great pasture region, and its locust is Œdipodæan. The Mediterranean district, as given by Wallace, is the region of mountains and deserts; the northern section, which is elevated and broken, has its peculiar locust, the *Caloptenus italicus;* the southern, or desert portion, has its own migratory species, *Acridium peregrinum;* the two belonging to the Acridian group of the family *Acrididæ*.

There is a fact which presents itself at this point that, although not directly necessary to this discussion, is worthy of notice, and may assist in solving the problem of locust-distribution in the Eastern Continent. Considering the Mediterranean subregion of Wallace as two sections, Southwestern Asia, or the region bounded by the Caspian, Black, and Mediterranean Seas and Persian Gulf, forms the point of union between the three locust districts, where we may naturally expect a commingling of the three species in their migratory movements. That such is the fact those who have attempted to trace the areas of distribution of the two great oriental species know too well.

Here, in fact, is the meeting ground of the three true locusts of the Eastern Continent; the area of the *P. migratorius* pressing into it on the north; that of *A. peregrinum* on the south and southwest: while that of *C. italicus* is thrust like a wedge between the two.

As an evidence of the commingling on this debatable ground of Western Asia, we have only to call attention to the statements of some of the authorities already quoted.

Pallas asserts the *C. italicus* extends not only to the Crimea, but beyond the European boundary even to the Irtish; thus invading the area of *P. migratorius.* Dr. Clark, who traveled over the northern part of this debatable section, remarks that the locusts—

Consisted of two species, *Gryllus tartaricus* and the *Gryllus migratorius*, or the common migratory locust. The first, almost twice the size of the second, because it precedes the other, bears the name of herald or messenger. The migratory locust has red legs and its inferior wings exhibit a lively red color.

His *G. tartaricus* is evidently *P. migratorius*, and his *G. migratorius* the *C. italicus.*

Niebuhr and Förskal speak of two migratory species being found in Arabia, Persia, and Syria, one of which, judging from their notices, is certainly *A. peregrinum*, which prevails almost to the exclusion of the others in Arabia and Southern Persia.

Palgrave notices the distinction between the species found in the south and north part of this region. Burkhardt mentions the fact of there being more than one species. It is now also well known, as asserted by Rev. William Houghton, in the able article "Locust," in Smith's Bible Dictionary, that both *P. migratorius* and *A. peregrinum* occur in Syria, Arabia &c., but we are inclined to think the former comparatively rare in Central and Southern Arabia.

From these notices, which might be multiplied, it is evident, notwithstanding the confusion and manifest errors, that more than one species of migratory locusts visit this southern portion of Asia, or meeting-point of the three faunal subregions. This is precisely what was to be expected upon the theory we are presenting in reference to the distribution of the three principal migratory species. Nor should the fact be overlooked that the southern district of Wallace's Mediterranean subregion extends eastward to the confines of India, where, as we have seen, it is probable that *A. peregrinum* is the migratory species. The reader will also note the close agreement of Major Moore's and Salt's statements with this theory.

It would be interesting to extend this examination to the locusts of the southern hemisphere, but this would require more space than we can devote to these collateral points; moreover, our data are not sufficient to render such an examination satisfactory. Let it suffice for us to state that from the meager data we have been able to obtain we are led to believe that the Australian and New Zealand locust or locusts (if distinct) are Œdipodæan and somewhat closely allied to *P. migratorius;* that the one which devastates Southern Africa is possibly *A. peregrinum* or some other species of *Acridium;* that there is probably but one migrating species of South America, *A. paranense*, which is closely allied to *A. americanum.* If we are correct in these conclusions, we are justified in stating, in general terms, that each species of migratory locust is confined, in its permanent distribution, to its own faunal region or district, across the boundaries of which it may and often does extend its migrations into other regions, but not to become naturalized therein.

We are fully aware that entomologists describe or note specimens, for example, of *P. migratorius* from numerous points immensely distant from the boundaries we have assigned it; but our experience in reference to *C. spretus* has convinced us that unless such specimens are known to have been from migrating hordes the evidence is of but little value in determining the question at issue. We freely confess the difficulty this fact introduces in the attempt to solve the problem; but when we take into consideration the additional fact of the difficulty of distinguishing such closely allied species as *C. spretus* and *C. atlantis* without a careful study of their habits, we can find at least one probable explanation.

From the evidence adduced and from our knowledge of our native locust, we conclude that each migratory species has its proper native habitat or permanent breeding ground, to which, whenever sufficient data are obtained, approximate boundaries may be assigned, but that as a general rule, to which we know of but one or two exceptions, they are essentially migratory within their respective regions of permanent distribution. The exceptions alluded to are *A. americanum*, which is not migratory in the United States, but is in the tropical regions, as before stated, and *P. cinerascens*, which is sedentary in parts of Europe at least, and also in some other sections. It is possible this is true in reference to some other migratory species, but if so we have no evidence of the fact; and, so far as our investigations show, is not true of *C. spretus*. That these permanent areas have expanded in the course of time from smaller areas to their present dimensions we think quite certain, but we will call attention to this hereafter.

CHARACTER OF THE PERMANENT BREEDING-GROUNDS.

That locusts prefer comparatively barren regions, or at least sections free from arboreal and rank vegetation, has already been affirmed. As preliminary to our remarks on this point, we call attention to the following passage in one of Humboldt's works:[170]

The different quarters of the world have been supposed to be characterized by the remark that Europe has its *heaths*, Asia its *steppes*, Africa its *deserts*, and America its *savannas;* but by this distinction contrasts are established that are not founded either on the nature of things or the genius of languages. The existence of a heath always supposes an association of plants of the family *Ericæ*; the steppes of Asia are not everywhere covered with saline plants; the savannas of Venezuela furnish not only the graminæ, but with them small herbaceous mimosa, legumina, and other dicotyledonous plants. The plains of Songaria, those which extend between the Don and Volga, and the *puszta* of Hungary are real savannas, pasturages abounding in grasses; while the savannas to the east and west of the Rocky Mountains and of New Mexico produce Chenopodiums containing carbonate and muriate of soda. Asia has real deserts destitute of vegetation in Arabia, Gobi, and in Persia. Since we have be-

[170] Personal Narrative of a Journey to the Equinoctial Regions of the New Continent. Bohn's ed., 1852, vol. ii, p. 85.

come better acquainted with the deserts in Africa, so long and so vaguely confounded under the name of "the Desert of Sahara," it has been observed that in this continent, towards the east, savannas and pastures are found situated in the midst of naked and desert tracts.

The treeless areas, especially when elevated, are the ones the locusts appear to prefer, and where, as a general thing, we find their homes, one species preferring the more elevated, broken, and mountainous sections, while another selects the lower broad barren plains.

The two parts of the Mediterranean subregion are briefly described by Wallace as follows:

The northern section is almost wholly a region of mountains and elevated plateaus. On the west, Spain is mainly a table-land of more than 2,000 feet elevation, deeply penetrated by extensive valleys and rising into lofty mountain chains. Italy, Corsica, Sardinia, and Sicily are all very mountainous, and much of their surface considerably elevated. Farther east we have all European Turkey and Greece, a mountain region, with a comparatively small extent of level plain.

Asia Minor to the Caspian is also of a similar character.

This is the district of *Caloptenus italicus*, in some part of which it is to be found every year in greater or less abundance and more or less migratory. The exact limits of its permanent distribution, and whether it is essentially migratory within these limits, are facts which do not appear to have been satisfactorily ascertained by European entomologists.

The character of this region presents, in many respects, a striking similarity to the home of the Rocky Mountain locust. Here is an elevated region, consisting of mountain ranges and peaks rising to the height of ten, twelve, and even fourteen thousand feet above the sea, with extensive intervening treeless plateaus elevated from four to six thousand feet above the sea. The broad mountain ranges have their sides gashed by narrow valleys, whose slopes are usually treeless, and grassy at least on the lower portion. A lack of arboreal vegetation, except in the heavier mountain masses, is a marked characteristic. The mountain area is bordered on its eastern flank by a broad, treeless plain, reaching from the northern lake region of British America to Mexico and extending eastward to the Missouri, its western border having an average elevation of four thousand feet and sloping eastward at the rate of five to ten feet per mile.

That these two districts, resembling each other so much in general character, should be the homes of two migratory locusts so closely allied as to belong to the same genus cannot be accidental, but results from some law of Acridian life which has not yet been discovered. To attempt its solution would carry us back into the history of the climatic changes of the country, the vexed question of specific evolution, and into an examination of the more recent geological changes.

The native habitat of the migratory locust, *P. migratorius*, as we have already seen, consists chiefly of more or less elevated grassy plains, usually called steppes, resembling in some respects the treeless plains of the West; in other words, the great pasture lands of Western Asia and Eastern Europe, the ancient Scythian hive, and the present home of the

Cossacks and Tartars. It is therefore essentially different from the districts of the two migratory *Caloptені*, agreeing with them only in want of arboreal vegetation and dryness.

The region which forms the home of *A. peregrinum* is essentially different from either of the others. It is composed of the arid and desert plains of Northern Africa and Arabia, where rain but seldom falls and tropical heat reaches its maximum. Although the term *desert* has been applied to this region, the fact must be borne in mind, as stated by Humboldt, that extensive areas in the midst of these deserts are covered with at least a scanty vegetation, often sufficient for limited pasturage.

It is therefore apparent that locusts avoid the heavily forest-clad areas and select the open regions as their abode. It is also evident that they seek the drier areas, avoiding the moist sections, where the rain precipitation is abundant. Some, as *A. peregrinum* and *A. americanum*,* require also the fervent heat of the tropics to develop them in migratory swarms, whilst others, as *C. spretus*, although delighting in the warm sunshine of summer days, will, if the atmosphere be dry, flourish in a moderate degree of cold.

As heretofore stated, it is much more difficult to draw the line of the permanent distribution of *C. spretus* than that which marks the limits of its migrations. That the former falls without (east of) the mountain range as far south as Denver, we may assume pretty well settled by the observations of the commissioners in person, each having gone over this ground in a different season from the others. That it bends westward and enters the mountains a short distance south of this point, we think may be safely assumed from the evidence we have obtained. Proceeding northward from Denver, it bends eastward as we advance, embracing the western portion of Nebraska and a large part of Dakota, and extending northward from thence into British America, following approximately the 103° meridian until it reaches the southern limit of the forests, about the 53d parallel of latitude. Thence it bends westward, as given in map No. 1. The portion of the plains east of the mountains which should be included in this area is a matter of considerable uncertainty, nor is the line one that can be rigidly marked.

The north and northwest boundary appears to be somewhat strictly limited by the forest line, though our data in reference to the regions beyond this line cannot be considered as conclusive.

The western boundary is yet a matter of uncertainty, but it is quite probable, from all the facts we have been able to gather, that most of Idaho, Wyoming, and the northern half of Utah will have to be included, if we define the breeding-grounds in the sense heretofore explained.

This region may be briefly characterized as follows: Starting at the point where the southern boundary of Colorado crosses the 105th meridian, the main or eastern range of the Rocky Mountains runs almost

* NOTE.—Although I have throughout spoken of *A. americanum* as migratory in Central America, I would not be surprised if the species found migratory there should prove to be distinct.

directly northward to the 43d parallel of latitude; here it bends northwest, reaching about the 113th meridian, where it crosses the northern boundary of the United States, varying in height from 8,000 to 12,000 feet above sea level, with peaks here and there shooting up to 14,000 feet. The heaviest mountain masses are found in Colorado and Northwestern Wyoming, the former being interrupted by elevated basins or parks eight to ten thousand feet above sea level; the latter by valleys extending north and south. Passing westward from this eastern mountain wall (for such it really is), in Colorado and Wyoming, we traverse a broad, barren plain, with Artemisia as its characteristic plant, until we reach the Wasatch range or western wall, in Utah. This broad area, which averages in elevation about 6,000 feet, is here and there broken into rolling hills with occasional ridges, and is almost entirely free from forests. Passing to the west side of the Wasatch, in Utah, we enter the great Salt Lake basin, which is also mostly barren, with scanty vegetation, and is interrupted by numerous narrow ridges running north and south. It has an average elevation of about 4,000 feet. Passing west of the Teton range, from Wyoming into Idaho, we enter upon the broad, level, and comparatively barren valley of Snake River, which is also without forests. The portion of Montana west of the first range is rugged, being broken into a series of ridges and valleys running north and south, more or less clothed with coniferous forests. The chief timber areas in this extensive region are found upon the mountain masses in Colorado and Northwestern Wyoming and in the western part of Montana.

The main or eastern range, as heretore stated, is flanked on the east by a broad and treeless plain extending from its base eastward to the Missouri River. That portion of this plain where it leaves the mountains in Colorado and Wyoming has generally an elevation of from 5,000 to 6,000 feet and slopes eastward at a rate varying from 6 to 15 feet per mile. As we proceed northward along the mountain flank from the Black Hills, the elevation grows less and less, so that the great barren plateau of Central Montana ranges from 2,000 to 3,000 feet above sea level.

The term "barren" as here used is not to be taken in the sense of *desert*, but as implying without arboreal vegetation, and as usually clothed with a moderate growth of grass, sage, and other plants of a similar nature adapted to a dry climate, and generally suited for pasturage. The forests, wherever found, consist almost entirely of pine and fir, and are confined almost entirely to the mountain ranges where the snow is most abundant.

There is no part of this district where agricultural operations can be carried on without irrigation, as the rainfall seldom exceeds, in any portion, 20 inches in a year, and in many parts does not average more than 6 or 7. The air is very dry, the relative humidity sometimes falling in the summer as low as 20 and seldom reaching 60, as will be seen by reference to the meteorological data furnished by Professor Abbe and found in our former report, and to that found in a succeeding chapter.

In studying carefully the climatic conditions of the various locust areas, we notice this difference between those in the Eastern Continent north of the equator and that of our species. The former have their greatest extension east and west, and in the case of *P. migratorius* and *C. italicus* in the direction of the migrations, while that of *C. spretus* extends north and south, or at least presents its best-defined side toward the east and at an angle to the usual course of migrations. The area of *A. peregrinum* has its greatest extension east and west, the western half at right angles to the usual course of migrations. In speaking of the character of the area occupied by this last-named species, we omitted to mention the elevated portion along the southern limits.

As *P. migratorius* has its chief, or, as we might say, central area about the Caucasus range, and a mountain home or back-ground appears essential to the migratory *Caloptenі*, it is possible that this characteristic is more important to the development of locusts than has generally been supposed.

CHAPTER IV.

HABITS OR CHARACTERISTICS OF LOCUSTS IN ALL COUNTRIES WITHIN THEIR AREAS OF PERMANENT DISTRIBUTION, SO FAR AS THESE RELATE TO THEIR MOVEMENTS.

The chief items of importance under this topic are the following: First. Are they normally sedentary in the permanent area, developing under favorable climatic conditions in immense numbers and becoming migratory from some cause connected with this development; or are they essentially migratory in character? Second. Do they breed annually throughout this entire area, or only in certain portions, changing from time to time from one locality to another?

In our First Report, in the chapter on "Permanent Breeding Grounds," we expressed briefly our opinion on these points in reference to the Rocky Mountain locust, as follows:

It is not to be inferred that the locust breeds continuously over the whole extent of this area each year, as it is to be understood that the locust within its native, permanent habitat is *essentially migratory in its habits*, and while for a series of years it may deposit its eggs in a given river valley, in some park, or in some favorable area on the plains lying about the mountain, in a certain year or for several years in succession it may desert its customary breeding grounds for adjoining regions or cross a low range of mountains and breed in a more distant valley. Moreover, the true breeding grounds in this area are, for the most part, confined to the river bottoms or sunny slopes of uplands, or to the subalpine grassy areas among the mountains, rather than continuously over the more elevated, dry bleak plains.

When Mr. Thomas begun to study them in the field in 1869, he was led to believe from his observations of that season that they are normally sedentary, but subsequent investigations have served to convince him as well as the other members of the Commission that they are essentially migratory in their native habitats.

The evidence upon which this conclusion is founded consists of the numerous facts gathered from the various sections of the mountain area, showing that year after year they are observed migrating in greater or less swarms from point to point within that area. Also the fact that in the mountain valleys and cañons, during years when there is no general movement, little swarms may be seen rising and flying away to other points. Last season Mr. Thomas, while on the top of Pike's Peak, captured two or three full-fledged individuals which had probably been brought down by the rain of the preceding evening in their attempt to pass over, yet no swarm was observed passing during the entire season.

It is, therefore, evident that their flights do not depend upon numbers, but that the brood of a single female, when they attain the proper age, will migrate.

Another fact, which has been repeatedly observed, tends to confirm this opinion, to wit, that they do not breed annually over the entire Permanent area. In passing over the mountain section of Wyoming, Colorado, Utah, Idaho, and Montana, we have found it universally the case that they are confined to limited districts which are much more extended in some years than others. A section infested in one year may be entirely free the next. That certain favorable points are more generally selected as breeding grounds than others is certainly true.

It is true, there is some evidence which tends to cast doubt upon the correctness of our conclusions on this point; for example, the repeated finding of specimens throughout the summer in localities where no migrations have been observed; but the flight of a few grasshoppers in these sections is so common an occurrence that it is not likely to attract attention. It is more than probable that many individuals never fly, but these are exceptions which do not invalidate the general rule. That they are not habitually sedentary in any known locality, as *A. americanum* is, is certainly a fact that cannot be denied.

FLIGHTS.

As the subject of flights is one of the most important relating to the history and habits of the migratory locusts, the Commission has taken special care to procure all the data possible in reference to the flights of *C. spretus*. Our success in this respect may be seen by referring to our former report. That we have exhausted the subject we do not contend, but we may fairly claim that now the movements of *C. spretus* are better known to the world than those of any other locust; and although we do not wish to appear as boasting, we do feel as we think a justifiable pride in asserting the fact.

Our somewhat full, though far from complete, account of flights in our First Report will render it unnecessary to state much that might appear to be required in a full discussion of locust migrations: we therefore refer the reader to that report to fill out such lacunæ as appear here.

In studying the subject of flights, we have found it convenient not only to note such points or subdivisions as the mode of flight, direction of flight, density and extent of swarms, distance over which they move, date of flights, hours of rising and alighting, the height at which they fly, rate of movement, meteorological influences, as effect of wind, rain, heat, &c., flights at night, cause of flights, &c.; but also, in the case of our locust, to distinguish between invading swarms, returning swarms, and local flights. As we may have occasion to make frequent use of the latter terms, we will explain them first, adding, at the same time, what we may have to say in reference thereto.

1. DIRECTION OF MOVEMENTS.

A careful study of the migrations of the Rocky Mountain locust for some years past has revealed the fact that the general or combined movements of this species, so far as the direction or course is concerned, may be designated by the three terms, Invading swarms, Returning swarms, and Local flights.

a. Invading swarms.—This term, when used with reference to the movements of *C. spretus* east of the mountains, applies to those swarms or hordes which move down from their native hatching grounds in the west and northwest into those sections where they are not in any sense permanent residents. It is only applied to those which, leaving the permanent area, pass across its boundary into the temporary regions shown in our map.

The facts showing that the swarms which invade the temporary region come from the permanent regions of the west and northwest are so numerous and have been so fully presented in our former report that it is unnecessary for us to dwell on them at any length at this time, as we have but little to add that is new in reference thereto. It is true that but few swarms have been traced from their points of departure in the permanent regions to their stopping places in the temporary section; yet the circumstantial evidence is so strong as to no longer admit of any reasonable doubt.

This evidence may be briefly summarized as follows:

First. That the invading swarms, especially in years when eggs have not been deposited the previous season, are very generally, if not always, observed in the temporary region east of the mountains to come from the west or northwest, usually from the latter direction. The following brief summary from our former report [1] is strongly corroborative of this assertion:

1821.—Swarms of locusts entered Missouri from the northwest.

1864.—Swarms entered Iowa and Minnesota from the northwest.

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[1] Page 148 *et seq.*

1865.—Locusts flew into Minnesota from the west and northwest.

1866.—There was a general invasion from the west and northwest, which reached to Texas.

1868.—Locusts appeared in Riley County, Kans., from a northerly direction, the exact direction not clearly ascertained.

1873.—Locusts entered Texas in September from the north.

1874.—This was a very general invasion, and all accounts show that the flights were from the northwest.

1875.—Eagle Pass, Texas, was visited by swarms, moving from the north, in September. From Dakota the locusts migrated from the middle of July until the middle of August, moving south or southeast. But there appears to have been no general invasion of the intermediate States and Territories.

1876.—There were fresh arrivals in Texas from the north and northwest. During the same year Missouri, Kansas, Nebraska, and Iowa were visited by heavy swarms, always coming from the northwest.

Some of the swarms this season were traced back nearly or quite to the borders of Montana, at least to the northwestern portion of Dakota.

This is conclusive as to the direction from which invading swarms usually arrive in the temporary region, but before it can be made conclusive of the proposition, and of value in studying the life history of the species, it is necessary to eliminate two possible explanations which may be given without recourse to the hypothesis advanced.

First. It may be contended, as the writer and Dr. Scudder at one time held, following the idea advanced by Keferstein, Zinnani, Schrank, Köppen, and some other European entomologists, that these invasions may be from points much nearer the place of arrival than generally supposed and indicated in the above proposition. For illustration, may not the swarms that reach Texas come from Eastern Colorado or Indian Territory; those arriving in Kansas, from Western Nebraska; those reaching Nebraska, from Southwestern Dakota, &c., thus moving on in successive waves, each wave representing a generation? And is it not more than likely that the circumstances which cause excessive multiplication at one of these points will have the same effect in the other, when these circumstances operate generally over a large area, as in 1866, 1874, and 1876, and hence the movements be apparently the same as if all the swarms came from the permanent region of the northwest?

Secondly. As it has been ascertained that the invading swarms seldom arrive earlier than July, and often as late as August and the first of September, and as those locusts hatched in Texas become full-fledged in April and May, those of Kansas in May and June, and those of Nebraska in June, and almost universally fly northward soon afterwards, may not the invading swarms be the same that moved northward, again returning southward?

The second supposition is easily disposed of. That "returning swarms," or swarms flying from the temporary region northwest, toward the permanent area, do often change their course and again move south, and are sometimes taken for "invaders," is certainly true, as we know from data collected in 1877. But this will not apply in years when no swarms move northward, as was the case in 1867 and 1874, and to a large extent in 1876. Experience has now also enabled those who have carefully studied their characteristics to distinguish, in most cases, "invaders" from those hatched in the temporary regions. A corresponding fact in the case of *A. peregrinum* will hereafter be noticed, where the difference in color alone is sufficient to distinguish between the invading and returning swarms. In the case of *C. spretus* the difference in color is slight, the most marked being the somewhat fiery red of the pronotum in the invaders; and the position of the wings in repose presents also a variation. Practice and experience will even enable those who have never paid any attention to the study of entomology to distinguish between the two.

The first supposition, which appears very plausible, fails also, in part at least, when we test it by the facts. In the first place, the intermediate plains where he swarms would have to develop are so frequently traversed now by stockmen that the fact of their presence would be communicated. In the second place, it is now a well-ascertained fact that locusts hatched anywhere in the temporary region south of the southern line of Dakota almost always move northward when they begin to fly, whereas the supposition requires them to go south or southeast. Thirdly, as we know, from positive data, the returning swarms from as far south as Texas reach Western Dakota and even into Montana, it is therefore highly probable that the invading swarms extend their flight in a single season a like distance southward. Lastly, the facts ascertained, although showing some exceptions, warrant the general conclusion as we have stated it.*

As illustrating this, we present the following facts in reference to 1875 and 1876, the former being considered a year of "returning swarms" from the temporary region, and the latter a year of "invading swarms" from the permanent region. Most of the facts stated will be found scattered through our former report.

1875.—In Texas a swarm arrived at Eagle Pass from the north in September, "but north of this State up to the United States boundary line there was no general invasion from the northwest."

In Indian Territory locusts hatched out this year in large numbers, and "during the month of May they departed in a generally north and west direction." Large numbers flew westward.

In reference to Kansas, the record states that "the locusts hatched out mostly in April and early May, and became fledged May 28 to June 15, and then all flew in a general northwest direction," and that "there were no invasions from the north or west that year."

The same thing was also true in reference to Nebraska, but some of the swarms which flew north in June appear to have returned southward in August, the diseased condition of the latter showing that they had evidently been hatched in the temporary region.[172]

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[172] See Appendix, pp. 129 and 130, First Report.

NOTE.—Facts recently ascertained appear to somewhat modify this conclusion.

Some sections of Minnesota, Dakota, and Northern Iowa were visited in this year, but it is impossible to ascertain now whether these were "invaders" or not. It is known that in some cases they were from the south.

1876.—It is only necessary to refer to our former report to see that this year was one of general invasion from the northwest reaching from Dakota to Texas.

Now let us refer to the locust movements during these years in the permanent region.

In 1875 the locusts visiting Fort Benton and Eastern Montana were from the east and southeast; while those which appeared in 1876 came from the northwest in immense swarms.

In Wyoming vast numbers were observed at Laramie City in 1875, flying south and southeast. In August of 1876 swarms were observed in Southeast Wyoming, east of the Big Horn Mountains and north of Black Hills, flying southeast. In Colorado the flights of 1875 were from the north and northwest, over Greeley and Denver.

In 1875, as stated by Professor Dawson—

> Foreign swarms from the south crossed the 49th parallel with a wide front stretching from the 98th to the 108th meridian, and are quite distinguishable from those produced in the country (British Columbia), from the fact that many of them arrived before the latter were mature. These flights constituted the extreme northern part of the army returning northward and northwestward from the States ravaged in the autumn of 1874.

From the same authority we learn that the locusts hatched north of the boundary line in 1876 flew southward into the United States.

These facts are sufficient to show that the invading swarms which visit the temporary regions south of Dakota come, as a general and almost universal rule, from the permanent area lying to the northwest; and that the resulting brood of the following year return over the same course to the northwest.

The movements in Wyoming and Colorado appear to be independent; coming out of the mountains, they move down the east flank into Colorado, sometimes stopping and producing a brood which next year either returns northwestward over the mountains, or as is sometimes the case moves farther southward, some passing southwest into South Park and adjoining regions, and at other times passing southeast into Texas. This will account for the appearance in Texas of invading swarms when in the sections north, as in 1875, there were no invading swarms.

It appears that returning swarms moving north from Kansas and Nebraska through Dakota often turn westward near the middle of the Territory, following up the course of the Missouri.

Those invading Manitoba come from the west generally, sometimes from the northwest, but occasionally from the direction of Eastern Montana. Those invading Minnesota, from the west and northwest.

In the western States these invading swarms are very commonly designated as "foreigners" to distinguish them from those which are bred in the temporary region.

b. Returning swarms.—This term has already been explained by the use we have made of it in speaking of invading swarms. But there it is limited to those which, having been bred in the temporary region between the Mississippi and the Rocky Mountains, soon after becoming full fledged fly back toward the section from which their progenitors of the preceding season came. It may be used in a general sense to apply to all swarms returning from the temporary regions to which they or their progenitors may have flown to their native habitats.

How far this habit of returning prevails on the Pacific side of the permanent area we are as yet unable to say, our data not being sufficient to determine.

So far as we have been able to ascertain, the disposition to return to the home of their ancestors is not exhibited by *P. migratorius;* at least we have been unable to find any notice of it in the voluminous locust literature of Europe.

Köppen expresses some doubt as to the correctness of the opinion that it is a characteristic of the species to move *only* from the east to the west, and cites instances where it has been known to move northward, especially on the east side of the Black Sea; but there is nothing whatever shown to indicate that there is a disposition of the resulting brood or of the invaders to return to their native habitat; in fact, all the data we can find appear to contradict this. It is more than probable that if the least indication of this had shown itself it would have been noticed, whereas the European writers on locusts assert that they *always* move from the east toward the west.

The difference in this respect between the *C. spretus* and *P. migratorius* is somewhat remarkable, and as yet we are unable to fully explain it; but of this we will speak more fully when we have noticed the meager data in reference to the habits of the other species in this respect.

We have no data whatever on this point in reference to *C. italicus*, which indicates that the attention of European entomologists has not been called to it, and hence we presume is not so marked as in *C. spretus*.

The general direction of the movements of *A. peregrinum* varies in different sections; in Northern Africa, west of Egypt, the invading swarms are from the south, as asserted by Lallemant and Girard, come from the region of the Atlas range. South of this range, in Central Africa, the invading swarms move southward and southwest; [173] in Egypt and Arabia the movements vary, but are generally more or less east and west.

In the states of North Africa, as we might suppose, there are indications of a return movement similar to that observed in the case of *C. spretus*. Lallemant[174] states that the locusts that live for a long time in the adult state become a rosy color, and at length migrate southward

[173] Girard, in Ann. Soc. Ent. France, 4th Ser. 1867, Bull. x-xii.

[174] See last quoted authority.

in the middle of the summer; and return in the winter, when they are of a maroon color, with the extremities yellow. It is evident that the winter brood is not the same as the summer brood going south, nor do we presume the language used was intended to convey this idea. It appears from the statement of M. Girard that those hatched in Algiers, in 1866, migrated westward and southwest in January, but this is spoken of as unusual.

There is some evidence, though not decisive, that in Central Africa the resulting swarms return northward, as, for example, the swarm seen by Barth in July, 1854.

M. Brue[175] mentions the fact of swarms which had moved southward in Senegal returning northward to the desert. The same disposition to return to the land of their nativity is exhibited by the offspring of those visiting Southern Africa.

The locusts which plagued Pharaoh came from the east (Arabia) on an east wind, and in attempting to return on a west wind were engulphed in the sea[176]. Richard Jobson,[177] notes a similar case. Niebuhr[178] says that swarms frequently cross the Red Sea a second time and *return* to Egypt, the upper part of which, adjoining the deserts of Lybia seems to be the cradle of these animals. Whether correct or not in reference to their "cradle," these reverse movements indicate clearly a disposition to return to the place of their nativity.

From these facts, and others which might be mentioned, we feel justified in assuming that it is a characteristic of this species, as of *C. spretus*, for the resulting broods to return to their normal habitat, especially where the direction of the invading movements is northward or southward.

Shaw mentions expressly that the locusts return to the desert to deposit their eggs. Speaking of his observations in Barbary, he says that towards the middle of April (1724) the locusts had so multiplied that they formed clouds which darkened the sun. About the middle of May their ovaries were filled and they began to move backwards into the plains of Metidja and other adjoining regions in order to deposit their eggs.

The same disposition to return to their native breeding grounds is shown by the *A. paranense* in its movements in Paraguay, as indicated by Rengger.[179]

c. Local flights.—In our former report this term was applied only to the movements of those locusts hatched in the temporary regions to and fro, from point to point, within that region. We adopted it chiefly to avoid circumlocution, and explained it to avoid confusion. The neglect to distinguish between such movements and real migrations has often led

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[175] Ritter Heuschreckenplage 19, Labat, Relat de l'Afrique, Occ. 2, 176.
[176] Ex. X.
[177] Visit to Gambora, Purchas, ii 1046.
[178] Travels in Arabia, &c., Transl. ii 334, &c.
[179] Reise nach Paraguay, p. 420.

to incorrect conclusions; hence we have found it necessary, in discussing points relating to migrations, to use some term that would distinguish these flights from what may be more properly termed true migrations.

Strange as it may appear to those who have not carefully studied the characteristics and habits of our western locust that it should be possible to distinguish a local from an invading swarm; yet, as we have heretofore stated, this may be done in almost every instance, even when moving in the same direction, and apparently from the same point. As an illustration of the use of the term, we call attention to the records of autumn flights of 1877 in Appendix XII of our former report. These were in nearly every instance, where south of Minnesota, from the northwest, yet, as was then pretty well known, and as since ascertained, those hatched in the temporary regions, most of which having flown north as far as Dakota again turned southward, being joined usually by those of the section where they again started southward. In some instances our data from local observers enabled us to designate the time and section when and where this change of course began.

The data obtained for 1877—which, as will be seen by reference to our former report, are very full—show that there is considerable difference in these local flights in the area from Dakota south to Texas and the area embracing Minnesota and Northern Iowa, the Coteau des Prairies forming the dividing line. In the former the flights were uniformly northward until in July, after which they were southward until in September, the turning point being somewhere in Dakota, after which there was but little flying either way, the locusts doubtless perishing after their flight southward, and generally without doing injury or depositing any eggs. On the other hand, there were, as will be seen by the following extract from Mr. Whitman's report, repeated flights to the northwest and southeast through Minnesota:

> To sum up; July 1 the air was thick with locusts over a considerable portion of the State. July 3 to 6 they moved across the State to the northwest, and turning at Morris westward; on July 8 to 10, crossed the State to the southeast; July 11 and 12, crossed the State to the northwest; July 20 and 21, after the wind had been blowing from the northwest for four days, they crossed the State again to the southeast; July 28, after some flying to the northwest, crossed the southwestern corner of the State to the southeast; August 2, crossed the State to the southeast in full force. To all appearance the locusts have spent the greater part of their time in the air since July 10.

In 1875 the local flights were not so marked as in 1877; in that year the return flights generally reached their destination—their native habitats in the permanent region—but in the latter year, on account of adverse winds or their diseased condition, which was very marked, they failed to accomplish the apparent object of their return flights, and hence became aimless wanderers, driven to and fro, the weaker dropping out and dying as they moved until all had disappeared. Our local reports are full of accounts of their dropping as swarms moved over.

As heretofore stated, it is true that it is possible in almost every instance to distinguish an invading from a local swarm, although moving in the same direction and apparently from the same point. Those who have had considerable experience with them are generally able, from an inspection of the insects alone, to decide with reasonable certainty this point. But there are other and still more important methods of determining it.

It may appear of but little importance to the farmers and agriculturists of Kansas or Nebraska, on whose fields a swarm of locusts has fallen, whether they are from the plains of Montana or from the prairies of an adjoining State; but if a careful study of their habits shows it to be a general rule that the invading swarms are always, or nearly always, destructive in their operations, and that the local swarms are seldom injurious, then this knowledge is important.

One object of the Commission has been to study carefully this point, for the purpose of ascertaining whether there is any difference in this respect between the invading swarms and those which are local or returning swarms; not only on account of its direct importance to the agriculturists of the invaded States, but also on account of its bearing upon the question of their continued vitality in these States.

Early in the season, when rumors of flying locusts came from the South, the commissioners in the field were asked to express an opinion as to the result; each, when asked, expressed his opinion without hesitation, and allowed it to be published far and wide:

> We do not apprehend any danger from them. In fact, this is precisely what the Commission anticipated, and is one of the strongest possible corroborations of the theory held, that these insects can never become permanent residents of this part of the Mississippi Valley.

The result confirmed to the fullest extent this opinion, and our predictions were fulfilled in a most remarkable manner. Although from the middle of June to the last of August of that year swarms were constantly moving over Minnesota, Dakota, Iowa, Nebraska, and Kansas, some days covering an area equal to any two of these States, yet in all that time, though visited by myriads after myriads, scarcely a dozen fields in all these States were reported as injured. It may therefore be stated as a general rule that returning and local swarms do but little injury. It is possible that with a different season the result may be different, but, so far as the facts heretofore ascertained are concerned, they point to the same conclusion; therefore, with the experience of the past season added, we are justified in giving this as one general rule in reference to their habits.

From the facts we have obtained it is evident that there is a marked difference between local flights in the permanent and temporary regions. In the latter, as just stated, the swarms appear to have little disposition to injure vegetation or to deposit eggs, the presumable reasons for which are given in our former report. While in the permanent area, apparently feeling themselves at home wherever they stop, they follow out their desire for reproduction.

Our data in reference to the local flights of other locusts are not sufficient to admit of comparison in this respect with what is known of *C. spretus*.

We notice here a few statements by travelers and others in reference to local movements of other species, but they throw little light on the subject now under discussion. J. Morier,[180] while at Smyrna, in the months of July and August, observed somewhat carefully the locusts which had hatched out very abundantly there that year (1800). We judge from his very brief description that the species was *A. peregrinum*. He remarks: "It was now completely evident that their devastations were to curse the land. They remained until July and August upon the fields, driven now inland, now oceanwards by the winds; laid their eggs in the autumn, and destroyed, when the corn was already growing, by preference, the cotton, mulberry trees, and fig trees."

The great swarm which entered Germany in 1693 produced successive broods for three years before they entirely disappeared, affording Ludolph an opportunity of studying their habits, of which he, several years afterwards, gave an account.[181] In this he speaks of their passage from one part of the empire to another, corresponding to the movements of *C. spretus*, which we term "local flights." But they deposited eggs and continued to reproduce until 1696 before disappearing.

In the great irruption of 1748–1752 their movements were somewhat different, as the resulting broods continued to press on westward.

2. DISTANCE A SWARM MAY TRAVEL IN THE COURSE OF ITS MIGRATIONS.

In reference to migrations two extremes have been maintained by entomologists and other writers on the subject, which may be well shown by the following extract from Kefferstein's paper:

> It is usually held, and Fabricius himself says, that the *Gryllus migratorius* dwells properly in Tartary, and issuing from thence in great masses comes in his migrations even to Germany and lays waste everything here; but when we consider the immense distance which this insect must pass over from the plains of Tartary in order to reach Germany, crossing rivers and mountains, as compared with the very short period of existence of the mature insect whose end is merely propagation, in order to die upon the completion of this life task, it is clear that the assumption of the migration from Tartary into Germany is an empty hypothesis resting only upon the fact that the *G. migratorius* is found abundantly in Tartary. Moreover, we have never, according to any existing observations on the subject, been able to follow any locust swarm back from Germany into Tartary. Of the same opinion is also Schrank; and this acute naturalist believes that the locusts wherever they show themselves destructive were there likewise born.

He then proceeds to illustrate by reference to the appearance of locusts at various points in Europe, where he contends they originated, even

[180] Second journey, 99, 100.

[181] Beschreibung von allerlei Insecten in Deutchland. Berlin, 1730. Th. 9, p. 6.—Kefferstein.

contending that those observed in England in 1784 must have originated there. Köppen appears to lean toward the same opinion, at least so far as Southern Russia is concerned. But, as heretofore intimated, the facts given by Keferstein and Köppen themselves show beyond doubt that the locusts do pass beyond the limits of their usual hatching grounds into sections where they are not able to maintain their existence.

While the Tartary of the older entomologists and travelers is an uncertain land, and while we must admit that the belief held by many that the locusts in a single season or single migration pass from the regions of the Caspian Sea to Germany is not based upon any ascertained fact, and unfounded, yet that by successive stages they have passed from Bessarabia and Southern Russia into Poland and Germany has been established beyond doubt. That in our own country *C. spretus* has migrated in a single season from Montana into Nebraska and Kansas appears now to be too well established to any longer admit of doubt. The writer for some time was disposed to doubt this as was also Mr. S. H. Scudder, but the facts ascertained by the commission have proven it beyond question.

The most positive evidence we have in reference to the distance swarms of the Rocky Mountain locust travel is to be drawn from the records of return flights.

As we have now ascertained somewhat definitely the date at which they acquire wings at different latitudes we can judge with considerable certainty as to the latitude in which an early swarm seen flying northward originated. As our record of flights in 1877 is very full and we may say almost complete as to the area east of the mountains, we are enabled to trace with almost positive certainty the earlier swarms to their starting point. Those hatched in Kansas did not commence to move until in June, the earliest noted being about the 10th or 12th, but it is quite probable some small swarms left the more southern parts a few days earlier. In the southern part of Nebraska there was no general movement, but the earliest of which we have any record was in the latter part of June. In Texas, the movement commenced soon after the middle of April, from the central part of the State, and by the 10th of May all had departed.

On the 15th of May a swarm was observed at Amazon, in Franklin County, Nebraska, flying north; swarms were observed two days later, passing northward over Trego County, Kansas. From this time until the 25th of the month, numerous swarms were observed passing northward over the western part of Kansas and Nebraska, and the northeast corner of Colorado. And in the latter part of the month some swarms from the south settled down at the Black Hills, and there deposited their eggs. As the locusts in Kansas, Nebraska, Colorado, and in this latitude were not yet fully fledged, it is certain that those seen flying came from some point south of Kansas; and from the meager reports we received from Indian Territory (the only section from which they are not full) we are warranted in saying they were from some point still farther south. These facts make it certain that the swarms of May were from Texas; and, as we know from the abandant data received from that State, chiefly from the central part. The distance traveled over in this movement was some 900 or 1,000 miles. From similar testimony it can be shown that the locusts hatched in Kansas and Nebraska, in 1875, moved as far north in their return flights as the Saskatchewan in British Columbia, or about thirteen degrees of latitude. Invading swarms from the northwest can be occasionally traced an equal distance in their movements southward and southeast.

If we count the entire distance back and forth, north and south, which some of the locusts evidently traveled in 1877, it will certainly exceed a thousand miles. It is, therefore, possible for a swarm of the Rocky Mountain locusts to travel in the course of their migrations a distance of at least a thousand miles, with favorable winds, and it is also certain that they do frequently traverse this distance. The fact that our locust can and frequently does travel a thousand miles being established, there is nothing to forbid the supposition that *P. migratorius* may extend its migrations in a single season from the Crimea or farther east to Poland and Germany, and that the resulting brood may reach England the following season if the climatic conditions are favorable. Nor is there anything impossible in the statement of Major Moore, that *A. peregrinum* passed from Arabia into India in a single migration. *C. italicus* does not appear to be capable of such extended movements.

As a matter of course the extent of their movements depends very largely on the winds, as we shall hereafter see when we touch upon this point.

3. THE SPACE OVER WHICH A SINGLE FLIGHT MAY EXTEND.

This is a question more difficult to decide, and one in reference to which there are still greater differences of opinion.

That it is the usual rule for swarms to alight in the evening and arise again in the morning if the wind and weather favor is undoubtedly true, as will hereafter be shown; but that they may, and sometimes do, fly in the night, can be clearly shown. As they rely chiefly upon the wind to bear them along, the distance to which a single flight may extend depends upon the rate at which the wind moves and the length of time the locusts can sustain themselves in the air. That they can sustain themselves an entire day in the air is too well established to require any further proof here. The experience of 1877 led many persons in the West to the conclusion that they can remain in the air for days without coming down. While this is an extreme opinion, there are incontrovertible facts which go to prove that they do sometimes continue their flights for at least an entire day or more.

The rate at which they travel is variously estimated at from three to twenty miles per hour, according to the rate at which the wind they are on bears them.

A day's flight may therefore be estimated at from twenty to one hundred and fifty miles. But there are numerous facts which go to prove that a single flight may extend much farther than the longer distance here given.

Before presenting the facts bearing on this point, we desire to call attention for a moment to the statement so often made, as an argument to show their powers of prolonged flight, that they cross the Mediterranean Sea from Africa to Italy. This appears to have been first made by Pliny, as already quoted, to refute the theories of certain other authors, that they are unable to fly at night. Most subsequent writers, even down to the present day, who have alluded to this statement, appear to have relied upon it, without for a moment questioning its truth and without investigation. The only other authors we have been able to find who appear to corroborate this assertion by additional evidence are Otho Frisingenses, who says they came over from Africa into Italy and France in 1353 and 1374, and Dor, who believes the invasion of 1858 came from the same country. This is not only contradicted by the statement of Lucretiis, who, residing in that part of Europe, had the best opportunity of knowing the facts in the case; but it is rendered in the highest degree improbable, from the fact, as heretofore shown, that the only migratory species known in North Africa is *A. peregrinum*, which has never been seen in Italy, and, according to Bolivar and Lallemant, never approaches nearer to it than the Balearic Islands. We allude to this not only for the purpose of proving it incorrect, but also to show how long an erroneous statement in reference to locusts, based upon theory, may be accepted as true even by entomologists.*

That locusts can and do often cross over considerable bodies of water is clearly shown by the fact that they reach the Canary Islands from the African coast; come into Cyprus from the neighboring coasts of Asia Minor; cross over the Red Sea at least at its northern and southern extremities, and that *A. peregrinum* has been seen in the Balearic Islands, having come from Northern Africa. *P. migratorius* has also been taken in the vicinity of Edinburg, Scotland, having without doubt crossed over from the Continent. Statements are on record of swarms of the same species having been seen crossing over the Black Sea. Ritter asserts it, and even an official report made to the Russian Government states the same thing. Yet Köppen, who has so carefully studied the history and habits of the locusts in Crimea and Southern Russia, doubts the correctness of these statements. And the more carefully these insects are studied in their native habitats and in the regions to which they migrate, the more we find such opinions fading away before the facts.

* NOTE.—I see it stated recently in a newspaper that a swarm of locusts had this season fallen on the shores of Italy from Africa. Whether the statement as to their appearance, let alone their nativity, be true has not been ascertained up to the time this goes to press.

The facts which are generally quoted as evidence of their power of prolonged flight are the numerous statements of their having been seen at sea a distance of five hundred miles or more from the nearest land from which they could have come. We add here one of these statements as an illustration:

Locusts at sea.—The Essex (Massachusetts) Register published the following account on authority of a letter from the mate of the brig Levant, of Boston, to his friend in Beverly, dated Montevideo, January 17, last past. The mate writes that after having encountered a severe gale on the 13th of September when in latitude of 18° north, and the nearest land being over 450 miles, they were surrounded for two days by large swarms of locusts of a large size; and in the afternoon of the second day in a squall from the northwest, the sky was completely black with them. They covered every part of the brig immediately, sails, rigging, cabin, &c. It is a little singular how they could have supported themselves in the air so long, as there was no land to the northwest for several thousand miles. Two days afterwards, the weather being moderate, the brig sailed through swarms of them floating dead upon the water.[182]

If these statements are received as true, and some of them at least are too well authenticated for us to doubt their correctness, they render it certain that it is possible for locusts, under favorable conditions, to be conveyed this great distance over the ocean.

But does it follow as a necessary conclusion that they have flown to this distance at a single flight? If the remarkable statement by Sir Hans Sloane, which we have heretofore quoted, is to be relied upon, we may be enabled to account for their appearance in mid-ocean without having to assume that these points were reached in a single flight. That locusts may fall into the water in such masses as to buoy many without being submerged, which may afterwards take flight, is not impossible. Lallemant observing a swarm cast into the sea off the shores of Algiers, remarked that many thrown upon the beach by the waves regained their vitality under the influence of the sun. The same thing has also been frequently observed elsewhere.

It is also possible for them to be carried long distances over the ocean by whirlwinds and by violent winds which ascend on leaving the land, the force of which is sufficient to carry them forward in spite of the apparent natural tendency they have to drop when over the water.

We therefore are not inclined to accept these isolated and unusual occurrences as applicable to the question now under discussion; not that we deny the possibility of a swarm passing over a distance of 500 miles in a single flight with a favorable wind, but that the evidence to show these were regular flights is wanting, and from the fact, which will be hereafter shown, that when they come over large bodies of water they have a natural or at least almost universal tendency to fall.

All the facts, therefore, which we have been able to gather in reference to their power of flight lead us to believe that with a strong and long-continued wind they may pass over a distance of from three to five hundred miles, and possibly even more before alighting. The fact that they are driven by the wind instead of really flying as does a bird,

[182] Annals of Natural History, vol. vi, page 527.

and hence have only to sustain themselves in the air, the labor of which is less and less as the velocity of the wind increases, renders the statements of such extended flights less improbable than they would otherwise appear.

4. THE MODE OF FLIGHT; AND MANNER IN WHICH SWARMS ARE FORMED AND MOVE.

The position of the individuals during flight has not yet been studied with sufficient care in this country to enable us to speak as exactly in regard to it as we desire. So far as the observations of the Commission in reference to it extend, and the reports of local observers go, it appears to be their rule when the wind is any ways strong to turn their heads to the wind, the hind portion of the body dropping so that the axis of the body forms an angle of 30° or 40° with the plane of their flights. In this position the beating of their wings against the wind has a tendency to carry them upwards; in fact, the force of the wind against the expanded wings would have this tendency. This, as will be observed, is the easiest possible position they can assume, and the one that requires the least muscular effort; it follows also that the stronger the wind the less the effort necessary to keep them up. When the wind is very light and insufficient to support them with a moderate exertion of muscular power, they either come down, or turning their heads in the direction the breeze is moving, propel themselves by true flying.

An accurate observer writing from Marshall, Lyon County, Minnesota, says:

> They only float with the wind when flying high, and go just as fast as the wind blows. With a strong glass I can plainly see locusts and cottonwood-seeds flying together, and they keep the same rate of progress, but the locusts will leave the seed to the right and left and go below and above them, showing that they make use of their wings to keep up and gyrate in flying, but I think they propel ahead none at all after they get high, but fly forward and upward very fast when rising from the ground to fly away or for short flights.—[D. F. Weymouth.

Now this statement, which corresponds with most of the statements on this point by our local observers and our own observations, makes it evident that the locusts when high were moving backwards, that is, with the head to the wind and opposite the direction in which they were moving; for there is no position they can assume with the head forward, in which the wind can buoy them up and drive them forward. The only position they could assume to accomplish this end would be with the abdomen turned obliquely upward and the head downward, an impossible posture for them to maintain.

Another correspondent says:

> They always travel with the wind, that is in the same direction; of a calm day they travel as fast as the wind, but when the wind is strong they *right about face, letting the wind carry them.*—[H. M. Cox.

This corresponds exactly with theory and with our own observations. When the air is nearly calm and they attempt flight they must necessarily propel themselves by the use of their wings, and this can only be done with the head in the direction they are moving.

But one very careful observer (A. L. Child) whose letter is quoted hereafter says that they move faster than the wind. How this can be, except where the wind is light and they are moving by real flight, it is impossible to conceive, at least it is impossible if they move backwards as heretofore stated.

Köppen[183] says that during flight they have the feet drawn up under the thighs. He also quotes the observation of his father, P. Köppen,[184] that—

The locusts came over the sea, having come without doubt out of the land of the Cossacks of the Black Sea, from north-northeast to south-southwest. All, as distinctly seen, did not have their bodies straight in the direction of the flight held; probably necessitated so to steer themselves in their flight through the air.

Frauenfeld,[185] who observed an immense locust flight in Manila, says that—

Usually they fly regularly with the tibiæ drawn up, the body at an angle of 40° or 50° to the direct line of flight, with the tip of the left wing below.

Köppen, from whose work we take this quotation, adds that he has also observed this sidewise posture of the locust during flight. That many a time of an evening when circling toward the north or south he had observed that they flew sidewise, with the head toward the sun, and at the same time sweeping with the wind, which was blowing out of the west; in their fall they had thus, as in their flight, the wind on the side.

We may add that we have also observed this sidewise movement, which appears to be very common with them, and is probably adopted when they desire to vary their course somewhat from that of the wind.

Russegger[186] remarks that what struck him most forcibly was that the locusts when about to alight for repose, or to eat, turned round with their heads opposite to the direction of flight, and that this was so constantly observed that he concluded it was a characteristic of the animal.

Lichtenstein informed Köppen that he had observed in Africa great locust flights, not against and not with the wind, but, as might be said, with half wind.

When the air is calm and warm and they are ready to move they will be seen rising in the air, in short flights, and often moving aimlessly in circles. They appear to be seeking a current of air to bear them away.

The following statement from Colonel Byers, formerly editor of the Rocky Mountain News, quoted in our First Report, describes very vividly their mode of descending:

Along towards noon on bright warm days they rise by circular flights, each seeming to act individually, to a considerable height, and then all sail away with tolerable regularity, in one general direction. If there is no wind, many of them continue

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[183] Heuschrecken in Süd Russland, 41.

[184] In Bull. de Moscou, 1859, III.

[185] Der Aufenthalt auf Manila während der Weltreise der k.-k. Fregatte Novara. in Verh. der k.-k. Zool. Bot. Ges. in Wien, xi, 1861, 275.

[186] Reise in Egypten, Nubia, und Ost-Sudan, 2 ter. Th. 242. Köppen.

whirling about in the air, like bees swarming, but away beyond myriads can be seen moving across the sun toward the southwest, looking like snowflakes. If there is a change in the atmosphere, such as the approach of a thunder-storm or gale of wind they come down precipitately, seeming to fold their wings and descend by the force of gravity, thousands being killed by the fall, if it be on stone or other hard substance. If not interrupted by such causes, they descend during the afternoon.

It is proper to add that this applies to the east base and within the mountain region, where the atmosphere near the surface of the ground is protected by the mountain wall, while an upper current may be moving eastward or southeast—a condition not found on the plains. The commissioners have also had the pleasure of witnessing this habit of the locust of circling upward in the mountain region, behind some projecting ridge, and in the narrow cañons, apparently for the purpose of ascertaining the condition or direction of the upper currents, and suddenly dropping, if from any cause it proved unfavorable. This habit of dropping suddenly and with folded wings is very marked, and when first observed by the writer attracted his attention more than any single point connected with their movements. Nor does this habit appear to be confined to our native species, but is true to a certain extent both of *P. migratorius* and *A. peregrinum*.

Lucretius says that when they find themselves in a condition not to sustain a long journey they at first drop and then fall precipitately to the ground.

Richard Jobson,[187] describing the fall of locusts in a storm, says:

As we returned homeward there came so many of them behind us that they seemed to be blows of stones and staves.

Captain Frankland,[188] while at Smyrna in the latter part of July, observed a large swarm; in speaking of them he remarks that—

They passed over the city, falling upon the roofs of the houses, where they lay two or three inches deep, and tumbling into the sea in such quantities that they could be traced in continuous streams for many leagues from the land.

Although the method of falling is not described, it is evident from what he says that it was precipitately.

The formation and movements of swarms.—The disposition to mass together begins at an early stage in the life of these insects; in fact, as stated in our former report, it is shown in *C. spretus* from the first, though, as Köppen remarks in reference to *P. migratorius*, no decided association for the purpose of moving forward appears until the second or third stage. But from the third stage onward until they acquire wings this disposition to move forward in armies is shown quite distinctly. The fact that they combine together and move in immense swarms in the winged state, often in such numbers as to darken the sun for hours, is too well known to require any further proof. This habit appears to have given origin at a very early date to the belief that they are led by kings—a belief which, judging from some of our locust cor-

[187] Loc. cit.

[188] Travels to and from Constantinople in 1827-'28, I, 264.

respondence, is not yet wholly given up. We find it frequently stated in the older writers that these kings or leaders with a few companions go before the army a day's journey as it were to find out suitable stopping places, to which the main body comes with unerring certainty. Solomon says (Prov. xxx, 27), "The locusts have no king, yet go they forth all of them by bands," and in this he is certainly correct. But we may add with quaint old Purchas, "Though they be *sine rege sine lege*, yet have they a conspiring agreement to do mischief."

Sometimes they arise suddenly over a large area, as if inspired instantaneously by the same impulse, and fly away. This usually happens under the following circumstances. A swarm makes a start in a given direction, and are stopped by an adverse wind; they remain, generally doing more or less injury, until the wind again turns to the original course. If this change happens during the warm part of the day, and somewhat suddenly, almost in an instant all are on the wing.

The following extract from a letter by Capt. Leslie Smith, then stationed at Fort Sully, Dak., is directly to the point:

It has been observed by me that when the grasshoppers are on the wing, if the wind is fair, they do not alight; but should the wind suddenly change and blow a little fresh, they immediately alight, and remain until the wind becomes favorable again, when they, with wonderful unanimity, take wing and fly off on their intended course.

Norton, Norton County, Kansas, August 13, 1877:

The divide between Prairie Dog and the Sapper was literally covered with locusts at 9 o'clock, and at 10.35 a gust of wind came from a little west of north, when the whole of them rose and started off on their southern tour.—[Thomas Beaumont.

It also occasionally happens that they depart suddenly and in concert from the section in which they have been reared; but their desire to depart will be shown previously by constantly rising in the air in the hot part of the day, taking short flights and circling around in an uneasy and impatient manner. This occurs usually while the air is calm, but the moment it turns in the proper direction, if during the warm part of the day, they are off. But it is usually the case that the larger swarms are formed by constant additions to the ranks of those which first start. Those of a given locality starting, as they move along, others arise and join them. Lallemant, who has studied very carefully the history and habits of the locusts of Algiers (*A. peregrinum*), paying particular attention to their migrations, gives this as his opinion.[189] This is also confirmed by the statements of a number of our Western correspondents.

The following notice of their methods of forming bands is given in the account of the invasion of Transylvania in 1747, and the resulting brood of 1748.[190] Speaking of the resulting brood, the writer says:

As soon as any of them found themselves able to use their wings, they soared up, and by flying around the others enticed them to join them, their numbers increasing daily; they took circular flights of twenty or thirty yards square, until they were

[189] Ann. Soc. Ent. Belg., ix.

[190] Phil. Trans., vol. 46; also, Shaw's Gen. Zool., vi, 130.

joined by the rest, and, after miserably laying waste their native fields, they proceeded elsewhere in large troops.

That they will migrate even in small numbers is evident from the numerous statements bearing upon this point to be found in the appendices to our former report. The members of the Commission can all bear testimony also to this fact from personal observation. The brood of a single female will migrate and even cross over the Rocky Mountain Range without other associates, and during the flying season, on almost any clear, warm day, more or less may be seen in the air moving with the wind, sometimes so few and scattering that only here one and there one can be seen far up toward the sun by the flash of their silvery wings, appearing like floating snow-flakes.

A much stricter discipline (if such a term can be applied to them) appears to prevail in the swarms which come from the permanent region than in the local flights within the temporary area.

We have assumed throughout our discussion of their flights that they move only with the wind when flying in swarms. Although there are occasional apparent exceptions to this rule, we think they are only apparent, and that there are no real exceptions. The facts already given show so conclusively that this is the general rule that it is unnecessary for us to present further proof now, though we may have something more to say when we come to speak of the meteorological influences on flights. That no well-attested instance of a swarm flying directly against the wind can be shown, we are quite confident; but that they can and do occasionally vary their course from the direction of the wind, beating around to the right or left, is certainly true. In addition to the one or two instances mentioned in our report, we add the following from Bowles,[191] who appears to speak from personal observation:

I have seen a troop of locusts pass through Malaga and enter for a quarter of a league over the sea; but when the people began to take pleasure in the hope that they would disappear and be drowned, they gave a sweep toward the left, flew straight to the earth, and paused to deposit their eggs.

The following from our correspondents in reference to the movements of the Rocky Mountain locusts, and from authors in reference to the swarms of the Old World, will probably illustrate their method of movement in masses better than any explanation we can give.

The following letter from Dr. Child, who acted as local observer for us at Plattsmouth, Nebr., from which we have already quoted, is so interesting that we give it in full:

PLATTSMOUTH, CASS COUNTY, *June* 7, 1877.

1867, *July* 2.—General south to north direction on gentle breeze (signal office nomenclature of winds) from south. First noticed about 9 a. m.; continued on the 3d in a heavy body, as also on the 4th, until 3 p. m., when a heavy rain of 1.60 inches in 1½ hours obscured (?) them. A very few were found on the ground after the storm, but not .0001 of what were seen before the clouds obscured them. What became of them? Frequent observations since have shown that when flying with the wind which brings

[191] Introduz., &c., *l. c.*

a storm they simply disappear from view as the clouds obscure the sky. But if a wind adverse to their course meets them they come down in large numbers. The 2d, 3d, and 4th, up to 3 p. m., were nearly or quite clear and wind continued southerly.

1868, *August* 8, 10, *and* 11.—Each day much the same calm, but few clouds in the forenoon, and immense swarms passing from south to north; but each day from 1 to 3 p. m. a northwest to north wind from strong to fresh brought them down like a hail-storm.

Many memoranda were made of flights and arrivals from 1868 to 1875 too lengthy to copy, but all to this general effect: They were invisible when passing over-head until near 9 o'clock a. m., or in the afternoon much after 3 o'clock. They must be nearly in a line with the sun to be visible, and the sun falling below this angle of some 45° leaving untold myriads of them in the air; yet I never knew them to come down after that time (unless driven down by an adverse wind). Again in June, 1875, from the 13th to the 24th, on every day, if the sun shone out, they were passing over, but none were seen descending at night. The locust rarely moves much in the morning till the sun warms up the air as also the locust, and I have no record or recollection of their rising till from 9 a. m. to 11 a. m., yet the mass above would be seen by or before that time high up on their regular course. Such immense masses could not descend each night without literally covering or burying the ground.

Does the main army continue its march night and day, only dropping a few stragglers as they become too weary or hungry to keep up?

1 *b. August*, 1868.—On the 8th, 18th, 19th, and 20th, days of flight, the thermometer ranged from 57° to 86°.

July, 1875.—From the 13th to the 22d the maximum temperature was from 70° to 94°, the minimum from 52° to 66°.

June 14 and 16.—The flight was from northeast to north on northerly winds; 57° to 79°.

August 24 to 28.—Northeast wind; 59° to 86°.

August 29.—Wind south, immense numbers; 74° to 86°.

I do not think they rise to join the crowd above (I never knew them to rise unless there were swarms passing over at the time) in cloudy weather. Still, when in regular flight I do not think clouds stop them, although it obscures them from view. As the sun has appeared through broken clouds I have often seen them passing, while when the sun was obscured they were invisible.

1 *a and c.* Invariably in the direction of the wind, be its force more or less.

1 *c.* By arranging the focal distance of a spy-glass at a known horizontal distance, and comparison of appearance, and size of locusts; I think the passing swarms are from ½ to 1 mile high, varying at times, probably seeking currents of wind of greater or less velocity. In case of sudden or heavy rains, when the air was full of them, none of consequence came down with the rain. It seems impossible that they could fly through the storm. Do they rise above it? In heavy swarms my glasses show them as dense as they can move without interference.

The extent of the swarm it is difficult to ascertain, as the observer can only see a small belt. They may extend indefinitely right or left. During the flight from June 15 to 25 of 1875, I telegraphed east and west. I found a continuous line moving northward of 110 miles, and then somewhat broken 40 miles farther. The movements of the winds for five days (15th to 20th) averaged about 10 miles per hour; and the locust evidently moved considerably faster than the wind, at least 15 miles per hour. The swarm I estimated at from one-quarter to one-half mile deep. It seemed like piercing the milky-way of the heavens; my glass found no limits to them. They might have been a mile or more in depth. They were visible from six to seven hours of each of the successive five days, and I can see no reason to suppose that their flight was checked during the whole five days. If so, the army in the line of advance would be 120 hours by 15 miles per hour = 1,800 miles in length, and say at even 110 miles in width, an area of 198,000 miles! and then from one-quarter to one-half mile deep. This is utterly incredible, yet how can we put it aside?

All my records and recollections say they rise to depart between 9 a. m. and 12 m., and never unless there is a swarm in motion overhead.

2 *a. June* 13 *to* 15, 1868.—Towards northwest on a southeast wind.

1869, *June* 20.—After a four days' southerly wind, they came down largely on a north wind.

1875, *June* 13 *to* 22.—The air was full of them every day, the wind generally from south or southeast. The locusts went with it; two short changes to northeast brought them to the ground.

June 24.—During the forenoon the wind was light from the north, and locusts with it (a rare case). At noon full calm, and progress stopped. They circled round and round, and many came down.

25th to 28th.—Wind southeast. Locusts on it to northwest.

June 14 *and* 15, 1876.—To the southward on northerly winds.

August 10.—No wind and no general course.

August 24 *and* 25.—Northwest and northeast winds brought a few.

On the above times the winds were generally light, from five to ten miles per hour. The weather fair, of course, where the locusts were visible, for they are invisible in cloudy weather.

2 *b.* The temperature at the time of rising has ranged from 70° to 90°. Cold or cool weather renders them sluggish.

2 *c.* The direction always corresponds with the flocks above, of which I have spoken above. I have rarely seen a large number rise at once. The lower air will be very full of them, but at least four-fifths of them rise, take long horizontal flights, but seemingly unable to rise, come to the ground again. I presume they have to make several attempts before they succeed.

August 24, 1876.—I first noticed them. I know nothing of any marching or traveling except as they march across a field of grain or other food and leave a bare plain behind them. When on the wing I am inclined to think they fly all night. Their movement must be regulated largely by the wind they are on, and this they out-travel, according to my observation.

Yesterday, July 22, about noon, I noticed they were passing over in very large numbers; a light southerly wind blew them northward. I gave my entire attention to them, and watched them, assisted with a spyglass. The swarm was of great depth, at least one-quarter mile; how wide I had no means of determining. Through some peculiarity of the atmosphere, probably aided by a lower flight than usual (the barometer indicated from 30.019 to 30.062 inches pressure) I kept them in view until after 7 p. m. with no perceptible diminution of numbers. Careful observations in the evening, and again this morning, show not a single one on the ground.

At 8.30 this morning I succeeded in getting sight of them again overhead, and as the sun rose higher developed numbers about the same as yesterday. (Query: was the flight continuous through the night?)

For several years I have observed the locust, and have seen no exception to the general rule that it is very sluggish in the cool of the morning, *i. e.*, on the earth. It does not leave its perch, roost, or bed until the air is warmed up from 8 to 10 a. m. Supposing this swarm had descended somewhere; it must have literally more than covered the ground; yet, in violation of their general habit of late rising, here they are at 8½ a. m. in regular flight overhead. The thermometer last night was at 68°, this morning at 7 a. m. at 64°. A minimum thermometer fell during the night to 55°, altogether too cool for them to have risen from the earth to recommence their flight this morning. But, on the other side, if cold renders the locust sluggish, how does it succeed in keeping on its way in the upper strata of air, which are much colder than that on the earth? Does its action develop enough heat to enable it to keep up its flight? When met by opposing winds I have seen them come down in large numbers, but by common consent to descend *en masse* I have no knowledge of it. I see no way to avoid the conclusion that they fly all night.

A. L. CHILD, *M. D.*

MARSHALL, LYON COUNTY, MINNESOTA.

When flying high in the air, old locusts always go direct with the wind, but often beat up against the wind or at some angle of it by short flights near the surface. In 1865, July 13, a large caravan passed across my claim, going west in the teeth of a strong northwest wind. The advance was two days ahead of the rear guard, and between them there was at least a grasshopper to the square inch all the way and all the time. I do not think they went quite a mile an hour, and they eat all in their way and left the country as soon as the wind changed to the southeast. They had been hatched in the lower valley of the Redwood and eaten it clean, and started west for food, and pressed on as fast as the winds would admit; and when they could not fly in the usual way they flew as far as they could and then flew again, feeding as they went. The same swarm of locusts will fly in every direction, short flights. I have most satisfactory evidence that they have flown from the north part of Lyon County to Lake Benton—say 40 miles—in one day, and returned to the central part of Lyon County the third day, and, after remaining a day or two, gone east and not returned.

They do not fly high in cloudy weather, but will go from one wheat-field to another. Do not fly high in hard winds, and never are seen flying except between 8 a. m. and 7 p. m., generally from 10 a. m. to 4 p. m. If they fly nights no one knows it. If they go to roost they are in the same spot the next morning, and do not move until they breakfast and the dew is all off. They only float with the wind when flying high, and go just as fast as the wind blows. With a strong glass I can plainly see locusts and cottonwood seeds flying together, and they keep the same rate of progress; but the locusts will leave the cottonwood seeds to the right and left and go below and above them, showing that they make use of their wings to keep up and gyrate in flying; but I think they propel ahead none at all after they get high, but fly forward and upward very fast when rising from the ground to fly away or for short flights.

As to how far they fly I have no reliable data nor much basis for an opinion. But we can, at least, judge pretty certainly at the age of a locust; for a locust breeds but once, never couples until it has flown, but does directly after, doing his courting flying, and does not live long after it lays its eggs. So we can judge by their age in what latitude they hatched, and by that give a good guess how far they have traveled. Now, those that came here in 1873, June 17, began to couple as soon as they lit. They hatched and came to the winged state far south of this, and came here pretty rapidly. Last summer flights came here in August (I cannot fix date) and began to couple as soon as they alighted. We could trace them back by telegraph as far as Manitoba. I believe they came from Saskatchewan Valley and hatched after the middle of June. I think they fly above the limits of human or telescopic vision in long journeys, and, it may be, day and night for a thousand miles.—[D. F. Weymouth.

Mr. Weymouth evidently speaks of a movement on foot where he says "they went west in the teeth of a strong northwest wind."

Mr. G. S. Coddington, of Dell Rapids, Minnehaha County, Dakota, in his letter of December 10, 1877, published in the appendix of our first report, gives the following description of a singular movement observed by him:

The immense swarms, of which I had just kept in advance on the route from Redwood Falls, came rolling over the country. The word "rolling" seems to express the appearance of the movement. The movement of the mass seemed like a great roller moving over the ground. They would drop and rise, make a curved flight, and drop again.

We can understand this if we imagine an immense swarm moving along the ground by short flights, those behind flying over to the front and alighting, the next tier or portion, which would now be behind, moving forward in the same way; a movement which the writer of this chapter has observed on a small scale.

Denon,[192] speaking of a flight he observed, says:

Information was brought that the plain was covered with birds, which traveled in close phalanxes and descended from the east to the west. From a distance they actually saw that the fields seemed to roll along the plain in the direction mentioned. Instead of birds, they found a cloud of locusts, who only skimmed along the land, stopping at every blade of corn to devour it and then flying to fresh prey.

The following description of their movement by the traveler Andersson is worth repeating [193]:

The several columns that crossed our path in the course of the day must each have been many miles in length and breadth. The noise of their wings was very great, not unlike that caused by a gale of wind whistling through the shrouds of a ship at anchor. It was interesting to witness at a distance the various shapes and forms that these columns assumed, more especially when crossing mountain ranges. At one time they would rise abruptly in a compact body, as if propelled by a strong gust of wind: then, suddenly sinking, they would disperse into smaller battalions, not unlike vapors floating about a hillside at early morn, and when slightly agitated by the breeze; or they would resemble huge columns of sand or smoke, changing every minute their shape and evolutions.

During their flight numbers were constantly alighting; an action which has not inaptly been compared to the falling of large snowflakes.

The Italian author Lucretiis, from whose paper we have already frequently quoted, makes the following statement in reference to their movements:

Upon the emigration of locusts, certain circumstances, as common as they are unheeded, merit the attention of the observer. Their flight is more certain, and at a greater altitude, whenever the atmosphere is of a heated temperature, and the air clear and calm (?). On the other hand, when the atmosphere is charged with mist or with rain, or pervaded by a chilly element, or even about the rising or the setting of the sun, they move more slowly, exhibiting a certain rigidity, moving their wings with difficulty, and not rising to any great height. And when they attempt to continue their raids in a rainy season, or one tending to cold, they begin by agitating their wings and exerting all their strength to rise; but not finding themselves in a condition to sustain a long journey, they at first droop, and then fall precipitately to the ground, and are compelled to continue their journey on foot.

Bowles,[194] who believes the chief cause of their migration is the flight of the females to avoid the importunities of the males, says:

In their efforts to escape they begin to rise little by little into the air, and finally to the height of 400 or 500 feet, forming a cloud which intercepts the rays of the sun. The clear and serene sky of Spain is obscured and becomes in the midst of summer more dark and gloomy than that of Germany in spring. The rustling of so many millions of wings forms a dull roar similar to that which a sudden blast of wind produces in a forest full of leafy trees. The route which the first formidable swarm takes always follows the wind, and this first flight is usually prolonged about two leagues, but if the weather is calm and serene the length of their flight is less. In these fatal pauses the locusts commit the most frightful ravages. By their exquisite sensibility to odors they scent from a great height in the air a field of grain or a garden. I have seen them turn from the course of their march more than a half a league obliquely to de-

[192] Travels in Upper and Lower Egypt, Eng. Trans.
[193] Lake Ngami, 282.
[194] Introduzione alla Storia Nat. et Geog., fisica Spagna, T. 2, pp. 1–24.

stroy a field of grain, and after they had devoured it, rise again and resume their first direction which they had left.

The species here alluded to is *Caloptenus italicus.*

Lallemant (*l. c.*) says, in reference to the Algerine species (*A. peregrinum*), that—

> By striking their wings one against another they produce a loud noise resembling that of a swarm of bees when heard at a distance. Gifted with a very strong flight, and above all favored by the wind, the locusts are able to pass over considerable distances without repose. Indeed they have been encountered more than 60 leagues at sea, even at the Balearic Isles, and upon the coast of Spain. The hotter the sun the stronger and more rapid is their flight.

He also states further, that if the Sirocco blows and is strong they appear to accomplish a journey of 20 leagues in a single day, flying frequently at a very great height.

The noise made by the locusts of the Old World during flight is frequently mentioned by travelers. In addition to what is already mentioned on this subject, we may add that Niebuhr says that "the noise they make in flying is frightful and stunning, like that of a waterfall." But so far only one correspondent has mentioned anything of the kind in reference to our Western locust.

5. FLIGHTS AT NIGHT.

That as a general rule swarms alight as night approaches, and wait in the morning until the dew is off and the warmth of the sun is felt before starting again upon their journey, is so well established in reference to locusts in all parts of the world as to need no proof here. But that this rule has its exceptions we asserted in our former report and gave there some reasons for entertaining this belief. Further investigation of this point has served not only to confirm this opinion, but to induce us to believe that the exceptions are much more numerous than we then supposed. This fact and the strong probability, or, as we think we may say, certainty, that swarms frequently are at such a height as to be invisible in daytime, are absolutely necessary to explain some of the phenomena of locust movements. We should therefore be led to this belief even if we had no direct testimony on these points.

As we have heretofore seen, the question of flights at night was a subject of discussion even in the days of Pliny, who held the affirmative in opposition to some authors who asserted that they were unable to fly at night on account of the cold. This author attempted to prove his position, not by any actual observations on the point made by himself or others, but from the supposed fact that locusts passed over the Mediterranean Sea from Africa to Italy, and hence, on account of the time required, must necessarily fly at night. That he was mistaken in reference to the case cited as proof we have already shown, yet we think he was correct in his conclusion.

So far as we have been able to ascertain, this question has received but little attention from European naturalists, although so important in explaining some facts in reference to locust movements.

Kohl[195] says that they fly in the night on their native southern steppes in July and August, but not later than 12 o'clock, and in warm, clear nights when it is light. Demole denies this, and asserts that they fly only during the day, remaining at rest at night. But the facts given in our former report, and the statement made by Mr. Child, quoted above, are corroborated by the following direct testimony of Captain Frankland:[196]

> The passage of these animals lasted during many days, and at night as they crossed over the disk of the moon, by reflecting the light as they shot across the face of the planet, they resembled so many flakes of snow or almost as many shooting stars. The heat of the weather at this period, 87°, was so intense that during the night I was obliged to sleep with my window open, the consequence of which was that the locusts used to tumble into my room and upon my musquito-curtains, and by hopping about the floor and creeping into my bed generally annoyed me extremely.

The fact that it is the general habit of locusts to alight in the evening and resume their journey next day after sunrise, if the wind is favorable, together with the difficulty of observing them at night, even when the moon is shining, have led to the general impression that there are no exceptions to this rule.

In the data obtained by us in 1877 we found repeated statements by our correspondents of the sudden appearance of locusts in the morning in localities where none had been seen the day before.

There were also several accounts of swarms seen flying over localities in continuous streams for several days during the entire day, but none alighting. It was impossible to account for these and some other facts, too well attested to be doubted, without supposing the swarms continued their flights during the night. Starting with this clue, we sought for all the information we could obtain bearing on this subject. This, so far as received at the time our first report was published, was then given. Since then a somewhat thorough examination of the locust literature of Europe and the statements of travelers in other countries who note their observations of the locusts, although bringing to light but few positive statements, such as that given above by Captain Frankland, has convinced us, as the facts in reference to the flights of *C. spretus* did, that it is no uncommon thing for locusts to fly at night when the weather is quite warm and the wind favorable. It is possible they prefer nights when the moon shines, but we do not think they are confined to these; the warmth and wind being the influencing conditions. Certainly this point, as Pliny seems to have been aware, is an important item in determining the possible distance to which single flights may extend. Flying two days and one night, say thirty hours, with a moderate wind, moving 15 miles an hour, will carry them 450 miles.

[195] Reisen in Südrussland, iii, 163.

[196] *Loc. cit.*

6. THE HEIGHT AT WHICH SWARMS MOVE.

In studying the flights of *C. spretus* over the temporary region certain facts, as the sudden appearance of swarms in the afternoon of bright, clear days at certain points, when nothing had been seen or heard of them over the surrounding area; and large swarms departing from one section in a certain direction over a well-settled area, though nothing could be seen or heard of them in that direction, &c., led us to investigate this subject also with special care, to ascertain, if possible, how this was to be accounted for.

There appeared to be no other possible solution of the problem than that the swarms flew at such a height as to be entirely out of sight.

Observations of flying swarms soon made it apparent that although, when seen at some distance approaching and flying rather low, the swarm is observed as a *mass* resembling a cloud, yet when passing overhead the locusts are seen only as *individuals*. This fact rendered it evident that the height at which it was possible to see them was much less than would generally be supposed from the descriptions of locust flights given by travelers in the Old World. It is also probable that what is said here in reference to the invisibility of swarms of Rocky Mountain locusts is not fully applicable to swarms of the larger Oriental species.

It is not possible to determine with any exactitude the height of swarms even when visible, as they do not move in broad sheets, as many who have never observed a flight imagine, nor are they generally in a compact body whose boundary is well defined, forming a clear line, but more like a vast body of fleecy clouds, or, still more correctly, a cloud of snow flakes, often having a depth that reaches from comparatively near the ground to a height that baffles the keenest eye to distinguish the insects in the upper stratum. Professor Aughey has made some attempts at measuring the height of swarms, and in some instances has succeeded in ascertaining pretty correctly the elevation above the surface, and also the depth of the swarm. But the only important question to be decided in reference to this point is, whether they can and do fly at an elevation so great as to carry the entire swarm out of view on a clear day.

The facts already mentioned, which could be accounted for in no other way, and which were of repeated occurrence, render this not only highly probable, but almost certain, and we would be justified in assuming the affirmative even if we had no other evidence.

But, as stated in our former report, the strongest evidence in favor of the view that they do often fly at an elevation above the plains of the border States which renders them entirely beyond the natural vision, is the fact that they *can* fly at that height. That it is no uncommon thing for cranes and wild geese to fly north and south along the Mississippi at a height which carries them entirely out of view is well known, as their notes can frequently be heard overhead when the eye searches in vain for them. At what elevation these move it is impossible to tell, but it is not probable that it is much, if any, over two miles; and it is reasonable to suppose that a height which would render them invisible would render a swarm of locusts invisible when passing overhead, as the latter, as before stated, are seen, not as a mass, but as individuals.

The statement by Mr. Byers,[197] that while on Long's Peak he observed swarms flying over as high as the eye could reach, and that of Mr. Putnam to the same effect, show very conclusively that it is possible for them to fly as much above the reach of the natural eye as the tops of Long's and Parry's Peaks are above the plains of Kansas and Nebraska—about 10,000 feet. The writer has taken specimens on the very summit of Pike's Peak, brought down, probably, by a preceding shower of rain, yet no swarm had been noticed passing over by the Signal Service officer in charge of the station. The Signal Service officer at Bismarck states that with a glass he observed a swarm on one occasion flying above the clouds.

The careful and interesting observations of Dr. A. L. Child, of Plattsmouth, Nebr., whose letter has already been quoted, appear to settle this point beyond dispute; and although we have other evidence pointing to the same conclusion, we deem it unnecessary to present it. We conclude, therefore, that as a general rule swarms of *C. spretus* are not visible to the natural eye at a height of more than seven or eight thousand feet above the plains of the temporary region; that in their long flights, when invading and returning, they not only often, but probably generally, fly, during part of the distance traversed, so high as to be out of sight, and that sometimes they pass above the lower and rain clouds, though as a general rule it is only during clear weather, when the sky is cloudless, that they fly.

If we are correct in these conclusions, they, together with the fact that the locusts also occasionally fly at night, will enable us to understand why it is so difficult to trace the flight of a swarm, and will also serve as an explanation of much of the mystery that has surrounded their movements.

It is somewhat strange that this question should have been overlooked by European entomologists, when it would have sufficed as an explanation of some of the points long in controversy.

Köppen[196] says:

> The height of the flight is quite variable; they direct themselves according to the wind and weather, and may vary during the continuation of the flight. I observed the flight of locusts soon after their last moult; it was in the evening and on a moderate west wind; they mostly flew at a height of 15 or 20 feet; single individuals only reached a height of 40 or 50 feet.

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[197] First Report, 144.

[198] Heuschr. Süd-Russ, 52.

Yersin[199] gives 40 or 50 feet as the height. Kohl[200] says that in fine warm weather the locusts fly very high, from 20 to 30 fathoms (150 to 200 feet); but in cloudy weather they fly much lower, scarcely a fathom high. These statements evidently apply only to short local flights, as these writers were fully aware of the fact that *P. migratorius*, of which they are speaking, frequently passes over extensive mountain ranges covered with forests, which would of necessity require a greater elevation than that given. Bowles[201] says that *C. italicus*, when starting on a flight in swarms, gradually rises to the height of 400 or 500 feet.

As the elevation given by these writers is so far below that at which swarms of *C. spretus* attain in a general movement, we presume no attempt was made to ascertain the greatest height reached.

7. OTHER FACTS IN REFERENCE TO FLIGHT.

As stated in our former report, flights in different directions at the same time and place are not of frequent occurrence, but have been occasionally observed in the case of *C. spretus*. These are always one above the other and in different air currents, sometimes in directly opposite directions, sometimes one column crossing the other obliquely. The instances mentioned in our first report are the only ones of which we have any knowledge.

Whether a swarm ever, by ascending or descending into a different current of air, changes its course without alighting, is a question as yet undecided. From their well-known habit of usually coming down to the ground whenever met by an opposing current, we would suppose such a case very rarely if ever occurs. Professor Aughey noticed in one instance where two swarms were moving in opposite directions, that some from the upper column dropped into the lower, where, as a matter of course, they could no longer be distinguished from the others, but doubtless were borne along by the current in the direction this column was moving.

There are some other points relating to flight which might properly be mentioned here, but as they have some connection with meteorological conditions we will defer mentioning them until we have discussed the bearing of meteorological influences on the migrations of locusts.

But this branch of the subject will be included in a separate chapter; hence all points inseparably connected therewith will be included in that chapter. We will therefore pass to the other divisions of our subject, referring to the chapter on meteorology as may be necessary as though it had been introduced at this point in our discussion.

Supposed tendency of swarms approaching the sea to drive onward and fall into it.—In the preceding portion of this chapter relating to locust flights in other countries, the reader will observe frequent mention of

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199 Biblioth. Univ. de Geneva. 1858, 272. 200 Reise in Südrussland, iii, 162. 201 *l. c.*

swarms plunging into the sea, often in such immense numbers that when thrown upon the shore by the waves the stench arising from their decay produced epidemical diseases among the inhabitants residing in the vicinity. We might add numerous other instances of a like character, but this is unnecessary, as our object at present is only to call attention to the fact and suggest a possible explanation which appears to have been overlooked by those who have written upon the subject.

Köppen[202] says:

The abundance of such instances has led many to believe that they fall into the sea not from an external cause, but from an inner propensity. Thus, says Erichson, "It is well known that the locusts gladly draw toward the sea and there become the spoil of the waves. It seems also that a hidden instinct drives these animals into this element, which thus in great masses are destroyed."

He looks upon this opinion as somewhat hypothetical, but remarks that it is nevertheless not without its parallel among insects, of which *Anisoplia austriaca* presents an example.

Darwin's explanation, as given by this author, is, that the insects, searching in vain for shelter of tree or hill, are driven by a land-wind into the sea; an explanation which Köppen thinks the most satisfactory, as it suits well the treeless and hill-less steppes of Southern Russia.

If we can judge correctly in reference to the characteristics of other locusts by what we know of *C. spretus*, we should decide unhesitatingly against the idea that the locusts have any propensity to plunge into the water; on the contrary, we believe they avoid, as a rule, flying over it, and only do so when driven by strong winds or by excessive hunger.

As will be seen hereafter in the chapter on meteorological influences, and as indicated in our First Report,[203] a sudden change in the temperature or humidity of the atmosphere has a tendency to bring down a flying swarm. Whether the amount of moisture over a large body of water caused by evaporation, and the difference in temperature, as compared with that of the atmosphere over the parched, barren, bordering lands, would be sufficient to sensibly affect the locusts may be doubted; but, notwithstanding their apparent hardiness, they are extremely sensitive to changes in the condition of the atmosphere. Facts already given, as the case mentioned by Bowles, where a swarm varied its course in order to return to land; the similar circumstance mentioned in reference to the flights in Australia, and others of a like character which might be quoted, show an evident desire to avoid the danger of falling into the water where the *danger* is *perceived* and *there is any chance of avoiding it.* A strong confirmation of this fact in the history of the migrations of *C. spretus* is, that in their approach to the Gulf of Mexico in their flights southward through Texas they have always stopped a few miles from the shore. It was reported at one time that swarms had been observed passing on to the Gulf, but careful inquiry has not only failed to confirm this, but, on the contrary, to indicate that no such case has been known.

[202] Heusch. Sud-Russ., 49.

[203] Page 182.

But one well-attested case of locusts or grasshoppers being driven into the waters of a gulf or lake in this country, except instances where swarms have fallen into Salt Lake, is known. This occurred in August of 1879. A vast number of *C. femur rubrum* were observed floating in Lake Michigan, between Racine and Waukegan. So numerous were they that myriads were cast ashore by the waves in winrows along the beach. A hundred specimens of these, collected by the well-known naturalist Dr. Hoy, and sent to Mr. Thomas, were all of the species named. These were cast into the lake by the severe wind-storm of the day preceding that on which they were observed.

The writer of this chapter, after a careful examination of all the accounts he could find of locust swarms *actually observed* falling into the sea, is led to the conclusion that as a very general, if not an almost universal rule, they are driven against their will by severe wind. The chief exceptions, if there are any, appear to be where they attempt to cross over large bodies of water, as to the Canary Islands, from the African shore. In such cases their coming down may be accounted for in several ways consistent with what we know of the laws governing their flights, without resorting to the hypothesis of the abnormal propensity heretofore mentioned. It may be on account of the difference in the temperature and humidity of the atmosphere already suggested. It may be occasioned by meeting an adverse current of air, or that the current on which they are borne is fading out.

Kirby and Spence record an example of the great flying power of the locust. The ship Georgia, which sailed from Lisbon to Havana with a light wind from the southeast, found itself on the 21st of November, 1811, at a distance of 200 English miles from the Canarian Islands, the nearest land; suddenly there came on a calm, a light breeze rose from the northwest, and at the same time there fell from the clouds a countless multitude of great locusts, so that they covered the deck, the masts, and every part of the ship on which they could alight. They appeared not in the least tired, but sprang, on the contrary, quickly up when it was sought to catch them, and tried to escape. The calm or a very light breeze lasted a full hour, and during this time a shower continued falling upon and around the vessel.[204] Otto von Kotzebue observes, in his Voyage round the World, that the course from Plymouth to Teneriffe having been very long, protracted by many calms, only one noteworthy circumstance struck him, namely, a vast multitude of locusts, with which the sea was covered for many miles.[205]

It is possible that these voyagers, possessing such keen eyes, in searching out the green fields of the plains, are deceived by the dark green hue of the sea. Aeronauts could possibly enlighten us on this point.

It is somewhat strange that Köppen, after showing, as he does, that locusts avoid wooded and mountain regions, should accept Darwin's ex-

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[204] Introduction to Entomology, Oken's Edn., vol. i, p. 246.

[205] Allgemeine geographische Ephemeriden von Bertuch. 19r Jahrgang, Feb. 1806, p. 254.

planation as the most satisfactory. Our native species, instead of seeking forests as a place of shelter, appear to avoid them as far as possible.

Darwin's theory is undoubtedly contradicted by the characteristics of all the migratory species.

8. THE CAUSES OF MIGRATION.

As stated in our First Report,[206] "we must recognize the fact that the influences bearing on migration fall into two distinct categories, viz, *remote* or general, and *immediate* or special." We shall therefore briefly consider the two classes separately.[207]

a. Remote causes.—Why one species of insect should at certain times develop in immense numbers and migrate, while another closely allied species, inhabiting the same locality, and to all appearance subject to the same influences, never increases to the same extent and never exhibits a disposition to migrate, is a question which has long puzzled entomologists.

If entomologists are asked why locusts migrate, ninety-nine out of every hundred will probably answer, "On account of *excessive numbers*." We might press the inquiry farther and ask why they develop in such excessive numbers. But we propose, at present, to seek for the remote causes by another road, as the attempt to press back the inquiry step by step would lead us into a labyrinth of biological questions which we have no occasion to enter upon at this time.

A thorough and exhaustive examination of this question would carry us back into the last geological changes of the earth's surface; but this we have not the time to undertake if we felt qualified to do so, which we by no means claim.

As we have heretofore shown, migratory locusts are found only in treeless, dry, and more or less barren regions, and, as a very general rule, their breeding grounds are in areas or plateaus of considerable elevation. The native home, for example, of *P. migratorius*, appears to have been the *steppes* of Southern Siberia and Tartary. *A. peregrinum* has its points of greatest development in Central Arabia and the dry, elevated table-lands of Northern Africa; *A. paranense*, in the higher barren plateaus of Argentine Republic; and *C. spretus*, in the high, barren regions of the Rocky Mountains, and the elevated plains of Montana, Western Dakota, and British America. The marked characteristics of all these regions are, absence of forests, more than ordinary dryness, and rarefied air. Keferstein remarks that—

> A dry, warm, uncultivated, treeless plain, where the brood can be deposited undisturbed and left to grow up, is especially favorable to the propagation of the locust, and in such districts of country the locust plague appears most frequently and regu-

[206] Page 249.

[207] It is proper to state here that while the Commissioners agree in the main as to the causes of migration the writer of this chapter must be held alone responsible for some of the views advanced here.

larly; this is especially found in the district lying between the Libyan Desert and Iran, between the Arabian and Persian Gulfs; in Arabistan, shut in by its adjacent States, and, in a broader sense, with the regions of the Jordan and Euphrates southward toward Jemen.

As a further evidence that all these conditions are necessary to their excessive increase and the development of the migratory instinct, it is found that *P. migratorius* is unable to maintain continued existence in Germany or Poland; and that *C. spretus* cannot remain permanent on the prairies of Texas, Kansas, or Nebraska, or, in fact, in any portion of the area we have denominated the "temporary region." The same thing is also doubtless true in reference to the other migratory species.

It is apparent, therefore, that a more than ordinarily dry and rarefied air is necessary to the development of the migratory instinct; at least we are justified by the facts in assuming this. If it is argued that this condition is necessary to their excessive increase in numbers, and that this increase makes change of place necessary in order to procure food, and that this is the cause of migration, we reply that *C. spretus*, at least, is essentially migratory in its native habitat, and that it will migrate whether in excessive numbers or not; and that the same fact appears to be true of *P. migratorius*. It follows, then, that the disposition to migrate does not depend upon numbers, but is owing to some other cause; for why should *C. spretus* and *P. migratorius* become so excessively multiplied under this influence and other species under the same conditions not?

As a further proof that want of food is not only not the remote cause of migration, but is not always the immediate cause, we may adduce the now well-known fact that swarms reared in the temporary regions will leave the fields of wheat and barley, and the rich grass of the prairies, to return to the barren plains from which their ancestors came. It is also a fact that those reared in the mountain cañons, where there is abundant food, even though there be but few compared with the supply of food, will, when they have reached the proper age, fly away with the first favorable wind. Nor is this only an occasional occurrence but a constant habit; in fact it is almost universally the case. Both on the plains and in the mountains, even when there is abundant food at hand, often when the day is warm and clear and no wind is blowing, they may be seen circling upwards, evidently desiring, as shown by their uneasy movements, to move away, only waiting for the air to assist them.

These facts, which are brought out more fully elsewhere, I think show conclusively that the desire to migrate is not caused by want of food. And as it is manifested to the same extent in their native habitats as in the temporary regions, when parasites are absent as well as present, it cannot depend upon the presence of parasites.

As we have heretofore stated, Bowles assumes that the males are largely in excess of the females; that their ardor is excessive, while the females, needing a larger supply of food, are always intent on feeding. That when the sun has dried off the dew in the morning, the females, to avoid the importunities of the males, after repeated short flights, at length rise up and float away with the wind.

Our only comment upon this eccentric writer's view is, that a careful count of a large number of specimens of *C. spretus* in different collections shows no marked difference in the number of one sex as compared with the other. In our First Report this subject was alluded to[207], and we see no reason to modify what is there stated.

Keferstein remarks[208] that—

> The same causes which impel the *Gryllus italicus* to take the field, move also the *Gryllus migratorius* to his wanderings, namely, want of food; the instinct of breeding, which the female, well knowing that thereby her life-aim will be accomplished, and she must then die, believes will be accomplished through the migration; and, finally, the instinct to seek out a suitable place of abode for their progeny. So then the flight of all species of locusts may be said to depend upon similar causes at bottom: necessity, love, and instinct drive them thereto.

That the desire to seek places to deposit their eggs in localities which are best adapted to the young, influences locusts as well as other insects, cannot be doubted: and that this is one cause of migration is more than probable. But this will not account for the fact that they are essentially migratory even in their native habitats. Nor is there any reason, so far as we know, why it should operate in one species of *Acrididæ* more than another when placed under the same circumstances. *Œdipoda carolina* is found throughout the area occupied by *C. spretus*, and has ample wings to assist it in flight, but it is never found migrating in any true sense; yet the maternal solicitude for the welfare of the young is doubtless as strong in the one species as the other. Neither of the reasons given, therefore, appears to be satisfactory.

Darwin's opinion, as already quoted, appears to be, that excessive heat causes a kind of irritation or uneasy feeling in the locusts, which makes them restless and desirous of seeking some place where they can be sheltered from the rays of the sun. That some kind of irritation caused by excessive heat and dryness may render them restless and uneasy, is not only possible but probable; but that this causes them to fly in search of the shelter of hills and forests is very questionable, especially when we take into consideration, as heretofore suggested, the well-known fact that, as an almost universal rule, they avoid forests and forest-clad areas.

The only certain fact, then, that we have to start with in our investigation as to the origin of the migratory impulse is, that it is in some way connected with a more than ordinarily dry and rarefied condition of the atmosphere. If we suppose this impulse or instinct to be once formed by such climatic conditions, we can then easily explain the flights in the lower plains of the temporary region where the atmosphere is more dense and humid. These conditions, combined with unusual heat, may produce a kind of irritation in the air-tubes, and this may cause them to arise in search of a more rarefied condition of the air; the moving breeze is found to favor respiration and tends to allay the irritation or uneasy

[207] Page 250.

[208] Loc. cit.

sensation, and hence they continue to move upward until they reach a current of air of sufficient strength to bear them onward; they continue to float on this until exhausted, a change in the condition of the atmosphere causes them to descend, or a suitable place for depositing eggs or procuring food is observed.

That a dry condition of the atmosphere does originate this migrating instinct I think is evident not only from the fact that migratory locusts are only found in dry and arid regions, but from the additional fact that in excessively dry years we see in this country *Acridium americanum*, *Caloptenus differentialis*, *C. atlantis*, and *C. femur-rubrum*, exhibiting a strong tendency to mass together and migrate. Even their forms appear to be modified so as to adapt them to this purpose. *C. femur-rubrum*, under such circumstances, I am satisfied from numerous observations made in the last twenty years, undergoes certain modifications which bring it nearer *C. spretus*. This, as a matter of course, is only distinctly apparent when two or three unusually dry years follow in succession. One fact noticed, and for which no satisfactory explanation can so far be given, is the tendency (among the Acridians) of the last segment of the male to become elongated and pointed, and generally to become notched at the tip, or where there is a notch, as in the species of *Cyrtacanthacris* (*Acridium americanum* and *allies*) to change from the square or U form to the sharp or V form. Whether the same thing is true with reference to the Œdipodeans I am unable to say; so far as my observations extend, I have observed nothing of the kind in any species of this group.[209]

Another fact worthy of notice is that as a very general rule—so far as I am aware without exception—the elytra are spotted, the spots usually more or less quadrate.

A careful comparison of the internal anatomy of the migratory and closely allied non-migratory species would probably reveal some constant peculiarity which would assist in explaining how the climatic conditions mentioned bring about this disposition or propensity to migrate. I am inclined to think it is largely due to the effect these atmospheric conditions have on the air-tubes and air-sacs. The vivi-dissections made by Mr. Packard, and recorded in our First Report, tend to confirm this view by showing the important bearing the numerous and large air-sacs must have on the flight of the insect; and the large amount of tracheal surface brought in contact with the air and thereby rendered sensible to its changes.

Our conclusion, therefore, is that the migratory habit or instinct of locusts, whether in the Eastern or Western Continent, is directly attributable to the arid condition of the area in which they originate; that the unusually dry and rarified state of the atmosphere is the chief factor in originating this instinct; that while it affects, to a greater or less extent, all parts of the insect its chief influence is produced by its effect on the tracheæ and air-sacs. It also must have a tendency to harden the integuments and to

[209] I have since noticed the same tendency in *Œ. atrox*.

shrink or lessen the size of the softer parts. As a very general rule, more species of the Œdipoid groups are found in barren areas than of the Acrididæ; the Acrididæ, on the other hand, are generally fleshier or, to use a botanical term, more succulent than the Œdipodæ; it follows, therefore, that the effect of unusual dryness would manifest itself much sooner in the Acridians than in the Œdipodeans, and such is undoubtedly the fact. Although we are unable to follow out fully the effect of the dry condition of the atmosphere on the locust system and tell just how and why it results in the migratory habit, yet we are satisfied we are now on the direct course toward and very near the solution of the question. The usually slender form and unusually hard and horny condition of the external crust agree with this theory, as does also the tendency of the ultimate sternite of the male (sub-anal plate) to grow narrower and become elongated. During the long-continued dry seasons of 1874–1876 the effect was very visible on *Caloptenus differentialis*, a species which delights in rank vegetation, and is, if possible, more lubberly than *C. bivittatus*. Examining specimens of a swarm that had flown from Kentucky and had fallen in the streets of Cairo, Ill., in large numbers, I was astonished at the change from the typical form; they had a wild, ferocious look similar to that observed in *C. spretus;* their bodies were much slenderer than usual; there was a compactness or, to use a term which expresses exactly their appearance, a "trimness" of form never before observed in them.

If the theory here advanced is correct—and it is really but a slight extension of an opinion long maintained and generally received—we have a partial explanation at least of the reason why *C. spretus* became migratory and the Œdipodeans, inhabiting the same region, did not. We also have a theory which agrees with all the data bearing upon the question and which explains most of the facts and does not stand in opposition to any. If this theory is correct, and we are not to suppose a species was formed with a migratory instinct, then it follows that whatever produced or brought about the arid condition of the area where a migrating species originated or became migratory was the ultimate cause of the migratory instinct.

As the arid condition of the mountain region and plains of the West is, in a geological sense, of comparatively recent date, I think it more than probable that *C. spretus* is but a modified form of *C. femur-rubrum;* and that several of the apparently local species found in Kansas, Nebraska, Texas, and Minnesota, which are closely allied, are, so to speak, but results of the visits of *C. spretus;* stragglers, left in their attempt to return to their native habitats, produce a second brood in limited numbers and a combination of favorable circumstances preserve them from the usual fate, and in this way the local form results.

Immediate causes.—If the theory advanced is correct there is no necessity for searching after immediate causes, as they are essentially or we might say constitutionally migratory and will take to flight without any additional impulse. I think it more than probable that the effect of the dry and rarefied condition of the air upon them is such that when they arrive at the perfect state and the season of their amours arrives the migratory impulse is increased by irritation of some kind which causes an uneasy, restless feeling. Although I do not believe their migrations are for the purpose of carrying on their amours, yet I think it highly probable that at this stage of their lives the migratory impulse is strongest, and that the excited condition of all the internal organs is probably one cause of its being strongest at this time. But that the migratory impulse does not depend upon the perfected condition of the insects is shown by the strong disposition of the young to migrate. Hence, the cause which operates to produce this effect acts upon the larvæ and pupæ as well as the perfect insects.

There are some things connected with the movements of the locusts which appear to indicate something more than an impulse *simply to fly*, which is the weak point of the theory if limited to irritating or uneasy sensations as the only cause of migration; one is the evident disposition often manifested by the locusts to go in a given direction. This was shown in our first report and need not be repeated here.

That hunger will cause them to move from place to place in search of food is certainly true, but it would be a violent presumption to say that a swarm in Montana starts from there on a voyage to Nebraska in search of food, or from Southern Russia to Germany. Having the migratory instinct already implanted in them, and with it the adaptation to long flights, when once they start in search of food it is not inconsistent with reason to suppose they continue on their course as driven by the wind until they find food or are exhausted. So far we can connect cause and effect, but we must confess that there are still facts connected with their movements unexplained. For example, as will hereafter be shown in the chapter on meteorological influences, those bred in the temporary regions in their attempts to return to their native breeding-grounds are not governed by the prevailing course of the winds, for if this were so some would go in one direction and some in another; whereas those bred in Nebraska and southward exhibit a uniform disposition to go northward or northwest even when the prevailing course of the wind is adverse.

CHAPTER V.

INFLUENCE OF METEOROLOGICAL CONDITIONS ON THE DEVELOPMENT AND MIGRATIONS OF LOCUSTS.

That the increase and diminution of insects depend very largely upon meteorological conditions is now too well known to require further proof. As a very general rule, which has but few exceptions, warm, dry years are favorable to an increase of insect life, while cold, wet seasons have a tendency to diminish their numbers. Not only is this true, but the development is to a large degree in proportion to the heat and dryness; that is to say, when the season is unusually hot and the drought excessive, insects abound and enormously exceed their ordinary numbers. This is especially noticeable in the case of such insects as the true locusts and other Acridians, the chinch-bugs, most of the *Aphides* and many *Lepidoptera*. But as a general rule the maximum development of a species requires two successive favorable years; at least, such is the case with the locusts and chinch-bugs.

We may state, therefore, as a proposition which we presume will be admitted as correct, *that the development and movements of the locusts are very largely influenced by meteorological conditions.* The *extent* to which these conditions effect their development and govern their movements is a point not yet fully settled, but much of the uncertainty in this respect has been cleared up by the investigations of the commission.

The effect of wind, heat, cold, and moisture upon the movements of the locusts is so marked that it had been observed before the days of Pliny; even the writers of the Old Testament show by their statements that they were aware that the wind is necessary to aid them in flight. Moses states,[202] "And the Lord brought an east wind upon the land all that day, and all that night; and when it was morning, the east wind brought the locusts;" and again: [203] "And the Lord turned a mighty strong west wind, which took away the locusts, and cast them into the Red Sea."

Pliny, as heretofore stated, mentions the fact that certain authors contend that they could not fly at night on account of the cold, although he tries to disprove this by the hypothesis that they cross the Mediterranean Sea from Africa to Italy; yet it shows that these writers had observed the effect of cold upon their flights.

A. *Heat and dryness.*—As already mentioned in this chapter, migratory locusts are found only in regions of more than ordinary dryness, which are free from the shade and moisture-retaining influence of forests; at least indicating, if not proving, that the migratory instinct is caused by, or in some way depends upon, this dry condition of the region inhabited.

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[202] Ex., x, 13.

[203] Ex., x, 19.

That heat and dryness are the climatic conditions most favorable to the development and migrations of the locusts has been maintained by all who have paid any particular attention to the subject and have expressed their views in reference thereto. Köppen[204] asserts that "Heat and dryness are both necessary to the extraordinary increase of the locusts;" and the views of other European entomologists accord with this. In our former report we expressed the same opinion in reference to the development and migrations of the Rocky Mountain locusts. Some attempt to show this by the meteorological records was made, and although not so full and satisfactory as we desired, was all we were then able to present, as there was not time, previous to the date fixed for publication, to examine and discuss thoroughly these records in their bearing upon this subject, though the material was readily furnished by the courtesy of the Chief Signal Officer, to whom we are under many obligations for favors on this subject. A further examination of the older records and of new data which have been very kindly prepared and furnished us by the Signal Service Bureau, a summary of which is here presented, has served to somewhat modify our views on this point. Not that it has caused us to doubt the general correctness of the statement that heat and dryness are the climatic conditions most favorable to the increase of locusts, and hence of their distribution by migration, but that the mode in which these influences operate is not precisely, nor so direct and immediate, as heretofore supposed. But before discussing the point we will present our additional meteorological data, referring the reader to what has been given in our former report in order to avoid repeating it here.

As we shall have occasion to refer repeatedly to Mr. Packard's table of locust years, we insert it here as a means of ready reference.

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[204] Heuschr. Süd-Russ, 68.

Tabular view of locust (C. spretus) years.

Texas.	Arkansas.	Indian Ter.	Missouri.	Kansas.	Nebraska.	Iowa.	Minnesota.	Dakota.	Montana.	Idaho.	Wyoming.	Colorado.	Utah.	New Mexico.	Arizona.	Nevada.	Washington T. and Oregon.	British N. America.
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1854				1854									1854					
1855							?1855				?1855 or		**1855**					
1856				1856		1856	1856				1856		**1856**					
1857				1857	1857	1857	1857				1857		1857					1857
***1858**					*1858								1858					*1858
													1858					
				1860									1860					
					1861				1861				1861					
									1862				1862					
							1863	1863	1863				1863					
					1864	1864	1864	1864	1864			**1864**	**1864**	1864				**1864**
						*1865	1865	1865	**1865**			**1865**	1865	1865				*1865
1866			**1866**	**1866**	**1866**	1866	1866	1866	**1866**			1866	**1866**					
1867			**1867**	**1867**	**1867**	**1867**	1867	1867	**1867**			***1867**	**1867**					
*1868			*1868	1868	*1868	1868		1868	1868				**1868**					
			1869	*1869			1869	1869	**1869**	1869		1869	1869					
						1870	1870	1870	1870	1870	1870		1870			1870		
						*1871	1871	1871	1871				**1871**			1871		
?1872				1872			1872	1872	1872			1872	1872					**1872**
1873					1873	1873	1873	1873	1873		**1873**	*1873						*1873
1874		1874	**1874**	**1874**	**1874**	**1874**	**1874**	**1874**	**1874**		**1874**	**1874**						**1874**
*1875		*1875	***1875**	***1875**	***1875**	*1875	*1875	**1875**	**1875**		**1875**	**1875**	1875				1875	**1875**
1876	1876	1876	**1876**	**1876**	**1876**	**1876**	**1876**	**1876**	**1876**	1876	**1876**	**1876**	**1876**	1876			1876 or	**1876**
***1877**	1877	*1877	*1877	*1877	*1877	*1877	1877	1877	*1877	**1877**	*1877	*1877	*1877			1877	1877 or	*1877

As this table was intended only to illustrate the chapter on chronology, it does not indicate the years of invasion of the temporary region. We therefore call attention to the fact that the years of great locust invasions of these regions, to which we shall chiefly limit the present discussion, were 1876, 1874, and 1866. The year 1864 was also marked by the appearance of numerous invading swarms in the northwest, but the locust distribution was nothing like so general over the west as in 1866. According to Mr. Alexander Taylor, 1855 was also a noted locust year, especially in the intermontane area, on the Pacific slope, and in Mexico; but he speaks also of them as abundant in that and the following year in Nebraska, Kansas, and Minnesota Territories. As the meteorological records that reach back as far as 1855 are too meager to be of any real value, we shall of necessity confine our investigations to the period embracing 1864, 1866, 1874, and 1876.

The following table of rainfall for the years 1860–1866, at the stations named is taken chiefly from Schott's Table of Ratios.[205] The figures, except in the bottom line, are the *ratios* of the rainfall in the different years mentioned, to the mean annual rainfall of the station named at the head of the column. The bottom line shows the mean rainfall in inches at the different stations. A few omissions in Schott's table have been filled out from the record in the Reports of the Agricultural Department:

TABLE I.—*Ratios of rainfall for the years* 1860–1866.

Year.	Fort Ripley, Minn.	Fort Ridgley, Minn.	Fort Madison, Iowa.	Dubuque, Iowa.	Muscatine, Iowa.	Saint Louis, Mo.	Fort Leavenworth, Kans.	Fort Riley.	Fort Abercrombie, Dak.	Fort Kearney and Bellevue, Nebr.	Edwina, Mo.	Average of the eleven stations.
1860	1.22	.66	.77	.80	.....	.71	.61	.76	1.08	.67	.68	.78
1861	1.29	.90	.74	1.15	1.00	.90	.86	1.34	1.35	.77	.92	1.02
1862	.57	1.17	.89	1.05	1.24	1.04	.93	.86	.66	.87	1.13	.95
1863	.69	.73	.72	1.01	.88*	.88	.96	1.16	.77	1.00*	.81	.87
1864	.48	.56	.74	.75	.86	.79	.51	.61	.97	.85†	.87	.73
1865	1.00	1.36	1.06	1.08	.80	1.11	1.61	.94	.....	.93†	1.33	1.02
1866	1.00	1.00*	1.00	1.08	.....	.99	1.52	1.15	1.16	1.03†	1.36	1.13
Annual mean in inches	25.11	25.69	41.96	32.24	42.88	42.18	31.74	28.62	17.34	25.55	30.48	31.25

* Ratio of the nearest stations for the year. Those of 1866, Fort Ripley and Fort Ridgley are the average within less than .01 of those stations in Minnesota west of the Mississippi.

† Ratios of the Bellevue records.

A careful study of this table brings out several interesting facts, of which we may mention the following as most important. The mean ratio of 1864 is the smallest of the series, and as all the ratios for that year fall below the average of the several stations, it, so far as dryness is concerned, was favorable to the increase and migrations of the locusts; and, as heretofore stated, they did appear in portions of the Northwest,

205 Tables and Results of the Precipitations of Rain and Snow in the United States, 147-152.

especially in Nebraska, Iowa, Minnesota and Manitoba. This was also a year of visitation in Utah, Montana, parts of Dakota, Colorado, and the northern portion of New Mexico. But in numbers and general distribution in the region east of the mountains, it was far exceeded by the locust invasion of 1866; in fact it is not usually counted as one of the great locust years.

Before passing to other points suggested by this table we desire to present other evidence showing the unusually favorable conditions of this year for the increase and spread of the locusts so far as dryness is concerned.

First we call attention to the fact that there had been a gradual decrease in the rainfall the two preceding years, as will be seen by reference to the column of means. In 1862 the mean of all the stations was .95; in 1863 it was .87, falling in 1864 to .73.

Does the character of 1864, as shown by these figures, correspond with that of the year throughout the West? By reference to Schott's tables, we find these ratios given for that year in the following States and Territories. The names of the stations are not mentioned here, as our object is only to show the general character of the season in reference to humidity, as compared with the mean annual rainfall. Each ratio represents the rainfall of a station for 1864, in the same manner as given in the foregoing tables:

Texas, .81.
Tennessee, .89.
Kentucky, .93.
Ohio, .96, 1.19, .74, .96.
Michigan, .86.
Indiana, .79, .87.
Illinois, .79, .83.
Wisconsin, .98.
Minnesota, .48, .56, .75, .61.
Iowa, .74, .86, .75.
Missouri, .79, .87, .96, .94.
Kansas, .51, .51, .66.
New Mexico, .76, 1.25.
California, .99, .81, .91, .86.
Washington Ter., .81, .69.
Oregon, .91, 78.
Idaho, .82.
Utah, 1.00, 1.20.
Dakota, .87.
Nebraska, .70.

The general average of these ratios is .83, or 17 per cent. less than the usual rainfall throughout the entire West; and what is rather unusual, and indicative of the general prevalence of the dry season over the entire western portion of the United States, is that, with the exception of one station in Ohio, one in New Mexico, which is estimated, and the two in Utah, the records all show less than the average precipitation. So far, therefore, as the amount of moisture is concerned, this was evidently a favorable year for the locusts.

Now let us turn to the record of temperature and see whether that was favorable or unfavorable. For this we have recourse to the reports of the Agricultural Department as the only data at hand adapted to our purpose. As our object is to compare the meteorology of 1864 with that of 1866, we present, in the following table, in parallel columns, the record of monthly means of temperature of the two years in Minnesota, Iowa, Nebraska, Kansas, and Missouri.

TABLE II.—*Average monthly temperature for* 1864 *and* 1866.

Months.	Minnesota.		Iowa.		Nebraska.		Kansas		Missouri	
	1864.	1866.	1864.	1866	1864.	1866.	1864.	1866.	1864.	1866
	°	°	°	°	°	°	°	°	°	°
January	11.4	11.5	17.0	17.8	17.4	20.6	25.1	27.7	24.4	29.5
February	22.5	9.3	26.6	18.1	31.2	24.5	39.6	30.2	36.7	30.2
March	27.0	19.1	32.6	28.2	34.0	29.5	40.0	38.7	40.8	39.7
April	41.9	42.8	45.7	49.6	45.8	51.4	51.3	56.4	50.6	58.6
May	60.8	56.8	61.3	58.3	63.4	60.7	65.4	73.1	66.6	62.6
June	66.9	65.2	72.0	67.6	74.3	68.3	76.9	70.0	75.5	71.9
July	72.3	74.8	75.5	76.4	77.5	78.4	83.6	77.2	80.2	79.4
August	70.7	65.5	72.1	67.4	74.6	72.6	80.2	73.6	74.1	73.0
September	62.2	55.5	63.7	57.2	66.9	58.4	73.3	61.5	68.3	61.6
October	45.0	47.9	46.5	51.4	45.7	51.8	50.5	55.8	49.7	56.0
November	30.0	33.6	33.1	38.0	33.7	40.7	37.8	42.4	39.8	44.8
December	11.3	17.0	17.5	22.2	19.9	24.6	28.1	29.8	24.5	32.4
Annual mean	43.58	41.58	47.05	46.01	48.7	48.46	54.31	53.03	52.6	53.31

From this table we see that the average temperature of 1864 in each one of the States mentioned except Missouri, was slightly in excess of that of 1866, showing that the former year was somewhat warmer than the latter. A comparison of the monthly means, brings out no fact that would have a tendency to change the bearing of the annual means on the locust question. The months of April, October, November and December are the only ones in which the temperature of 1866 was generally higher than that of 1864.

Do the records of the rainfall for 1866 over the entire West correspond with what is shown in our first table? In order to test this, we present here the ratios of this year in the different States and Territories in the same manner as heretofore given for 1864.

Texas, 1.34.
Tennessee, .96.
Kentucky, 1.23, 1.09.
Ohio, 1.11, 1.18, 1.11.
Michigan, 1.05.
Indiana, 1.31, .96, 1.33.
Illinois, .88. 1.02, 1.13, 1.03, .91.
Wisconsin, 1.19.
Iowa, 1.00, 1.08, 1.03, 1.45, .91.
Missouri, .99, 1.36, 1.22.
Kansas, 1.15, 1.52.
California, 1.36, 1.57, 1.57.
Utah, 1.60.
Montana, 1.30.
Nebraska, 1.03.
Minnesota, 1.00, 1.08, .81

Adding those ratios together and dividing by the number of stations represented, we obtain as the general average 1.16, showing that the rain precipitation over the West in 1866 was about 16 per. cent more than the average annual amount. We are fully aware that in order to obtain strictly correct results on which to base calculations as to the absolute amount of rain precipitation, each station must be compared only with itself at different times; but the method here adopted does give a correct idea of the character of the year in reference to humidity so far as meterological records will show it. In fact, we can obtain a general idea of a season over an extended area, from meterological records, in no other way.

What do our investigations thus far show in reference to the years

1864 and 1866 being favorable or unfavorable to the increase and spread of the locust?

First. That 1864, as regards heat and dryness, was unusually favorable for their development, and that the decrease in the rainfall the two immediately preceding years, rendered the conditions still more favorable than they would otherwise have been.

Secondly. That in 1866 all these conditions were reversed, the rainfall was considerably in excess of the average amount, the season throughout the entire Northwest was somewhat colder than in 1864, and the preceding year presented these adverse conditions to an equal if not greater extent.

If it be true, as heretofore stated, that unusual heat and dryness are both necessary to the excessive development and spread of locusts, how are we to explain the apparent contradiction of this theory shown by the data presented?

So far as the data given relate to 1864, the facts accord with the theory, the only cause for surprise being that the invasion of the temporary region was not more general. The difficulty is to explain how those relating to 1866 can be made to accord with it. That the locusts did invade Kansas, Nebraska, Missouri, and a part of Texas this year in large numbers is a fact that cannot be disputed, and that large swarms appeared in Montana is also true; that the season throughout the entire West was generally of a slightly lower temperature and considerably more humid than the average is clearly shown by the meteorological data given.

Shall we contend that meteorological records do not always correctly indicate the general character of the season? This would be virtually saying that they are of no practical value, a proposition we are unwilling to assume. Shall we abandon a theory in reference to the increase of insect life which accords with the experience of a thousand years, and which no one has ever ventured to dispute? By no means. Whether able to explain this apparent contradiction or not we are not prepared to abandon either of these views.

Before attempting an explanation we will present fuller records of the seasons named as given in the annual reports of the Agricultural Department, and also bring forward the meteorological data relating to the great invasions of 1874 and 1876.

Table III shows the monthly means of rainfall by States, being the averages of all the stations in a State. It is from the records in the reports of the Agricultural Department.

TABLE III.—*Rain-fall of the years 1863 to 1867.*

Months.	Kansas. 1863.	Kansas. 1864.	Kansas. 1865.	Kansas. 1866.	Kansas. 1867.
	In.	*In.*	*In.*	*In.*	*In.*
January	0.57	0.82	0.33	2.48	1.18
February ...	1.80	0.37	1.88	0.36	5.11
March	2.42	1.59	2.27	1.66	2.42
April	3.74	2.86	1.58	3.64	3.27
May	4.87	1.57	1.57	4.78	7.36
June	5.91	2.19	6.72	8.12	4.31
July	2.33	3.55	4.61	6.38	6.36
August	4.72	2.14	5.04	1.10	0.98
September	0.55	2.23	1.00	7.36	1.87
October	1.39	0.68	.....	2.10	1.08
November ...	1.86	2.67	.....	2.64	1.11
December ...	3.99	1.10	1.25	2.51	0.44
Total...	34.15*	21.77*	......	43.19	35.49

Months.	Nebraska. 1863.	Nebraska. 1864.	Nebraska. 1865.	Nebraska. 1866.	Nebraska. 1867.
	In.	*In.*	*In.*	*In.*	*In.*
January	0.75	0.41	.21	2.05	1.97
February ...	0.73	.	5.88	0.53	2.06
March	0.50	....	2.05	1.48	1.98
April	0.75	2.40	4.69	2.28	2.29
May	2.86	..	2.19	1.88	7.28
June	2.81	2.86	5.05	5.60	3.85
July	2.25	0.71	5.11	2.16	4.10
August	2.70	1.48	1.70	2.34	1.55
September	1.75	1.77	1.31	5.78	1.69
October	0.75	4.23	3.32	0.17	0.96
November ...	2.00	1.45		1.24	0.04
December ...	3.37	0.3	1.01	1.56	0.64
Total...	21.25*	.....	......	26.07	28.41

Months.	Minnesota. 1863.	Minnesota. 1864.	Minnesota. 1865.	Minnesota. 1866.	Minnesota. 1867.
	In.	*In.*	*In.*	*In.*	*In.*
January	1.18	0.38	.60	2.30	2.92
February ...	1.18	1.07	1.56	0.65	0.89
March	0.63	1.42	1.90	0.64	1.24
April	0.75	0.34	3.74	2.53	1.83
May	1.94	0.74	4.21	0.41	3.27
June	.27	1.43	4.33	4.56	9.01
July	0.63	4.01	3.61	2.77	5.08
August	3.19	2.09	6.17	6.85	2.32
September	1.87	1.59	3.74	2.66	5.18
October	1.37	2.02	2.38	2.02	1.30
November ...	0.25	1.03	.43	2.13	0.47
December ...	1.31	0.80	1.44	0.37	0.76
Total...	14.57	19.70*	34.11	27.89	34.27

Months.	Iowa. 1863.	Iowa. 1864.	Iowa. 1865.	Iowa. 1866.	Iowa. 1867.
	In.	*In.*	*In.*	*In.*	*In.*
January	2.57	1.28	.32	3.76	1.60
February ...	2.30	0.47	4.68	1.56	3.93
March	1.91	2.58	3.88	1.98	2.59
April	1.07	3.58	5.42	3.27	2.11
May	3.55	3.02	1.83	2.15	6.38
June	1.54	4.29	6.85	5.21	7.13
July	3.44	4.70	6.47	5.21	4.37
August	5.24	3.60	3.95	6.73	3.29
September	3.65	2.79	4.62	5.58	3.40
October	3.66	3.13	5.17	2.55	1.87
November ...	2.89	2.97	.41	1.05	1.11
December ...	5.47	2.3	.71	2.42	1.31
Total...	37.99	34.63	49.31	41.47	37.09

Months.	Missouri. 1863.	Missouri. 1864.	Missouri. 1865.	Missouri. 1866.	Missouri. 1867.
	In.	*In.*	*In.*	*In.*	*In.*
January	3.88	1.86	.34	3.16	2.04
February ...	3.47	7.67	3.99	1.80	3.95
March	3.17	1.67	6.84	2.62	2.49
April	1.45	4.84	5.96	4.00	2.10
May	2.41	4.01	7.22	2.65	6.84
June	.65	1.71	5.89	3.95	3.13
July	1.64	3.71	8.55	5.13	5.41
August	3.54	3.11	3.64	2.70	1.91
September	2.86	4.08	4.78	9.71	1.11
October	3.87	3.27	2.98	3.16	1.77
November ...	1.26	4.06	5.7	1.61	1.55
December ...	5.54	3.0	1.87	2.17	1.37
Total...	35.99	33.50	53.82	42.75	34.27

* Estimated.

Table IV shows the monthly means of the temperature by States, and is from the same records as the preceding.

TABLE IV.—*Temperature of the years* 1863 *to* 1867.

Months.	Kansas.					Nebraska.					Minnesota.					Iowa.					Missouri.				
	1863	1864.	1865.	1866.	1867.	1863.	1864.	1865.	1866.	1867.	1863.	1864.	1865.	1866.	1867.	1863.	1864.	1865.	1866.	1867.	1863.	1864.	1865.	1866.	1867.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January	24.7	25.1	28.6	27.7	22.1	29.8	17.4	22.3	20.6	15.9	19.4	11.4	13.0	11.5	9.0	28.0	17.0	17.9	17.8	14.2	42.9	24.4	23.9	29.5	23.7
February	30.2	39.6	35.8	30.2	33.3	24.9	31.2	29.5	24.5	23.3	15.5	22.5	22.8	9.3	15.0	25.0	26.6	27.5	18.1	24.0	41.9	36.7	33.4	30.2	36.1
March	44.4	40.0	41.	38.7	25.4	36.1	34.0	31.4	29.5	15.8	28.9	27.0	23.8	19.1	13.2	33.1	32.6	30.7	28.2	24.6	43.2	40.8	41.8	39.7	30.4
April	59.3	51.3	53.8	56.4	50.7	53.1	45.8	46.	51.4	45.2	47.2	41.9	42.2	42.8	41.0	50.2	45.7	46.	49.6	44.2	51.5	50.6	51.9	58.6	53.4
May	69.5	65.4	66.3	73.1	59.1	63.4	63.6	62.7	60.7	55.5	57.3	61.3	58.5	56.8	48.4	62.7	66.6	60.	58.3	51.4	55.3	65.4	66.1	62.6	59.1
June	71.50	76.9	75.1	70.0	74.2	67.69	74.3	72.7	68.3	72.6	61.9	66.9	67.7	65.2	64.6	68.2	72.0	71.2	67.6	70.9	72.7	75.5	74.5	71.9	74.8
July	76.3	83.6	76.0	77.2	77.3	71.8	77.5	72.5	78.4	74.7	68.5	73.3	67.6	74.8	68.2	72.5	75.5	69.1	76.4	72.7	76.9	80.2	74.2	79.4	76.5
August	77.8	80.2	75.7	73.6	78.2	72.5	74.6	73.5	72.6	75.3	67.0	70.7	68.5	65.5	67.3	74.9	72.1	71.4	67.4	73.3	77.7	74.1	75.6	73.0	77.1
September	72.6	73.3	74.4	61.5	69.3	65.6	66.9	72.2	58.4	66.3	59.1	62.2	67.1	55.5	58.2	62.2	63.7	71.1	57.2	63.7	69.0	68.3	74.8	61.6	68.7
October	49.1	50.5	55.5	55.8	57.4	39.6	45.7	54.8	51.8	53.2	39.2	45.0	48.1	47.9	47.7	42.7	46.5	49.9	51.4	52.8	47.6	49.7	56.6	56.0	56.8
November	40.6	37.8	46.3	42.4	45.2	39.3	33.7	43.5	40.7	39.9	30.5	30.0	38.0	33.6	34.7	34.8	33.1	39.1	38.0	39.0	40.1	39.8	46.0	44.8	45.9
December	27.8	28.1	21.2	29.8	34.9	21.9	19.9	16.0	24.6	26.9	20.6	11.3	11.0	17.0	14.9	25.9	17.5	19.4	22.2	22.2	31.1	24.5	26.6	32.4	36.4
Annual	53.65	56.8	54.1	53.	52.2	48.8	48.7	49.7	48.4	47.1	42.9	43.6	44.	41.	39.	48.3	47.4	48.1	46.	46.	54.1	52.5	53.7	53.3	53.3

Table III is so imperfect that it is of but little value, and moreover it is formed of the averages of monthly means of the rainfall of all the stations, varying from two or three to twelve or fifteen in a State. As new stations are added they may very materially change the average from what it would otherwise be. Although a combination of this kind, of the rain-fall records at different stations over a State or Territory, may be valuable as showing the average rain-fall over a State for a single year, it is of little or no value as expressing the variation in different years, unless from the same stations. It is given, therefore, simply as one means of enabling the reader to form a general idea of the rain-fall in the Northwest in the years specified.

Table No. IV, showing the monthly and annual means of the temperature, consists of the average means of all the stations in the State, as the preceding, but is more complete and of more value in the discussion of the question we are now considering. As will be seen by reference to the annual averages it corresponds generally with what has already been said in reference to the temperature of 1866, though not in a marked degree.

The year 1865, according to this table, appears to have been as warm as any, if not the warmest, of the five. But the differences are too slight to indicate any law bearing upon the locust problem. An examination of the monthly averages also fails to reveal anything worthy of notice in this connection unless it be that July as a rule was warmer in 1864 and 1866 than in the other years. The only fact which can be drawn from the table which appears to be of any value in this discussion is shown by the following exhibit of the extreme variations in the monthly means, and this only because it appears to correspond somewhat with what will hereafter be shown in reference to the years 1872–'78.

TABLE V.—*Extreme variations of monthly mean temperature from 1863 to 1867.*

Months.	Minnesota.	Iowa.	Missouri.	Kansas.	Nebraska.	Averages.
	°	°	°	°	°	
January	10.4	13.8	19.2	6.5	13.9	12.8
February	13.5	12.5	11.7	9.4	7.9	11.0
March	15.7	19.9	12.8	19.0	20.3	17.5
April	5.3	9.2	8.0	8.6	7.9	7.8
May	12.9	15.2	10.8	14.0	8.1	12.2
June	5.8	7.4	3.6	6.9	6.4	6.0
July	7.2	7.3	3.7	7.6	6.6	6.5
August	5.4	7.5	4.7	6.6	2.8	5.4
September	11.6	13.9	13.2	12.9	13.8	13.1
October	8.9	10.1	9.2	8.3	15.2	10.3
November	8.0	6.0	6.2	8.5	9.8	7.7
December	9.6	8.4	11.9	13.7	10.9	10.9

An inspection of the averages shows that the chief variations are in the winter or cold months, from December to March. The variations in May and September are somewhat remarkable, and, as will be seen hereafter, do not correspond with what is shown by the reports of the Signal Service Bureau.

That no fact of any value bearing on this question can be obtained by an examination of the annual mean temperature can readily be shown by a few examples. For instance, the extreme variation of the annual mean at Fort Leavenworth for 40 years is only 7.83°, and the extreme variation from 1860 to 1870 is only 5.20°; at Muscatine, Iowa, for 25 years it is but 8.13°; at Fort Snelling, Minn., for 42 years it is only 8.40°.

The following tables of temperature and rainfall for the years 1872 to 1878 are extracted from the annual reports of the Signal Service Bureau. The records of the different stations are brought together so that the variations may be readily seen by running the eye over the columns.

TABLE VI.—*Monthly and annual mean temperature from* 1872 *to* 1878.

Years and stations.	Annual.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
FORT BENTON, MONT.													
		°	°	°	°	°	°	°	°	°	°	°	°
1872	......	......	......	......	......	......	......	......	......	......	47.2	24.3	11.3
1873	42.5	16.5	18.4	36.4	40.7	52.4	64.1	69.8	69.3	53.2	40.3	35.1	13.7
1874	42.4	11.3	22.4	18.4	44.4	59.2	63.0	75.1	69.1	58.0	49.8	19.4	29.6
1875	43.5	−8.6	13.9	27.8	43.0	58.1	62.0	74.5	68.9	60.6	51.1	17.1	36.8
1876	......	13.9	16.7	13.3	47.4	56.8	63.8	......	......	......	......	......	......
1877	......	......	......	......	......	......	......	......	......	......	......	......	......
1878	......	......	......	......	......	......	......	......	......	......	......	......	......
PEMBINA, DAK.													
1872	......	......	......	......	......	......	......	......	......	......	......	18.4	......
1873	......	......	......	12.9	33.9	52.3	66.1	65.2	64.4	46.8	35.4	16.1	6.6
1874	......	−3.0	2.6	11.9	29.4	55.3	64.4	69.9	67.0	56.2	42.2	14.4	......
1875	......	......	......	......	32.9	53.3	59.2	64.9	64.3	52.7	37.5	11.1	.8.1
1876	36.3	−2.6	− 4.5	6.5	35.4	54.6	60.5	67.4	63.7	51.9	37.1	15.4	−6.3
1877	38.9	−5.2	+17.4	8.3	33.1	56.8	55.7	68.1	64.3	55.4	40.0	25.7	27.4
1878	......	11.2	25.5	36.2	45.5	47.9	63.7	......	......	......	......	......	......
VIRGINIA CITY, MONT.													
1872	......	......	......	......	......	......	......	......	......	......	43.9	23.6	18.8
1873	......	23.4	15.6	......	......	......	56.9	......	......	......	......	35 6	16.7
1874	40.4	23.1	18.4	24.1	38.4	51.1	53.9	67.7	61.8	50.2	45.8	25.7	24.9
1875	39.4	1.7	22.8	22.8	37.9	47.1	56.2	63.8	60.8	55.9	47.7	25.9	30.5
1876	43.1	17.1	28.1	24.7	37.9	46.4	57.1	64.5	58.5	53.5	44.9	30.9	24.4
1877	40.3	18.8	27.5	33.2	36.5	44.0	52.8	65.2	65.2	51.7	39.1	28.1	24.0
1878	......	23.1	27.9	37.8	39.8	45.5	58.6	......	......	......	......	......	......
BISMARCK, MONT.													
1874	......	......	......	......	......	......	......	......	......	......	41.3	18.1	15.6
1875	36.9	−8.9	−5.9	15.3	33.9	56.1	60.9	69.3	66.2	56.1	42.7	17.2	20.1
1876	36.8	7.9	4.9	13.1	40.3	56.0	61.4	70.3	68.0	53.7	40.7	18.3	6.8
1877	41.6	6.3	26.5	19.0	40.4	56.9	59.0	70.9	69.7	60.5	42.3	28.6	29.1
1878	......	17.5	27.8	40.4	47.6	50.8	60.1	......	......	......	......	......	......
BRECKENRIDGE, MINN.													
1872	......	......	......	......	41.0	53.0	65.0	67.1	65.1	58.3	45.0	21.0	0.4
1873	35.2	2.3	8.0	10.4	35.0	52.0	69.5	67.6	67.0	49.1	38.2	23.4	8.0
1874	38.0	2.6	4.2	15.1	34.0	60.2	65.9	70.2	67.8	57.7	43.8	21.4	12.8
1875	34.6	−9.5	−7.9	14.7	36.1	56.0	60.8	67.7	63.8	55.4	42.0	18.3	18.1
1876	35.7	6.3	4.3	10.5	38.3	56.3	63.1	70.9	67.6	53.8	38.1	18.7	0.1
1877	38.1	−0.9	21.5	15.2	40.5	58.4	58.9	69.5	65.9	58.5	41.9	27.0	28.3
1878	......	14.7	27.4	39.2	47.6	51.2	64.9	......	......	......	......	......	......
FORT SULLEY, DAK.													
1872	......	......	......	......	...	58.3	70.3	73.5	72.2	62.4	52.3	24.5	11.5
1873	45.5	9.6	14.7	32.4	41.5	54.5	74.2	74.3	75.5	57.3	42.1	35.1	14.9
1874	38.8	16.1	20.3	27.7	43.9	63.2	70.2	79.2	76.1	65.2	50.9	26.2	26.9
1875	41.5	0.1	4.2	22.3	39.2	60.1	66.0	73.9	71.4	61.3	48.9	24.4	27.0
1876	......	18.7	14.4	15.9	......	61.7	68.1	75.6	73.1	58.6	......	......	13.7
1877	......	13.9	33.4	23.8	44.7	58.6	63.6	74.9	72.7	64.7	45.0	......	......

TABLE VI.—*Monthly and annual mean temperature from 1872 to 1878*—Continued.

Years and stations.	Annual.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
YANKTON, DAK.	°	°	°	°	°	°	°	°	°	°	°	°	°
1872	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1873	.....	.....	.....	.....	40.1	54.2	72.6	74.7	77.1	60.4	46.1	35.9	18.1
1874	46.6	15.6	18.8	30.6	44.4	62.1	70.7	78.2	74.2	61.7	49.4	30.4	23.0
1875	41.3	0.6	2.5	23.7	40.4	61.2	66.1	71.8	68.3	60.6	47.2	25.9	27.3
1876	43.5	18.9	20.7	20.4	46.7	61.6	65.7	73.3	72.1	58.1	45.4	27.1	12.2
1877	41.4	13.6	36.4	28.5	45.8	58.8	65.0	73.4	71.2	64.7	46.8	31.3	34.2
1878	.....	21.8	33.2	43.4	50.5	54.5	66.5	.....	.....	.....	.....	.....	.....
NORTH PLATTE, NEBR.													
1874	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	52.4	35.7	28.3
1875	46.7	7.4	21.3	33.2	42.2	61.3	69.9	72.5	71.7	62.5	53.4	31.5	34.0
1876	48.0	23.6	32.4	27.9	50.3	59.6	67.9	76.3	72.8	60.1	47.9	36.4	21.2
1877	47.9	17.4	34.1	32.7	45.4	57.9	66.2	75.5	72.8	64.6	44.6	33.4	30.7
1878	.....	24.9	34.6	44.3	51.0	54.9	66.0	.....	.....	.....	.....	.....	.....
OMAHA, NEBR.													
1872	20.0	19.0	27.5	31.0	51.0	61.0	72.7	77.0	75.6	62.8	53.0	30.6	19.0
1873	48.2	16.9	26.9	38.2	44.2	59.0	74.4	75.7	71.1	60.6	48.5	38.5	25.2
1874	45.7	22.3	23.4	33.8	45.1	66.6	73.2	80.0	77.3	63.0	54.0	36.0	28.4
1875	46.9	16.1	13.8	30.5	45.4	63.2	71.1	74.4	70.2	62.9	49.6	32.6	33.5
1876	48.5	26.8	30.1	29.3	51.3	63.6	68.6	75.1	75.4	60.0	50.3	33.2	19.2
1877	51.1	20.2	37.3	33.7	50.5	60.7	69.1	76.0	73.2	66.6	51.1	36.3	39.2
1878	.....	28.9	36.9	48.1	55.0	58.5	68.4	.....	.....	.....	.....	.....	.....
KEOKUK, IOWA.													
1872	51.6	25.8	30.4	35.0	53.9	64.5	75.2	78.6	77.3	68.2	55.5	34.6	20.5
1873	50.5	17.6	23.1	38.7	48.5	61.5	77.9	76.3	78.7	63.9	49.8	38.9	32.0
1874	52.9	27.8	29.4	38.3	44.6	67.2	76.7	80.5	76.8	67.1	55.7	40.2	31.6
1875	48.1	16.7	18.1	34.1	49.5	62.9	71.4	76.3	71.6	64.3	51.1	35.3	36.5
1876	51.2	34.1	35.0	34.9	53.0	63.9	70.1	76.5	76.2	64.4	52.2	36.0	19.0
1877	53.3	22.5	38.4	32.6	51.0	62.3	71.7	76.7	74.4	70.1	55.3	39.6	44.8
1878	.....	33.3	37.8	50.3	57.5	60.3	70.7	.....	.....	.....	.....	.....	.....
SAINT PAUL, MINN.													
1872	41.2	15.1	20.3	21.9	45.1	55.2	67.9	71.2	69.2	57.6	47.2	23.8	.....
1873	41.6	6.7	14.3	26.7	41.9	55.1	73.0	71.0	70.7	54.1	41.3	25.6	18.6
1874	43.5	13.8	14.4	23.7	37.5	62.2	68.7	74.7	70.5	60.9	49.4	28.7	18.8
1875	38.3	−2.4	−1.8	22.0	39.7	58.8	63.6	73.8	66.6	57.2	42.8	25.2	25.5
1876	.....	16.6	17.4	24.3	43.9	59.2	66.3	.....	69.9	56.8	43.2	29.6	8.4
1877	46.9	10.0	32.0	23.7	46.2	62.0	63.7	73.6	72.2	66.6	45.7	32.4	33.9
1878	.....	22.5	31.6	44.4	51.1	55.1	66.6	.....	.....	.....	.....	.....	.....
CHEYENNE, WYO.													
1872	42.0	26.6	30.9	33.0	38.3	52.0	51.5	64.5	65.1	55.6	45.2	28.2	23.4
1873	45.6	24.6	25.0	39.7	34.4	49.2	69.5	69.7	69.2	55.9	42.5	40.1	27.6
1874	45.7	30.4	22.9	28.9	39.0	56.6	65.2	71.8	68.6	54.2	46.7	35.8	29.1
1875	42.7	12.5	25.6	24.3	36.9	54.7	63.7	64.0	63.2	56.0	47.9	30.3	33.4
1876	44.5	23.8	30.7	26.8	42.4	50.6	60.8	72.3	66.5	57.3	46.9	33.2	23.4
1877	45.3	25.0	31.6	35.9	38.2	50.8	59.0	70.2	67.9	56.2	40.0	30.1	28.9
1878	.....	25.3	30.9	38.7	43.5	47.9	58.6	.....	.....	.....	.....	.....	.....
DAVENPORT, IOWA.													
1872	49.0	23.0	27.8	33.3	50.9	61.5	73.2	76.3	74.6	64.6	52.1	32.9	18.7
1873	49.8	17.1	23.9	36.7	46.9	59.6	77.9	75.6	78.0	62.3	48.3	34.6	29.7
1874	49.8	23.7	25.0	34.7	41.6	64.5	73.2	78.0	74.4	65.5	52.5	36.4	27.9
1875	45.7	9.4	10.9	30.4	46.3	60.9	68.6	74.0	69.9	61.7	48.8	33.5	34.5
1876	49.0	29.8	29.0	32.2	51.2	62.4	69.4	75.9	74.9	62.5	49.3	35.3	15.6
1877	51.0	17.2	36.1	28.7	49.8	62.2	69.2	75.3	72.8	67.3	53.7	37.2	42.7
1878	.....	30.9	36.9	48.4	55.0	57.7	68.2	.....	.....	.....	.....	.....	.....
DENVER, COL.													
1872	47.8	23.8	33.7	36.3	46.2	57.7	67.3	69.3	69.8	60.1	50.1	32.5	27.6
1873	48.0	30.0	30.3	44.0	39.9	53.3	68.9	71.5	70.8	59.8	45.2	40.6	22.4
1874	50.0	31.5	24.7	36.4	43.1	61.9	70.0	76.1	73.0	59.0	52.9	42.2	29.7
1875	48.8	16.8	32.3	33.4	44.5	60.2	70.4	68.1	69.0	61.7	54.1	37.3	37.8
1876	49.8	28.3	37.7	34.4	49.3	57.1	65.8	76.4	70.1	61.5	51.7	37.1	27.2
1877	48.6	24.1	34.5	42.8	44.2	56.5	65.1	73.8	70.9	61.9	44.7	34.8	30.0
1878	.....	26.1	36.2	44.3	49.9	54.9	64.3	.....	.....	.....	.....	.....	.....

TABLE VI.—*Monthly and annual mean temperature from* 1872 *to* 1878—Continued.

Years and stations.	Annual.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
COLORADO SPRINGS, COL.	°	°	°	°	°	°	°	°	°	°	°	°	°
1873	......	......	......	......	......	......	......	......	......	......	......	37.4	42.7
1874	47.7	30.3	25.5	34.5	38.5	58.6	68.9	73.2	70.3	56.7	49.9	37.9	28.1
1875	46.4	19.1	29.2	30.4	41.6	57.3	67.9	64.6	65.3	57.9	51.3	37.1	35.4
1876	......	28.2	35.0	33.5	46.5	54.9	64.0	72.0	......	......	......	......	......
DODGE CITY, KANS.													
1874	......	......	......	......	......	......	......	......	......	......	60.7	38.4	34.2
1875	52.1	13.2	29.8	38.1	47.9	65.4	75.4	75.5	74.6	68.7	56.6	39.9	40.7
1876	54.2	35.3	41.5	34.7	56.6	64.5	71.2	79.6	77.2	66.7	52.6	38.4	22.8
1877	53.2	23.9	37.1	42.6	50.1	62.7	70.6	77.5	76.2	68.4	51.7	38.6	39.0
1878	......	32.0	38.2	49.3	55.9	61.9	70.5	......	......	......	......	......	......
FORT GIBSON, IND. TER.													
1873	......	......	......	......	56.2	67.6	70.6	80.7	78.8	70.2	56.9	49.8	40.6
1874	60.9	39.5	41.3	52.2	53.0	70.3	78.6	83.1	86.1	71.5	60.9	50.7	43.4
1875	58.2	27.7	38.7	47.7	56.7	67.6	77.9	80.0	74.6	70.8	57.7	49.4	48.4
1876	59.2	45.4	47.6	44.4	63.4	69.6	73.6	81.0	81.4	71.8	58.4	44.8	29.9
1877	59.0	33.7	44.8	49.2	57.9	68.2	75.3	78.2	77.1	70.5	60.5	44.3	48.6
1878	......	39.2	45.4	57.3	64.4	68.5	74.9	......	......	......	......	......	......
LEAVENWORTH, KANS.													
1872	52.4	25.0	30.9	37.0	56.2	65.6	77.2	78.4	78.4	67.7	56.4	35.0	21.0
1873	52.5	19.0	30.0	42.1	48.6	63.0	75.5	77.5	79.2	65.4	56.9	41.8	31.9
1874	54.4	28.4	28.8	40.0	49.0	67.3	77.4	82.8	81.3	66.8	57.0	40.0	32.7
1875	51.4	16.7	22.3	37.6	49.8	65.8	76.7	77.6	73.1	66.6	53.6	37.3	39.9
1876	53.2	35.4	38.3	35.7	55.2	65.5	71.2	78.9	78.2	66.0	53.7	37.6	23.3
1877	54.1	24.6	39.5	38.4	53.3	63.8	71.9	76.3	75.1	67.9	54.5	39.5	44.2
1878	......	33.8	40.2	50.9	58.8	62.3	70.5	......	......	......	......	......	......
SANTA FÉ, N. MEX.													
1872	48.3	27.0	34.0	38.8	45.8	58.1	66.9	67.6	67.0	60.0	49.0	33.0	32.6
1873	48.8	29.0	32.0	44.0	44.0	56.0	65.6	71.0	66.0	61.0	51.0	41.1	25.8
1874	48.9	31.0	27.8	36.2	42.1	59.8	69.3	71.1	69.9	60.5	52.3	38.7	29.2
1875	48.6	28.1	31.4	34.4	47.4	59.2	67.9	65.2	66.5	58.7	53.5	38.7	32.6
1876	47.9	29.0	32.8	36.5	50.2	55.9	66.0	69.2	65.2	60.2	48.6	35.7	28.5
1877	48.3	31.7	33.3	44.4	42.3	54.4	66.6	68.6	68.4	61.4	47.3	33.4	27.8
1878	......	21.4	30.0	40.7	47.4	55.8	62.9	......	......	......	......	......	......

TABLE VII—*Monthly and annual rainfall in inches from 1872 to 1878.*

Years and stations	Annual	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
PEMBINA, DAK.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1872												0.84	
1873				0.04	0.25	2.16	2.90	1.47	2.86	1.95	0.40	0.42	0.18
1874		0.06	0.06	0.44	0.15	1.51	3.45	1.40	3.02	1.70	0.40	0.30	
1875					0.47	1.87	3.83	1.18	2.62	0.92	1.26	0.70	0.56
1876	25.75	0.17	0.53	1.09	0.49	6.55	3.43	5.52	6.47	0.54	0.14	0.39	0.43
1877	21.67	0.06	0.10	1.13	0.68	4.15	9.85	1.47	0.51	1.40	0.69	0.55	1.08
1878		0.12	0.26	4.50	5.78	2.54	3.57						
FORT BENTON, MONT.													
1872											0.19	0.61	0.59
1873	11.19	0.60	0.65	0.23	1.14	3.03	1.67	1.29	1.59	0.58	0.19	0.86	0.12
1874	10.45	0.67	0.10	0.64	0.43	2.98	2.16	0.10	1.17	0.49	0.56	0.58	0.60
1875	12.75	0.66	1.11	0.22	1.04	1.60	2.57	2.24	1.19	0.13	0.71	0.85	0.43
1876		0.71	0.28	1.53	1.25	11.06	1.45						
BISMARCK, DAK.													
1874										0.64	0.83	2.18	0.37
1875	27.43	1.05	1.32	2.06	4.22	3.40	5.02	1.53	2.89	1.85	2.37	1.33	0.39
1876	31.00	0.78	1.50	3.30	2.77	5.74	1.24	1.48	6.55	5.61	0.30	0.86	0.87
1877	17.68	1.64	0.19	0.77	1.32	4.15	4.60	2.52	0.35	0.11	0.94	0.40	0.69
1878		0.00	0.26	1.46	5.71	3.15	2.78						
BRECKINRIDGE, MINN.													
1872											2.17	1.03	1.14
1873	27.39	1.63	2.21	1.81	2.11	2.33	4.17	2.78	7.20	0.38	1.25	1.04	0.48
1874	27.63	1.74	0.57	2.21	0.55	2.08	8.21	1.23	7.27	1.43	1.55	0.25	0.54
1875	17.75	0.30	0.67	2.11	1.07	2.01	4.95	0.70	3.31	1.80	0.37	0.24	0.22
1876	18.13	0.10	0.19	1.63	1.87	1.87	0.85	2.34	5.84	2.26	1.10	0.02	0.06
1877	29.38	0.03	0.01	0.30	2.08	2.81	7.44	6.54	3.36	2.50	2.85	0.29	1.17
1878		0.06	0.18	4.07	7.77	2.77	7.01						
VIRGINIA CITY, MONT.													
1872											0.12	0.52	0.16
1873		0.13	0.19				0.71					0.09	0.06
1874	16.32	0.11	0.06	0.14	0.10	4.18	3.58	1.10	3.11	1.46	1.12	1.20	0.16
1875	17.00	1.29	1.37	1.50	0.30	4.16	1.54	0.73	2.94	1.25	0.81	0.91	0.22
1876	17.63	0.59	0.49	1.06	0.84	5.58	2.65	1.96	1.56	0.88	0.91	0.20	0.91
1877	17.47	0.56	0.73	1.35	1.38	3.93	2.08	1.79	0.23	2.70	1.39	1.19	0.14
1878		0.45	0.62	0.91	1.83	5.13	3.78						
FORT SULLY, DAK.													
1872											0.02	1.28	0.57
1873	14.62	1.00	0.29	0.49	1.06	3.17	3.23	1.86	2.66	0.07	0.56	0.15	0.08
1874	16.24	0.09	0.17	0.92	0.21	5.05	6.24	0.67	0.57	0.18	1.51	0.55	0.08
1875	13.99	0.53	0.91	0.58	1.60	2.62	2.36	0.51	3.26	0.89	0.38	0.20	0.15
1876		0.09	0.10	0.91		1.37	4.25	1.99	4.14	4.09			0.56
1877		1.01	0.03	2.52	4.14	4.02	1.76	3.69	0.84	0.44	1.11		
SAINT PAUL, MINN.													
1872											0.52	1.91	
1873	33.74	1.31	1.54	1.34	2.44	4.63	7.74	3.83	4.61	2.56	2.57	0.79	0.38
1874	35.51	0.49	1.07	2.24	0.95	1.65	11.67	1.95	3.90	5.76	3.21	1.90	0.72
1875	30.66	1.41	1.72	2.19	2.27	3.06	4.33	0.82	8.74	2.16	1.56	0.84	1.56
1876	23.67	0.73	0.66	1.43	2.23	3.15	2.02	2.73	5.28	2.99	1.27	0.93	0.25
1877	28.86	0.55	0.07	1.57	1.93	5.43	7.13	0.52	2.83	2.56	3.62	1.24	1.42
1878		1.00	0.67	1.24	2.43	2.33	3.58						
YANKTON, DAK.													
1873											1.49	0.03	0.52
1874	23.83	0.57	0.65	0.79	0.24	2.59	6.65	3.84	4.05	1.74	1.64	0.56	0.51
1875	37.15	1.07	1.51	1.79	5.26	2.04	9.21	5.53	4.95	5.33	0.14	0.12	0.20
1876	28.84	0.32	1.10	2.18	0.97	3.15	3.18	5.49	5.14	5.26	0.88	0.80	0.37
1877	28.17	0.74	0.33	1.37	5.99	4.45	5.07	1.17	1.16	1.23	3.66	0.54	2.46
1878		0.20	0.27	0.93	5.14	4.04	7.83						

TABLE VII.—*Monthly and annual rainfall in inches from* 1872 *to* 1878—Continued.

Years and stations.	Annual.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
OMAHA, NEBR.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1872	......	......	......	......	......	......	......	......	......	......	3.89	0.87	0.11
1873	27.05	0.64	0.02	0.44	3.83	5.59	5.86	4.27	1.60	1.86	1.82	0.19	0.93
1874	25.75	0.32	0.92	1.49	2.01	1.24	6.93	0.54	2.08	7.18	1.45	1.05	0.54
1875	42.89	0.26	0.51	1.24	3.06	4.25	10.95	10.01	7.77	2.55	1.16	0.13	1.00
1876	32.51	0.22	0.40	3.18	2.65	2.07	3.47	7.30	6.27	4.93	0.69	1.17	0.16
1877	40.95	0.53	0.44	1.26	6.24	8.62	8.36	0.96	3.13	2.05	5.86	1.36	2.14
1878	......	1.13	0.14	3.09	3.97	5.77	8.48	......	......	......	......	......	......
DAVENPORT, IOWA.													
1872	......	......	......	......	......	......	......	......	......	......	0.61	1.86	0.61
1873	28.08	3.56	0.77	1.43	3.96	6.37	2.16	2.37	0.51	1.00	1.48	0.63	3.84
1874	36.79	4.34	0.74	1.34	2.64	3.45	5.37	3.10	3.68	7.86	1.30	2.47	0.50
1875	31.99	0.38	1.09	0.88	2.30	2.01	4.91	9.36	1.73	4.05	1.63	0.57	3.08
1876	46.82	3.47	3.63	4.35	5.39	6.70	4.25	4.82	4.27	5.50	1.54	2.54	0.36
1877	35.10	1.41	0.07	3.91	3.28	2.82	5.80	3.42	3.21	1.45	4.88	2.53	2.32
1878	......	0.36	1.09	2.21	2.89	5.14	4.36	......	......	......	......	......	......
CHEYENNE, WYO.													
1872	......	......	......	......	......	......	......	......	......	......	0.33	0.03	0.03
1873	10.01	0.03	0.02	0.38	0.92	2.41	1.77	1.10	2.07	0.36	0.70	0.17	0.08
1874	9.71	0.11	0.11	0.74	0.61	1.50	1.34	1.87	0.44	0.93	1.86	0.04	0.16
1875	12.10	0.42	0.06	0.23	0.50	1.20	0.29	4.47	2.12	1.34	0.60	0.84	0.03
1876	3.03	0.02	0.06	0.54	0.23	2.50	0.10	0.79	0.26	0.00	0.00	0.32	0.21
1877	11.71	0.20	0.14	0.98	1.11	2.24	1.27	0.43	0.83	2.02	1.99	0.17	0.33
1878	......	0.08	0.13	1.16	0.19	4.46	1.71	......	......	......	......	......	......
NORTH PLATTE, NEBR.													
1874	......	......	......	......	......	......	......	......	......	0.85	1.46	0.57	0.34
1875	15.35	0.24	0.26	0.40	6.21	1.69	1.62	2.12	0.66	1.40	0.14	0.52	0.09
1876	11.84	0.09	0.13	0.49	0.51	2.97	0.49	1.16	2.46	1.47	1.07	0.49	0.51
1877	25.47	1.38	0.37	0.19	0.37	3.22	2.99	2.04	5.03	4.49	1.23	0.30	3.86
1878	......	0.00	0.18	1.40	1.15	3.24	5.85	......	......	......	......	......	......
KEOKUK, IOWA.													
1872	......	......	......	......	......	......	......	......	......	......	0.42	0.74	0.50
1873	41.99	3.31	0.53	0.51	5.65	3.42	1.21	8.77	0.54	3.37	4.69	1.43	8.56
1874	35.45	3.66	0.89	1.14	2.40	1.65	4.01	4.54	3.87	7.92	1.94	2.17	1.26
1875	48.42	0.61	1.84	1.67	0.89	6.70	8.33	12.70	3.83	4.62	2.71	0.59	3.93
1876	51.65	3.68	1.45	3.45	3.99	5.28	6.73	6.79	4.03	11.08	2.12	2.82	0.23
1877	48.59	0.84	0.15	3.76	4.22	5.55	7.82	7.06	2.52	3.61	7.11	3.05	2.90
1878	......	0.17	2.95	3.78	2.31	3.47	3.93	......	......	......	......	......	......
DENVER, COLO.													
1872	......	......	......	......	......	......	......	......	......	......	0.68	0.69	0.29
1873	41.73	0.13	0.24	0.22	2.43	0.75	2.24	2.00	1.41	0.89	0.73	0.16	0.53
1874	13.46	0.84	0.53	0.49	1.70	2.43	1.21	3.35	0.68	1.34	0.64	0.08	0.17
1875	20.26	3.38	0.60	0.39	2.24	1.94	0.43	4.32	1.97	2.89	0.22	1.28	0.59
1876	18.64	0.21	0.11	1.80	0.22	8.57	1.10	1.22	1.16	2.03	0.60	0.12	1.50
1877	......	1.70	1.90	0.40	1.40	2.77	2.30	1.93	......	......	......	......	......
DODGE CITY, KANS.													
1874	......	......	......	......	......	......	......	......	......	0.94	0.22	0.23	..05
1875	10.78	0.12	0.10	0.04	0.72	2.26	0.73	3.28	2.06	1.32	0.06	0.00	0.09
1876	15.40	0.00	0.05	3.59	0.16	1.15	2.53	2.26	1.03	2.13	1.00	1.35	0.15
1877	27.89	0.18	0.56	0.25	3.38	4.96	3.92	1.79	4.09	0.50	3.34	0.56	4.36
1878	......	0.21	1.13	1.01	1.06	4.63	2.19	......	......	......	......	......	......
LEAVENWORTH, KANS.													
1872	......	......	......	......	......	......	......	......	......	......	2.06	0.06	1.34
1873	34.17	3.02	1.03	1.75	5.07	5.38	3.15	2.04	2.40	3.64	1.56	0.89	5.24
1874	33.65	3.14	1.35	3.05	2.80	1.60	4.96	3.23	1.72	5.50	1.49	3.46	1.35
1875	31.26	0.23	1.25	2.50	1.67	3.53	3.85	8.82	3.73	1.97	0.72	0.39	2.60
1876	44.48	1.42	0.20	5.78	7.65	6.78	5.71	4.01	3.40	3.56	2.79	2.87	0.31
1877	52.06	0.73	0.50	4.39	7.14	8.67	10.00	5.34	2.85	1.95	4.87	2.44	3.18
1878	......	2.34	2.94	2.35	2.86	5.28	5.27	......	......	......	......	......	......

TABLE VII.—*Monthly and annual rainfall in inches from 1872 to 1878*—Continued.

Years and stations.	Annual.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
COLORADO SPRINGS, COLO.													
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1874	16.53	0.06	0.54	0.50	3.55	5.90	0.20	0.81	0.91	3.37	0.19	0.35	0.15
1875	17.37	0.24	0.56	1.12	0.30	1.03	1.82	6.07	2.39	2.23	0.13	1.19	0.29
1876	......	0.12	0.19	0.63	0.52	3.83	1.89	......	......	......	......	......	......
SAINT LOUIS, MO.													
1872	......	......	......	......	......	......	......	......	......	......	0.55	2.01	1.7[illegible]
1873	45.02	3.53	1.52	2.10	6.86	5.27	6.68	5.96	0.07	3.02	3.27	1.64	5.10
1874	37.79	3.04	3.66	4.36	3.43	3.70	2.00	6.71	4.70	2.32	1.09	2.32	1.46
1875	42.99	0.54	2.59	4.08	2.53	5.48	10.84	9.49	2.66	0.24	1.23	0.89	2.42
1876	48.46	4.75	2.86	6.90	2.25	3.13	6.43	6.90	5.03	7.63	1.66	1.74	0.18
1877	41.26	1.24	0.88	3.41	2.86	3.11	8.69	2.88	2.61	3.56	4.92	3.76	3.34
1878	......	2.36	1.69	2.79	6.74	4.63	2.40	......	......	......	......	......	......
SANTA FE, N. MEX.													
1872	......	......	......	......	......	......	......	......	......	......	0.25	0.01	0.04
1873	9.47	0.55	0.14	0.15	0.26	0.33	1.72	1.02	2.79	1.23	0.07	0.38	0.83
1874	19.83	1.39	1.60	1.51	1.71	0.70	0.54	3.92	1.73	1.42	2.47	0.58	2.26
1875	18.97	0.67	0.72	1.37	0.33	0.88	0.33	6.91	1.59	4.14	0.06	1.50	0.47
1876	15.07	0.61	0.40	0.64	0.46	0.83	1.62	5.43	2.13	0.85	0.75	0.97	0.38
1877	13.15	0.18	1.08	0.14	1.83	0.92	0.13	3.54	1.72	0.96	1.32	0.70	0.63
1878	......	0.21	0.89	0.73	0.22	1.01	3.18	......	......	......	......	......	......
FORT GIBSON, IND. T.													
1873	......	......	......	......	......	......	......	......	......	......	2.80	1.97	3.66
1874	38.88	3.69	3.44	2.91	5.83	3.54	3.38	1.99	1.54	4.41	0.81	4.64	2.70
1875	44.10	0.64	0.73	2.48	8.74	5.59	3.52	10.93	4.27	1.34	1.19	2.26	2.41
1876	35.48	4.94	0.64	5.67	1.85	1.94	6.82	6.06	0.94	2.43	1.10	2.89	0.20
1877	46.79	0.29	1.47	2.27	7.77	4.82	7.74	2.89	3.78	2.21	6.36	4.19	3.00
1878	......	2.79	2.40	1.44	2.83	7.52	6.61	......	......	......	......	......	......

We propose to discuss first the record of temperature; but in order to do this in a way to be clearly and easily understood, it is necessary to consider each point or bearing separately, and so far as possible tabulate the results.

As heretofore intimated, it is unnecessary to take any further notice of the annual mean temperature; we shall therefore confine our discussion to the monthly means as shown in Table VI.

If the excessive development of locusts depends upon unusual heat as one of the necessary meteorological influences, and no adequate variation is shown in the annual means, it ought to appear in the monthly means, for it is absurd to suppose it depends upon the temperature of one or two days, and a considerable variation in several days will be shown in the monthly means.

If, after all, this excessive development does not depend so much upon the absolute degree of heat above the normal condition as upon the absence of excessive changes at the periods when they are most easily affected, then a careful examination and comparison of the monthly means ought to reveal the particular months or periods of the year in which these excessive changes are most likely to occur. If it depends upon the *sum* of the heat—that is, the number of hours they are exposed in the egg and larval states to a given degree of heat—this can only be obtained accurately by the daily records, but should be indicated by a comparison of the monthly means. This point is not considered in the discussion of these tables, but will be alluded to further on.

Two conditions are absolutely necessary to excessive development; *first*, that the parents shall be in a healthy condition and properly deposit the eggs; *second*, that the eggs shall very generally hatch out. There are other conditions that retard or favor, but these are absolutely necessary. It follows, therefore, that there are critical periods in the life of the insect, and hence it may be necessary, in order to ascertain the meteorological conditions favoring the development of excessive numbers in one year, to examine the meteorological records of the previous years.

Another fact to be taken into consideration in the discussion is that, although excessive numbers may hatch, they may be killed, greatly diminished, or rendered diseased by unusual moisture; or their development may be retarded, and migrating to a great degree prevented, by unusually low temperature.

Bearing these facts in mind and remembering also that 1874 and 1876 were the years of the great locust invasions, let us see if any important fact bearing upon the subject can be drawn from the foregoing table of the monthly temperature of the Northwest in the locust area.

If we examine the fluctuations in the same month for the different years and select the extreme variations—that is, the difference between the highest and lowest means—we shall find them to be as shown in Table VIII.

TABLE VIII.—*Extreme fluctuations in monthly mean temperature.*

Months.	Breckenridge.	Fort Sully.	Yankton.	Omaha.	Keokuk.	Saint Paul.	Leavenworth.	Santa Fé.	Cheyenne.	Denver.	Fort Benton.	Pembina.	Virginia City.	Bismarck.	Average.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January	24.2	18.6	21.2	12.8	17.4	24.9	18.7	10.3	17.9	14.7	25.1	16.4	21.7	26.4	19.3
February	35.3	19.2	33.9	16.3	20.3	33.8	17.9	6.2	8.0	13.0	8.5	30.0	12.5	33.7	20.6
March	38.8	16.5	13.0	18.8	17.7	22.4	15.2	10.0	15.4	10.9	23.1	29.7	15.0	27.3	19.6
April	13.6	5.5	10.4	10.8	12.9	13.6	10.2	8.1	9.1	10.0	6.7	16.1	3.3	13.7	10.3
May	9.0	8.7	7.9	8.1	6.9	7.1	5.0	5.4	8.7	8.6	6.8	8.9	7.1	6.1	7.5
June	10.6	10.6	7.6	5.8	7.8	9.4	6.9	6.4	18.0	6.1	2.1	10.4	5.8	2.4	7.8
July	10.4	5.7	6.4	5.6	4.2	3.7	6.5	5.9	8.3	8.3	5.3	5.0	3.9	1.6	5.8
August	4.0	4.7	8.8	7.1	7.1	5.6	8.2	4.7	6.0	4.0	0.4	3.3	6.7	3.5	5.3
September	9.4	7.9	6.6	6.6	6.2	12.5	2.5	2.7	3.1	2.9	7.4	9.4	5.7	6.8	6.4
October	6.9	10.2	4.0	5.5	5.9	8.1	3.3	6.2	7.9	9.4	10.8	6.8	8.6	2.0	6.8
November	6.7	10.7	10.0	7.9	5.6	8.6	6.8	8.1	11.9	9.7	18.0	14.6	12.0	11.4	10.1
December	28.2	15.5	22.0	20.2	25.8	25.5	23.2	6.8	10.0	15.4	23.1	33.7	13.8	22.3	20.4

Average variation of winter and spring taken together, 16.8 (that is, from November to April).
Average variation of summer and autumn taken together, 6.6 (that is, from May to October).

In this table each number in a column shows the extreme variation, during the series of years included in Table VI, of the mean for the month opposite, and at the station mentioned at the head of the column. For example, in the Breckenridge column 24°.2 is the number given;

this shows that the difference between the highest and lowest mean for January in the series of years was 24°.2. By reference to the Breckenridge record in Table VI it will be seen that the lowest January mean was in 1875 (−9°.5), while the highest was in 1878 (+14°.7); the difference between these two is 24°.2, as given in the above table of extreme variation of monthly means. The right-hand column shows the average of all the stations for each month.

The value of this table consists in the fact that it shows at a glance the months in which the greatest variations occur. This is, as is well known to all who have made meteorology a study, in the winter half of the year; but reference to the column of averages shows that in the West and Northwest this is true to an unusual degree, the average variation for the winter half (from November to April) being 16°.8, while for the summer half (from May to October) it is only 6°.6.

If we confine the examination to the northwestern stations, Breckenridge, Fort Sully, Yankton, Fort Benton, Pembina, Virginia City, and Bismarck, we find the averages to be as follows: January, 21°.9; February, 24°.7; March, 23°.3; April, 9°.9; May, 7°.8; June, 7°.1; July, 5°.5; August, 4°.5; September, 7°.6; October, 7°.0; November, 11°.9; December, 22°.7; the average of the winter half of the year, 19°.1, and of the summer half, 6°.6, showing the difference to be still greater.

But in order to apply the law which these figures appear to indicate more directly to the subject under discussion, we present here a table of a similar kind, made up from the same series of years, differing from the last only in the fact that it shows the greatest variation between the monthly means of two consecutive years.

TABLE IX.—*Greatest variations between monthly means of two consecutive years.*

Months.	Breckenridge.	Fort Sully.	Yankton.	Omaha.	Keokuk.	Saint Paul.	Leavenworth.	Santa Fé.	Cheyenne.	Denver.	Fort Benton.	Pembina.	Virginia City.	Bismarck.	Average.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January	15. 8	18. 6	18. 3	10. 7	17. 4	19. 0	18. 7	10. 3	17. 9	14. 7	22. 5	16. 4	21. 4	16. 8	17. 03
February	17. 2	19. 0	18. 2	16. 8	16. 9	19. 2	16. 0	4. 2	5. 9	7. 6	8. 5	21. 9	5. 3	21. 6	14. 13
March	24. 0	7. 9	14. 9	14. 4	17. 7	20. 7	12 5	7. 9	10. 8	8. 4	18. 0	27. 9	8. 5	21. 4	15. 36
April	7. 1	4. 7	6. 3	6. 8	6. 5	4. 9	7. 6	7. 9	5. 5	6. 3	4. 4	12. 4	3. 3	7. 2	6. 49
May	8. 2	8. 7	7. 9	7. 6	5. 7	7. 1	4. 3	3. 3	7. 4	8. 6	6. 8	8. 9	4. 0	6. 1	6. 76
June	6. 0	4. 5	4. 6	2. 5	5. 3	5. 1	5. 5	3. 7	*18	4. 6	1. 8	8. 0	5. 8	2. 4	5. 56 or 4. 58
July	3. 2	5. 3	6. 4	5. 6	4. 2	3. 7	5. 3	4. 9	7. 8	8. 3	5. 3	5. 0	3. 9	1. 0	5. 00
August	4. 0	4. 7	5. 9	7. 1	5. 2	3. 9	8. 2	3. 4	5. 4	4. 0	0. 2	2. 7	6. 7	1. 8	4. 51
September	9. 2	7. 9	6. 6	6. 6	5. 7	9. 8	2. 3	1. 8	1. 8	2. 7	4. 8	9. 4	5. 7	6. 8	5. 79
October	6. 8	10. 2	3. 3	5. 5	5. 9	8. 1	3. 4	4. 9	6. 9	7. 7	9. 5	6. 8	5. 8	2. 0	6. 20
November	8. 3	10. 6	5. 5	7. 9	4. 9	4. 4	6. 8	8. 1	11. 9	8. 1	15. 7	10. 3	12. 0	10. 3	8. 91
December	28. 2	13. 3	22. 0	20. 0	25. 8	25. 5	20. 9	6. 8	10. 0	10. 6	15. 9	33. 7	8. 2	22. 3	18. 80
Year	3. 4	6. 7	5. 3	8. 2	7. 1	5. 2	3. 0	0. 7	3. 6	2. 0	1. 1	....	3. 7	4. 8	4. 21

* This large variation indicates an evident error in the mean of this month for 1872. Omitting 1872, the extreme variation is 4.3.

Precisely the same rule holds good here as in the preceding table. The chief variations are in the months of December, January, February and March.

If the excessive increase of locusts depends to any considerable degree upon the temperature, and this excessive increase is the exception and not the rule, then we must seek for the cause in the abnormal conditions of the temperature. These we see from the foregoing table are found chiefly in the winter of the year, the variation in the means of the summer months being comparatively unimportant.

The condition as to moisture must, as a matter of course, be combined with that of temperature in making the direct application and comparing the locust years with the non-locust years, but at present we are only endeavoring to ascertain if possible in what respects the records of temperature show a variation likely to affect the increase or development of the locusts.

As the eggs are deposited before December, and do not hatch out in the northern latitudes of their native habitats until after March, it follows that if the excessive changes of this part of the year affect them in any way it must be by their action upon the eggs. But the facts presented in our first report tend to the conclusion that the eggs of *C. spretus* are but little affected by changes of temperature.

There are some other facts presented in Table VI worthy of notice.

If we compare the winters preceding the locust years with those of other years, we find that in the series 1873 to 1877, as a rule, the former were warmer than the latter.

Variations between months of consecutive years.

Years and stations.	December.	January.	February.	Mean.
BRECKENRIDGE.				
1873-'74	8.0	2.3	8.0	6.1
1874-'75	12.8	— 9.5	— 7.9	— 1.5
1875-'76	18.1	6.3	4.3	9.6
1876-'77	0.1	— 0.9	21.5	6.9
1877-'78	28.3	14.7	27.4	23.5
FORT SULLY.				
1873-'74	14.9	16.1	20.3	17.1
1874-'75	26.9	0.1	4.2	10.4
1875-'76	27.0	18.7	14.4	20.0
1876-'77	13.7	13.9	33.4	20.3
YANKTON.				
1873-'74	18.1	15.6	18.8	17.5
1874-'75	23.0	0.6	2.5	8.7
1875-'76	27.3	18.9	20.7	22.3
1876-'77	12.2	13.6	36.4	20.7
FORT BENTON.				
1872-'73	11.3	16.5	18.4	15.4
1873-'74	13.7	11.3	22.4	15.8
1874-'75	29.6	— 8.6	13.9	11.6
1875-'76	36.8	13.9	16.7	22.5
PEMBINA.				
1873-'74	6.6	— 3.0	2.6	2.1
1875-'76	8.1	— 2.6	— 4.5	0.3
1876-'77	— 6.3	— 5.2	17.4	2.0
1877-'78	—27.4	11.2	25.5	21.4

Variations between months of consecutive years—Continued.

Years and stations.	December.	January.	February.	Mean.
VIRGINIA CITY.				
1872–'73	18.8	23.4	15.6	19.3
1873–'74	16.7	23.1	18.4	19.2
1874–'75	24.9	1.7	22.8	19.8
1875–'76	30.5	17.1	28.1	25.2
1876–'77	24.4	18.8	27.5	23.6
1877–'78	24.0	23.1	27.9	25.0
OMAHA.				
1872–'73	19.0	16.9	26.9	20.9
1873–'74	25.2	22.3	23.4	23.6
1874–'75	28.4	16.1	13.8	19.4
1875–'76	33.5	26.8	30.1	30.1
1876–'77	19.2	20.2	37.3	25.6
1877–'78	39.2	28.9	36.9	35.0

It will be seen by comparing these means that as a very general rule the temperature was higher in the winters of 1873–'74 and 1875–'76 than the preceding or following winters, but that to this rule the winter of 1877–'78 forms a remarkable exception. But in these cases the winters appear to correspond with the general character of the year. The results are scarcely sufficiently marked and uniform to justify the conclusion that they present a clew to the solution of the problem.

An inspection of the summer months in Table VI shows a much smaller variation; for example, at Breckenridge, where the differences between the winter means are the greatest, the summer means are as follows: 1873, 52°.2; 1874, 53°.4; 1875, 51°.0; 1876, 52°.6; 1877, 52°.6; the extreme variation being but 2°.4.

Yankton:

1874	65°.2
1875	61°.4
1876	62°.9
1877	63°.1

Virginia City:

1874	53°.8
1875	53°.6
1876	53°.0
1877	52°.6

A longer series of years would doubtless show greater variations, but if these furnish any indication of the general rule, it is evident the means of summer temperature furnish no such differences as would seem to be required for such important results. So far, then, as the records of temperature thus far examined are concerned, neither the annual nor the monthly means show any important fact to sustain the assumption that unusual heat is one of the conditions necessary to the excessive development of the locusts. If they show any important fact bearing upon the subject, it is that the winter season (including March) has more to do with their development than the temperature of the summer season.

So far as the annual and monthly means show, the year 1873 was about as favorable as to temperature as 1874; and as may be seen by reference to the table of rainfall (Table VII), it was equally favorable in this respect. As there was no marked or general invasion in 1871 or 1872, it cannot be claimed that the permanent breeding grounds had been exhausted by migrations, as it is conceded that there was no general invasion in 1873, but was in 1874. Let us look to the daily records of the former and compare them with those of the latter year and see if they show any important differences.

For this purpose we select Fort Sully as the station within the permanent breeding grounds showing the most complete record. The following table is the daily record of the maximum and minimum temperature from October, 1872, to June, 1875.

TABLE X.—*Maximum and minimum temperature at Fort Sully.*

Day of month.	1872.						1873.											
	October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	85	43	45	28	47	35	16	-1	-5	-25	15	-7	62	31	58	42	81	56
2	92	44	40	27	40	29	25	-9	3	-21	10	-6	59	39	75	36	78	54
3	83	45	45	31	39	19	19	-1	28	-11	16	-12	69	41	74	40	80	56
4	67	53	39	32	39	25	16	-6	25	2	49	12	55	33	59	52	94	55
5	72	47	44	31	44	25	22	-13	36	14	51	26	41	33	75	50	98	62
6	72	38	63	31	48	18	44	6	45	23	65	36	35	30	60	51	102	66
7	85	45	53	35	51	34	41	-5	39	25	51	28	32	25	64	44	88	63
8	72	48	60	30	41	6	2	-12	40	20	54	36	39	23	59	37	71	59
9	49	31	59	35	24	2	3	-17	41	16	55	29	50	18	56	34	73	51
10	63	21	36	20	35	10	17	-17	36	23	50	34	48	29	63	40	77	49
11	70	25	31	20	28	8	33	-3	27	11	41	26	62	25	74	43	91	57
12	65	45	26	10	40	7	43	19	24	10	63	27	81	40	63	51	88	66
13	57	40	19	3	34	17	28	7	28	12	59	38	63	40	53	57	98	61
14	80	36	20	13	19	-4	22	10	34	16	52	35	43	30	69	34	89	60
15	62	38	25	16	17	-10	20	-3	43	19	42	30	38	25	66	36	102	59
16	73	31	39	14	29	-8	11	-12	40	26	60	26	46	24	67	45	98	65
17	70	42	17	2	17	5	13	-4	30	15	55	28	67	24	56	46	102	71
18	80	35	38	12	-1	-19	41	10	20	8	58	32	56	33	57	46	100	68
19	.....	.....	27	5	5	-18	41	35	33	2	47	25	73	33	66	48	92	59
20	69	40	37	1	-4	-22	45	35	-2	-17	50	16	70	32	69	49	103	64
21	54	36	38	24	11	-30	37	19	0	-10	50	29	56	26	73	45	105	69
22	65	24	47	28	7	-22	19	4	0	-20	40	16	36	18	65	46	95	63
23	74	36	34	22	-14	-26	6	-9	12	-9	32	8	39	25	66	50	83	54
24	73	45	33	16	10	-23	5	-14	9	-3	26	1	43	25	60	45	92	56
25	70	45	36	6	11	-20	8	-2	19	-3	22	-7	65	29	72	49	108	72
26	64	44	23	-5	-5	-22	4	-10	17	4	46	5	67	27	68	51	95	71
27	68	34	6	-11	11	-12	-2	-20	14	-2	46	26	72	40	86	48	92	65
28	57	37	0	-10	23	-4	5	-28	18	-9	49	33	69	34	80	53	83	58
29	45	31	14	-15	20	-2	41	-10	.....	.....	71	24	50	42	60	51	82	56
30	45	33	46	10	17	2	35	-8	.....	.....	56	32	59	44	57	42	77	62
31	54	32	.....	.....	13	-18	-6	-20	.....	.....	50	34	.....	.....	57	54	.....	.....
Range	.....	.....	42°		45°		.....	.....	53°		47°		36°		53°		.....	
Monthly means	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE X.—*Maximum and minimum temperature at Fort Sully*—Continued.

Day of month.	1873.												1874.											
	July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	86	52	68	58	92	53	67	28	53	17	19	13	47	23	30	11	65	27	54	28	73	55	62	57
2	93	64	85	52	95	67	56	31	46	33	13	—1	50	30	32	10	52	33	55	18	57	34	67	57
3	100	63	91	59	88	61	53	35	72	28	3	—9	30	—12	28	7	39	7	31	22	51	38	90	52
4	85	64	96	66	75	52	77	35	49	22	—2	—20	16	—16	28	—5	26	4	25	16	57	41	77	52
5	77	58	102	73	71	43	52	36	48	21	4	—27	40	13	30	16	39	7	51	16	70	42	79	52
6	85	54	97	63	68	50	76	26	58	21	18	—2	40	25	32	10	33	17	45	23	71	43	74	56
7	85	61	97	62	75	38	81	40	59	21	25	8	47	1	36	16	24	5	56	26	90	55	84	58
8	87	58	100	69	87	57	76	42	64	29	27	9	45	30	32	10	25	6	49	26	96	59	68	56
9	79	60	89	63	91	55	74	49	61	31	12	0	45	24	36	0	27	12	63	32	82	59	67	52
10	83	60	92	68	100	55	66	47	60	30	30	8	38	16	24	11	26	2	75	33	60	39	58	39
11	93	63	84	66	85	59	68	38	45	33	25	3	19	10	35	8	28	7	58	23	46	35	70	42
12	101	65	91	68	60	43	78	43	46	26	25	—3	25	—3	18	7	31	1	78	39	55	40	83	50
13	85	63	107	72	75	34	65	47	43	17	38	21	0	—11	19	3	43	18	67	43	52	38	76	56
14	91	61	92	65	89	52	61	35	67	21	27	8	2	—14	10	—3	57	34	51	36	59	47	64	57
15	108	73	78	57	74	53	56	40	61	43	28	2	13	—7	41	—1	64	29	55	22	70	43	79	56
16	88	72	87	51	90	45	50	41	56	40	30	5	33	3	34	14	60	43	63	25	71	50	97	63
17	81	61	94	59	81	56	50	38	61	33	23	6	50	24	56	25	44	32	61	35	73	46	98	65
18	76	55	101	63	57	36	47	35	33	18	25	12	40	—3	46	33	34	25	42	25	80	46	87	67
19	89	54	104	60	67	27	61	40	42	15	25	0	20	13	34	9	48	13	64	22	76	50	87	63
20	101	61	95	64	70	42	73	39	47	24	12	—19	35	7	43	7	42	28	47	28	78	48	101	67
21	106	69	81	54	63	44	56	29	41	20	19	—3	14	—1	14	—7	49	23	51	31	82	60	105	74
22	94	73	83	53	68	32	36	20	43	23	29	3	5	—10	22	6	40	20	45	26	91	63	111	75
23	101	62	89	68	65	41	39	14	49	26	41	16	12	—6	8	—9	38	10	60	23	98	62	97	73
24	89	69	94	58	50	39	28	16	50	30	30	10	20	—5	18	—10	65	18	63	42	77	62	99	75
25	85	64	89	62	77	35	28	22	38	23	44	21	22	—6	32	—4	49	20	60	32	93	53	100	69
26	85	57	89	60	55	41	41	11	46	16	32	8	48	6	41	14	20	4	49	37	101	74	100	77
27	79	60	104	69	51	35	36	19	21	8	32	4	38	15	54	22	31	11	64	39	99	66	80	57
28	90	60	90	66	46	32	40	11	29	1	33	14	44	8	58	22	34	19	81	33	96	62	76	55
29	99	60	93	54	60	25	52	38	25	4	27	4	43	—7	......	......	53	12	89	52	69	60	86	61
30	83	57	88	67	58	37	44	16	22	12	23	1	5	—13	......	......	38	17	93	49	74	61	80	60
31	94	61	83	60	......	......	37	5	......	......	46	13	15	—8	......	......	49	13	......	......	82	54	......	......
Range	72°		71°		73°		66°		68°.5		64°		77°		67°		72°		54°		48°		69°	
Monthly means	44°.1		35°.1		14°.9		16°.1		20°.3		27°.7		43°.9		63°.2		70°.2		79°.2		76°.1		65°.2	

TABLE X.—*Maximum and minimum temperature at Fort Sully*—Continued.

Day of month.	1874.												1875.											
	July.		August.		September.		October.		November.		December.		January		February.		March.		April.		May.		June.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	90	59	91	57	82	65	70	50	42	18	44	28	24	—3	24	3	16	4	50	23	40	25	61	47
2	80	70	96	63	65	52	72	38	39	21	50	27	10	—8	3	—16	25	5	60	33	41	30	69	47
3	106	79	92	55	70	39	71	54	37	27	47	29	0	—13	—12	—24	24	8	58	33	60	33	73	40
4	101	72	103	69	74	49	73	52	45	25	44	32	0	—15	5	—30	35	16	47	22	72	38	59	44
5	105	71	91	67	94	55	71	44	53	35	48	32	3	—21	6	—10	28	15	23	11	66	40	74	37
6	91	67	95	67	101	55	66	32	59	45	45	35	11	—16	4	—9	27	—3	25	15	79	52	66	43
7	93	67	94	60	107	69	81	41	57	32	48	26	12	—16	9	—12	22	6	30	21	64	54	84	42
8	99	70	92	64	95	72	71	48	52	32	46	26	—2	—31	11	—4	24	18	30	15	66	47	77	54
9	97	66	96	70	83	70	79	42	44	27	27	20	12	—23	27	—9	37	15	40	20	64	44	82	47
10	91	57	92	70	82	51	57	43	42	24	32	21	8	—10	22	—4	41	18	41	26	58	39	83	58
11	91	64	86	59	75	55	63	30	32	25	24	8	11	—13	2	21	35	20	34	23	64	44	71	45
12	96	67	80	55	81	38	63	22	30	25	37	12	—3	—27	14	—2	45	15	39	22	75	40	88	44
13	98	63	94	57	77	49	69	42	51	30	30	16	—20	32	14	5	34	20	52	28	78	45	100	61
14	94	67	99	63	65	39	70	45	39	32	57	11	—6	—31	11	—13	25	4	66	21	80	45	101	63
15	86	55	102	68	82	41	72	36	35	26	50	20	—6	—14	16	—2	5	—6	53	26	74	49	97	61
16	93	73	93	64	74	55	83	41	29	7	32	17	0	—21	25	—8	7	—7	45	18	73	51	95	68
17	94	60	78	57	65	42	74	40	15	0	45	9	2	—17	13	—22	9	—13	65	25	71	58	80	66
18	100	74	97	60	60	50	85	42	9	—7	48	31	—5	—27	25	5	8	—6	83	33	81	52	76	61
19	81	61	91	66	68	46	79	48	28	4	36	18	15	—30	32	9	20	—14	66	44	92	56	64	57
20	71	59	100	66	71	45	61	37	36	12	48	14	30	9	32	—3	30	7	60	35	87	56	85	54
21	89	64	82	61	76	43	63	28	47	20	38	23	32	14	28	—13	29	8	65	42	87	55	94	60
22	102	67	94	63	83	46	72	34	30	9	44	22	26	—10	17	—2	42	14	69	37	94	59	86	60
23	97	65	88	59	91	45	71	44	10	2	34	23	22	—6	14	—10	40	22	53	35	83	59	82	61
24	101	73	85	58	91	50	71	45	16	—4	40	14	20	—7	7	—9	40	10	54	34	84	56	97	58
25	85	62	91	59	85	54	59	42	25	12	36	7	16	—11	7	—16	57	30	53	32	93	54	82	59
26	78	52	93	68	72	47	46	32	29	7	29	6	15	—6	6	—6	51	28	68	29	88	54	77	55
27	87	61	93	63	60	51	42	37	22	—3	33	10	14	—1	11	—8	41	25	64	40	63	53	83	54
28	97	59	86	65	66	45	40	29	23	3	23	—12	15	—3	15	—6	57	24	59	42	74	42	92	54
29	99	66	89	62	72	52	34	26	14	4	9	—15	24	3	......	......	57	35	47	31	89	46	83	60
30	106	65	95	57	67	44	26	15	44	12	15	—13	22	—1	......	......	36	29	38	30	83	59	73	58
31	88	69	103	72	......	......	36	9	......	......	38	—4	31	—9	......	......	38	22	......	......	79	55	......	......
Range	54°		48°		69°		76°		66°		72°		64°		62°		71°		94°		69°		64°	
Monthly means	79°.2		76°.1		65°.2		50°.9		26°.2		26°.9		0°.1		4°.2		22°.3		39°.2		60°.1		66°	

TABLE X.—*Maximum and minimum temperature at Fort Sully*—Continued.

Day of month.	1875. July. Max.	July. Min.	August. Max.	August. Min.	September. Max.	September. Min.	October. Max.	October. Min.	November. Max.	November. Min.	December. Max.	December. Min.
	°	°	°	°	°	°	°	°	°	°	°	°
1	68	57	92	67	83	50	65	32	46	26	36	27
2	90	61	99	62	86	61	81	38	57	28	45	20
3	79	57	103	63	90	53	58	43	52	22	43	19
4	69	55	100	60	86	55	57	32	48	16	41	20
5	79	55	81	65	91	52	53	36	58	38	36	12
6	93	55	95	57	92	58	68	34	61	23	22	1
7	95	59	103	65	100	63	71	41	58	32	25	12
8	97	65	104	64	95	64	55	38	42	21	25	12
9	87	62	88	63	66	47	68	42	51	17	42	12
10	82	64	84	59	74	39	43	36	69	34	28	15
11	91	63	89	59	76	48	47	26	56	32	48	24
12	97	67	90	58	78	41	71	34	39	15	50	34
13	96	63	89	58	85	61	73	43	55	22	47	26
14	100	62	80	57	83	57	58	37	43	14	58	28
15	102	66	82	54	82	58	72	45	15	2	49	25
16	83	63	80	56	59	43	80	45	18	6	30	0
17	80	60	81	51	75	48	61	40	50	5	27	1
18	95	51	84	49	62	48	74	33	42	12	27	6
19	98	65	92	50	56	32	81	39	20	9	30	3
20	101	62	88	59	59	29	84	42	19	—8	44	22
21	95	62	86	49	72	32	88	39	7	—13	52	26
22	96	64	93	57	84	45	79	46	32	5	65	38
23	96	62	93	62	93	42	68	42	15	—7	38	22
24	83	64	89	65	71	46	57	(*)	24	—1	30	13
25	84	53	82	62	78	35	45	31	20	10	32	6
26	83	59	82	56	89	34	37	27	16	—4	22	1
27	91	60	76	57	81	50	48	29	25	4	20	4
28	97	62	73	50	86	48	56	39	4	—15	31	4
29	92	62	90	50	75	44	40	29	15	—18	44	31
30	90	56	81	56	60	43	41	27	41	8	41	30
31	87	62	83	54	......	......	49	25	......	......	30	10
Range	51°		25°		35°		38°		35°		33°	
Monthly means	73°.9		82°.9		40°.7		70°.6		65°.7		61°.6	

Day of month.	1876. January. Max.	January. Min.	February. Max.	February. Min.	March. Max.	March. Min.	April. Max.	April. Min.	May. Max.	May. Min.	June. Max.	June. Min.
	°	°	°	°	°	°	°	°	°	°	°	°
1	34	16	—5	—28	25	8	......	......	61	30	59	42
2	37	8	7	—11	28	—2	......	......	77	30	51	38
3	26	—3	1	—10	30	6	......	......	55	27	62	38
4	19	4	14	—10	44	7	......	......	46	37	83	41
5	47	8	40	6	34	7	......	......	58	36	89	52
6	53	28	18	5	23	—1	......	......	57	43	94	59
7	41	24	12	—1	28	—5	......	......	61	41	71	59
8	34	14	17	1	26	11	......	......	75	36	81	55
9	26	0	25	14	12	0	......	......	79	46	93	55
10	31	—12	33	13	4	—4	......	......	91	47	75	56
11	36	13	47	5	5	—12	......	......	73	49	68	54
12	26	5	32	8	11	—16	......	......	72	38	82	51
13	43	7	21	1	27	5	......	......	71	56	90	53
14	43	11	17	2	18	10	......	......	89	55	94	59
15	50	18	22	7	14	5	......	......	70	52	77	58
16	55	25	34	13	19	0	......	......	76	49	78	48
17	47	30	52	9	11	—5	......	......	83	49	71	45
18	32	17	42	18	16	—22	......	......	91	57	74	46
19	23	4	40	13	11	—8	......	......	83	58	78	50
20	8	—4	29	2	22	—18	......	......	78	49	96	48
21	5	—6	35	—3	29	—3	......	......	75	52	111	58
22	12	—10	16	3	36	20	......	......	77	46	96	69
23	1	—17	40	2	49	24	......	......	80	41	98	59
24	2	—24	65	16	39	22	......	......	80	48	105	60
25	17	—16	46	10	38	31	......	......	81	54	93	71
26	40	—5	13	3	35	26	......	......	89	54	77	61
27	36	4	11	5	27	18	......	......	89	·57	84	59
28	31	—6	21	0	32	7	......	......	96	56	83	55
29	33	—16	15	4	34	15	......	......	94	64	85	51
30	42	1	......	......	35	15	......	......	91	57	72	56
31	2	—22	......	......	38	16	......	......	79	58	......	......
Range	32°		39°		40°		29°		35°		24°	
Monthly means	60°.9		60°.0		61°.0		69°.7		76°.1		82°.2	

TABLE X.—*Maximum and minimum temperature at Fort Sully*—**Continued.**

Day of month.	1876.												1877.											
	July.		August.		September.		October.		November.		December.		January.		February.		March.		April.		May.		June.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	80	55	90	74	76	53	71	23	......	......	22	-1	14	-1	47	36	36	26	29	12	69	38	58	43
2	88	56	90	71	89	58	67	39	......	......	23	4	24	-8	46	25	28	7	35	17	55	43	64	42
3	83	60	97	68	86	56	49	36	......	......	23	3	28	14	43	27	30	2	49	26	58	35	75	44
4	85	56	93	63	66	54	47	32	......	......	31	4	39	23	43	32	31	9	47	27	71	44	63	50
5	88	52	82	63	70	59	65	40	......	......	50	8	38	29	49	29	41	6	57	39	56	48	75	50
6	95	68	92	54	72	57	56	40	......	......	38	18	39	15	46	31	34	16	65	33	61	36	71	54
7	103	80	107	72	70	55	60	38	52	......	37	24	17	-8	40	26	21	-9	62	41	64	36	75	44
8	96	76	104	79	59	50	63	27	63	39	35	-8	15	-10	42	20	9	-13	46	28	68	49	63	45
9	91	60	102	60	58	49	73	35	70	27	25	-3	24	9	51	26	16	-7	54	27	75	51	74	38
10	101	67	79	51	61	50	52	27	68	26	42	12	29	3	49	23	21	-17	56	27	61	52	66	54
11	90	64	99	58	60	53	59	28	46	26	51	40	9	-16	24	13	24	-1	49	34	60	54	70	54
12	85	64	91	64	59	52	61	30	26	14	56	35	6	-16	34	3	33	11	58	41	69	48	67	50
13	80	59	77	60	66	50	58	34	16	-4	40	27	29	-16	45	21	38	13	70	37	59	52	71	47
14	80	62	70	53	71	46	43	21	22	-2	35	3	22	-11	46	23	26	4	70	47	79	55	72	54
15	85	61	76	57	78	48	71	26	38	7	43	0	15	-16	45	27	22	16	68	40	74	52	77	47
16	92	70	70	59	81	60	71	31	37	20	20	-3	4	-20	50	18	17	2	62	41	76	48	91	53
17	91	63	70	63	75	51	72	32	34	15	14	-3	8	-5	58	26	27	9	52	45	73	56	100	69
18	94	64	86	60	77	56	72	38	23	6	35	-2	10	-15	54	34	39	9	49	43	74	56	79	69
19	88	74	81	61	72	53	55	45	38	15	19	1	20	-20	47	25	37	20	65	37	75	57	78	53
20	91	58	81	60	71	43	49	44	37	20	24	7	31	-1	62	31	39	20	70	40	61	45	81	60
21	99	67	91	69	84	51	47	36	36	15	36	14	25	8	50	33	44	25	66	50	70	49	88	55
22	80	64	88	65	73	56	58	28	34	22	16	-1	13	-8	42	29	25	14	52	35	39	51	94	63
23	82	63	84	61	81	45	56	40	43	16	-1	-8	25	4	39	19	23	12	46	30	65	52	80	57
24	85	56	78	55	70	54	52	32	41	32	9	-4	26	3	39	20	41	18	61	32	67	55	81	49
25	82	62	75	48	71	47	53	26	38	27	3	-11	35	1	36	19	55	31	63	42	64	53	84	51
26	84	68	83	56	71	44	55	30	42	32	-4	-26	39	15	29	20	41	30	54	36	72	53	81	47
27	83	53	88	60	80	47	60	30	37	28	24	-18	44	20	36	21	36	28	54	32	80	53	81	60
28	96	64	85	66	63	43	......	......	30	18	10	-3	38	14	43	19	40	29	53	28	89	60	86	56
29	102	59	84	64	52	37	......	......	18	6	0	-21	35	12	......	......	50	36	56	30	89	66	99	60
30	101	75	92	64	53	25	......	......	15	-6	13	-12	40	17	......	......	50	38	68	31	84	61	78	57
31	103	74	76	59	......	......	......	......	......	......	15	-13	46	31	......	......	44	29	......	......	64	46	......	......
Range	51°		59°		64°		......	......	......	......	82°		66°		59°		72°		58°		54°		62°	
Monthly means	75°.6		73°.1		58°.6		......	......	......	......	13°.7		13°.9		33°.4		23°.8		44°.7		58°.6		63°.6	

The first thing we notice in this table worthy of remark is the continuous low temperature from the middle of December, 1872, to the 3d of February, 1873, the minimum thermometer making during this period 42 days below zero, while during the same period in the winter of 1873–'74 it stood below zero only 17 days. We also observe that during the former the maximum temperature was below zero 7 days, while it fell below zero only one day during the winter of 1873–'74. A further comparison of the two winters shows that the latter was decidedly more favorable to the locust than the former, if the eggs are at all affected by long continued and extreme cold, which is very doubtful.

The Fort Benton record not only corresponds with this showing, but the contrast is still more marked; that of Fort Garry, Manitoba, shows very little difference between the two winters in this respect; the record of Virginia City presents no marked difference,

Reference to the record of Fort Sully for the winter of 1874–'75, given in the preceding table, will show that, while December was comparatively mild, there was a long continued cold spell in January and February. The Fort Garry minimum thermometer shows an unbroken succession of minuses (below zero marks) from December 28 to March 7; also a continuous maximum below zero from January 2 to 19.

The maximum and minimum record for Fort Sully for the winter of 1875–'76, preceding the invasion of 1876, is even more favorable than that of 1873–'74, if comparative mildness is favorable.

Whether the records of but six or seven years will justify us in assuming any law as established thereby in reference to the subject now under consideration is very doubtful; certainly not, unless the data are uniform in their bearing on the point. Still there are sufficient indications in the facts just presented to lead us to believe it probable that here we shall find, in part at least, what we are hunting for, but if so we must confess that it is in a very different quarter from what we supposed.

If we now turn to the record of rainfall, as shown in Table VII, we find that the amount for the winter months at the stations within or near the borders of the permanent breeding-grounds is so small throughout the years included that the differences can cut no important figure in the matter under discussion. On inspection of the records, the months of May and June, at Fort Sully, shows, contrary to the theory heretofore advanced, that the rainfall in 1874 was greater than 1873 or 1875; the same thing is also true in reference to Breckenridge; but at Saint Paul, Omaha, and Keokuk the case is reversed. At the other points the difference is not very marked either way. The total for the years at the different stations also fails to reveal any very marked difference favorable to the theory advanced, except that as a general rule that of 1874 appears to be below the average; but at Saint Paul, Fort Sully, Virginia City, and Breckenridge the amount in 1874 was actually greater than in 1875.

We are therefore forced to the conclusion that the meteorological data, so far as we have considered them, fail to reveal any facts that tend to confirm in a marked or distinct manner the theory that heat and dryness are absolutely necessary to an excessive development of locusts. But we think the investigation is not without profit, *first*, because it shows that a longer series of years is necessary to determine satisfactorily the relation between meteorological conditions and the locust development; *second*, because it shows that annual and monthly means, so far as temperature is concerned, are of but little value in the solution of this question; *third*, because it indicates the necessity of paying more attention to the temperature in winter, in reference to this question, than we have been disposed to allow; *fourth*, because it presents some facts which indicate the necessity of somewhat modifying the theory advanced in our First Report, and maintained in the previous part of this chapter. We have assumed in our First Report, as well as the present, that as a very general rule the locust swarms that invade Nebraska, Iowa, and Kansas come directly from their native breeding-grounds in British America, Montana, and Western Dakota. Now, several facts presented by the meteorological data agree better with the idea that two seasons at least are required for this purpose; that is, that those developed by a favorable season in these northern regions migrate that season to Southern Dakota and Northern Nebraska, and, if the next season is favorable in this region, move farther south in increased numbers; if the season is unfavorable they proceed no farther, or in very diminished numbers. The temperature and rainfall in 1862–'63, and 1872–'73, appear to accord better with this theory than the other.

Be this as it may, we have given the facts as we find them, that those who desire to investigate the subject may have the data at hand properly arranged so as to show their bearing upon the question. We confess our disappointment in the result of our attempt to prove a theory so long maintained, and so universally believed; but, as before stated, we are unwilling to abandon it, notwithstanding the meteorological records fail to confirm it in the marked manner we expected, for personal experience and observation have too often confirmed it.

There is still another way in which the relation of temperature to the development of the locusts may be viewed which does not appear to have been brought forward until touched upon in our First Report.

Professor Cleveland Abbe, of the Signal Service Bureau, has suggested the idea that the development of the eggs may depend upon the *sum* of the heat rather than the degree; that is to say, the number of hours they are subject to heat above a certain degree. This opinion impressed itself very favorably upon our minds, and the ingenious method adopted by the Professor to demonstrante it, as given in our First Report[206] agreed so well with the facts that we were disposed to accept it as the true key to the relation between temperature and locust development.

Without at present deciding as to its value we must confess that a more thorough examination of it has tended to render us somewhat skeptical as to the value of the theory when applied to the data in solving the prob-

[206] Pages 425–432.

lem under discussion. That it serves to bring to view an important factor that had not been sufficiently considered is undoubtedly true; it also clearly indicates, so to speak, an inner law of the influence of heat.

Referring the reader to our First Report for an explanation and illustration of the theory as given by Professor Abbe, we propose to discuss it briefly here.

That there is a limiting temperature below which, if continuous, the eggs will not hatch must be admitted. Just what that limit is has not yet been accurately determined, though approximately reached by the experiments made by Mr. Riley in 1876–'77.

But in-door experiments, although conducted with the utmost skill and precision, are likely to vary more or less, in their results, from what will be found to be true in the actual out-door life of the species; still they form a good basis upon which to work, and serve as an excellent guide to the fact sought for.

Professor Abbe assumes the following as a "working hypothesis:"[207] that, at a uniform temperature of 50° Fahr. the eggs require 65 whole days, or 1,560 hours, to hatch.

At a uniform temperature of 60°, they require 60 whole days, or 1,440 hours, to hatch.

At a uniform temperature of 70°, they require 55 whole days, or 1,320 hours, to hatch.

It is proper to call attention in this connection to note 94, on page 428 of our First Report, but the object we now have in view does not require any explanation of the difference there alluded to.

That eggs have repeatedly hatched in some of the northern sections when the maximum temperature had not at any time during the spring exceeded 52° or 53°, and seldom rose to 50°, is evident from data obtained by the Commission. We may therefore safely assume that a temperature of 50° is not below the hatching point. We may also assume as borne out by the facts that eggs deposited early in the season will, as a rule, hatch out, under the same conditions, earlier the next spring than those deposited later. Mr. Stolley, of Hall County, Nebraska, who is in the habit of observing and recording the dates of depositing and hatching, had already noticed this fact, and so informed us in 1877. Professor Whitman and others have also observed the same thing. It appears, therefore, that the process of forming the embryo commences in the fall, and that the *sum* of the heat above a certain degree is a factor not to be overlooked; and we may remark here, as indicated by what has been shown in this chapter, that the *sum* of the cold below a certain degree also appears to be an important factor in the problem.

As Mr. Stolley gives us the exact date at which eggs were first deposited in Hall County in 1877, let us try Professor Abbe's "working basis" and theory by an examination of this case. It is true we have no meteorological record for that immediate section, but as Omaha and

[207] First Report, page 428.

North Platte are on the same parallel, and Mr. Stolley's locality is about midway between them in the same valley or plain we may take the mean of the records of these two places, which differ very slightly, as representing that of Hall County.

In this case the eggs were deposited August 13 and 14, 1876, and began to hatch April 13 and 14, 1877.

The number of days during which the maximum temperature was 50° or over, and also the number of days during which it was 60° or over, were as follows:

Months.	50°	60°
August	17	17
September	29	28
October	27	19
November	10	4
December	3	1
January	0	0
February	12	1
March	13	5
April	11	6
Total	122	81

In order to ascertain the number of hours they were exposed to these degrees of heat, respectively, we will follow Professor Abbe's estimate as nearly as possible, keeping in mind and making proper allowance for the difference between the surface temperature and that at which the eggs are placed. We obtain the total number of hours the eggs were exposed to the degree of heat specified by multiplying the number of hours during a day in which the maximum was at or above the given degree by the number of days given above each month.

Months.	Number of hours each day.	Number of days maximum above 50°.	Product in hours.	Number of hours each day.	Number of days maximum above 60°.	Product in hours.
August	24	17	408	22	17	374
September	22	29	638	18	28	504
October	18	27	486	12	19	228
November	11	10	110	6	4	24
December	4	3	12	4	1	4
January	0	0	0	0	0	0
February	8	12	96	4	1	4
March	10	13	130	6	5	30
April	12	11	132	10	6	60
Total	....	122	2,012	....	81	1,228

From this we see that if 50° be taken as the minimum, it requires 2,012 hours, 1,228 of which must be above 60°, to hatch the eggs in the latitude of Grand Island, Hall County, Nebraska; or, to be more exact, 784 hours between 50° and 60°+ 988 hours between 60° and 75°+ 240 hours above 75°=2,012 hours.

Let us take another case; and this time we will select one at North Platte, Nebr., one of the points selected by Professor Abbe in illustrating his theory. With the explanation given above, the following table will be understood. Eggs were deposited from July 10 to 25, in 1876, and hatched April 25 to May 12, 1877. We will therefore select as our dates July 25, 1876, and April 30, 1877.

Months.	Number of days maximum above 50°.	Number of hours each day.	Product in hours.	Number of days maximum above 60°.	Number of hours each day.	Product in hours.
July	7	24	168	7	24	168
August	31	24	744	31	22	682
September	29	22	638	28	16	448
October	25	18	450	23	11	253
November	14	11	154	5	6	30
December	7	4	28	1	4	4
January	0	0	0	0	0	0
February	12	8	96	0	0	0
March	15	10	150	7	6	42
April	22	12	264	12	12	144
Total	162	....	2,692	115	....	1,771

It is true Professor Abbe's calculations lead him to fix upon April 30 as the time for hatching to begin at this point, but this is upon the assumption the eggs are deposited about September 1, when, in fact, they were deposited in 1876 by the 25th of July. If we take his working basis, that is, 1,440 hours at 60°, the hatching in this case should have taken place in October; with 50° and 1,560 hours as the basis, it should have occurred in November.

Another fact is revealed by comparing the results of the two places mentioned. Hall County and North Platte, in the same latitude, similarly situated in the same valley and not very far apart, present a wide difference in the number of hours required to hatch the eggs. At a temperature of 60°+ it required 1,228 hours in one place, and 1,771 at the other; at 50°+ it required 2,012 at one place, and 2,692 at the other, both calculated on precisely the same basis.

At North Platte, taking 50° as a minimum, it required 2,692 hours, 1,771 of them 60°+, to hatch the eggs; or, to be exact, as in the former case, 921 hours between 50° and 60°+ 1,411 hours between 60° and 75°+ 360 hours above 75°.

As a third example, we select Moorhead, in Clay County, Minnesota, where the eggs were deposited July 20 to August 20, 1876, and hatched May 15 to 30, 1877. We take, as the dates to be used, August 1, 1876, and May 22, 1877, and use the meteorological record of Breckenridge, which is in the same level valley, and but a short distance away.

Months.	Number of days maximum 50°.	Number of hours each day.	Product in hours.	Number of days maximum 60°+.	Number of hours each day.	Product in hours.
August	31	23	713	31	20	620
September	28	18	504	24	14	336
October	16	12	192	7	10	70
November	2	8	16	1	6	6
December	0	0	0	0	0	0
January	0	0	0	0	0	0
February	1	4	4	0	0	0
March	0	0	0	0	0	0
April	19	8	152	9	6	54
May	21	12	252	19	10	190
Total	118	....	1,833	91	....	1,276

The result in this case approximates very closely to that at Grand Island, if we take 60° as the minimum. As the data in reference to North Platte is not so positive as that in reference to the other two, we may take the latter as giving approximately the length of exposure to a given degree of temperature that is necessary to hatch the eggs in their natural position.

Taking the results at these two places and Mr. Riley's experiments, let us from them test Professor Abbe's "working basis." Mr. Riley found by actual experiment that at a temperature of 85°, from 28 to 33—say 31 days—744 hours were required to hatch the eggs; that at a temperature of 75°—42 days—1,008 hours were required. By taking the number of hours at which they were exposed, at these two places, to a temperature between 50° and 60°, 60° and 75°, and above 75°, to wit, Grand Island, 784, 988, and 240 hours, respectively, as given above, and Moorhead, 921, 1,411, and 360 hours, and reducing them by proportion to 50° and 60°, we obtain the following results:

The time required to hatch the eggs at a uniform temperature of 85° is 31 whole days, or 744 hours; at 75° is 42 whole days, or 1,008 hours; at 60° is 60 whole days, or 1,440 hours; at 50° is 116 whole days, or 2,784 hours.

The result at 60° is precisely that given by Professor Abbe, the difference between the two places being only one day—one 60 days, the other 61. The number of days at 50° in the average of 112 and 120.

Notwithstanding the close agreement between Mr. Riley's experiments and Professor Abbe's theory, there are so many elements of uncertainty entering into the calculation that it can at most be considered but as a means of approximating, as Professor Abbe truly says, the fact.

If the hatching depends entirely on the spring temperature and not on the *sum* during the time they are in the ground, then the length of time required is not only very brief but is by no means uniform; but the results of the foregoing calculations would appear to render it certain that the *sum* is a necessary factor, and for bringing this out we must thank Professor Abbe; but we must not forget that *time* also is a factor which must be considered, otherwise the southern localities ought to produce two broods in the year.

The direct influence of the temperature and winds on flights.—For the purpose of illustrating this we introduce here the daily records of temperature and wind during the summer of 1877. It is limited to six of the most important northwestern stations, and has been kindly furnished to the Commission by the Chief of the Signal Service Bureau, to whom we are under obligations for numerous favors.

TABLE XI.—*Statement showing the readings of the exposed thermometer and direction and velocity of the wind at 7 a. m., 2 and 9 p. m. (local time) daily, and daily maximum and minimum temperatures at the stations of observation of the Signal Service, U. S. A., at Denver, Colo., Cheyenne, Wyo., Virginia City, Mont., Bismarck and Yankton, Dak., and North Platte, Nebr., during the months of June, July, and August, 1877.*

[Compiled from the records on file in the office of the Chief Signal Officer, U. S. A.]

Date.	Time (local).	Denver, Colo.					Cheyenne, Wyo.					Virginia City, Mont.				
		Thermometer.			Wind.		Thermometer.			Wind.		Thermometer.			Wind.	
		Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).
1877. June 1	7 a. m.	48			S.	4	46			NW.	34	39			0	0
	2 p. m.	69	74	44	W.	4	61	61	37	W.	28	48	52	33	W.	12
	9 p. m.	61			SW.	4	47			NW.	8	41			0	0
2	7 a. m.	54			S.	4	50			NW.	20	43			0	0
	2 p. m.	72	73	42	N.	3	66	70	39	W.	8	57	62	36	NW.	8
	9 p. m.	62			S.	4	53			W.	1	48			SE.	4
3	7 a. m.	60			S.	3	54			W.	2	53			0	0
	2 p. m.	74	77	53	NW.	2	65	70	39	E.	8	50	59	42	W.	8
	9 p. m.	62			N.	15	54			S.	4	48			SW.	11
4	7 a. m.	59			W.	8	51			NW.	12	46			SW.	3
	2 p. m.	72	76	49	NW.	13	61	65	45	N.	16	63	68	39	SW.	10
	9 p. m.	61			S.	2	50			NE.	1	56			0	0
5	7 a. m.	54			0	0	57			SW.	8	42			0	0
	2 p. m.	78	81	43	NW.	5	71	75	42	SW.	16	54	57	40	SW.	16
	9 p. m.	61			N.	16	52			W.	4	41			W.	4
6	7 a. m.	49			W.	16	49			NW.	20	41			SW.	3
	2 p. m.	65	71	46	NE.	5	61	66	43	W.	24	52	56	32	W.	4
	9 p. m.	60			E.	4	51			NE.	8	47			0	0
7	7 a. m.	51			N.	5	39			NW.	16	41			SW.	5
	2 p. m.	52	60	45	N.	16	49	53	38	NE.	16	49	52	38	E.	4
	9 p. m.	45			N.	16	42			NE.	16	39			NE.	12
8	7 a. m.	41			N.	15	38			N.	20	41			E.	1
	2 p. m.	51	53	39	NW.	4	47	49	36	N.	20	54	62	33	NW.	3
	9 p. m.	48			NW.	1	38			N.	8	49			SE.	8
9	7 a. m.	47			S.	5	45			W.	1	52			0	0
	2 p. m.	69	75	39	S.	4	67	69	32	NW.	20	66	70	39	W.	12
	9 p. m.	62			W.	5	57			NW.	4	56			SW.	16
10	7 a. m.	64			W.	8	47			N.	20	51.5			0	0
	2 p. m.	64	69	54	NE.	4	57	61	43	N.	16	64	68	40	W.	6
	9 p. m.	55			E.	2	51			N.	4	56			SE.	4

TABLE XI.—*Statement showing the readings of the exposed thermometer and direction and velocity of the wind, &c.*—Continued.

Date.	Time (local).	Denver, Colo.					Cheyenne, Wyo.					Virginia City, Mont.				
		Thermometer.			Wind.		Thermometer.			Wind.		Thermometer.			Wind.	
		Ex.	Daily.		Direction.	Velocity (miles per hour).	Ex.	Daily.		Direction.	Velocity (miles per hour).	Ex.	Daily.		Direction.	Velocity (miles per hour).
			Max.	Min.				Max.	Min.				Max.	Min.		
1877. June 11	7 a. m	47			S.	4	49			W.	8	54			0	0
	2 p. m	64	71	45	E.	4	61	65	38	N.	16	69	73	45	NW.	8
	9 p. m	58			SE.	5	55			SW.	8	64			SW.	12
12	7 a. m	62			S.	4	63			W.	8	54			SE.	4
	2 p. m	82	83	51	NE.	4	66	70	43	N.	16	66	71	48	W.	3
	9 p. m	64			NE.	4	54			NE.	8	49			SE.	16
13	7 a. m	53			0	0	45			SE.	12	50			0	0
	2 p. m	70	80	49	N.	4	64	67	43	S.	20	66	73	38	SW.	5
	9 p. m	64			NW.	4	55			SE.	16	59			SE.	4
14	7 a. m	58			S.	4	61			S.	4	41			NE.	16
	2 p. m	84	85	50	NE.	5	74	78	43	S.	16	54	61	35	NE.	11
	9 p. m	59			N.	20	47			N.	28	49			SE.	4
15	7 a. m	50			NE.	4	48			E.	2	51			0	0
	2 p. m	70	77	49	N.	3	70	72	38	S.	8	71	75	37	W.	14
	9 p. m	64			0	0	56			S.	8	60			SE.	12
16	7 a. m	59			0	0	62			W.	2	57			0	0
	2 p. m	87	92	50	SE.	4	83	85	45	S.	16	80	80	46	SW.	14
	9 p. m	73			S.	5	67			S.	16	66			S.	6
17	7 a. m	67			S.	5	67			W.	8	58			NW.	12
	2 p. m	90	94	56	W.	20	85	86	47	W.	20	68	72	50	W.	16
	9 p. m	74			W.	8	57			NW.	8	60			NE.	18
18	7 a. m	62			N.	12	59			E.	8	58			E.	6
	2 p. m	70	74	54	NW.	4	73	75	50	SE.	20	68	69	47	NE.	6
	9 p. m	67			0	0	62			SE.	20	62			S.	6
19	7 a. m	63			S.	4	64			SW.	4	56			0	0
	2 p. m	87	92	52	SW.	5	85	87	50	S.	8	66	66	49	SE.	1
	9 p. m	72			0	0	61			W.	8	57			NE.	16
20	7 a. m	63			0	0	58			N.	16	52			0	0
	2 p. m	82	90	50	NE.	4	70	78	49	SE.	8	68	74	44	W.	2
	9 p. m	63			N.	10	59			SE.	2	59			S.	7
21	7 a. m	65			S.	3	62			W.	4	55			0	0
	2 p. m	88	92	55	SE.	4	77	81	48	S.	4	76	79	44	W.	10
	9 p. m	69			0	0	62			NE.	1	65			SW.	4

22	7 a. m	61	95	54	0	0	64	85	49	SW.	4	62	69	45	0	0
	2 p. m	86			N.	8	78			S.	16	56			S.	2
	9 p. m	71			W.	5	63			NW.	12	47			W.	4
23	7 a. m	61	88	54	0	0	57	74	50	NW.	16	40	49	32	SW.	10
	2 p. m	82			W.	15	73			W.	20	47			W.	19
	9 p. m	64			SE.	3	53			NW.	20	44			SW.	12
24	7 a. m	58	82	48	0	0	52	75	42	SW.	12	46	56	39	W.	14
	2 p. m	78			NW.	4	72			S.	16	43			W.	1
	9 p. m	65			0	0	56			N.	12	42			0	0
25	7 a. m	55	80	50	SE.	4	53	71	44	W.	10	40	53	31	0	0
	2 p. m	75			E.	8	67			NW.	20	52			0	0
	9 p. m	65			SW.	2	60			NE.	12	48			SE.	6
26	7 a. m	54	77	47	0	0	51	72	41	S.	12	41	52	38	SE.	10
	2 p. m	71			N.	5	69			SE.	20	48			E.	6
	9 p. m	60			NW.	5	60			S.	4	44			0	0
27	7 a. m	55	89	45	0	0	54	81	41	NW.	2	45	64	35	0	0
	2 p. m	86			SE.	5	80			S.	12	60			S.	2
	9 p. m	74			SW.	4	68			S.	8	53			SE.	6
28	7 a. m	60	85	54	0	0	56	81	49	N.	4	53	71	38	E.	4
	2 p. m	83			NW.	8	80			S.	24	60			N.	10
	9 p. m	74			S.	4	73			S.	12	47			SW.	6
29	7 a. m	72	88	58	S.	16	72	75	56	SW.	16	44	53	41	SW.	4
	2 p. m	83			W.	15	71			W.	36	53			SW.	14
	9 p. m	72			SW.	8	56			NW.	4	48			SW.	12
30	7 a. m	59	86	46	S.	3	59	79	49	W.	8	44	60	35	0	0
	2 p. m	80			NW.	8	77			S.	12	57			W.	6
	9 p. m	70			0	0	63			SE.	4	47			0	0
July 1	7 a. m	65	89	57	SW.	4	60	79	47	S.	8	45	61	38	NW.	2
	2 p. m	86			W.	15	75			NW.	28	57			NW.	6
	9 p. m	72			S.	10	56			NW.	8	53			SE.	8
2	7 a. m	57	92	48	S.	4	58	86	44	SW.	12	50	65	43	0	0
	2 p. m	85			SE.	5	81			SW.	8	59			S.	10
	9 p. m	74			SE.	4	68			S.	8	55			S.	2
3	7 a. m	68	99	57	S.	4	69	93	46	W.	8	54	75	44	0	0
	2 p. m	91			W.	4	89			SW.	8	73			SW.	8
	9 p. m	78			NW.	4	73			0	0	57			SE.	10
4	7 a. m	74	92	70	SW.	5	68	91	53	NW.	4	60	82	50	W.	2
	2 p. m	89			NW.	5	89			SW.	8	78			S.	10
	9 p. m	75			S.	4	70			SW.	1	66			E.	3
5	7 a. m	70	98	61	S.	4	73	96	53	NW.	8	60	86	49	0	0
	2 p. m	95			E.	4	94			S.	8	81			SW.	18
	9 p. m	79			S.	5	76			NW.	12	70			S.	10
6	7 a. m	70	98	65	S.	3	73	96	61	NW.	2	65	84	55	W.	1
	2 p. m	94			S.	4	93			S.	12	81			SW.	10
	9 p. m	75			S.	5	78			NW.	8	64			0	0
7	7 a. m	73	92	63	S.	4	73	89	59	W.	6	54	80	47	0	0
	2 p. m	87			N.	3	86			W.	12	77			NW.	4
	9 p. m	77			N.	1	75			E.	4	60			NE.	15
8	7 a. m	69	77	68	N.	2	66	75	63	NE.	12	63	80	56	E.	10
	2 p. m	74			E.	4	74			SE.	12	78			0	0
	9 p. m	67			0	0	64			SE.	8	70			E.	6

TABLE XI.—*Statement showing the readings of the exposed thermometer and direction and velocity of the wind, &c.*—Continued.

Date.	Time (local).	Denver, Colo.					Cheyenne, Wyo.					Virginia City, Mont.				
		Thermometer.			Wind.		Thermometer.			Wind.		Thermometer.			Wind.	
		Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).
1877. 9	7 a. m	62			S.	2	69			SW.	8	66			E.	4
	2 p. m	83	85	60	E.	4	83	84	54	S.	12	82	86	58	0	0
	9 p. m	67			NE.	5	59			SE.	12	77			SE.	4
10	7 a. m	61			SE.	1	65			W.	1	65			W.	1
	2 p. m	82	89	57	NW.	4	81	85	51	SE.	8	82	89	50	SE.	1
	9 p. m	72			SE.	8	70			S.	4	71			SE.	8
11	7 a. m	65			S.	4	69			SW.	1	62			0	0
	2 p. m	89	92	60	SW.	12	68	89	58	N.	16	79	85	57	W.	5
	9 p. m	73			E.	4	71			SW.	8	70			NE.	18
12	7 a. m	71			SW.	4	71			S.	4	59			SE.	4
	2 p. m	87	92	69	NW.	5	77	89	57	SW.	8	74	78	51	W.	8
	9 p. m	74			SE.	5	72			S.	2	66			NE.	10
13	7 a. m	70			S.	4	65			N.	16	58			0	0
	2 p. m	91	96	62	NE.	5	82	90	56	S.	12	75	80	48	W.	14
	9 p. m	73			S.	4	74			NW.	2	67			S.	6
14	7 a. m	74			S.	7	72			W.	12	62			W.	16
	2 p. m	92	99	64	NW.	12	88	91	57	NW.	20	68	73	60	NW.	18
	9 p. m	79			W.	2	69			N.	12	60			NE.	12
15	7 a. m	63			S.	4	56			S.	2	51			0	0
	2 p. m	79	85	55	NW.	8	77	79	43	SW.	12	65	72	43	NW.	8
	9 p. m	73			W.	5	61			SE.	4	61			SE.	8
16	7 a. m	59			W.	4	60			SE.	12	56			0	0
	2 p. m	80	87	55	NW.	5	81	85	43	S.	12	76	80	46	E.	1
	9 p. m	74			SE.	10	74			W.	16	72			SW.	6
17	7 a. m	73			S.	4	70			W.	4	64				0
	2 p. m	87	90	63	NW.	4	77	79	61	N.	8	73	79	61	N.	10
	9 p. m	65			S.	5	63			N.	2	66			SE.	4
18	7 a. m	65			N.	4	62			N.	8	65			SE.	6
	2 p. m	79	85	58	N.	5	77	80	50	S.	8	79	81	57	NW.	4
	9 p. m	72			NW.	2	60			W.	4	72			NE.	10
19	7 a. m	60			NW.	5	59			SE.	2	64			SE.	10
	2 p. m	77	82	57	NW.	8	76	77	45	NE.	12	82	83	62	NE.	4
	9 p. m	73			E.	5	64			0	0	74			SE.	1

	20	7 a. m	60	80	55	N.	8	57	79	46	SE.	8	63	88	56	0	0
		2 p. m	73			N.	12	75			SE.	8	84			NE.	6
		9 p. m	67			E.	5	59			S.	8	79			SE.	4
	21	7 a. m	61	90	54	S.	2	60	86	44	SW.	2	70	94	63	0	0
		2 p. m	83			N.	6	82			NW.	8	91			S.	8
		9 p. m	72			W.	2	73			S.	3	80			SE.	8
	22	7 a. m	65	94	58	S.	5	66	90	48	W.	4	76	88	67	SW.	10
		2 p. m	88			NW.	5	88			SE.	8	86			SW.	4
		9 p. m	74			S.	6	69			SE.	12	68			E.	5
	23	7 a. m	65	93	57	S.	4	66	86	48	W.	1	67	83	54	0	0
		2 p. m	86			W.	6	83			S.	16	82			SE.	6
		9 p. m	74			SE.	16	69			S.	20	65			SE.	8
	24	7 a. m	64	80	58	W.	5	60	80	50	S.	12	64	76	57	NW.	8
		2 p. m	75			NW.	5	79			S.	12	70			W.	1
		9 p. m	71			W.	4	64			W.	12	62			SE.	10
	25	7 a. m	68	85	62	SW.	4	61	82	54	N.	12	58	74	48	0	0
		2 p. m	81			NW.	3	78			E.	8	70			SE.	10
		9 p. m	69			SW.	4	61			S.	2	55			NE.	14
	26	7 a. m	65	91	56	SE.	4	70	84	53	W.	8	46	58	43	0	0
		2 p. m	85			E.	16	81			NW.	16	53			W.	4
		9 p. m	71			W.	12	60			NW.	12	50			0	0
	27	7 a. m	63	80	55	NW.	4	54	76	45	N.	12	48	69	44	0	0
		2 p. m	75			N.	5	71			NW.	8	63			NW.	2
		9 p. m	64			S.	4	62			NE.	4	58			SE.	6
	28	7 a. m	62	93	55	S.	4	63	87	44	SW.	4	57	80	48	0	0
		2 p. m	84			SE.	6	84			S.	8	76			S.	6
		9 p. m	76			SW.	4	71			S.	8	66			NE.	4
	29	7 a. m	68	99	62	S.	4	67	90	52	NW.	4	65	79	49	0	0
		2 p. m	89			W.	4	86			NW.	8	71			SW.	2
		9 p. m	75			SW.	5	73			NW.	4	57			NE.	4
	30	7 a. m	69	95	60	S.	4	67	87	53	0	0	41	57	38	SW.	6
		2 p. m	88			N.	4	82			W.	4	47			SW.	12
		9 p. m	71			S.	3	63			NW.	20	49			SW.	8
	31	7 a. m	59	86	52	SE.	6	58	81	45	N.	8	45	69	39	0	0
		2 p. m	81			NE.	12	80			S.	8	63			NW.	6
		9 p. m	72			NW.	12	67			S.	2	57			SW.	10
Aug.	1	7 a. m	63	92	55	S.	3	60	87	44	SW.	2	54	79	44	0	0
		2 p. m	86			NE.	5	83			E.	8	73			W.	6
		9 p. m	73			SE.	12	67			E.	12	66			SE.	6
	2	7 a. m	63	85	61	NW.	4	64	85	55	S.	4	63	86	52	0	0
		2 p. m	81			SE.	12	84			S.	20	84			S.	12
		9 p. m	72			SE.	20	64			E.	12	72			S.	6
	3	7 a. m	63	94	57	SE.	2	67	86	51	W.	4	65	80	50	0	0
		2 p. m	89			NW.	4	79			NW.	20	79			S.	16
		9 p. m	72			W.	12	65			S.	12	65			S.	10
	4	7 a. m	66	90	60	S.	4	68	88	60	SW.	8	47	71	45	0	0
		2 p. m	82			NW.	15	84			SW.	4	66			NW.	5
		9 p. m	73			SE.	4	69			S.	16	57			E.	13
	5	7 a. m	67	99	63	SE.	6	71	88	58	SW.	4	58	77	41	W.	5
		2 p. m	91			NW.	5	85			NW.	8	69			W.	4
		9 p. m	81			W.	2	78			SW.	4	63			SE.	10

TABLE XI.—*Statement showing the readings of the exposed thermometer and direction and velocity of the wind, &c.*—Continued.

Date.	Time (local).	Denver, Colo.					Cheyenne, Wyo.					Virginia City, Mont.				
		Thermometer.			Wind.		Thermometer.			Wind.		Thermometer.			Wind.	
		Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).
1877.																
6	7 a. m	70			NW.	5	60			N.	12	56			0	0
	2 p. m	83	90	59	W.	4	74	78	53	E.	12	73	78	49	NW.	6
	9 p. m	59			E.	12	54			SW.	4	65			SE.	3
7	7 a. m	60			0	0	64			NW.	4	58			0	0
	2 p. m	80	83	53	SE.	12	51	82	46	NE.	20	75	79	50	NW.	8
	9 p. m	63			NW.	5	63			SW.	4	69			SE.	10
8	7 a. m	59			NW.	8	54			N.	8	60			0	0
	2 p. m	75	82	56	NW.	4	78	79	46	SE.	8	84	88	50	SE.	5
	9 p. m	69			W.	4	62			S.	4	73			SE.	5
9	7 a. m	60			0	0	64			W.	8	65			N.	4
	2 p. m	89	95	57	SE.	4	90	91	51	SE.	8	80	84	57	NW.	3
	9 p. m	75			SE.	3	72			S.	8	71			S.	6
10	7 a. m	69			0	0	73			W.	16	59			SE.	3
	2 p. m	90	92	62	E.	8	82	89	54	N.	8	77	83	55	NW.	8
	9 p. m	70			NW.	8	70			SW.	12	71			NE.	10
11	7 a. m	67			SE.	2	69			NW.	12	66			0	0
	2 p. m	83	88	63	W.	7	76	79	55	SW.	8	79	82	56	0	0
	9 p. m	69			NW.	2	63			N.	8	68			E.	6
12	7 a. m	63			SE.	4	60			NW.	8	61			0	0
	2 p. m	74	76	60	NW.	8	73	78	49	N.	4	77	80	58	0	0
	9 p. m	63			NW.	4	62			SW.	4	68			NE.	18
13	7 a. m	60			0	0	55			NE.	8	59			0	0
	2 p. m	76	80	55	N.	10	73	77	48	SE.	4	79	83	54	W.	4
	9 p. m	68			E.	8	62			SE.	8	70			E.	2
14	7 a. m	61			0	0	58			SE.	4	65			0	0
	2 p. m	75	79	59	SE.	8	71	77	49	SW.	4	79	80	55	NW.	3
	9 p. m	60			N.	12	62			S.	4	70			SE.	4
15	7 a. m	59			NW.	2	58			W.	8	60			0	0
	2 p. m	79	85	53	W.	4	79	79	48	NW.	12	80	82	52	NW.	6
	9 p. m	67			SW.	4	67			NW.	1	70			NE.	10
16	7 a. m	61			S.	4	61			NW.	8	60			0	0
	2 p. m	82	89	52	NW.	4	79	81	48	NW.	8	83	84	54	NW.	2
	9 p. m	71			S.	4	61			SW.	2	74			SE.	8

17	7 a. m	59			0	0	67			N.	4	65			0	0
	2 p. m	83	90	55	N.	12	79	81	51	N.	12	82	83	63	NE.	6
	9 p. m	70			SW.	4	67			E.	2	73			NE.	5
18	7 a. m	59			SE.	4	57			W.	4	65			0	0
	2 p. m	82	85	51	NW.	4	84	84	46	S.	12	76	80	56	0	0
	9 p. m	68			S.	5	69			SE.	12	65			SE.	4
19	7 a. m	65			W.	2	67			W.	12	60			0	0
	2 p. m	82	86	59	NW.	5	76	80	54	S.	16	65	72	52	W	5
	9 p. m	68			W.	3	59			W.	4	59			0	0
20	7 a. m	62			S.	4	59			NW.	8	55			0	0
	2 p. m	77	80	57	NW.	5	68	73	53	E.	12	68	70	47	SE.	8
	9 p. m	61			NE.	6	53			W.	8	58			SE.	12
21	7 a. m	52			SE.	4	51			S.	8	50			0	0
	2 p. m	77	83	47	W.	20	73	74	45	S.	8	67	71	45	NW.	8
	9 p. m	68			W.	12	59			E.	8	57			SE.	8
Aug. 22	7 a m	53			N.	12	52			SE.	8	50			0	0
	2 p. m	73	84	51	NW.	4	74	79	45	W.	4	74	78	43	W.	14
	9 p. m	66			S.	4	63			S.	12	66			SW.	1
23	7 a. m	57			S.	5	61			NW.	12	55			0	0
	2 p. m	87	94	49	N.	4	83	85	48	NW.	8	77	80	45	S.	12
	9 p. m	74			0	0	71			S.	12	65			E.	1
24	7 a. m	60			S.	7	59			W.	4	55			0	0
	2 p. m	87	90	58	W.	5	86	88	49	W.	12	77	78	44	S.	16
	9 p. m	73			S.	4	73			NW.	8	60			S.	1
25	7 a. m	59			SE.	6	60			NW.	4	55			SW.	12
	2 p. m	91	94	54	N.	6	84	87	55	S.	12	60	64	44	NW.	6
	9 p. m	76			W.	4	72			NW.	8	49			NW.	3
26	7 a. m	60			S.	4	59			NE.	4	45			0	0
	2 p. m	80	92	54	NE.	7	77	79	47	S.	4	57	62	37	NW.	6
	9 p. m	73			E.	5	63			E.	4	50			SE.	10
27	7 a. m	60			0	0	56			SE.	8	45			0	0
	2 p. m	83	90	58	NW.	8	78	80	47	SE.	16	63	69	39	NW.	5
	9 p. m	74			W.	2	72			E.	4	55			SE.	10
28	7 a. m	62			S.	5	59			N.	16	50			0	0
	2 p. m	84	92	59	E.	5	82	84	51	SE.	12	71	78	41	NW.	5
	9 p. m	76			E.	4	67			SE.	12	61			SE.	8
29	7 a. m	62			S.	4	62			SW.	4	55			0	0
	2 p. m	88	95	57	N.	15	88	91	52	SW.	8	78	82	44	0	0
	9 p. m	73			SE.	4	81			SW.	12	67			SE.	10
30	7 a. m	67			SE.	5	69			W.	8	60			0	0
	2 p. m	82	92	61	NW.	4	84	88	58	S.	20	71	75	51	NW.	16
	9 p. m	73			S.	4	74			W.	8	65			SE.	6
31	7 a. m	62			0	0	58			N.	16	51			0	0
	2 p. m	83	90	57	N.	5	73	75	49	E.	8	73	77	48	NW.	4
	9 p. m	67			N.	5	64			E.	8	65			SE.	8

TABLE XI.—*Statement showing the readings of the exposed thermometer and direction and velocity of the wind, &c.*—Continued.

Date.	Time (local).	Bismarck, Dak.					Yankton, Dak.					North Platte, Nebr.				
		Thermometer.			Wind.		Thermometer.			Wind.		Thermometer.			Wind.	
		Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).
1887. June 1	7 a. m	41			W.	6	50			W.	14	50			NW.	16
	2 p. m	50	50	37	NW.	18	63	65	46	W.	18	68	72	40	NW.	22
	9 p. m	39			NW.	15	53			NW.	8	60			N.	4
2	7 a. m	42			NW.	14	59			W.	12	55			0	0
	2 p. m	49	52	36	NW.	12	72	72	48	W.	16	75	77	48	W.	17
	9 p. m	47			NW.	1	54			N.	4	66			S.	4
3	7 a. m	50			NW.	6	56			0	0	68			S.	18
	2 p. m	62	64	44	N.	10	73	73	47	S.	3	81	83	53	SW.	16
	9 p. m	54			0	0	62			0	0	59			S.	16
4	7 a. m	54			NW.	2	62			E.	4	61			W.	2
	2 p. m	73	73	43	W.	4	76	76	50	E.	4	67	72	47	W.	12
	9 p. m	60			0	0	62			NW.	3	57			N.	10
5	7 a. m	64			S.	6	58			0	0	58			W.	4
	2 p. m	75	75	47	S.	16	72	72	56	SW.	3	80	81	45	S.	16
	9 p. m	64			SE.	7	64			SE.	8	67			SE.	38
6	7 a. m	56			N.	10	64			SE.	8	60			N.	16
	2 p. m	65	67	53	N.	11	73	73	57	SE.	12	57	68	55	N.	20
	9 p. m	55			NW.	13	58			N.	30	56			N.	6
7	7 a. m	60			W.	2	59			NW.	14	55			0	0
	2 p. m	65	65	42	NW.	14	71	71	54	NW.	8	66	68	45	E.	12
	9 p. m	52			NW.	12	60			N.	2	59			NE.	12
8	7 a. m	37			NW.	18	52			NW.	16	49			N.	40
	2 p. m	55	57	34	N.	24	54	59	43	NW.	24	56	58	45	N.	28
	9 p. m	47			N.	6	43			NW.	7	46			N.	12
9	7 a. m	52			W.	4	46			NW.	17	47			W.	12
	2 p. m	69	73	35	NW.	4	63	65	38	NW	15	65	71	34	W.	12
	9 p. m	57			NE.	2	54			SW	1	57			W.	12
10	7 a. m	56			NW.	19	60			NW.	18	59			N.	32
	2 p. m	57	58	49	NW.	26	68	69	46	NW.	28	62	67	44	N.	40
	9 p. m	51			NW.	13	52			NW.	13	57			N.	5
11	7 a. m	51			NW.	12	51			NW	16	55			W.	12
	2 p. m	60	64	45	NW.	10	58	64	49	NW.	16	64	66	42	NW.	20
	9 p. m	52			0	0	55			N	1	56			NW.	12

	12	7 a. m.	52			NW.	4	54			E.	3	67			W.	12
		2 p. m.	65	66	48	NW.	1	59	62	45	NE.	14	76	78	48	NW.	28
		9 p. m.	49			S.	4	51			NE.	1	61			N.	16
	13	7 a. m.	50			N.	7	55			W.	9	57			NE.	2
		2 p. m.	61	63	44	N.	8	69	70	49	NW.	10	69	73	52	E.	8
		9 p. m.	53			E.	2	63			0	0	61			E.	12
	14	7 a. m.	51			E.	2	60			SE.	13	58			SE.	12
		2 p. m.	54	55	48	NE.	2	81	82	55	S.	18	77	85	53	S.	8
		9 p. m.	51			N.	5	67			NW.	9	61			N.	28
	15	7 a. m.	56			0	0	57			N.	16	55			N.	20
		2 p. m.	69	71	43	S.	11	63	65	57	NE.	18	67	77	53	W.	4
		9 p. m.	59			SE.	5	59			W.	1	61			NW.	10
	16	7 a. m.	60			N.	7	64			SW.	1	60			S.	20
		2 p. m.	72	76	52	NE.	4	80	81	52	SW.	8	82	84	55	S.	24
		9 p. m.	64			NE.	7	69			SE.	7	72			E.	24
	17	7 a. m.	74			N.	4	70			S.	12	75			S.	12
		2 p. m.	87	87	60	NW.	12	84	87	61	SE.	20	94	95	63	S.	16
		9 p. m.	66			NW.	9	78			S.	13	80			S.	2
	18	7 a. m.	58.5			NW.	14	73			NE.	14	20			E.	20
		2 p. m.	64	66	52	N.	11	79	79	62	N.	15	78	79	65	E.	24
		9 p. m.	57			NE.	4	63			N.	7	69			NE.	8
	19	7 a. m.	57			NE.	4	61			NE.	13	66			E.	16
		2 p. m.	53	75	46	SE.	12	80	81	54	SE.	14	86	89	58	S.	26
		9 p. m.	63			NE.	6	72			SE.	9	71			SE.	8
June.	20	7 a. m.	61			NW.	8	73			SE.	8	71			NE.	12
		2 p. m.	74	74	57	NW.	13	82	84	64	NW.	20	82	83	62	NE.	20
		9 p. m.	58			N.	4	65			N.	6	71			NW.	36
	21	7 a. m.	65			0	0	69			0	0	65			E.	7
		2 p. m.	73	77	48	E.	4	79	79	53	E.	2	84	86	57	S.	20
		9 p. m.	64			E.	5	70			SE.	5	74			S.	33
	22	7 a. m.	67			SE.	9	68			SE.	7	72			SE.	24
		2 p. m.	83	85	56	SE.	12	81	81	65	S.	24	85	86	61	S.	32
		9 p. m.	75			SW.	4	72			SE.	20	67			SE.	12
	23	7 a. m.	68			W.	4	67			S.	17	63			E.	5
		2 p. m.	74	74	56	NW.	15	67	80	62	SW.	24	78	87	60	SE.	4
		9 p. m.	60			NW.	3	63			SE.	6	68			W.	5
	24	7 a. m.	60			W.	12	61			W.	9	62			W.	4
		2 p. m.	69	71	52	W.	17	74	74	55	SW.	4	81	82	49	SE.	8
		9 p. m.	57			0	0	67			SE.	8	69			NE.	20
	25	7 a. m.	61			E.	2	62			SE.	8	68			E.	12
		2 p. m.	67	68	43	NW.	10	74	75	61	SE.	11	77	78	53	W.	20
		9 p. m.	53			NW.	13	63			SW.	1	61			NW.	12
	26	7 a. m.	57			NW.	6	64			W.	6	57			E.	8
		2 p. m.	67	69	46	NW.	19	73	74	53	S.	5	71	76	51	E.	5
		9 p. m.	58			N.	2	66			SE.	4	58			NE.	24
	27	7 a. m.	57			NE.	10	62			S.	3	69			SW.	16
		2 p. m.	60	63	54	N.	16	78	79	59	SE.	7	82	85	55	S.	12
		9 p. m.	55			0	0	70			SE.	12	74			S.	12
	28	7 a. m.	58			NW.	2	72			SE.	1	65			SE.	15
		2 p. m.	72	74	44	SE.	2	80	83	62	NE.	8	72	77	58	SE.	20
		9 p. m.	65			E.	4	73			E.	6	70			SE.	20

TABLE XI.—*Statement showing the readings of the exposed thermometer and direction and velocity of the wind, &c.*—Continued.

Date.	Time (local).	Bismarck, Dak.					Yankton, Dak.					North Platte, Nebr.				
		Thermometer.			Wind.		Thermometer.			Wind.		Thermometer.			Wind.	
		Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).
1877. 29	7 a. m.	57			NE.	19	73			SE.	14	79			S.	20
	2 p. m.	66	66	53	NE.	9	82	84	67	SE.	18	88	93	65	N.	36
	9 p. m.	61			W.	2	67			NW.	11	66			NW.	12
30	7 a. m.	57			NW.	6	68			W.	16	64			NW.	12
	2 p. m.	68	71	56	NW.	18	79	79	58	W.	28	80	83	47	W.	12
	9 p. m.	61			NW.	6	64			NW.	3	66			S.	8
Jnly 1	7 a. m.	60			NW.	1	65			SW.	3	64			E.	12
	2 p. m.	66	67	50	NE.	2	77	77	52	E.	14	75	79	53	E.	16
	9 p. m.	59			NE.	6	65			SE.	6	66			NW.	12
2	7 a. m.	56			NW.	9	63			W.	18	61			W.	8
	2 p. m.	68	70	54	N.	1	77	78	55	W.	17	82	84	48	S.	8
	9 p. m.	63			0	0	68			W.	1	68			S.	20
3	7 a. m.	63			0	0	70			E.	3	74			SE.	20
	2 p. m.	77	78	55	SE.	8	83	85	58	SE.	14	89	94	55	SE.	10
	9 p. m.	72			E.	12	77			SE.	6	77			E.	8
4	7 a. m.	69			E.	15	77			SE.	8	76			E.	6
	2 p. m.	83	83	62	E.	10	88	89	71	SE.	12	100	102	65	0	0
	9 p. m.	77			E.	14	80			E.	2	84			S.	2
5	7 a. m.	72			E	18	79			E.	1	78			SW.	4
	2 p. m.	88	88	66	SE.	9	93	93	71	E.	4	100	107	67	SE.	6
	9 p. m.	68			E.	8	81			SE.	7	83			SE.	12
6	7 a. m.	72			S.	6	79			SE.	20	83			SW.	3
	2 p. m.	88	90	65	W.	6	92	92	75	SE.	11	101	104	68	S.	28
	9 p. m.	78			N.	1	82			SE.	13	83			S.	20
7	7 a. m.	73			N.	12	80			E.	11	83			E.	4
	2 p. m.	84	85	66	N.	11	95	96	74	S.	9	97	101	69	N.	5
	9 p. m.	72			N.	10	86			W.	1	85			N.	12
8	7 a. m.	71			NW.	6	77			NE.	8	72			NE.	12
	2 p. m.	80	81	51	NW.	12	83	85	68	N.	14	65	84	64	NE.	8
	9 p. m.	72			NW.	5	69			NW.	1	65			N.	6
9	7 a. m.	67			NW.	9	76			0	0	66			W.	8
	2 p. m.	82	82	61	N.	11	84	85	59	N.	12	85	90	55	W.	8
	9 p. m.	70			N.	4	69			NW.	4	74			W.	4

10	7 a. m	67			NE.	5	68			NE.	4	73			E.	4
	2 p. m	78	77	55	SE.	1	79	79	58	N.	6	93	95	62	S.	10
	9 p. m	65			E.	2	67			NE.	2	72			E.	10
11	7 a. m	70			SE.	15	61			SE.	9	70			E.	8
	2 p. m	77	80	48	SE.	9	76	78	59	SE.	12	90	93	62	S.	24
	9 p. m	70			E.	3	67			SE.	8	80			S.	32
12	7 a. m	67			SE.	4	69			SE.	10	75			S.	32
	2 p. m	75	75	65	NW.	12	85	86	63	S.	20	92	94	66	S.	32
	9 p. m	68			N.	6	78			S.	20	82			S.	28
13	7 a. m	70			SE.	3	73			SW.	7	77			S.	32
	2 p. m	78	79	54	W.	12	86	89	72	S.	12	92	100	65	S.	5
	9 p. m	65			E.	7	78			SW.	5	81			SW.	24
14	7 a. m	71			S.	9	73			SE.	18	82			SW.	3
	2 p. m	81	84	58	NW.	20	89	90	68	S.	18	104	105	66	S.	20
	9 p. m	63			W.	18	82			SW.	12	79			NW.	20
15	7 a. m	62			W.	16	65			NW.	7	65			NE.	16
	2 p. m	70	72	59	W.	20	78	81	58	NW.	15	77	86	59	NE.	12
	9 p. m	68			W.	13	66			SW.	1	66			NE.	8
16	7 a. m	63			W.	6	70			W.	5	66			E.	3
	2 p. m	78	78	55	W.	16	83	83	54	W.	13	86	87	54	S.	18
	9 p. m	75			W.	2	70			S.	4	71			S.	16
17	7 a. m	68			W.	3	73			W.	2	71			S.	8
	2 p. m	76	78	59	NW.	29	78	85	64	SW.	12	77	80	62	SE.	8
	9 p. m	60			N.	2	69			NW.	3	68			N.	4
18	7 a. m	59			N.	14	62			NW.	10	67			NW.	5
	2 p. m	65	68	51	N.	21	69	71	53	NW.	26	80	81	55	NW.	16
	9 p. m	60			N.	2	57			NW.	6	65			NE.	4
19	7 a. m	54			N.	2	58			NW.	14	61			N.	2
	2 p. m	66	67	48	N.	14	66	67	50	NW.	22	73	74	50	N.	16
	9 p. m	56			N.	2	59			NW.	5	62			N.	10
20	7 a. m	59			W.	2	55			N.	14	59			N.	6
	2 p. m	73	76	48	N.	6	74	75	51	NE.	16	70	72	45	NE.	12
	9 p. m	70			SE.	1	59			N.	1	61			N.	4
21	7 a. m	70			S.	1	61			NW.	1	65			NW.	1
	2 p. m	77	79	52	S.	4	79	80	44	SE.	3	84	85	50	S.	12
	9 p. m	74			E.	1	63			SE.	3	68			SE.	24
22	7 a. m	65			NE.	8	66			NE.	2	68			SE.	6
	2 p. m	81	82	60	S.	12	82	82	49	SE.	13	88	89	54	S.	20
	9 p. m	73			E.	11	67			SE.	7	70			SE.	32
23	7 a. m	70			S.	5	69			S.	7	68			S.	24
	2 p. m	85	87	66	S.	18	81	81	56	SE.	15	84	86	59	S.	28
	9 p. m	81			S.	12	67			SE.	6	69			S.	32
24	7 a. m	75			S.	7	68			SE.	8	69			S.	40
	2 p. m	85	88	69	S.	12	82	83	57	S.	18	84	85	58	SE.	44
	9 p. m	79			S.	8	70			SE.	10	69			SE.	28
25	7 a. m	66			NW.	11	68			SE.	4	69			S.	32
	2 p. m	70	77	64	SW.	3	86	86	61	SE.	16	88	89	61	S.	20
	9 p. m	65			NE.	9	74			SE.	13	72			S.	8
26	7 a. m	70			W.	1	74			S.	4	75			S.	5
	2 p. m	79	80	55	SE.	6	88	88	68	S.	18	93	93	58	S.	18
	9 p. m	71			SW.	4	75			SE.	12	67			S.	32

TABLE XL.—*Statement showing the readings of the exposed thermometer and direction and velocity of the wind, &c.*—Continued.

Date.	Time (local).	Bismarck, Dak.					Yankton, Dak.					North Platte, Nebr.				
		Thermometer.			Wind.		Thermometer.			Wind.		Thermometer.			Wind.	
		Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).
1877. 27	7 a. m	68			W.	11	70			W.	7	68			NE.	12
	2 p. m	74	75	61	SW.	15	73	81	64	NW.	17	73	79	61	NE.	16
	9 p. m	69			W.	16	65			SW.	6	67			0	0
28	7 a. m	65			NW.	7	71			W.	1	67			W.	2
	2 p. m	74	78	57	NW.	6	84	85	58	NW.	15	88	91	52	SE.	6
	9 p. m	75			E.	4	71			SE.	5	75			S.	24
29	7 a. m	70			E.	3	73			SE.	4	77			SW.	20
	2 p. m	83	84	71	S.	6	90	90	60	S.	22	94	95	61	S.	32
	9 p. m	76			E.	4	75			S.	14	80			S.	20
30	7 a. m	77			S.	5	73			S.	16	74			S.	32
	2 p. m	90	91	72	S.	15	85	86	65	S.	22	90	92	64	S.	42
	9 p. m	76			W.	7	75			SE.	16	75			SE.	14
31	7 a. m	68			SW.	7	67			NE.	6	63			NE.	12
	2 p. m	78	78	63	SW.	18	82	82	67	N.	13	80	88	59	NE.	8
	9 p. m	68			W.	8	69			NW.	5	70			S.	4
Aug. 1	7 a. m	61			W.	27	71			W.	1	64			SE.	28
	2 p. m	74	75	57	W.	24	86	86	58	W.	6	89	91	61	S.	14
	9 p. m	75			0	0	67			N.	5	70			S.	12
2	7 a. m	70			NE.	4	70			E.	2	67			NE.	10
	2 p. m	81	81	53	SE.	9	83	83	56	SE.	10	87	90	60	SE.	16
	9 p. m	72			S.	9	72			SE.	9	73			SE.	28
3	7 a. m	65			SE.	6	71			SE.	7	72			SE.	28
	2 p. m	88	88	61	S.	13	81	81	64	S.	14	81	83	65	S.	32
	9 p. m	77			E.	8	71			SE.	12	67			S.	26
4	7 a. m	75			S.	20	69			S.	8	62			SE.	36
	2 p. m	86	88	67	S.	10	81	81	63	S.	17	71	78	61	SE.	24
	9 p. m	78			S.	7	73			S.	8	70			SE.	16
5	7 a. m	75			S.	3	71			S.	10	72			SE.	16
	2 p. m	75	81	65	N.	24	85	86	68	S.	14	93	95	65	SW.	8
	9 p. m	68			W.	6	71			N.	32	81			SW.	12
6	7 a. m	65			W.	13	67			NW.	12	75			NE.	8
	2 p. m	81	82	55	W.	6	82	82	64	NW.	7	82	83	59	E.	12
	9 p. m	68			0	0	69			NW.	5	64			S.	38

7	7 a. m	66			W.	4	69			SW.	1	66			W.	4
	2 p. m	77	78	56	NW.	20	87	88	58	W.	8	85	89	54	SW.	5
	9 p. m	67			NW.	11	69			0	0	71			NW.	12
8	7 a. m	67			NW.	8	66			NW.	9	67			NW.	8
	2 p. m	76	76	53	NW.	16	81	83	58	NW.	10	83	89	59	E.	4
	9 p. m	64			NE.	8	63			NW.	6	71			S.	4
9	7 a. m	65			E.	2	63			NW.	4	73			SE.	4
	2 p. m	81	83	50	NE.	8	79	79	53	E.	4	92	95	62	S.	16
	9 p. m	68			E.	9	69			SE.	7	76			S.	28
10	7 a. m	67			E.	2	72			S.	4	75			NW.	5
	2 p. m	80	84	56	NE.	12	89	91	64	E.	6	96	97	65	NW.	12
	9 p. m	69			NE.	11	76			NE.	7	77			NW.	13
11	7 a. m	65			W.	7	67			N.	10	71			N.	8
	2 p. m	77	78	56	N.	24	85	86	64	SE.	6	90	90	58	E.	8
	9 p. m	62			NW.	8	74			W.	6	59			NE.	36
12	7 a. m	62			N.	16	67			NW.	1	67			W.	8
	2 p. m	70	72	49	NW.	24	80	80	59	NW.	20	79	83	56	N.	8
	9 p. m	59			NW.	10	61			NW.	6	71			0	0
13	7 a. m	57			NW.	15	61			NW.	16	62			NW.	8
	2 p. m	75	77	52	NW.	11	75	76	54	NW.	16	73	75	55	N.	12
	9 p. m	72			0	0	61			NW.	4	63			N.	4
14	7 a. m	65			0	0	61			0	0	56			N.	1
	2 p. m	78	83	51	S.	3	80	80	51	SE.	8	78	80	51	NE.	4
	9 p. m	69			NE.	3	61			NW.	2	66			E.	4
15	7 a. m	64			E.	2	61			0	0	64			SE.	4
	2 p. m	85	86	51	SE.	4	78	79	50	E.	6	80	84	56	SE.	10
	9 p. m	76			NW.	1	65			S.	5	61			SE.	24
16	7 a. m	64			NW.	4	65			E.	2	64			E.	8
	2 p. m	84	84	55	W.	14	79	79	58	S.	3	82	83	58	S.	4
	9 p. m	67			0	0	65			S.	1	66			SE.	8
17	7 a. m	63			NW.	4	64			SE.	1	64			NW.	4
	2 p. m	79	81	55	0	0	84	84	55	E.	5	89	94	58	S.	8
	9 p. m	75			N.	1	69			S.	4	73			NW.	6
18	7 a. m	69			0	0	66			0	0	69			E.	3
	2 p. m	84	86	54	S.	10	85	85	56	E.	5	84	91	60	E.	8
	9 p. m	76			E.	3	70			S.	6	71			S.	20
19	7 a. m	72			E.	5	71			S.	3	70			S.	16
	2 p. m	88	92	59	S.	18	84	85	64	S.	18	84	85	62	S.	28
	9 p. m	80			0	0	72			S.	13	73			S.	8
20	7 a. m	74			W.	2	72			S.	16	71			SW.	16
	2 p. m	62	92	54	NW.	22	77	80	60	SW.	13	80	81	64	NW.	20
	9 p. m	56			N.	8	60			NW.	8	65			NE.	10
21	7 a. m	52			W.	1	55			NW.	10	56			NW.	6
	2 p. m	70	72	44	W.	20	72	72	49	N.	17	75	85	48	NW.	6
	9 p. m	69			0	0	58			SW.	1	61			NW.	6
22	7 a. m	58			N.	2	57			0	0	62			SW.	14
	2 p. m	78	79	44	S.	10	76	77	46	S.	10	76	77	54	S.	20
	9 p. m	66			SE.	5	61			S.	3	60			S.	24
23	7 a. m	66			E.	1	63			SE.	1	61			S.	8
	2 p. m	89	91	55	S.	10	81	81	50	S.	16	82	84	53	S.	28
	9 p. m	75			NW.	2	65			SE.	2	69			S.	12

TABLE XI.—*Statement showing the readings of the exposed thermometer and direction and velocity of the wind, &c.*—Continued.

Date.	Time (local).	Bismarck, Dak.					Yankton, Dak.					North Platte, Nebr.				
		Thermometer.			Wind.		Thermometer.			Wind.		Thermometer.			Wind.	
		Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction.	Velocity (miles per hour).	Ex.	Daily. Max.	Daily. Min.	Direction	Velocity (miles per hour).
1877. 24	7 a. m	59			NE.	16	66			SE.	4	59			E.	6
	2 p. m	72	75	58	NE.	13	83	84	54	SE.	15	91	95	54	SE.	20
	9 p. m	66			E.	8	71			SE.	17	79			SE.	32
25	7 a. m	63			E.	7	69			S.	18	69			NW.	6
	2 p. m	85	85	60	SW.	7	85	86	63	S.	15	90	92	62	S.	24
	9 p. m	73			N.	9	71			E.	22	72			SE.	4
26	7 a. m	60			N.	11	67			SE.	10	67			N.	16
	2 p. m	74	78	57	W.	9	80	80	65	E.	6	82	82	63	N.	20
	9 p. m	59			N.	12	69			NE.	4	69			NE.	3
27	7 a. m	49			0	0	62			N.	1	62			E.	14
	2 p. m	66	66	42.5	S.	9	82	83	51	E.	11	84	86	57	SE.	12
	9 p. m	59			NW.	5	75			E.	10	74			E.	4
28	7 a. m	55			0	0	69			E.	2	66			E.	4
	2 p. m	74	75	47	N.	13	83	85	66	E.	4	83	87	56	NW.	8
	9 p. m	68			E.	3	70			N.	6	72			NE.	6
29	7 a. m	57			E.	2	65			E.	4	69			E.	16
	2 p. m	77	83	49	SW.	10	75	82	56	SE.	15	92	95	63	SE.	32
	9 p. m	74			E.	2	73			SE.	9	80			SE.	28
30	7 a. m	63			N.	3	73			S.	8	74			NW.	8
	2 p. m	86	87	60	N.	17	92	93	71	S.	12	101	102	65	S.	24
	9 p. m	64			N.	20	84			SW.	20	85			NE.	8
31	7 a. m	51			N.	7	71			N.	12	69			NE.	16
	2 p. m	68	70	45	N.	5	81	83	60	N.	16	79	85	66	NE.	24
	9 p. m	58			N.	4	61			NE.	12	67			NE.	18

WAR DEPARTMENT, OFFICE OF THE CHIEF SIGNAL-OFFICER, U. S. A.,
Washington, D. C., March 8, 1879.

The best way in which we can show the relation between the flights and the temperature and wind, is to compare statements in our First Report with this table, which was made out after the report was printed; all the statements relate to 1877.

At page 172 it is stated that the first flight observed in Iowa was June 14, from the south, and that the locusts *came down* in the vicinity of Sioux City, in the extreme northwest part, where they *remained some days*. By reference to the Yankton column, it appears that the temperature rose on the 13th and 14th, and fell again on the 15th; the wind was from the north until the 14th, when it changed and blew from the south, wheeling again in the evening to the north. On the 16th it was again from the south, and the temperature again rose, and this condition continued through the 17th. By reference to page 173, it will be seen there was a heavy flight northward across the southeastern counties of Dakota. This is one out of hundreds of similar cases which show not only the relation between the temperature and flights, but that the locusts are not easily turned back by adverse winds when they start in a given direction—though in 1877 this was not so marked as is usually the case. Invading swarms from the permanent breeding grounds will come down and remain for days waiting for the wind to blow in the right direction, and seldom, if ever, are turned back. With local flights, to which category those of 1877 chiefly belong, the case is different. The fall in temperature has much to do with their coming down, as in the case just given, as we find that afterwards those which went northward did generally return southward in 1877; but the case was different in 1876.

From July 2 to 7 the weather was excessively warm, as will be seen by reference to the records for Yankton and North Platte, and the direction of the wind was west or northwest. By turning to the record of flights for 1877 (appendix, 168–173), it will be seen that these were the days of the great flights to the west and northwest, the air being full of locusts over Minnesota, Northern Iowa, Dakota, and Nebraska.

Page 174: "*July* 8.—Swarms returning, moving generally a little east of south." Compare this, which applies to Minnesota and Dakota, with records of Bismarck, Yankton, and North Platte for July 8.

It is unnecessary for us to add more illustrations, as the readers can compare the records of flights as given in our First Report with this meteorological table for themselves. It appears from a careful comparison of this kind that whenever the maximum temperature falls below 70° and the minimum below 60° that there is no flying. See for illustration the records of flights, July 18 and 19, appendix, p. [182], so far as it relates to Dakota, and compare with the Bismarck record in the table for the same dates.

CHAPTER VI.

THE SOUTHERN LIMITS OF THE DISTRIBUTION OF THE ROCKY MOUNTAIN LOCUST.

In view of the probable speedy completion of the Atchison, Topeka, and Santa Fé Railroad and the Southern Pacific Railroad, and the projected lines of the Atlantic and Pacific, and Southern Pacific Railroads connecting the Pacific coast and Gulf States, as well as the lower valley of the Mississippi River, and thus opening up to settlement the arable lands of portions of New Mexico and Arizona, it has become of a good deal of practical importance to define with some degree of certainty the southern limits of the distribution of the Rocky Mountain locust.

For this purpose we made a journey in the summer of 1879 to Santa Fé, N. Mex., and adjoining places, and were able to obtain much new information regarding the distribution of this locust in New Mexico and also to learn something of its occurrence in the adjoining Territory of Arizona. The facts collected have been embodied in the map accompanying this report and in the pages farther on.

It appears from our investigations that the permanent breeding grounds of the locust scarcely extend into New Mexico, and probably not at all into Arizona. The area, however, into which they periodically emigrate from the permanent region embraces the northern half of New Mexico and the northeastern corner of Arizona, *i. e.*, that portion adjacent to New Mexico and possibly to Utah. From this it appears that those portions of the valleys of the Pecos and Rio Grande Rivers lying in the northern two-thirds of the Territory of New Mexico are periodically invaded by the Rocky Mountain locust, the source of supply being the mountain valleys and parks of Southern and Southwestern Colorado. But it is most probable that the fertile valley of the Rio Grande lying south of Fort Craig, and most valuable as a wine-growing district, will never suffer from the invasions of this pest.

To recapitulate what the Commission has been able to ascertain regarding the southern limits of the locust region, we may say that in Texas it reaches, and is bounded on the south by, the Rio Grande; in one year * the locusts having crossed the river and entered Mexican territory for the distance of a mile or so. The species is apparently absent from Southern New Mexico and from Central and Southern Arizona, as well as from Southern Nevada; unless it should eventually be found existing in limited numbers on the subalpine mountain peaks of these regions. There is every probability that the locust (*Caloptenus spretus*) will not be found in Lower California and the Peninsula of California, and that it does not inhabit Mexico. That this is the case seems probable from

* 1873. See First Report of the Commission, pp. 59, 60.

the fact that no collections from Mexico and Southern Arizona and California have contained this species.

HISTORY OF THE RAVAGES OF THE LOCUST IN NEW MEXICO.

The information given in our First Report regarding the ravages of locusts in this Territory was scanty, since it was difficult to obtain information from this region. The following facts were obtained by us during a journey to Santa Fé, in July, 1879. We are indebted to Ex-Governor Arny, of Santa Fé, and his son, William Arny, who acted as interpreter for us among the Pueblo Indians of San Juan, and to the Mexicans for much new information and kind aid in obtaining data. We will arrange the facts collected in chronological form:

1864.—As stated in our First Report, locusts were destructive at Taos this year. No fresh facts were learned.

1865.—At the Indian pueblo of San Juan locusts were numerous and destructive. The pueblo of Pojuaqué was visited this year by swarms which came from the northwest and destroyed all the wheat. As stated in our First Report (p. 105), locusts devoured the crops at Taos this year.

1868.—This year also the Indian pueblo of Pojuaqué was again visited by locusts, but they came at the end of August, after the wheat had been harvested, and only damaged the fruit trees. In this year the counties of Valentia, Bernalillo (and Socorro ?) were invaded by locusts.

1869.—In the summer of this year Mr. Thomas found a few specimens south of the Raton Mountains, probably in Colfax County. (First Report, p. 105.)

1871.—A few locusts were seen this year at Santa Fé, according to Ex-Governor Arny.

1873.—Between Otero and Cimarron, Colfax County, corn was black with locusts; they laid their eggs.

1874.—This was a notable locust year in Santa Fé. Ex-Governor Arny informed us that he saw swarms passing over for nearly a whole day. In Colfax County a few locusts were seen between Otero and Cimarron. Rio Ariba was also invaded.

1876.—In October of this year, the locusts came to the pueblo of San Juan, as we were informed by the Messrs. Eldodt Brothers, the agents of this pueblo, to whom we were indebted for many courtesies during our stay at their agency. The locusts came from the north of Taos and extended ten or twelve miles south of San Juan, and spread to the west and northwest. While most of the Indian wheat and other crops had been harvested, they ate up the cabbages in a single night, destroyed the corn on the Indian farms, and devoured the leaves and bark of trees. They laid their eggs very thickly, and the young hatched in April of the following year.

1877.—At Abiquiu, about fifty miles northwest of Santa Fé, the "whole crop" and fruit and the leaves of trees were eaten this year. It should be observed that this town is about fifty miles from the Colorado border, Taos being about thirty-five miles from the Colorado line. In July of this year, the crops in the counties of Rio Ariba, Taos, Santa Fé, and San Miguel, as well as Costilla and Culebra Counties, in Southern Colorado, "were almost entirely destroyed" by locusts, and the people of these afflicted counties had to call for help on the southern counties of New Mexico, whose inhabitants sent provisions. It is most probable that the injury was done by the young which hatched from eggs laid the previous autumn.

At Santa Fé the locusts were seen passing over in swarms from the southwest in July, filling the air, and flying towards Taos, but as a rule they came from Taos, which lies to the northeast of Santa Fé. They were abundant and destructive at Las Vegas, San Miguel County, this year.

The Pueblo Indians, an industrious and thrifty people, nearly as advanced in civilization and rather more respectable than the average Mexican inhabitants of New Mexico, suffered severely this year with their neighbors. Governor Arny informed us that the following Pueblo villages suffered this year: Santa Ildefonse, situated sixteen miles northwest of Santa Fe; also the pueblos of Tezuque, Santa Clara, Pojauqué, Nambe, and especially of Taos. These Indians lay up supplies of grain two or three years in advance to provide against drought and locusts.

The Mexican name for grasshopper or locust is *Chopolin* (a corruption of *Chapulin?*); the Pueblo Indian name is *Kowe* or *Kohe*, or the word is pronounced with a guttural accent like *Khone*.

We were told by Mr. John Bouquet, of Pojauqué, that locusts hatched there in the spring of 1877 and eat up half of the crop. It is evident that the light swarms from Southern Colorado which visited the region about San Juan and southward in October, and attracted little attention, laid eggs over a pretty extensive region in Northern New Mexico, and that the progeny of these flights did the damage recorded in 1877, and that as soon as the young became fledged they flew northward back to the region from which their parents came. This agrees with the general facts observed in the region of the Western Mississippi States from Missouri to Texas, when the winds early in summer blow from the southward, carrying the newly-fledged locusts back to the permanent breeding-grounds, from which they fly south and west in the autumn with the northwesterly winds then prevailing.

1878.—A few locusts were at San Juan in this year. They were also seen in the mountains, and seemed to disappear west of the Rio Grande River. We were told that in October of this year a few locusts flew from the northeast to Paña Blanca, hatching out in 1879. (This statement needs confirmation; it may have been confounded with the October flight from the northward of 1876.) Locusts, however, hatched out at Taos in 1878, and when fledged flew towards the northwest into Colorado.

1879.—We were told at San Juan that there were a few locusts on the grain-fields at this point, but on examination found only a few of the native grasshoppers, such as species of *Œdipoda*. We believe that none existed in New Mexico in 1879, unless scattered individuals among the mountains near the Colorado line. The summer of 1879 was exceptionally dry—the "driest since 1852." As already stated, it was also exceptionally dry in Colorado and Utah.

SOUTHERN RANGE OF THE LOCUST IN NEW MEXICO.

The Rocky Mountain locust (*Caloptenus spretus*) in the year 1868 seemed to have extended farther south than any year before or since, so far as we could ascertain. As ex-Governor Arny informed us, the farthest point south to which they flew was one hundred and forty miles south of Santa Fé; this would carry the southern limits of the region periodically visited by this species of locust as far south as Fort Craig on the Rio Grande River in Socorro County. So that we may infer that occasionally, though rarely, the northern two-thirds of New Mexico, *i. e.*, the portion lying north of the 34th parallel, are liable to invasion from locusts breeding in the Arkansas and San Juan valleys of Southern Colorado. In accordance with these facts, we have altered the map and extended the Temporary Region so as to cover the northern two-thirds of the Territory of New Mexico.

Ex-Governor Arny, who was agent of the Navajo Indians and lived on this reservation in the northwestern corner of the Territory, thinks that the locusts breed in that region of Arizona lying northwest of Valencia County, New Mexico, and that it is not improbable that the locusts breed in Eastern Arizona, *i. e.*, that part next to Socorro County, New Mexico, and extending northward to the Navajo Agency. As stated in our First Report, Mr. Thomas has seen a few specimens from Arizona collected by Lieutenant Wheeler's expeditions during the four years previous to 1877. We venture to predict that this species will yet be found in the Mogollon Mountains of Eastern Arizona.

CHANGES IN THE MAP SHOWING THE DISTRIBUTION, MIGRATIONS, AND BREEDING GROUNDS OF THE ROCKY MOUNTAIN LOCUST.

The following changes in the large folding map showing the distribution, migrations, permanent and subpermanent breeding grounds, &c., of the Rocky Mountain locust in the First Report, have been rendered necessary by the investigations made during the summers of 1878 and 1879, and the historical data collected in New Mexico during the last summer.

In the map as originally published, the Uintah Mountain region in Utah, and the valley of the White River in Western Colorado, and the San Luis Valley and adjacent mountainous region in Colorado, and the Wind River region and Yellowstone Park in Wyoming, as well as the valley of the Upper Big Horn region, were not included in the Permanent Region, for want of sufficient data. The boundary of the permanent breeding grounds has then to be extended considerably to the west, so as to include the patch in Northern Utah and the region in Idaho lying south of Virginia City, Montana. This makes the Permanent Region an uninterrupted rudely triangular or oval area, widest on the Northern United States boundary line, and narrowing southward, the apex of the triangle or smaller end of the oval resting near the southern line of Colorado, on or near the 37th parallel of latitude.

North of the 44th parallel the Permanent Region has been extended eastward to a line nearly identical with the eastern border of the Plateau of the Coteau of the Missouri, extending northward through the Turtle Mountains and to the region lying a little west of Manitoba.

In New Mexico, the region periodically visited has been extended southward to Fort Craig, New Mexico, and made to include the northeastern section of Arizona.

These alterations have been made in the colored map of the arable lands, etc., accompanying this report.

CHAPTER VII.

SUMMARY OF LOCUST FLIGHTS FROM 1877 TO 1879.

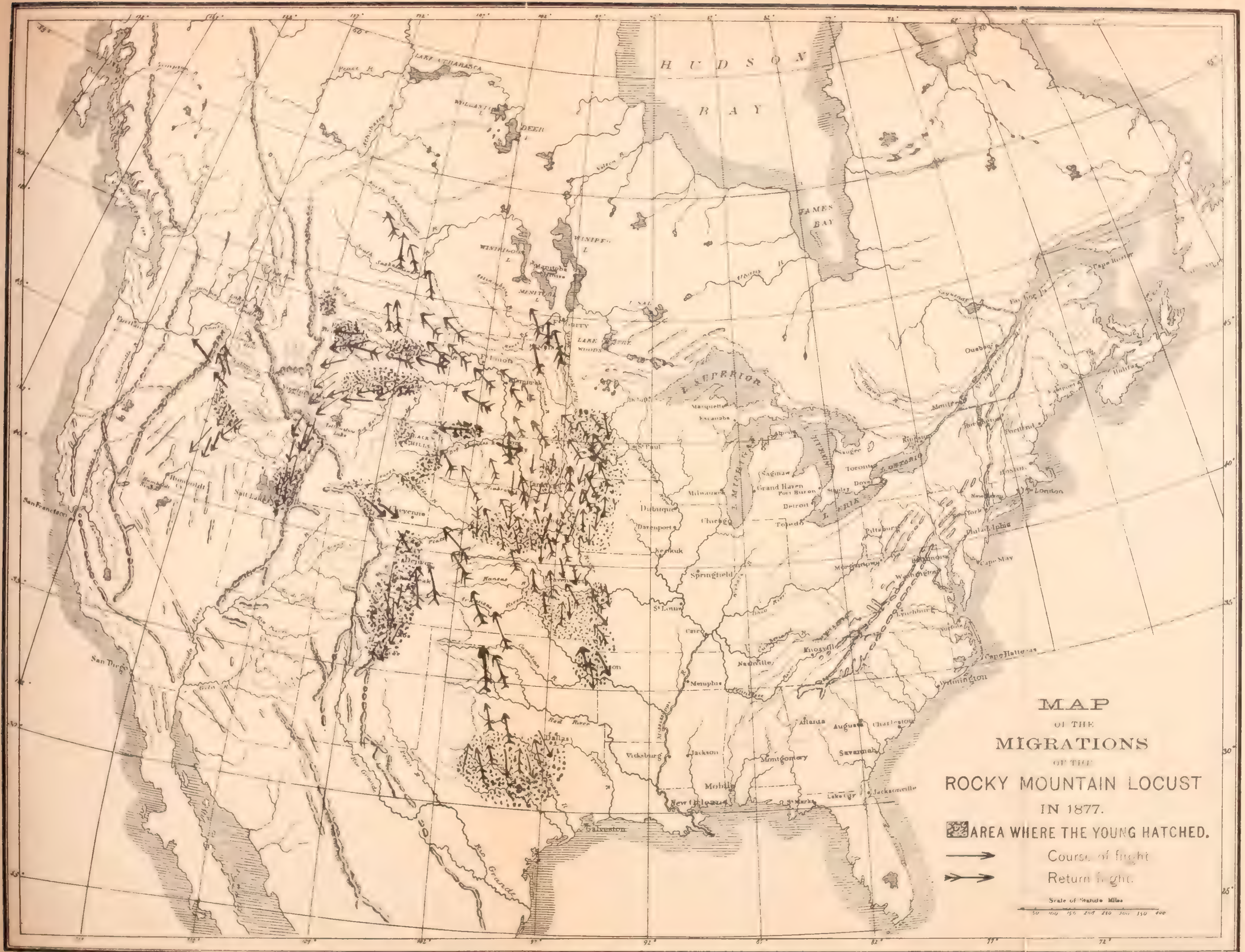
FLIGHTS IN 1877.

We have prepared the accompanying maps (Nos. 2–4) in order to give at a glance a succinct view of the leading facts regarding the distribution of the hatching-grounds and course taken by the resulting swarms in 1877, 1878, and 1879, respectively. These maps may be compared with those for 1874 and 1876 in the First Annual Report of the Commission.

The majority of the facts regarding the flights in 1877 are taken from the First Annual Report. By looking at Map No. 2 (1877) it will be seen that the large majority of the hatching-grounds were those made by the locusts which invaded the Temporary Region, lying in general east of the 104th meridian, in 1876. It will be remembered that the young of these locusts hatched in the spring of 1877, and, while most of them were killed by the cold and late rains, many winged their way towards the Northwest, some dropping down and alighting by the way, while a comparatively few reached the permanent breeding-grounds on the Rocky Mountain Plateau, whence their progenitors of the year previous departed for the regions lying to the southwest.

A few scattered arrows without barbs will, however, be seen in Texas, Indian Territory, Western Arkansas, Southeastern Kansas, Southeastern Nebraska, Southeastern Dakota, Western Iowa, and Southwestern Minnesota. These indicate the scattered flights which, late in the sea-

Map No. 2.


MAP
OF THE
MIGRATIONS
OF THE
ROCKY MOUNTAIN LOCUST
IN 1877.
AREA WHERE THE YOUNG HATCHED.
Course of flight
Return flight
Scale of Statute Miles
HUDSON
BAY
JAMES BAY
LAKE ATHABASCA
SUPERIOR
San Francisco
San Diego
Salt Lake
Cheyenne
St Paul
St Louis
Dubuque
Davenport
Keokuk
Springfield
Milwaukee
Chicago
Grand Haven
Toledo
Pittsburg
Philadelphia
Cape May
Boston
Portland
Montreal
Quebec
Halifax
Kingston
Toronto
Memphis
Nashville
Knoxville
Lynchburg
Wilmington
Cape Hatteras
Atlanta
Augusta
Charleston
Savannah
Jacksonville
Montgomery
Jackson
Mobile
Vicksburg
New Orleans
Galveston
Dallas
Red River
Rio Grande
Humboldt
Marquette
Escanaba
Saginaw
Port Huron
Dover
Cape Breton
Lake Winnipeg
Lake of the Woods


MAP
OF THE
MIGRATIONS
OF THE
ROCKY MOUNTAIN LOCUST
IN 1878.
AREA WHERE THE YOUNG HATCHED.
Course of flight.
Return flight.
H U D S O N
B A Y
JAMES BAY
LAKE ATHABASCA
WINIPEG L
SUPERIOR
ONTARIO
ERIE
Salt Lake
Cheyenne
Denver
Pikes Peak
Fort Sully
Yankton
Omaha
Leavenworth
Dubuque
Davenport
Keokuk
Springfield
St. Louis
Cairo
Ft. Gibson
Memphis
Nashville
Knoxville
Dallas
Vicksburg
Jackson
Mobile
New Orleans
Galveston
Montgomery
Atlanta
Augusta
Charleston
Savannah
Jacksonville
Milwaukee
Chicago
Toledo
Detroit
Saginaw
Grand Haven
Port Huron
Marquette
Toronto
Kingston
Montreal
Quebec
Halifax
Portland
Boston
New London
New York
Philadelphia
Pittsburg
Baltimore
Washington
Cape May
Lynchburg
Norfolk
Cape Hatteras
Wilmington
San Diego
Cape Hatteras


MAP
OF THE
MIGRATIONS
OF THE
ROCKY MOUNTAIN LOCUST
IN 1879.
AREA WHERE THE YOUNG HATCHED.
Course of flight.
Return flight.
HUDSON
BAY
JAMES BAY
SUPERIOR
Denver
Pikes Peak
Omaha
Bismarck
Fort Sully
Leavenworth
St Louis
Cairo
Memphis
Vicksburg
New Orleans
Mobile
Galveston
Dallas
Jackson
Montgomery
Atlanta
Augusta
Charleston
Savannah
Jacksonville
Nashville
Knoxville
Wilmington
Lynchburg
Philadelphia
Pittsburg
Toledo
Detroit
Saginaw
Grand Haven
Port Huron
Chicago
Milwaukee
Dubuque
Davenport
Keokuk
Springfield
St Paul
Marquette
Escanaba
Taos
Santa Fe
San Diego
San Francisco
Ft Gibson
Rio Grande
Red River
Cape Hatteras
London
Toronto
Scale of Statute Miles

son, invaded these areas. But that they laid few, if any, eggs will be seen by reference to Map 3 for 1878, where no hatching-grounds are indicated.

In Colorado also many hatched about Greeley and Denver, but owing to the unusually heavy rains, with a light fall of snow, and cold weather late in April and early in May, the young died in great numbers. A few hatched in Lake County along the Arkansas, and in Park County, as well as in the San Luis Valley and Wet Mountain Valley, while the injury from the unfledged locusts was greater than in any other part of the State.

In New Mexico the valley of Taos was devastated by the unfledged young, and they were abundant at Las Vegas, and at Santa Fé northward to San Juan.

In Wyoming the hatching-grounds this year lay between a point 50 miles northeast of Laramie City extending to Custer near the Black Hills, and about Fort Reno, as well as in the valley of Hay Creek, while the flight of early swarms indicate that they originated from hatching-grounds situated not far northwest of Rock Creek Station and Como, on the Union Pacific Railway. It seems also most probable that a few hatched out northeast of the Black Hills, as we have indicated on the map, small flights being seen on the Belle Fourche in the Black Hills, about the middle of June, going westward.

In Utah hatching-grounds of limited extent occupied tracts about Salt Lake City and Farmington, and many hatched out in the northern part of the Territory, viz, in Malade, Cache, Morgan, Weber, and Davis Counties. When fledged the locusts fled southward.

In Idaho locusts bred in considerable quantities at Boise City, and when fledged it is most probable that these were the visitants which late in July and early in August proved so destructive to the southwest of Boise in the Bruneau Valley.

The hatching-grounds in Montana were evidently of considerable extent, the young, when winged, almost wholly flying southward into Idaho and Utah, none to any extent, so far as known, flying eastward upon the plains. The young were observed hatching out in the valley of Marias River, also about Fort Benton, as well as near Fort Peck and Wolf Point, while extensive hatching-grounds extended along the Yellowstone River from Froze-to-death Creek to Clark's Fork.

In British America locusts hatched at Fort McLeod, northwest of Fort Benton.

FLIGHTS IN 1878.

In 1878 the hatching-grounds were much more limited in number and extent than in the previous year. None worthy of mention existed east of the Rocky Mountains, and it was only in Montana that the young appeared to any considerable extent. Two small, scattered flights, causing, however, no local damage, crossed the southwest corner of Minnesota late in the summer, one of them passing into the northwestern corner of Iowa.

In Nebraska small local flights, going in different directions, were seen at Schuyler, and a small brood hatched out twenty miles west of Lincoln, while Omaha was, about the middle of June, visited by a few locusts from the south.

In Indian Territory a swarm of considerable extent visited Fort Sill and deposited eggs, but nothing was heard from them the succeeding year. In Kansas, Dodge City was visited in September. There were also small local flights in Barton and Sumner Counties, Kansas.

A larger number of flights from the northwest occurred in Dakota, extending from the neighborhood of Bismarck into Montana, and in June Bismarck was visited by a swarm from the southeast.

While in Colorado the locust annually breeds in small numbers on the mountains, above an elevation of about 8,000 feet, only a few local flights were observed, viz, at Summit, in Estes Park, and at White River Agency; also along the Upper Bear River Valley, where eggs were deposited. The progeny of the latter swarm went east the next summer (1879), passing over Denver and alighting a few miles to the southeast. A small swarm was observed going in a northwesterly course near Las Animas, on the Topeka, Atchison and Santa Fé Railroad.

In Wyoming a large swarm at the end of July flew in an easterly direction over Como, and were supposed to have come from the Wind River and Bighorn region, while a few flew over Cheyenne. The northwestern portion of the Territory was visited by swarms from the northeast which flew southwest.

About Taos and Santa Fé, in New Mexico, as has already been stated, considerable local damage ensued and young hatched, but none were to be seen in the year succeeding.

Utah, in 1878, was freer from locusts than in the year previous, but still the farmers in Summit County lost nearly half their wheat crop from the young, which hatched out in large numbers and, on becoming fledged, flew in a northerly course to Morgan County. Flights entered Malade and Cache Valleys late in August, arriving from Idaho, and locusts were seen at various points, late in July and during August, between Franklin and the Montana line, near Pleasant Valley. The breeding-ground of these locusts was in Central Montana, as indicated on Map 3. In Montana, also, flights arrived in the central arable part of the Territory from the Yellowstone Valley on the east and from British America on the north. (See also pages 7 and 8 of the present report.)

FLIGHTS IN 1879.

The flights east of the Permanent Region were on the whole fewer this year than in 1878, as may be seen by an inspection of Map No. 4; though in Nebraska, Iowa, Minnesota, and Dakota there were more extensive hatching-grounds, and a greater number of local flights from the northwest, but none as in the year previous from the region where the insect breeds permanently. It will be seen that in 1880 a few local flights of unimportance resulted from the progeny of these 1879 swarms.

In this year also Central and Eastern Montana was, for the first time since 1861, the year of the settlement of the Territory, free from this pest, and to the fact of the freedom from incoming swarms in 1879 is due the entire immunity of Montana from locusts (*C. spretus*) in 1880. We thus have two years in succession in this Territory of entire freedom from this pest, although the very citadel whence in former years hordes of locusts have invaded the regions East and South. For notices of the slight swarms observed in other portions of the Permanent Region, the reader may turn back to Chapter I, pp. 10–14.

CHAPTER VIII.

THE WESTERN CRICKET.

ITS HABITS AND RAVAGES.

Very destructive in the Great Basin, to crops of wheat and other cereals and to grass is a large, stout, thick-bodied, dark insect, bearing a general resemblance to an ordinary cricket, but much larger and nearly wingless. Like the cricket, it is nocturnal in its habits, hiding by day under grass, sage-bushes, and leaves or stones, and appearing at dusk or soon after sunset.

Unlike the Rocky Mountain locust, which usually breeds in river bottoms and in the less elevated prairies and plains, the cricket breeds almost wholly on dry, sterile uplands, where the sage-bush flourishes, and in the foot-hills of the Rocky Mountains and its spurs, up to an elevation of 12,000 feet; and while the locust may, and often does, breed at as high an elevation as the *Anabrus*, still its more abundant and normal breeding grounds are, as a rule, situated below the natural habitat of this cricket.

For example, the Colorado species (*Anabrus purpurascens*, Fig. 1), is only seen in Colorado, as far as we are aware, between an altitude of 7,000 or 8,000 feet, up to an elevation of 12,000 or 13,000 feet, *i. e.*, from the foot-hills of the eastern slope of the Rocky Mountain range up to about 1,000 feet above the timber line, which at Gray's and Pike's Peak is about 11,000 feet above the sea-level. I have met with *Anabrus purpur-*

FIG. 1.—Anabrus purpurascens, nat. size; *a*, female; *c*, end of male abdomen, showing the claspers, *b*.

ascens most abundantly on the Alps or grassy slopes of Gray's Peak, between the timber line and the bare rocky summit, *i. e.*, between 11,000 and 13,000 feet, the mountain being 14,341 feet elevation.

In Utah, Eastern Idaho, and Montana *Anabrus simplex* (Fig. 2) abounds at elevations of much less height, and its breeding grounds adjoin those of the locust. For example, the black cricket of the Great Salt Lake region breeds and lives on the bench-lands surrounding the lake; but even here they do not usually lay their eggs in the more fertile, moist, cultivated lands infested by the Rocky Mountain locust. From the bench-lands of the Great Salt Lake the cricket ranges up as far at least as about 8,000 feet in the Wasatch Mountains, breeding in great quantities about the mining towns, and in the passes among the mountains.

FIG. 2.—Anabrus simplex nat. size: *a*, female *b*, end of body of male, showing the claspers.

Although, therefore, ordinarily the crickets lay their eggs and the young develop in the dry bench-lands and sides of the foot-hills, they emigrate from this region, press down sometimes in great numbers and invade the wheat-fields, corn-fields, and pasture lands in the lower, moister tracts. I have often been informed that this was the habit of the cricket in the vicinity of Salt Lake City. This is corroborated by the observations of Mr. Thomas, published in Hayden's Report on the Geology of Montana for 1871. Referring to *Anabrus simplex*, the common brown cricket of Northern Utah and Eastern Idaho, he writes as follows:

At some points we found them so abundant as literally to cover the ground. In two or three instances they all appeared to be moving in one direction, as if impelled by some common motive. I recollect one instance, on Portneuf River, where an army was crossing the road. It was probably as much as 200 yards in width. I could form no idea as to its length. I only know that as far as I could distinguish objects of this size (being on horseback) I could see them marching on. I think that in all the cases where I saw them thus moving, it was towards a stream of water. They appear to be very fond of gathering along the banks and in the vicinity of streams. In the north part of Cache Valley I frequently noticed the ditches and little streams covered with these insects, which, having fallen in, were floating down on the surface of the water, and, though watching them for hours, they would flow on in an undiminished stream. While encamped on a little creek near Franklin, in this valley, it was with difficulty we could keep them out of our bedding; and when one went to breakfast, we found the underside and legs of the table and stools covered with them, all the vigilance of the cook being required to keep them out of the victuals.

The following account of the movements of an army of the large brown cricket (*Anabrus simplex*) is extracted from Mr. Thomas's notes of his journey in 1871:

June 18, Sunday, between Carpenter's Station and the toll-gate at Portneuf Crossing, I saw a large army of this species moving in regular order; they were crossing the road towards the northwest in one continuous stream 150 to 200 yards wide, and literally covering the earth. The length of the army was not ascertained, but it was much greater than the width, not less, at least, than a half a mile. The ground was so thickly covered that the horses could not walk without crushing numbers at every step. Large hawks were numerous, feasting on them.

The ravages occasionally committed by the *Anabrus* in its wholesale descent upon the cultivated lowlands is very great. The most aggravated case brought to our notice occurred in Northern Nevada. According to my informant, Mr. C. C. Wheeler, of Cornucopia, Nev., in the summer of 1876 crickets devoured about $3,000 worth of wheat and other grain. As the cultivated areas in Nevada are small, the attacks of the cricket, which are liable to be repeated annually, are much dreaded. Mr. Wheeler observed that the cricket was very destructive in the northern parts of the Territory. In August, 1878, crickets were very thick between Elko and Humboldt, Nev., filling the wells and spoiling the water so that the people had to use brook water.

In Oregon, east of the Cascade Mountains, where the country is dry and hot, with a climate and soil much like that of Nevada and Central Utah, the cricket often proves very annoying to the farmers. The following statements by Mr. Henry Edwards, formerly of San Francisco, is taken from a brief account of this insect from Hayden's Ninth Report of the United States Geological Survey of the Territories.[209]

The large brown cricket (probably *Anabrus simplex*) is a great trouble to the farmers of this region (the Dalles), and this year [1873?] has been unusually common. It appears that they march to attack the corn-fields in columns, and the only way left to the farmers to protect themselves is to dig trenches around their fields, into which the crickets fall in enormous crowds and are killed by their own numbers. The upper individuals, however, manage to make a bridge of the bodies of their companions, and sometimes cross the ditches in great quantities. Pigs eat these insects very greedily. They seem to be periodical in their appearance, the great swarms only occurring once in six years. I think their depredations are mostly committed in the night, as I saw none during the heat of the day, but toward twilight they swarmed on the stems of artemisia and other low plants, and were exceedingly active.

While the cricket is annoying in Arizona according to information received from Maj. J. W. Powell, it is particularly destructive in Utah, both in the scattered oases or farming hamlets and villages of the southern and central portions, as well as in the more fertile valley of the Great Salt Lake, and in Cache and Malade Valley northward on the borders of Idaho. About Payson, Utah, the cricket has been "exceedingly destructive." Mr. B. F. Johnson, of Spring Lake, states that in 1865, when the Rocky Mountain locust devastated that section of Utah, "large crickets made their appearance, not only in this, but in the surrounding settlements, in great numbers, and helped the destructive 'hoppers to devour the crops."

The cricket was more abundant formerly in Utah than of late years; they then moved in armies which could not be turned back in their re-

[209]Report on the Rocky Mountain locust and other insects now injuring or likely to injure field and garden crops in the Western States and Territories. By A. S. Packard, jr., 1877. 8°. pp. 589-815.

sistless march; they were especially destructive to young wheat and corn in early summer.

Food of the cricket.—As may be seen by the account of the internal structure of the cricket, especially of the organs of digestion, the cricket must be a very voracious creature. The jaws are large, armed with teeth, and adapted for cutting leaves from twigs and for cutting grass. The crop is very capacious, and in the specimens examined was stuffed with vegetable matter in a partially digested state. Mr. Thomas, in his journey from Ogden, Utah, to Fort Hall, noticed these crickets in great abundance along the route in the middle of June. From Worm Creek to Bear River the large brown cricket (*Anabrus simplex*) was very abundant, in some places almost covering the ground. He noticed on Worm Creek this cricket climbing up the bushes and eating the Cicadæ, which were equally abundant. Indeed, this appeared to be a habit, the *Anabrus* devouring the Cicadæ whenever they could catch them. They are exceedingly voracious, not only eating the Cicadæ with avidity, but they even attack the crippled and dying of their own species, and devour them so far as they can manage the tough integument. They also devour greedily the droppings of horses.

On the other hand, the cricket has been used as food by the Ute Indians of Utah, and still is by the Pi-Utes in Nevada, who eat them alive after pulling off the legs. They also roast them with hot stones in the ground and then eat them.

Enemies and internal parasites.—Though these large insects are protected by a dense, tough skin, it appears from the observations of Mr. Thomas that they are eaten by hawks, and it has been frequently observed that the gulls of the Great Salt Lake collect upon the benches or terraces of the lake and devour them. So useful are these birds that the Mormons once passed a law forbidding the destruction of gulls, fixing a penalty for the offense. When they live near the summits of the mountain the ptarmigan feed upon them, as Colonel Berthoud informs us that he has found the crops of these birds filled with them on the summit of Maclellan Mountain, Colorado, during the middle of October. On one occasion (June 15, on Worm Creek), when the crickets were so numerous that they covered the surfaces of the smaller streams and *acequias*, a large toad was noticed by Mr. Thomas following the stream and eating the *Anabri* or crickets which had fallen therein.

So far as is known the *Anabrus* has no insect enemies external or internal. They are sometimes, however, tenanted by the hair-worm, which lives within the body, coiled around the intestine. This fact was observed by Dr. Hayden's party at one time while camped in Idaho, on Camas Creek, where numbers affected were observed at the creek. The habits of the hair-worms have been described in the First Report of this Commission (pp. 326–334).

Breeding habits.—Few direct observations by naturalists have been made on the breeding habits of the Western crickets. The most explicit observations as to the time and mode of deposition of the eggs have been made by Mr. Thomas. We extract the following statement from his notes:

On my return from Montana, in the latter part of July, 1871, as I passed through Malade Valley, Northern Utah, I noticed thousands of *Anabrus simplex* depositing eggs. The female thrust her ovipositor straight down into the ground its full length. I did not have time to stop and watch the operation as I was in the stage.

I am convinced from an examination of the ovaries of a number of *Anabrus purpurascens* collected on the flanks of Gray's Peak, above timber line, in the latter part of August, that this species deposits its eggs in August and early in September, and that from fifty to seventy-five eggs are laid by the female. The eggs of this species are cylindrical long oval, as are those of *A. simplex*, which are long, with the surface very minutely, microscopically pitted, and pearly white.

How they are placed in the earth, whether in sacks like those of the locust, is not known. The young hatch out probably rather late in the spring, and it is during the early stages of growth, and soon after reaching maturity, that they are most gregarious, moving about after food in armies, and thus proving most destructive.

Mr. Thomas observed, June 14, 1871, little groups of young, he thinks from 60 to 75 in a group, evidently hatched from eggs laid by one female.

REMEDIES.

As the crickets usually breed in the more elevated, dry, and sterile region of the Western Territories, for the most part away from farms, their habits are not well known, as they are secluded from ordinary observation; hence they are only observed when full-sized and while making their descents upon the farms lying near the water-courses and irrigating ditches. When, however, fields of grain are invaded, or in danger of being invaded, by the crickets, ditching dry and wet, with the liberal use of coal-oil, is the easiest, most thorough, and practical remedy. This mode of destroying crickets should be put into practice in the same manner as recommended by the Commission in its First Annual Report. The cricket, so far as known, has done little or no mischief in Colorado, as it lives among the foot-hills and the higher mountains, far above the agricultural region. In Utah, Nevada, and Idaho, however, it infests cultivated regions, and in these regions, unfortunately, locusts are not fought so energetically and systematically as by the farmers of Colorado and the border States. Where irrigation is practiced it would be easy to protect fields of grain by allowing coal-oil to drop from a pail on the surface of the water running in the ditches. These, as well as all other insects, do not breathe by the mouth, but the air enters the body for respiration by an internal system of air-tubes (*tracheæ*), through a series of air-holes or spiracles situated along the sides of the body. If a film of oil covers these holes the insect is choked to death, *i. e.*, becomes suffocated, and speedily dies. Hence the use of coal-oil, or any oily or greasy matter, is sure death, provided the oily substance comes in contact with the body or any part of it. As quickly as the oil touches the insect it spreads rapidly over the skin, covering the spiracles or air-holes with a thin film.

As fields of young grain and corn are sometimes attacked by the crickets, one of the best means of getting rid of them adopted in Utah is to drive a flock of sheep into the grain-field, keeping them compactly herded. By so doing the grain is not materially damaged, we are told, and great numbers of the crickets are stamped to death.

It is obvious that most of the means used in fighting the young of the Rocky Mountain locust, and already described at length in the First Report of the Commission, may be applied to the cricket.

Geographical distribution of the species of Anabrus.—The species of this genus are characteristic of the central province of the United States, as none are found east of longitude 95°, and none on the Pacific slope of the Cascade Mountains and the Sierra Nevadas. In fact, the geographical limits of the Western cricket are probably nearly or quite co-extensive with those of the Rocky Mountain locust.[210] The northern and southern limits have not been ascertained. The species are known, however, to extend northward as far as Manitoba, and southward into Northern New Mexico and into Arizona, but these limits are very indefinitely known.

Within the limits of the central zoo-geographical province there are two distinct regions tenanted by different species of *Anabrus*, the line of division being the great continental divide, *i. e.*, the highest range of the Rocky Mountains. The great basin, with adjoining regions, extending from the Columbia River on the north to Nevada and Central—and probably Southern—Utah and Arizona on the south, is tenanted by *Anabrus simplex;* while the eastern flank of the Rocky Mountain range, with the great plains eastward to about longitude 97°, extending from Manitoba on the north to Northwestern Texas on the south, is the home of *Anabrus purpurascens* and its ally, *Anabrus coloradus.*

Mr. Thomas has noticed during his journeys into Utah, Idaho, Montana, and Colorado, that whenever he passed to the east side of the Rocky Mountain divide, no matter at what point of the range, *Anabrus purpurascens* prevailed, no specimens of *Anabrus simplex* appearing; while, on the other hand, when he passed to the next side *Anabrus simplex* prevailed, no specimens of *A. purpurascens* appearing. He never knew of any exception to this rule. Our own observations and the recorded statements of others bear out this conclusion.[211]

So far as ascertained, the northern limits of distribution of *Anabrus*

[210] While the distribution of the Rocky Mountain locust has been given in the First Report of this Commission and mapped, the general characteristics distinguishing the central province from the eastern and Pacific or western, have been briefly discussed in the *American Naturalist* for August, 1878; the species of *Anabrus* may be added to the insects there enumerated.

[211] Mr. Thomas has observed *A. purpurascens* at the following places in addition to Colorado, to wit: Nebraska; Southeast Dakota, to the west boundary of Minnesota; on the Sweetwater, in Wyoming; also in Montana, from Pleasant Valley, where we cross the range to Virginia City.

simplex are the Dalles on the Columbia River, where it is abundant and injurious. I have received it from the Malheur River Indian Reservation in Eastern Oregon, where it is also abundant. It also inhabits Montana, Idaho west of the Rocky Mountain divide, and, without doubt, the whole of Utah. Mr. J. D. Putnam[212] reports it as common in the valley of the Wind River, on the plains along the base of the Wind River Mountains, Wyoming, in July, 1873. "It is called 'Mesch' by the Shoshone Indians, who are said to sometimes use it for food." Mr. Putnam also states that it was "very common in Middle Park, Colorado, in September, 1872. Scarcely any two specimens were colored alike. The male was frequently seen 'singing' while seated in the top of a wild sage-bush, the female being found on the ground below."

Col. E. L. Berthoud writes us that—

> October 4–7, 1878, the large, black cricket [without doubt *A. simplex*], so common in Utah and Idaho, were very abundant at Taghee and Henry's Passes, Henry's Lake, and on Henry's Fork. At Taghee Pass, altitude 6,970 feet above the sea, they seemed, in spite of cold and snow, to be scarcely hindered by a temperature of 7° above zero.

At Portneuf Cañon this species was abundant in 1878.

Of its southern limits, whether it occurs in Arizona, Southern Nevada, Utah, and in New Mexico, nothing is known. Its southern range, however, is probably co-extensive with that of the Rocky Mountain locust (*Caloptenus spretus.*)

Anabrus coloradus thus far has only been found in two points, Manitoba on the north, and Southern Colorado and adjacent regions on the south. Mr. Thomas has received specimens from Manitoba, and has collected it in Colorado, east of the Rocky Mountain divide. Mr. Scudder records it as having been collected by Lieut. W. L. Carpenter, U. S. A., in Southern Colorado, June 11–20, and on Taos Peak, Sangre de Cristo Mountains, New Mexico, at a height of 13,000 feet above timber line. This cricket is closely allied to *Anabrus simplex*, and appears to represent that species in the plains lying east of the Rocky Mountain divide. It appears thus far to have a greater northern and southern range than any of the other species.

SYNOPSIS OF THE SPECIES OF ANABRUS AND ITS ALLIES.[213]

The following brief synopsis of the *Decticides*, made partly from that of Otto Hermann[214] and partly from the arrangement of the *Locustidæ* by Ignacio Bolivar,[215] will show the relation of *Anabrus* to the other genera of the group, and the chief distinguishing characters:

A. Prosternum with two spines between the base of the anterior legs. This division contains *Pterolepis, Rhacocleis, Thyreonotus,* and several other genera. As *Anabrus Haldemanii* has the prosternum spined it belongs here, probably in *Pterolepis.*

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212 Proceedings of the Davenport Academy of Natural Sciences, vol. i, p. 266.

213 By Cyrus Thomas.

214 Verhand. d. k-k, Zool-bot. Ges., 1874.

215 Ortopteros Espan. et Port, 1878.

A. A. Prosternum unarmed.

a. The styles of the subgenital plate of the male fixed (not movable). *Steirosys.* Herm.

aa. Styles of the subgenital plate of the males articulated (movable).

b. Median carina of the pronotum distinct throughout ....*Decticus.* Serv.

bb. Median carina of the pronotum wanting or visible only on the posterior portion.

c. Dorsum of the pronotum rugose; elytra squamæform; wings absent. *Psorodonotus.* Burm.

cc. Dorsum of the pronotum smooth.

d. Elytra short but not squamæform ....*Platycleis.* Fieb.

dd. Elytra squamæform; pronotum without distinct lateral carinæ.

e. Anterior tibiæ with but three or four spines in front; in one row...................... ....*Thamnotrizon.* Fisch.

ee. Anterior tibiæ with six to eight spines in front; in two rows. *Anabrus.* Hald.

From this table it will be seen, as stated, that *A. Haldemanii* Girard does not belong to the genus in which it was originally placed. For this reason we have omitted it from the present paper.

We may note in passing that according to the arrangement of the genera as here given, *Thamnotrizon scabricollis* Thos., which appears to be closely allied to this genus, and will by most unscientific observers be taken for *A. purpurascens*, must be removed to the genus *Psorodonotus.*

The genus *Anabrus* appears to be represented only in that portion of North America north of Mexico and west of the Mississippi. Four species are mentioned, *A. simplex* Hald., *A. purpurascens* Uhl., *A. similis* Scudd., and *A. coloradus* Thos. The third, *A. similis* Scudd., appears to be but a variety of *A. purpurascens;* we therefore have but three distinct species.

These may be distinguished from each other by the following characters: *A. coloradus* is the smallest, and has the abdomen distinctly marked by transverse bands. *A. purpurascens*, dark purplish-brown, mottled with yellow. *A. simplex*, dark shining brown. This species varies considerably in color, being found of every shade from light brownish-yellow to almost entirely black; specimens are sometimes found that are partly yellow and partly black or dark-purple.

ANATOMY OF ANABRUS.

External anatomy (Figs. 3, 4).—The following account is based on the external structure of *Anabrus simplex.*

The head.—In these crickets, the first region of the body, or head, is large and rounded, the *epicranium*, or piece composing the bulk of the head, being large, while the eyes are small and situated far apart; between them the vertex rises into a shield-shaped prominence, on each side of the base of which is situated a simple eye (*ocellus*), forming two pale, oval, roundish spots easily overlooked. The third ocellus is more easily discoverable, being a round, impressed spot, some distance in advance of the end of the vertical prominence. The front edge of the epicranium is broad, the front or square edge extending on each side to the posterior region of the head.

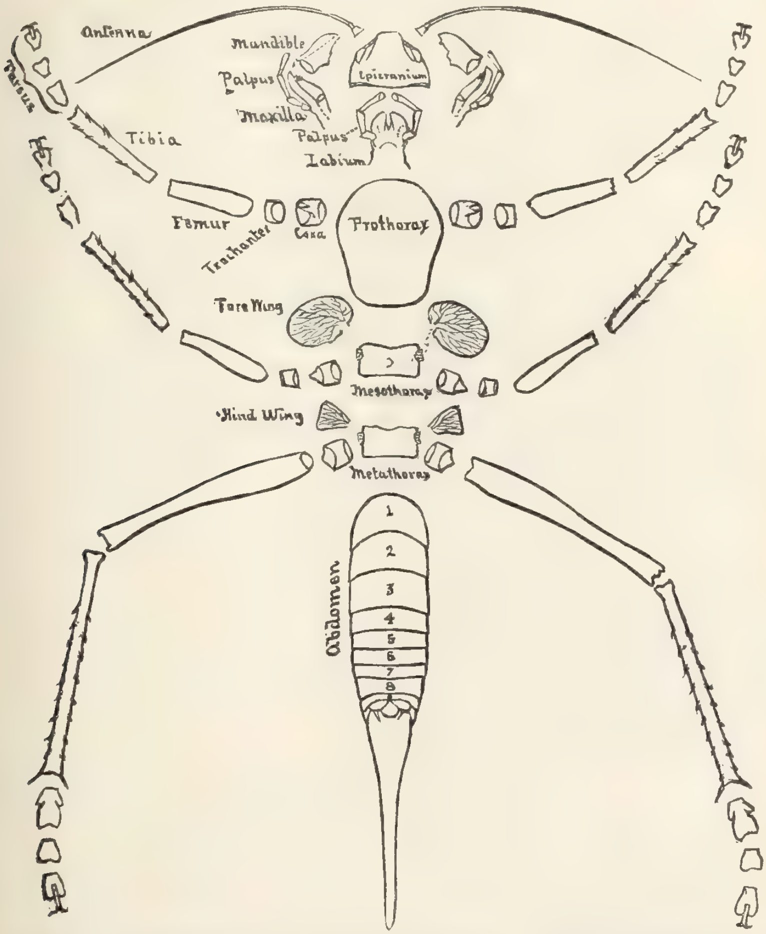

FIG. 3.—External anatomy of *Anabrus*, seen from above. Drawn by J. S. Kingsley.

The *clypeus*, or piece to which the upper lip (*labrum*) is attached, is faintly divided by a broad, slight furrow into a basal and an anterior portion, the latter part raised and sinuous on the front edge, while the sides of the clypeus are bounded by the base of the mandibles.

The upper lip (*labrum*) is rounded pad-like, as long as broad, moving freely on the clypeus, so that when the jaws are opened widely the labrum drops down between them.

The antennæ are very long and slender, reaching to the base of the ovipositor, with the second joint (of the scape) large and flat.

The jaws (mandibles) are very large and stout, the ends when closed overlapped by the upper lip. The accessory jaws (maxillæ, Fig. 3) are divided, as in the grasshopper and other Orthopterous insects, into three lobes; of these the inner, called the *lacinia*, is sinuous, narrow, horny, and ends in three long teeth; the middle lobe (galea) is a little longer than the inner, is membranous, while the third division forms a five-jointed palpus, the fifth joint the longest and truncated or docked at the end.

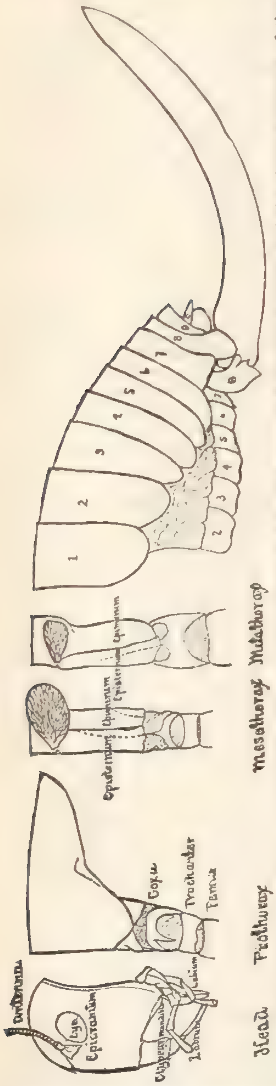

FIG. 4.—Side view of a female Anabrus dissected so as to show the head separate from the thorax, and the three segments of the latter; and the abdomen terminating in the sabre-like ovipositor. Drawn by J. S. Kingsley.

Coming now to the under lip, or *labium*, we find that its base, called the *submentum*, is a little longer than broad; the sides being slightly upturned, sinuous, and contracted near the base, while the front edge is hollowed out to receive the *mentum*, which is a square piece. From under each corner of the front edge arise the *labial palpi* (Fig. 3) which are three-jointed. From the under side of the labium (*i. e.*, the front piece or *mentum*) arises the *ligulæ* (these co-originating with the palpi), which consists of two lateral, squarish, membranous outer lobes, and two acutely conical inner lobes. The *lingua* or tongue is situated above the ligula, and is a three-angled (triquetate) organ, partly chitinous, with a high median ridge; it fills the space between the maxillæ and jaws, and partly closes the mouth-opening, which lies directly under the labrum or upper lip and between the jaws (mandibles.)

Thorax.—This region is peculiar from the fact that the wings are but partially developed. As in all insects it consists of three segments or rings variously modified, and each consisting of a number of pieces. The first ring, called the *prothorax*, is very large above, the dorsal part (tergum) forming a large shield-like plate, which is bent down at the sides to the legs; behind it grows narrower, and extends along the back so as to cover the basal half of the first abdominal segment. The flanks (*episternum* and *epimerum*) are small and rudimentary; the ventral or under piece (sternum) forms a broad V-shaped horny or chitinous portion.

The second segment (meso-thorax) is a ring one-half as long as broad; the *scutellum* is quite indistinct, and forms a blister-like swelling on the top of the segment. The flank pieces (*episternum* and *epimerum*) are of nearly equal size, being short and deep, and rather shorter and smaller than those of the metathorax, or third thoracic segment. The ventral piece (sternum) is crescent-shaped, while that of the metathorax is twice as large and transversely ovate.

The third segment (meta-thorax) is of the same size as the middle ring, but is slightly swollen on the sides, and a slightly marked, indefinite swelling above represents the scutellum. The flanks are larger, as they afford insertions for the muscles of the much larger hind legs. Both of the hinder thoracic segments have broad, flattened, spine-like expansions of the sternum; and on each side of the prothorax is a sharp slender spine. The third pair of legs are twice as large as the second.

The breathing holes or spiracles by which the air enters the air-tubes within the body, for no insects breathe through their mouths as in the higher (vertebrate) animals, are eighteen in number, there being nine pairs. The first pair forms a large slit-like opening situated on each side of the prothorax, and concealed by the *tergum* or dorsal piece. The second pair are on the sides of the meso-thorax, and are of the same size as the eight abdominal pairs which are situated on the eight basal abdominal segment.

The wings are concealed by the prothorax; the fore pair are small and rounded, as broad as long; they are considerably larger in the male than in the other sex. The hinder pair are minute, rudimentary, rolled up, and flattened down upon the body, but when opened are seen to be oval in form. The wings of the female are smaller than those of the male; they are flattened, with the veins not strongly marked, and with no means for producing sounds. On the contrary, those of the male are much larger; the veins are raised and strongly marked, with the costal region, which is full and large, bent down; the subcostal and median veins are large and distinct, while there is a clear oval space between the median and outer branch of the submedian. Below and nearer the outer edge of the wing is a second large subtriangular, clear, resonant space. The main submedian vein is large and much thickened, with a row of dense, fine teeth along the middle. This forms the "file" which rubs against the other wing. The sound may be produced in an alcoholic specimen by rubbing one wing upon the other. The "file" produces the sound, the vibrations being rendered audible by the resonant, tense, elastic, clear spaces in the other wing, which throw a mass of air into pulsations. Thus the file may be compared to a violin bow, the veins of the wing to the strings of the violin, and the resonant surfaces to the box of the violin, or the elastic wing may be compared to the sounding-board of a piano. Not only does one fore wing rub upon the other, the rasping noise being produced by partially opening and closing the wing, but it seems probable that the file rubs over the stiff, horny, upcurved hinder edge of the meso-thoracic segment. At any rate the mechanism in the fore wings is amply sufficient to produce the sounds referred to by Mr. Thomas in his notes, wherein he states that "the males utter a sharp sound, not much like that of the katydid-like grasshopper (*Phaneroptera*), but which may be described as nearly like that of the Œcanthus, only not long continued, but sharper and stronger." The want of continuity in the shrilling noise is probably owing to the small size and expanse of the wings as compared with the fully developed wings of the katydids and the cricket. That the hind wings are not concerned in making the sound is proved by their undeveloped, soft, limp condition.

The hind body, or abdomen.—This region is about half as long as the body, and is a little flattened sideways, ending abruptly, and in the female terminates in the large saber-shaped ovipositor. It consists of seven well-marked segments, the other three being rudimentary. Beneath are eight hard pieces (sternites, Fig. 4, 2–8), surrounded by a membrane; the four basal ones are broader than long; the fifth nearly twice as long as broad; the sixth large, rounded, shield-shaped; the seventh thickened, boss-like, and one-half as large as the sixth. The eighth piece forms a large (oviducal) plate, which is broad, square, beveled off at the posterior end, with a slight median ridge, and a sharp spine at each side of the posterior edge. From each side of the plate is sent off a spatulate lobe reaching to the base of the spine below.

The tenth ring forms the supra-anal plate, the pointed end of which is subtriangular, sunken in the middle and with raised edges, this posterior portion forming a depressed flap covering the anal opening. On each side of this supra-anal flap is a *cercus* or appendage (Fig. 4, *c*), each acute, small, and slightly hairy. Two rounded, fleshy infra-anal flaps are situated each side of and below the supra-anal flap, and partly conceal the vent.

The ovipositor is a little over one-half as long as the body, it is compressed, and the base is as broad as deep. It can easily be separated into three pairs of blades called *rhabdites*. The eggs pass out through the inner of the three pairs of blades constituting the ovipositor. For example, an egg after leaving the mouth of the oviduct passes along between the lower (or middle) and the inner pair of blades. The base of the lower pair of blades has a chitinous lobe, which is flattened, closing tightly, and when the ovipositor is depressed fills or covers the mouth of the oviduct. The lower pair of blades is lined at the base with a membrane, while the passage for the egg is roofed over by a membrane connecting the base of the inner blades.

In the abdomen of the male the tenth segment is separated by the supra-anal plate, which covers nearly twice the area it does in the female; it is nearly one-half as long as wide, with a triangular furrow, which is membranous at the bottom, so as to allow the two sides of the plate to move together, and thus approximate the claspers. The *cerci*, which are simple pointed appendages in the female, are here converted into a pair of stout claspers (Fig. 1, 2, *b*, *c*), ending in two unequal hooks, the larger hook bent at right angles; the claspers, owing to the triangular membranous furrow, can thus be brought together so as to seize the body of the female during sexual union.

The plate corresponding to the oviducal plate of the female is narrow behind and notched at the end, with the edges folded up; the ends of the lobes thus formed bear each a movable, cylindrical, short appendage. The intromittent organ is at base soft and membranous, consisting of two irregular pairs of lobes, to the upper of which the fork-shaped penis is attached, consisting of a pair of slender boot-shaped spines, which are capable of separating and thus retaining their hold in the copulatory sac of the female by the toe of each "boot" pointing outwards and sticking into the walls of the sac. Along the exterior, corresponding to the leg of each "boot," are two or three spines.

Internal anatomy. — The following description is based on the structure of *Anabrus purpurascens*, gathered in Colorado in the summer of 1878, and preserved carefully in strong alcohol. From these specimens the elaborate drawing by Mr. E. Burgess was made, to which the reader is referred (Fig. 5).

Digestive system. — The mouth-opening is rather large, and the throat (*œsophagus*) begins on the roof of the mouth; it curves upward and a little backward as far as the center of the head, where it slightly contracts before the canal dilates into the large spacious crop (*ingluvies*), which is filled with partly digested vegetable food. In *A. simplex* it extends half way through the abdomen,

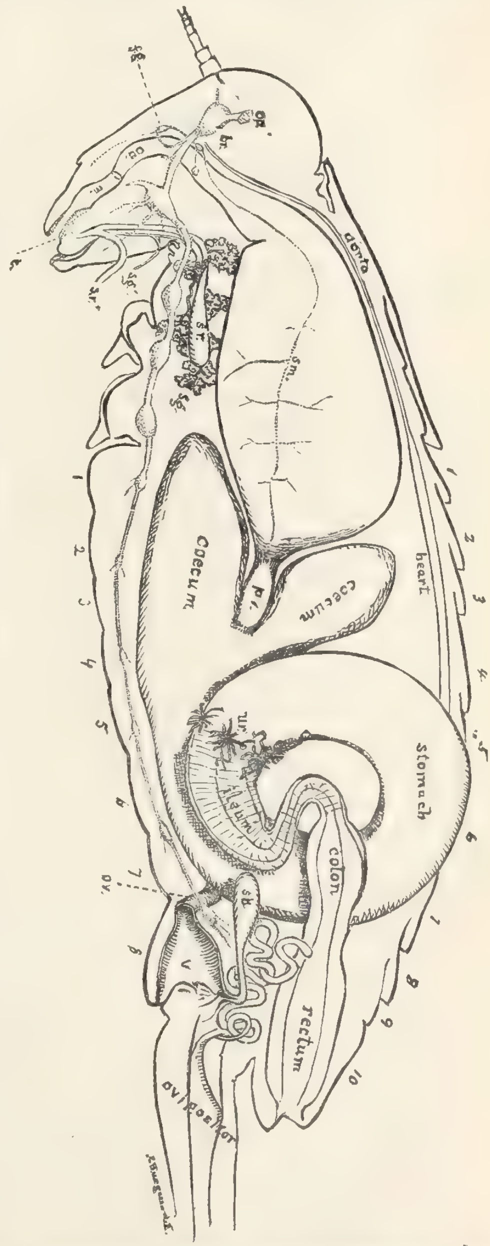

Fig. 5.—Internal anatomy of *Anabrus*: *t*, tongue; *fg*, frontal ganglion; *br*, brain; *sr*, salivary reservoir; *ur*, origin of urinary tubes; *sb*, sebaceous gland.

being, when distended, a quarter of an inch thick; while in *A. purpurascens* it is a little shorter, only extending into the base of the abdomen. At its junction with the *proventriculus* or fore stomach (Fig. 5, *pv*) six toothed, chitinous plates or horny ridges radiate from the opening into the proventriculus, being the continuations of the six principal denticulate ridges in the proventricle. The latter division of the digestive canal is small, oval, rounded, no longer than thick, and provided on the inner surface with six rows of large, sharp, finely serrate, triangular, antero-posteriorly compressed teeth, with a small spine on each side at the base, while on each side adjoining are secondary small conical teeth; there are about fifteen larger teeth, with a row of fifteen lateral ones on each side, making 45 in each set or series, so that there are 270 teeth in all. Each of the six series or rows is separated by a long, narrow, linear chitinous band. The smaller lateral teeth are not antero-posteriorly compressed, but are rounded, and stand separate from each other.

At the beginning of the true stomach (chyle-stomach or ventricle) are appended two cœcal appendages, one above and one below, and much broader than the narrow stomach itself, each forming a flattened docked flap, with about 12 longitudinal folds, especially marked on the sides next to the crop. The stomach is slender, and without diminishing in thickness passes backward in the abdomen, then making one turn before terminating, the end being situated where the numerous urinary tubes (Fig. 5, *ur*) originate. These long, fine, thread-like tubes are very numerous and are over an inch long, twisting about the alimentary canal, and, in many cases, are firmly attached by their ends to the free ends of the two cœcal lobes of the stomach.

The stomach is succeeded by the intestine, which is divided into a short ileum and a colon. The former is but little smaller in front than the stomach, but becoming smaller posteriorly; it makes a deep S-shaped bend. The colon is smaller than the ileum. The long, thick rectum is situated directly under the tegument of the back of the end of the abdomen, the anal opening being but little smaller than the diameter of the rectum. The rectal glands are but slightly developed compared with those of the locust. The salivary glands (Fig. 5, *sg*) are in loose botryoidal masses somewhat as in the locust (*Caloptenus femur-rubrum*). They discharge the salivary fluid through the salivary ducts (Fig. 5, *s r′*) into the base of the mouth near the tongue (Fig. 5, *t*).

The ovaries are two in number, situated one on each side of the turn of the stomach. Each ovary forms a triangular conical mass, the base being broad. They are each composed of about 40 long, slender ovarian tubes, each tube being accompanied by a tracheal branch. These ovarian tubes unite to form the secondary oviducts, which are moderately long and unite directly under the last ganglion to form the main oviduct which ends in the copulatory pouch (Fig. 5, *v*).

The nervous system is in its general disposition like that figured and described in our account of *Caloptenus*. Besides the brain and subesophageal ganglia, there are three thoracic ganglia, the last one being situated opposite the insertion of the third pair of legs. There are six abdominal ganglia, the sixth and last one being the largest; the first one is situated quite near the last thoracic.

The sympathetic nerve (Fig. 5, *sm*) is composed of two branches, which arise from the under side of the œsophagus, and extend back to the end of the crop (*ingluvies*) next to the proventricle, where two minute ganglia are situated, one on each side. There are three small sympathetic ganglia under and near the brain, the anterior one being called the frontal ganglion (Fig. 5, *fg*).

The breathing apparatus consists, in insects, of air-tubes, called tracheæ which originate at the breathing pores (spiracles), and ramify throughout the interior of the body, and thus carry the air into every part of the body; thus everywhere coming in contact with the blood, which flows freely into all the interstices of the body, among the viscera and muscles, not being contained in arteries and veins.

There are two kinds of tracheæ in the *Anabrus*, those which are simple, and those which are dilated, but there are no air vesicles or sacs, such as exist in the locust and other flying insects; so far as is known no larval or creeping, unwinged insects possess air-sacs, and we see that in an insect like the *Anabrus*, when the wings are but partially developed, but not used to fly with, they are not present.

The tracheæ of *Anabrus purpurascens* are small where they arise from the spiracles, but certain of the branches after leaving the small spiracular opening are dilated. There are eight sets of dilated tracheæ in the abdomen; the anterior ones are imbedded in the muscles of the sides of the body. The fifth set of abdominal dilated tracheæ supply the ovaries, there being about 40 branches distributed among the tubes, one for each of the ovarian tubes. The sixth set send branches to the stomach, which is provided with eight large dilated tracheæ, four on a side, by which the organ is held loosely in place. No tracheæ are apparently sent to the ingluvies or crop. The seventh set of abdominal tracheæ distribute their branches to the intestine, a pair of these being large, long, sinuous, dilated tracheæ. The tracheæ branching from the eighth (and last) pair of abdominal spiracles supply the rectum, and a pair of dilated tracheæ are very large, forming a barrel or spindle-shaped sac, situated on each side of the rectum just within the anus. These two large sac-like tracheæ might at first sight be mistaken for true air-sacs, but they have the same structure apparently under the microscope as the tracheæ themselves, the spiral thread being well developed.

On the lower side of the abdomen, under the digestive canal, may be found the two main longitudinal (stigmatal) tracheæ corresponding to the two stigmatal tracheæ of *Caloptenus*.[216] They lie one on each side of the nervous cord, and are supplied with horizontal branches from the spiracles, and the pair extend into the head.

[216] Compare the description and Figs. 16 and 17 *s*, p. 268, First Report of the U. S. Entomological Commission, 1878.

From each of the two very large prothoracic spiracles, besides two small tracheæ, a very large barrel-shaped dilated trachea is directed downwards to the sternum. It communicates directly with the large spiracle as the point of a needle or knife when passed through the spiracle entered directly into this trachea.

CHAPTER IX.

THE AIR-SACS OF LOCUSTS WITH REFERENCE TO THEIR POWERS OF FLIGHT. (Plate I.)

In the ninth chapter of our First Report we briefly described the distribution of the air sacs in the locust, and indicated that its great powers of flight were largely due to the fact that this insect is an aëronaut. For want of space we did not discuss what had been done by others in this direction, nor did we describe the mode of distribution of these air-sacs in other insects.

These air-sacs were first noticed by Swammerdam, and afterward by Sir John Hunter. Swammerdam, a Dutch naturalist, whose famous work entitled The Book of Nature, appeared at Leyden in 1737, first described and figured them in a lamellicorn beetle (*Geotrupes nasicornis*). Afterward they were discovered by Sir John Hunter in the bee, and subsequently Prof. K. Sprengel[217] discovered them in other insects. They were in 1828 described and illustrated in a very elaborate and detailed way by Straus Dürckheim in his great work on the anatomy of the cockchafer.[218] Afterward special attention was paid to them by Marcel de Serres, who published a detailed account and figures of the air-tubes and sacs or vesicles of a grasshopper (*Truxalis nasutus*). Marcel de Serres's figure is truer to nature than that of L. Dufour, published in his work on the anatomy of the *Orthoptera*,[219] &c., and show well the great number of these air-sacs as seen in a dorsal view of the insect. The English anatomist, G. Newport, has also described and figured the air-sacs in the abdomen of the male bumble-bee in the Philosophical Transactions of the Royal Society of London, 1836.

From Newport's article "Insecta," in Todd's Cyclopædia of Anatomy and Physiology, we take the following statements regarding the distribution of these sacs in different insects.

These air-sacs are found most developed in bees, wasps, &c. (*Hymenoptera*), moths and butterflies, flies (*Diptera*), and some beetles and some bugs (*Hemiptera*), though in the immature or larval state of all these insects there is not the slightest trace of them. They thus do not occur

[217] Commentarius de partibus quibus insecta spiritus ducunt. Lipsiæ, 1815.

[218] Considérations générales sur l'Anatomie comparée des Animaux articulés. Par Hercule Straus-Dürckheim. Paris, 1828.

[219] Recherches anatomiques et physiologiques sur les Orthoptères, les Hyménoptères et les Névroptères; par M. Léon Dufour, Mémoires Mathématiques des Savants étrangers, Paris, 1841.

PLATE I.

Fig. 1. Face of locust, showing distribution of air-sacs: *oc*, ocular dilated sacs: *ct*, cephalic trachea.

Fig. 2. Upper side of head of locust; *oc*, outer ocular sac; *ioc*, inner ocular sac; *cl*, clypeal trachea.

Fig. 3. Main ventral air-tubes of abdomen.

Fig. 4. Distribution of air-tubes in hind leg.

in purely creeping and running insects, but only in those which leap and always in those which fly. In the two-winged flies (*Diptera*) the vesicles are both large and numerous, as any one can see by opening the body of the common house fly.

According to Marcel de Serres, the *Asilidæ* have an immense number of small elongated vesicles on each side. In one species they amount to so many as sixty. Burmeister remarks that in the *Lepidoptera* vesicles in the *Sphingidæ* and moths are chiefly found in the males, which agrees with our own observations in *Hymenoptera*.

The air-sacs in the family of locusts (*Acrydii*) are as numerous and there are as many large ones as in any group of insects, the females being as well provided with them as the males. To the general account given in our First Report (pp. 267–270) we may add a few facts, and present in Plate I some enlarged views of the upper side of the head and the face, showing better than in the wood-cuts in the First Report their mode of distribution. Without repeating the distribution of the air-sacs in the head the reader is referred to page 269 of the First Report and to Figs. 1 and 2 of Plate I of the present report.

Our Fig. 3 (Plate I) represents the course of the main ventral tracheæ or air-tubes extending along the floor of the hind-body or abdomen under the digestive canal. They are indicated in Fig. 16 V of the First Report. In that figure, however, the relation of this ventral system of air-tubes to the air-sacs is not shown. By reference to our figure on Plate I it will be seen that from these tubes arise small tracheal twigs in the thorax, which give off numerous minute globular or oval air-sacs; these are also very abundant at the base of the abdomen, especially in the front and hinder part of the first or basal segment of the abdomen, while a few line the walls behind, and others are seen near the middle of the abdomen in the fourth segment. Again they become noticeable in the end of the abdomen near the base of the ovipositor, where the smaller twigs from the ends of the two main tracheæ each end in numerous small sacs.

Fig. 4 of the same plate represents the distribution of the air-tubes in the hind legs of a common locust (*Œdipoda sordida*). In the fore and middle as well as hinder pair of legs, the thigh joint (femur) is provided with two large dilated air-tubes, but there are only four minute, slender air-sacs at the base (not represented in the drawing). At the end of the femur these two tubes dilate or expand considerably. A large dilated air-tube (*t. tr*), with numerous small branches, passes along through the shin-joint or tibia, lying between the muscles, and this trachea extends through the five toe-joints, ending in several small branches in the fifth joint at the insertion of the claws.

Use of the air-sacs in flight.—We described in our First Report (pp. 269, 270) the mode of inhalation of the air, or of breathing in the locust, and briefly pointed out the way in which the air-sacs are filled by the air drawn in through the spiracle or breathing holes. It thus appears that the powers of the locust as an aëronaut are as great or greater than in any other kind of insect.

That the use of the air-sacs is to buoy up the insect in the air, and that by filling and partially emptying the sacs during the process of breathing the insect can enlarge its bulk and change its specific gravity at will, so as to render itself capable of supporting itself on the wing with little effort, was first discovered by Sir John Hunter. Newport, in his treatise on insects, remarks:

That this is the use of the sacs may be inferred from their non-existence in the larva state, or in insects that constantly reside on the ground, more particularly in creeping insects; and it seems further confirmed by the fact that among volant insects those have the largest and greatest number of vesicles which sustain the longest and most powerful flight. Thus the vesicles are found most developed in the *Hymenoptera*, *Lepidoptera* *Diptera*, and some *Coleoptera*, and *Hemiptera*, in all which, in the larva state, there is not the slightest trace of them. A still further proof that they are for lightening the body is found in *Lucanus cervus*. In the male of this insect the large and heavy mandibles and head, but more especially the mandibles, are not filled with solid muscle, as in the *Hydröus* and others in which these parts are more in proportion to the size of other parts of the body, but with an immense number of vesicles, which in the mandibles are developed in the greatest abundance in sacs from long tracheæ, that are extended from one end of the organ to the other, so that the interior is almost entirely filled with vesicles. By this beautiful provision these projecting and apparently unwieldy structures are rendered exceedingly light, while their solid interior fits them for all the purposes of strength required by the insect. The large and apparently heavy body of the humble-bee is lightened in a similar manner. In this insect and others of the same order the vesicles are fewer, but very much larger than in *Coleoptera*. The lateral tracheæ in the abdomen form one continuous chain of dilatations, which are larger in the males of the species than in the females.[220]

Also, in his article "on the formation and use of the air-sacs and dilated tracheæ in insects,"[221] Newport gives further information regarding the presence of these sacs in other insects:

In the most active *Neuroptera* the sacs are very numerous and capacious, especially in the dragon-flies, but they are much smaller and fewer in number in the *Ephemeræ*, the *Sialidæ*, and the scorpion-flies. In the *Coleoptera* the sacs exist only in the volant species, and are more or less numerous and capacious in these in proportion to the bulkiness of the insect and its degree of activity on the wing. This difference exists not only in different genera, but in different species of the same genus, according as they are winged or apterous species. Thus distinct vesicles are found in the winged *Carabidæ*, but not in the apterous, in which the respiratory organs are simply tracheal. In the more heavy-bodied genera the vesicles are not confined to the abdominal and thoracic regions, but are sometimes extended into other parts, as in the unwieldy stag-beetles, in which they are extremely numerous, and occupy the chief portion of the interior of the mandibles. In the *Lepidoptera*, as in the *Neuroptera*, they are largest in the swiftest and most powerful species, and more especially so in those in the males, which are known to be most active on the wing. On the contrary, in the majority of the *Orthoptera*, which are merely saltatorial in their habits, the tracheæ never assume the form of distinct vesicles, excepting in a few genera, which have the power of flight. They retain the arborescent form in the perfect as in the larva state, but are considerably enlarged throughout the greater part of their course, their ex-

[220] Todd's Cyclopædia of Anatomy and Physiology. Article, *Insecta*.

[221] Transactions of the Linnæan Society of London, 1851, vol. xx, p. 419–423.

treme ramifications only retaining their original setiform structure and distribution. In the truly apterous insects the tracheæ are invariably arborescent, and diminish in size from their origin to their extremest point in their perfect as in their larva condition, and they are invariably smaller in diameter and have fewer ramifications in the most inactive species.

In the flying locusts the air-sacs or vesicles are not less numerous than in the bee, and we think that in proportion to the body they are more numerous, while it is obvious that there is a greater number of large sacs. When we add to these the large number of broad, expanded, or dilated air-tubes, some of which would easily be confounded with the sacs themselves, we can appreciate the wonderful powers of the Rocky Mountain locust as an aëronaut. With a greater expanse of wing than in any of its congeners, and as complex an arrangement of air-tubes and sacs, it is able to rise from the ground in the morning and, if the day proves clear, remain floating in the air for hours, until near sunset, borne hither and thither by gentle baffling breezes, or wafted straight on in its course eastward from its mountain home for miles over the plains, should the breeze be strong and steady. Meanwhile scarcely as much muscular force is spent through the day as is exerted during a few vigorous hops when it alights on the ground.

In the possession and use during flight of these air-sacs, locusts and other insects may, as Newport suggests, be compared with birds.

In birds the respiratory organs are not only vesicular but are more extensively distributed over the whole body than in any other vertebrata. These, as every anatomist knows, are not confined merely to the great cavities of the body, but are extended to every part of the skeleton, as in insects. They communicate directly with the interior of the bones of the wings and legs, as the tracheæ of the thorax are extended also into these parts in insects. This distribution in both is more extensive and complete in the most active species. In birds which are unaccustomed to flight, as in the ostrich, as remarked by Mr. Owen,[222] the communication of the respiratory organs with the bones is imperfect; while in insects, although tracheæ exist in all, the vesicles are found only in those of flight. This fact extends even to the sexes of the same species. Thus vesicles exist in the males of the common glow-worm, which is winged, and designed to search out the apterous female, in which the respiratory organs are simply tracheal. The like conditions exist in the common winter-moth, *Geometra brunaria*. In the male of this insect I have found the vesicles large and numerous, but not a trace of these occurs in the female. The tracheæ in this sex, which has only the rudiments of wings, are larger relatively than in the female glow-worm, and are precisely in that condition in which I have found them in the diurnal Lepidoptera shortly before changing to the pupa. These anatomical facts are inferential of the real use of the vesicles, and are supported by an observation which I have been able to make on the common dung-beetle, *Geotrupes stercorarius*, at the moment when it is preparing to take flight. A specimen of this insect which had been in confinement for about twenty-four hours, and consequently had not expanded its wings during that time, when placed on a table immediately prepared to escape. After walking away quickly for a short distance it began to respire freely, alternately shortening and elongating its abdominal segments at the rate of about forty respirations per minute. It then ceased for an instant and slightly separated its elytra without elevating them, and began again to respire more rapidly. At first its respiration was

[222] Cyclopædia of Anatomy and Physiology, Art. Aves., vol. i, p. 341.

slowly but gradually increased, until a few seconds before it attempted to expand its wings and to elevate itself upon them, when the acts of respiration became exceedingly rapid, and amounted to at least 120 per minute. These were most rapidly performed, and were then suddenly arrested at the instant before it attempted to unfold the wings. During this increased respiration the abdomen of the insect was distinctly enlarged, and it was quite evident that this enlargement and the expansion of its wings were being effected by forced inspirations, and maintained by the expansion of the air-sacs over the whole body, and the communication of these with the tracheal vessels in the wings themselves. As, however, the wings had become stiffened and dried through many hours, it did not completely succeed in its attempts to escape, but only partially raised itself upon them. The results were nevertheless sufficiently satisfactory to prove to me that the respiratory organs became distended previous to the act of flight, as the entire body was distinctly enlarged; the effect of which enlargement, together with an increased evolution of heat in the body, as the result of increased respiration, must, of consequence, be to diminish the specific gravity of the insect, and thus, by lessening the degree of muscular force required to raise it on its wings, considerably augment its powers of locomotion, which seems to be the chief use for which the vesicles are developed.

Origin of the air-sacs.—When we carefully examine the tracheæ and observe that in the locusts many are dilated and so expanded that at first one is inclined to regard them as simply long vesicles, and then observe the form of some of the vesicles and their relations to the tracheæ from which they originate, one is inclined to accept the following theory as to their origin given by the distinguished English anatomist whom we have just quoted.

The respiratory organs are always simply tracheal in the larva state of all insects, and it is not until the period of change to the pupa is fast approaching that they begin to be enlarged even in those in which vesicles are afterwards the most numerous. The enlargement, as I have elsewhere shown, commences in Lepidopterous insects at about the time when the larva ceases to feed. It is perceptible first in the longitudinal tracheæ of the thoracic segments of the Sphinx, immediately before the insect enters the earth; and by the time that the cell in which it is to undergo its transformation is completed, the tracheæ from the second to the fifth spiracles are distinctly enlarged. In the diurnal species, which do not enter the earth but undergo their changes in the open air, the dilatation of the tracheæ commences while the insects are spinning their silken threads. When this labor is finished and they have remained for a few hours at rest, the skin is fissured along the dorsal surface of the thoracic segments and thrown off, the change to the pupa is effected, and the longitudinal tracheæ in the fifth and sixth segments are dilated into vesicles, which continue to be enlarged during the first few days after the change. The tracheæ of the third and fourth segments each give off a small trunk on their external surface, which is divided into two branches, and is involved in a fold of the new tegument that is formd beneath the old skin of the larva some days before its change. The fold of tegument on each side of the third and fourth segments is supplied with ramifications of tracheæ from these minute trunks, and very closely resembles in appearance the external abdominal branchiæ of the aquatic larvæ of *Neuroptera*. It is these folds which become the most important organs in the perfect state of the insect, its wings. When the old skin of the larva is fissured and the thoracic segments become shortened, as the skin is thrown off, previous to their forming one region, the thorax, the tracheæ in these folds are rapidly enlarged and elongated, and mainly assist in inducing a rush of blood into these structures, which are thus expanded on the sides of the new pupa as the rudimentary wings. This elongation of the small trunks at the sides of the longitudinal tracheæ in the thorax relieves them of a portion of that tension which results from the powerful respiratory efforts of the insect in effecting its change, and which, with a tendency to enlarge by the natural forces of growth in these structures, results in the dilatation first of the tracheæ at the base of the abdomen into distinct sacs. This is the manner in which the air-sacs are formed in all insects. After the main trunks have become dilated their ramifications also are enlarged in like manner, and this enlargement continues from the time when the insect enters its pupa to that of its appearance in the perfect state.

There is no more admirable instance in nature of the adaptation of organs to the performance of certain functions than this of the air-sacs, which render certain insects true aëronauts. This delicate correlation of these organs to the aërial habits of the insects which possess them, seems to be in the relation of cause to effect. It has been seen that they do not arise until the final winged state of the insect—the time when they are first brought into use—and this is an indication that they are the result of forces acting upon the organism during its adult winged life. This special adaptation of the air-tubes to the exigencies of its aërial life may have been suddenly induced, the tracheæ in some favored race of bee, moth, or locust having been distended during the rapid, violent respiratory efforts of the insect during flight, and resulted in a permanent enlargement of the air-tubes. These initiatory sacs being found useful were probably transmitted to the offspring, until they became permanent improvements in the organization of certain races of different groups of flying insects, and remained wanting in other even closely allied groups which did not possess wings. Thus we see that changes in the mode of life, the influence of the environment upon the insect, provoked the variation, *i.e.*, the sudden rise of what ultimately proved to be useful organs which became further perfected and finally absolutely indispensable and unfailingly present in the descendants of those forms in which they at first originated. Such is the line of thought or argument which we are compelled to adopt in endeavoring to trace the origin of such organs as those under consideration. In brief, it is the influence of external causes upon the animal, certain changes in the environment, which become perpetuated by internal causes or inheritance force.

CHAPTER X.

HISTOLOGY OF THE LOCUST (CALOPTENUS) AND THE CRICKET (ANABRUS). (Plates II–VIII.)

By Dr. Charles Sedgwick Minot.

Insects have hitherto been but little studied by histologists. The science of general anatomy or histology, which was first established by Bichât in France, acquired a fresh importance and new meaning through the investigations of German naturalists, and above all through the great discovery of Schwann that all animals are composed, like plants, of certain minute elements or units, which are now familiar to all naturalists under the name of cells. Cells are found only in living bodies; and it is very probable, though by no means certain, that no life exists outside of cells, or in any other bodies. For this reason, to determine the essential powers and peculiarities of cells, and to discover the modifications they undergo, is the fundamental problem of zoology and botany at present. Indeed, biology might almost be defined as the *science of cells.*

Since, however, microscopic anatomy, which is that branch of science which deals especially with the forms and appearance of cells, has been more actively prosecuted by medical men than by zoologists, our knowledge of the tissues of the higher vertebrates is much more complete than of the lower animals. Of the histological structure of insects singularly little is known, although they are particularly favorable objects for microscopic investigation. The most extensive series of observations are those of Leydig, which are summarized in part in his invaluable *Lehrbuch der Histologie*, published in 1858, and in part in shorter special papers scattered through various scientific journals of the last twenty years. Max Schultze has made several important contributions, and there are besides a few excellent single papers, by various authors, notably Dr. Von Basch, Landois, Claparède, Graber, O. Schmidt, &c. Several of Professor Rudolph Leuckart's pupils have made very valuable additions to our knowledge of insect histology. The writings of earlier naturalists contain many observations of importance, but the ground covered by them must now be gone over again and viewed from the stand-point of modern anatomy.

When I began the work the results of which are here described in detail,[223] I found that very few histological observations had been made on the grasshoppers, or, indeed, on other insects. I feel that this is very unfortunate, because it prevents my judging of the accuracy of my own observations by comparing them with the results obtained by others. I must therefore anticipate that some at least of my conclusions will hereafter require modification.

I regret very much the incompleteness of this report, occasioned in large part by my inability to devote myself longer than a little over five months to the work. My results are derived chiefly from the study of the locust,[224] to which I have added a limited number of observations on *Anabrus purpurascens*. I have endeavored to increase the value of the article by incorporating a considerable number of bibliographical references. I hope that with these additions this report will assist other American students in becoming acquainted with the present state of our knowledge of the histology of insects without having to search far and wide for the authorities. In brief, I attempt to give a bibliographical index to the general outline of the subject, and to describe in detail such

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[223] A preliminary report has been published in the First Annual Report of the Commission, pp. 273–277.

[224] The observations are mostly made of the *Caloptenus femur-rubrum*, the common red-legged locust, and on *Œdipoda sordida*.

EXPLANATION OF PLATES II–VIII.

All the figures on Plates II–VII, except those specially otherwise designated, are taken from preparations made from *Caloptenus femur-rubrum*. The figures on Plate VIII, are all from *Anabrus purpurascens*. All but three or four of the figures were drawn in outline with the *camera lucida*, and the details added afterward with free hand. The drawings, with the partial exception of Fig. 58, are nowise diagrammatic, but fall short in clearness of the actual preparations.

EXPLANATION OF THE LETTERING.

An., anus.
art., articulating membran
Bd., muscular band.
ch., cord of ovarian tube.
col., colon.
conn., connective tissue.
Cr.,[1] *Cr.*,[2] crop, 1st, 2d segment.
cu., cuticula.
cys., wall of spermatocyst.
D., dorsal arch of body wall.
d.′, *d.″*, dental processes.
Div., diverticulum of stomach.
D. R., dorsal nerve roots.
Eg., egg.
Ej. D., ductus ejaculatorius.
Ep., epithelium.
F., furrow between intestinal folds.
Gr., granular layer, inside epithelium.
G. Z., ganglion-cells.
h. h.′, cuticular hairs.
Il., ileum.
In. m., internal muscular coat.
L., longitudinal muscles.
M., mouth.
mus., muscle.
mus. C., circular muscles.
M. v., malpighian vessels.
Oe., œsophagus.
Ov., ovary.
Ovd., anterior cœcum of oviduct.
P., proventriculus.
p., pore canals.
r. m., musculus respiratorius.
rid., cuticular ridges.
Te., testes.
Tr., tracheæ.
Tu., external tunic.
Ut., uterus.
V., ventral arch of body wall.
Ven., ventriculus.
V. R., ventral nerve roots.
V. sem., vesiculæ seminales.

PLATES II-VI, CALOPTENUS AND OEDIPODA; PLATE VIII, ANABRUS.

PLATE II.

FIG. 1.—Section through the abdomen of a female at the level of the posterior part of ventricle. *D.*, Dorsal arch; *V.*, ventral arch; *Ov.*, ovary; *Ovd.*, blind end of oviduct; *Ut.*, uterus; *Tr.*, trachea; *art.*, articulation between dorsal and ventral arches; *St.*, stomach.

FIG. 2.—Section through the abdomen of a male at the level of the colon. *D.*, dorsal arch; *V.*, ventral arch; *art.*, articulation between the two arches; *Tr.*, tracheæ; *Te.*, testes; *col.*, colon; *r. m.*, respiratory muscle; *V. sem.*, vesiculæ seminales.

FIG. 3.—Section of cuticula of abdomen. Letters as before.

FIG. 4.—Section of cuticula, *p. p.*, pore canals; *h. h.'*, cuticular hairs.

FIG. 5.—Transverse section of wing muscles.

FIG. 6.—Part of transverse section of abdomen to show the respiratory muscle *r. m.*; *D.*, dorsal arch; *V.*, ventral arch; *art.*, articular membrane; *Ep.*, epidermis; *cu.*, cuticula; *h.*, hairs; *conn.*, connective tissue.

FIG. 7.—Fine tracheæ of rectum; *n.'*, triangular nucleus in fork.

FIG. 8.—Tracheal branchlet.

FIG. 9.—Bundle of striated muscle from the head.

FIG. 10.—Spiral trachea of malpighian vessel.

FIG. 11.—Diagrammatic section of last ventral ganglion; *D. R.*, dorsal roots; *V. R.*, ventral roots; *G. Z.*, ganglion cells.

FIG. 12.—Ramification of tracheæ in muscles; x, fine terminations.

FIG. 13.—Ramification of tracheæ on the ovary.

HISTOLOGY OF THE LOCUST

PLATE III.

FIG. 14.—Ramification of tracheæ on the oviduct (uterus.)

FIG. 15.—Connective tissue cells (fat body ?) from between the seminiferous tubes.

FIG. 16.—Section of a ripe ovarian follicle; *Eg.*, egg; *Sh.*, shell (?) secreted by the epithelium, *Ep.*

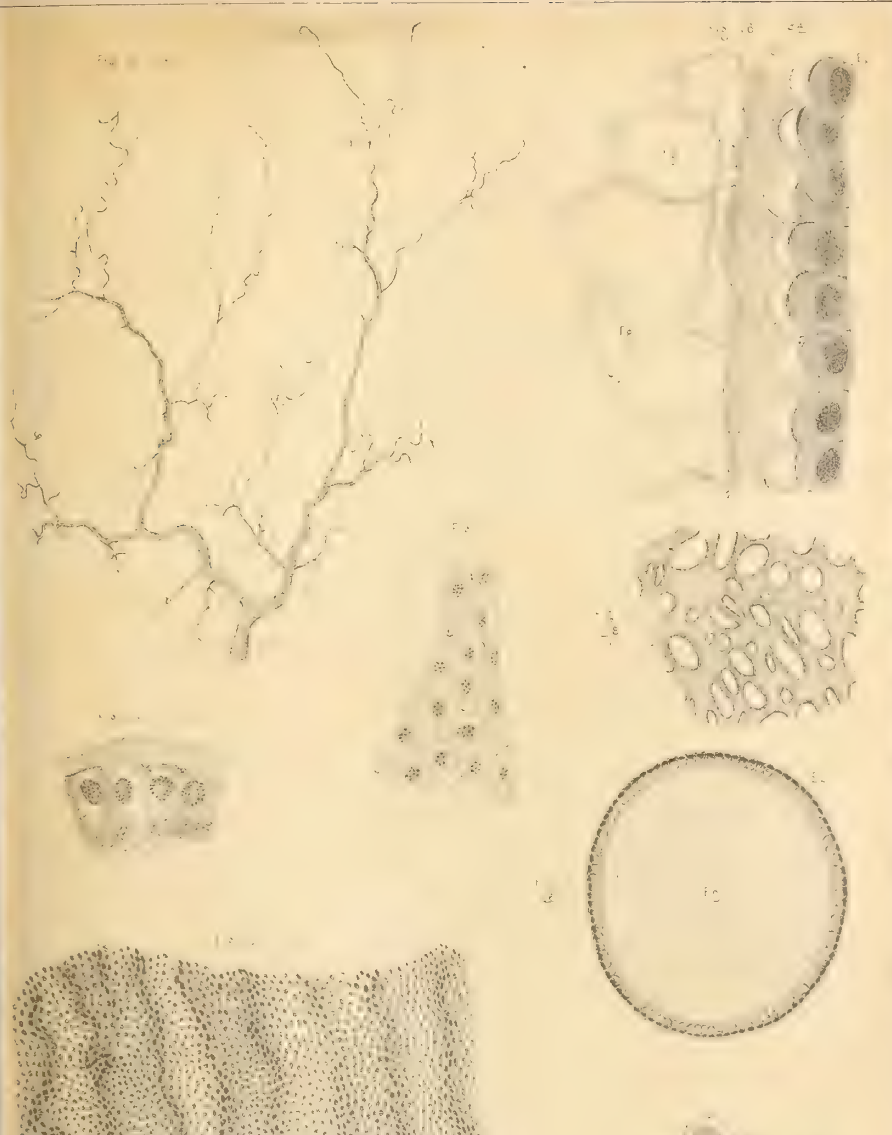
FIG. 17.—*Œdipoda sordida.* Connective tissue around the ovary.

FIG. 18.—*Œdipoda sordida.* Epithelium of uterus seen in section.

FIG. 19.—Transverse section of a whole, ripe ovarian follicle; *Eg.*, egg; *Ep.*, epithelium.

FIG. 20.—Surface view of the follicular epithelium of the ovary.

FIG. 21.—*Œdipoda sordida.* Inner surface of uterus.



HISTOLOGY OF THE LOCUST

PLATE IV.

FIG. 22.—*Œdipoda sordida.* Longitudinal section of the uterus; *Gr.*, granular layer; *Ep.*, epithelium; *conn.*, tunica propria; *muc.*, longitudinal muscular coat.

FIG. 23. *Œdipoda sordida.* Surface view of uterine epithelium.

FIG. 24. Section through the upper part (first segment) of seminiferous tube; *Cys.*, walls of the spermatocysts; *Tu.*, external tunic.

FIG. 25.—*Caloptenus spretus.* Seminiferous tube, isolated; *conn.*, connective tissue; I, II, III, and IV, the four segments of the tubes.

FIG. 26.—Young spermatoblast.

FIG. 27.—Spermatoblasts just divided.

—— —— A, Spermatoblast in process of dividing.

FIG. 28.—Older spermatoblasts.

FIG. 29.—Transverse section of bundle of young spermatozoa.

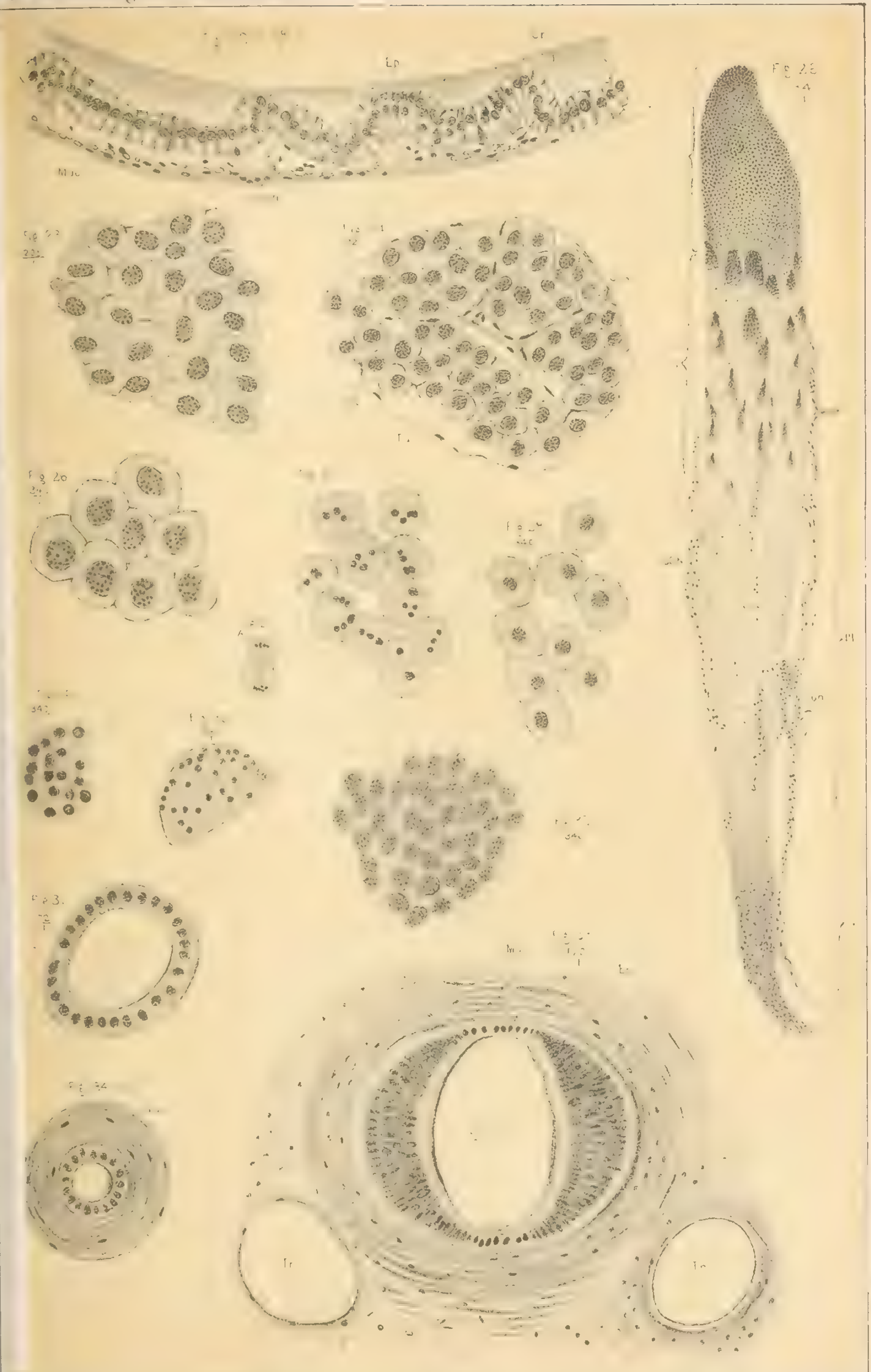
FIG. 30.—Transverse section of older bundle.

FIG. 31.—Section of the upper part of a vesicula seminalis.

FIG. 32.—Epithelium of the upper part of a vesicula seminalis.

FIG. 33.—Transverse section of the ejaculatory duct, *Ej.*, D; *Ep.*, epithelium; *muc.*, circular muscle; *Tr. Tr.'*, tracheæ.

FIG. 34.—Transverse section of the muscular portion of a vesicula seminalis.



C. S. Minot del.

HISTOLOGY OF THE LOCUST.

PLATE V.

FIG. 35.—Transverse section of the hind part of the crop. *Ss.*, spines; *rid.*, ridges; *L.*, longitudinal; *muc. C.*, circular muscles.

FIG. 36.—Section of the ventricular wall; *d.*, duct of follicle; *cu.*, cuticula; *Ep.*, epithelium; *conn.*, connective tissue; *muc.*, muscles; *Tr.*, tracheæ.

FIG. 37.—Transverse section of a diverticulum. *Tr.*, trachea; *muc.*, circular muscular coat.

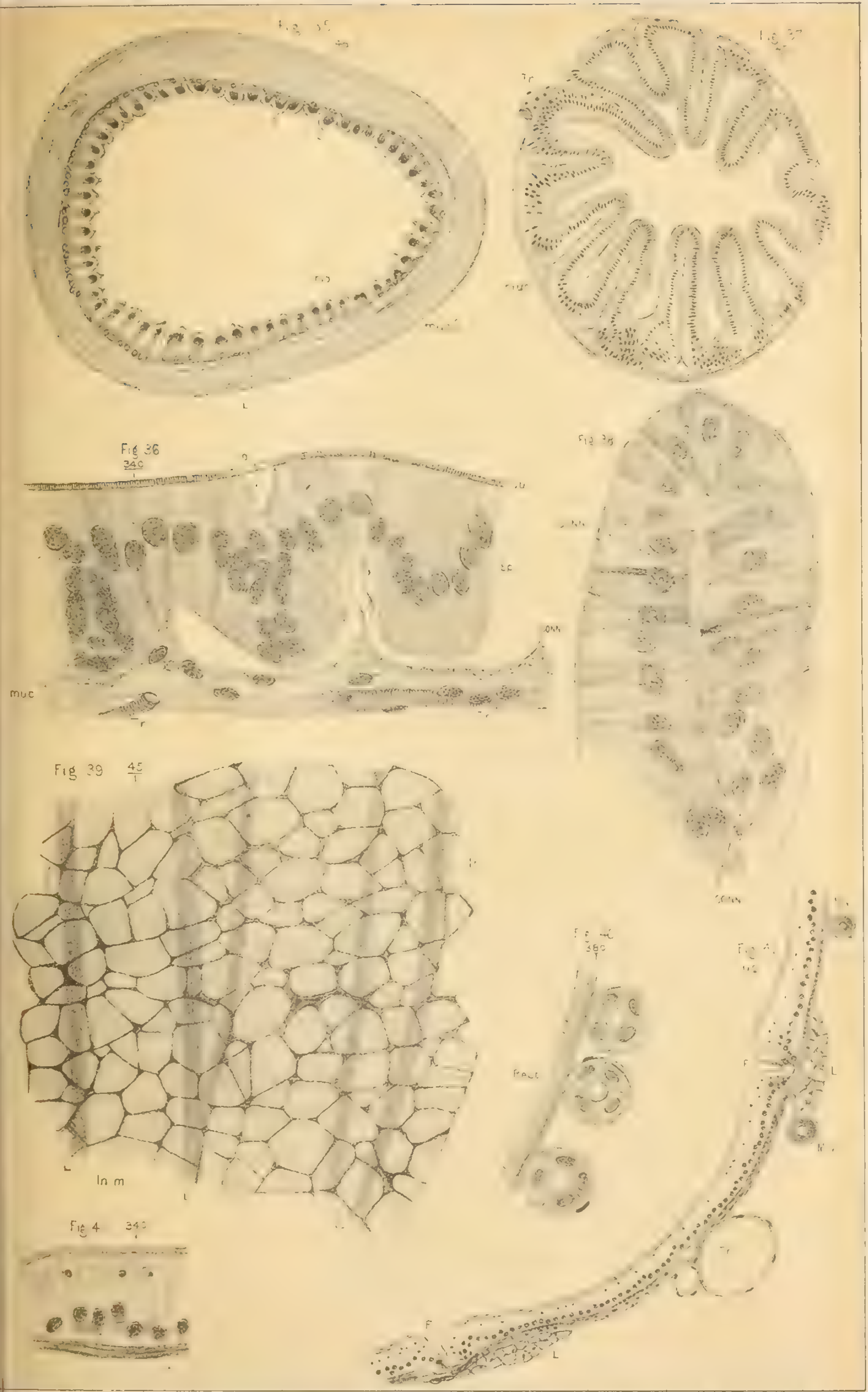
FIG. 38.—Section of a single fold of a diverticulum; *conn.*, connective tissue or *tunica propria.*

FIG. 39.—Inner surface of ventricle, with the epithelium removed. *In. m.*, circular; *L.*, longitudinal muscles.

FIG. 40.—Transverse sections of three Malpighian vessels lying against the muscular walls of the rectum, *rect.*

FIG. 41.—*Caloptenus spretus.* Section of the epithelium of the rectum.

FIG. 42.—Transverse section of rectal folds. *F. F.*[1], furrows between the folds; *L. L.*, longitudinal muscle; *M. v.*, Malpighian vessels.



S. Minot del

HISTOLOGY OF THE LOCUST.

PLATE VI.

Fig. 43.—*Oedipoda sordida.* Epithelial cells of gastro-ileal folds.

Fig. 44.—*Oedipoda sordida.* Part of transverse section of gastro-ileal folds: *c.*, cuticula; *mus.*, muscle.

Fig. 45.—Longitudinal median section of *Caloptenus femur-rubrum*, female, to show the digestive canal. *M.*, mouth; *Oc.*, oesophagus; *Cr.*¹, anterior; *Cr.*², posterior division of crop; *p.*, proventriculus; *Div.*, diverticulum; *Ven.*, ventricle; *Il.*, ileum; *col.*, colon; *R.*, rectum; *An.*, anus.

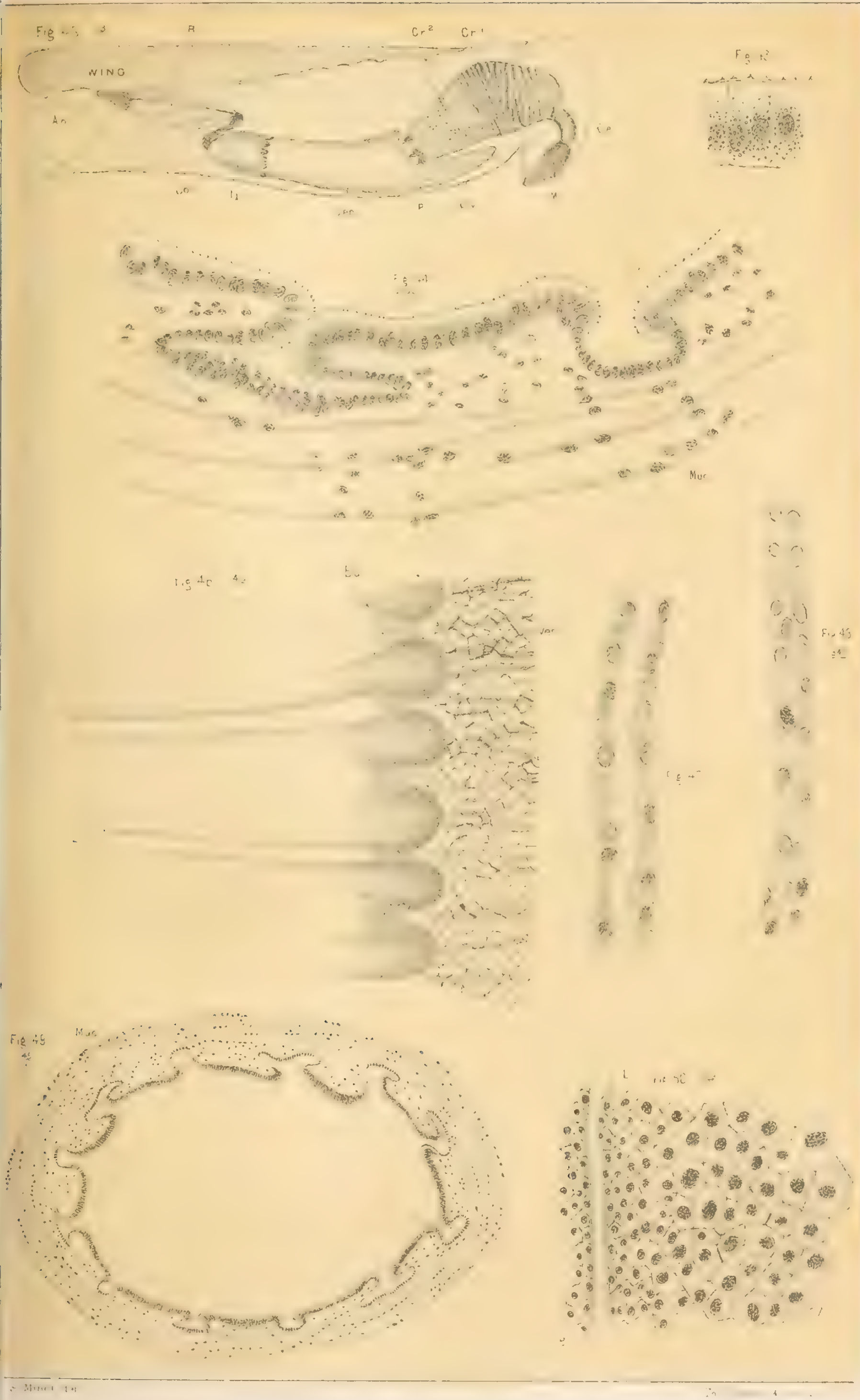
Fig. 46.—Surface view of the gastro-ileal folds. *Ven.*, ventricle; *Bd.*, circular muscular band under the folds; *Il.*, ileum.

Fig. 47.—Optical section of Malpighian tube.

Fig. 48.—Malpighian vessel.

Fig. 49.—*Oedipoda sordida*; transverse section of gastro-ileal folds; *mus.*, muscular band; *Bd.*, of Fig. 45.

Fig. 50.—Epithelium of ileal folds. *A.*, middle of folds; *B.*, furrow between folds; *L.*, longitudinal muscular bands.



HISTOLOGY OF THE LOCUST.

PLATE VII.

FIG. 51.—Transverse section of ileum. *L.*, longitudinal muscular bands; *muc. C.*, circular muscular coat; *Ep.*, epithelium.

FIG. 52.—Transverse section through the furrow between two ileal folds. *F.*, furrow; *cu.*, cuticula; *Ep.*, epithelium; *conn.*, connective tissue; *muc. C.*, circular muscles. *L.*, longitudinal muscular band.

FIG. 53.—*Caloptenus spretus.* Epithelium of rectal glands.

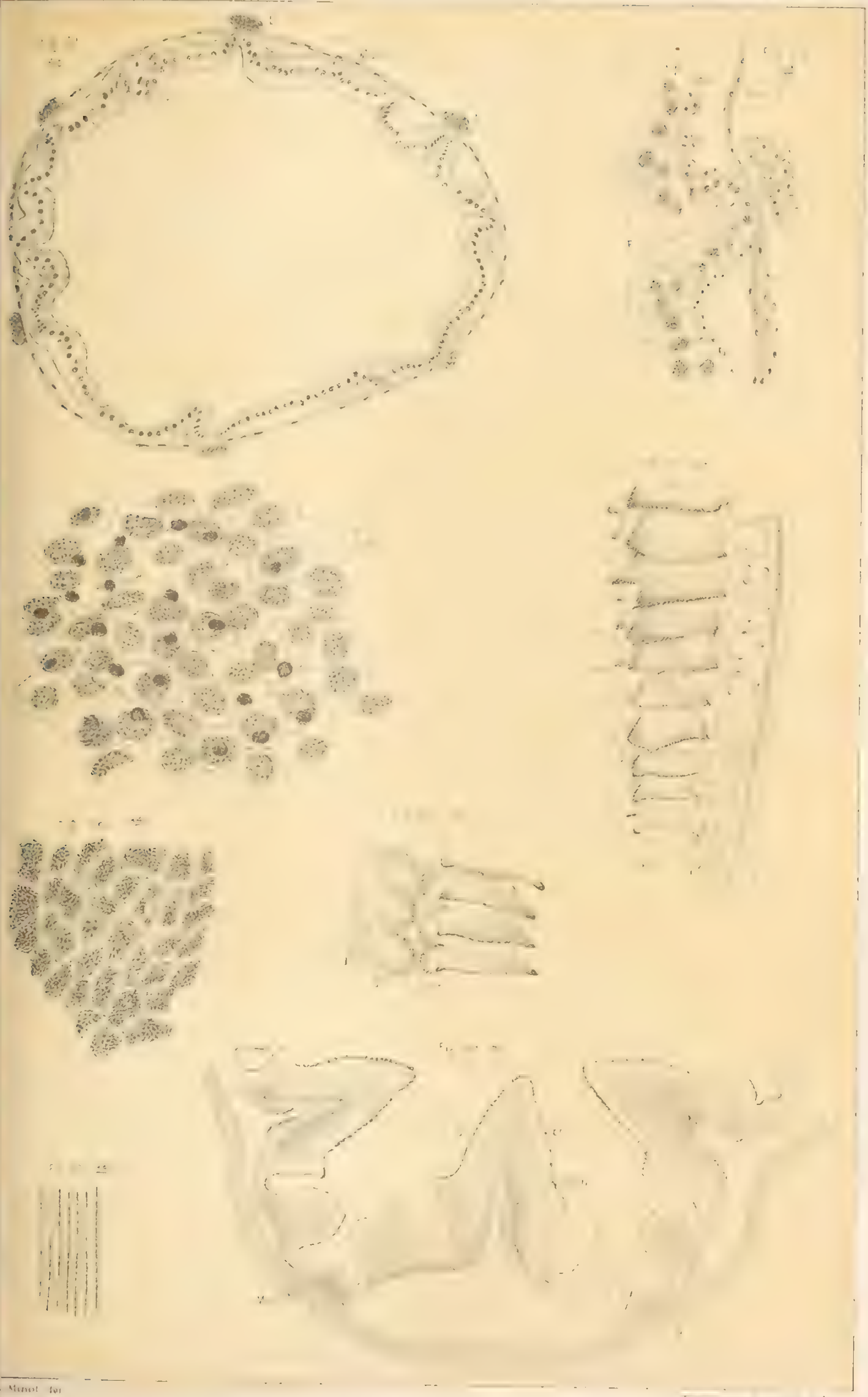
FIG. 54.—Surface view of the interior of the proventriculus; *d*, central; *d''*, molar processes of the teeth; *a.*, longitudinal, interdental ridge.

FIG. 55.—Longitudinal section of the wall of the proventriculus.

FIG. 56.—Epidermal cells, seen from their outer surface.

FIG. 57.—Spiral threads of the same trachea.

FIG. 58.—Transverse section of the proventriculus; *d'*, central: *d''*, molar process of the teeth; *ep.*, epithelium; *conn.*, connective tissue; *a.*, longitudinal ridge; *C.*, subdental canal; *muc.*, muscularis.



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HISTOLOGY OF THE LOCUST AND CRICKET.

PLATE VIII.

FIG. 59.—Cuticula from the lateral portion of one of the middle abdominal segments, to show the nodules *b b* and hairs.

FIG. 60.—Cuticula of the crop.

FIG. 61.—Tracheal epithelium, from a large trunk.

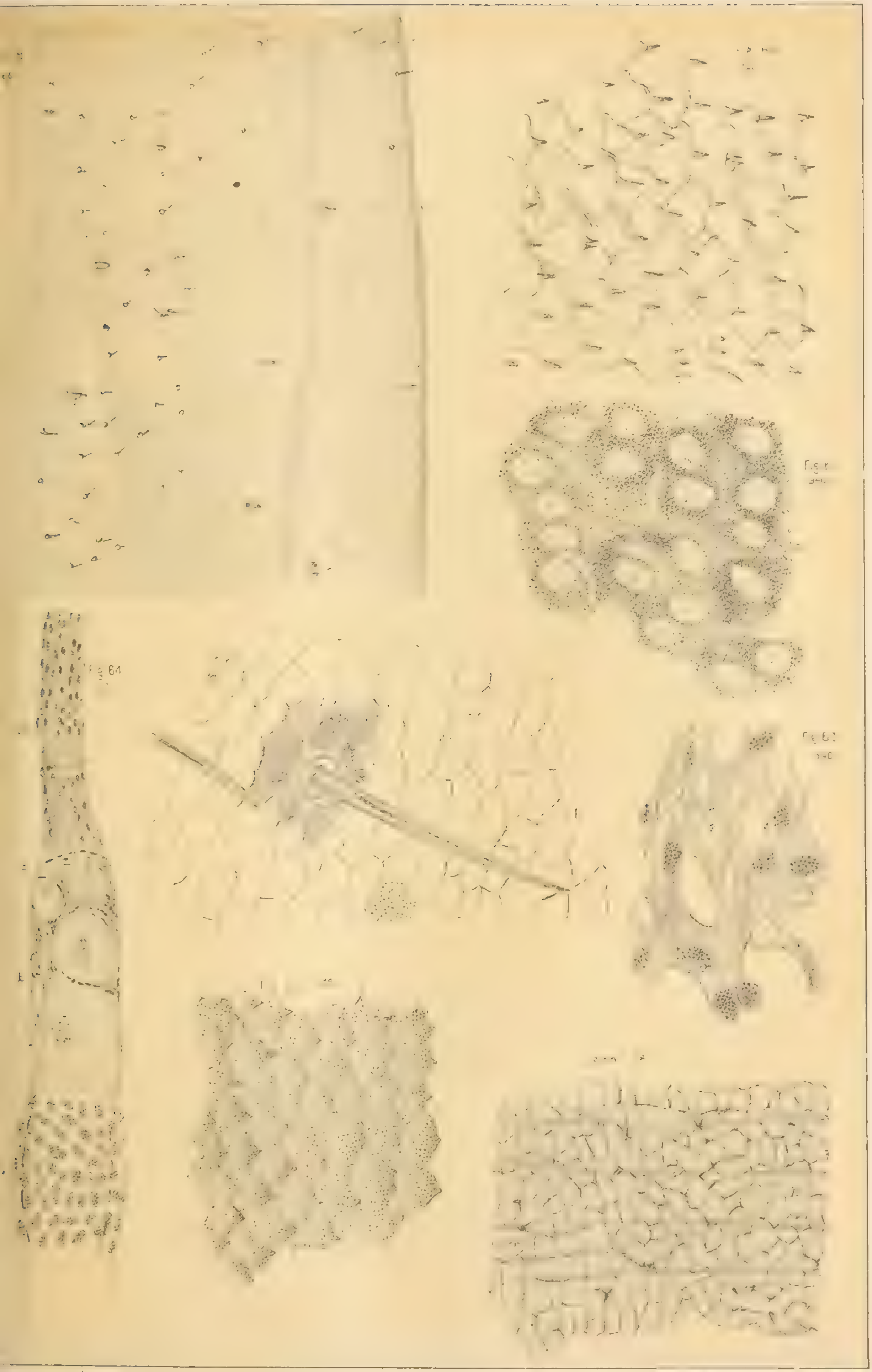
FIG. 62.—Connective tissue from the ovary.

FIG. 63.—Cuticula from the upper and anterior portions of the dorsal arch of one of the middle abdominal segments. *h.*, cuticular hair.

FIG. 64.—Ovarian tube. *Ch.*, cord; *a–b*, region in which the eggs are first formed. *Tu.*, part of the external tunic. In order to draw this part the focus had to be changed.

FIG. 65.—Cuticula from the side of the dorsal arch of one of the middle abdomina segments.

FIG. 66.—Wall of the ventricle after removal of the epithelial and glandular cells.



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HISTOLOGY OF ANABRUS

of my own observations as I believe to be new. I shall give a more complete account of the digestive canal than of any other system. The figures on Plates II–VIII are numbered consecutively from 1 to 66.

In order to make the relation of the various organs to one another more evident, and at the same time to explain the classification of the tissues, which has been generally adopted upon embryological grounds, I figure and describe two sections through the abdomen of the grasshopper, Plate II, Figs. 1 and 2. They are both semi-diagrammatic, being intended to represent rather the general arrangement of the parts than their exact disposition in a particular section. To insure accuracy, however, the outlines of both the drawings were made with the camera lucida from actual sections, and these outlines were then changed only so much as was necessary to remove very slight irregularities.

Fig. 1 is a transverse section through the abdomen of a female at the level of the posterior part of the stomach. The outer wall *D*, *art.*, *V*, is shaded and represented of nearly uniform thickness, which is not quite exact. Outermost is the cuticula, next the epidermis, or cellular matrix, and innermost the muscles—the three parts that make up the outer wall of the body. The same is true of the section through the male, Fig. 2. This section, however, is taken further back in the abdomen, being through the colon; compare Fig. 45 *col.* The walls of the abdomen are divided into a large dorsal arch, *D*, and a smaller ventral arch, *V*, the two being united on either side by an articulating membrane, *art.*, which will be described in speaking of the cuticula further on. The dorsal arch is really composed of the tergite and the pleurites fused together into one piece.[225] Within the body walls, which form, so to speak, a continuous tube, there runs from mouth to anus a second tube of smaller diameter, the digestive canal, the general course of which is shown very clearly in a longitudinal section through a whole grasshopper, see Fig. 45. In a transverse section the digestive tract also appears (Fig. 1, *St.*, stomach, Fig. 2, *col.*, colon), separated by a considerable space from the body walls. In this intervening space there lie various other organs, notably those of reproduction. In the female, Fig. 1, it so happens that at the level of the stomach the sexual organs lie *above* the intestinal canal, while in the male, at the point represented in Fig. 2, the sexual organs lie partly above, partly below, the colon. In the female we notice first the round tubes of the ovary, *Ov*; second, the ovarian ducts, *ovd.*, and, third, on each side the large uterus, *Ut.*, or upper end of the oviduct, into which the ovarian ducts open directly. In the male, on the other hand, we see the testes, *Te.*, lying above the intestine, the single tubes round in section, being embedded in or surrounded by connective tissue (*Leydig's zellig-blasiges Gewebe*), and below the colon, *col.*, lie the spermiducts or *vasa deferentia*, (*v. def.*) Finally, between the inner and outer tubes lie various muscles, the Malpighian vessels, and the numerous branches of the tracheæ. These are all left out in the drawing except a

[225] *Graber* Die Tympanalen Sinnesapparate der Orthopteren. *Denkschr. Wien. Akad, Bd.* 36 (1876), *p.* 75.

few of the tracheæ, *Tr.*, and in Fig. 2 the muscle *r. m.*, to which I shall refer later.

In brief, the grasshopper is built up, 1, of the outer body wall; 2, of the inner tube, digestive canal; and, 3, of the organs which intervene between the two first. Accordingly, I shall describe, 1st, the outer body wall; 2d, the intervening tissue (mesoderm); 3d, the digestive canal and its appendages.[226]

Before entering into the special subjects, I would remark that the Orthoptera, and indeed all insects, are, it seems to me, remarkably favorable objects for histological investigations. As regards *Caloptenus* and *Œdipoda*, it may be mentioned in general that the cellular elements of their bodies are particularly large, and the nuclei of the cells distinguished by being, for the most part, strikingly granulated and seldom exhibiting distinct nucleoli.

ECTODERM.

Cuticula.—It is well known that insects have an external crust or shell, the cuticula, which is supposed to always consist mainly of a peculiar substance, chitine, often mingled with earthy salts, such as carbonate of lime and magnesia.

In both locusts and crickets the abdominal segments present differences in the characteristics of the cuticula of different regions. There are at least three distinct modifications—first, upon the dorsal arch; second, on the spiracular or articular fold, which intervenes between the two main arches; and, third, the main portion of the ventral arch—but in the locusts the dorsal and ventral portions are very similar. The dorsal arch, as seen in transverse sections (Fig. 3 *d*), is much the larger, covering the back and sides of the body, and the articular membrane, *art.*, is a comparatively narrow band. Upon the living locust, or one recently killed, it is easy to observe that the dorsal and ventral arches are movable upon one another in consequence of the extreme elasticity and flexibility of the articular membrane (Fig. 6, *art.*). Both the dorsal and ventral portions of the cuticula are rigid, and, in the locusts at least, present a faint striation parallel to the circumference of the section. This striation may indicate a fibrillar structure. The inner surface of the cuticula presents certain peculiarities in the distribution of a reddish-brown pigment, probably part of the matrix, but otherwise this surface appears quite smooth, while the external surface is somewhat roughened, and is beautifully sculptured in *Anabrus*, as I will shortly describe. The thickness of the cuticula is about the same in both arches; it has a yellowish tinge, shading off into brown at the posterior edges of the abdominal segments. The rigid portions of the cuticula are further characterized by the pores (*Poren-canälchen*) and hairs. The pores are quite large in diameter (see Fig. 4 *p*), and are widened at each end;

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[226] For the relation of these parts the reader may also consult chapter IX of the First Annual Report of the Commission, pp. 257–272.

they always run nearly perpendicular to the surface to the cuticula. Directly over each pore there sits a stiff chitinous tapering hair (Fig. 4 *h* and h¹), which is generally slightly curved. This relation of the hairs and pores has also been described by Leydig,[227] and is well known to naturalists. The hairs are all small, though very unequal in size, the difference in the extremes being much greater than between *h* and *h*¹ in Fig. 4. The hairs do not stand upright, but are so inclined as to point towards the posterior end of the body.

Each hair is constricted around its base (Fig. 63 *h*), forming a narrow neck, below which it expands again, spreading out to make the circular covering membrane of the hair pore. This membrane is very thin, but has a thickened rim. In consequence of this constriction these hairs are commonly said to be articulated. They are not homogeneous, but have a distinct medulla (Fig. 63 *h*), which is probably a prolongation of the cell which forms the hair. These cells have been described by Graber.[228] They were formerly called "*Hautdrüsen*" by Leydig and others. They are, as it were, suspended from the inner side of the large pores as the hairs are from the outer. They are somewhat pear-shaped, and four or five times the diameter of the ordinary epidermal cells, and have correspondingly large *round* nuclei; their contents are very granular. There are usually two or three, rarely but one nucleus in each hair-cell. Graber suggests the name of *trichogens* for these cells. They are probably strictly homogeneous with the scale-cells of the Lepidoptera; the cells differ in the two orders of insects in that they bear a round hair in one case, a flattened hair in the other. The plausibility of this suggestion must, I think, strike every one who is acquainted with the account of the structure and development of the scales in butterflies given by Semper.[229] If the homology is correct, these hair or scale cells must be regarded as specially characteristic of insects, or, possibly, of arthropods generally.

The articular membrane, though a part of the cuticula, has either no, or at most very few, hairs. In the locusts the cuticula at the joint is much thicker and paler in color than elsewhere (Fig. 5, *art.*), being not only thrown up into folds, but also covered with numerous minute pyramidal spines. In the locust the first abdominal segment lacks an independent articular membrane, its own entering into the formation of the sterno-coxal membrane, or articular capsule of the third or metathoracic limb. On the sides of the segment a kidney-shaped piece of the cuticula undergoes peculiar modifications to enter into the formation of the tympanal apparatus.

In *Anabrus* the cuticula presents the following characteristics, besides those which have been mentioned as found in both it and the locusts:

First, there are projecting conical nodules scattered irregularly over it, as can be seen in a surface view. (Fig. 59, *b b*.) These cones are less

[227] *Leydig:* Lehrbuch der Histologie, 1857, p. 111, Fig. 56.
[228] *Graber:* Denk. Wien. Akad., xxxvi, p. 35 (1876).
[229] *Semper:* Zeit. für wiss. Zool. Bd. viii, p. 328.

numerous, much thicker, and shorter than the cuticular hairs. They have rounded apices, and are inclined backward. They do not seem to correspond in any way to the hairs, for they do not rest over pores, nor have I seen any specially modified cells underlying them. As far as I have observed, they are mere local irregularities, each nodule being apparently supported by some four or six unmodified epidermal cells.[230] The cones in those specimens I have examined are entirely wanting in the ventral arch, in the upper portion of the dorsal arch, but on the sides of the dorsal arches they are of considerably greater dimensions than upon the spiracular membrane, and finally they are larger and more numerous on the anterior than on the posterior abdominal segments. I have not, however, attempted to follow out the distribution of these structures in greater detail.

Second, the whole of the cuticula except the cones just described and the hairs, is divided into numerous minute fields (Figs. 63 and 65), each of which corresponds to a single cell of the underlying epidermis. Each field is bounded by a distinct polygonal outline, and its surface is either covered by a large number of extremely minute projecting points (Fig. 65), as on the dorsal arch, or is smooth as upon the articular membrane and ventral arch. Upon the sides of the dorsal arch and upon the spiracular membrane each field has a projecting spine or sometimes two or even three. Fig. 65 represents a surface view of part of the side of one of the dorsal arches. Upon the articular cuticula each spine springs from a short basal collar. Fig. 63 represents a surface view of the upper and anterior part of the dorsal arch. The fine sculpture is drawn only on a few of the fields, none of which have spines. The figure is intended to show that from the smooth circular area around the base of the hairs, *h*, the fine points of the sculpturing appear to radiate, while elsewhere they are only irregularly distributed. I have been unable to determine how this radiating appearance is caused.

The ventral arch has a quite smooth surface and but few hairs. The articular membrane has few hairs, a number of broad cones, and sculptured fields, bearing spines, which have a thick collar around their bases. The dorsal arch resembles this membrane generally, but differs from it by the simpler character of its spines, by their absence from its upper portions, and by its brownish tinge. The cuticula between the segments resembles the spiracular membrane.

The cuticula forms also the stigmata or openings of the tracheal system. Immediately around each opening the cuticula is perfectly smooth, while to form the stigmata it undergoes various modifications, which I have not studied. The cuticula of the thorax, head, and limbs I have not examined.

Epidermis.—The cuticula is secreted by an underlying layer of cells, the epidermis proper, often called the matrix or hypodermis, but inas-

[230] I think it possible that the examination of sections, which the imperfect preservation of the parts prevented my making, will show that the cones are after all really produced by specialized cells. The surface views I have obtained are none of them thoroughly satisfactory in this respect.

much as this layer is homologous with the epidermis of other animals, it seems desirable to secure uniformity of nomenclature by adopting this name for the subcuticular layer of cells. I have not devoted much attention to this tissue. Its relations and proportionate size in locusts to the cuticula, *Cu.*, can be seen at *Ep.*, in Fig. 7. The cells composing it are cylindrical and form but a single layer, interspersed through which are numerous hair cells, as above described.

In *Anabrus*, the epidermis is composed of high cylinder-cells, which contain a great deal of granular pigment, often sufficient to completely hide the nucleus. Seen from the surface these cells present polygonal outlines (Fig. 56). When in such a view the nucleus is visible, the character of the cuticular matrix is at once evident, and it becomes certain that Leydig was entirely wrong in his assertion that the "hypodermis" of insects is formed by connective tissue and not by an epithelium. This mistake has already been carefully and accurately pointed out by Graber.[231]

The coloration of *Anabrus* depends principally upon the pigment of the epidermis shining through the cuticula. Most of the cells contain dull reddish-brown granules, but scattered in among them are patches of cells bright green in color. I have observed no cells intermediate in color; on the contrary the passage is abrupt, a brown or red cell lying next a green one. Indeed I have never seen any microscopic object more bizarre than a piece of the epidermis of *Anabrus* spread out and viewed from the surface. My thought upon first seeing such a preparation was that my reagents must have played me some trick, but preparations made from alcoholic specimens, and examined in alcohol, without having been exposed, to my knowledge, to any other reagent, exhibited the same peculiarities.

The student will find observations on the coloration of the epidermis and cuticula of insects in an article by Dr. Hagen,[232] and a memoir by Leydig.[233]

Sense organs.—This would be the proper place to describe the sense organs, the eyes, and auditory apparatus, &c., but the extreme difficulty of preparing these organs satisfactorily induced me to neglect them entirely, in order to devote my whole time to the investigation of other points, concerning which results were more readily attainable. For the convenience of those who may wish to know the present state of our knowledge concerning these obscure structures, I quote below the titles of some of the more important recent papers,[234] especially those which give references to the earlier publications.

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[231] *Graber:* Denkschr. Wien. Akad. wiss. Bd. xxxvi. (1876), p. 33.

[232] *Hagen:* American Naturalist, vol. vi, p. 388.

[233] *Leydig:* Bemerkungen über die Farben der Hautdecke, etc., bei Insekten. A. f. m. A., Bd. xiii, s. 536 (1876).

[234] *Leydig:* Geruchs-und Gehörorgan der Krebse und Insekten. Müller's Archiv., 1860, p. 292.

Wolf: Das Riechorgan der Biene. Nova. Acta, xxxviii., No. 1.

Grobben: Ueber Bläschenförmige Sinnesorgane der Larve von Ptychoptera contaminata. Sitzber. Wien. Akad., Bd. lxxii. (1876). (List continued on next page.)

Nervous system.—This requires special methods and unusual pains in determining its histological character. I was the less unwilling to let this omission remain, because the nervous system of insects has been the subject of elaborate histological investigations on the part of Professor Leydig,[235] of Bonn, to whose work I may refer those who are desirous of further information on this subject.

A recent article, by Hans Schultze, in vol. xvi, page 57, of the Archiv für mikroskopische Anatomie, is valuable. There is also an extensive memoir by K. R. Krieger,[236] on the nervous system of the crayfish, and another by Bellonci[237] on that of Squilla.

In order, however, to illustrate the general structure of the nervous ganglia, I have given, in Fig. 11, a drawing of a section through the last abdominal ganglion of Caloptenus. The figure is somewhat diagrammatic. A ganglion consists of two parts, the central fibrous portion, from which the nerves arise, and the peripheral layer of ganglion cells, GZ. On each side of these are two nerve roots, one the dorsal, DR, the other the ventral, VR. These Professor Semper,[238] in his article on strobilation and segmentation, homologizes with the roots of the spinal nerves in vertebrates, but I do not know how far his conclusions on this point have been accepted by zoologists. It will be noticed that the four nerve roots in Fig. 11 pass out from the central fibrous mass, through the cellular layer, which latter is thus divided into four fields.

The structure of the supræsophageal ganglion, the so-called brain, is very much more complicated in insects than was formerly supposed. It differs very essentially from any of the abdominal ganglia. The brain of insects has been recently investigated by Dietl,[239] Flögel,[240] and Newton.[241]

Graber: Ueber die tympanalen Sinnesorgane der Orthopteren. Denkschr. Wien. Akad., Bd. xxxvi, (1876), 2 abth., p. 1.

——: Ueber neue Otocystenartige Sinnesorgane der Insekten. Arch. für mikros. Anat., Bd. xvi, p. 36 (1878).

Mayer: Sopra certi organi di senso nelle antenne dei Ditteri. Mem. Reale Accad. dei Lincei. Roma, 4 Maggio, 1879. (A criticism of Graber's paper on Otocysts.)

Grenacher: Untersuchungen über das Arthropodenauge. Klinische Monatsblätter für Augenheilkunde, Jahrg. 15, Beilageheft zum Maiheft, 1877.

Newton: Eye of Homarus. Quart. Journal Micros. Sci., 1875.

Lowne: On the modification of the simple and compound eyes of Insects. Phil. Trans. R. Soc., London, vol. 169, p. 577.

Bullar: On the Development of the parasitic Isopoda. Phil. Trans. Roy. Soc., London, vol. 169, p. 513, 514 (structure of eye).

Graber: Ueber das unicorneale Tracheaten, und speciell des Arachnoideen- und Myriapodenauge. Arch. f. micros. Anat., xvii, p. 58 (1880).

[235] Vom Bau des Thierischen Körpers, Tübingen, 1864. Histologie des Nervensysteme der Arthropoden, pp. 214–226; bei Orthopteren, p. 262.

[236] *Krieger:* Ueber das Centralnervensystem des Flusskrebses. Zeitsch. f. wiss. Zool., xxxiii (1880), p. 527. Taf. xxxi–xxxiii.

[237] *Bellonci, G.:* Morfologia della systema nervose della Squilla mantis. Annali Museo civico stor. Nat. di Genova, vol. xii (1878), pp. 518–545.

[238] *Semper:* Arbeiten des Zool. zoot. Inst., Würzburg, Bd. iii.

[239] *Dietl:* Die Organisation des Arthropodengehirns. Zeit. f. wiss. Zoologie, xxvii, p. 488.

[240] *Flögel:* Ueber den einheitlichen Bau des Gehirns in den verschiedenen Insectenordnungen. Zeitsch. f. wiss. Zool., Bd. xxx, Suppl. (1877), p. 556.

[241] *E. T. Newton:* On the brain of the cockroach, Blatta orientalis. Quatr. Jour. Micros. Sci., vol. xix 1879), p. 340.

Tracheæ.—The tracheæ of insects have long attracted the attention of comparative anatomists, and the curious spiral thread which lies within their interior has been frequently mentioned both by the older as well as the more recent writers. Those who wish to become acquainted with the opinions of the authors of the beginning of this century, will find a capital summary in Shuckard's Burmeister, p. 170. It may, also, be well to state that the tracheæ do not consist of an "external serous and internal mucous membrane," as quoted by Dr. Packard on pp. 40–41 of his invaluable "Guide to the Study of Insects," that idea of their structure being now known to be incorrect. The true structure of these interesting air tubes was not known until 1875, when Dr. Chun, one of Leuckart's pupils, published an article[242] on the "*Rectaldrüsen der Insecten,*" in which he incidentally describes with approximate exactitude

Fig. 6.—Testis of *Anabrus*, showing the ramifications of the tracheæ.

the structure of the tracheæ. Leydig[243] had previously found that the inner membrane consists of two layers, and that the spiral filaments are not distinct and separate, but, on the contrary, intimately connected with the inner membrane. Leydig also found the tracheæ to have an outer layer, which contained nuclei, and which he wrongly supposed to be connective tissue, even venturing to say that no one could think of regarding it as an epithelium. Chun, in his paper above cited, was the first to show that Leydig was in error in making this statement, and that, in a variety of insects, the cellular matrix, which secretes the inner membrane and the spiral thread, is really an epithelium. At the same time I made similar observations on various insects, particularly on the large water

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[242] *Chun:* Ueber den Bau, die Entwickelung und physiologische Bedeutung der Rectaldrüsen bei den Insekten. Abh. Senkberg. Natforsch. Ges. Frankfurt, 1876, Bd. x, p. 27. Structur der Tracheen, p. 39.

[243] *Leydig:* Arch. f. Anat. u. Physiol., 1855, p. 458. Lehrbuch der Histologie, p. 386. Vom Bau des Thierischen Körpers, p. 41.

beetle, *Hydrophilus piceus.* The results of my investigations were afterwards published in Paris.[244] A few months later Graber also described the structure of the tracheæ, pointing out Leydig's error. Graber's observations are published incidentally in his article on the tympanal organs of the Orthoptera.[245]

I have found that the account I then published of the minute anatomy of the air tubes in *Hydrophilus* is applicable, almost without change, to the grasshoppers, and I have, moreover, been able to convince myself that the epithelium is not columnar, but a true pavement epithelium (*Pflasterepithel*) as I had previously found it to be in *Hydrophilus* and other insects. My own observations certainly imply that Dr. Chun is in error as to the nature of this layer in those species that he examined.

In order to avoid repetition I reproduce here a figure (7) of a longitudinal section of a trachea of the European water beetle, taken from the *American Naturalist*, July, 1877. Externally lies the epithelium *ep*, which is readily recognized by the flattened elongated nuclei. Next follows the inner layer of the cuticula, *cu*, and interiorly the darker colored inner layer, in which are imbedded the dark colored spiral filaments *f*. This arrangement recurs in a number of insects and probably in all, the variations being merely in the proportionate thicknesses of the various parts, and the relative size of the spiral threads.

Fig. 7.—Longitudinal section of large tracheæ of Hydrophilus piceus.

If short pieces of the tracheæ be pulled out, then stained with carmine or hæmatoxiline and mounted, it will be noticed that the size of the spiral filaments, and also the distance between them, diminishes with the size of the tracheæ. Where a smaller trachea springs from a larger one, there is not a gradual passage from the large to the small threads, but at the point of origin the filaments of the large tracheæ bend apart so as to leave a space in which the tracheal branch takes rise, beginning at once with small spiral threads.

The preparations we are now considering further show that there is not a single spiral thread, but several, which run parallel to one another, as I have shown before[246], and end after making a few turns around the trachea. The single threads terminate not abruptly but by tapering down to a point and so disappearing.

The nuclei (Figs. 8 and 61) of the tracheal epithelium are elliptical in outline, much flattened, though considerably thicker than the body of the cells. Their long axis is more or less nearly parallel with that of the trachea, and they all have a very distinct and highly refringent nucleolus; sometimes two. The nucleoli are, I believe, always eccentrically

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[244] Archives de Physiologie Normale et Pathologique, 1876, p. 1, and in Ranvier's Travaux du Laboratoire, etc., 1876, p. 1.

[245] *Graber:* Denk. Wien. Akad, xxxvi, p. 35.

[246] *Minot:* Recherches histologiques sur les Trachées de l'Hydrophilus picous. Arch. de Physiol. expt. 1876, p. 1.

placed. The nuclei can be seen in *Anabrus* in tracheæ that have been mounted in balsam, without being stained, for the flat cells are surcharged with unusually large, highly refringent, reddish-brown pigment granules of nearly uniform size (Fig. 61), hence the nuclei appear as clear ovals in the midst of the dark bodies of the cells.

The spiral threads are unusually delicate in *Anabrus* (Fig. 57), and lie quite close together.

In the finer branches of the tracheal system the structure is slightly modified (Fig. 8). In the first place, the nuclei are farther apart, showing that the cells are much larger than in the main tubes, and the nuclei appear much elongated, though their volume does not seem much, if at all, changed. The fine branches divide mainly by forking. In the crotch of the fork there often sits a triangular nucleus of entirely different shape from those on the other parts of the respiratory apparatus (Fig 7 n').

The peculiar elongated shape of the nuclei on the finer tracheæ renders it possible to follow the course of the delicate air tubes (in stained preparations) through the other tissues with considerable ease. Nevertheless it is advantageous in studying the distribution of the tracheæ in the various organs to examine them immediately after the insect is killed, because they are then injected with air, so that under the microscope the large tubes appear silvery and the fine branchlets as dark lines in the fresh tissue. It will then be found that their distribution is almost as characteristic of the single organs as is the course of the blood-vessels in vertebrates. Williams[247] has reported some observations on this subject, but his statements are generally received with some questioning.

Sir John Lubbock[248] has published a valuable and extensive memoir on the distribution of the tracheæ, containing the results of observations on a very large number of insects of all orders. As far as I have been able to express my own results in general terms, I believe they are confirmed by the facts recorded by Lubbock. I find that the distribution of the tracheæ depends, *first*, upon the shape of the organs, and, *secondly*, upon the size of those whose size is variable; whereby it must be remembered that *the tracheæ, as far as at present known, are exclusively confined to the connective tissue, including, of course, the fat body.* No epithelium is ever penetrated by the air tubes in any instances known to me, through either my own observations or the writings of others. I give descriptions of the distribution of the tracheæ in certain organs of *Caloptenus* and *Œdipoda.* Around the large organs (intestine, sexual organs), with interior cavities, the tracheæ ramify in all directions, as on the ovary, for instance, Fig. 13, forking so that the branches diverge at a wide angle. In the organs which have muscular walls, like the oviduct (Fig. 14), for example, the tracheæ run straight when the walls are distended, but have a sinuous course, as in the figure (14), when

[247] *Williams:* Ann. Mag. Nat. Hist. (1854), vol. xiii, p. 194.
[248] *Lubbock:* Distribution of the tracheæ of insects. Phil. Trans. 1860, vol. xxiii, p. 194.

the walls are contracted. This shows, as I also know from direct observation, that the tracheæ, though capable of great elongation, are more easily bent than compressed, so as to diminish their length. Around the organs of more elongated form the branches of the tracheæ run more longitudinally, as is shown by the air tubes of the muscles, which also present some peculiarities worthy of especial notice. A short thick trunk (see Fig. 12) arrives at the muscular bundle, and, dividing very rapidly, breaks up into a large number of delicate tubes, which penetrate between the muscular fibers, there terminating in tubes of exceeding fineness, which, at first sight, seem to form a network that might well be called a *rete mirabile*. A closer examination, however, reveals that it is not a real network, but rather an interlacing, confusing to the eye. The longitudinal direction of the tracheæ of the muscles presents a striking contrast to the system of divarication, represented in Figs. 13 and 14. The course of the tracheæ of the Malpighian tubes is also very curious. It is represented in Fig. 10. There is one large trachea which winds around the tube in a long spiral, giving off numerous small branches, which run to the surface of the tube, upon which they form delicate ramifications. Each tube has but a single main trachea, and I think the trachea continues the whole length of the tube, but of this last point I am not quite sure.

Many organs, as for instance the testis of *Anabrus* (Fig. 6 in the text), are supplied by a few large tracheal trunks, which give off many small branches, the ramifications of which penetrate the organ in question.

The fine terminations of the tracheæ have been investigated, as far as I am aware, only by Max Schultze,[249] Weismann,[250] and H. Meyer.[251]

They all agree in stating that they end blindly in stellate and branching cells. Max Schultze discovered that these terminal cells are dyed black by per-osmic acid, so that they are then very sharply marked off from all the surrounding tissues. The tracheæ extend into the interior of these terminal cells. Graber[252] gives a singular account of the termination of the tracheæ in *Phthirius inguinalis*. I cannot but think that his description is based upon a false interpretation of his observations.

The development of the tracheæ has been studied by Weismann and Meyer in the papers just cited, and also by Semper,[253] in an admirable paper on the development of the wings in Lepidoptera.

Dr. Williams, in his article published in the Annals and Magazine of Natural History for 1854, vol. xiii, maintained that the finer branches anastomosed, resembling in that respect the capillaries of vertebrates. Lubbock has already pointed out that the tracheal anastomoses are con-

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[249] *Max Schultze:* Zur Kenntniss der Leuchtorgane von Lampyris splendidula. Arch. f. mikros. Anat. 1, p. 124; Tracheen, p. 130, ff.; figs. 4, 5, 8, and 9.

[250] *Weismann:* Die Entwickelung der Dipteren im Ei. Zeitschrift für Wiss. Zool. Bd. XIII (1863), p. 193.

[251] *H. Meyer:* Ueber die Entwickelung des Fettkörpers, der Tracheen und der keimbereitenden Geschlechtstheile bei den Lepidopteren. Zeitsch. f. wiss. Zool. Bd. I, p. 174.

[252] *Graber:* Zeit. f. Wiss. Zool. XXII, 147 (1872).

[253] Zeit. Wiss. Zool. VIII, p. 328.

fined to the larger branches. My observations on the grasshoppers entirely confirm Lubbock's opinion, and probably his conclusion may be safely made general for all insects.

Air-sacks and spiracles.—Concerning the latter I have made no observations, considering that an account of their structure belongs rather to the anatomist. Of the air-sacks I have only to say that in them the spiral filament is wanting, their inner walls being thrown up into quite high and somewhat irregular folds, but concerning the histological elements of the sacks I can add nothing to what is already known. The absence of the spiral thread had already been noticed by the older authors.[254] The true air-sacks must be distinguished from simple tracheal dilatations.

MUSCLES.

By far the majority of the muscular fibres in *Caloptenus* and *Œdipoda* are transversely striated. Examined with a high power they are found to resemble closely the fibres of the common water-beetle, which has been so often figured and studied.[255] First there is a broad dark band, then a broad light band, which is, however, divided in two by a narrow dark line, just as in the fibres of *Hydrophilus*, figured in the accompanying woodcut.

FIG. 8.—Muscular fibre of Hydrophilus piceus.—After Minot.

The way in which the muscular fibres are grouped together varies very much in different parts of the body. For instance, in some of the muscles of the head the fibres are not collected in bundles, but are more or less isolated, as appears with the utmost distinctness in a transverse section like Fig. 5, while the muscles of the thorax form bundles of more or less cylindrical form, as appears in Figs. 9 and 6 *r. m.* The single fibres are not round, as might be thought upon looking at one spread out longitudinally, but polygonal in section, as is seen in Fig. 5, the corners being rounded off. They are commonly four-sided, but sometimes three or five-sided. In every muscular bundle there are to be seen oval nuclei, whose long axes lie more or less nearly parallel with the direction of the muscular fibres. The nuclei are small and flattened, slightly granular, and many of them (Fig. 9) contain a small eccentric nucleolus. They are situated on the surface of the fibres, to which I think they belong, though they are perhaps the nuclei of the sarcolemma.

Besides the striated muscles there are also smooth fibres to be found around the intestine, as will be more particularly described hereafter.

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[254] *Burmeister:* Manual of Entomology, translated by Shuckard, p. 178.

[255] *Ranvier:* Traité Technique d' Histologie, p. 477 ff.

Dr. T. Dwight: Structure and action of striated muscular fibre; in the Proc. Boston S. N. H. (1873-'74), vol. xvi, p. 119.

Engelmann: Plüger's Archiv. für Physiologie, Bd. vii, pp. 33 and 155, and Bd. xviii, p. 1, and many others.

This is not the place to describe the single muscles of the body, but there is one which I will mention, because its disposition can hardly be seen as clearly in any other way but in a section through the abdomen. The muscle in question is shown in Fig. 6 *r. m.*, and may be called the *M. respiratorius*, for it serves to approximate the upper and lower cuticular arches (Fig. 2 *D* and *V*) and so to diminish the capacity of the abdomen, hence it is to be concluded that it subserves the act of expiration. It has a broad attachment to the lower part of the side of the dorsal arch (cf. Fig. 2 *r. m.*) and a narrow insertion into the upper edge or rim of the ventral arch. It is surrounded by a network of fibrous connective tissue. Graber[256] calls this muscle the "dorso-ventral." In the living grasshopper the respiratory movements of the two arches are readily seen.

ORGANS OF CIRCULATION.

These organs I have not examined with sufficient attention to justify the publication of my fragmentary observations. The two most recent articles on the heart are by Graber[257] and Dogiel,[258] both of whom refer to the older literature. I wish also to use this occasion to refer to the investigations of Graber[259] on the pulsating ventral sinus of insects, and the discovery of ganglion cells in the heart of crustacea by Dogiel[260] and Berger.[261] The student should also compare Burger's paper[262] on the so-called ventral vessel, which he shows to be really a cord of connective tissue surrounding the ventral ganglionic cord.

CONNECTIVE TISSUE.

In insects all the internal organs of the body are, so to speak, spun around by a web of fibrous and fatty tissue, which extends in the space between the outer body wall and the digestive tract, so as to surround all the intermediate parts. This is the connective tissue, which also acts as carrier or staging of the tracheæ. The arrangement of this network is such that the spaces left between the beams or threads of it form a system of lacunar spaces, which serve as channels for the circulation by being directly connected with the arteries on the one hand and the veins on the other. Indeed it is not improbable that the distinctive blood-vessels are nothing more than specialized lacunæ of the connective tissue, so that it would be eminently proper to consider the vas-

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[256] *Graber:* Denkschr. Wien. Akad., Bd. 36, p. 75.

[257] *Graber:* Ueber den propulsatorischen Apparat der Insecten. Arch., f. mikros. Anat., ix (1873), p. 129.

[258] *Dogiel:* Anatomie und Physiologie des Herzens der Larve von Corethra plumicornis. Mem. Acad. St. Petersb., xxiv, No. x (1877).

[259] *Graber:* Ueber den pulsirenden Bauchsinus der Insecten. Arch. f. mikros. Anat., xii (1876), p. 575.

[260] *Dogiel:* De la Structure et des Fonctions du Cœur des Crustacés. Arch. Phys., 1877, p. 401.

[261] *Berger:* Ueber das Vorkommen von Ganglienzellen im Herzen des Flusskrebse, Vienna, 1877, published by Gerolds Sohn.

[262] *Burger, Dionys:* Über das sogenannte Bauchgefäss der Lepidopteren, nebst, etc. Niederl. Arch. f. Zool., iii (1876), p. 97.

cular system under this head had the time at my disposal permitted my investigating it.

In the connective tissue we find, first, long fibres upon which sit small compressed and elongated nuclei (Fig. 6 *con.*), and which form a loose network; second, the pale round cells, with a nucleus at the periphery (Leydig's *zellig blasiges Gewebe*[263]) : third, the fat-cells[264] (Fig. 15); and, fourth, the connective tissue with stout trabeculæ and small meshes around the ovary (Fig. 17). I shall here speak only of the third and fourth kinds of tissue. The "*Fettkörper*" of the Germans, or the fat-body, is generally, and I think correctly, supposed to be merely a modification of the connective tissue. Fig. 15 is from a section cut from the object after it had been imbedded in paraffine, so that the action of turpentine on the cells, while the object was being prepared for imbedding, probably altered their appearance from what is natural by dissolving a portion of the fat they originally contained. In a preparation of this kind, which has been colored by hæmatoxiline, the outlines and nuclei of the cells appear very distinctly. The cells are nearly of uniform size, and so crowded together (Fig. 15) that their walls are flattened by mutual pressure. The nucleus is placed in the center of the cell and is nearly or quite spherical, and especially characterized by containing some fifteen to twenty or more large granules of nearly uniform size and darkly colored by the logwood, while the intervening spaces are quite pale and clear. The nature of the body of the cell is obscured by numerous indistinct lines and dots, the real nature of which I have been unable to make out.

Graber has described some interesting peculiarities in the fatbody of insects, especially in *Pthirius*.[265] He found the cells in this insect to be elongated, charged with greenish pigment, with spherical nuclei. One end of the cells is pointed and free, the other is united with a cord of connective tissue, the ultimate course of which he could not follow. Graber suggests that these cords contain tracheæ running to terminate in the fat-cells themselves. Besides these Graber saw other fat-cells in which he discerned no nucleus. The presence of pigment in the fat-cells is very common. The pigment is usually green or yellow, but sometimes of other colors.

As regards the connective meshes with stout trabeculæ around the follicles of the ovary, I believe that Fig. 17 illustrates its appearance in the locusts better than any description I could give. I will, therefore, only call attention to the rounded form of the openings and their unequal size, and I have often seen them much larger than any in Fig. 17. Of this same ovarian tissue I have obtained very beautiful preparations from *Anabrus* (Fig. 62), showing both its fibrous character and the shape and form of its nuclei. The fibres are exceedingly fine, and show a tend-

[263] *Leydig* Vom Bau des Thierischen Körper's. Tübingen, 1864, p. 29.

[264] See particularly *Leydig* Ueber den Fettkörper der Arthropoden, Müller's Arch., 1863, p. 192.

[265] Graber Z. Z., xxii, p. 152–157. Taf. xi, fig. 7 *b*.

ency to gather themselves into bundles, which, though they run in various directions, have a common trend parallel to the ovarian tubes. The interspaces of the network are, for the most part, of an elongated, rounded form, their long axes being parallel with the general trend of the fibres. The majority of the nuclei are irregularly oval in shape, and contain numerous granules, which are darkly stained by hæmatoxiline. Whether these nuclei belong to the fibrous tissue itself or to an endothelium covering it, I cannot say. The latter view seems to me more probable.

A very singular modification of this tissue may be found in the *tunica propria* of the Malpighian vessels of *Anabrus*. Spiral bands wind round the tubes. These bands are composed of a network of fine fibres, with small meshes and occasional granular oval nuclei, each of which is surrounded by a little *court* ("*hof*") of protoplasm. At first sight these bands might be taken for a nervous plexus, but closer examination reveals their true character. In the locusts, as will be described shortly, there is a trachea which winds round each Malpighian tube in a spiral. It is possible that a similar disposition exists in *Anabrus*, though I have not observed it. In that case the spiral bands of connective tissue in the latter insect may be the means of fastening the trachea to the walls of the Malpighian tube.

The trabecular or retiform modification of the connective tissue is probably very generally, if not always, to be found in all invertebrates above the *Cœlenterata*. It does not seem to me necessary to give extended references. I will, however, mention Grobben's figure.[266]

The nervous chain of Lepidoptera is covered in the abdomen, but not in the thorax, by a cord of connective tissue, originally described by Treviranus as a ventral vessel, "Bauchgefäss." Its true nature was first recognized by Leydig in 1862, and more recently it has been the object of a special study by Dionys Burger,[267] who proposes for it the name of *chorda supraspinalis*. It is to be hoped that subsequent investigators will search for this organ in the Orthoptera and other insects in which we may reasonably expect to find it.

SEXUAL ORGANS.

I.—Female organs.

Ovary.—The ovary is composed of a number of separate tubes, each of which is more or less independent. They all have essentially the same structure histologically, the differences I have observed relating merely to the proportions of the parts to one another. Every ovarian tube begins in the thorax with a small cord (Fig. 64 *ch.*) of connective tissue, which is said to be attached to the heart.[268] Graber states that in

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[266] *Grobben:* Die Geschlechtorgane von Squilla mantis. Sitzber. Wien Akad., Bd. lxxiv 1. Abth., p. 389. (Fig. 8 of plate.)

[267] *Burger, Dionys:* Über das sogenannte Bauchgefäss, etc. Niederl. Archiv. für Zool., iii (1876), p. 97.

[268] Leydig, Burmeister, Waldeyer, Lubbock, and others.

Phthirius, *three* cords spring from each ovarian tube, instead of one as in most insects. Leydig[269] considers this cord to be hollow, while most other authors describe it as solid in the insects they have examined. Neither in the locust or the cricket have I seen any trace of an interior cavity. The cord is covered by an external membrane, very thin, and apparently homogeneous, except for the nuclei, which enter into its composition, and appear in stained preparations as dark bodies projecting above the general level of the membrane, which, in short, very closely resembles the *tunica propria* of the Malpighian tubes. In the interior of the cord are numerous granular oval nuclei (Fig. 64 *ch.*), their long axes being nearly parallel with that of the cords. If a cord be teazed out with needles, each nucleus is found to lie in the middle of a spindle-shaped body, from either end of which a thread-like process runs out lengthwise of the cord. In what manner these threads terminate I do not know. This cord runs to the rounded tip of the ovarian tube, which begins quite abruptly, quickly attaining twice the diameter of the cord in *Anabrus* (Fig. 64), or three or four times in the locusts. From the tip downwards the tube is divided into compartments, each of which contains a single egg. The lower we go, the wider the tube and the more advanced in development the egg. Between every two fully-developed compartments the tube is somewhat constricted. In *Anabrus*, a long narrow piece sometimes intervenes between two adjacent compartments. In locusts, at least, the tubes are narrowed by a marked constriction just before they open into the oviduct. In *Anabrus* (Fig. 64 *a*), the commencement of the upper end of the ovarian tube proper is marked by the transverse direction of a few oval nuclei. Immediately below these are found rounded nuclei, and among them lie a few cells which have already assumed the distinctive characters of eggs; these latter cells are larger the lower their position. In this part of the tube (Fig. 64 *a b*) there is no distinct division into compartments. The corresponding region in locusts differs in that at the upper end or very tip I could distinguish only one kind of cells, which had clear nuclei and distinct nucleoli. Lower down some of the cells become larger than their fellows, and partly surrounded by them; still lower the large cells appear isolated, larger, and completely inclosed by a layer of cells that form a perfect epithelial follicular wall.

The remaining lower and largest part of the ovarian tubes is divided into distinct compartments or follicles. As we proceed downward in our examination of the tube we see that the egg-cells, which were at first spherical, become elongated in the direction of the axis of the tube, while at the same time the nucleus becomes indistinct, and the protoplasm of the original cell charged with yolk granules, the deutoplasm of Édouard van Beneden.[270]

It will thus be seen that the development of the eggs in *Caloptenus*

[269] *Leydig:* Zum feineren Bau der Arthropoden. Müller's Archiv., 1855, p. 472–3.

[270] Composition et Signification de l'œuf. Mém. cour. Academie Royale Belg., T. xxxiv, p. 1 (1870.)

and *Anabrus* is identical with that observed in other insects,[271] for which I refer the reader to Waldeyer,[272] Leydig,[273] and particularly to the elaborate and accurate memoir of Dr. Ludwig.[274]

I wish to describe somewhat carefully the relation of the egg to the cells of the follicular wall in the locust. If a bit of the wall of one of the largest follicles be spread out on a slide and colored with carmine it will be seen that it is composed of very large and beautiful cells, Fig. 20. The cells are for the most part pentagonal in outline, a few being hexagonal. The nuclei are very large, taking up a great part of the cells, in the center of which they lie. They are slightly oval, though departing but little from a circular outline. They are darkly colored by carmine, and are filled with innumerable small granules, which prevented my ascertaining whether there is any nucleolus, though in many cases there seemed to be one of considerable size. A transverse section through the whole follicle, such as is reproduced in Fig. 19, shows that the cells form a single continuous layer, *Ep*, around the egg, *Eg*. Examined with a higher power, Fig. 16, such a section reveals the form of the cells. The free or outer surface of the epithelium, *Ep*, is nearly flat, while the side towards the egg, *Eg*, is dome-shaped. Between the epithelium and the egg there is a layer, *Sh*, of finely-granulated and very pale substance that is not colored by carmine or hæmatoxiline. This layer has its outer surface hollowed out into little cups, each of which is intended to receive the dome-shaped end of one of the epithelial cells, as is shown very plainly in Figs. 16 and 19, which represent sections in which the epithelium is artificially raised from the granular layer. In the normal condition the cells rest directly on the layer, and there is no clear space, as indicated in Fig. 16. It is to be added that the layer in question consists of three strata: 1, a very delicate external membrane, which rests against the epithelium; 2, the middle granular portion; and 3, a fibrous stratum, which assumes a roseate hue after staining with carmine, and which lies next the egg. The layer is formed in the follicles, and is probably secreted by the follicular epithelium. It is not to be found in the upper part of the ovarian tube. If I am not mistaken, it passes over with the egg into the oviduct, being destined to form part of the shell. I cannot help suspecting that it is this structure which has given rise to the opinion that, at least in some insects, the wall of the egg follicle passes off with the egg to form part of the shell.

In the egg proper of locusts, Figs. 16 and 19, *Eg*, the enormous masses of nutritive yolk deserve special mention, though I have been unable to determine their relation to the protoplasm of the egg.

The ovarian tubes have further an external tunic, which I have studied

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[271] Excellent diagrams of the development of eggs in insects are given in Gegenbaur's Grundzüge der Vergleichenden Anatomie. 2 Aufl., p. 463, fig. 121, and an even better figure of *Vanessa urticæ* is given by Waldeyer in Stricker's Handbuch der Lehre von den Geweben, p. 563, fig. 195.

[272] *Waldeyer:* Eierstock und Ei, Leipzig (1870), p. 86, and especially *p.* 90.

[273] *Leydig:* Eierstock und Samentasche der Insecten. *Nov. Act. Caes. Leop.*, xxxiii (1867).

[274] *H. Ludwig:* Semper's Arbeiten. Bd. I.

in Anabrus only, Fig. 64, *Tu*, continuous with the *tunica externa* of the cord *ch*. The appearance of the tunic is represented at *Tu*, the rest of Fig. 64 being drawn with the objective focused lower. The membrane is thin, delicate, and entirely distinct from the follicular epithelium, which has shrunk away from it, as seen in the figure. The external tunic is very transparent, and contains more or less nearly oval, flattened nuclei, with no distinct outline or apparent nucleolus, and containing a single layer of fine granules, all of which are darkly stained by hæmatoxiline. Apparently every granule lies by itself, and is separated from its fellows by a clear space, only very slightly tinged by the logwood. Toward the upper end of the tube the nuclei are smaller and lie closer together. They lend a peculiar character to the tunic, and remind one of the similar nuclei in the *tunica externa* of the spermatic tubes of locusts.

The peculiar net-work of connective tissue which surrounds the ovary, and which is represented in Figs. 17 and 62, has already been described.

Anterior cæcum of the oviduct.—By this name I designate the narrow convoluted anterior prolongation of the oviduct in locusts, which Dufour[275] calls the "boyau borgne et flexueux, qui termine l'ovaire en avant," and which is represented on his Plate II, Fig. 18 *c*. In a transverse section through the middle of the abdomen, the two cæca are cut across several times, *ovd*, in Fig. 1. It is then seen that they are tubes with thick walls and a cavity of moderate size. The main thickness of the wall is made up by the epithelium, the real character of which is obscure in my preparations, there being a great many oval nuclei scattered through it at all levels, while the limits of the single cells do not appear. Outside the epithelium is a distinct but thin layer formed by the connective tissue, tracheæ, and muscular fibres, which, as far as I can make out, seem to run circularly. It is very possible that in better preparations longitudinal fibres will be likewise found.

Uterus of locusts.—I employ this name to designate the enlarged upper end of the oviduct, or that division which Dufour in his classical memoir calls the "calice."[276] Of this organ I have obtained some very beautiful preparations from *Œdipoda sordida*. If the whole uterus just before the eggs descend into it be hardened in alcohol and then examined, it will be found to be compressed laterally. With a very sharp razor it may then be cut in halves, so as to obtain two flat pieces; some granular matter and coagulated secretions will be found adherent to the inner surface, which may be removed under alcohol by the careful use of a camel's hair brush. The piece may then be colored with hæmatoxiline, and mounted, with the inner surface upwards, in Canada balsam. Part of such a preparation is represented in Fig. 21. The inner surface is seen to be lined by a beautiful epithelium, which is thrown up into broad transverse folds, with intervening depressions of about

[275] Recherches Anatomiques et physiologiques sur les Orthoptères Mémoirés à l'Acad. R. des Sci. Inst. France, 1834, p. 324.

[276] *Dufour:* l. c. Planche II., *fig.* 18.

the same width; the folds are not quite regular, but sinuous in outline, though, roughly speaking, they are all parallel to one another. Under a higher power, the epithelium is seen to be composed of cells, which, viewed from above, present a polygonal outline, varying with each cell, as is seen in Fig. 23; the nuclei appear nearly in the center of the cells; they are oval, and coarsely granular, the granules being darkly colored by hæmatoxiline and all of nearly uniform size; I failed to detect any nucleolus. The relations of the epithelium to the remaining layers of the uterine walls appear best in longitudinal sections, because in them the folds are cut across. Fig. 22 is taken from a section of a uterus *distended* with eggs, and therefore with the folds very much drawn out. The cells of the epithelium, Fig. 22 *ep*, are "*cylinder cells*," with the large nuclei lying somewhat towards their free or *inner* ends. Their appearance is better shown in the enlarged drawing, Fig. 18; they are sharply separated from one another; their protoplasm is finely granular, the granules being unequally distributed so that some parts of the cells appear clearer than others. The free surface of the cells is nearly if not quite flat, while their outer ends or those which rest upon the connective tissue (*conn.*) are often rounded; finally, the cells are not all of the same height. Outside the epithelium follows a layer of fibrous tissue, in which the tracheæ ramify, Fig. 22, and which contains numerous small, oval nuclei belonging to the cells of the tissue and elongated nuclei of the fine tracheal branches, as represented in Fig. 7. Outside the connective tissue lie the muscular layers, Fig. 22 *muc.*, the fibres of which are all smooth and not striated. They are arranged so as to form an internal circular, and a much more powerful external longitudinal coat, that is very distinctly shown in Fig. 22. Within, the epithelium is covered by a layer of fibrous matter, *Gr.*, that fills up the whole space between the uterine walls and the eggs. In many sections there are nuclei contained in this mass, closely similar to those in the underlying epithelium. As to the nature of this layer and the source of the nuclei I cannot venture an opinion.

The remaining portions of the efferent ducts of the female apparatus I have not investigated. I particularly regret my inability to give some account of the receptaculum seminis. The reader will find some unsatisfactory, because very brief, notices of the female appendices in Leydig's Textbook,[277] and a more elaborate monograph[278] by the same author giving a general account of the structure of the *receptaculum* in insects, but containing no new observations on the Orthoptera, though in a previous article[279] Leydig has described the "*Samentasche*" in this order as being lined by an epithelium, which rests on a *tunica propria* and bears a chitinous cuticula, and outside of which is a thin layer of striated muscle. The part that Dufour[280] calls the "*glande sébifique*" is really the

[277] *Leydig:* Lehrbuch der Histologie, p. 544.

[278] ——— Nova Acta, xxxiii (1867).

[279] Müller's Arch., 1859, p. 86.

[280] *Dufour:* Recherches sur les Orthoptères, l. c. 325, Pl. II, fig. 17 *c*.

receptaculum seminis. A description of the receptaculum and its ducts in *Phthirius* is given by Graber.[281]

2.—Male organs.

The close analogy between the male and female genital systems in insects is shown by the correspondence of their divisions, and has been repeatedly pointed out. The analogy in the way in which the sexual products are developed, though attention has been called to it, has not been so often emphasized. The testes are elongated sacks or tubes whose upper ends terminate blindly and whose lower ends open into the efferent ducts. The spermatozoa begin their development in the cæcal end, in which, accordingly, we find the earliest stages always represented, while the more advanced zoosperms all lie further down in the sack, just as we find the youngest stages of the eggs in the upper, the oldest in the lower part of the ovarian tubules. The simplicity and distinctness of the parts and straightness of the seminiferous tubes in the grasshoppers renders the testes of these insects the very best object to demonstrate the development of the spermatozoa, with which I am acquainted, as in a single preparation all the principal stages are often distinctly shown.

Testis.[282]—The male glands are composed of tubes which, instead of ascending from below *forwards* as do the ovarian tubes, incline from below *backwards*. The whole set of tubes is inclosed in a common sack-like envelope (Fig. 6, p. 191, testis of *Anabrus*), and from this the tubes must be isolated. I have found the most convenient way of doing this to carefully harden a whole male insect in alcohol, and then to cut the whole abdomen in two along the median line, after which if a little pains is taken the single seminiferous tubes, which will be easily recognized lying over the stomach, can be isolated under alcohol with needles. The following account refers to locusts only. The general shape of one of the tubes is shown in Fig. 25. The upper end is rounded off, and from the tip downwards it widens very rapidly, the tube soon attaining its maximum diameter, which it then maintains through the rest of its upper half; the lower half gradually tapers down to a comparatively small tube. The whole, when isolated in the manner described, is more or less surrounded by connective tissue, as shown in the drawing, *conn.* The tube may be roughly divided into four segments as indicated by the numbered brackets of Fig. 25. The upper segment [I] is filled with aggregations of cells in various stages of transformation into spermatozoa, but still distinctively cellular in their appearance. In the second segment [II] the cells are gathered into distinct bundles, each bundle being as shown in the figure in a different stage of development, those lowest down being most advanced; in Fig. 25 each one of the dark masses represents one of the bundles, each of which is composed of a

[281] *Graber:* Z. Z., xxii (1872), pp. 161–162.

[282] This account of the testis is taken mainly from *Caloptenus spretus*.

great many cells or spermatozoa, the dark portions indicating, however, only the heads of the zoosperms, the tails being many times longer, but very pale; it will be noticed that the shape of the bundles changes from above downwards, being broad with rounded ends in the upper part, and becoming narrower and sharply pointed lower down. In the third segment [III] the interior of the tube is entirely filled up with the long tails of the spermatozoa, the tails belonging to each set of heads being themselves gathered into a sinuous bundle, which are perhaps fifteen or twenty times as long as the bundles of the heads. Finally, the fourth segment is filled with globules of various sizes, highly colored by the hæmatoxiline, very slightly refringent, and closely crowded together, leaving room only for small interspaces and a few bundles of spermatozoa tails which extend down among them.

Before entering into the description of various details, which can be studied on the isolated tube, I will describe a transverse section through the upper part of the first segment, such a section as is represented in Fig. 24. The whole tube is formed by an external membrane, *Tu.*, and its interior is divided up by septae, *cys.*, into several distinct cavities, the *spermatocysts*, each of which contains a number of cellular elements, the *spermatoblasts*, all in about the same stage of development. In the walls of the spermatocysts there are a number of peculiar nuclei, so flattened that in a transverse section they appear as hardly more than a narrow dark line, as is indicated in the figure. The cells of the spermatoblasts are large and distinct, and are destined to be transformed each one into one or more spermatozoa. Near the top of the tube the spermatoblasts are round cells, the protoplasm of which is highly tinged with hæmatoxiline, and which are provided with a bulky central nucleus each, as is shown in Fig. 26. The nuclei are approximately spherical and very coarsely granular, the granulations being dyed almost black by hæmatoxiline. Judging from the analogy with other animals, the parts just described must be interpreted as follows: The whole of each *spermatocyst* arises from a single cell, in which the original single nucleus gives rise by division to the secondary nuclei, each of which becomes a *spermatoblast*, the original cell enlarging until it becomes a cyst; the mother nucleus also divides into nuclei like itself, which become transformed into the peculiar nuclei before mentioned, in the wall of the cyst. This is of course all hypothetical, not based upon direct observation, for in all the seminiferous tubes I have had an opportunity of examining the cysts and spermatoblasts were all fully formed. The most complete and satisfactory account which I am acquainted with of the development of the spermatozoon is that given of the frog by La Vallette.[283] I would also refer those who wish to understand the great theoretical importance of these facts to the brief summary of the observations previously made, which I have published elsewhere.[284]

[283] *La Vallette:* Archiv für Mikros. Anat., Bd. xii, s. 797, Taf. xxiv, xxxv (1876).

[284] *Minot:* Theory of Impregnation. Proc. Boston S. N. H., 1877, vol. xix, p. 165.

Let us now return to the examination of an isolated tube. In it also we can recognize the single cysts, and we perceive at once that each cyst pursues its independent development, and gradually changes into one of the bundles that appear so very plainly in the second segment, Fig. 25 II. It will next be noticed that the further we descend the more numerous and the smaller the spermatoblasts in each cyst, the nucleus diminishing in size with especial rapidity. The nature of these changes appears in Figs. 26, 28, 29. Fig. 26 represents a few spermatoblasts from the upper portion of segment I; their characters have been already described. Fig. 28 is taken from lower down. Fig. 29 is taken from a transverse section of one of the upper bundles of the second segment. The cells have begun to lengthen, but the nuclei have not changed much. To this fact I shall recur directly.

Segments I and II, Fig. 25, correspond to two natural stages in the development of the spermatozoa; first, the multiplication of the spermatoblasts; second, the metamorphosis of the spermatoblasts into the spermatic threads (*Samenfäden*). It is therefore only in the first segment that we find the signs of division, which have been frequently noticed in the development of the male products in various animals (I may mention the Batrachians in particular[285]), but have, I believe, hitherto puzzled all naturalists, without exception. These signs of division are the cells, such as are shown in Fig. 27, which, instead of the ordinary nuclei, contain a number of very dark and very large granules, often somewhat irregularly distributed. I have been so fortunate as to obtain some of these cells isolated, and saw at once that they were in process of division, and upon closer examination, with a very high power (Tolle's immersion $\frac{1}{12}$th), I was able to see that many of them were in the condition indicated by Fig. 27 A, elongated, constricted in the middle, the granules accumulated at the two opposite poles, and running between the two accumulations a faint striation. There can be no doubt that this represents the last stage of the division of the nuclei, by the formation of a *Kernspindel*, that remarkable phenomenon which has been so actively studied in Germany and Switzerland during the last two years by so many distinguished observers.[286] This discovery naturally leads to a variety of theoretical considerations, which cannot be appropriately introduced here. I will add that I have observed several other stages in the formation of the *Kernspindel*, but as my investigations on this point are still incomplete, I will reserve further details for another occasion.

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[285] *Spengel:* Urogenital System der Amphibien. Semper's Arbeiten, iii, p. 1, plate ii, figs. 27–34, Spermatozoa of Epicrium glutinosum.

[286] *Bütschli:* Studien über die ersten Entwickelungsvorgänge der Eizelle, etc. Senkberg. Natf. Ges., Frankfort, Bd. x, p. 1.

——— Zur Kenntniss der Theilungsprocess der Knorpelzellen. Zeitsch. Wiss. Zool., xxix, p. 206.

——— Entwickelungsgeschichtliche Beiträge. Zur Kenntniss der Furchungsprocess bei Nephelis. Z. Z. xxix, p, 239.

O. Hertwig: Befruchtung, etc. Morph. Jahrb. i, p. 347; iii, p. 1 and p. 271.

H. Fol: Sur le Developpement des Ptéropodes. Arch. Zool. Expt. Gén. (1875), Tome iii, p. 104; also, same journal, T. V, Fasc. ii.

Compare also the writings of Auerbach, Strassburger, Balfour, *et al.*

Since the peculiar cells of Fig. 27 are signs of division they are not always present, but in some tubes they are absent altogether. The multiplication of the spermatoblasts by self-division is interesting because it shows that all the male elements do not arise directly from the mother nucleus, a fact of most profound theoretical meaning.

We must now pass to the consideration of the alterations of form which the spermatoblasts undergo after their multiplication ceases. As before stated, these changes occur altogether in the second segment of the tube. The body of the spermatoblasts begins to change before the nucleus, as is frequently the case with other animals,[287] and is perhaps even the general rule. In the grasshopper the cells begin to elongate, the nucleus remaining in the upper part. There remains a small head of protoplasm around the nucleus, while the rest of the protoplasm lengthens out to form a long tail, so that when the spermatozoon is about half-developed it consists of a head with a small, spherical, granulated nucleus surrounded by a little protoplasm, which is prolonged into a thread-like tail. The further metamorphosis consists mainly in the elongation of the nucleus, it first becoming pointed at both ends and bulging in the middle, then growing more and more rod-like until it is quite filamentous and about six times its original length; meanwhile the protoplasm around the nucleus gradually disappears, forming probably the little thread that extends beyond the nucleus, and also contributing to the growth of the tail. The nucleus, while lengthening out, does not remain perfectly straight, but at a certain period of its formation is curved somewhat in the form of an S. The nuclei afterwards straighten out again forming the heads of the spermatozoa and they then lay themselves parallel to one another, and as they become more perfectly packed together they form the sharp-pointed bundles, which are so characteristic of the lower part of the second segment of the seminiferous tubes, Fig. 25, II. In a transverse section through the head of a bundle of spermatozoa, the heads appear as minute dots closely crowded together, while in a section of a younger bundle, Fig. 30, they lie at some distance apart.[288]

There now remain to be mentioned the very singular nuclei which appear in the walls of the seminiferous tubes in the lower three-quarters of their length. They are irregularly distributed, oval, very much flattened, quite large, and contain a few large granules, which alone are stained by hæmatoxiline, the intervening space remaining perfectly clear.

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[287] *La Vallette St. George:* Der Hoden in Stricker's Handbuch i, p. 522, especially figs. 183, 188, 189.
——Ueber die Genese der Samenkörper. 4. Mittheilung. Arch. Mikros. Anat., Bd. xii, p. 797.
Spengel: l. c.
Braun: Das Urogenital System der einheimischen Reptilien. Semper's Arbeiten, iv, p. 113. Hoden, p. 158 ff.
Kölliker: Handbuch der Gewebelehre, 5 Aufl., 1867, pp. 526–528.
Sertoli: Sulla Struthora delli Canalicoli seminiferi, etc. Archivio delle Scienze Mediche, vol. ii, p. 107 (1877).

[288] For other accounts of the development of spermatozoa in insects the reader is referred to H. Meyer, Zeit. Wiss. Zool., Bd. i, p. 187.

I think these nuclei are probably the degenerating remains of the nuclei in the walls of the spermatocysts, and which I regard as the mother nuclei of the spermatoblasts.

Vasa deferentia of locusts.—These are long, nearly cylindrical tubes, the walls of which are composed of an interior lining epithelium and an external layer hardly one-fourth as thick as the epithelium, and composed of connective tissue and tracheae, and, as far as I have been able to observe, entirely without muscular fibres. The epithelium is formed of cylindrical cells, with large and distinct nuclei in the basal third of each cell. It is interesting to compare these ducts with the corresponding canals of crustacea, the histology of which has been recently studied by Grobben[289] and by August Gruber.[290] It now seems probable that further observations will soon render it possible to give a description of the minute structure of the male ducts which shall correctly record the typical form among arthropods.

Ductus ejaculatorius of locusts.—If we make a transverse section through the abdomen of a male *C. femur-rubrum* at the level where the ejaculatory duct runs straight along underneath the dorsum a section of the duct will be obtained of the appearance indicated in the unfinished drawing Fig. 33. The canal of the duct, *Ej. D*, is oval. Below, on either side, is the section of a large trachea, *Tr.* and *Tr*[1]. The *duct* itself is lined by an epithelium, *Ep.*, the height of which is very great at the sides of, but inconsiderable above and below the duct, so that while the cavity appears oval in section the external outline of the epithelium is more nearly circular. Above and below, where the epithelium is narrow, there is but a single row of nuclei, but in the broad lateral portions the nuclei are at very various levels, though never outside a certain central zone of the cells, so that just below the inner, and likewise the outer, surface of the epithelium there is a clear space in which there lie no nuclei. The epithelium is surrounded by a muscular coat, *Muc*, of circular fibres, which form a layer of considerable thickness. This coat, as will be seen from the figure, is not really separated by the neighboring connective tissue. In fact, the external limits of the wall of the duct are not defined.

Vesiculae seminales of locusts.—These are blind cylindrical tubes of larger diameter than the *vasa deferentia.* They consist of an upper, wider, non-muscular, and a narrower lower division that has a muscular coat. The passage from the upper to the lower portion is gradual, not sudden.

A section through the upper part, Fig. 31, shows that its walls are formed mainly by a cylindrical epithelium, with slightly oval nuclei, nearly in the center of each cell. I think, but am not sure, that the nuclei are nucleolated. There is a delicate interior cuticula. I thought

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[289] *Grobben:* Beiträge zur Kenntniss der männl. Geschlechtsorg. der Decapoden, etc. Arb. Zool. Inst. Wien. (1878).

[290] *A. Gruber:* Uber zwei Süsswasser Calaniden, Leipzig, 1878. Beiträge zur Kenntniss der Generationsorgane der freilebenden Copepoden. Z. Z., xxxii (1879), p. 407.

in some sections that I could see cilia, but this point I could not settle to my satisfaction. There is a thin, but distinct, layer of connective tissue around the epithelium. The character of the epithelium is not the same throughout this upper division. In the lower part, when seen from the inner surface, the epithelium presents the appearance represented in Fig. 32, the nuclei being oval, of nearly uniform size, and quite closely crowded together. Higher up the nuclei are further apart and vary considerably in their dimensions; the outlines of the cells also appear more clearly as pentagonal. Near the rounded tip the distance apart of the nuclei is still greater, and they are more irregular in size. In some of the specimens I have examined the whole upper division of the tube was crowded with bundles of spermatozoa. In one tube I counted over 200 bundles.

The lower end of the upper division tapers off, the nuclei becoming smaller and even more crowded than in Fig. 32. The muscular coat appears thin at first, but, increasing, soon acquires its full thickness, the caliber of the tube diminishing at the same time. A transverse section of this lower part of the vesicula (Fig. 34) shows that the epithelial cells are very much smaller than in the upper portion (compare Fig. 34 with Fig 31, both being equally magnified $\frac{172}{1}$); the walls, however, rendered very much thicker by the enormous muscular coat, Fig 34 *Muc*, the fibres of which appear to be exclusively circular.

I have also made a complete series of sections through the posterior end of the abdomen of the male, some of which display very beautifully the relations of the parts, but these structures are so complicated that an elaborate investigation is necessary to secure a satisfactory interpretation of the sections. Therefore I must reserve the subject for another occasion.

DIGESTIVE CANAL.

Of the digestive canal I shall give a more complete histological description than I have of the other systems. Of the cavity of the mouth and of the œsophagus I shall say but little. The salivary glands I have not studied at all, for want of proper material. Those in the cockroach have been described by von Basch,[291] and also in the more recent superb monograph of Kupffer.[292] Leydig[293] has made some valuable observations. The glands have likewise been studied in other insects by various authors, to whom I need not refer here.

In order to render my description easier to follow, I will preface my account by a brief review of the divisions of the digestive canal in locusts; my own investigations having shown that the divisions adopted by the older authors,[4] and since generally introduced in all text-books,

[291] *S. Basch:* Untersuchungen ueber das Chylopoetische und Uropoetische System der Blatta orientalis. Sitzber. Wien. Akad., xxxiii (1858), pp. 234. Speicheldrüsen, p. 235, Taf. v, Fig. 11.

[292] *Kupffer:* Die Speicheldrüsen von Periplaneta orientalis und ihr Nervenapparat. Beiträge Anat. Phys., C. Ludwig gewidmet, p. 64, Taf. ix.

[293] Müller's Arch., 1859, pp. 59–70.

are not quite sufficient. The descriptions, both general and histological, refer to the locusts unless expressly stated to refer to the cricket.

The best method with which I am acquainted for readily obtaining a general view of the course and divisions of the digestive tract is the following: Place a female (a male will do, but is not quite so good) in alcohol of about 50 to 60 per cent. for from 12 to 24 hours; then put it in strong alcohol (96 per cent.) for a day or longer; then, with a sharp razor, cut it carefully into halves along the median line, so as to have the right and left sides separately. Lay the pieces under alcohol, and carefully remove the contents of the digestive canal, which will then appear very plainly, its course being as represented in Fig. 45. The cavity of the mouth, *M*, ascends obliquely forward, and is generally found filled with a black mass, the coagulated "*molasses*" which grasshoppers pour out when caught or irritated. The œsophagus, *oe.*, is narrower, of uniform diameter, it curves upwards and backwards, terminating very nearly in the center of the head, where it opens into the very large crop, *Cr.* The crop extends through the posterior half of the head and the whole of the thorax; it attains its greatest diameter in the prothorax, behind which it descends, tapering off slightly, and ending in the proventiculus, *P.* The crop itself is divisible into two distinct portions: 1, the anterior ($Cr.^1$) lies in the head and prothorax, and is characterized by the somewhat irregular transverse ridges on its inner surface; in *Caloptenus spretus*, the Rocky Mountain locust, these ridges are somewhat less numerous and powerful than in *C. femur-rubrum*; 2, the posterior ($Cr.^2$), in which the ridges are longitudinal and much smaller and closer together than in the front segment; the shape of the posterior division is that of a truncated cone. The proventriculus (*Kaumagen*) P, is so much reduced in the grasshopper that it appears as hardly more than the terminal portion of the crop, instead of being a large and distinct segment of the digestive canal as in other Orthoptera. The *Kaumagen* opens into the large "chylific stomach" or ventricle, *ven.*, which extends along the ventral surface about half the length of the abdomen. At its anterior end it gives off the six blind pouches, so long known and so frequently described; in a longitudinal section only one of these can be seen (*Div.*) extending forwards underneath the crop. The first part of the intestine I propose to call the *Ileum*, *Il.* It appears at first sight as the direct continuation, or rather as the posterior division, of the stomach, from which, however, it is in reality perfectly distinct, both by its structure and by its separation through a peculiar valve, which I shall describe later. The Malpighian vessels open just underneath and in front of this valve. The second division of the intestine I call the colon, *col.*, a name sometimes applied by older authors to the rectum. The colon is smaller in diameter than any other part of the digestive tube; it ascends and opens into the rectum, *R.* The rectum extends horizontally directly underneath the dorsum; its diameter is about two-thirds that of the stomach; its inner surface is thrown up into six longitudinal folds, the rectal glands, three of which are found in each half-section. The rectum opens into the short anal tube, *An.*, which opens externally on the back just in front of the upper clasper.

Crop.—Both divisions have their walls composed of the same layers: 1, an internal chitinous cuticula, which forms the hard covering of the ridges; 2, the underlying epithelium, the matrix of the cuticula, which seems to be pigmented, but unfortunately is not very distinct in my preparations; 3, an inner layer of longitudinal muscles; and 4, an external layer of circular muscular fibres. The muscular fibres of the crop are all striated. There is a layer of connective tissue between the muscles and the epithelium (Wilde), making five layers in all. As it is not distinct in my preparations I do not enumerate it with those I have myself made out. In the front division the ridges are transverse, somewhat irregular, but each one continuous and not formed of single teeth; they are much more numerous and closely crowded in *femur-rubrum* than in *spretus*. The inner covering of the ridges is the thick cuticula. Upon the posterior edge of each ridge there is a row of sharp chitinous spines which point inwards and backwards. The ridges are not all parallel, as is shown in Fig. 45. Those next the œsophagus are broader than the rest and are armed with several rows of spines. The posterior ridges become first slightly irregular, then zigzag, and so gradually change their direction until they become longitudinal and very regularly parallel. The area where the ridges are zigzag marks the limit between the two divisions of the crop. The two muscular layers are well developed in the front division, the longitudinal, which are of course transverse to the ridges, being particularly powerful.

The posterior segment of the crop, Fig. 45, *Cr.*^{2}, has longitudinal ridges. In a transverse section, Fig. 35, it is seen that the ridges are small, *rid.*, rounded on top, with small projecting cuticular spines of yellowish color, *s*, *s*. In each ridge the pigmented epithelium appears as a dark layer underneath the cuticula. The inner muscular coat, *L*, of longitudinal fibres is but little developed in comparison with the enormous coat of circular fibers, *muc. C.* Thus we see that, in both parts of the crop, that muscular coat obtains predominance whose fibres run transversely to the direction of the ridges. An examination of the inner surface of the hind part of the crop reveals the fact that the ridges are not continuous, but composed of rows of imperfectly individualized oblong teeth, each of which is armed with a few small spines.

It will be seen that the general character of the crop is the same as in the cockroach, according to the descriptions of Basch,[294] who adds that the epithelium corresponds to Ramdohr's "*flockige-Lage*," and is the same as the *membrana propria* of Straus-Durckheim and Burmeister. Finally, I must call particular attention to the recent capital memoir[295] of

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[294] *S. Basch. Sitzber. Wien. Akad.* (1858), xxxiii, p. 242.

[295] *K. F. Wilde.* Untersuchungen über den Kaumagen der Orthopteren. Arch. f. Naturgesch. Jahrg. xliv, 1. Bd., p. 135 (1877).

Dr. Wilde, of Leipzig, in which, p. 139, he gives the most accurate account of the crop and proventriculus of the Acridians and other Orthoptera which has yet been published.

The crop of *Anabrus* is not divided into two parts, and its cuticula forms no ridges, but is divided up into distinct fields (Fig. 60), each of which corresponds to a single epithelial cell, for in preparations colored with logwood, and examined from the surface, a sharply defined, round nucleus appears in the middle of each field. Each field has a spine, which rises from its posterior part and points backward. These spines are more developed than their fellows on the cuticula of the epidermis. The close resemblance of the two cuticulæ serves to corroborate the view that the crop of insects arises in the embryo, as a secondary invagination of the ectoderm.

Proventriculus.—Dr. Wilde, in the article just mentioned, speaks of the "*Kaumagen*" as the terminal portion of the crop, but I see no objection to considering it entirely distinct and fully equivalent to the proventriculus of other insects with which it is homologous, as Wilde has already pointed out. Wilde appears to have overlooked the fact that it is sharply limited both in front and behind, and in his figure (l. c., Plate IX, Fig. 2) the front limit is not marked.

An examination of the proventriculus opened, and spread out so as to expose the inner surface, shows that there are six large teeth, which present a triangular outline, the base facing frontwards, the apex pointing backwards. The ridges of the crop become zigzag just in front of the bases of these teeth close to which they terminate. Between the single teeth of the proventriculus there are a few parallel ridges, which are not continuous with those of the crop, and which terminate abruptly with rounded ends, at the level of the apices of the large teeth, that is to say at the entrance to the stomach. In the apical portions of the large teeth there is more or less pigment, while in the basal portions there is almost none. The base of the large teeth is notched; the apex rounded off; and their surface covered with a multitude of minute conical spines, which project up from the cuticula.

In *Anabrus* the proventriculus is fully developed, and resembles that of other crickets.[296] It consists, as in *Gryllus domesticus*, of two parts: one, anterior, serves as the communication between the crop and the proventriculus proper. This anterior part has no definite limit either in front or behind. Both parts are traversed by six rows of teeth, but, though the rows are continuous, the form of the teeth differs in the two parts. If a single row be examined it will be seen that the change from one form of tooth to the other is gradual, not abrupt. A transverse section through the posterior part of the proventriculus shows the disposition of the parts to be as drawn in Fig. 58. Externally is the muscular coat, consisting mainly of circular fibres, intermingled with tracheæ. I have not succeeded in detecting any longitudinal fibres in transverse

[296] *Wilde*, l. c. Arch. f. Naturgesch., 1877, 1. Bd., pp. 159–165.

sections, though in surface views they appear very plainly; inside the coat of circular muscles all the fibres are transversely striated. The teeth form six distinct arches, and are united with the muscular coat only at their sides. The attachments of the adjacent teeth to the *muscularis* are separated by a longitudinal ridge, *a*, which runs unbroken through the length of the crop, separating the neighboring rows of teeth (compare a surface view Fig. 54 *a*). Each tooth is tripartite, having a central pointed division, *d'*, and two lateral protuberances, *d''*, which Wilde terms "molar" (*mahlzahnartig*). The shape of these is best explained by the figure. The whole proventriculus is lined by a continuous resistent cuticula, which rests upon a cylinder-epithelium, that varies greatly in height in different regions of the teeth, as is plainly shown in Fig. 58, *ep*. The epithelium rests on a layer of connective tissue *conn.*, beneath which is the space left by the dental arch; this space, *C*, corresponds to a large canal which runs under each row of teeth. Examined from the surface, Fig. 54, the same disposition of the parts can be seen, though less plainly. The central process of each tooth is pointed and inclined backwards, so as to slightly overlap the next following tooth. Certain of the anterior "molar" protuberances are distinguished from the posterior, by having three dark colored projections of their cuticula. The cuticula is armed with spines upon the central dental division, and with numerous bristles upon the "molar" protuberances and interdental ridge. A side view, Fig. 55, is also given in order to make the relation of the teeth to one another as plain as possible.

In the anterior part of the proventriculus the teeth are simpler in form, and the longitudinal ridge and "*molar*" protuberances are wanting. The cuticula gives off a dense coat of long hairs. The edge of each tooth is deeply serrated on both sides of its point, instead of being merely somewhat roughened as in the posterior part. Finally these anterior teeth are convex on their front, concave on their hinder sides. They become smaller as we go forward, the rows spreading apart as they widen out to form the crop.

Posteriorly the rows of teeth stop quite suddenly. The interdental ridge runs somewhat further on, and is rounded off at its termination. On the last five or six teeth the middle process gradually loses its prominence, and on the last two the "*molar*" processes are also very much reduced.

The total number of teeth in each row is twenty three or four, of which eight or nine belong to the anterior and fifteen to the posterior division. In *Gryllus campestris* and *domesticus* the crop, likewise, forms two divisions, in the posterior of which there are fifteen teeth in each row. It is to the posterior division alone that Wilde (l. c.) restricts the name proventriculus, but I cannot see what grounds he has for so doing, for the two parts have essentially the same characteristics.

Stomach.—This name I apply to the ventriculus of authors, the *Chylusmagen* of the Germans, Fig. 45, *ven.* Of no part of the digestive canal is our present knowledge so unsatisfactory as of this. The few observations that have been made are eminently incomplete. It is known that there is no thick cuticula; that the muscular layers are less powerful than in other parts, and certain other details, which a brief examination suffices to clear up. Frey and Leuckart[297] pointed out that the walls of the stomach were not folded, but that the secretory surface was increased in some cases (in many Coleoptera, for instance) by the epithelium and connective tissue forming villi, a fact already noticed by H. Meckel.[298] Sirodot[299] subsequently showed that there are also gastric glands in many insects, and describes particularly (l. c., pl. 13, Fig. 3) how in the field cricket the gastric follicles occupy the interspaces of a network formed by the sinuous fibers of the connective tissue, "*tunica propria*" *auct.* I have found essentially the same structure to exist in grasshoppers (*Caloptenus* and *Oedipoda*). The description of the minute anatomy of the ventriculus which Leydig gives[300] is very meager and insufficient, while that given of the epithelium and glands in the stomach of the cockroach by von Basch[301] will probably require some modification.

The walls of the stomach are composed of an internal epithelium, a layer of connective tissue, an inner layer of unstriated circular muscular fibres, and an external layer of longitudinal fibres of striated muscle. In studying these layers I have found it best to begin by viewing them from the inner surface. If the walls of the stomach be spread out and stained and then mounted in glycerine or Canada balsam, it will be seen that the nuclei of the epithelium are not uniformly distributed, but there are little clusters, each of which corresponds to a small gland or follicle; it can be further seen that each gland has a cavity or duct; each follicle lies in a cup of connective tissue, which separates it from its neighbors. If a piece of the wall spread out on a glass slide in a drop or two of water, is gently brushed with a fine camel's hair pencil, the epithelium can be removed, and if the specimen be then stained and mounted the structure of the remaining layers will be displayed as shown in Fig. 39. The connective tissue, *tunica propria*, forms a somewhat irregular network,[302] the meshes of which vary in size only between certain limits. In the figure the network is drawn somewhat darker than it appears in reality, in order to make it stand out more plainly. The spaces of the network are the cups before mentioned in which the gastric follicles lie. The tissue has a fibrous character and also forms the bottoms of the cups, as is shown by sections. Underneath the connective tissue follows the internal muscular coat, *In. m.*, composed of a great number

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[297] *Frey und Leuckart:* Anat. Physiol. Ubersicht. Thierreichs, 1855, p. 114.

[298] *Meckel.* Mikrographie einiger Drüsenapparate niederer Seethiere. Müller's Arch., 1846. Die Eintheilung des Darmcanals bei den Insekten. Par. 4, p. 23.

[299] *Sirodot* Recherches sur les secretions chez les Insectes. *Ann. Sci. Nat. Zool.* Sér. 4. Tome X, p. 183 (1858).

[300] *Leydig.* Lehrbuch der Histologie, 1858, p. 337.

[301] *Basch,* l. c., Wien. Akad. Sitzber., xxxiii, 248, ff

[302] Compare Sirodot, l. c., Pl. 13, Fig. 3.

of pale fibres, running singly, and parallel to one another around the stomach. Between this layer and the *tunica propria* there are some indistinct *longitudinal* fibres that may be muscular; these fibres also appear in transverse sections. If my supposition as to their nature is correct, then there are two layers of unstriated muscles, the longitudinal layer being innermost, just as we found with the striated muscles of the œsophagus. Most externally are the longitudinal striped muscles, which are distributed in single bundles (*L*, *L*,) and do not form a continuous layer. Each bundle is composed of a number of fibres and pursues its own course; the bundles are not parallel, as will be evident upon glancing at the Fig. 39; sometimes two bundles unite, or one bundle connects two others; in spite of these irregularities, however, the trend of the muscles is lengthwise of the stomach. Finally, it must be mentioned that numerous tracheal branches penetrate the muscular layers and ramify both through them and also through the connective tissue.

A transverse section (Fig. 36) through the walls of the stomach exhibits further structural features. The epithelium is composed of cylindrical cells, with large, finely granular nuclei, in some of which a nucleolus can be distinguished; the limits of the single cells are not well defined. The follicles are formed by simple involutions of the epithelium, there being no apparent change in the general character of the cells except in their shape, which is not plain enough in sections for me to describe it with real accuracy. They are, however, certainly not spherical, as affirmed by Sirodot. The epithelium is covered by a cuticula, *cu.*, which also descends into the follicles, and is traversed by numerous pore-canals. I cannot make out any basement membrane, but apparently the epithelium rests immediately upon the connective tissue, *conn.* The manner in which this layer extends up between the follicles is seen very plainly in transverse section; it is comparatively thin, as is also the circular coat, *muc.*, of unstriated muscles. In the part figured it so happens that there are no longitudinal bundles of striated muscle, but the tracheæ, *Tr.*, appear very distinctly.

The ventricle of *Anabrus* differs from that of the locusts, as far as I have observed, only in unimportant details. The diameter of the glands is somewhat greater, as shown by the size of the "cups" of connective tissue (Cf. Figs. 66 and 39) in which they rest. The longitudinal muscles form more regular bundles than in the locusts, and fibres cross less frequently from one bundle to another.

Diverticula.—I employ this name for the six cæcal pouches, frequently called the *appendices ventriculares.* It has been commonly stated that these cæca do not differ in structure from the stomach, a statement which, though quite incorrect, is repeated even by so exact an author as Milne-Edwards, in his magnificient compilation of Anatomy and Physiology.[303] Yet, that there is a great difference, had been noted in 1846 by H. Meckel,[304]

[303] *Milne-Edwards:* Leçons sur la Physiologie. Tome v., p. 608–609.

[304] *Meckel:* Müller's Arch., 1846, p. 38 ff.

whose observations are also cited by Leydig on p. 337 of his "*Handbuch.*" Sirodot[305] repeats the old and incorrect statement, while Gräber[306] expressly states that their structure is not the same as that of the stomach, and that they are not "einfache Aussackungen des Chylusmagens." More recently M. F. Plateau[307] has again called attention to the incorrectness of the old view.

In fact, a single transverse section of one of the diverticula (Fig. 37) demonstrates at once that its structure is entirely different from that of the stomach. Its inner surface is thrown up into longitudinal folds, generally twelve in number. These folds shine through the outer walls, and are, accordingly, indicated in the drawings of Dufour, Gräber, and others. The whole diverticulum has an external muscular envelope, outside of which are a few isolated longitudinal muscular bands. The folds within are formed mainly by the high cylindrical epithelium, which lines the whole interior of the cavity. The shape of the folds will be more comprehensible from the Fig. 37 than from any description I can give. They are not all of the same height, but they form two opposite groups, the folds in the center of each group being the highest. On either side and between the two groups there are smaller folds. Whatever the height of the folds, however, they all have the same general histological character, which is indicated by Fig. 38. The cells are large and cylindrical, slightly granular, those near the top of each fold being slightly pigmented with brownish matter that obscures their definition. The nuclei are large, oval, coarsely granular, and lie in the middle or lower parts of the cells. The cells are protected by a delicate but very distinct cuticula, in which I can detect no pore-canals, though it otherwise resembles the cuticula in the ventriculus. In the center of each fold there runs up a thin partition of fibrous tissue (Fig. 38, *conn*), which separates the epithelium of the two sides, and is itself an offshoot of the connective tissue, *tunica propria*, that intervenes between the muscles, *muc.*, and the epithelial layer. The tracheæ ramify throughout all the layers outside the epithelium; one of the main trunks running to the wall is shown at *Tr.* (Fig. 37). It sometimes looked as if there were glandular follicles in the bottom of the spaces between the folds, but of this I could not make sure.

Towards the tips of the diverticula the folds decrease in height as the diameter of sacks diminishes, until finally they disappear almost completely.

Gastro-ileal folds.—I have now to speak of some very curious and striking formations which seem to have escaped notice until now, for I find no description of them in any of the works on insect anatomy which

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[305] *L. c.*, p. 157.

[306] *V. Gräber:* Zur näheren Kenntniss des Proventriculus und der Appendices ventriculares bei den Grillen und Laubheuschrecken. Sitzber. Wien. Akad. (1869), lix, p. 33.

[307] *F. Plateau:* Recherches sur les Phenomènes de la Digestion chez les Insectes. Mémoires Acad. Roy. Belg. (1875), tome xli, p. 75.

I have been able to consult. It is impossible to follow Dufour's account[308] of the termination of the stomach and the origin of the intestine, for it seems to me not only incomplete but also inaccurate.

I have already referred to these folds, p 209, as the valve which marks the termination of the stomach. They are indicated in Fig. 45 as six dark spots, round in front, and lying at the anterior end of the ileum, *Il.*, so as to form a ring around the interior of the intestine. If this part of the digestive tract be opened, spread out, colored, and mounted, it will appear as represented in Fig. 46. In front lies the stomach, *ven.*, from which the epithelial lining has been removed, and which can therefore be readily recognized by the network of connective tissue before described and the isolated, longitudinal, muscular bundles. Behind the protuberances comes the ileum, *Il.*, which is traversed by six broad and low longitudinal folds, three of which appear in the figure. On the line between the ileum and the ventricle lie the strongly pigmented gastro-ileal folds. They are twelve in number, and all alike. Their shape is best indicated by the figure. They are rounded off in front, where they are broadest and stand up highest; they narrow down backwards; the pigment disappears, and they gradually fade out into the ileal folds; directly underneath them, and just at the posterior termination of the ventricle, there is a strong band of circular striated muscular fibers 0.14^{mm} wide.

These folds are found in *C. femur-rubrum*, *C. spretus*, and *Œdipoda sordida*, and probably in all grasshoppers. I have made sections of them from *Œdipoda*, Figs. 49, 43, and 44. Fig. 49 shows the general arrangement of the folds; there are twelve of them, all pedunculated with broad tops and thick stems. They are covered with an epithelium, the cells of which are smaller and for the most part not pigmented *between* the folds, and larger with a great deal of pigment *on* the folds, as also appears in Fig. 45. The muscular coat, *muc.*, is very powerful, and of even thickness throughout. Between it and the epithelium there is a well-developed tunic of connective tissue. Examined with a higher power it is seen, Fig. 44, that the epithelial cells are large, with an oval nucleus in the lower half of each cell. The cells in the valleys are not so high as on the folds, though the nuclei are not any smaller. The epithelium is covered by a thin cuticula, which is armed on the surface of the folds with minute conical spines, Fig. 44, *cu.*, which are generally, but not always, wanting between the folds; the spines are sharp-pointed and inclined backwards. The connective tissue is fibrous, and contains a good many small, granular, oval nuclei. The layer of circular muscles is composed of three or four parallel layers of bundles. I think there are some few longitudinal fibres between the muscular coat and connective tunic.

Returning now to the epithelium, we find cells in all stages of pigmentation. The pigment is in fine granules of various sizes; they first

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[308] Dufour, Sur les Orthoptères, l. c., p. 314.

collect around the nucleus, Fig. 43, and as they accumulate they extend through all the rest of the cell, except the upper part underneath the cuticula, which portion always remains clear, as is seen in Fig. 44. Viewed from above the epithelial cells appear as polygonal pigmented fields, each separated from its neighbors by a clear line. Posteriorly the cells become less and less pigmented, and pass by gradual changes into the epithelium of the ileum.

Ileum.—The ileum is traversed by six longitudinal folds, with intervening furrows. Outside each furrow is a longitudinal muscular band. Viewed from the inner surface, the epithelium is seen to have an unusual character. The cells in the middle of each of the flat folds are quite large (Fig. 50 A), polygonal in outline, with large, round, granular nuclei, which stain very darkly with hæmatoxiline. Toward the furrows the cells become very much smaller, those at the edge of the furrow being not more than one-sixth the size of those in the middle (Fig. 50 B). Underneath the furrow, the longitudinal muscles (Fig. 50 L) are seen shining through.

A transverse section (Fig. 51) shows that the walls are double; the inner leaf is composed of epithelium, *Ep.*, and connective tissue, the outer leaf, of the circular muscles, *muc. C.* The furrows are indicated by the six bands of longitudinal muscles, *L L.* It is only opposite these bands that the two leaves are united, as is shown more plainly in Fig. 52. The epithelium, *Ep.*, rests directly upon and is intimately united with the connective tissue, so forming a single leaf, which then bends down, making a furrow, *F*, opposite the longitudinal muscle, *L L*, where it is united with the circular muscular layer, *muc C.* The consequence of this arrangement is that underneath each fold there is a very large longitudinal cavity between the *propria* and the *muscularis.*

The cuticula (Fig. 52), *cu.*, is thin, but probably chitinous; it resembles that on the gastro-ileal folds, except that there are no spines, but it is not in the least like the ventricular cuticula. It extends equally over the folds and the furrows.

The epithelium has round nuclei; the size both of the cells and of the nuclei diminishes rapidly towards the bottom of the furrows (Fig. 52), F. The bases of the cells are somewhat dome-shaped. The nuclei are surcharged with granules, and have a less distinct outline than the nuclei from other parts of the body.

The circular muscles are moderately developed. Each longitudinal muscular band consists of 10 to 15 single bundles. The fibres are striped.

Colon.—In the colon the six longitudinal folds of the ileum are continued, but their surface, instead of being smooth as in the ileum, is thrown up in numerous irregular curved and zigzag secondary folds, as is imperfectly indicated in Fig. 2, *col.* The cells of the epithelium are of uniform size, and contain, especially at the summits of the secondary folds, pigment granules like those in the cells of the gastro-ileal valve. The epithelium is covered by a highly refringent cuticula without spines, and, like that on the ileum, it rests upon a layer of connective tissue, beyond which follows (1) an internal coat of longitudinal, and (2) an external coat of circular muscular fibres, which are striated.

Rectum.—The rectum of insects is remarkable for containing certain curious structures now generally known as rectal glands. They are incidentally mentioned by older authors, but Frey and Leuckart[309] were, as far as I am aware, the first to recognize their general distribution and importance. Leydig[310] was the first to give an accurate account of their histological structure. Since then they have received but little attention until 1876, when Dr. Chun published his investigations,[311] which were made under the guidance of Professor Leuckart. Chun extended his researches over a variety of insects, but gives no account of the glands as found in the grasshoppers, though he studied the closely allied Katydid (*Locusta viridissima*, l. c., p. 32). He describes the glands as six flat folds, formed by a high epithelium and well-defined cuticula: the connective tissue (tunica propria) is largely predominant; there is a coat of circular muscular fibers, and six external longitudinal muscular bands, corresponding to the furrows between the glands. This description is applicable also to the grasshoppers I have investigated, the only differences being in the structural details of the single layers.

Seen from the inner surface the epithelium presents a most curious and puzzling aspect, Fig. 53, because there are two kinds of nuclei at different levels; small, spherical nuclei nearest the surface, and larger nuclei of oval form deeper down. The small nuclei are less numerous than the large; in the portion represented in Fig. 48 there are 21 small and 49 large nuclei, or, in other words, less than half as many of the superficial as of the deep nuclei. As the two sets are at different levels they cannot both be in focus at once, hence in drawing Fig. 53 with the camera-lucida, the large nuclei were first focused and drawn, and then the smaller nuclei were drawn in the same way over the first. When we focus upon the large nuclei, the polygonal outlines of the cells can be seen in successful preparations as represented in the figure; as there are no spaces between the cells with the large nuclei, the cells belonging to the small nuclei do not extend so far down, though the cells of the large nuclei do reach up among the small nuclei, as can be seen in sections. The outlines of the cells to which the small nuclei belong, I have not been able to distinguish.

The small nuclei are spherical, very refringent, and have a sharp outline. The large nuclei are oval, their long axes lying generally lengthwise rather than transversely on the folds of the rectum. An epithelium presenting a somewhat analogous peculiarity has been described from the epididymis of mammals by Klein.[312] He figures small darkly stained

[309] *Frey* and *Leuckart:* Uebersicht des Thierreichs, 1855, p. 116.

[310] *Leydig:* Lehrbuch der Histologie, p. 337.

[311] *C. Chun:* Ueber den Bau, die Entwickelung und physiologische Bedeutung der Rectaldrüsen bei den Insecten. *Abh.:* Senckb. Natforsch. Ges. (Frankfort) Bd. x, p. 27, mit drei Tafeln.

[312] *Klein:* Observations on the structure of cells and nuclei. Quart. Journ. Micros. Sci., XIX, (1879), p. 138, pl. VII, fig. 9.

cells lying at the *bases* of the high columnar ciliated epithelium. It is, however, uncertain whether these small cells lie between the others, or form a sub epithelial endothelium, similar to that described by Debove.[313]

Underneath the epithelium appear the round nuclei of the tunica propria, and the very much elongated nuclei of the tracheal ramifications.

In a transverse section, Fig. 42, it is seen that each gland is a low flat fold of the epithelium; each fold is separated from its neighbor on either side by a deep but narrow furrow, *F*, *F′*, and is covered internally by a cuticula, which is quite resistent, highly refringent, and very slightly tinged with yellow. The epithelium, Fig. 41, is, as was to be expected from the presence of the two sets of nuclei, composed of two kinds of cells; 1st, cylindrical cells corresponding to the oval nuclei; in sections these nuclei appear round and are seen to lie in the basal portion of the cells; 2d, cells corresponding to the superficial nuclei; each of these nuclei is surrounded by a clear space, as indicated in Fig. 41, but this space has not a sharp outline as there represented; the shape of these cells I have been unable to determine.

The epithelium rests upon a layer of connective tissue, in which there are round granular nuclei, as before stated. Outside of the connective tissue there is a thin layer of circular muscular fibres, Fig. 42, *muc.* The tracheæ, with their distinctive nuclei, ramify throughout all parts of these two layers. Opposite each furrow there is a longitudinal muscular band, Fig. 42, *L L′*, composed of some twenty or more striated bundles. Attached to the outer walls are found large tracheal trunks, *Tr.*, and Malpighian vessels, *M. v.*

At the points where the epithelium of the folds descends to form the intervening furrows, there is a little accumulation of pigment granules.

From the above description it will be seen that the rectal folds do not offer the least appearance of glandular structure; neither is any evidence deducible from their microscopic anatomy to indicate that their function is that of absorption. Neither does it appear to me that Chun, in his memoir, has elucidated their function in other insects, and the opinions he expresses with apparent confidence I cannot regard as anything more than speculative.

SUMMARY OF OBSERVATIONS ON THE DIGESTIVE CANAL.

If we now glance back at the descriptions above given of the histological peculiarities of the various divisions of the digestive canal, there are certain general features which deserve especial attention. In the first place it will be recognized that the digestive tract is composed of three main divisions: 1, the œsophagus, crop, and proventriculus; 2, the ventricle and diverticula; 3, the ileum, colon, and rectum.

In the first division there are two coats of muscles, an internal longi-

[313] *Debove:* Mémoire sur la couche endotheliale sous-épithéliale des membranes muqueuses. Arch. de Physiol., 1874, p. 19.

tudinal and external circular coat; the fibres are all striped. The lining epithelium is not much developed, but forms a thick, hard, and very refringent cuticula that is thrown up into ridges, that may be armed with spines. The chitinous lining, or the cuticula, is undoubtedly always secreted by an epithelium,[314] and does not belong in the series of connective tissues, as Leydig has maintained.[315] It will be seen that these features are common to all the subdivisions of the anterior segment of the digestive canal, the principal variations being in the form and development of the ridges, and the muscular layers, as I have already described in detail. The thick cuticula of the "*Vorderdarm*" has been observed in many insects,[316] and of all orders.

The second division of the alimentary canal is distinguished from the first by the epithelium being composed of very high cylindrical cells, which make up the greater part of the thickness of the walls; by the presence of a very delicate, and but slightly refringent, cuticula, and the absence of ridges; by the unstriated muscular coats, and, finally, by the development of glandular follicles and folds. The ventricle and diverticula have all these peculiarities in common, while no other part of the digestive canal resembles them in the least. Essentially the same peculiarities distinguish the "Mitteldarm" of *Phthirius inguinalis*, Leach[317], except that there are no glandular follicles. Landois[318] has wrongly homologized this part with the crop of the Orthoptera.

The third division (intestine and rectum) has an epithelium, the cells of which are intermediate in size between those of the first and second division. The cells are often pigmented; they are covered by a cuticula much firmer than that of the ventricle, but not so thick and hard as that of the first division. The very refringent cuticula is not transformed into ridges, though in some parts it is covered with delicate conical spines, which are very short. The epithelium and underlying connective tissue (*tunica propria*) are thrown up into *six* folds, which run longitudinally, being regular in the ileum and rectum (as the rectal glands), but very irregular in the colon. Outside the depression between each two neighboring folds there is a longitudinal muscular band, thus making six bands. This peculiar disposition of the longitudinal muscles does not occur in any other part of the canal; it is therefore especially characteristic of the third division. From this statement of the characteristics of the three divisions, it is evident that the gastroileal valves belong to the third.

The curious repetition of the number six may be pointed out here. I cannot but think it will be ultimately found to have some hitherto unsuspected meaning. There are six rows of teeth in the proventriculus,

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[314] *Semper*: Ueber die Entstehung der Schuppen bei den Lepidopteren. *Zeit. Wiss. Zool.*, VIII. Cf. also, Gegenbaur, Chun, Braun, *et al.*

[315] *Leydig*: Vom Bau des Thierschen Körpers, p. 38, ff.

[316] For example: Phthirius inguinalis Leach. Graber. Z. Z. XXII, 141.

[317] *Graber*: *Zeit. Wiss., Zool.* XXII, 142-144.

[318] *Landois*: *Zeit. Wiss. Zool.*, XIV, p. 1, and XV, 502.

six diverticula arising from the stomach, and twelve longitudinal folds in each diverticulum. There are twelve (twice six) gastroileal folds, arranged in twos, each pair appearing as the double anterior termination of one of the six ileal folds, which, changing their character, extend backwards through the colon; finally, in the rectum there are six rectal glands.

The three divisions of the digestive canal are perfectly natural; their existence of itself suggests that they represent the three segments which are usually distinguished upon embryological grounds, namely, the *foregut*, *midgut*, *hindgut* (*Vorderdarm*, *Mitteldarm*, and *Hinterdarm*). This supposition is strengthened by Bobretzky's[319] observation that in decapods the embryological *foregut* forms the œsophagus and *Kaumagen*, while the midgut forms the follicular stomach and diverticula (liver). This is a strong confirmation of the conclusion that I have been induced to consider probable upon purely anatomical grounds. It seems to me, moreover, that Hatschek's[320] observations also point to the same conclusion, viz, that the ventriculus (*Chylusmagen*), together with its appendages, represents the midgut, all in front being foregut, and all posterior to it arising from the hindgut.

The principal respects in which the middle division differs from the other two is by, 1, its glandular character; 2, the presence of a delicate cuticula, probably not chitinous; and, 3, of unstriated muscles. It seems to me now a legitimate problem in insect anatomy to determine whether these characteristics are applicable to the midgut of all insects.

In all parts of the digestive tract the succession of the layers is the same: 1st, a cuticula; 2d, an epithelium; 3d, connective tissue; 4th, muscles. Besides which there is stated to be a pavement epithelium (*serosa*) outside the muscles in some insects. This I have not observed in the grasshoppers, though it may be present.

Of the physiological functions of the single parts of the digestive canal little is really known, though some observations have been published by Sirodot and Plateaux.

I should like to interpolate here a comparison, which is curious and odd rather than of scientific value. After Malpighi had shown that the grasshopper had several stomachs, some of the older authors, according to *Colin*, considered these insects to be ruminants, comparing the various parts of their digestive canal with the divisions of the stomach in the true ruminants. Of course this idea is now entirely rejected, but it is nevertheless curious to notice that with our present knowledge we can trace an analogy between the crop and the rumen, the ventricle of the grasshopper and the sheep, while the diverticula with their leaf-like folds singularly imitate the structure of the psalter. Those who are not familiar with the anatomy of ruminants, will find a clear and excellent account in Huxley's Anatomy of Vertebrated Animals.

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319 *Bobretzky:* Zur Embryologie der Arthropoden (in Russian) as abstracted by Hoyer in Hoffmann und Schwalbe. Jahresbericht der Physiol. u. Anat. für 1873, p. 314.

320 *B. Hatschek:* Beiträge zur Entro. Lepidopteren. *Jena Zeitschr.* Bd. XI. (1877), (p. 17 des Separatabdruckes.)

PLATE IX.

Fig. 1. Front view of the brain of *Caloptenus femur-rubrum*: *opt. gang.*, optic ganglion; *oc.*, ocelli and nerves leading to them from the two hemispheres, each ocellar nerve arising from the region containing the calices; *m. oc.*, median ocellar nerve; *opt. l.*, optic lobe sending off the optic nerve to the optic ganglion; *ant. l.*, antennal or olfactory lobe; *ant. n.*, antennal nerve; *f. g.*, frontal ganglion of sympathetic nerve; *lbr. n.*, nerve to labrum; *x*, cross-nerve or commissure between the two hemispheres; *œ. c.*, œsophageal commissure to subœsophageal ganglion.

2. Side view of the brain and subœsophageal ganglion (lettering of brain as in fig. 1): *s. g.*, stomatogastric or sympathetic nerve; *a. s. g.*, anterior, and *p. s. g.*, posterior, sympathetic ganglia; *g.* 2, subœsophageal ganglion; *md.*, nerve to mandible; *mx.*, maxillary nerve; *ln.*, labial nerve; *n. ?*, unknown nerve, perhaps salivary?

3. Interior view of the right half of the head, showing the brain in its natural position: *an.*, antenna; *cl.*, clypeus; *lbr.*, labrum; *m.*, mouth cavity; *md.*, mandible; *t.*, tongue; *œ.*, œsophagus; *c*, crop; *en.*, right half of the endocranium or X-shaped bone, through the anterior angle of which the œsophagus passes, while the great mandibular muscles play in the lateral angles. The moon-shaped edge is that made by the knife passing through the center of the X.

4. View of brain from above (letters as before).

5. Subœsophageal ganglion from above: *t. c.*, commissure to the succeeding thoracic ganglion; other letters as before.

Fig. 3 is enlarged eight times; all the rest twenty-five times.

NOTE.—The figures on this plate were drawn from original dissections by Mr. Edward Burgess.

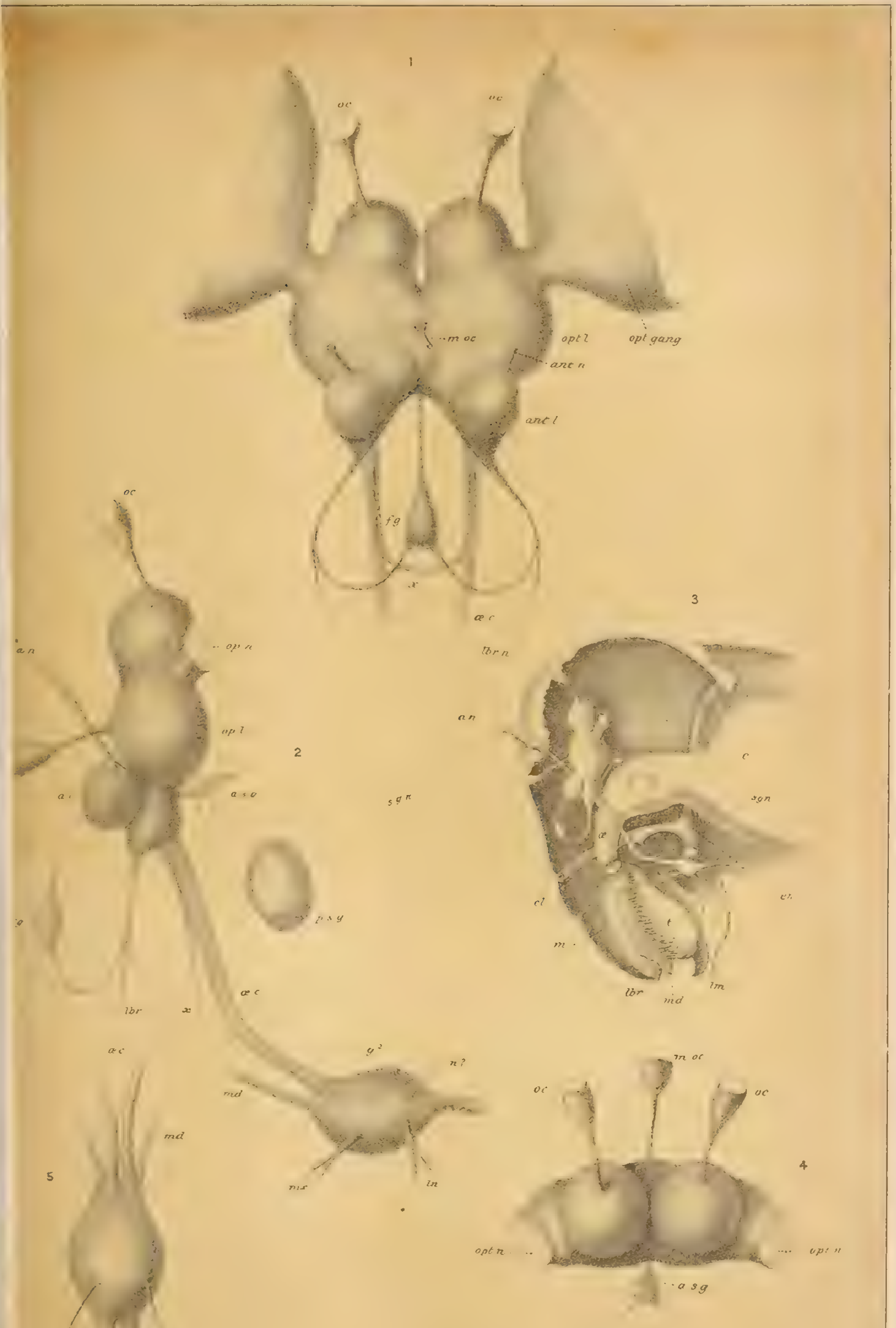

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PLATE X.

Fig. 1.—Frontal section 16, through the front of the brain of adult *Caloptenus spretus*; × ⅙ inch objective, A. eye-piece.

Fig. 2.—Section 17, showing the central body (*centr. b.*) and mushroom body, optic and antennal lobes, and commissural lobes; × ⅙ A.

Fig. 3.—Enlarged view of the trabecula and its nerves, of the mushroom body, its calices and stalk, and the origin of the optic nerves; for lettering see schedule. × ⅙ A., 225 diameters.

Fig. 4.—Section 18, passing through the back of the central body, showing the double nature of the stalk of the mushroom body, and passing through the back of the commissural lobes and behind the trabecula and the base of the stalk; × ⅙ A. Are *oc. n.*? the origins of the ocellar nerves?

Fig. 5.—Vertical (longitudinal) section through one of the hemispheres, showing the origin of the commissural and antennal nerves and the optic lobe.

Fig. 6.—Longitudinal section through the brain and subœsophageal ganglion (× 50 diameters), showing the two portions of the calyx, the antennal lobe, and in the subœsophageal ganglion the three lobes giving off respectively the mandibular, maxillary, and labial nerves.

Fig. 7.—Longitudinal section through the optic ganglion and the eye; × 50 diameters.

Fig. 8.—Longitudinal section through the brain, showing the calyx, antennal lobes, and commissural lobes; × 50 diameters.

Fig. 8 *a*.—Enlarged view of Fig. 8 (× ⅙ B.), showing the relations in a longitudinal section of the calyx to the stalk, although the direct connection of the stalk with the calyx is not seen in this section.

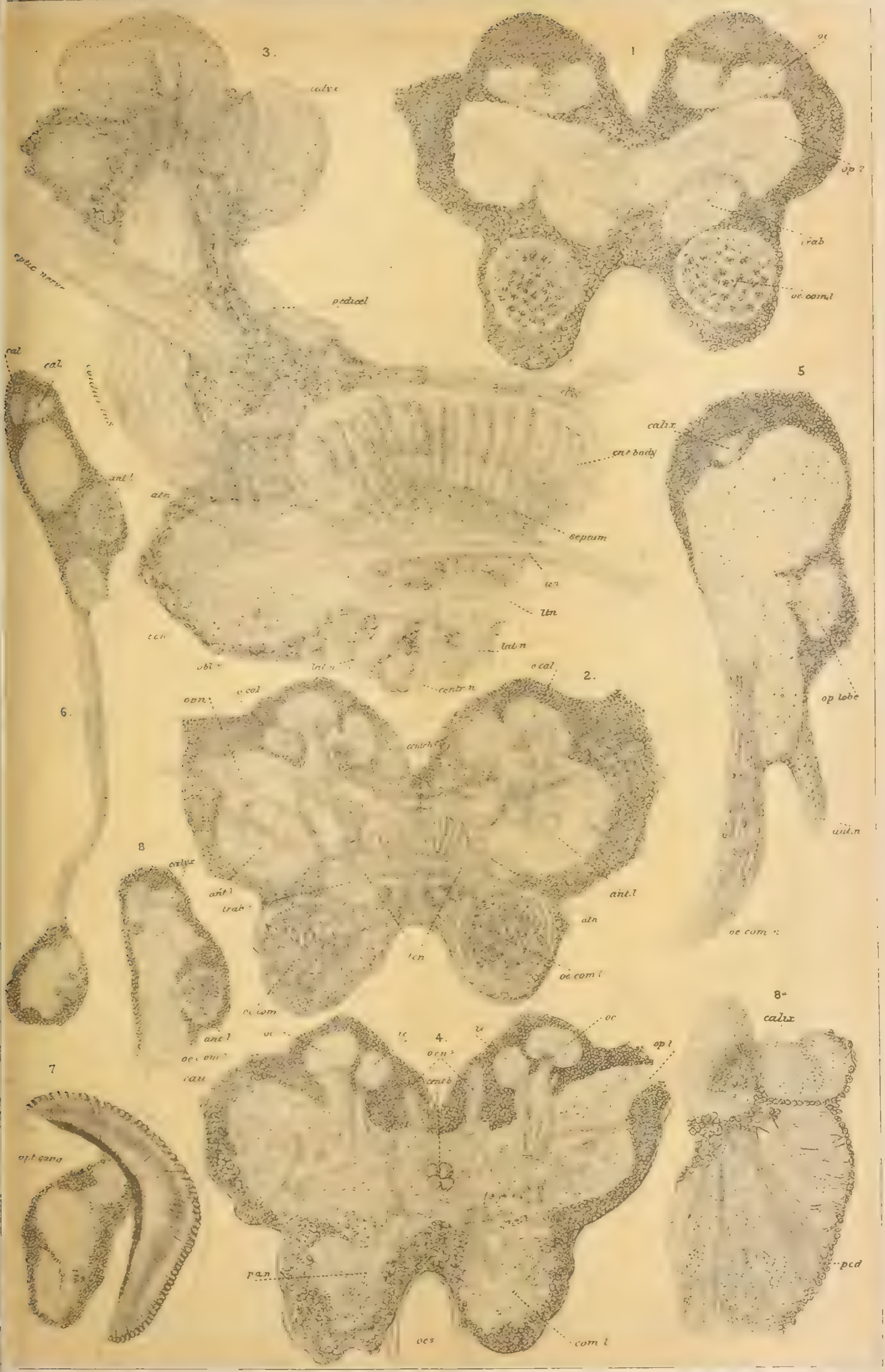
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PLATE XI.

FIG. 1.—Section 19 ($\times \frac{1}{2}$ A.), passing through the back of the brain, showing the posterior edge of the calices and antennal lobes and œsophageal commissural nerves and optic nerve. *tr.*, small tracheæ.

FIG. 2.—Section 20, passing through the back of the brain, showing the relation of the optic nerve to the optic ganglion and eye; the cornea, cones, rods, and retina of the eye are shown; $\times \frac{1}{2}$ A. *sup. n.*, superior, *m. n.*, median, and *inf. n.*, inferior commissural nerves connecting the hemispheres.

FIG. 3.—Enlarged view of upper part of the stalk and calyx, and the ganglion cells surrounding and filling the latter; $\times$ 225 diameters. 3 *a*, *b*, *c*, *d*, different ganglion cells seen from different directions, 3 *c* showing the large nucleus filled with coarse granules, but showing no nucleolus; one, however, is seen in Fig. 3 *b. ncl.*; $\times$ 725 diameters.

FIG. 4.—Longitudinal section of the brain and subœsophageal ganglion, magnified 50 diameters, showing the relations between the two, and of the origin of the œsophageal commissure from the upper side of each ganglion, *i. e.*, from the back of the brain and the upper side of the subœsophageal ganglion.

FIG. 5.—Enlarged view ($\times \frac{1}{2}$ B) of the subœsophageal ganglion of Fig. 6, Pl. X, showing the origin of the commissure to the first thoracic ganglion, and on the under side the three lobes (mandibular, maxillary, and labial), whence the nerves are sent to the mouth-appendages. *mand. l.*, mandibular lobe; *max. l.*, maxillary, and *max. l'.*, 2d maxillary or labial lobe; *com.*, commissure to subœsophageal ganglion.

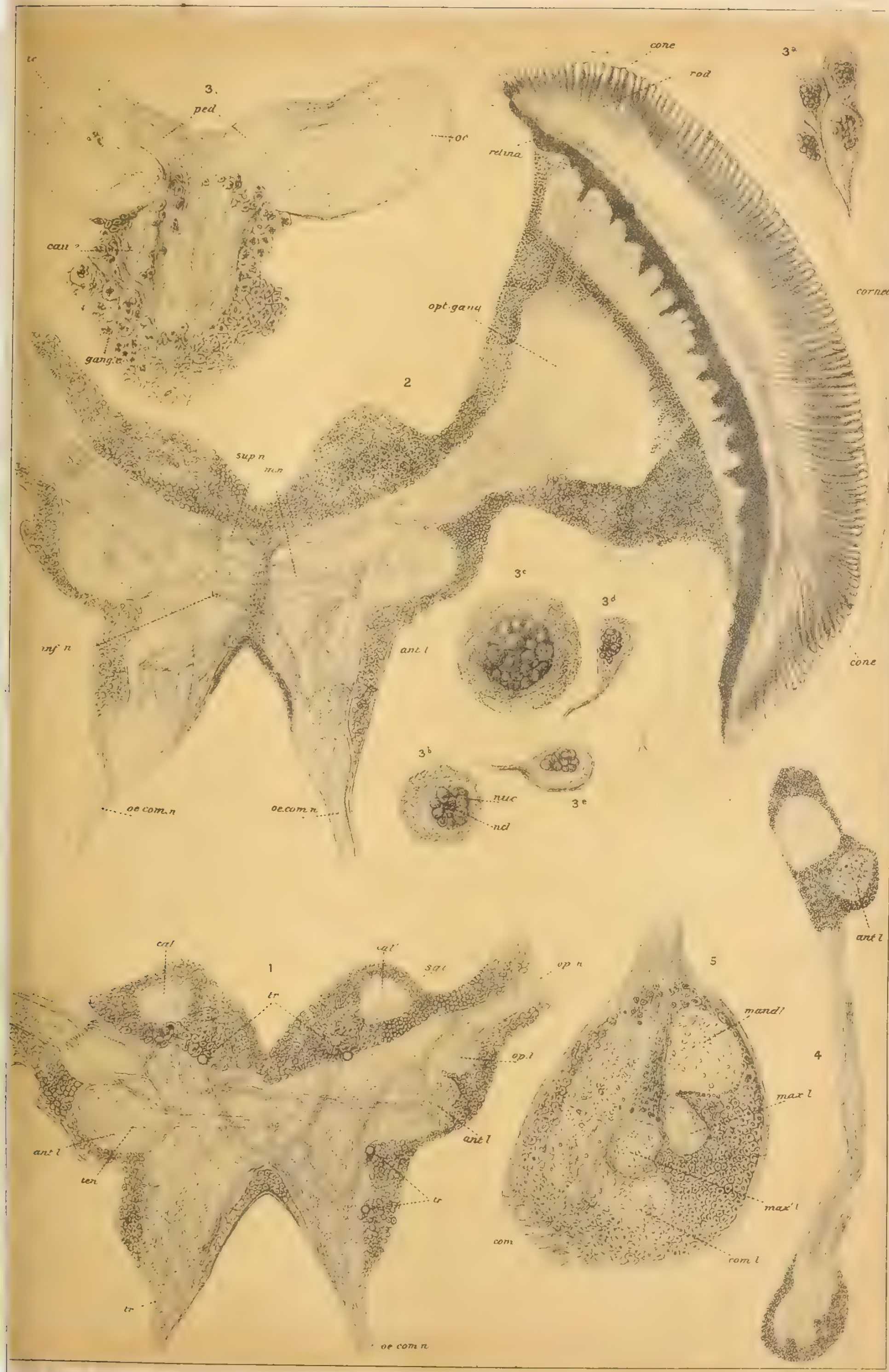
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PLATE XII.

Fig. 1. Section No. 7 of brain of embryo *C. spretus*, earliest stage observed, passing through the upper and lower cerebral (embryonic) lobes (*up. l.*, *low. l.*). (Do the upper cerebral lobes become the calices and the lower cerebral lobes ultimately become the trabeculæ?) (See fig. 8, *low. l.*). *op. l.*, optic lobe; *ant. l.*, antennal lobe; *eye*, outline of the eyes; × ½, Tolles's objective, A eye-piece.

Fig. 1*a*. Portion of the left upper cerebral lobe of fig. 1, magnified 400 diameters, showing the gradual passage of the cortical ganglion cells into the central granular nervous substance, the granules (*gran.*) extending and filling up the spaces between the nucleated ganglion cells (*gang. c.*); it will be noticed that there are at this time no nervous fibers.

Fig. 2. Section No. 5 of head of a more advanced embryo, just ready to hatch, the section not including any part of the brain, the cells represented being connective-tissue cells enveloping the brain. The portions left blank in figs. 1, 7, and 9 are in the actual sections filled with similar connective-tissue (mesodermic) cells.

Fig. 3. Section No. 6 of the same embryo, passing through the optic and antennal lobes.

Fig. 4. Section No. 7 of the same, passing through the "upper cerebral lobes" or calices of the future mushroom body (*cer. l.*), and also through the optic and antennal lobes.

Fig. 5. Section No. 8, passing through the brain (next behind No. 7).

Fig. 6. Section No. 9, passing through what is probably (?) the mushroom body marked as the cerebral lobe (*cer. l.*).

Fig. 7. Section No. 10. The parts not well defined.

Fig. 8. Section No. 11, through the brain of the same embryo as figs. 2–7, and passing through the upper and lower cerebral lobes, and the central body (*cent. b.*), at this point clearly indicated. Probably the "lower cerebral lobes" become the trabeculæ of the adult insect. The sections do not enable us to determine with exactitude the history of the embryonic upper and lower cerebral lobes. (For enlarged views of the upper and lower cerebral lobes and the central body see Plate xiii, fig. 4); *int.* indicates the integument of the head.

Fig. 9. Section No. 12 of the same embryo: *up. l.*, upper, *low. l.*, lower, cerebral lobes; *œs.*, œsophagus (compare also figs. 6 and 7 of Plate xiii, representing sections behind the head of the same embryo).

Fig. 10. Section No. 6 of the younger embryo, passing in front of No. 7, fig. 1, of this plate, and representing the subœsophageal ganglion, showing the form of the ganglion and the relation of the central granular nervous matter (*gran.*) to the envelope of cortical cells (*gang. c.*); × ½, Tolles's objective, B eye-piece.

Figs. 2–9 were drawn with the same objective, A eye-piece.

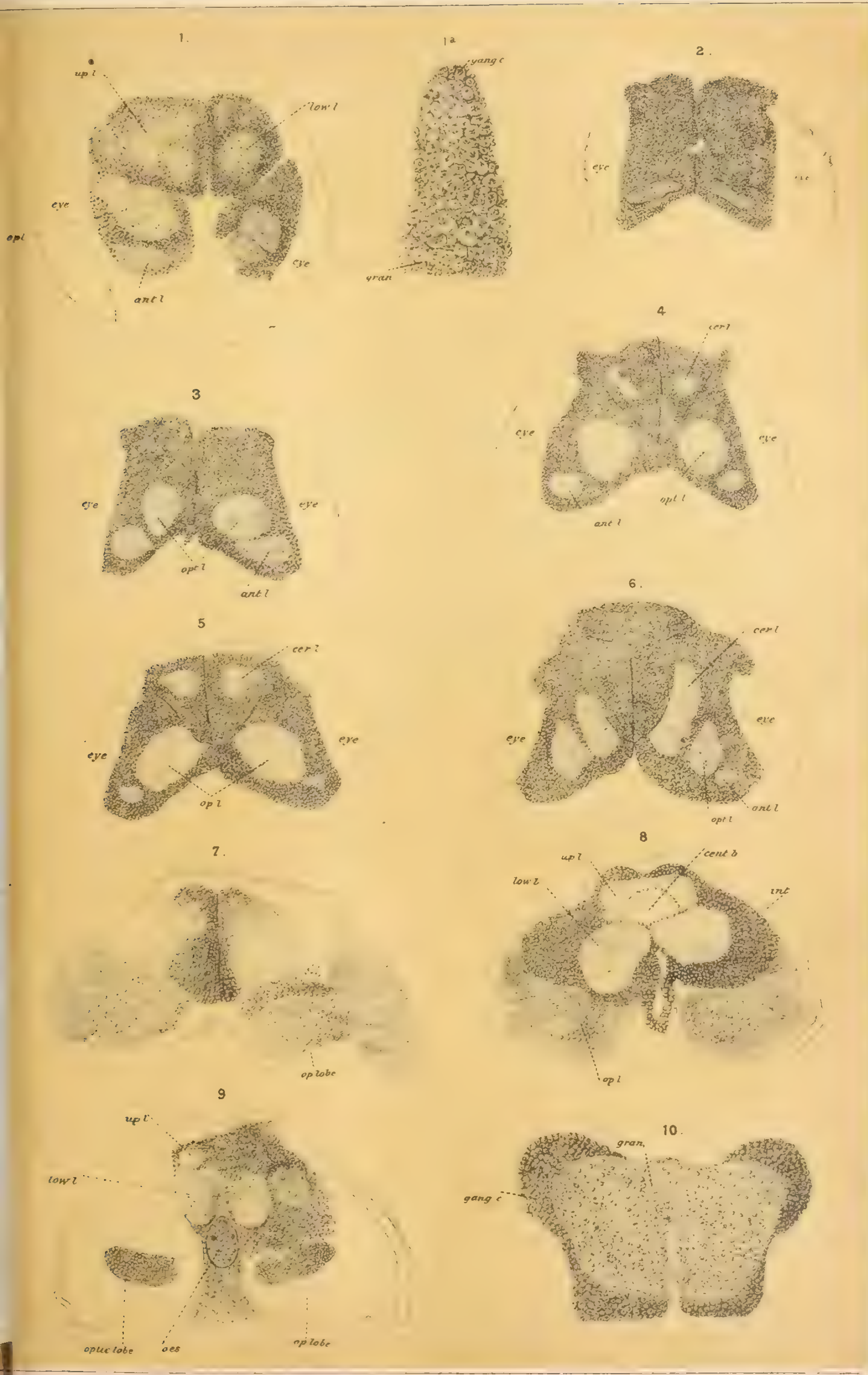
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PLATE XIII.

Fig. 1. Section through the brain of *Caloptenus bivittatus* in the third larval stage, showing the two hemispheres or sides of the brain and the ocelli and ocellar nerves, which are seen to arise from the top of the hemispheres directly over the calices (compare Plate ix, fig. —); *o. cal.*, outer calyx of left mushroom body. The lighter portions represent the granulo-fibrous central part of the brain, and the dark the cortical ganglionic cells; $\times \frac{1}{2}$ A.

Fig. 2. The right hemisphere of fig. 1 magnified 225 diameters, showing the mushroom body, its peduncle (*p.*), cauliculus (*cau.*), and outer (*o. cal.*) and inner (*i. cal.*) calices, and the bundles of fibers variously distributed to the optic and commissural lobes.

Fig. 3. Section passing immediately in front of that represented in fig. 1, and showing the calices without the stalk, and the œsophageal commissural lobe and its commissure (*com.*); the two hemispheres are united below; separate in fig. 1.

Fig. 4. Enlarged view ($\times$ 400 diameters) of the central body and contiguous parts from section 11 of the older embryo of *C. spretus*, represented in Plate xii, fig. 8, *cent. b.* and *low. l.* The central body is seen to be separated from the other parts by a partition of ganglion cells. Are the four ganglion cells in the upper part the rudimentary cellular bodies? Only the right half of the central body is drawn. The right half of the upper cerebral lobe is represented (*up. l.*), and below the entire trabecula, as it appears to be.

Fig. 5. Section No. 8 of the first thoracic ganglion of the youngest embryo (see, also, Plate xii, figs. 1, 1*a*, and fig. 10). The hour-glass-shaped ganglion consists of inner granular nervous matter (*gran.*), with no fibers present, and of a layer of cortical ganglionic cells (*gang. c.*), the layer being thickest on the under side of the ganglion and wanting at and near the middle of the upper side. Magnified 225 diameters.

Fig. 6. Section No. 15 of older embryo, represented also by figs. 2–9 of Plate xii, showing the nervous cord (*n. c.*), surrounded by connective-tissue cells; $\times \frac{1}{2}$ A.

Fig. 7. Section No. 16 through the same embryo, posterior to section 15, the cord being smaller than in section 15. These sections were cut just in front of the stomach and cœca.

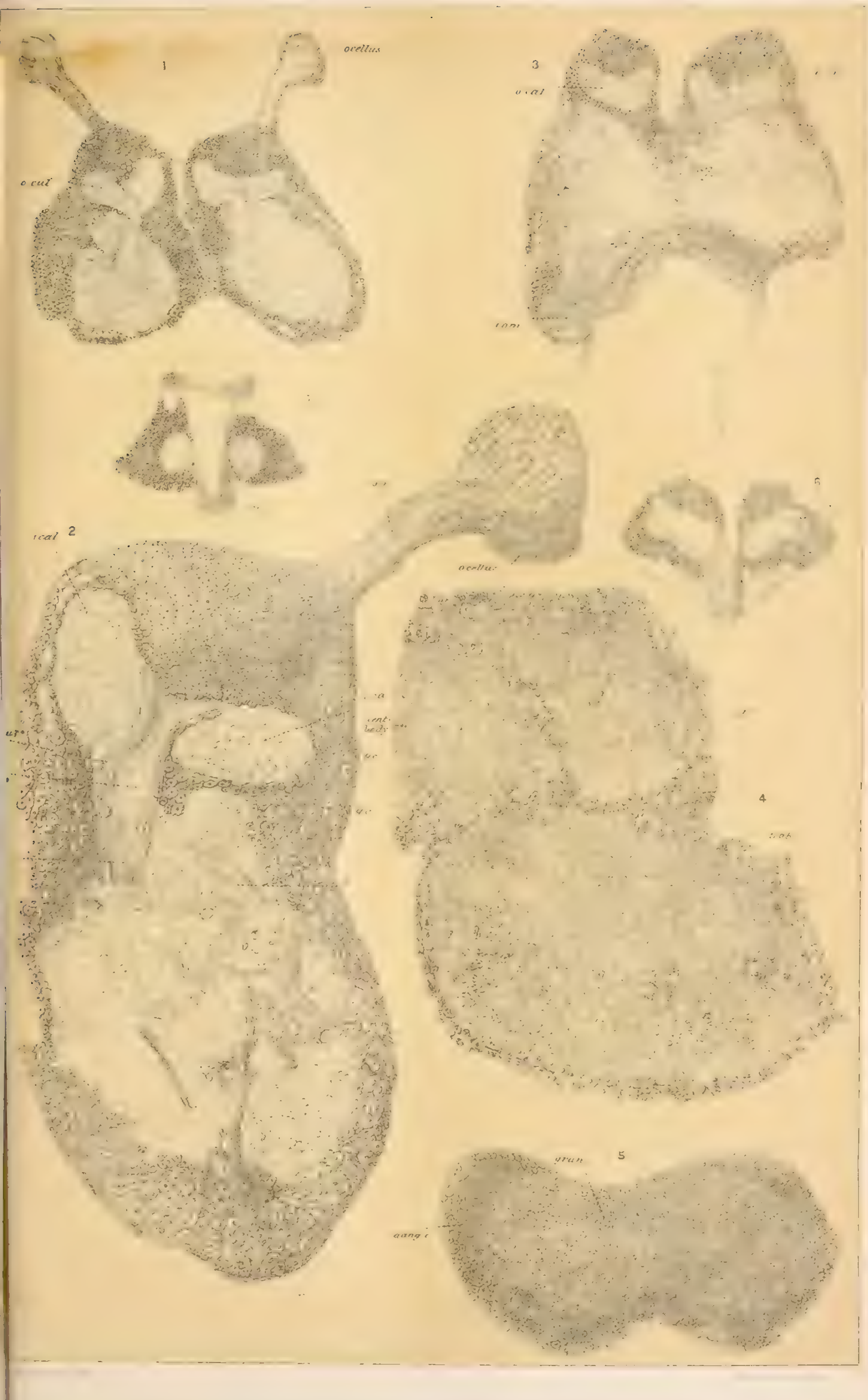

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PLATE XIV.

FIG. 1.—Enlarged view of brain and eye of *C. spretus* in the second pupal stage; × ½ A. This view of the brain is taken from the same preparation (No. 10) as Fig. 1, Plate XV. *Centr. b.*, the central body, showing the two series of cells in the lower division and the two rows of unicellular bodies in the superior division; *œ com. l.*, œsophageal commissural lobes, with the ball-like masses distinctly seen, though this preparation was stained only with picrocarmine, *œ. com.*, œsophageal commissure; *opt. nvl.*, optic nervules; *retina*, retina with rods and cones beyond, the cornea not shown.

FIG. 2.—The central body of adult *C. spretus*, from section 17, showing the inferior and superior divisions, the cells in inferior division (*inf.*) and the two rows of unicellular bodies (*ce. cell. b.*) in the superior division (*sup*). Magnified 225 diameters.

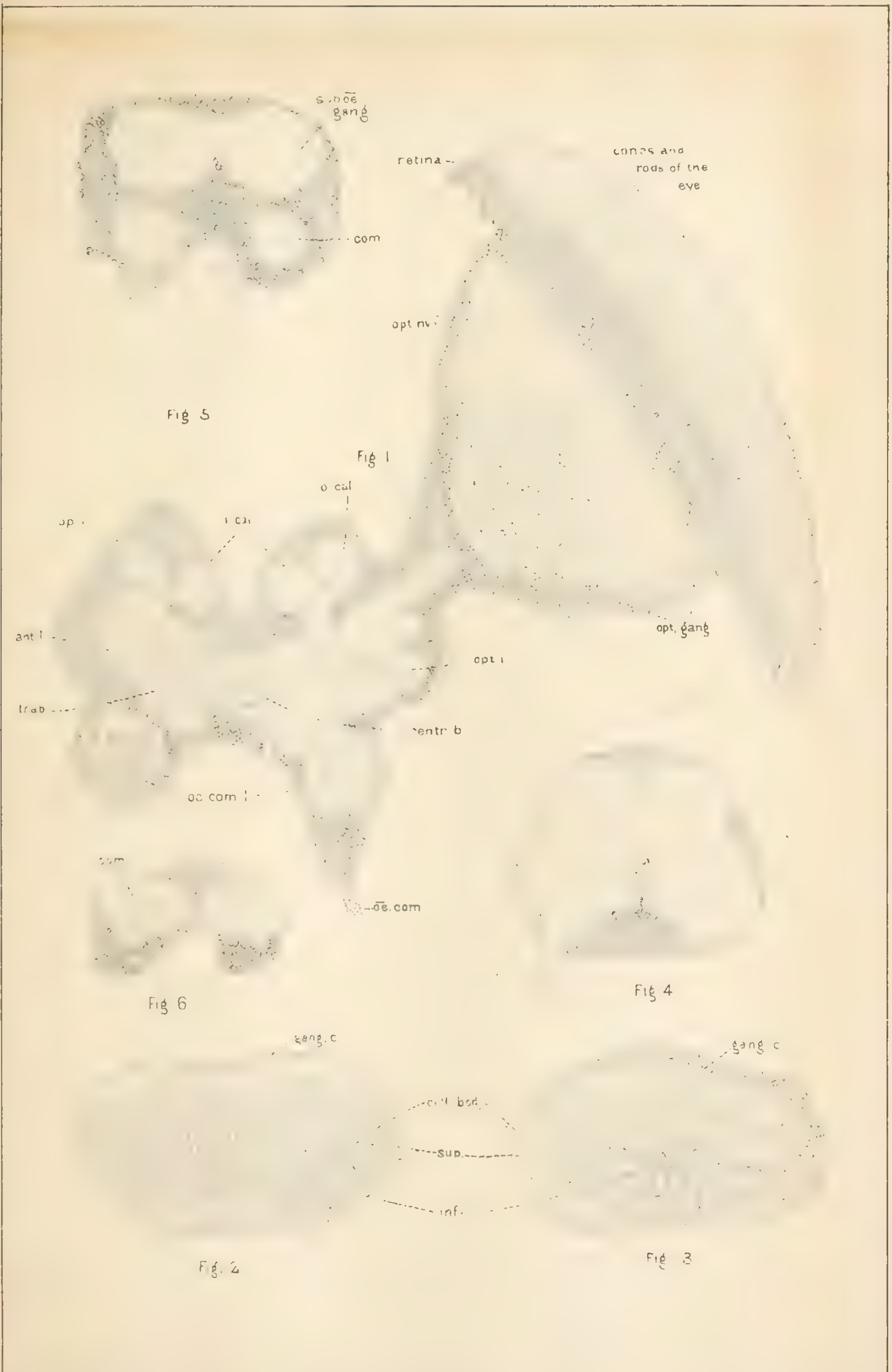
FIG. 3.—The central body of the second or last pupal state, from section No. 10; *c*, cells in the fibrous septum between the lower and upper divisions of the central body, from section No. 11. × 225 diameters.

FIG. 4.—Vertical section of the subœsophageal ganglion of the cockroach (*Blatta orientalis*), showing the commissure on the left side.

FIG. 5.—A section farther behind, showing the back of the ganglion (*gang.*), seen separate from the commissure (*com*).

FIG. 6.—A section through the commissure just behind the ganglion.

All the sections represented on this plate were stained with picrocarmine.



A S Packard del

THE BRAIN OF THE LOCUST.

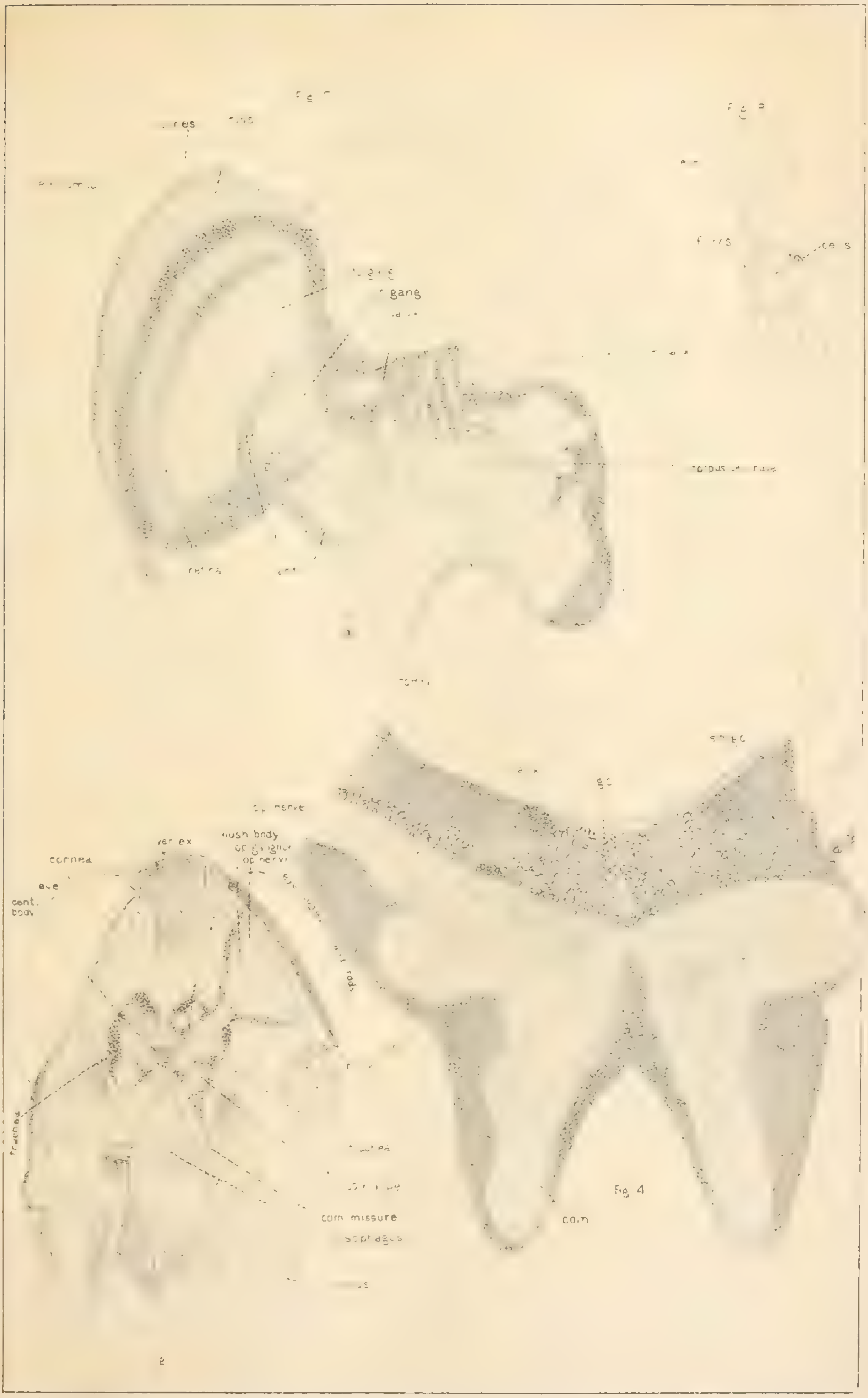
PLATE XV.

FIG. 1.—Frontal section No. 10, through the head of second or last pupal stage of *C. spretus*, passing through the middle of the brain, the optic ganglion, and eyes, and cutting across the œsophagus. Drawn in order to show the relation of the brain to the eyes and the exterior of the head: magnified 30 diameters. In the brain the right mushroom body is seen, while the optic and antennal lobes are not so well marked. The central body (*centr. b.*) is cut through near the middle; below are the trabeculæ (*trab.*), next to the commissural lobes, two tracheæ (*tr.*) or air-tubes passing near the brain. The commissure to the subœsophageal ganglion is drawn on the right side, passing down the œsophagus. In the eye the cornea, the respective portions composed of rods and cones, the black retina, the stratum of optic nervules, and the optic ganglion and optic nerve passing off from the optic lobe are all well marked.

FIG. 2.—Section through the brain and eyes of the same second pupa of *C. spretus*, passing through the anterior part of the calices, but not through the central body. The section is oblique and does not well represent the right side.

FIG. 3.—Calyx of the section represented by Fig. 2: magnified 225 diameters. It is composed of granulated nerve substance with a few fibers, the continuation of those of the stalk, and with a few ganglion cells.

FIG. 4.—Section through the back of brain of the adult *Locusta Carolina*, passing behind the mushroom body, showing the œsophageal commissures, the antennal lobes, and the bundle of nerve-fibers crossing to the right hemisphere. The left calyx is cut through, the microtome-razor passing behind and not grazing the right mushroom body. The distribution of the large (*l. g. c.*) and small ganglion cells (*sm. g. c.*) is well seen in this section. It will be seen that the brain of *Locusta Carolina* does not differ in any respect from that of *Caloptenus spretus*, so far as the sections show.



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THE BRAIN OF THE LOCUST.

CHAPTER XI.

THE BRAIN OF THE LOCUST.

In order to appreciate the habits, migratory, reproductive, &c., of the locust, and to learn something of its general intelligence as an insect and as compared with other insects, it is necessary for us to study with a good deal of care the organ of the locust's *mind*, *i. e.*, its nervous system, comprising its nervous centers and the nerves arising from them. The present chapter will be devoted to a study of the brain.

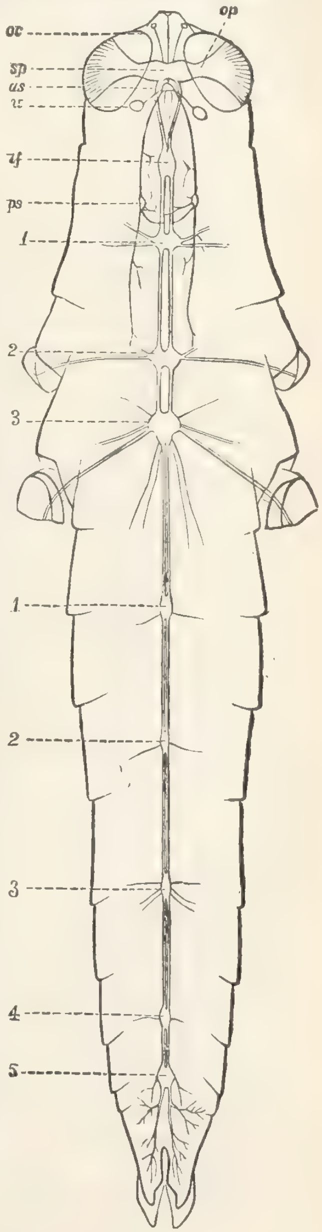

FIG. 9.

The nervous system in general.—The nervous system of the locust has been described in a general way in the First Annual Report of the Commission (p. 264, Figs. 14, 15). It consists of a series of nerve centers or *ganglia*, connected by nervous cords called *commissures.* There are ten of these ganglia in the locust, *i. e.*, two in the head, the first and largest of which is called the "*brain*"; there are three ganglia in the thorax, and five in the hind-body or abdomen. The brain is situated in the upper part of the head, resting upon the gullet or œsophagus, whence its true name *supraœsophageal ganglion.* (Plate IX, Fig. 1.) The succeeding nerve-center is situated in the lower part of the head, behind the mouth and under the œsophagus, hence it is called the *subœsophageal ganglion.* (Plate IX, Fig. 5.) The supraœsophageal ganglion is larger than the succeeding ones, and is compressed from before and behind, its height being much greater than its length, while the other ganglia are more or less lens-shaped and flattened vertically, being broader than thick. The brain really is a double ganglion, being composed of two hemispheres, each hemisphere being a single ganglion or nerve-center; all the succeeding ganglia are also double ganglia; but for convenience we will call the "brain" and each of the succeeding nerve-centers a *ganglion.* Each side of the brain contracts, and then swells out into a rounded portion next to the eye, called the *optic ganglion.* From this optic ganglion the optic fibers proceed to the facets of the eye. The optic ganglion connects with the brain by the large optic nerve. There are, then, two *optic nerves*, besides three slender nerves (*ocellar nerves*) sent to each of the three *ocelli* or simple eyes; moreover, a nerve is sent to each of the antennæ and are hence called the *antennal* nerves. The relations of the brain to the head, and to the succeeding ganglion, and the origins of the nerves distributed to the eyes, antennæ and ocelli, as well as of the nerves sent to the jaws, etc., are clearly seen in the figures on Plate IX.

On the other hand the mouth parts, *i. e.*, the jaws (*mandibles*) and accessory jaws (first and second *maxillæ*, the latter called the *labium* or under lip) are each supplied by a pair of nerves, called, respectively, the *mandibular*, *maxillary*, and *labial* nerves. These three pairs of nerves arise from the subœsophageal ganglion. (See Pl. IX, Fig. 2.)

The brain of insects as distinguished from the brain of vertebrates.—The "brain" or supraœsophageal ganglion is, as we shall see, a much more complicated organ than any of the succeeding ganglia, having important parts which are wanting in all the others, hence it is *par excellence* nearer to our idea of a brain than any of the other nervous centers. It should be remembered, however, that the word "brain" is applied to this compound ganglion simply by courtesy and as a matter of convenience, as it does not correspond to the brain of a vertebrate animal, the brain of the horse or man being composed of several distinct pairs of ganglia. Moreover, the brain and nervous cord of the fish or man is fundamentally different, or not homologous with that of the lower or invertebrate animals, though the nervous system of the insects and crustacea present greater analogies to that of the vertebrates than any other of the lower animals, with the exception, perhaps, of the cuttle-fish. The nervous cord of the insect consists of a chain of ganglia connected by nerves or commissures, while the spinal cord of the fish or man is essentially "a double and fused series of nerve-centers." Moreover, if this cord is cut through, a section shows that it consists of two kinds of substances or tissues, called the "gray" and "white" substance. The gray matter is situated in the center, and consists largely of nerve or so-called "ganglion cells," while the external white matter of the brain or cord is composed of a mass of nerve fibers. Now, in the nervous system of insects there is nothing to compare with these substances, but the ganglia, on the contrary, as we shall see farther on, consist primarily of an external layer of ganglion cells, whose fibers pass in to form a central fibrous mass or net-work, the meshes of which are filled with a fine granulated nerve substance, the nature of which is not clearly understood. Moreover, the entire brain of an insect is white, as are all the ganglia.

A ganglion in its simplest form is a little rounded mass, or nodule, of ganglion cells, with fibers leading from them; such cells are represented by Fig. 3*a*, on Plate XI. Now when the fibers lead in from the sensitive hairs on the crust of the insect, or from the antennæ, or the eyes or ears, and end in separate masses or lobes, which are modified ganglia, such ganglia are regarded as "sensory ganglia," and the nerves leading in from them are called ingoing or "afferent nerves," while the ganglia which give rise to the outgoing or "efferent" nerves, *i. e.*, those going to the muscles of the wings, legs, &c., are called "motor ganglia," as stated by Bastian, in his popular and excellent work "The Brain as an Organ of Mind." As to the term ganglion we quote as follows from Bastian:

> Two or more sensory ganglia, or two or more motor ganglia, may grow together into a single mass; or, what is equally common, a sensory and its corresponding motor ganglion, or two or more pairs of these, may fuse into a single larger nodule, which may be called a "nerve-center." The term ganglia is, however, commonly applied to any round, ovoid nodule containing nerve-cells, whatever its size or degree of internal complexity. Many ganglia in the lower animals, which are typically deserving of the name as regards mere form and separateness, are also, by reason of their compound nature, true nerve-centers. The two terms are, therefore, to a considerable extent, interchangeable.

Referring the reader to Bastian's book, or to the text-books on physiology by Huxley, Foster, or Dalton, for information regarding the structure and physiology of the nervous system in general, we will proceed to describe that of the locust. It should be borne in mind, however, that the subœsophageal ganglion, or "brain," of the insect is much more complex than any other ganglion, consisting more exclusively both of sensory as well as motor ganglia and their nerves. But it should also be borne in mind that the subœsophageal ganglion also receives nerves of special sense, situated possibly on the palpi and possibly on the tongue, at least the latter is the case with the bee; hence, this ganglion is probably complex, consisting of sensory and motor ganglia. The third thoracic ganglion is also, without doubt, a complex one, as in the locusts the auditory nerves pass into it from the ears, which are situated at the base of the abdomen. But in the green grasshoppers, such as the katydids and their allies, whose ears are situated in their fore-legs, the first thoracic ganglion is a complex one. In the cockroach and in the *Leptis* (Chrysopila), a common fly, the caudal appendages bear what are probably olfactory organs, and as these parts are undoubtedly supplied from the last abdominal ganglion, this is probably composed of sensory and motor ganglia; so that we have in the ganglionated cord of insects a series of brains, as it were, running from head to tail, and thus in a still stronger sense than in vertebrates the entire nervous system, and not the brain alone, is the organ of the *mind*, or psychological endowment, of the insect.

We will now proceed to examine the brain of the adult *Caloptenus spretus*, and compare it with that of other insects; then study its development in the embryo, and finally examine the changes it undergoes in the larva and pupal stages before attaining the fully developed structure of the adult locust.

THE BRAIN OF THE ADULT LOCUST.

The method of examination employed by us has been to cut the brain into a number of thin sections by means of the microtome, previously hardening the tissues in alcohol. The labor of cutting these sections has been performed by Mr. Norman N. Mason, of Providence, R. I., who has brought to his work an unusual degree of skill and care in preparing such delicate sections. In all these sections the brain was not previously removed from the head, but the entire head was cut through, having previously been hardened in absolute alcohol for twenty-four hours or more, and then soaked in gum arabic for one or two or more days. The objects were then embedded in a preparation of paraffine and sweet-oil and wax, or, in some cases, in soap and oil. After the sections were cut they were stained with picrocarmine, or partially stained with osmic acid, and then treated with picrocarmine. Finally the slices were mounted in glycerine jelly for study under the microscope.

The sections were in most cases *frontal* ones, namely, cut transversely from the front of the head or brain backwards, while a few were longitudinal or *vertical* ones, viz, cut parallel to the median line of the body. They were either $\frac{1}{500}$ or $\frac{1}{1000}$ of an inch in thickness.

It should be observed that the brain is divided by a furrow into two halves or hemispheres; these are deepest above and below, and the upper and lower portions may be called, respectively, the *frontal* and *posterior* furrow.

The brain is mostly surrounded by a thin delicate membrane, the neurilemma, also called by Krieger the *perineurium;* it is formed of very dense fibrous connective tissue.

Histological elements of the brain.—The brain is histologically or structurally divided into two kinds of tissue or cellular elements.

I. An outer, slightly darker, usually pale grayish white portion is made up of "cortical cells," or "ganglion cells." (Pl. XI, Fig. 3, *a*, *b*, *c*, *d*.) This portion is stained red by carmine, the ganglion cells composing it readily taking the stain; when thus stained by carmine, the nucleus of the cells is rendered quite distinct, but the cell wall is also distinct; when stained by hæmatoxylin the large nuclei are remarkably distinct, but the cell walls are not well brought out; when stained by osmic acid these cells are not so clearly shown as by a picrocarmine or carmine stain, and the nucleus is less distinct than when treated by the two other stains mentioned.

This outer loose cellular envelope of the brain consists of large and small ganglion cells. Where the tissue consists of small ganglion cells, it is naturally from the denser arrangement of the smaller cells, which are packed closer together, rather darker than in those regions where the tissue consists of the more loosely disposed, large ganglion cells.

A. The large ganglion cells (Pl. XI, Figs. 3, 3 *a*, 3 *b*, 3 *c*, 3 *d*, 3 *e*) are oval, and send off usually a single nerve fiber; they have a thin fibrous cell wall, and the contents are finely granular. The nucleus is very large, often one-half the diameter of the entire cell, and is composed of large round refractive granules, usually concealing the nucleolus (the granules are much larger and fewer in number and the nucleolus is less distinct than in the brain of Limulus, the king crab). These large ganglion cells are most abundant and largest on each side of the upper furrow, and in front of the "central body," also at the bottom of the lower furrow, and along the exterior of the optic and antennal lobes, and along the commissural lobes.

B. The small ganglion cells apparently differ chiefly in size from the large ones, and are most numerous in the front swelling of each hemisphere; they surround and fill the calices of the mushroom bodies, and they extend along each optic nerve and form a large proportion of each optic ganglion, especially the layer next to the retina of the eye, though they are replaced by large ganglion cells at the junction of the fibrous part of the optic nerve with the dilated granular portion. The brain is surrounded more or less completely by the connective tissue cells belonging to the mesoderm or middle germ layer, and which are sometimes liable to be confounded with the ganglion cells, as they stain the same tint with carmine. It should be borne in mind that the nervous system, ganglia and nerves, originate from the tegumental or exodermal layer.

II. The medullary or inner part of the brain consists of matter which remains white or unstained after the preparation has remained thoroughly exposed to the action of the carmine. It consists of minute granules and interlacing fibers. The latter often forms a fine irregular net-work inclosing masses of finely granulated nerve matter.

In the antennal and commissural lobes is a third kind of matter, in addition to the granular and fibrous substances, which forms irregularly rounded masses, cream-colored in picro-carmine preparations, and which stain dark with osmic acid. This is called by Dietl "*marksubstanz*," and is described by Newton as "a peculiar arrangement of nervous matter, which appears sometimes as fine fibrillæ, with an axial arrangement, sometimes as a very fine net-work of different thicknesses, and sometimes as thin lamellæ, or altogether homogeneous. Under all these forms this third group of textures is characterized by turning very dark under the influence of osmic acid, whilst the other elements are only turned brown."

It is to be noticed that this central unstained portion contains few, if any, ganglion cells, and it is most probable that the fibers of which it is composed originate from the cortical ganglion cells. At one or two points at Fig. 3, Pl. XI, I have seen the fibers passing in from ganglion cells towards the middle of the brain. In the horseshoe crab (Limulus), owing to the simple structure of the brain, it is evident that the optic and ocellar nerves and posterior commissures originate from the large ganglion cells which in this animal are situated in or near the center of the brain. In the last abdominal ganglion also the fibers arising from the peripheral ganglion cells can very plainly be seen passing in towards the center of the ganglion and mingling with the fibers forming it. Hence in all probability the fibrous mass of the central part of the brain mostly originates from the peripheral or cortical ganglion cells.

To briefly describe the brain of the locust, it is a modified ganglion, but structurally entirely different from and far more complicated than the other ganglia of the nervous system. It possesses a "central body," and in each hemisphere a "mushroom body," optic lobe, and optic ganglion, and olfactory lobe, with their connecting and commissural nerve fibers, not found in the other ganglia. In the succeeding ganglia the lobes are in general motor; the fibers composing the œsophageal commissures, and which arise from the œsophageal commissural lobes, extend not only to the subœsophageal ganglion, but pass along through the succeeding ganglia to the last pair of abdominal nerve centers.[326] Since, then, there is a direct continuity in the fibers forming the two main longitudinal commissures of the nervous cord, and which originate in the brain, it seems to follow that the movements of the body are in large part directed or co-ordinated by the brain.[327] Still, however, a second brain, so to speak, is found in the third thoracic ganglion of the locust, which receives the auditory nerves from the ears situated in the base of the abdomen; or in the first thoracic ganglion of the green grasshoppers (katydids, &c.), whose ears are in their fore legs; while even the last abdominal ganglion in the cockroach and mole cricket is, so to speak, a secondary brain, since it receives sensory nerves from the caudal stylets which are provided with sense organs.

Description of the sections of the brain.—We will now describe the sections upon which the subsequent account of the brain is founded. The sections, unless otherwise stated, are *frontal*, *i. e.*, cut transversely across

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[326] We have seen that the two great longitudinal commissures pass directly from the brain into and then pass backward from the subœsophageal ganglion, but beyond that point have not traced their course, as it is generally supposed that they extend uninterruptedly to the last abdominal ganglia. This has indeed been shown to be the case by Michels in his admirable treatise on the nervous system of a beetle (Oryctes) in Siebold and Kölliker's Zeitschrift für wissen. Zoologie, Band 34, Heft. 4, 1880. Michels states that each commissure is formed of three parallel bundles of elementary nerve fibers, which pass continuously from one end of the ventral or nervous cord to the other. "The commissures take their origin neither out of a central "punct substanz (or marksubstanz), nor from the peripheral ganglion cells of the several ganglia, but are mere continuations of the longitudinal fibers which decrease posteriorly in thickness, and extend anteriorly through the commissures forming the œsophageal ring to the brain."

[327] The following extract from Newton's paper shows, however, that the infra or subœsophageal ganglion, according to Faivre, has the power of co-ordinating the movements of the body; still it seems to us that the brain may be primarily concerned in the exercise of this power, as the nerves from the subœsophageal ganglion supply only the mouth parts. "The physiological experiments of Faivre in 1857 (Ann. J. Sci. Nat., tom. viii, p. 245), upon the brain of Dytiscus in relation to locomotion, are of very considerable interest, showing, as they appear to do, that the power of co-ordinating the movements of the body is lodged in the infra-œsophageal ganglion. And such being the case, both the upper and lower pairs of ganglia ought to be regarded as forming parts of the insect's brain." Quart. Jour. Micr. Sc., 1879, p. 342.

the face from before backwards; in cutting thus through the head, twelve sections were made before the front part of the brain was touched, the thirteenth grazing the front of the brain. Section 14 passed through the anterior part of both *calices*, but did not touch the stalk of the *mushroom body* (these terms will be explained farther on). It passed through the central region of each hemisphere, including the front part of the *trabeculæ* or base of the stalk of the mushroom body. The section passed through the commissural lobes, the lower third being composed of ganglion cells, but the substance of the commissure itself is filled with the ball-like masses of "marksubstanz." The commissures to the subœsophageal ganglion were not touched, and do not appear in the section, since they arise from the back of the brain.

In section 15 no additional organs are exposed. In section 16 (Pl. X, Fig. 1) the trabeculæ are seen, when magnified 225 diameters, to be composed of ascending fibers, which form the base or origin of the double stalk of the mushroom body.

Section 17 (Pl. X, Fig. 2) is the most important of all the sections, as the entire mushroom body and the central body are cut through, together with the antennal lobes, and the commissural lobes, and also the origin of the optic nerves.

In section 18 (Pl. X, Fig. 4) the double nature of the stalk of the mushroom body is seen; the optic lobes are now well marked, and the razor grazed the back of the commissural lobes, as well as the inner side of the optic ganglion. The section passed behind the trabeculæ and the base of the stalk and through the back of the central body. The calices are each seen to be so furrowed and uneven as to appear in the section as two separate portions. Two important nerves (Pl. X, Fig. 4, *p. a. n.*) are seen to arise from the commissural lobes, and to pass upwards. ending on each side of the upper furrow, near the origin of what we think are possibly the ocellar nerves (*o. c. n.?*).

Section 19 (Pl. XI, Fig. 1) passed through the back of the brain (compare Fig 4. of the same plate, which represents a vertical or longitudinal section of the brain), through the œsophageal commissures, and the back edge of the calices, while the antennal lobes and a part of the optic lobes are well seen in the section. A transverse commissural nerve (*t c n*) connects the two antennal lobes, and the commissural nerves are seen to cross at the bottom of the furrow.

Section 20 (Pl. XI, Fig. 2), which passes through the extreme back of the brain, shows in this plane four transverse bundles of nerve fibers connecting the two hemispheres, *i. e.*, the inferior (*inf. n.*), two median (m. n.) and, a superior nerve (*sup. n.*). In this section the relations of the optic ganglion and eye to the brain are clearly seen, the optic ganglion being situated in the posterior region of the brain. It will also be seen that the two hemispheres are at this point only connected anteriorly.

In sections 22, 23, and 24 the brain nearly disappeared, and only the optic ganglia were cut through by the microtome, affording instructive sections of the three lenticular masses of white unstained granulo-fibrous substance surrounded by ganglion cells.

INTERNAL TOPOGRAPHY OF THE BRAIN.

Disregarding the envelope of cortical ganglionic cells, though they are evidently of primary importance in the physiology of the insect's brain, we will now describe the internal topography of the brain. It consists primarily of an irregular net-work of nerve-fibers, inclosing masses of granulated nerve matter. This mass is divided into a number of separate areas or lobes, of which the "central body" (*corpus centrale* of Flögel and Newton) is single and situated between or in the median line of the two hemispheres. There is also a primitive superior and inferior central region, better shown, however, in the brain of the embryo and larval locust than in the adult. Besides these areas are the rounded masses or "lobes," *i. e.*, the optic, antennal, or olfactory and commissural lobes; the optic nerves arising from the optic lobes, the antennal nerves from the antennal lobes, and the commissures surrounding the œsophagus and connecting the brain with the subœsophageal ganglion; these arise from the commissural lobes. Finally a "mushroom body" is situated in the upper and central part of each hemisphere.

The central body.—This is the only single or unpaired organ in the brain. It is best seen in section 17 (Pl. X, Fig. 2), which also passes through the optic and antennal lobes and the trabeculæ and mushroom bodies. This singular organ is apparently present in all winged insects, though differing somewhat in structure in different insects. It is, as seen in Pl. X, Fig. 2, situated in the same plane as the peduncle and in the same plane as the center of the entire mushroom body, and rests upon the inner sides of the trabeculæ. Section 16 does not pass through it, though the next section, which is $\frac{1}{500}$ inch thick, passes through its middle. Section 18 (Fig. 4) passes through its back, while the next section does not include any part of it; hence its antero-posterior diameter is slightly over $\frac{1}{500}$ of an inch. It is about twice as broad as high, and thus is a small body, though from the universality of its occurrence in winged insects, it may be one of considerable importance.

It is surrounded by a dense net-work of fibers containing a few small ganglionic cells, the fibres in front continuous with those near the bottom of the frontal median furrow and connecting the two optic lobes. Posteriorly the fibers apparently are not continuous with those of the trabeculæ; hence the central body appears to be quite isolated from the rest of the brain. Its substance, when magnified 400 diameters, appears to be a white granular matter like the adjoining parts of the brain. It is divided into two parts, the superior and inferior, the former part constituting the larger part of the body. The inferior portion is separated by fibers from the superior; it contains numerous nucleated spherical cells situated either irregularly or perhaps primarily (see Pl. XIV, Fig. 3, of the pupa), in two rows when fewer in number than in the adult. The superior and larger division of the central body contains the series of what we may call *unicellular bodies*, sixteen in a series. The lower series are spherical or slightly elongated, and rest in the fibrous partition or septum, forming the floor of the superior division of the central body. The upper row of bodies are cylindrical, and about three or four times as long as thick. They are separated by thin fibrous septa. Pl. XIV, Fig. 2, represents the central body enlarged 225 diameters. When we examine the central body in an earlier stage, *i. e.*, the second pupal (Pl. XIV, Fig. 3), we see that the body is covered above by a stratum of nucleated ganglion cells continuous with those next to the bottom of the upper furrow; and that the fibrous septum between the upper and lower division also contains small cells. These cells disappear in the adult, and evidently give rise to the fibers which take their place. It will also be seen that the "unicellular bodies" are shorter, more cell-like, than in the adult; hence they seem to be modified ganglion cells, which have at an early date lost their nucleus and nucleolus. My observations on the central body of the locust agree in the main with those of Newton (compare his Fig. 9). His drawings are not especially clear and definite, but the differences appear to be unimportant. There are perhaps two (16 instead of "12 or 14") more cellular bodies in the locust than in the cockroach. Unfortunately my sections of the brain of the cockroach do not show the central body. Dietl states that the central body is a "median commissural system." This description we would accept in a modified sense. We have shown that the unicellular bodies and the cells beneath them were once like the ganglion cells, but that they have lost their nuclei and nucleoli; hence the functions of the central body must be unlike that of an ordinary commissural lobe. Flögel states that the number of "sections," or what I call unicellular bodies, is eight; we have counted sixteen. Both Flögel and Newton appear to regard these bodies as simply spaces or sections between fibrous partitions; but it would appear that these sections are really modified cells, and that the fibrous septa, are possibly the cell-walls, somewhat modified.

The mushroom bodies.—These curious organs have attracted a good deal of attention from writers on the brain of insects. Dujardin, in 1850, first drew attention to them. His memoir we have not at hand to refer to, but as stated by Newton [328]—

Dujardin pointed out that in some insects there were to be seen upon the upper part of the brain certain convoluted portions which he compared to the convolutions of the mammalian brain, and, inasmuch as they seemed to be more developed in those insects which are remarkable for their intelligence, such as ants, bees, wasps, &c., he seemed to think the intelligence of insects stood in direct relationship to the development of these bodies. The form of these structures is described by the same author as being, when fully developed, as in the bee, like a pair of disks upon each side,

[328] On the Brain of the Cockroach. By E. T. Newton. Quart. Journ. Microscopical Science, July, 1879, H, pp. 341,342.

each disk being folded together and bent downwards before and behind, its border being thickened and the inner portion radiated. By very careful dissection he found these bodies to be connected on each side with a short pedicle, which bifurcates below to end in two tubercles. One of these tubercles is directed towards the middle line, and approaches but does not touch the corresponding process of the opposite side. The second tubercle is directed forwards, and is in close relation to the front wall of the head, being only covered by the pia mater [neurilemma]. These convoluted bodies and the stalks upon which they are mounted are compared by Dajardin to certain kinds of mushrooms, and this idea has been retained by more recent writers on the subject.

The form of the mushroom body is much more complicated in the bee or ant than in insects of other orders. In the cockroach and in other Orthoptera, notably the locust, the four divisions of the calices are united into two; while the structure of the calyx in the cockroach is quite different from that of the locust. Mr. Newton, in his description, notwithstanding Dujardin's statement, appears to practically limit the term "mushroom body" to the cap or calyx on the end of the stalk. In the following description we apply the term "mushroom body" to the entire structure, including the base or trabecula, the double stalk, and the cap or calyx.

So far as we have been able to observe, the double stalk of the mushroom body rests on a rounded mass of granulo-fibrous nerve matter; this rounded mass or base of the column is called the *trabecula* (Pl. X, Fig. 2, *trab.*). The two trabeculæ (one in each hemisphere) are much more widely separated (in my sections) than in the cockroach or in those insects studied by Flögel; the space between them being filled by a loose cellular mass containing small nucleated cells. The thickness of each trabecula is greater than that of the double stalk. Section 14 passes through the outer or anterior edge of the trabecula, and also through the calices at some distance from the edge. Section 18 (Fig. 4) does not include it, though showing well the mushroom body, with the exception of the base of the double stalk. It follows that the thickness of the trabecula is about $\frac{3}{500}$ of an inch.

The substance of the trabecula is seen to be minutely fibrous under a power of 725 diameters, with masses of granules among the fibers which are much finer than in the optic or antennal lobes. At the point passed through by section 17 the trabeculæ appear to have no connection with the stalk, but the latter appear to stop abruptly just before reaching it, the envelope of ganglionic cells and fibers surrounding the trabeculæ being interposed between the base of the stalk and the trabecula. (This does not preclude the fact that the stalk does not arise from the trabecula, though there are no signs of it in this section; for it clearly appears to thus arise in the drawings and descriptions of Dietl, Flögel, and Newton).

The structure of the trabeculæ in the locust, judging from our sections, appears to be more complex than would be inferred from the observations of the other observers just mentioned. Section 17 (Pl. X, Fig. 2, *trab.*) passes through the middle of each of these bodies, and it then appears that there are four bundles of nerve-fibers passing out of each body. A bundle of transverse nerve-fibers (Fig. 2 *t. c. n.* and Fig. 3) passes along under the central body, directly through the middle of the trabeculæ, and anastomoses with the fibrous envelope of each trabecula. In front of this transverse intra-trabecular nerve is a small short ascending bundle of fibers (Fig. 3, *a. t. n.*) which passes next to the pedicel, but does not apparently form a part of it, but anastomoses with the fibers on each side of the central body. Below, the fibres pass downward and outward to apparently connect with the fibrous envelope of the trabecula. Another short bundle passes out from the trabecula obliquely towards the central body and anastomoses with the fibrous envelope of the central body.

Below, but in the same plane, is another transverse bundle of fibers (Fig. 3, *l. t. n.*), which is slightly curved and on the left side its fibers are distinctly seen to enter the trabecula. This lower intratrabecular nerve, as we may call it, connects with three vertical short nerves arising from near the edge of the lower furrow between the hemispheres of the brain. Of these, the central one (*centr. n.*) is in the median line of the brain, and the lateral ones (*lat. n.*) are on each side. There would thus seem to be a direct double nervous communication between the two trabeculæ, and with the fibers surrounding the central body, and hence with the rest of the brain. This seems to be opposed to the statement of Newton that the trabeculæ, and the mushroom bodies in general, have no nervous connection with the rest of the brain. This section also clearly indicates the origin of the optic nerve, which passes *behind* the stalk of the mushroom body, and also the relation of the fibers of the stalk to the calices, as they appear to penetrate far into the interior of the body of each calyx.

The double stalk (*cauliculus* and *peduncle*).—These names are applied to the larger and smaller divisions of the stalk of the "mushroom body." They are represented in the eighteenth section (Fig. 4) where the outer part of the stalk (*cauliculus*) supports the outer calyx, and the inner slenderer column of fibers supports or ends in the inner division of the calyx. These two bundles of fibers are somewhat curved, but as they do not appear in sections 16 and 19, must be less than $\frac{2}{500}$ of an inch thick. Their fibers are seen to penetrate deeply into the base of the calices, and thus to directly communicate with the fine granular substance of the calices.

The calices.—The cups of the mushroom bodies in the locust differ decidedly in form from those of the cockroach, and this part of the mushroom body is more variable in form in the different orders of insects than any of the other parts of the brain. It is nearly obsolete, or, as Flögel states, "not more than rudimentary" in hemipterous insects (notably *Syromastes*), and is less completely developed in many smaller moths, beetles, and flies, as well as Neuroptera (*Æschna*), according to Flögel, than in the larger moths, in the Orthoptera, and especially in the

Hymenoptera, where it is well developed. We have been unable to find it as yet in the brain of myriopods or of the spider. In the locust each body is more or less rounded and rudely saucer-like rather than cup-like, with the rim very thick: the hollow of the cup, if it be hollow, is small in proportion to the thickness of the saucer-like cup. The diameter of a calyx is about $\frac{1}{500}$. The anterior edge reaches to the front edge of each hemisphere of the brain, but does not extend to the back part of the brain. The relations in a vertical, *i. e.*, longitudinal section of the mushroom body to the rest of the brain are seen in (Pl. X, Fig. 8 *a*). It thus appears that the double stalk is situated near the center of the brain, and that the cap projects far forward, but posteriorly does not extend behind the antennal lobes or the commissures. In section 18 (Fig. 4) the calices are seen to be double, the outer (*o. cal.*) attached to the cauliculus (*cau.*) and the inner arising from the peduncle. Fig. 8 *a* gives an idea of the two calices and their mode of attachment to the stalk. The peduncle (if we interpret that division of the stalk aright) subdivides, sending a thick bundle of fibers to each calyx, ending abruptly in the hollow of the calyx. The substance of the calices is finely granular, with some coarse granules, and apparently short scattered irregular fibers. The structure of the calices of the locust appears to be more homogeneous than that of the cockroach, judging by our sections of the latter. Owing to different treatment by reagents the dark masses described by Newton as existing in the cockroach were not so clearly shown in my sections ($\frac{1}{1000}$ inch thick) as in those made by Mr. Newton. The substance of the calices when examined under a power of 725 diameters is much the same both in the cockroach and the locust, the dark bodies not appearing in either. The form of the calices is very different in the cockroach, the calices being truly cup-like, the disk being deeply folded, and the edges of each cup being thin compared with those of the locust.

The optic lobes.—As seen in section 19 (Pl. XI, Fig. 1 *op. l.*) these bodies are larger than the antennal lobes, and consist of numerous irregular small bundles of fibers besides those composing the optic nerve, the interspaces being filled with fine granular nerve substance. The optic nerve is much larger at the outer edge of the lobe before passing into the optic ganglion, the fibers still being immersed in the finely granular nervous substance.

The optic ganglion.—This is situated at the back of the brain, and is a large rounded mass of white fine granular nervous matter, enveloped in very numerous but small ganglion cells, which stain dark red by carmine, the granular matter remaining unstained by the picrocarmine. The granular or white portion is subdivided into three rudely lens-shaped masses (see Pl. XV, Fig. 1), the one nearest the eye being much the largest. The structure of the optic ganglion is substantially as described by Newton, as seen in his description and our preparations. A farther description is reserved for our account of the eye, which we hope to give in the next report.

The antennal or olfactory lobes.—Section 19. (Pl. XI, Fig. 1., *ant. l.*) These are smaller than the optic lobes, though in section 19 they appear larger. They give rise to the antennal nerve, and as the locust carries its ears at the base of the abdomen, the auditory nerves entering the third thoracic ganglion, reasoning by exclusion the antennæ in Orthoptera must be organs of smell, and the lobes and nerves to the antennæ are consequently olfactory. This is the opinion of some recent writers, notably Hauser.[329] The lobes are, as described by the other observers, filled with ball-like yellowish masses, which stain dark by osmic acid, much as in the commissural lobes. Nerve fibers are seen in section 19 to pass from one antennal lobe to the other in the rear of the central body and of the trabeculæ, while other nerve fibers are seen to pass into the optic lobes and the commissural lobes. This system of intralobal nerves demonstrates that there is a nervous intercommunication between these cerebral lobes and the ganglionic chain of the entire body.

The commissural lobes.—From these large bodies proceed the two great longitudinal commissural nerves, forming the connecting threads of the nervous cord, and which extend from the brain to the last abdominal ganglion, passing through the intermediate nerve centers. The lobes are filled with ball-like masses, of the same general appearance as in the antennal lobes, but more distinct and numerous.

Comparison of the brain of the locust with that of other insects.—Newton rightly regards the cockroach's brain as a generalized form of brain, which may serve as a standard of comparison. The cockroach is geologically one of the oldest of insects; its external and internal structure is on a generalized plan, and the brain conforms to this order of things. Our knowledge of the cockroach's brain is derived from the photographs and account of Flögel, and Newton's excellent descriptions and figures, supplemented by two sets of sections made for us by Mr. Mason, but which, unfortunately, are quite defective as regards the trabeculæ and stalk of the mushroom body. The shape of the calices of the cockroach, as already stated, is very different from that of these bodies in the locust, and indeed from any other insect, the cup being very deep and the sides thin; but the intimate structure seems nearly the same in the two insects.

In the cockroach the antennal and commissural lobes are of much looser texture, with large and numerous ball-like masses (*ballensubstanz*); these are, when magnified 400 diameters, not only larger, but more distinct from the rest of the nervous matter of the lobe than in the locust. When magnified as mentioned, the ball-like masses appear to be simple masses of finely granular nervous matter, with darker granules, much like the rest of the granular portions of the brain, but with coarser granular masses than in the substance of the optic lobes. These ball-like masses are surrounded by a loose net-work of anastomosing nerve fibers continuous with those of the antennal nerve, and with scattered

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[329] Physiologische und histiologische Untersuchungen über das Geruchsorgan der Insekten. Siebold und Kölliker's Zeitschrift für Wissen. Zoologie, Bd. 34, Heft. 3.

nucleated cells, which become very numerous in the antennal nerve. The nerve fibers are stained reddish by the picrocarmine.

Turning now to other orthopterous insects, Flögel mentions Acrydium, but states that he had no serviceable preparations, and after describing the brain of Forficula, the ear-wig, says: "As I observe in Acrydium, the cells and fibers in this animal are especially large, and these objects invite further investigation." Flögel's photograph and description of the brain of Forficula, a representative of an aberrant family of Orthoptera, and Dietl's beautiful figures and descriptions of the brain of the mole-cricket (*Gryllotalpa vulgaris*) and the cricket (*Acheta campestris*) show that the orthopterous brain, judging from these representative forms, is constructed on a common type, the most variable part being the calices of the mushroom body.

From these facts we should judge that, on the whole, the locusts were as highly endowed intellectually as any other insects, with the exception of the ants, bees, or wasps, *i. e.*, the social species; while in a number of insects the brain is less developed than in the locust. It would thus appear that, as in the vertebrates, there are different grades of brain-development, considerable extremes existing in the same sub-class of insects, as in the same sub-class of mammals.

The brain of the bee and ant, as shown by Dujardin and demonstrated by Dietl and Flögel, is constructed on a higher, more complicated type than in the other winged insects, owing to the much greater complexity of the folds of the calices or folded disk-like bodies capping the double stalk of this organ.

STRUCTURE OF THE BRAIN IN THE EMBRYO LOCUST.

Much light may be thrown upon the structure of different parts of the adult brain if we can trace their origin in the embryo, or in the larval and pupal conditions. Hence, we have, with what material we could obtain, made a series of sections of the embryo and different stages of the larva and pupa, with some results of considerable interest and importance. No one has yet examined the brain of the embryo insect. The only observer who has studied the brain of the larva, as compared with the adult, has been Flögel. Speaking of the cockroach, he says:

> Of especial interest would be an investigation of the development of the separate parts of the brain. The difficulty of making preparations of small heads has been such that no particular results have been reached. Still, I can say this much, that in small creatures 7–8^{mm} in length all the parts are present, only of a finer and more delicate structure than in the large adult 25^{mm} in length.

He says that in the Hymenoptera he has discovered much concerning the development of the parts of the brain; that in bee larvæ the calices are present, though very small and with thin walls. The peduncle and trabecula have reached their ultimate proportions more nearly than the cauliculus, which is still very thin. In the larval ants the central body and entire mushroom bodies are present, though an early larval stage shows, in place of the calices, four symmetrically situated balls of much smaller size; the central body was very flat, and the other parts were wanting. In the pupa all the parts had attained their definite shape. It appears from his observations that the calices are the last to be developed.

He then gives the results of his examination of the brain of caterpillars, as compared with that of the adult sphinx moth. In a caterpillar examined near the time of pupation, the central body is very much undeveloped, forming a small linear transverse body (Querleiste), while the different parts of the mushroom body are indicated. In smaller caterpillars it is scarcely possible to work out the development of the brain. In that of *Pontia brassicæ* the mushroom body and central body were undeveloped, while in that of an Euprepia larva the double stalk of the mushroom body was developed as well as roundish calyx masses. But in a Noctuid larva the entire mushroom body, including well-developed trabeculæ and a very flat central body, was present.

The brain of the mature pupæ of Lepidoptera, for example *Saturnia carpini*, contains all the portions of the adult brain, and in the same relative proportions. But a brain of *Sphinx ligustri*, in a considerably younger stage of development, did not differ much from the brain of the larva.

We offer the following observations on the brain of the embryo locust, shortly before hatching, with much diffidence, as we are liable to be corrected by future observations in the same directions. The embryos were taken from the egg-shell, hardened in the usual manner, and then cut by Mr. Mason, the sections being frontal, the entire insect being embedded in a mixture of paraffine, wax, and oil.

In the youngest stage (which we will call stage A) observed, the body and appendages were formed and the eyes with their facets, the pigment mass coloring the cornea pale reddish.

At this stage, as seen in section 7 (Pl. XII, Fig. 1), the antennal and optic lobes of the brain are indicated, but the central body and mushroom bodies are not yet differentiated. In a plane lying in front of the optic and antennal lobes, the brain is divided in each hemisphere into two regions or lobes, *i. e.*, an upper (Figs. 1 and 8, *up l*) and lower cerebral lobe (*low l*). From these embryonic cerebral lobes are eventually developed the central body and the two mushroom bodies. The stratum of cortical ganglionic cells is, at this period, quite distinct from the paler unstained granular brain matter. Pl. XII, Fig. 1 *a*, represents the structure of the ganglionic cell-portion, which gradually passes into the central white brain substance, which is composed of fine granules or nuclei alone, and which do not apparently differ from the granules scattered among the ganglion cells. It is to be observed that there are no fibers among the granules. It thus appears that the brain of insects, like the other ganglia, originally consists of a paler portion formed of fine clear granules (nuclei?), enveloped by a thick irregular layer of nucleated cells, containing fine granules outside of the nucleus.

As the fibers of the adult brain are evidently secondary products, it would appear that they must be transformed granules or nuclei, and not in all cases, at least, the fibers thrown off from the ganglion cells, although at this time the ganglion cells have no fibers, the fibers of those seen in the adult brain being also secondary growths. It may be that the white inner granulo-fibrous matter of the adult brain is (1) made up of modified granules, which in some cases remain such, and in others form fibers, and (2) of fibers sent in from the cortical ganglion cells.

Comparison of the brain at this stage with the first thoracic ganglion.—If we compare at this stage of development of the nervous system the brain with one of the ganglia of the trunk, we shall obtain a fair idea of the primitive difference between the brain and one of the ordinary ganglia (Pl. XIII, Fig. 5). By a glance at the figures of the two it will be seen that the organization of the thoracic ganglion is essentially simple. It is divided into two portions or regions. The central granular region is enveloped by a thick stratum of cortical ganglion cells. The whole ganglion in section is rudely hour-glass-shaped and much smaller than the brain. There is no differentiation into distinct lobes as in the brain. The formation of the brain, as is well known by embryologists, is one of the earliest steps in the development of the nervous system, the entire system being at an early date in the life of the embryo set apart from the epidermis or integument, the latter with the nervous system originating from the ectoderm or outer germ-layer.

Second embryonic stage, B (Pl. XII, Figs. 2–9).—In embryos more advanced, and just ready to hatch, the eyes being now dark red, the central body is formed, but our sections do not show any traces of a mushroom body. The sections are frontal, and we will describe them in order. The fifth section is through the head and front part of the eyes, but does not graze the brain itself. Fig. 2 shows the structure of the interior of the head, being filled with connective tissue cells not distinguishable from the ganglion cells.

Section 6 (Fig. 3) passes through the outer portion of the optic and antennal lobes, now clearly differentiated.

In section 7 the cerebral lobes are seen, and in section 8 are larger, as are the optic lobes, while the antennal lobes are somewhat reduced in size. Section 10 passes through the cerebral lobes and also grazes the optic lobes, passing through the optic ganglion.

Section 11 (Fig. 8) shows the central body, separated from the upper cerebral lobes by a thin layer of loose ganglionic cells. The relation of the central body to the upper and lower cerebral lobes is well shown in this section.

Plate XIII, Fig. 4, shows the relation of these and their structure greatly enlarged. Through the granular substance of the lobes are sparsely scattered ganglionic cells.

Section 12 passes through the lower cerebral lobes and the upper left cerebral lobe and the optic ganglion. The œsophagus is situated beneath the cleft under the lower cerebral lobes. The next section (13) passes behind the brain, not touching it. These sections are $\frac{1}{500}$ inch thick.

Structure of the subœsophageal ganglion (Pl. XII, Fig. 10).—In its form this nerve center is more like the brain than the first thoracic ganglion. The figure is drawn from the youngest embryo observed. The ganglion seen in section is very much larger and quite different in shape from the thoracic ganglia. It expands above the lower fissure between the two sides, being very deep and narrow, while the superior furrow is broad and shallow. The internal paler portion (when magnified 400 diameters) is seen to consist of granules. The stratum of outer cells (the future ganglion cells) is thickest on the outside of the upper part of the ganglion, and at the base of each hemisphere.

The brain of the freshly-hatched larva of C. spretus.—In the larva but a few hours after hatching, the brain, so far as I can learn from four sections, does not essentially differ from that of the embryo just before hatching, as the interval is apparently too short for a decided change to take place. It is evident that by the end of the first larval stage the brain attains the development seen in the third larval state of the two-banded species.

For illustrations of the different larval and pupal stages of development of the locust the reader is referred to the first Report of the Commission (Plates I, II, III).

Third larval stage of Caloptenus bivittatus (Pl. XIII, Fig. 1–3).—In the third larval condition of another species, the common *Caloptenus bivittatus* of our gardens, the different parts of the brain have attained nearly the same structure and proportions as in the adult. Pl. XIII, Fig. 1, represents a section passing through the front of the brain, and also the lateral ocelli and the right eye. The ganglion cells surrounding and filling the calices are smaller and more crowded than elsewhere. The mushroom bodies are now formed, though the trabeculæ are not to be seen in our section, but the entire double stalk and calices are very clearly seen. The fibers from the stalk are observed to extend along the inner edge of each calyx and to suddenly stop just beyond the middle. The granular calices contain slight irregularities and sinuous lines, as shown in Fig. 2, *i. cal.*, *o ca.*, but to what these appearances are due it is difficult to say; there are also a few scattered large granules. As the section passes through the front of the brain, where the hemispheres are separated by the frontal furrow, the lobes are not well marked, but the substance is made up of irregular intercrossing bundles of fibers, with the interspaces filled with granulated matter. In Fig. 3 the regular saucer-like form of the calyx is well shown. Fig. 2 is an enlarged view of the right side of Fig. 1, and at this stage large important bundles of fibers are seen passing into the optic, antennal, and commissural lobes.

First pupal stage of Caloptenus spretus.—My sections are too imperfect to describe, but the form of the brain is closely like that of the next stage.

Second or last pupal stage of Caloptenus spretus.—A number (14) of very successful sections made by Mr. Mason from one head give an excellent opportunity for studying the head of the locust in this stage, just before becoming fledged (see first Report, Pl. I, Fig. 5). Of these sections, Nos. 8 and 9 pass through the calices and œsophageal lobes, but do not reach the central body. Section 10 (Fig. 1 of Pl. XIV) passes through the central body, which is $\frac{1}{500}$ of an inch in thickness, the section itself being of the same thickness. In the optic ganglion the section passes through the front of it, but two lenticular masses appear. The trabeculæ are as in the adult, and the superior and inferior intra-trabecular nerves are clearly seen to pass into the center of each trabecula just as in the adult. On the left side the origin of the cauliculus and peduncle is clearly seen, under a power of 225 and of 400 diameters, the relation of parts being exactly as in the adult (see Pl. X, Fig. 3). The base of the two divisions of the double stalk arise suddenly, as if inserted into or resting simply upon, rather than arising from, the trabeculæ; the bases of the cauliculus and peduncle being in the same line with the base of the center of the upper division of the central body. It appears as if a few nerve fibers passed under the base of the stalk between it and the trabecula; at any rate, I have been unable to observe either in the pupa or larva or adult, among a number of preparations, any continuity between the trabeculæ and the double stalk.

In this section the curving of the double stalk backwards and the passage in front of this double column is to be clearly seen, and is just as we have described it from similar sections of the adult brain (Fig. 3 of Pl. X). The ball-like masses in the œsophageal commissures are as distinctly shown as in the adult.

Section 11 passes behind the central body, not showing it nor the basal part of the double stalk of the mushroom body. This section, and those behind it, show well the structure of the optic ganglion. In section 11 the three lenticular bodies clearly appear.

The main, and almost the only, difference between the second pupa and the adult appears to be in the degree of development of the central body. In the second pupa (Pl. XIV, Fig. 3) it is rather more elementary than in the adult, the upper and lower series of unicellular bodies being a little shorter and rounder, nearer their primitive condition, and the septa between them are plainly fibrous. Their contents are as finely granular as the adjoining parts of the body.

Section 11 is instructive as showing a bundle of directly ascending and obliquely ascending fibers from the back part of the trabecula, of which a portion is contained in the section. Two large bundles enter the commissural lobes, one from above and one from the inner side under the central body, the bundle from above passing down into the lobe from around the upper side of the trabecula. From this fact we should infer that there is a partial nervous communication between the trabeculæ and the commissural lobes. The fibers enveloping the trabecula above are more numerous, the mass of fibers much thicker than in section 10, showing that what we supposed to be fibers separating the stalk from the trabecula appear to be really such.

A broad bundle of fibers is also seen on the right side, passing down from the upper side inside of the upper end of the peduncle, down outside and back of the central body, and to enter the commissural lobe on its inner side, terminating at the point where the ascending fibers to the upper side of the trabecula originate. There is thus a direct communication between the upper part of the brain and the œsophageal commissure in the lower part. It appears, also, that three large nerves or bundles of fibers enter each commissural lobe from above.

At the under side of the commissural lobes the cortical ganglion cells (some of them very large) appear to send their fibers into others to build up the mass of fibers enveloping the lobe. Flögel states that the opinion that the ganglionic cells in winged insects are in direct relation through the fibers with the organs of the body are unfortunately provisionally contradicted by his observations. But here (seen in a portion of the commissural lobe not represented in Fig. 3 of Pl. XI), as in one or two other places, we think we have seen fibers from the cortical ganglion cells passing into and aiding in building up the nerves. Such a relation is very plain in the brain of the horseshoe-crab, *Limulus polyphemus*.

LIST OF WORKS ON THE INTERNAL STRUCTURE OF THE BRAIN OF CRUSTACEA AND INSECTS.

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MICHELS. Beschreibung des nervensystems von Oryctes nasicornis in Larven, Puppen, und Käferzustande. Von H. Michels. Zeitschrift für wissens. Zoologie. Bd. xxxiv, p. 641-702. Pl. 33-36. 1880.

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CHAPTER XII.

LOCUST RAVAGES IN CALIFORNIA.

As the chronology of the history of the locusts in California has been given in our first report, we only add here the data obtained since that time and such as we deem of importance then omitted.

Up to the present time the question as to whether *Caloptenus spretus* ever invades California remains an open one which we have been unable to answer decisively.[830] That *Camnula pellucida* (*Œdipoda atrox* is a synonym) is often very destructive, is conclusively shown by the data here given, furnished by Mr. J. G. Lemmon, of Sierra Valley, California. But that this species is truly migratory, or migratory in the sense this term is usually understood when applied to locusts, appears very doubtful; in fact, as will be seen by reference to Mr. Lemmon's statement, there are strong reasons for believing it is not, which agrees with our opinion judging from the insect alone.

FIG. 10.—*Camnula pellucida.*

As introductory to the data furnished by Mr. Lemmon we give here a description of this species and also the generic characters.

Before presenting a description from the specimens now before us we will indicate briefly the position the genus occupies in the family, according to recent classification.

By reference to pages 34 and 35 of our First Report the reader will observe that the subfamily *Acridinæ*, so far as represented in this coun-

[830] It should be mentioned, however, that Mr. Packard, as the result of his journey through California, Western Washington Territory, and Oregon, has stated his belief that the Rocky Mountain locust (*C. spretus*) does not inhabit nor visit the Pacific Coast, nor pass west of the Sierra Nevada and Cascade Mountains.—[See first report, p. 455, and Appendix, p. 142.]

try, is divided into three groups, *Truxalini*, *Acridini*, and *Œdipodini*, the migratory species being confined to the second and third, which are distinguished from each other by the presence or absence of a prosternal spine or tubercle, thus:

a Prosternum or front breast armed with a spine or tubercle .... *Acridini.*
aa Prosternum unarmed.. *Œdipodini.*

To the former group belong most of the migratory species, to wit: *Acridium peregrinum*, *A. paranense*, *A. americanum* (if this is the Central American locust, which is doubtful), *Caloptenus italicus*, and *C. spretus.* To the latter belong *Pachytylus migratorius* and *Camnula pellucida.* The former of these two species, which is large, measuring about two inches in length, is found only on the Eastern Continent; the latter, which is comparatively small, is found only in North America.

The genus *Camnula*, which was established by Stål, is, according to that author, distinguished from other genera of the same group by the following characteristics:

The fastigium of the vertex slightly deflexed, rather narrow; seen from the side it forms an obtuse angle with the frontal costa, concave, not carinated (that is, without a median carina), nor terminated posteriorly by a carina, but in fact by a slender transverse impression; frontal costa slightly sulcate, distinctly narrowed below the ocellus; the pronotum with the lateral margins distinctly carinated; the (posterior) sulcus divides the median carina, but is usually interrupted by the lateral carinæ which are usually severed by the middle or anterior sulcus; the posterior lobe is distinctly longer than the anterior surface, not granulated or rugose.

CAMNULA PELLUCIDA.

Œdipoda pellucida Scudd., Bost. Jour. Nat. Hist. VII, 1862.
atrox Scudd., Hayden's Geol. Surv. Neb., 253.
Camnula tricarinata Stål, Recens. Orthop., 1873.

In order that the reader may judge for himself in reference to the identity of the species, we give here the three original descriptions.

Œ. pellucida Scudd.

Ash-brown; face reddish brown; antennæ yellowish at base, dark brown toward tip; a triangular black spot behind the eye, the apex touching it; a quadrate transverse black spot on the anterior upper portion of the sides of pronotum; pronotum above, sometimes with a dark band down the middle; wing covers with the basal half dark brown, with small yellowish spots and transverse streaks, especially on front border; apical half clear, with dark brown rounded spots, prevalent along the middle, decreasing in size toward the tip; when closed the upper surface is dark brown, with a rather broad yellowish vitta along each angle on the upper surface; wings pellucid, with black nervules; legs dark brown, the hind femora yellowish or reddish brown, with two or three rather broad diagonal dark brown streaks, dark at the apex; hind tibiæ yellowish brown, reddish toward the tip, with a very narrow, generally faint, annulation of dark brown at the base; spines tipped with black.

Length of body: male .65 inch, female 1 inch; spread of wings: male 1.3 inches, female 1.6 inches; depth of wings: male .33 inch; female .4 inch.

Œ. atrox Scudd.

Head uniform, pale brownish yellow; the raised edge of the vertex dotted with fuscous; a dark fuscous spot behind the eye, broadening posteriorly, but not extending upon the pronotum. Antennæ as long as the head and pronotum together, dull honey yellow, growing dusky toward the tip. Pronotum dark brownish yellow, the sides darker anteriorly; median carina extending the whole length of the pronotum, moderately raised, cut once by a transverse line a little in advance of the middle; lateral carinæ prominent, extending across the anterior two-thirds of the pronotum; anterior border of the pronotum smooth, very slightly angulated; posterior border delicately marginate, bent at a very little more than a right angle, the apex rounded; tegmina dull yellowish on the basal half, with distinct fuscous spots; toward the apex obscurely fuscous, with indistinct fuscous markings; humeral ridge yellowish, and, when the tegmina are in repose, inclosing a brownish fuscous triangular stripe; the spots are scattered mostly in the median field, consisting in the basal two-fifths of the tegmina of small roundish spots and one larger longitudinal spot in the middle of the basal half; there is a large irregular spot in the middle of the tegmina, and beyond a smaller transverse spot, followed by indistinct markings; wings hyaline, slightly fuliginous at the extreme tip; the veins, especially in the apical half, fuscous; legs uniform brownish fuscous; apical half of spines of hind tibiæ black.

Length of body, 0.9 inch; of tegmina, 0.9 inch; of body and tegmina, 1.125 inches; of pronotum, 0.2 inch; of hind femora, 0.5 inch.

It bears a strong resemblance to Œdipoda pellucida Scudd, common in Northern New England.

Camnula tricarinata Stål.

Pale brownish-yellow; front on each side from the base to the lateral foveolæ and usually a stripe on each cheek below the eyes, black. Elytra in front of the middle somewhat brownish, fuscous, costal area pale, with fuscous spots; behind the middle dull hyaline with fuscous veins, and obsoletely clouded. Wings hyaline, colorless, with fuscous veins, posterior femora with two oblique fuscous stripes; posterior tibiæ pale; spines except at the base, black.

Appearance and markings very similar to *Tragocephala* [*Œdipoda*] *sordida;* vertex and fastigium narrower, sulcus of the frontal costa not reaching the base, antennæ slenderer, lateral margins of the pronotum distinctly carinated throughout; median carina less elevated, elytra narrower; intercalate veins visible, radial area of the wings with no dilated areolæ, and the exterior margin behind the middle obsoletely fuscous, posterior tibiæ pale. Frontal costa sparsely punctulate, middle slightly excavated, base narrow. Vertex behind the fastigium furnished with a slender, abbreviated, longitudinal carina; fastigium slightly deflexed slightly narrowed, slightly concave, lateral margins raised, marked with minute black lines. Lateral foveolæ distinct, triangular. Pronotum with shallow punctures on the lateral lobes but smooth on the dorsum which is flat; median carina subcristate and equal throughout; lateral margins distinctly keeled throughout, before the middle lobe parallel, distinctly diverging posteriorly; dorsum more or less distinctly fuscous, sides paler; the lateral lobes are often marked with black or fuscous spots, the anterior of these spots interrupted by oblique paler marking. The mesosternal lobe in the male about double as wide, in the female a little more distant, as the metasternal lobes. Posterior femora medium, the margins entire.

Vancouver's Island, Western North America.

The following description is drawn up by Mr. Thomas from specimens collected in Sierra Valley, California, by Mr. Lemmon, directly out of the hordes injuring the crops, from others collected by Mr. Marten, at Fort Peck Agency, Montana, and also by Mr. Thomas in Colorado:

Camnula pellucida Scudd.

Male.—Length of body .65–.90 inch; to tips of elytra .80–1 inch; expanse of elytra 1.50 inches. *Female.*—Length of body .80–1 inch; to tips of elytra 1 to 1.25 inches; expanse of elytra 1.75 inches.

Occiput rising slightly above the pronotum, with a minute longitudinal median carina usually obsolete behind, more distinct in front where it extends to the transverse incision in the posterior part of the median foveola of the vertex. Vertex in front of the eyes deflexed at about an angle of 25° from horizontal; margins raised forming an ovate median foveola which is narrowed and closed in front; there is usually a slight but distinct linear transverse depression across the posterior part of this foveola opposite the upper canthus of the eyes; there is also occasionally visible a very minute median carina, but this has been observed only in some of the California specimens, in which the lateral margins are rather less elevated than in the specimens obtained elsewhere; lateral foveola more or less distinct, triangular, the sharpest angle forward, base pressed closely against the eye. Frontal costa rather broad, narrowed, prominent and punctate above, widened and slightly depressed at the ocellus, slightly narrowed and soon fading out below the ocellus, not reaching the clypeus; it is rather more than usually broad at the ocellus and not sulcate above or below it.

Antennæ scarcely reaching beyond the tip of the pronotum, rather slender, somewhat flattened and very slightly enlarged toward the apex. Eyes rather small, not prominent; posterior margin semicircular, less convex in front. Pronotum short, the greatest length about equal to the depth; the constriction, which is slight, very near the front, expanding posteriorly; the median and lateral carinæ distinct, extending the whole length; the median subcristate, straight on top, or very nearly so, usually distinctly, but sharply, severed in advance of the middle by the posterior sulcus; the lateral carinæ are sharply defined, but less prominent than the median, parallel on the front lobe, but diverging from thence to the posterior margin. These (lateral carinæ) are usually more or less distinctly severed by one of the transverse impressed lines, but vary as to the one, sometimes by the first, sometimes by the second, sometimes by the third, and occasionally by two of them. The dorsum is flat and not granulated or rugose; the anterior margin very obtusely angled; posterior margin forming an angle a little larger than a right angle, rounded at the extreme tip; posterior lateral angle about a right angle. Elytra rather narrow, furnished with a distinct intercalate vein; basal half opaque, apical half, or at least the apical third, nearly transparent, extending slightly—from one-tenth to one-fifth their length—beyond the tip of the abdomen.

The wings rather less than medium width, very thin and delicate, resembling very closely the wings of *C. spretus*, but more delicate and transparent; the width of the subcostal area is marked on the external (apical) margin by a distinct notch.

Abdomen in both sexes very distinctly carinated above. In the female the cerci, as usual, very small, the valves of the ovipositor are quite slender and very sharp. In the male the cerci are rather longer than usual in Œdipodini, cylindrical, slightly tapering, the tip of the abdomen usually curved more or less upward, the subanal plate curving upward strongly, somewhat prolonged, tapering, and broadly subtruncate at the tip; it and the cerci slightly hairy.

Posterior femora rather slender for the group to which the species belongs, upper carina elevated, entire, and very thin and sharp; in the females they scarcely reach the tip of the abdomen—the same thing appears to be true in reference to the males. The posterior tibiæ very slightly shorter than the femora, slender; the spurs at the base robust; the spines rather small, usually nine or ten in the outer and ten or eleven in the inner row.

Color.—The general or ground color of the California specimens is considerably lighter than that of the Rocky Mountain or eastern specimens; if a number, with the wings closed, are placed together there is a quite distinct dull yellowish shade observed; but the general color is a dull (earthy) brown, varied by lighter and darker shades, the dark shade increasing toward the head, being a decided brown on the head and pronotum—not so distinct in the California specimens. The cheeks and sides of the posterior lobe of the pronotum dull yellow. The chief characteristic markings are to be found on the elytra; these have a yellowish ray more or less tinged with reddish extending along the inner margin from the base to where it fades out at the inner margin about one-third the length from the tip; the costal area is marked with from one to three dark brown or fuscous spots, the one next the base and opposite the costal angle the largest, one or both the others, which are small, often wanting; the discal or middle marked with rather large spots of the same kind, which are somewhat transverse, and fading toward the apex where they are obliterated. Wings pellucid, veins and veinlets of the outer (anterior when spread) half dark, except the strong subcostal vein, which is white or pale yellow; those of the inner half mostly yellowish. Posterior femora varying in color from dull yellow to brown; usually, but not always, marked externally with two oblique brownish bands. Posterior tibiæ yellowish.

THE LOCUST IN CALIFORNIA IN 1878.

The following extracts will give an idea of the injury in 1878:

This valley has been infested by locusts increasing so much of late as to totally destroy the crops and strike terror to the inhabitants. While botanizing here two years ago, I collected specimens of various locusts and sent them to the Academy of Sciences, at San Francisco. No report. Last season I was absent in Southern California, so I have no specimens of the locusts that devastated this valley, and whose eggs are thickly deposited on many of the sunny knolls.

I think these locusts come from the desert northeast of us by easy stages, yearly. This valley lies in latitude 39° 40′ north, and longitude 129° 30′ west, at an altitude of about 5,000 feet.

As this valley, 35 miles long by half as wide, lies in the Sierra Nevada, to the *west* of one of its loftiest chains, it will be interesting to know if the true *C. spretus* is the locust that is devouring our herbage.

To perfectly understand the problem, it is fair to state that the valley is connected to the great basin through this Sierra barrier by the low pass of Beckwourth, though the locusts did not come through it, but, as supposed, they came eating their way from over the ridge to the northward as stated.

I will in due time send forward specimens of the species here, with notes of their habits, ravages, &c.

The excellent and useful report of your Commission (First Annual Report United States Entomological Commission, 1877), is in my hands. Wish I knew whether it was advisable to exhort the farmers to fight the pest with coal-oil and machinery. They have bred here for three years, and seem on the increase. Eat up grain and late grass. Last year damage estimated at $30,000 in a population of 2,000.—[J. G. Lemmon in a letter to C. V. Riley, March 10, 1879.

GRASSHOPPERS IN SIERRA VALLEY.—Reno *Journal*, July 8: A gentleman in from Sierra Valley informs us that the grasshoppers are destroying a great deal of grain in the valley. Out of one field, from which 400 tons ought to have been cut, only 150 tons were left, and even this was saved by the exertions of the farmers. The hoppers are now all in the north end of the valley, but when this is all eaten up they will no doubt turn their attention to the lower end. They rise in such clouds that the sun is darkened, and shortly after they light on a field nothing is left but a mass of unsightly stalks. They do not touch the wet land, nor will they touch the hay after it is cut and cured. Cases are cited where the insects have gone just ahead of the mowers and destroyed the majority of the grain. In one such case, out of 200 tons only 25 were saved. Dairymen are suffering considerably because their grazing lands are being destroyed, and this, with the low price of butter, is causing many to leave that business entirely. Probably one-half of the entire crop of the valley will be lost. Fortunately 2,000 tons of hay was carried over from last year. This will keep the price this year about as usual, but next year it is likely a notable advance in the price will be apparent. The grasshoppers have possession of Sierra Valley, and what is worse, young ones are hatching every day, while the old ones are laying eggs and eating grass.—[*Pacific Rural Press*, July 13, 1878.

SIERRA VALLEY HOPPERS.—Reno *Journal:* We spoke yesterday of the myriads of grasshoppers in the Sierra Valley, and of the imminent danger the crops were in. Another gentleman tells us that there is a mile square in the center of the valley, which is completely covered with the young insects, which have appetites like cross-cut saws. He suggests that the farmers club together, and, by rolling over this tract with heavy rollers, kill at least the major portion of them, for should they all survive, they will not gratefully spare the green acres around them. The crops never looked better, and the farmers have only this one thing to fear. One has no idea of the magnitude or destructibility of this plague. Flying in clouds so thick as to darken the sky for an hour at a time, they leave the country over which they pass as bleak as if a fire had swept it. Millions may be killed, but like the war with China, there are ten to take the place of every one that falls. It is not profitable to raise grain for grasshoppers' use. We hope our Sierra Valley friends will escape the impending danger.—[Ibid, June 22, 1878.

Reports from Sierra County, California, state that the grasshoppers appeared there in May and June, since when they have become very numerous, destroying almost the entire crops in the Sierra Valley.—[*Rocky Mountain News*, October 30, 1878.

Grasshoppers are so plenty in the mountains which the Central Pacific climbs that trains can hardly mount the grades, and the brakes sometimes fail coming down.—[*Boston Journal*, 1878.

The following more comprehensive account was communicated by Mr. J. G. Lemmon to the Truckee *Republican*, and published in several numbers of that journal:

APRIL 5, 1879.

The amount of damage to crops in Sierra Valley last year (1878) by a certain ravenous grasshopper, or, properly, locust, and the fact that millions of eggs were deposited on hitherto non-visited ranches, menacing a larger area of land than ever, naturally causes a deep interest to be taken in the terrible scourge, and justifies a somewhat careful examination of the whole subject.

I have just been down through the infected district, making observations upon the eggs, and taking notes from the inhabitants on the origin and habits of the locusts, which I will first give, then draw conclusions in regard to the insects, methods of fighting them, hopes and fears for the future, &c.

THE SCOURGE NEAR LOYALTON.

Thomas F. West states that the locusts came from Clover and Last Chance Valleys. Saw them in the latter three years ago. Breeding ground previous year (1877) was on what is known as "The Island," some few miles out in the valley south of Beckwourth; arrived at his ranch in myriads June 1st. Their flight was only a few feet from the ground, striking heavily against fences and buildings. In the morning hours many of them flew southward, then turned, after feeding, perhaps, and returned in the afternoon. Many remained and deposited eggs in August, on warm, sunny knolls, the rest disappearing southwestward. Loss, about $500.

F. M. West suffered very severely, and is fearful that his crops will all be taken this year, since eggs are so thickly deposited on his ranch. The insect selects warm, dry knolls for this purpose; large patches are literally filled with eggs. They came from the northeast, staid two or three weeks, then went southwest. Did not fight against them; "as well contend against the wind." Loss, 125 tons of hay, $625, and his fall feed, estimated at $100. Ranch of 240 acres. Many hatched on his ranch in May, but the bulk came from "The Island" about June 20.

D. T. Machomick lost 120 tons of hay, $600; had no grain; ranch of 160 acres. Other items same as the Wests.

John Young lost 65 tons of hay.

W. A. Poole lost 75 acres of oats, worth $1,800; hay not injured much. Locusts came about July 20 from northeast. But few remained to lay eggs. Most of the damage was done in two to four weeks. Disappeared to the southwest.

A. R. Dodge, not much injured; has a ranch of 200 acres.

Joe Dyson lost everything in 1877; last year, 200 tons of hay, worth $1,000; had no grain. The locusts hatched mostly on his ranch from May to August very numerously; covered the ground; flew low.

Mr. Lewis lost heavily, estimated at $3,000, mostly of grain. The other farms above Loyalton, Dooley's, Parker's, and Robinson's, suffered more or less.

D. B. Patterson lost 75 tons of oats from choice seed, costing 3 cents per pound, from which he expected, it standing so well on the ground, 3,000 bushels, worth $2,000. Lost one-third of his hay, 100 tons, worth $500, with a valuable garden, potatoes, &c. Fall feed eaten up. Farm of 640 acres. The atrocious gourmands came originally from Clover Valley, and mowed down his oats seemingly in twenty-four hours; many laid eggs; the bulk disappeared to the westward. Hosts of 'hoppers, some of them flying high, darkening the sun.

John Schroeder lost 65 acres of oats, worth $2,500. Came from the north, about July 1, eating his grass; greatest damage to grain about July 16. The array came from "The Island," divided near his ranch, one wing continuing up Smith's Neck, the other turning westward; were about three weeks eating his crops; many laid eggs, the female dying afterward. He fought them diligently with his large family, saving garden and potatoes thereby, worth $800. Drove them off with papers tied to sticks, which were brandished about the small inclosures. Insects very thick, covering the ground; near fences and buildings they were gathered in heaps. This ranch of 320 acres was not affected the year before. Flew low, not more than 20 feet at the highest. They reminded him of 'hoppers met with on the Humboldt in 1854, though those were more destructive, eating willows and sage-brush.

J. C. Brown lost heavily in grass and garden. Came from the eastward; filled the air, stopping his horses while raking hay, and pelted fences and buildings like hail; devoured cured hay in the bunch, before he could get it drawn into the barn. His mother made a desperate fight for her garden; had to protect face and eyes by nearly closing her bonnet with one hand, while with the other she swung her besom of destruction; were ravenous four weeks; left many eggs; disappeared by death and by going west.

W. S. Paine lost 75 acres of oats worth $1,500, with hay and fall feed worth $200. Oats were just in full stand when attacked, about July 20. Ate for two weeks. He made desperate and temporarily successful efforts to defend his crop; took 200 yards of baling rope, fastened papers to it, and swept over his grain, driving the locusts before the shaking papers; "drove them out forty times; was overpowered by the numbers of the enemy and cleaned out." Many remained on the ground, deposited eggs, and died on dry knolls. Those that left went westward. Thinks they came from "The Island." For four days during the morning hours they poured in upon his ranch of 500 acres from over the hill, eastward. Proposes to never give up, but to fight them still.

Silas Sturgeon lost heavily of oats, barley, and wheat.

Dan Ebe lost $1,000 worth of oats; barley damaged. Came from northeast; went on southwest; many laying eggs; farm of 450 acres.

W. T. Wilson's former ranch up in Antelope Neck was saved by the late arrival of the pests.

J. B. Eachus lost 40 acres of oats. Thinks the eggs were hatched out early in March.

J. H. Sims lost $400, mostly in hay and pasture. The locusts arrived from the northeast during the first week in July; flew low; deposited eggs and disappeared southwest; ranch of 480 acres.

VICINITY OF SIERRAVILLE.

The brothers H. P. and William Robbins suffered slight losses of grass and grain.

A. J. Flint got ahead of the tireless harvesters with four mowers, securing his hay, but a small patch of wheat was munched as a dainty morsel in a few hours.

Mrs. Chandler was relieved from the expense of finishing a field of grass that stood well at eve; ere noon of next day it was full of locusts, shearing it close to the ground.

D. D. Newman lost 75 acres of oats and much fall feed. A small field of rye was not attacked, so he takes the precaution to sow all his grain land to this cereal.

Jonah T. Jones lost but part of his oat crop, owing to the late arrival of the scourge. In his granary I obtained mutilated specimens of the insect (they had been through the thresher and fanner) that confirmed my suspicions of the true character and name of the species.

George P. Haine suffered but little, being mostly beyond the last stragglers of the army. Has had occasion to pass among the ranches near Adams's Neck during summer seasons. Has observed the habits of the young; correctly distinguishes between them and the full-fledged grouse locust, often mistaken for them. Saw young, half-grown, wingless locusts once seeking fresh pastures on Moffatt's ranch. Stopped by a stream, they retracted the flanks of their column, and crossed a bridge, as thick on the ground as they could be and move; were four days crossing; thinks they can be ditched,

Merritt Harding, being fond of tempting trout from his streams with grasshoppers, made a most important discovery. The insect was found to be infested by a little red louse. When carrying six to eight of these blood-sucking enemies the locust looked sickly and was very weak. These were late comers.

T. S. Battelle, Peter Olsen, B. F. Lemmon, the Himes Brothers, and Jack Campbell have each their quota of eggs deposited by the last vanguard of the army late in July and August, menacing their own and adjoining ranches this summer.

The reported damages foregoing foot up: Grain, $15,000; hay, $5,250; feed, $1,400; vegetables, $600; total, $22,250. This should be increased about one-third by the addition of those farmers not reported—$30,000.

The damages in the vicinity of Beckwourth and the Summit, and along the west side of the valley and the interior, was perhaps half as great, which, added to the above, gives a total of damage of $45,000 in Sierra Valley for the year 1878.

Now, what is this fell destroyer? What its relatives, its habits, its enemies, and how can its attacks be averted?

From examination of specimens with a microscope and comparisons with descriptions and illustrations in my possession, I have determined that this locust is not the terrible migratory Rocky Mountain locust of the interior. Added to which all the facts given concerning the habits of this insect prove it different. In regard to the scientific names of these two kinds of locusts, the unscientific will notice that they are very aptly conferred. The Rocky Mountain locust is called *Caloptenus spretus.* The first or generic name means "beautiful wing," and refers to the bright silvery sheen of the wings when seen at great heights in flight, resembling snow-flakes; the last or specific name means "despised," "hated." This locust has its permanent breeding grounds mostly on the eastern side of the Rockies, from the parks of Colorado northward 200 miles beyond the boundary between the States and British America. It makes irregular forays eastward or southward, devastating large areas in the manner so forcibly described by the prophet Joel: "The appearance of them is as the appearance of horses, and as a horseman so shall they run. Like the noise of chariots on the tops of mountains shall they leap; like the noise of a flame of fire that devoureth the stubble; as a strong people set in battle array. The land is a garden of Eden before them, behind them a desolate wilderness."

During the three years from 1874 to 1877 the damage done to the border States was estimated at the enormous sum of $300,000,000. This "hated" *spretus* moves in vast swarms several hundred miles long and wide, and often a mile or more thick. They have been seen passing at a great height over the highest peaks of the Rockies. Although there are breeding grounds just north of Salt Lake and along the valley of Snake River, in Idaho, from which they sally west and southward, no instance is recorded of their ever reaching the Sierra Nevada range. There are two other species of *Caloptenus* that are also migratory and terribly destructive at times; the *C. atlanis* or "lesser locust," and *C. femur-rubrum*, the "red-legged locust"; and these species being of wider range have, perhaps, ravaged portions of California, but the principal damage in our State has been done by the culprit that is now menacing Sierra Valley, and which we will proceed to name and describe.

ŒDIPODA ATROX.

The compound Greek word Œdipoda (accented on the second syllable with the short sound of i) means "swelled-leg," and refers to the large thigh of the hind or leaping legs. The specific name *atrox* means "atrocious," "cruel," "destructive," or "direful." This atrocious locust breeds all over the country from Florida to Alaska annually, but does not often become so numerous as to be destructive. When forced to migrate for food they form vast swarms, reported (perhaps not this species) as "flying about 200 feet high for the noon hours of two days over the city of Sacramento in 1855, resembling a snow storm. They destroyed half of the crops of Sacramento County." In 1877 locusts (the *Œdipoda atrox*) ravaged the coast from Point Concepcion to Santa Barbara, their habits and mischief closely observed by the distinguished naturalist, Elwood Cooper, of Santa Barbara, who recommends deep plowing under of the eggs. He has completely averted the scourge by that means, while sowing on and harvesting crops as usual. The same year the damage in Fresno County was $20,000. Great damage is reported in Fresno as early as 1856. The same year two swarms passed over the Big Trees into San Joaquin Valley, doing great damage.

In 1859 locusts devastated the valley on the west side of Pitt and Fall Rivers (Northeast California); covered the ground; annoying to travelers and stock men.

In 1862 and 1863 at Hornitos they came in June and July "like a glistening cloud; ate the bark off of peach trees."

In 1866 and 1867 a swarm 15 miles wide passed over Stockton from the north, "so abundant that they filled a well."

In 1869 they visited Tulare County from the southwest in May and June; staid three weeks, eating grain and grapes.

In 1873 they migrated to Southern California, doing great damage. The last ravages, in 1877, have been stated.

The species doing the injury in the cases is unknown, for want of care in preserving specimens and in descriptions; most probably they were true *migratores*, as *atlanis* and *femur-rubrum*. The locust of 1877 was the *Œdipoda atrox*, which of late, for some as yet mysterious reason, has become numerous and migratory to a limited extent.

As stated by eye-witnesses, ours have come by easy stages from the northward, entering Sierra Valley from Clover and Last Chance Valleys, and at first deposited but few eggs. The eggs are about the size of small, slightly curved rice kernels of a light buff color. They are deposited during the latter part of the season, from July to September, in sunny exposures, at a depth of half an inch to an inch, in nests or pockets of about 28 eggs each. The female is supposed to make several deposits—three or four—and then perishes. Neither male nor female of this species lives through the winter. The earliest laid eggs hatch first, about May 10th. Hatching continues all the forepart of summer. The insect, while yet in the omnion or sheath, wriggles itself to the surface of the ground, where first the pelticle gives way to pressure beneath in the region of the back and neck. The head emerges, then the antennæ and limbs, all very soft and white. In a few minutes the little rogue, now black and shining, with stiff legs and a fierce look, hops off in search of something to eat—and trouble begins.

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LOCUST ENEMIES.

First in importance, though silent and unseen, are insects of its own great class. They prey upon it from the egg to the adult, while roosting at night or flying by day. It is a law of nature that every animal meets with check. A particular plant-feeder may swarm to an alarming extent one year, and be unheard of the next, being checked, perhaps, by an unseen foe. The Locust Commission referred to, report, describe, and illustrate a host of insects, including minute mites, no larger than pin heads, flies, wasps, beetles and the like, whose larvæ feed upon the eggs. Wasps, hornets, and flies attack the grown insect.

Mr. Merritt Harden, through his piscatorial proclivities, happily discovered that our *atrox* is badly parasitised with the "red mite" *Trombidium locustarum,* described and named by Professor Riley. Should this parasite multiply, the instinct of the locust will cause it to avoid the vicinity, as was distinctly proved in the East with the "hated" *spretus.*

A certain fly (Tachina) seeks out the locust to deposit by a quick dart upon it an egg, which speedily hatches, gnaws into the body of the locust and preys upon its vitals, soon killing it. Swarms of these flies have been known to drive out or turn the course of an army of locusts. The so-called "hair-worm" lives a portion of its life in the locust. It never originates from horse hairs, as often thought.

The whole bird family, from the swan to the pee-wee, are valiant friends of man in the contest. So important is this aid that public sentiment as well as legislation in all the West protects the birds from wanton destruction. Prof. S. Aughey, of Nebraska, investigated this subject in aid of the commission, and names 260 kinds of useful birds in the crops or stomachs of which he found locusts. Principal of these are domestic fowls, robins, black-birds, larks, bluebirds, swallows, snipe, plover, ducks, doves, grouse, magpies, crows, &c.

Several quadrupeds rally for the destruction of locusts, including the common skunk, which for signal service in this cause is voted a benefactor in the locust region, and is petted, despite his odor.

The Indians of the interior, usually so stolid, become quite excited at the approach of locusts, not with fear, but joy, as they proceed to harvest a winter's store of "click-ets," in this respect resembling the Arab of the desert, who, at sight of the coming cloud, falls on his face, with loud cries of praise to Allah and the Prophet, for sending him food.

PROTECTION AND DEFENSES.

These are of five sorts: 1st. Encouragement of natural locust enemies; 2d. Destruction of the eggs; 3d. Destruction of the unfledged young; 4th. Destruction of the flyers; 5th. Warding off by frightful objects or sounds. The best means of destroying the eggs is by plowing them under, harrowing them out of their nests in autumn and exposing to winter weather and birds, irrigating and rotting them, or making the ground too hard for egress by rolling.

When it is remembered that the young locust does not *dig* its way out of the ground—only wriggles out of the loose soil with its mantle still on—the feasibility of plowing, harrowing, and rolling is apparent, and I am surprised that not a farmer of Sierra Valley is reported as trying these remedies. Certain knolls known to be full of eggs could be thus treated, and the vast bulk of our local pest be destroyed in the egg. I say "local pest" advisedly. The *Œdipoda atrox* is not a true *migratore,* does not rise in vast swarms to a great height, and journey for days in a given direction; hence its destruction may be compassed or completed by vigorous concert of action.

And this is the comfort we may gather from all this investigation; that this is not the hateful *spretus* of the Rocky Mountains, liable at any day to drop out of the sky in overwhelming myriads, but only a local and usually harmless species, that for some, perhaps evanescent, cause has multiplied to a destructive extent. The theory lately advanced in the *Republican* (which I fear may be credited to me, as the editor refers to me in the outset,) is radically wrong. The statement is made that "to put in grain crops would only foster the scourge, while to let the ground lie idle may starve the rapacious insects into emigrating."

No, no. Plow and sow, and harrow and roll, spade and ditch the infected spots. Aided by friends, seen and unseen, the plague may be averted. Take the example of the farmers of the East, who fight the "hated" locust, though it is like contending against the wind, at great expense, with coal-oil cans, with gathering machines, with fire and water. Failing to fight them here and now, the creatures may take possession and breed in destructive numbers annually, since this is as natural a breeding ground as any other. For some reason the "check" is removed. Let us seek out another. Let fortunate farmers not gloat over the temporary advantages to them from the misfortunes of their neighbors, for the "atrocious" locust is perfectly at home here, and may radiate in any direction towards the most inviting fields. Let them rather get into full sympathy with the sufferers, remembering that really in calamities of this kind *all* the community suffers. Let all join as one man to limit, cripple, and kill off this common enemy—the "atrocious locust."

APRIL 2, 1879.

Three days after sending you the articles on the Sierra Valley scourge, I received a letter from Professor Riley, Chief of the United States Entomological Commission, accompanying a box of specimens of the various migratory species—as I had requested in March last. These specimens confirm my determinations as given, that our locust is not a true *migratore*. In the absence of full descriptions and perfect specimens the task of determining *what* species it was became the more difficult. There is little doubt, however, that I have named it correctly, as corroborated by the statements of its habits as given by my afflicted neighbors.

I have at this time several observations to make, derived from a close study of the young as they are hatching out. A pan of earth containing a large number of eggs in their pockets was brought in during the fine weather in February, and since have remained near the stove, in even temperature. On the 1st of April, the eggs began to hatch out, and the microscope, aided by plates and descriptions given in the report of the United States Entomological Commission, has revealed wonders in the early life of this terrible plague.

The young *atrox* pushes off the upper portion of the shell and the tough chorion or inner membrane, like a cap, and emerges by movements maggot-like in action, always striving to move upwards. It is still encased in a membrane or mantle (the amnion), that fits it like a glove, encasing every organ separately. In pushing its way upward to the light and air the little baby—about 20 hundredths of an inch long—is soft and pliable, freely turning in every direction. It is able to arrange this tough enveloping mantle into loose bands encircling its body; the lower edge of each band being free, is alternately expanded with great force, and then contracted. When expanded the outward edges of the inclined bands take hold of the earth, while the insect pushes its head upward with great force. Advancing by contracting its body and drawing it in a heap towards its head, it next expands, the band edges cope with the earth on all sides, while the head is advanced, as before. Arrived at the surface, the little white fellow lies on its side a moment, as if resting; then commences a series of contortions, resulting in the bursting of the mantle on the back of the neck. The slit extends soon around to nearly below, the edges sliding back each way, allowing the facile creature to emerge, the back of the neck first. The forward portion is soon slipped over the head and face, the antennæ and jaws withdrawn, the white shriveling mantle is pushed downward, releasing the legs, and in a few moments the whole is kicked off by the hind legs, a small crumpled mass resembling a minute mushroom. At first the insect is white and limber, but in the space of an hour becomes black, fully hardened, and active. Its eyes and head are relatively very large, its face sloping inward, with never a sign of a wing, but with sight, hearing, legs and appetite wonderfully strong.

These observations may lead to the conclusion that early life here, as in most instances, is very tenacious, and is carefully guarded by nature. Such is the force with which the atrocious villain presses in its mantle or pellicle—a writhing maggot—that plowing under, to be effectual, must be deep and thorough.

Harrowing the eggs to the surface in autumn, with the Rocky Mountain locust, is said to be very effective. The females deposit with the eggs a sebific or waxy substance that keeps the eggs in place, suitable for hatching. Brought to the surface, they are exposed to the rigors of winter, and to the attacks of birds; and in our valley, with its regular spring freshets, they would be floated off into the sloughs, feeding the trout. The eggs that survive all these conditions would become addled, or at least the insect would be too weak when hatched to be feared.

THE RED OR LOCUST MITE.

In the pan of earth and locust eggs there happened to be eggs of the red mite (the *Trombidium locustarum* Riley), and I have a full-grown female under thin glass for microscopic study. My specimen is 6 hundredths of an inch long, about the size of a flea. It was very fortunate to find this locust pest accompanying our species as it does the *spretus*. In some sections of the interior the abandonment of the country by locusts is charged entirely to the attack of this parasite. They often teem until the ground is tinged a bright scarlet color. It preys upon both eggs and mature insects. On the full-grown insect they fasten beneath the wings, suck the locust to a dry shell, then drop to earth to undergo transformation peculiar to the species.

Instinctively the fear of this red or locust mite is conveyed from parent to child, for a region once infested by it the locusts avoid for years after. This is one of the most singular phenomena connected with the locust problem, to wit, how the young swarms from abroad know that a certain section in advance of them is infested by their deadly enemy. They turn from such country with evident fear. Borne along by the wind, perhaps, as they approach the vicinity of the mites, they face about in a mass, or if the wind is too strong they drop and crawl hastily back in mortal fear and tumult, without feeding.

Some such "check" is sure to arrive in time to drive off or destroy our foe. So let the farmer take courage. The most disconsolate appearances at the East have been changed to rescue and safety in a single night by these "checks," adroitly brought in by old mother Nature, kind at last to all, if we but give her time to complete the cycles of her mysterious progress. In proof of this it may be cited that the locust-smitten localities of the interior are really the most prosperous in the Union. The locusts eat up certain noxious weeds, and the most abundant harvests follow their ravages of the year before. But there is this difference—the *spretus* never flourishes, from various causes, more than a year at a time in one place, being an emigrant from the Rockies; ours, the *atrox*, is indigenous here. Favoring circumstances have multiplied them, so that they moved slowly, year by year, along in search of food. May the powers of earth and air, birds, insects, and protozoa, the devices of man, and the love and skill of nature, speedily conspire to check this terrible, atrocious locust!

WEDNESDAY, *April* 9, 1879.

Have just been over a locust patch of eggs on the ranch of B. F. Lemmon, and was pleased to find the "red locust mite" in abundance. It was running over the ground only in the vicinity of the eggs, and thus leads the searcher for eggs at once to their locality. This parasite is now in its mature state, is often so large as to be distinctly noticed, and is commonly called the "red spider." It seeks out the locust eggs, deposits its own therein, besides eating freely; then, as the young locust hatches, it is menaced by the larval forms of this louse until the end of the season.

It is hoped that this auxiliary aid, thus brought in by nature, will be efficacious in averting the scourge.

The dreadful locust ravages and their menaces in future are still the all-absorbing themes of thought and speech in Sierra Valley. Though former articles on the subject are somewhat lengthy, yet the half was not told.

I have just completed the entire circuit of the valley, getting statements from nearly all the farmers on the north and west sides, portions of the valley quite as severely devastated as those reported previously, but for want of time to visit them then the damages generally were estimated.

Those estimates fall far short of the truth, as details clearly show. It will suffice now to give the aggregates of damages and the area of the several districts: Adam's Neck and vicinity, $18,000, from 22 large farms containing 14,000 acres; Beckwourth and vicinity, $15,000, 18 small farms of 9,000 acres; west side, $6,300, 15 small farms of 5,000 acres; interior (estimated), $5,000, 12 small farms of 4,000 acres. Totals, $45,800—67 farms of 35,000 acres. Add Loyalton and vicinity and Sierraville, as formerly reported, $30,000, 24 farms, 15,000 acres—grand totals, $75,800; 91 farms of 47,000 acres, being $30,000 damages more than estimated.

The statements from sufferers elicited on this circuit in regard to the appearance and habits of the locust, conform generally to those of others given in the first article, though some observers detected two or more kinds of grasshoppers, and it is quite likely that the culprits comprise more than the one species I have determined as the *Œdipoda atrox*. But all statements and all the specimens seen declare against the possibility that either of the three true migratory species are in our midst.

The satisfaction derived from this conclusion is that we of California are beyond the range of the all-devouring migratores that so often lay waste the interior. There they are liable to fall upon the farmer's field during any year of drought. Most of the border States have enacted expensive legislation to reduce the pest, by giving bounties of $1 to $5 per bushel for the locusts and $50 per gallon for eggs collected and destroyed, and also made it obligatory upon the able-bodied citizens to work a certain number of days to destroy them. Coal oil, Paris green, caustic potash, and several other chemical poisons are employed, and twenty-two kinds of machines, more or less elaborate and costly, are described and illustrated in the last report of the United States Entomological Commission, as being in use in the infested region. Extensive systems of irrigation are instituted, co-operative action arranged for burning the dry grass of the prairies at the right time to kill the unfledged locusts, &c. Fumigation, by burning dampened straw along the borders of growing crops, is found to ward off invading swarms. The aid of the military and Indian agents is invoked to assist in digging extensive trenches for trapping the young, and a signal corps of observation is suggested and shown to be of more prospective service than the present one devoted to "weather probabilities," involving, as the locust problem does, an annual average loss of about $40,000,000.

Professor Riley writes me: "Undoubtedly the same remedies that I have recommended [alluding to this report of the Locust Commission] will apply to your species."

The inutility of most of these remedies lies in the fact that a portion of the eggs are deposited in patches out in the sage-covered interior of the valley, where they cannot be treated with machines or with plow and harrow, fire or water, all too late for this year. But many observers speak of the young as moving in narrow columns, mowing swaths of grass in their progress. In this stage they might be precipitated into trenches, or trampled or crushed by rolling. These methods would be feasible only where the young locusts are not very numerous. Large masses thus ditched, if left uncovered, would bring in a worse pestilence—horrid diseases.

The insects huddle under dry grass and weeds during cool nights, where they may often be destroyed by fire.

A thin film of coal-oil, which will readily spread, upon a ditch of still water, will kill the locusts instantly if they try to swim across.

A shallow pan having a small quantity of coal-oil in it, if placed where the insects may fall into it, is very effective. The oil in these cases penetrates the breathing apparatus of the insects by way of the ten pairs of spiracles or breathing holes along the sides of the body.

The invasion of 17 years ago was only for one season. Why this one is prolonged for three years it would be interesting to know. It is hoped this is the last year of their ravages, if, indeed, they are allowed to complete their work, owing to the parasites, but will rise and flee away as soon as able.

The attacks of the "red louse," or "silky mite," have been alluded to in the previous articles. I have detected it in several localities, and should it become numerous, the atrocious locust is doomed, as appears from authentic accounts of its friendly services in the interior.

* * * * * * *

In 1861 Sierra Valley was but thinly settled, and the locust damages were not so important owing thereto, but statements from eye-witnesses convey the idea that in numbers the locusts far exceeded any experience of this invasion.

For a year or two they had been at work in the north end of the valley, just as now, rapidly increasing and traveling southward, precisely as in this case—but when they came around Newman's Point the broad living tide was immense, absolutely several inches in depth.

Dave Newman states that when he became aware of the direction of their approach, about the 5th of May, he, with Bill Peck and others, dug a trench 50 feet long by 3 feet wide and 3 feet deep across their course. The young locusts fell into it, smothered and died, while others traveled on over. He then shoveled out the dead ones and before night the trench was filled a second time, estimated at 50 bushels. He then desisted, for the stench of the dead he feared would be worse for his family than the loss of crops. They piled up against his barn like snowdrifts, to the height of several feet—estimated at 500 bushels.

Jonah T. Jones says they fell into and filled a row of post-holes to the top and died, amounting to a great many bushels.

George Humphry was driving a stage through the valley at the time, and says the road was often blocked as if with mud holes by grasshoppers; that they lay in banks along the fences and buildings.

No one reports any parasites on them, but as they were known to climb up from the ground to roost nights, where possible, it is supposed that the fear of the red mite which travels the ground was the cause, as this is the way with the Rocky Mountain locusts when so menaced. The autumn of that year saw the last of them. They did not fly away, it appears, but lay down and died in heaps before depositing eggs.

I have called attention to this locust enemy on every occasion, and much search has been instituted, but as yet only a few report the presence of the mite, and those in but a few places and in small numbers, it is to be feared that they are not numerous enough to destroy or drive out the locusts, but there is yet time for complete rescue. Their appearance at the East on our parallel is reported as occurring from April 17 to August 21.

Would that the welcome little red, silky locust-mite could be reported as reddening the ground of Sierra Valley in all the egg-infested localities.

THE LOCUST IN CALIFORNIA IN 1879.

The following items are taken from various sources:

I did not think, when investigating the locust ravages here last spring, that botany would take me away from the vicinity all summer, but so it has happened, and now I am just returned to find that the season has been a terrible one for this beautiful valley.

The damages by the same locust as last year, the *Œdipoda atrox*, exceeded that of last year, which was about $75,000, and may be estimated at $100,000 in a community of about 2,000 persons, with 91 farms of 47,000 acres. * * * The ravages of the *atrox* this season extended back for 20 miles on its old ground northward, and about 40 miles direct march to the southward.

Extensive egg-laying has been going on since July 1, and still continues in localities that do not admit of plow, harrow, or water. So the future is dark. No egg parasites yet noticed.—[J. G. Lemmon in letter to C. V. Riley, Aug. 27, 1879.]

Grasshoppers have invaded this section. Two large patches are on the Truckee meadows. The farmers are not alarmed to any great extent.—[Reno paper, May 9, 1879.

Nevada newspapers announce that vast numbers of grasshoppers' eggs are incubating in the Sierra Valley. A spadeful of soil is represented to have contained hundreds of thousands of eggs deposited in clusters. The farmers have not turned a furrow this spring, knowing that with these pests in the soil their work would be fruitless of result. Grain crops will only foster the scourge, while to let the ground remain idle may starve the insects into emigration. Fears are expressed that they may sweep down upon the fertile valleys of California.—[*Rocky Mountain Husbandman*, May 22, 1879.

THE MOUNTAIN GRASSHOPPERS.

Reports from the Sierra state that the grasshoppers, which have laid waste Sierra Valley for two years past, are now moving toward the west. David Evans, of Long Valley, tells the Reno Gazette that within the last ten days the grasshoppers have appeared in strong force in Grizzly Valley. They came from the head of Sierra Valley, where they are still numerous. Grizzly Valley is at a much greater elevation; so high that grain cannot be cultivated, and nothing but grass is grown. Mr. Evans thinks their next move will be into Indian Valley, whence their progress to Big Meadows, Plumas County, will be easy. And he surmises that the Sacramento Valley will next year suffer from the ravages of the insects. This is at present little more than conjecture, and though the scourge should be well watched it is too soon to become alarmed. The grasshopper of this slope is *Œdipoda atrox*, and not the famous Rocky Mountain locust (*Caloptenus spretus*). It would not matter much, of course, what difference there may be in names, but for the fact that our grasshopper has not shown such migratory and devastating power as the Rocky Mountain rascal, and the probability is that in the future his grievous work will be restricted to certain localities as it has been in the past. At all events we shall hope so until there is reason to think otherwise.—*Pacific Rural Press*, August 9, 1879.

THE SIERRA LOCUSTS.

Our contributor, Prof. J. G. Lemmon, writes to the Truckee Republican an account of his recent observations on the locust plague which has afflicted Sierra Valley, and to which we have frequently referred. His remarks on the various parasitic foes, which bid fair to reduce the evil considerably, are of much interest. The "red, silky mite" is here in great abundance, almost every locust in some sections being loaded with them, especially at the base and under the wings. So is the Tachina fly, chasing swiftly after the hopping or flying locust, darting upon it and depositing an egg, which speedily hatches, gnaws its way through the joints of the abdomen to the interior, becomes a large, many-legged maggot, swelling out of the body of the locust and eating its viscera fore and aft, until, weak and incumbered, the victim falls and dies. The Gordius, or hair worm, too, is here, and several other undetermined parasites, all seeming to riot upon the abundant food. A congener of the atrocious locust himself, a little yellow cricket about the same size, but ten times spryer, is seen to vigorously attack the locust on foot or flying, to bring him down, and instantly cutting off his head, devours a morsel, then twirls his antenna about, and cocks his eyes for another victim.

"And what of the future? When will this visitation cease, or is it overpast? The female locusts have been noted in vast numbers ovipositing in gravel beds, in dry knolls of the meadows, and in the sands under the sage bushes of the common. Those beginning this work early in the season—in July—it is feared laid perfect eggs and secured them well; those later, because so often found dead at their work with abdomen still prolonged down into the ground, it is hoped were prevented from producing perfect eggs, or from protecting them by gummy secretions from injuries by winter vicissitudes.

"As a clearing up of the business, I have just sent Professor Riley a box of all the species of locusts found here lately, including many individuals of our descriptive *Œdipoda atrox*, and of another suspicious species, which I fear is *Caloptenus atlanis*, one of the three true migratory species so much to be dreaded. This and the Atrocious locust are heavily parasitised, and, perhaps, may be living their last day."—[*Ibid*, September 13, 1879.

GRASSHOPPERS AND THE DAIRY FARMERS.

The mountains and valleys surrounding Truckee afford, during the summer season, excellent pasturage for a large number of dairy cattle; for dairymen make yearly pilgrimages from the valleys to the eastern slope of the Sierra to enjoy the delightful climate, and to allow their cattle to feed upon the luxuriant vegetation to be found there. Large quantities of butter and cheese are manufactured every season. This year, however, the dreaded grasshopper has visited these ranges and eaten everything in sight, and the dairymen have been compelled to seek pastures green and new. Joe Joerger, whose range is in Martin Valley, has been forced to move with his dairy of 120 cows. W. H. Williams, from Russell Valley, Mr. Barton, from the Little Truckee, Johnny Fleckenstien, from Sardine Valley, and the Perazo Brothers, from Sage Hen, have all been obliged to leave their ranges and go elsewhere with their dairies. These dairies in years past have been considered among the best in the State, but this year the grasshoppers have devoured almost everything in the shape of vegetation, leaving them barren, desolate wastes.—[Truckee *Republican*, August 6, 1879.

GRASSHOPPER RAID IN SHASTA.

Down at Shasta River, and on the flats toward Willow Creek, the country is overrun with grasshoppers, which devour everything in the vegetation line, and even climb trees to eat the leaves. They first appeared at Fiock's ranch after his grain was cut, and he cut his alfalfa immediately to save what he could of it for hay. At the Portuguese vegetable ranch below, formerly owned by W. J. Paul, the grasshoppers are devouring everything, and decimating his splendid crop of corn, tomatoes, cabbage, and vegetables of all kinds. Other ranches and gardens along the river are suffering from this pest. At Little Shasta several farms have been visited with the nuisance, but the grain, being too far advanced, has escaped injury. The second crops of alfalfa and all kinds of vegetables and late products, however, are being pretty well cleaned out. Grasshoppers are worse than crickets or locusts, as they travel around livelier and eat faster.—[*Yreka Journal*, August 6, 1879.

DESCRIPTIONS OF TWO SPECIES.

By Prof. CYRUS THOMAS.

From specimens sent to the commission by Mr. Lemmon, and others by J. K. Lum, of Lewis County, W. T., Profesor Thomas has described the following species. The other species will be noticed in our next report:

Œdipoda obliterata. Nov. sp.

Male and female. Length to tip of elytra, 1.50; to tip of abdomen, 1.10 to 1.30. Pale reddish-brown or dull yellowish, tinged with rufous, with irregular transverse bands of dark, fuscous spots.

Occiput not prominent. Vertex broad, moderately deflexed; margins with sharp carinæ, forming a distinct, sub-quadrate, median foveola, which is divided into two equal sections by a distinct, longitudinal, median carina that extends back part way upon the occiput; sides of the foveola parallel between the eyes, and bending abruptly inward toward the fastigium, in front, continuous with the sides of the frontal costa; fastigium with a double indentation. Frontal costa slightly sulcate, sub-tricarinate at the fastigium, widening at the ocellus and extending nearly or quite to the clypeus, but not expanding below; in the ♂ the width is almost uniform throughout. Pronotum, with the median carina sub-cristate, distinctly and deeply notched about the middle by the posterior sulcus; anterior portion irregularly arched, more elevated than the posterior portion, which has only the front part arched; lateral carinæ irregular and indistinct; the notch of the median carina is of the oblique type, more distinctly so in the male than in the female. Posterior lobe expanding rapidly from the posterior sulcus, nearly flat on the disk, which is more or less covered with elongate rugosities, more distinct and numerous in the female than in the male; posterior extremity obtuse-angled; anterior margin extended in a very obtuse angle upon the occiput. Elytra extending about one-third their length beyond the abdomen, of medium width, sinuous and obliquely excised at the tip. Wings narrow, the length very nearly twice the width, and slightly undulate on the outer margin; the nervules unusually regular and straight. Posterior femora with sharp and elevated carinæ above and below. Antennæ rather short, scarcely flattened, and very slightly acuminate at the tip.

Color (recent specimens dried).—Female somewhat darker than the male; face pale purplish, dotted with fuscous; occiput and pronotum fuscous brown, the latter with a carneous stripe along each lateral carina, which connect at the anterior sulcus and fade out near the posterior extremity; the disk of the posterior lobe dark brown. Elytra pale, dirty yellow, slightly tinged with rufous, crossed by three irregular bands formed of dark fuscous spots, the middle one broadest and usually the best defined; apex with irregular, cellular, fuscous spots, those next the costal margin most distinct. Wings pellucid, with a narrow marginal, rather pale, fuscous band, commencing behind the sub-costal area, where it is broadest, narrowing and fading toward the anal angle; the nerves and nervules, except in the apical portion of the sub-costal area and in the fuscous band, pale yellow, or white. Posterior femora crossed externally and internally by three oblique fuscous bands; posterior tibiæ pale yellow; spines tipped with black.

One male and one female from Sierra Valley, California, furnished by Mr. J. G. Lemmon.

This species approaches very near Mr. Scudder's *Trachyrhachys*, but appears to belong to *Œdipoda*, as at present limited. If Mr. Scudder's genus *Dissosteira* (of which he has given but an incomplete diagnosis) stands, this species will scarcely find a lodging-place in any of the numerous genera of this group.

In his paper on the Orthoptera collected by Lieutenant Wheeler's survey, published in 1876, where he first proposes this genus, he makes the following statement: "Stål's limitations of the genus *Œdipoda*, in his Recensio Orthopt. I, forces us to consider *Gryllus cœrulescens*, Linn. as the type, and not, as stated by Thomas, *Œdipoda carolina* (Burm)."

He alludes to a statement made in my paper on Orthoptera, in a previous report of the same survey, where I simply remark that Stål has retained our *Œ. carolina*, and that "this *appears to be* his typical [species]" (by typographical or clerical error "genus"). By reference to Proceedings Davenport Acad. Nat. Sci., vol. i, 1876, page 257, it will there be seen that I make the following statement in reference to the genus *Œdipoda* as given by Stål: "In my opinion *Œ. cœrulescens*, Linn. is the *proper type* of *Œdipoda*." This paper was published in June and July, 1876, the entire manuscript having been forwarded to Mr. Putnam some time previous thereto. I cannot give the exact date of publication of Mr. Scudder's paper, but his letter of transmittal to Lieutenant Wheeler bears date Cambridge, Mass., May 29, 1876.

I simply mention this in justice to myself.

As I have here referred to this paper by Mr. Scudder I may as well correct another error he has fallen into in reference to *Anabrus haldemanii*, Gir. He remarks (page 500) that "he [Thomas] further confuses his readers by stating that *A. haldemanii* Gir. has the prosternum distinctly spined, whereas it is clearly as amucronate as the prosternum of *A. simplex*." He falls into this error because he has not, or had not then, seen a specimen of *A. haldemanii*, which has the prosternum distinctly spined. The description and figure given in Marcy's Red River of Louisiana are so exact that with a true specimen in hand, as I now have before me, there is no possibility of making a mistake. This species is never, as I learn he supposes, found west of the Rocky Mountain range, nor *A. simplex* ever found east of it, unless, possibly, in Montana.

Cratypedes Putnami, Thomas.

Mr. A. J. Chipman, who visited Southern Colorado in 1880 on behalf of the United States Entomological Commission, was fortunate enough to obtain a fine specimen of this species, in color. From this I can now give the colors omitted in my original description: base of the wings, lemon yellow; hind tibiæ, bright red. In the female the yellow spots of the elytra are not so distinct as in the male. The same is also true in reference to the dark bands on the posterior femora.

At the close of his "Century of Orthoptera" (Reprint from Proceedings Bost. Soc. Nat. Hist., vols. 12–20, 1879, page 84) Mr. Scudder, in speaking of *Hippiscus lineatus*, Scudd., remarks as follows:

"*Hippiscus lineatus.*—This species I had formerly described (in MSS.) under the new generic name *Cratypedes*, but, before publishing, concluded it best to include it in *Hippiscus*. I do not recollect that I have ever mentioned this name to any one, and have never seen more than the single specimen of the species upon which I had proposed to found it, and which has never left my collection. It was, therefore, a complete mystery to me to find a closely allied species described by Mr. Thomas, Proc. Davenp. Acad. Nat. Sci., I, 257–58) as *Cratypedes Putnami*, with the remark, 'I have placed this species in this genus with some hesitancy, yet it certainly agrees very closely with it.' I disclaim any proprietorship in the generic name, and do not know to what Mr. Thomas refers. This remark is offered simply to aid any future student who may search for the origin of the name."

This statement by Mr. Scudder indicates a forgetfulness on his part of what he has written, as the reader will see by turning to his "List of Orthoptera, collected by Dr. A. S. Packard in Colorado and the neighboring Territories during the summer of 1875," page 267, where he will find the following statement: "*Stenopelmatus oculatus* and *Cratypedes lineata* are described from specimens dried after immersion in alcohol." This remark is offered simply to aid any future student who may search for the origin of the name.

CHAPTER XIII.

FURTHER FACTS ABOUT THE NATURAL ENEMIES OF THE LOCUSTS.

(Plate XVI.)

There is not much to add to the account in our First Report of the many different natural enemies of the Rocky Mountain Locust, but what little we do add will serve to clear up some unsettled questions, and to give emphasis to the important part that some of the more minute enemies play in keeping this pest in check.

BLISTER-BEETLE LARVÆ.—The habit in these interesting larvæ of feeding on locust eggs has been confirmed by obtaining them from the egg-masses of several other species, and the fact that they have a similar habit on the Pacific coast is shown by the frequent presence of the coarctate larva among the eggs of the destructive locust of California (*Camnula pellucida* Scudd[331]).

One experience with them is worthy of record in this connection, *i. e.*, the retarded development that is often manifest in certain individuals, as stated in a recent number of the *American Entomologist* :

"In the month of October, 1877, we hatched a number of triungulins from the same batch of eggs laid by a female of the Striped Blister-beetle (*Epicauta vittata*), and fed them on the eggs of the Differential Locust (*Caloptenus differentialis*). Several of the resulting beetles issued the following summer; three of them passed a second winter in the coarctate larva state, and issued as beetles the second summer; while one remained unchanged during this second summer of 1879. We examined it from month to month, always finding it healthy, but began to fear, as the present summer approached, that it must have been injured and was really dead. It was unchanged on the 3d of May of the present year, but on looking at it again on the 15th of June, we were gratified to find that it had left its rigid skin and presented itself in the form of the final or third larva. It had transformed to the true pupa on the 1st of July, and would undoubtedly have given out the beetle two weeks later had we not preferred to preserve it in the pupa state for our cabinet.

"In this case the individual, though submitted to exactly the same conditions as the other specimens, which had simultaneously hatched with it—but which went through all their transformations within either one or two years—remained dormant for nearly three years, with their repeated changes of season and temperature. With the exception of the first winter, when it was kept indoors without freezing and when development should have been presumably hastened, the specimen was kept in a tin box buried the proper distance beneath the ground out of doors, so as to be as nearly as possible under natural conditions."

This irregularity in the development of individuals is noticeable in many insects that are parasitic and whose mode of life is precarious. In the case of our blister-beetles, depending as they do on locust eggs, and especially in the case of those which feed particularly on the eggs of migratory species, it is not difficult to perceive how this trait may prove serviceable to the species possessing it. Migratory locusts occur in immense numbers in some particular part of the country at irregular intervals, and there are periods or years of absolute immunity from their presence in the same regions. The young blister-beetles that hatch the year following the advent of the locusts in immense numbers may frequently find few or no locust eggs upon which to prey, and the great bulk of them would, as a consequence, perish; while the young from such

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[331] *Œdipoda atrox* of our First Report.

exceptional individuals as should not develop till two, three, or more years after a locust invasion might stand a much better chance of finding appropriate food and of thus perpetuating the species. In this case and in most other cases of retarded development with which we are familiar, the exceptional retardation may and does become a benefit to the species, enabling it to bridge over periods of adversity. And we can see how, by the preservation of such favored individuals, the habit of irregular development may have become fixed in the species as a consequence of surrounding conditions and circumstances which render it advantageous.

SOLDIER-BEETLE LARVÆ.—We are not aware that the early larval characters of these beetles have ever before been observed. Since our First Report was written we have obtained the eggs of the Pennsylvania Soldier-beetle (*Chauliognathus pennsylvanicus*, De Geer) and hatched the young larvæ and fed them until they were nearly full grown. The eggs are deposited loosely in the ground in irregular batches very much in the same way as those of the blister-beetles, but are readily distinguished from these last by being almost spherical or but very slightly longer than wide. They are pure white and opaque, the shell being tolerably firm and having no sculpture. Mr. H. G. Hubbard, whom we charged with rearing the larvæ, found that they fed on a number of insects, but showed a great preference for those, like fly maggots for instance, which have a soft integument. They molt quite frequently, huddling together during the process, which would indicate that in their earlier stages at least they are more or less gregarious. We quote Mr. Hubbard's notes:

The eggs of *Chauliognathus pennsylvanicus*, which you gave me at Savannah, hatched during the night of August 9. The young larvæ were silver-gray in color. They were very timid, but sucked up the juices of plant-lice, the bodies of which were crushed for them against the sides of the breeding-jar. August 12 the larvæ retreated to the bottom of the earth in the bottle, and curled up in clusters. In two or three hours they had moulted, and immediately became very active, climbing all over the sides of the jar. The anal prop-leg acts as a sucker, and enables them to adhere to the glass in any position while sweeping the body around in every direction in search of food. I gave them crushed maggots of *Phora aletiæ*, and they sucked the juices greedily. They became bolder, and attacked the uninjured maggots, but were unable to pierce the skin. August 15 I gave them a species of large red *Aphis* found on cocklebur, but they did not relish them, and ate but little. They also ate sparingly of crushed *Aletia* larvæ, but preferred the *Phoras* to everything else. August 17 they retired to the bottom of the jar, and remained torpid two days. August 19 all had completed their second moult. They were now quite bold and strong, and able to pierce the skin of *Phora* maggots given them for food. In feeding, the maggot is punctured by the sharp tips of the jaws, which are then used as hooks to draw in a fold of the skin; this is held between the molar lobes at the base of the mandibles, and the juices are sucked by the pumping action of the œsophagus, which is thrown into peristaltic waves. The large mentum is very elastic and mobile, and evidently performs the usual office of a lower lip. An occasional quick movement of the jaws is made, either to give a squeeze with the molar surfaces, or to take a better hold with the hooked tips.

The basal joint of the antenna is very elastic, and enables the larva to elongate this organ considerably. After each moult the markings of the dorsum are very distinct, and the body is lead or mouse color, growing darker with each moult, but in the intervals fading to a silver-gray. The larvæ were lost September 6, at which time they had undergone five or six molts, but were not over one-third grown.

ASILID-FLIES.—We are not aware that the mode of egg-laying in these flies, or the nature of the eggs, have hitherto been recorded. Mr. Hubbard, during his work for the Commission, succeeded in watching the operation in a Florida species (*Mallophora orcina* Wied.), and has made the following notes thereon:

On September 3 or 4, while in the field, a species of Mallophora came flying and alighted in an open space between the rows of cotton. She seemed to have selected this spot at one glance as a suitable place in which to deposit her eggs, for without more ado she applied her abdomen to the surface of the ground and began working it into the earth with a slight oscillating movement. In two or three minutes she had buried it to its base. The eggs must have been very rapidly laid, for after a few moments she withdrew her body, filled up the hole with her abdomen, aided by her claws, brushed the surface carefully with the hairy tip of her body, and flew away. The entire proceeding occupied not more than four minutes, and the place of deposit was so carefully concealed that, although from my position six or eight feet distant I marked the exact spot with my eye, and immediately after drew a circle around it with my knife-blade, I could not detect the slightest disturbance of the surface. The soil was a tenacious clayey loam. I removed in one lump the earth within the circle made by my knife, and, on breaking it open, found five or six eggs, packed in a not very close cluster, at a depth of $\frac{1}{2}$ to $\frac{3}{8}$ of an inch. I placed the lump of earth containing the eggs in a metal box, where I found the young larvæ in the act of hatching a week later. The eggs are yellowish-white, elongate, rounded at the ends, and, though not very carefully examined, seemed to present no remarkable structure, but resemble the eggs of some of the smaller crickets.

BEE-FLY LARVÆ (Family *Bombyliidæ*).—We now come to the interesting and hitherto unrecorded life-history of two species of bee-flies, a family of two-winged flies that have a rapid darting flight and hover over flowers, from which they extract nectar by means of a long proboscis which characterizes most species. They derive the popular name from their hairiness and resemblance to bees, a resemblance enhanced by the humming which they produce in flight. On p. 305 of our First Report we figured an undetermined egg-parasite of the Rocky Mountain Locust, giving some account of its extensive occurrence in and about the egg-pods of that insect, and showing that next to the Anthomyia egg-parasite it was the most important enemy of the locust. The larva was somewhat anomalous. We were in doubt even as to what order of insects it belonged, placing it at the time in the Hymenoptera, and with a question among the *Ichneumonidæ*. From the absence of spiracles on the intermediate abdominal joints we suspected, soon after the publication of our First Report, that this larva would prove to be Dipterous rather than Hymenopterous.

From such poor descriptions and figures as were extant, that most nearly approached it, we deemed it might be Anthracid, and were subsequently confirmed in this view by obtaining in October, 1879, a single pupa from a lot of larvæ sent us by Mr. G. M. Dodge, of Glencoe, Nebr.

Mr. Dodge sent us, with the same lot of larvæ, what he supposed to be the parent fly, reared from a lot of locust eggs among which the larvæ were found. His flies, however, proved to be the Anthomyia egg-parasite (*A. augustifrons*, Meigen, First Report, p. 285). The single pupa thus obtained from Mr. Dodge's specimen agrees with those of *Systœchus oreas*[332] O. S., presently to be described.

During the past two years we have been in correspondence with Prof. J. G. Lemmon, of Sierra Valley, Cal., who has kindly sent us many specimens of the locusts occurring there, and especially the eggs and early stages of *Camnula pellucida.*

Among such eggs these bee-fly larvæ were, if anything, more common than we had found them among the eggs of *Caloptenus spretus* east of the mountains. We here quote one letter in illustration:

> By this mail I dispatch another cigar-box filled, this time, with sods containing eggs of the terrible locust that for three years past has devastated Sierra Valley; also the large, fat, white larva that lately made its appearance as a voracious feeder upon locust eggs. We don't know certainly what this larva becomes, but at a venture he is hailed with great joy.
>
> The ground that was first filled with locust eggs by the *Œdipoda atrox*, by the end of September looked as if scattered with loose shells, so thorough was the work of destruction.
>
> A few of them were detected in among the eggs in April, but not generally until August. One individual seems to empty several egg cases before retiring from the feast and coiling himself up in a case which he has emptied, or in a nidus of his own make.—[J. G. Lemmon, in letter to C. V. Riley, October 12, 1879.

During 1878 and 1879 we failed to rear any of them to the perfect state, but on June 20 of the present year, 1880, we obtained from these California larvæ the first fly. This proved to be a male of *Triodites mus* O. S.,[333] as kindly identified for us by Mr. S. W. Williston, of New Haven. The delay in the printing of this report enables us to complete the natural history of these insects. We have, during the summer, reared many additional specimens of this species and also of the *Systœchus oreas* O. S. already alluded to. Professor Lemmon and his brother, Mr. W. C. Lemmon, have also succeeded in obtaining the mature flies, and have observed this *Systœchus* abundantly buzzing about over the ground in which the locust eggs were laid, as the following extracts from the correspondence of these gentlemen will show:

> An enemy which has proved very destructive in Sierra Valley and vicinity is the larva of, as yet, an unknown insect. It is first observed as a large yellowish-white grub about half an inch or even three-fourths of an inch long when extended, it being usually curved so that the head and tail nearly touch. It is one-sixth to one-fifth of an inch thick just back of the head and tapers slightly towards the tail, also flattened slightly dorsally. It is usually found in a case of locust eggs which it has devoured, pushing the empty shells aside, and at last occupying the space where were 21 to 36 eggs. Often it is found in a little space below a number of emptied cases, as though it had feasted off the contents of several nests.

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[332] Western Diptera, p. 254; Bull. Hayden's Geol. and Geogr. Survey, III, No. 2.
[333] *Ibid.*, p. 246.

The grub was first noticed last April 20, in the egg deposits near Loyalton. This fall, September 7, it was detected in great quantity near Sierraville, and afterwards in several infested spots of the valley. A handful of such soil will generally display ten to twenty cases of locust eggs, more or less emptied, and half as many of the fine, fat, grubs.—[J. G. Lemmon, in the Sacramento, Cal., *Weekly Record-Union*, November 29, 1879.

The white grubs ate out and destroyed thousands of eggs last fall, but, to all appearance, have eaten nothing since, having lain dormant all winter, and being now found still among the eggs, which are fast hatching out.—[W. C. Lemmon, Sierra Valley, Cal., June 13, 1880.

I send to you by this mail another package of the locust-egg-eating grubs, some of which you will find more developed. My brother, Prof. J. G. Lemmon, came up from Oakland day before yesterday to spend a few days, and while looking at the grubs that I had gathered for you yesterday, one of them developed into the humble-bee fly which you have bred, and a half dozen specimens of which I have caught and envelop rolled up in paper.—[W. C. Lemmon, in letter to C. V. Riley, dated, Sierra Valley, Cal., July 18, 1880.

Happening home on a hurried visit, I find locusts and destruction all around—a sad, sad sight! Find my brother has tried to keep you posted up with specimens and notes. Am pleased to see a solution of the "big white grub" question. He developed into a species of fly, hosts of which are now seen in midday, buzzing about among the locusts.—[Prof. J. G. Lemmon, in letter to C. V. Riley, dated, Sierra Valley, Cal., July 18, 1880.

This habit in the larvæ of Bombyliids of preying on locust eggs has not before been suspected, and in this connection we will review what has hitherto been known of their habits.

Prof. J. O. Westwood has given, in the Transactions of the Entomological Society of London, 1876, pp. 497, 498, the following summary of observations upon the larval habits of Bombilii:

Thanks to the researches of previous observers, the economy and transformations of the *Bombylii* are now satisfactorily known to entomologists. Latreille rightly considered that the *Bombylii*, like *Anthrax*, were parasites, contrary to the opinion of Zetterstedt that the larvæ feed on the roots of plants (Ins. Lapp., p. 510). The pupa of *Bom. major* was first figured by M. Imhoff in the Isis for 1834, having been found by him in a situation which he had previously noticed to be frequented by *Andrena humilis* (vol. 1834, p. 536, pl. xii). In my Introduction (vol. 2, p. 538, 1840) I published a figure of the same pupa from a specimen discovered by M. C. Pickering in a sandy gravel-pit at Coombe Wood on the 28th of March, from which the imago was produced in a few days. The pupa is very similar to those of the species of *Anthrax*, which are known to be parasites, having the front and under side of the head armed with strong spines, and the dorsal segments of the abdomen furnished with transverse rows of strong reflexed hooklets. In 1852 M. H. Lucas published the description of a new Algerine species of the genus, *Bomb. Boghariensis*, in the Annals of the French Entomological Society, 2nd ser., vol. x, p. 11, pl. 1, No. 11, which he had reared from a pupa found under a stone in a damp, sandy situation, and, contrary to the opinion of Latreille, he expressed himself thus: "Je suis porté à croire que les larves qui composent ce genre ne sont pas parasites, comme le supposent Latreille et beaucoup d'autres Entomologistes, mais qu'elles vivent au contraire isolément dans la terre,—opinion, au reste, qui avait déjà été émise, mais avec doute, par M. Macquart, et que mon observation vient confirmer."

In 1858 the real history of the Bombylius was discovered by the veteran Léon Dufour, who in the spring found various exuviæ of the pupa of *B. major* sticking out of the ground, together with the newly-hatched insect, in places much frequented by various *Andrenidæ*, especially in the autumn, by digging on the spot, to find the larva,

PLATE XVI.

(Natural sizes indicated in hair-line.)

Fig. 1. Larva of *Systœchus oreas*, from the side; 1 *b*, head from side, still further enlarged; 1 *c*, same, from front; 1 *d*, left maxilla; 1 *e*, left mandible; 1 *f*, mesothoracic spiracle; 1 *g*, pre-anal spiracle.

2. Pupa of *Systœchus oreas*, ventral view; 2 *a*, same, side view; 2 *b*, dorsal part of anal end; 2 *c*, prothoracic spiracle; 2 *d*, form of dorsal horny plates and spines on the abdomen.

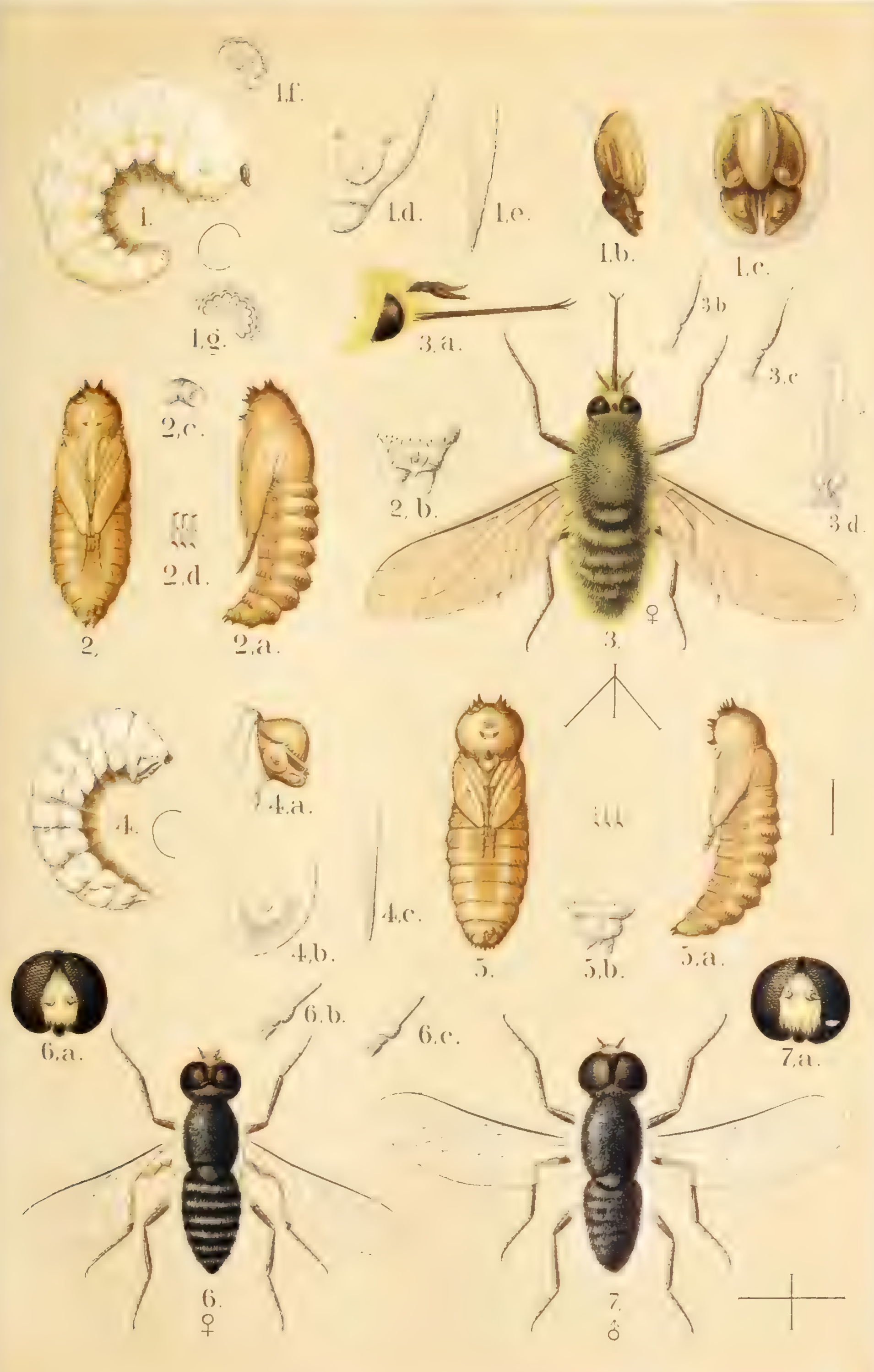
3. *Systœchus oreas*, ♀; 3 *a*, head of same from side; 3 *b*, antenna of same from above; 3 *c*, antenna of same from side; 3 *d*, mouth parts separated.

4. Larva of *Triodites mus* as it appears when contracted prior to pupation; 4 *a*, head from side; 4 *b*, left maxilla; 4 *c*, left mandible.

5. Pupa of *Triodites mus*, ventral view; 5 *a*, same, side view; 5 *b*, dorsal view of anal parts; 5 *c*, form of dorsal plates and spines on abdomen.

6. *Triodites mus*, ♀; 6 *a*, her head, front view; 6 *b*, her right antenna from above; 6 *c*, right antenna from side.

7. *Triodites mus*, ♂; 7 *a*, his head, front view.



C. V. Riley del. et pinx.

BEE-FLIES.

A. Hoen & Co. Lithocaustic Baltimore

"au milieu des déblais, où gisaient par-ci par-là des coques de Colletes" (Ann. Soc. Ent. France, 3d ser., tom. vi, p. 505, pl. 13, Fig. 111, and details). The larva is elongated, apod and fleshy, and of a white color. The preceding observations clearly prove that the larvæ of the Bombylii are parasites in the nests of other insects, in the manner of the cuckoo among birds.

The last statement of Professor Westwood is, however, not justified by Dufour's observations. On the contrary, Dufour expressly states that he did not observe upon what the larva fed; the inference which he draws is based upon the analogy of *Anthrax*,[334] and he inferred that it was upon the larvæ of *Colletes* that the grub fed; quite a different thing from being a cuckoo in the nest and feeding only upon the pollen. There is, in Dufour's paper, no evidence to prove that the *Bombylius* larva was found in the cocoons, or even in the cells of the bee; he states, in fact, that he failed to find it there, but found it among the clearings (*déblais*) which he had made in digging out the nests. Prof. Westwood himself found numbers of *Bombylius medius* flying in association with a species of *Andrena* in the unpaved Forum Triangulare of Pompeii, and found at the same spot the pupa-shell of the fly protuding from the ground.

Dr. Packard ("Guide," &c., p. 397) states that "a species [of *Bombylius*] is known in England to lay its eggs at the opening of the holes of Andrena, whose larvæ and pupæ are devoured by the larvæ of the fly." But no authority is given for the statement.

Messrs. Allen and Underhill, in *Science Gossip*, 1875, p. 80, express their belief that the *Bombylii* are parasitic on humble-bees. In the volume for 1876, p. 171, they say (speaking of *Sitaris*):

In relation to the larva of this beetle, we would remark that this year we have found it clinging to *Bombylii*. This is "circumstantial evidence" that Bombylii frequent the nests of Anthophora to lay their eggs, since Sitaris itself, from its manner of life, cannot be the parasite of a fly, but only of a bee.

Locust eggs might well have been in the spots where Lucas, Dufour, and Westwood found the *Bombylius*.

From all these notes, it is clear that the true habit of Bombyliid larvæ had not been clearly ascertained. That they preyed parasitically on nest-building Hymenoptera was rendered probable by what was known of the parasitism of the allied Anthracids; but we had only assumption without proof, and the experience we now record weakens the force of the assumption.

In his "Western Diptera" (l. c. p. 243) Baron Osten Sacken gives references to the published account of the parasitism of the Anthracid genus *Argyramœba* within the nests of *Cemonus* and *Chalicidoma*, cites

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[334] It has been clearly ascertained, and is well known that *Anthrax* feeds in the larval state upon the young of certain bees. The larva of the *Anthrax* before attaining its own full growth and before destroying its host must await the full growth of the latter, as it has, by several observers, been bred from the cocoons of the insects upon which it was parasitic.

Schiner's statement that the larvæ live parasitically in pupæ of Lepidoptera, and records the breeding of *A. cephus* and *A. fur* from the nest of a Texan mud-wasp, which he referred, with a question, to *Pelopæus*, but which, as we have ascertained from an examination of the mud tubes which are deposited in the Cambridge Museum of Comparative Zoology, belong to *Trypoxylon*. We have similar cells from Texas and other parts of the South. They differ from those of *Pelopæus*, in being wider, ribbed on the upper surface, and fastened not only side by side but in long tubes end to end. The *Pelopæus* spins a thin, yielding, semi-transparent, elongate cocoon of a golden-brown color, with more or less loose silk around it and the tail end thickened and docked: the *Trypoxylon* spins a tougher, thicker, more solid, and smooth cocoon of a dull, dark brown color, generally about half as long as the other (but varying greatly in size), and with the head-end often expanding into a flange.

We have reared what is very near to and probably identical with *Argyramœba fur* from larvæ that had preyed on *Trypoxylon albitarse* which had made use of the mud cells of *Pelopæus lunatus*, or the common mud-dab, in Texas; also from the same wasp that had made use of the burrows of a bee (*Anthophora abrupta* Say). The larva of *Argyramœba* has very much the same appearance as that of *Systœchus* and *Triodites* and the pupa is distinguished from the pupa of this last (Pl. XVI, Figs. 5, 5 *a*), principally by its longer and more numerous hairs, longer anal spines, and more conspicuous spiracles.

The discovery of the "parasitism" of these Bee-flies upon the locust eggs at once suggests a comparison with the similar diversity of parasitic habits among the *Meloïdæ*, as given in our First Report, some of them infesting Bee-cells, while others, as the true Blister-beetles (*Lyttini*) feed on locust eggs.

The Anthracids are now united, by the best authorities, with the *Bombyliidæ*, of which family as a whole Osten Sacken has said:[335] They are, "perhaps, the most characteristic and one of the most abundantly represented families of *Diptera* in the western region, including California." The abundance of blister-beetles is also well known to characterize this region, and we have shown how this abundance is connected with the abundance of locusts. It is of interest, therefore, to find that the Bee-flies bear a similar relationship of parasitism to the latter, and that the characterization of the fauna in these two groups is really dependent upon the presence of the locusts as well as upon the rich representation of the burrowing Hymenoptera.

With these general remarks we will now give a more full and descriptive account of the two bee-flies which, by rearing from the larva, we know to have this locust-egg-feeding habit.

Systœchus oreas.

The character of the eggs and the manner in which they are laid have not yet been observed. The larva (Pl. XVI, Fig. 1) has already been

[335] L. c., p. 225.

described in our First Report (p. 305), and is found in the locust egg-pods or near them, of different sizes, during most of the year. These larvæ begin to transform to the pupa state early in the summer, and the pupa (Pl. XVI, Fig. 2) pushes itself half way out of the ground in order to disclose the fly. These flies continue to issue during the summer months. As a rule but one year is required for full development, but there is, in this respect, great irregularity and the same tendency to retardation which we have called attention to in the case of the blister-beetles. We have had quite a number of the larvæ remain over unchanged till the second year, and all that we have said as to the philosophy of this retardation in the one case applies in the other. We are inclined to think that future observation will show that there is a still further parallel, in that the newly-hatched larvæ of the bee-flies are much more active than the later stages, and somewhat different in structure. The three later stages of the insect may be characterized as follows:

Larva (Pl. XVI, Fig. 1).—We quote herewith our former description:

Average length, 0.50 inch. Body curved, glabrous, tapering posteriorly, swollen anteriorly. Color opaque whitish, with translucent yellowish mottlings, and some venous marks at sutures, especially along medio-dorsum. Sutures deep. A lateral row of swellings. Head small, flattened, dark brown, in five pieces, consisting above of a frontal ovoid piece and two lateral pieces of somewhat similar form, and each bearing near tip a minute, two-jointed palpus; beneath of two broad, subtriangular jaws, having forward and lateral motion, and each, also, bearing near the center, in a depression, a two-jointed feeler. A spiracle each side in a fold between joints 2 and 3, and another on each side of the penultimate joint, 12. None otherwise perceptible.

With additional material we have been enabled to examine more fully the structure of the head. Underneath the median elevated piece which may represent the labrum we find two stout spines (Pl. XVI, Fig. 1 *e*), faintly notched on the outer edge, which are doubtless the mandibles and correspond to the two dark lance-like mandibles of other Dipterous larvæ, for they are retractile and run back into the thoracic joints, and remain after the other trophi are detached. The pair of feelers upon the upper lateral pieces, which seem to have no motion, might then represent the antennæ and the two lower jaws the maxillæ with their palpi, while the labium is shown in a chitinous point visible only when the larva extends and raises the other parts. A peculiarity in the movement of the maxillæ or the lower pair of horny pieces is worthy of note. They move in alternation with one another in the forward and backward, *i. e.* up and down, motion. The palpus of these lower pieces when viewed from above is, as represented in the figure (Pl. XVI, Fig. 1 *d*), circular, with two dark marks indicating minute appendages.

When the larva is fresh and plump it shows the greater swelling of the thoracic joints and the translucent mottlings mentioned above. Toward the period of pupation it becomes more opaque and more contracted.[336]

Pupa (Pl. XVI, Fig. 2).—Average length 8.5^{mm}. Color honey-yellow, but varying with age, the head and thorax assuming a dark color with maturity. Head narrow, with two sets of 3 stout, dark spines on the top, all on a common prominence, the two lower ones of each set connected at base; a pair of smaller frontal spines near the base of proboscis,

[336] So far as we can ascertain, there has hitherto been published no recognizable figure of the Bombyliid larva. Dufour, in his articles above alluded to, describes that of *Bombylius major* very indifferently and gives a dorsal view which shows little or no relation to the larva here described, while his description and figure of the mouth parts fail to indicate the different pieces we have observed in our larvæ. Yet in general form and structure the true Bombylius larva will undoubtedly be found to agree very closely with those here described.

which is protuberant and laid along the breast, extending to near the tips of the wings; the face with two parallel depressions running from between the triple tubercles and ending in two fossæ above the frontal spines; two basal, medio-dorsal tubercles. *Thorax* unarmed, the prothoracic spiracle very large and raised on a curved tubercle; meso-thoracic spiracle on a swelling at base of wings; front tibiæ stout and curved; front tarsi reaching to tips of wings; middle tarsi to abdominal joint beyond, and hind tarsi to third abdominal joint beyond. *Abdomen* curved, with the ninth joint very small: across the middle, dorsally, each joint has a series of parallel, longitudinal, narrow, chitinous plates having at each extremity a spine, the posterior one stoutest; both plates and spines diminishing laterally, gradually aborted on the extreme basal and posterior joints, and replaced on the small ninth joint by a group of four converging and truncate tubercles; two stouter anal spines on the subjoint and a ventral lobe with two short, obscurely articulate processes; each abdominal joint with a circle of hairs, those on lateral ridge stoutest and one-third the width of abdomen in length; 8 pair of abdominal spiracles (making 10 with those on thorax), the first and last pairs rather difficult of detection.

Imago.—The perfect fly (Pl. XVI, Fig. 3) is at once distinguished from the succeeding species by its broader form and long proboscis. The whole body is covered with long yellow or fulvous hairs. The species varies in the color of the legs and in size, some females being larger than the males. The species was originally described from Sierra County, California, and Mr. Williston informs us that he has a specimen from Washington Territory. We quote Osten Sacken's original description:

SYSTOECHUS OREAS.—Differs from *S. vulgaris* in the third antennal joint being a little broader, the mystax being more mixed with fulvous pile, the proboscis longer, the legs darker, the wings more grayish, the covering of pile more dense and of a paler shade of yellow, the ground-color less dark (when denuded), without reddish on the scutellum; on the average, the size is somewhat larger.

Male.—The blackish-gray ground-color of the body is entirely concealed (in intact specimens) under a thick covering of pale yellow pile, giving the body an elongated-oval shape, slightly broader about the middle of the abdomen; face and front covered with a recumbent fulvous tomentum, and erect black pile; mystax mixed of both; some black pile on the vertex; antennæ black, third joint considerably expanded on its proximal half; legs black; femora densely covered with the usual appressed whitish hairs, which conceal the ground-color; tibiæ reddish, but clothed with the same whitish pubescence; the latter part of the tibiæ is black, and on the inner side this color extends farther upward than externally; tarsi deep black. Wings with a decidedly grayish tinge, brownish-yellow at the base and in the costal and first basal cells. Length about 10^{mm} (including the length of the pile at both ends of the body, but excluding the antennæ).

Female.—I have a single somewhat damaged specimen, which evidently belongs here, although it is smaller, and the femora and tibiæ, except the tip, are yellowish-red. Length about 8^{mm}.

Hab.—Webber Lake, Sierra County, California, July 22–26. Three males and one female. None of my specimens show any reddish on the scutellum.

Triodites mus.

The habits of this insect in the larva state are precisely like those of the preceding.

Larva (Pl. XVI, Fig. 4).—So greatly resembling that of the *Systœchus* that it is well nigh impossible to separate the two with certainty. The head parts are somewhat broader, shorter, and less flattened, the maxillæ more blunt, the labrum paler, and the mandibles sharper and with a smoother outer edge. The thoracic joints bulge less beneath and the thoracic spiracle is more sunken and less conspicuous.

Pupa (Pl. XVI, Fig. 5).—Easily distinguished from that of *Systœchus* in the broader and more bulbous head; in the two sets of three stout spines at top being well separated; in the frontal pair being stouter, each with a conspicuous bristle externally; in having a single spine or tooth above these, and another much stouter, erect, recurved spine, bidentate at tip, below them or at base of tongue, which is here represented by a cordate lobe. There is a spine on the front anterior border of each wing;

the legs are all shorter; the prothoracic spiracles less conspicuous; the hairs on abdominal joints shorter; the transverse dorsal teeth smaller and in single row; the basal abdominal joint without spines, but with long stout hairs and the dorsal tubercles of abdominal joint 9 replaced by a single spine.

Imago (Pl. XVI, Figs. 6, 7).—The generic characters as indicated in our figures, and especially the larger head and eyes, more slender form, and short proboscis readily distinguish this from the *Systœchus*. The sexes are also readily separated by the more pronounced transverse rows of white or tawny hairs on the hind borders of the abdominal joints in the female. The genus in some degree connects the *Anthracini* with the more typical *Bombyliini*. In certain lights the tegument reveals a greenish tinge, and the pubescence of the thorax appears generally of a tawny color. The male sometimes has a white tomentum on the front, and in some specimens there is a stump of a vein extending into the discal cell. We quote the original description:

TRIODITES MUS, ♂ ♀.—Uniformly clothed with whitish-gray pile; face with white pile; wing hyaline. Length 8–9^{mm}.

Male.—Frontal triangle black, with short, erect, black pile; face with a dense covering of short snow-white pile; antennæ black; occiput black, with appressed white hairs along the orbits; thorax grayish-black, with a dense covering of delicate, downy, whitish-gray pile, which in an oblique light looks altogether white; the few bristles on the antescutellar callosities and on the scutellum are whitish, almost colorless; abdomen black, with the same covering of grayish-white pile, which is longer here on the sides. Halteres whitish; knob brownish. Legs black, densely clothed with white scales; spines on femora and tibiæ whitish-yellow. Wings, including the costal cell, of a pure hyaline; veins, except at the root, black; costal and first longitudinal brown.

Female.—Like the male, but the front is slightly brownish-pruinose, and has, besides the erect, black pile, some short, recumbent, yellowish hairs. The hind margin of the abdominal segments are beset with some short, appressed, whitish hairs, forming cross-bands.

Hab.—I have a single male, which I took near the Salt Lake, Utah, August 1. One of the females is from Sonoma County, California, July 6; the other from the Shasta district (H. Edwards, July, 1875).

As the larvæ from the Mississippi Valley, so far as ascertained, belong to *Systœchus*, and as the *Triodites* is not yet known to occur east of Utah, we conclude that the former genus is the one most affecting the locusts in the Mississippi Valley.[337]

[337] Since the above was written and in type we have met with an article, previously overlooked, "On the Economy, &c., of Bombylius," by T. Algernon Chapman, M. D., in the *Entomologist's Monthly Magazine* for February, 1878, vol. 14, p. 196. Mr. Chapman gives abundant proof of the parasitism of the European *B. major* on *Andrena labialis*. He records some observations on the oviposition of *Bombylius*, the small white egg being thrown with a short jerk against the earth near where the food of its future larva presumably occurred. This would also imply that, as in the case of the Blister-beetles, the newly-hatched larva must seek its food, and strengthens our suspicion that it will be found to be much more active than the mature larva. Mr. Chapman very fully describes the mature larva and the pupa, and his descriptions show that in all essential points the larva of *Bombylius* accords with those of *Triodites* and *Systœchus*. We quote his description of the head: "The head is set into this segment [the 1st thoracic] and is retractile. It is very small; its center is occupied by a prominent wedge-shaped portion, the point of the wedge being downwards and immediately in front of the mouth. Immediately behind this are two black, very sharp, setiform jaws(?); on each side is a papillary eminence (antenna?) of three joints set in a circle of softer tegument, and immediately below project downward on each side two large palpi (labrum?), looking like jaws, but having a vertical, not a lateral, mobility. On the anterior surface of each of these there is a palpus of some length, apparently unjointed, set in a circle." It will thus be seen that he homologizes the parts much as we have done, except that he refers the two lower palpigerous pieces, with a question, to the

HAIR-WORMS AND RED-MITES REMARKABLY ABUNDANT UPON LOCUSTS IN CALIFORNIA.—Since reading my brother's articles last week (being absent myself last fall and winter), I am reminded of having seen about one-fourth of an acre of my meadow, thickly filled last fall with eggs in the pools and along the creek, as the snow went off, covered with millions and millions of what I now think may have been *Gordius* (white hair-snakes), about one inch long; also, another quarter of an acre fairly covered with little red-mites, which I will hereafter observe more closely.—[W. C. Lemmon, Sierra Valley, California, June 13, 1880.

CHALCID FLIES.—The only instance in which these flies have been observed to attack locusts is described in the following quotation from an article by Professor Lemmon in the Sacramento, Cal., *Weekly Record-Union*, November 29, 1879:

Another enemy greatly feared by the locusts is a minute, ant-resembling fly of the *Chalcis* group. It has monstrous enlargements of the hind legs just above the foot; yellow, lenticular, and prominent, they resemble the pollen baskets of a bee. This little swift-flying insect pursues the locust, and hovering over its head, attempts, by a quick thrust of its ovipositor, to place an egg upon its head or in the sutures of its neck, meanwhile dexterously dodging the blows aimed at it by the frantic locust. My close-observing brother, B. F. Lemmon, and myself watched it particularly when attacking female locusts ovipositing. Frequently the locust would duck and dodge about, strike with her hind feet, or hasten away to another spot, but becoming wearied, or perhaps more concerned in her work of providing for the continuation of her own species, she often remained motionless, martyr-like enduring attacks from all quarters. How this pest is fostered or when or how born the writer cannot tell; circumstances prevented the examination necessary at the right times.

The egg-parasite, *Caloptenobia ovivora*, of our First Report, proves to be *Sparasion famelicus* of Say,[338] a member of the Hymenopterous family *Proctotrupidæ*. The insect, however, belongs not to *Sparasion*, but to the closely allied genus *Scelio*, Latreille, and should be known as *Scelio famelicus* (Say). In our types we note that the mandibles and tegulæ are honey yellow. From Say's description these specimens differ only in having two, instead of six, of the basal joints of the antennæ pale, and in the mandibles being hardly "piceous."

DIGGER WASPS.—Accompanying a letter dated July 11, 1880, Mr. W. C. Lemmon sends specimens of *Larra tarsata* Say, a digger wasp

labrum (misprint for labium?), which they cannot possibly be; they are evidently the maxillæ. The upper lateral pieces bearing the antennæ are much less conspicuous, judging from the description, in *Bombylius* than in *Systœchus*. The pupa of *Bombylius*, from Dr. Chapman's excellent description, differs in the greater prominence and somewhat different arrangement of the cephalic spines, the anterior pair being stouter and more bent forward than in either of the genera we have treated of. Dr. Chapman speaks of these spines forcibly reminding him of the tusks of a walrus, and of their admirable adaptation to tearing down the clay stopping and digging through, as "with mattock and shovel," the long burrows of the bee upon which it preys. The dorsal and anal spines are also much more prominent than in our locust-egg parasites. The pupa of *Systœchus* and *Triodites*, not being under the necessity of such strenuous digging, have a less formidable armature; otherwise, there is strict structural correspondence with *Bombylius*.

[338] Boston Journal of Natural History, vol. 1, p. 276 (1836).

differing from that figured on p. 317 of our First Report in nothing but its slightly larger size. Of it he says:

We have (to us) a new locust exterminator, that in certain localities kills and buries large numbers. It appears to kill the locust by stinging him, thrusting into his body an egg which hatches in a few days into a little grub.

The same species is referred to by Prof. J. G. Lemmon in a letter dated Sierra Valley, California, July 18, 1880:

I hear much and see a few specimens of a species of *Pompilus*, which has been seen very active in catching, stinging, and dragging locusts into holes dug in the sand, and covering them hastily—then seize new victims in rapid succession.

CHAPTER XIV.

COURSES THAT MAY BE ADOPTED BY THE GENERAL GOVERNMENT TO LESSEN LOCUST INJURY.

The First Report of the Commission was the result of labors directed against the unfledged locusts as they hatch out in the more fertile portions of the Mississippi Valley and ravage the crops in what we have designated as the Temporary region. An equally important—nay, more important—problem left for solution was how best to destroy the insect in its native or permanent breeding-grounds, or how to prevent the destructive migrations of the winged insects from the Permanent region to the more thickly settled and fertile country. As intimated two years ago, the solution of this problem, if at all possible, would require several years of investigation. The writer has been deeply impressed with the importance of concentrating all efforts of the Commission to the obtaining of facts that bear directly on this important question. Of the different means that have been suggested we mentioned six more particularly, in our first report, and discussed some of them hopefully, as follows:

"1. The protection and encouragement to the increase of the native locust-feeding birds. 2. The introduction of foreign locust-feeding birds. 3. Inducements offered to the Indians to collect and destroy the eggs and young. 4. Destroying the eggs or young by making the greatest possible use by artificial means of the natural water-supply. 5. Burning the young in spring. 6. Diverting winged swarms by means of smoke.

"While every one of these suggestions might be carried out in exceptional cases to advantage, and while it is the intention of the Commission to endeavor to acclimate certain foreign locust-feeding birds,[339] yet the

[339] In the summer of 1878, with the coöperation of Mr. Montague R. Leverson, of Leverson Ranch, Douglas County, Colorado, we imported two dozen English rooks with a view of sending them out to be acclimated in Colorado and in the belief that this bird would prove one of the most useful to acclimate there. The birds were badly handled on the voyage and detained in the custom-house in New York, and we ar-

last two methods are the only ones which at present we have any faith in as capable of sufficiently general application or as resulting in general good. The first question to consider is whether the insects can be prevented from migrating from their permanent breeding-grounds, and—considering excessive multiplication the immediate cause of migration—this virtually means whether they can be prevented from becoming excessively multiplied in such breeding-grounds. At first view it would seem hopeless to attempt anything of the sort, and a year ago we had such a vague and imperfect knowledge of these permanent breeding-grounds that any proposition looking to wholesale destruction of the insects in them would have appeared Utopian. But we have learned enough of the laws governing the movements of the species and of the country designated as the Permanent region to give us faith, not only in the possibility of thus keeping the species in check east of the Rocky Mountains, but in its feasibility.

"There is a popular notion that this pest breeds in and comes from sandy, desert countries. It is a popular error. The insect cannot live on sand, nor does it willingly oviposit in a loose, sandy soil. It does not thrive on cacti and sage-brush. It flourishes most on land clothed with grass, in which, when young, it can huddle and shelter. It can multiply prodigiously on those plains only that offer a tolerably rich vegetation—not rank and humid, as in much of the prairie of Illinois, Missouri, &c., but short and dry—such as is found over much of the prairies and plains of the Northwest. Now, the destruction of the eggs, which is so practicable and effectual in settled and cultivated sections, is out of the question in those vast unsettled prairies; but the destruction of the young locusts is possible. Those immense prairies are not only susceptible of easy burning, but it is difficult to prevent the fire from sweeping over them. Some system of preventing the extensive prairie-fires in autumn that are common in that country, and then subsequently firing the prairie in the spring, after the bulk of the young hatch, and before the new grass gets too rank, would be of untold value if it could be adopted. The more we study the question, and the more we learn of those breeding-grounds, the more feasible the plan grows in our minds. The Dominion Government has, fortunately, a well-organized mounted police force, which constantly patrols through the very regions where the insects breed north of our line. This force is intended to see that the peace is kept, to watch the Indians, to enforce the laws, and perform other police duties. It could be utilized, without impairing its efficiency as a police force, in the work we have indicated, or it might be augmented for that same work. We have conversed with the ministers of Agriculture and of the Interior, and with Governor

ranged with the present Commissioner of Agriculture to have them taken care of at the Department grounds before shipping them West. Those that had not died on the way arrived in such feeble condition, however, that they soon perished, with the exception of one which is probably yet living in the neighborhood of Washington

Morris, on the subject, and they see nothing impracticable in the plan. Indeed, it was suggested by Mr. Dawson in his first report on the subject of locust ravages in British America, and by Mr. Riley in his eighth Missouri report, for 1875 (p. 132). We have, on this side of the boundary line, a number of signal stations and military posts in the country where the insect breeds. We would have our own military force co-operate with the Dominion police force as a locust vigilance committee. Under the intelligent guidance and direction of some special commissioner or commission, we would have that whole country systematically studied every year by such a force with reference to the abundance or scarcity of the locusts. We would have such a vigilance force, by a proper system of fire-guards and surveillance, prevent the fall fires in sections where the insects or their eggs were known to abound, in order to burn them at the proper time the following spring.

"This would be a stupendous work, and perhaps too expensive ever to be carried out, did the insects breed over the whole of the region we have designated as the Permanent region; but, fortunately, the breeding-grounds are in limited areas in this region, comprising the richer valleys and plateaux and strips along water-courses. It is for the Commission to accurately map out in detail these areas, and to estimate with what force and at what expense to the two governments the work can be performed. We have no hope nor idea that the pest can ever by human means be exterminated from that vast region, but do believe that it may be so kept in check that it will not migrate. The constant expense will be limited to the employment of the necessary force, and only at intervals when danger threatens will it be necessary to go to the extra and exceptional expense of destroying the insects. Again, as may be gathered from Chapters VII and XV, there is a connection between locust-increase and seasons of drought, and we may take advantage of this knowledge by making especial effort whenever the character of the seasons indicates danger.

"The next question to consider is, whether the farmer can be protected from the invading swarms, in case the above-mentioned plans should fail and the insects had become numerous. We think that this is also, to a large extent, possible with the proper system and organization. We would, in such an event, have this same corps of observers watch carefully the development and movements of the locusts and forewarn the farmers of the country of threatened danger. There is no reason why the agricultural community should not be informed the previous autumn as to the extent to which eggs have been laid, and as to the particular locations where laid; or why, the following spring, they should not be informed of the prospects, so as to plant accordingly, as recommended in Chapter XIII, *i. e.*, put in a larger area of small grain that will be harvested before the winged swarms appear, and plant such crops as are best protected. Then, as the insects were commencing to migrate, their movements should be communicated to the people through the Signal Bureau. The information should be as minute, complete, and prompt as possible. These movements may be likened to those of a storm, and the people should receive in advance the danger signal, that they might guard against calamity. The "locust probabilities" are of far more importance than the weather probabilities to the people of the West, and the idea of having them telegraphed over the country does not appear half as chimerical to us now as that of having the weather foreshadowed did a few years ago.

"In this way the farmers could be fully forewarned of approaching danger. We would, in this connection, have the western farmers adopt some general plan of defense against possible invasion. The straw that is now allowed to rot in unsightly masses as it comes from the thrasher, and which encumbers the ground unless burned, should be utilized. Let it be stacked in small pyramids at every field-corner, and there let it remain until the locusts are descending upon the country. Then let the farmers in a township or a county or in larger areas simultaneously fire these pyramids, using whatever else is at hand to slacken combustion and increase the smoke, and the combined fumigation would partially or entirely drive the insects away, according as the swarm was extended or not.

"In short, we believe, first, that by proper co-operation on the part of the two governments interested, the excessive multiplication of this destructive insect may be measurably prevented in its natural breeding-grounds, and that the few thousand dollars that would be necessary to put into operation intelligent co-perative plans are most trifling in view of the vast interests at stake. With an efficient and properly organized Department of Agriculture, liberally supported by Congress; with the aid of the War Department, the Signal Bureau, the Post-Office Department, and the Indian Bureau, the plan could be perfected and carried out at a minimum expense. There is no reason why every signal officer, every postmaster, every mail-carrier, every Indian agent, and every other government employé in the Permanent region should not be ordered to do service of this kind, and made, under the direction of an intelligent head, a medium through which to gather the desired information. We believe, secondly, that where the multiplication of the insect cannot be prevented in its natural breeding-grounds, our farmers in the more thickly-settled sections may, by the use of smoke, measurably turn the course of the invading swarms and protect their crops—obliging the insects to resort to uncultivated areas.

"Did the injury continue for another three or four years as it has for the past four; were the western farmers to suffer a few more annual losses of $40,000,000, such schemes as we have suggested would soon be carried out. The danger is that during periods of immunity, indifference and forgetfulness intervene until another sweeping disaster takes us by surprise. The other danger is that the majority of our Congressmen and Senators at Washington, representing constituencies never troubled with this grievous pest, have not, and cannot well have, any just conception of the magnitude of its devastations, and are consequently without due appreciation of the importance of the subject."

It is with a view of ascertaining the feasibility and practicability of the last three methods there referred to that we have endeavored to get more accurate knowledge of the limits and character of the Permanent breeding-grounds, whence the destructive swarms emanate, so as to place facts rather than surmises before our readers. In this attempt we have been made fully aware of the difficulties which the problem presents, and to modify somewhat the views previously expressed; but while the difficulties in some portions of the country are practically insurmountable, yet, for a large portion of the country affected, especially the vast plains and prairie regions between the mountains on the one hand and the Mississippi and North Saskatchewan on the other, it is within man's power largely to avoid in the future the immense losses that have hitherto been sustained. The destruction of the eggs by plowing or harrowing may be advantageously carried on and stimulated by bounties in exceptional cases, especially in the Sub-permanent region, but does not admit of any general carrying out on a large scale; so that we need add nothing further here beyond what has been said on this score in Chapter II (pp. 25, 26, 30), to which the present chapter is largely supplementary.

In what way, then, can the national government help to bring about the desired result? There are, it seems to us, seven ways in which government action is possible, viz: 1. By encouraging settlement; 2. By encouraging the building of railroads; 3. By broad schemes of irrigation; 4. By guarding the present timber and encouraging the planting of forests; 5. By judicious burning; 6. By a permanent system of observations and warnings; 7. By co-operation with the Dominion Government in these various measures.

SURFACE CHARACTERISTICS OF THE PERMANENT REGION AND THE PROPORTION OF LAND IN IT UPON WHICH THE VEGETATION IS SUSCEPTIBLE OF BEING BURNED.

A consideration of the surface characteristics of this Western country, including soil and vegetation, will greatly help to intelligent discussion of either of the above propositions, and particularly of the fourth. To this end we have had prepared, in six separate parts, the large map (I) which indicates, as fully as present knowledge permits, the character of the vegetation in the region in question, and more particularly that which is sufficiently dense and luxuriant to permit of being burned over. The dividing lines between the probable breeding-grounds and the land that is grass-covered, as well as those between this last, the semi-desert and the desert land must needs, in many cases, be more or less arbitrary as they shade into each other, and the map cannot, even in those parts where every mile is familiar to us, be more than approximately correct.

Yet it serves admirably to show the small area over which the locusts really breed in great numbers, compared to the whole extent of the region. We have, also, in studying this question, so as to elaborate the general description given on p. 71, found it convenient to separately consider, 1, the Plains Area east of the Mountains; 2, the Mountain Area; 3, the Plateau Area; 4, the Great Basin Area: and in doing so we have not only been guided by the experience of each of the commissioners, but have drawn from other available sources.

The investigations of the past two years have led to a considerable enlargement of the Permanent region, as we intimated in our first mapping of the region[340] that they might do when Idaho and Montana had been more fully studied. Our former estimate was that the region covered, approximately, 300,000 square miles, whereas, owing to the inclusion of the western border of Dakota and larger portions of Western Wyoming, Utah, and Southern Colorado, as indicated in the map accompanying this report, it will probably embrace more nearly 400,000 square miles.

We are particularly under obligations to Mr. Henry Gannett, E. M., who, as topographer for many years of Hayden's Geological and Geographical Survey of the Territories, has obtained very thorough personal acquaintance with the country under consideration. He has kindly aided us in every way in his power, and furnished most of the data relative to the mountain and plateau areas.

The Plains Area East of the Mountains.

The vegetation of this area may be classified as follows:

1. The grasses which, though of many distinct species, are, on the uplands characterized by growing in bunches and never forming a sod, whence the general name *bunch grass*, by which they are popularly known. The commonest of these grasses on the plains is the Buffalo grass (*Buchloe dactyloides*). In the most southern of the Territories several species, known commonly as Grama grass, abound; the commonest of these is *Festuca macrostachya;*

2. *Artemisia*, or sage-brush, is perhaps the best known of the products of the West, as it is certainly the most abundant. Of these the species which is the widest spread is *A. tridentata;*

3. The cacti, of which the prickly pear, *Opuntia*, is the most abundant; and

4. Greasewood, a name applied to a variety of desert shrubs, the true greasewood being *Sarcobatus* (?) *vermicularis.*

As may be noticed, these staples of the uncultivated soil are by no means varied, nor are they, with the exception of the grasses, of much economic value.

Let us now take a glance at the general geographic distribution of these staples.

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[340] First Report, p. 131.

The Great Plains, extending from the North Saskatchewan to the Mexican boundary, are mainly covered with the various bunch grasses. The luxuriance of the growth differs greatly in different localities, being modified by the general and local climate. In general terms the growth is more luxuriant in the north than in the south, and in the eastern portion than towards the west, although at and near the base of the Rocky Mountains and Black Hills the growth is again quite luxuriant, owing to the increased moisture of climate produced by the proximity to the mountains.

Here and there, in the more arid localities, which will be defined in some detail farther on, are areas wholly or in part given over to sage, cactus, or the Spanish bayonet (*Yucca angustifolia*).

Passing beyond the wall of the Rocky Mountains one enters still more arid regions where the grasses give way still more to Artemisia, and other members of the arid flora, which, in the great interior basin, between the Rocky Mountains and the Sierra Nevada and Cascade Range, form the primary growths of such of the country as is not utterly sterile.

Everywhere, however, on the mountain slopes the country is better watered than in the valleys, and where not covered by timber the grasses are more luxuriant than below.

The bottom lands of rivers, too, are, for a greater or less breadth, in a measure artificially irrigated, and the grasses are more close, approaching a turf, and often grow much higher. Such areas, however, are comparatively insignificant in extent. Many of these bottom lands, too, are covered with willow and cottonwood trees, to the partial or total exclusion of grasses. In the region of the plains and the great interior valleys, these strips of timber along the streams are practically the only timber.

Greasewood takes the place of Artemisia in many localities, seeming to prefer a heavy alkaline clay soil, while sage grows indifferently on a clayey or sandy soil, but on the latter it grows most freely and luxuriantly.

"Burnable" land (and by this term we mean land susceptible of being burned over cheaply and economically) is *practically identical with grazing land.* Bunch and grama grasses burn with the greatest freedom, the only difficulty being to control the fire and prevent it from doing damage. Most sage-land has more or less grass among the sage. Indeed, grass-land grades into sage barrens by insensible degrees and as the latter are burnable only with difficulty, the line of division between burnable and non-burnable land must in this case be mainly an arbitrary one, drawn according to the judgment of the observer.

A heavy luxuriant growth of sage will burn freely, as travelers in the West have had frequent opportunity of observing, but a low, stunted growth of this plant, which covers great areas of thin, poor soil, can be coaxed into burning only by constant attention, and it would therefore be very expensive to burn over great areas.

Greasewood will not burn freely, owing to its being a sparse growth; and as the Rocky Mountain locust does not frequent the cold, clayey soils which produce this plant, such regions are of no importance in this connection.

Timbered lands are not considered in this connection, as these insects do not breed in a timbered country.

The great area of the plains, stretching eastward in a long inclined plain from the base of the Rocky Mountains, is therefore mainly covered with grasses, which are mostly low, seldom forming a sward but growing in bunches or tufts.

In the British Possessions the area of the plains, or level, untimbered regions, is divided by Mr. Dawson, the Canadian geologist, into three "prairie levels" or steppes—steppes with very slight rise and long trend. The first of these includes the region of the Lakes Winnipeg, Manitoba, Winnepegosis, &c. It is heavily timbered, except near its western border. Its mean elevation is not far from 1,000 feet. Rising from this, westward, in bluffs two or three hundred feet in height, is the eastern escarpment of the second prairie level, of which the Coteau des Prairies, in Minnesota, is the southern extension. This is tolerably fertile, well grassed, with timber only in the bottom lands of the streams and on knolls and the faces of bluffs. Its elevation is from 1,200 to 1,500 feet above the sea, gradually rising westward. The third prairie level is what corresponds, in the United States, to the plains proper and the Coteau du Missouri. It rises from the last in ill-defined bluffs, of small height. From the edge it gradually increases in height westward until, at the base of the Rocky Mountains, it is 4,000 to 5,000 feet above the sea. On this level the grass is shorter, less luxuriant, and in some places, especially near the boundary, shows the effect of a climate decidedly arid by the presence of sage and cacti. Timber is distributed very much as on the second level, but is decidedly more scarce.

As we proceed northward over the two upper prairie levels in the country between the forks of the Saskatchewan, the climate becomes moister with the increasing cold, and the vegetation approaches more and more the nature of that on the true prairies of the Mississippi Valley; and north of an undulating line which follows approximately the course of the 52d parallel, patches and belts of timber begin to diversify the surface, alternating with the rich grasses. The change from prairie to forest goes on gradually over a belt 50 to 75 miles in breadth, and the North Saskatchewan is reached before the forest has asserted sole proprietorship. South of Belly River, more arid conditions manifest themselves. At the base of the Rocky Mountains, and indeed for a hundred miles eastward, and about the Judith and Big Horn Ranges, the influence of the mountains in inducing a moister climate is plain; the grass is tolerably luxuriant everywhere, and especially so at the base of these ranges, gradually shading off in luxuriance with the distance from them.

Near the meridian of 117°, and just north of Milk River, begins an area of sparse vegetation, which extends southeast across Milk, Missouri, Musselshell, and Yellowstone Rivers, and terminates in the western part of Dakota, north of the Black Hills. Its boundaries are very ill-defined, as it grades off on all sides into the ordinary grass land of the prairies. Where it crosses the boundary line it is not far from 75 miles in width. Its western limit crosses the Missouri not many miles below Fort Benton, runs around the Judith Mountains at a distance from them of not far from 10 miles, crosses the Musselshell in longitude 110°, and thence bears generally southeast, keeping at a distance of a few miles from the eastern base of the Yellowstone and Big Horn Ranges. Its greatest southerly extension is reached between the Big Horn Range and the Black Hills. Thence passing northeast by the Black Hills, its line, now its eastern boundary, runs north in the longitude of the eastern base of the Black Hills, embracing the Bad Lands of the Little Missouri, the Powder, and Lower Yellowstone Rivers. Crossing the latter stream, it runs generally northwest to the point first mentioned. North of the Yellowstone, this region is characterized mainly by the sparsity of all vegetable growth, the grass is scanty and short, and there is much cactus. South of the Yellowstone, on the lower waters of that stream, the Powder, and Little Missouri, are Bad Lands, where the surface is much broken by minor typographical features, caused by the rapid erosion of soft strata. There is but little vegetation, with great areas of bare, powdery, clay soil. Higher up, on and between these streams, the prevalent growth is sage.

What has been said regarding the vegetation of the second and third prairie levels is equally true concerning the coteaus of the Minnesota and Dakota. While forming parts of these prairie levels, they are in fact plateaus of no great elevation, being 1,500 to 2,000 feet high, and well marked by bluffs everywhere, except on the north. They have a rough, undulating surface, gravelly or rocky soil, containing many "sinks," but are not well watered. The luxuriance of the grasses varies very much with the locality, but is nowhere too sparse to burn with the utmost freedom.

Within the United States the general character of the grasses may be thus briefly expressed:

In Central Nebraska and Kansas, Western Indian Territory, and Central Texas, which is the belt lying just west of the western border of timber, the grasses are high and luxuriant, as should be expected, on account of the comparative moisture of the climate. Westward, as the aridity becomes greater, the grasses become shorter and sparser, and this progression continues until we near the Rocky Mountains, where their influence in rendering the climate moister is shown in the increased luxuriance of the grasses.

In all this wide expanse of plains south of the Black Hills the area which cannot be easily burned over is very small. The Bad Lands between the Niobrara and White Rivers, and the sand hills on the latter stream, form the only exceptions worthy of note, and indeed it is doubtful whether they should be excepted. The Llano Estacado is mainly covered with fine grass, while Jornada del Muerto, of New Mexico, derives its name, not from having the characteristics of a desert, but solely from the dearth of water.

The Black Hills are an isolated group of mountains, some 75 miles in length by 50 in breadth, rising to a height of 6,000 to 7,000 feet above the sea, and about 3,000 feet above the surrounding level. They are heavily timbered throughout, while about their base the grasses are everywhere luxuriant.

The Mountain Area.

With regard to the Rocky Mountain region of British America, it may be briefly dismissed, as little is known about it in detail. It is essentially a heavily timbered region. It is made up of a number of ranges trending parallel to one another and separated by narrow valleys. It is a region of heavy rainfall and slight evaporation; and not only the mountains but the valleys also are covered with forests.

Within the Western United States the presence or absence, and even the comparative density and the prevalent species, of the forests may be predicted with a reasonable degree of certainty and detail from the latitude and elevation, *i. e.*, from the same elements as there determine the degree of moisture of the climate. Excepting in the northern part of Idaho, Washington, Montana, and Wyoming, the general level of the country is not sufficiently elevated to cover it with forests, and consequently they are, except in the localities summarized above, confined to mountain ranges and high plateaus. In southern latitudes, even, many ranges of considerable altitude are not sufficiently high to reach the lower level of timber, as in the case of the majority of the ranges in Nevada, Arizona, and Southern California.

Occupying the next zone below the forests, we find the grasses. They are found on the foothills of the mountains and the margins of the valleys, and, in cases where the elevation and latitude are sufficiently high to insure moisture enough, covering the valleys. In other cases a zone of sage succeeds, the two growths grading into one another, and this in turn in the most arid localities, as in the deserts of Utah, Nevada, and Southern California, is succeeded by scanty growth of cacti, yucca, and by naked soil without vegetation. This succession, being a direct result of the conditions of aridity, can be premised regarding a certain region with considerable certainty.

The more northern section of the Rocky Mountains in the United States, including the mountain region of Montana, Idaho, and Wyoming, is characterized, in the northern part, by a tolerably great precipitation, allowing a growth of forests almost as great as in the British Possessions. The whole of Kootenai County, Idaho, is covered by forests, extending southward, over the Bitterroot, the Cœur d'Alène, and Salmon Ranges, as far south as the Snake River Plains.

The Missouri, which in Northern Montana forms the front rank of the Rockies, is covered with timber. The valley of Flathead Lake, lying at its western base, contains but small patches of open grassy country. The valleys of the Deer Lodge, Bitterroot, and Hell Gate Rivers are all open and grassy. So with the valley of the Jefferson and its branches, the Madison and the Gallatin. These valleys, while not sufficiently moist for the growth of timber, are not too arid for grasses.

The Judith Mountains, the Little Rocky Mountains, and other minor groups scattered about in the more northern plains, are well timbered, the former particularly so.

The Yellowstone River heads in the Yellowstone National Park, whence it flows in a generally northern course, nearly to the latitude 46°, where it turns at right angles to the east, and after a long course eastward and northeastward it joins the Missouri at Fort Buford. Its upper course is walled in on the east by the Yellowstone Range, which separates its drainage. A heavy growth of coniferæ covers the country about the Upper Yellowstone, and that surrounding Yellowstone Lake. On the river, below the foot of the lake, extending from the Mud Geysers nearly to the Falls, a distance of about 10 miles, and westward from the river about the same distance, is an open grassy park country of rolling hills, which was in former times the bed of an arm of the lake. A similar area is found on Pelican Creek, a tributary to Yellowstone Lake, a few miles above its mouth. Aside from these open and burnable areas, very little open country is to be found on this river or its tributaries until we pass the Washburn group of mountains. This group of mountains is in the main part well timbered; the lower northeastern slopes, however, down towards the mouth of Tower Creek, contain little timber, and thenceforward the valley and plateaus of this drainage system are bare of trees and well grassed. Hayden's Meadows, opposite the mouth of the east fork of the Yellowstone, and the plateau above the third cañon of the river on its left-hand side, are nearly bare of trees.

Glancing now at the east fork of this stream, we find its immediate valley as far up as the mouth of Soda Butte Creek, the valley of the latter stream, and of Slough Creek, are all open and covered with grass and sage. The mountains about this stream, too, contain little timber on their lower slopes. The high, broad ridge which separates the east fork from the main river, of which Amethyst Mountain is the culminating point, contains very little timber, but is covered with grasses. The head of the east fork, however, is in the densely timbered region.

The next tributary of the Yellowstone of importance is Gardiner's River. This stream has an open valley extending from its mouth to the forks, a distance of about 6 miles, with an average width of 2 miles. Farther up the stream, on the middle and west forks, is an open valley, 3 miles long by 3 in width. These valleys are covered with the usual mixture of Artemisia and grass.

Below the mouth of Gardiner's River the Yellowstone flows for 8 miles in a sage valley containing enough grass to make it fair grazing land, while grass extends up the slopes of the limiting ranges for nearly 1,000 feet, when it is replaced by timber.

Below this valley follows the second cañon, where the wooded mountain slopes come close down to the river's margin. This is succeeded by a long, broad, grassy valley, extending down to the lower cañon, a distance of 29 miles. This open valley has an average width of 4 to 5 miles. On the east it extends to the base of the Yellowstone Range, and on the west to that of the Gallatin Range, which here separates the Yellowstone from the Gallatin River. This valley contains at present a small ranch population.

Below this fine valley is the short lower cañon, where the river has carved a passage through a bare ridge connecting the limiting ranges. Below this an open, grassy country extends down the river to the bend to the eastward, and up the valley of Shield's River, a large, left hand branch, nearly to its head.

All the open country on the drainage of the Yellowstone is susceptible of being easily burned over. The soil is almost everywhere more or less gravelly or sandy; nowhere a heavy clay.

The Madison River, like the Yellowstone, heads in the high, heavily-timbered country of the Yellowstone Park, opposite the heads of the Snake. Its drainage area is timbered as far north as the second cañon, below the mouths of its east and south forks. The valleys of these streams, too, are heavily timbered.

From the foot of the second cañon, northward to the lower cañon the Madison Valley consists almost entirely of a succession of terraces of gravelly soil, covered with grass and sage. This valley has a length of 50 miles and an average width of 6 or 7 miles. On either hand is a high range of mountains, timbered almost to their bases. All this valley can easily be burned over.

The lower cañon of the Madison is cut in sparsely timbered hills, below which the river enters the broad expanse known as the Gallatin Valley. This fine large basin, second to none in Montana for agricultural and grazing purposes, save perhaps that of the Bitterroot, has a total length of 32 miles, with a width of 25. It extends southward from the forks of the Missouri, up the Madison and Gallatin Rivers to the north ends of the Gallatin and Madison Ranges, and from the East Gallatin westward beyond the Madison River. The streams which traverse it are the Madison, the Gallatin, and several large branches of the latter, among which are Middle Creek, Bozeman Creek, and the East Gallatin River. These streams have broad bottom-lands, covered with grasses and scattered groves of cottonwoods and willows.

The valley is covered with a fine growth of bunch-grass and some sage. Probably the entire area of the valley can easily be burned over.

The Gallatin and its branches above this valley are in close cañon in a heavily-timbered mountain country.

The Gallatin Valley is partially settled, mainly by an agricultural population. It contains three small towns, Bozeman, Gallatin City, at the Forks of the Missouri, and Hamilton. A large part of the country along the streams is already taken up by ranches. The population of the valley in 1870 is given in the census report as 1,578 souls; and this is probably but slightly changed at present.

Proceeding now to the Jefferson River, the third fork of the Missouri, we find in its drainage area much less timber and more open, grassy country, than in those of the other two forks. The range separating its drainage from that of the Madison is timbered near its crest, but its foot-hills and lower slopes are devoid of trees and well grassed. The valleys of Red Rock Creek and Beaverhead River, are broad, open, and grassy. So with the valley of the Bighole, or Wisdom River, and the hills which form the divide between the latter and the Beaverhead. The mountains which stand at the head of the Beaverhead River, separating this drainage from the Snake River Plains, are well timbered except on the lower foothills.

All the open country on the Jefferson can easily be burned over.

Turning now to the Missouri, we find it flowing with a somewhat sluggish current through a tolerably broad bottom-land of fine grass and groves ot cottonwoods. The country on the west, as far as the base of the Missouri Range, is open and grassy, presenting many of the aspects of the plains. This character extends as far north as Helena.

On the east side of the river, the hills and lower mountains are grass-covered, while the higher groups of mountains are clothed with timber. Farther to the eastward, between the Missouri and Yellowstone Rivers, are the Judith, Snow, and Crazy Woman Ranges, all heavily timbered, while the surrounding country is well grassed.

The large valley at the eastern base of the Wind River Range, through which flow Wind River and the Popo-agies, is, near the mountains, well grassed; but as we proceed eastward, away from the mountains, the quality and abundance of its vegetation deteriorate, and on its lower parts it bears all the aspects of a desert.

The Wind River Mountains rise west of this valley and separate it from the Green River Basin. The peaks of this range rise to heights of nearly 14,000 feet. These mountains are heavily timbered from their base to the timber line, which in this range is at an elevation of about 10,000 feet.

The basin of the Bighorn, in most respects, resembles the valley of Wind River. On all sides, near the base of the mountains, is high, luxuriant grass, gradually shading off toward the interior of the basin into sage land and even to desert, in some localities. In the small tributary valleys of several of the western branches of the Bighorn the grass is exceptionally fine, and stock men are beginning to avail themselves of the excellent grazing. On the eastern and northern bases of the Bighorn Range, also, the grass is luxuriant, grading off northward and eastward into poor sage land.

The Bighorn Range, which surrounds the basin of the Bighorn on three sides, is described as being heavily timbered, while the country about its base is exceptionally fine for pasturage purposes, the grasses being very high and luxuriant.

Next we turn to that great area marked on our maps as the "Great American Desert," the Green River Basin. This district, occupying about 11,000 square miles, is limited sharply on the south by the Uinta Mountains. The southern part of the western boundary is ill-defined, being simply a broad, meridional swell in the surface, separating the basin from the valley of the Bear River, a large tributary to Great Salt Lake. Following this divide northward, however, it is seen to develop into high ridges, which, still farther north, have weathered into mountains, the Wyoming Range. The basin extends northward almost to a point, abutting against the Gros Ventre and Wind River Ranges, the latter of which forms a well defined eastern boundary as far as its end near South Pass. Beyond this the eastern boundary is as poorly defined as the opposite western boundary, the land rising by almost imperceptible grades from the basin to the plateaus of the continental watershed, above mentioned.

The northern part of this great area is slightly broken by spurs from the mountains and by fragments of mesas, which have been spared by the erosive agencies. The central and by far the larger part of the basin is unbroken, save by long, gentle undulations, like those of the plains and by the bluffs, which limit the valleys of the few streams which venture into this arid expanse. In its southern portion, on the other hand, the conditions which prevail in the plateau province proper begin to assert themselves. River benches and bluffs develop into cliffs, and valleys change to cañons.

A corresponding gradation in the character of the vegetation is also plainly traceable. While the southern and lower parts of the basin are as arid as almost any part of the North American Continent, the northern and higher parts are well grassed and contain comparatively little sage and no greasewood. The greater part of the basin, however, is of too desert a character to be burned over economically. Those parts where the reverse is the case may be summed up as follows:

The country between the Big Sandy River and the Wind River Mountains; indeed, all that near the southwestern base of this range, the southern part of the basin, extending as far south as Lead Creek, with the western rim as far as Fontenelle Creek, are sufficiently well grassed to burn with tolerable freedom.

The soil of the basin varies extremely in different parts. Near the mountains it is, in all cases, naturally gravelly, coarse or fine according to the distance from their base. At the foot of the Wind River Range, about the debouchure of the several branches of New Fork of the Green, glaciers have in former time brought down immense quantities of boulders, gravel and the like, which now cover great areas. Farther south, along the courses of the Sandys the soil is of the nature implied by these names, and, farther yet toward the southeast, near the South Pass, and extending thence far to the eastward along the south base of the Sweetwater Mountains is a long range of sand dunes, built up from the accumulations of the prevailing westerly winds.

The broad stretch of country included between the Big Sandy and Green River is mainly sandy, grading, in its southern part into an adhesive, alkaline clay. The soil of the southern part of the basin, *i. e.* that lying south of the latitude of the mouth of the Big Sandy is of the latter character, produced mainly by the disintegration of the Bridger beds. Along Bitter Creek, almost the sole vegetation is greasewood.

West of the Green, in this part of the basin, alkali does not form so large a component of the soils, and while sage is the predominant growth, still grass is found in some localities in sufficient abundance to afford fair pasturage. Passing northward on this side of the river we find the same gradation from a clay to a sandy soil.

The river bottoms of many of the streams contain fine meadow land, which can easily be burned over. Green River, from its head down to Green River City, has a belt of bottom land from one to two miles in width, all well grassed, and containing occasional groups of cottonwoods and willows. Bitter Creek has no bottom land, but flows mainly in an arroyo, cut in the clay soil. The Big Sandy has but little bottom land. From its mouth to that of the Little Sandy it flows in a low cañon, whose walls closely confine the stream. Above this point the bottom lands are narrow, being on an average probably not more than one-fourth of a mile in width.

The various branches of the New Fork of the Green have but narrow strips of bottom land, but they flow through a comparatively well-grassed country.

Nearly all the branches of the Green from the west have broad meadow lands along their courses, in many cases rivalling in width those of the main stream itself. Of these Horse, Marsh, Bitterroot, Piney, and Labarge Creeks have particularly fine bottom lands. The Fontenelle bottoms are narrower, probably averaging not more than a half mile in width, and limited by high bluffs. Slate Creek is an insignificant stream with no flood plain.

The bottom lands of Black's Fork are particularly broad and fine, being fully three miles in average breadth. On its main branch, Ham's Fork, they are nearly as broad, and the same may be said of Henry's Fork, which enters the Green just above its cañon in the Uinta Mountains.

These bottom lands are everywhere well grassed, and in the spring when the grass is dry can easily be burned over.

The rolling plateaus which separate the southern part of the Green River Basin from Bear River are, in this neighborhood, desert-like in character, Artemisia being the principal production. As we recede northward from the railroad toward the upper waters of Ham's Fork, the face of the country improves, and grass predominates. This continues northward nearly to the head of Ham's Fork, where timber usurps the soil.

Turning now to the headwaters of the Snake River, the southern fork of the Columbia, we find ourselves in a different region. It is in large part mountainous, and with the exception of a few open valleys, most of which are small, it is very heavily timbered. Indeed, this region about the heads of the Snake, the Yellowstone, and Madison Rivers, embraced almost entirely in the Yellowstone Park, is the most densely timbered region in the West, with the exception of Washington Territory and the western part of Oregon.

The Snake heads in a country of high mountains north of the Green River Basin, including the southern part of the Yellowstone Park. Its most northern branch, Lewis's Fork, takes its rise in Shoshone Lake, whence it flows southward. In a few miles it is joined by a large stream from the east. Both these streams flow through a heavily timbered country, where the grassy openings are of a very limited extent.

Below their junction the river keeps its southerly course, through a narrow wooded valley, as far as Jackson's Hole, at the east base of the Teton Range. On either side, the mountains are heavily wooded up to the timber line, which in this region is at about 10,000 feet above the sea.

Jackson's Hole is a large open valley 35 miles long by 10 miles in width, its length being in a north and south direction. Near its head, on the west side of the river, its surface is made up of low irregular hills of moraine deposits, which are very sparsely timbered, and otherwise covered with sage and grass, the former being the dominant growth. On the east side of the river the open valley is several miles in breadth, and extends far up two large branches known respectively as Buffalo Fork and Gros Ventre Creek, which here enter the Snake from the east. In this part, the surface of the valley is but slightly broken and is well grassed, with a due mixture of sage.

Farther down the valley on the west side of the river, that is, below the foot of Jackson's Lake, the surface is largely made up of bench land, producing a similar mixture of vegetation, while the river which here flows near the eastern side of the valley has a bottom land fully two miles in width, which supports a dense growth of large willows and cottonwoods. This broad timbered bottom land accompanies the river to the foot of the valley, while the river itself gradually moves diagonally across the valley to its western side, leaving a broad grassy area on the east, below the Gros Ventre Buttes.

Nearly all of this valley is burnable, the exception being the broad, timbered bottom land along the Snake. The soil throughout is gravelly, being coarsest in the northern part on and near the morainal deposits mentioned above.

The principal parts of the courses of the branches of the river which enter it in this valley are in heavily-timbered, mountainous country. The Teton Range is heavily timbered.

Below Jackson's Hole the Snake flows through a close cañon, passing through a great mass of mountains in seeking an exit to the Snake River Plains. In this part of its course it receives three large branches from the left. The upper of these, Hoback's River, heads in a partially open valley just north of the Green River Basin, in the angle between the Wyoming and Gros Ventre Ranges. The surface of this valley is considerably broken. It is well grassed, but on the minor ridges which diversify its surface are many groves of aspens and coniferæ. This valley can be burned over, but fires would require constant attention to prevent them from destroying the timber. Below this valley the stream flows in a cañon, by which it cuts its way across the Wyoming Range.

The entire course of John Day's River, the next branch of the Snake, is in a cañon valley between two high timbered ranges, known as the Wyoming and the Salt River Ranges. It is heavily timbered throughout with coniferæ.

Next we pass to Salt River, the third large branch of the Snake. Heading mainly in the Salt River Range, we find its main stream through its whole course in a broad valley, mainly of gravelly soil and covered with a sparse growth of sage and grass. It is probably burnable, though with some difficulty.

Continuing our examination of the country tributary to the Snake on the left-hand side, we find the region lying between the valleys of the Salt and Blackfoot Rivers to consist of a mass of hills, rising one above another toward the west to a crest, and thence falling somewhat abruptly to the Blackfoot. About its crest line these hills are well timbered with coniferæ and aspens, but the slopes and lower summits are covered with bunch-grass, varied by occasional small groves of aspens, a country easily burned over.

The region drained by the Blackfoot, the next left-hand branch of the Snake of note, is characterized by an almost total absence of timber, either in the valleys or on the hills. Most of the valley portion is overlaid by a floor of basalt, on which Artemisia grows luxuriantly. The hills are covered with bunch-grass. That portion of the drainage area of this stream which lies in and among the hills and low mountains can easily be burned over. The country about its lower course, which forms a part of the Great Snake River Plains, is not as combustible, as will be shown further on.

Next we turn to the Portneuf and its tributaries. Like the Bear and the Blackfoot, this stream has a very circuitous course through and around the lava fields which obstruct it. Starting with a southerly course it suddenly turns to the westward, declining the apparently easy route southward to the Bear, and cuts its way doggedly through the Portneuf Range. Its upper valley is well grassed, as are also the hills which lie to the eastward separating it from the valley of the Blackfoot. This upper valley, after being abandoned by the stream, continues on southward to the Bear, where it is known as Gentile Valley, and of which we have spoken above.

Passing through the Portneuf Range, the Portneuf enters, near its lower end, a broad, fine valley, occupied by Marsh Creek, the most important tributary of the river. This valley heads opposite that of the Malade, and extends, with a gradually decreasing width, 28 miles northward. Its greatest width is 12 miles. Bench land forms the greater part of the valley, and this produces mainly sage, with a small admixture of grass. Marsh Creek, the small stream which flows through this valley, has a marshy bottom land through most of its course, from one-fourth of a mile to a mile in breadth, which produces marsh grasses and willows. All the valley can be burned over, as well as the lower slopes of the Portneuf Range on the east and of the Bannack Range on the west. These ranges contain but little timber, and that near their crests.

West of the Bannack Range are the valleys of the upper waters of the Little Malade and of Bannack Creek, both open and grassy, with more or less sage, and both easily burnable.

At the foot of Marsh Creek Valley the Portneuf turns to the west for a few miles, cutting its way through a mass of high hills, then turns northwest, and, the mountains falling away on either hand, the river sweeps out into the Snake River Plains, in which it joins the Snake River.

The Snake River Plains are an enormous field of basalt extending westward from about longitude 112° nearly to the western boundary of Idaho, and from near latitude 42° north to the southern base of the Bitterroot and Salmon River Ranges. The surface is slightly undulating and is seamed with crevasses like a field of old ice. Most of the streams which enter this region soon disappear beneath its surface, perhaps to appear and disappear again. The soil is mainly a shifting sand, which, driven by the prevailing westerly winds, has collected in dunes on the eastern and northeastern border. This great area is mainly covered wlth sage, which grows luxuriantly, attaining arborescent proportions. In the interior and southern portions of this waste this mammoth growth of sage is the only product of the soil, but near the base of the mountains on the east and north grass gradually takes the place of sage, in a measure, and on the lower mountain slopes it monopolizes the soil to the practical exclusion of other growths.

The country along the northern margin of these plains, *i. e.*, that lying at the base of the Bitterroot and Salmon River Ranges, with the lower slopes of these mountains, can easily be burned over. The larger part of the area of these plains, however, falls in that debatable ground where it is very difficult to decide whether it is or is not burnable, economically. In some localities the Artemisia is so abundant and so luxuriant that there is no doubt about the case, but over most of the interior of this area the sage, though of enormous size, is not, probably, sufficiently abundant to sustain combustion without constant attendance.

The Snake River, on emerging from its long cañon, comes out on the eastern border of the Snake River Plains. Its course changes from west to south, and it flows thus across this basalt plain, keeping near its eastern margin. Near the southeastern corner of the plain the river turns west, and on that course skirts the southern border of this desert waste.

Shortly after leaving the mountains, the Snake receives a large branch from the north, known as Henry's Fork. This stream flows south along the eastern margin of the lava-field. Through most of its course its valley is heavily timbered. At its head, however, which is in a small lake in a loop of the main watershed is a small valley containing a few square miles of burnable land.

On Cascade Creek, a large left-hand branch of Henry's Fork, is a small valley, containing 20 to 30 square miles. It is open, very marshy, and grassy. Farther south, extending from the base of the Teton Range westward nearly to Henry's Fork, is a fine large valley, watered by Pierre's River, and known as Pierre's Hole or the Téton Basin. This valley has an area of open country of about 150 square miles, well grassed, but, of course, containing a due proportion of sage. Quite a large area in the middle of the valley is swampy.

With these exceptions, the country lying between Henry's Fork on the west and the Madison and the Snake Rivers on the east is very heavily timbered, with few openings of any magnitude whatever. In its northern part, it consists of a high basaltic plateau, cut by numerous cañons, while towards the south the lofty and rugged range of the Tetons separates the drainage system.

Below Henry's Fork the Snake receives no tributaries from the north for hundreds of miles—indeed, until it has passed the Snake River Plains. Then it is joined by the Malade, the Boisé, and Payette, which head in the Salmon River Mountains. Of this group of mountains little is known, as it has never been traversed by explorers, and it is but recently that mining discoveries have drawn settlement in that direction. These mountains seem to consist of a succession of ranges, trending parallel to the Rocky Mountains, *i. e.*, a few degrees west of north. The general fact that they are well clothed with timber, and that the forests descend well down into the valleys between the ranges, and into the broken country west of them is well known. Of the details of the distribution of forests and grass land it is at present unsafe to speak.

The southern section of the Rocky Mountain region is comprised in Southern Wyoming, Colorado, and New Mexico. It is characterized by the greatest elevation of the continental plateau, which rises as we pass southward from Southern Wyoming into Colorado, and near the center of the latter State attains a mean elevation of about 10,000 feet, and thence declines gradually southward, through New Mexico, and enters the Republic of Mexico with an elevation of about 4,000 feet.

In Southern Wyoming we meet first the Laramie Range, which rises to an elevation of about 9,000 feet above the sea. At its eastern base, and far up its slopes, the fine grass of the plains extends, growing more luxuriant with the altitude. On the summit of the mountains is a straggling growth of timber, nowhere heavy. The western slope is but a repetition of the eastern.

At the western base we enter the plains of Laramie. These lie between the Medicine Bow and Laramie Ranges, are limited on the north by the latter of these ranges, where it sweeps around to the west, and on the south they extend up into the angle of the junction of the Medicine Bow and Laramie Ranges. The surface of these plains, like that of the Great Plains, is chiefly rolling, entirely bare of timber, and covered mainly with bunch-grass. Here sage becomes rather more abundant than on the east side of the mountains, but is by no means the chief product.

Passing the Medicine Bow Range, we find the country, as far west as the valley of the North Platte, to resemble in most respects that of the Laramie Plains, being open and grassy.

West of the North Platte comes a broad plateau, separating the drainage of the Platte from that of the Colorado. This broad, ill-defined divide extends from the South Pass southeastward to the north end of the Park Range. It has an uneven, rolling surface, containing many sinks, in which disappear the waters gathered over large areas.

This region, from the railroad northward to the base of the Sweetwater Mountains, and from the North Platte to the Green River Basin, is almost a desert. It has a heavy, cold, alkaline, clay soil, which produces only a sparse growth of greasewood and stunted sage. It is not a region in which the locusts are likely to breed or frequent, neither is it to be burned over easily.

South of the railroad, these plateaus extend up to the base of the Park Range. As they recede from the railroad southerly, they rise to greater elevations and become correspondingly more inviting. The soil becomes more gravelly, greasewood disappears, while a luxuriant growth of sage and bunch-grass takes its place. Should it become necessary, these plateaus can be burned over at no great expense. This improvement in the vegetation seems to commence with Bridger's Pass and extends southward to the north end of the Park Range, and along its western flank far into Colorado. The western limit of these more fertile plateaus it is not easy to point out, as they grade insensibly into a more desert region, as the elevation decreases.

The valley of the Sweetwater River is everywhere well grassed, with but little sage brush. It is mainly bench land, with a gravelly soil, and is free from timber. The river bottom has an average width of about half a mile.

South of this valley, separating it from the deserts of the continental divide, is a range of low mountains, trending nearly east and west, and known as the Sweetwater Mountains. These mountains are timbered throughout.

North of the valley of the classic Sweetwater, extending from the Three Crossings eastward to the North Platte, are a succession of low granite ridges, which are covered with a luxuriant growth of bunch-grass. The group known as the Rattlesnake Mountains is timbered.

Turning to Colorado, we find a grand and simple arrangement of the mountain ranges on this crown of the continent. In the northern part there are two parallel ranges, trending a few degrees east of south—the Front and the Colorado Ranges. Between them lie the North and Middle Parks. The former, a nearly circular valley having an elevation of about 8,000 feet, is covered with a luxuriant growth of grass. The latter has a broken surface, being intersected by several short ranges of mountains. The valleys between them are well grassed, while the mountains are covered with forests.

In the central belt of Colorado the mountain portion is broader. West of the Park Range, beyond the valley of the Upper Arkansas, is the Sawatch, trending parallel to the others, and still further westward the groups and short ranges known as the Elk Mountains. In this portion the interval between the Front and Park Ranges is occupied by the South Park, elliptic in form, and having an elevation of 8,000 to 10,000 feet above the sea. Timber comes down well to the bases of the surrounding ranges and even trenches on the domain of the valley. The little ridges which traverse the valley are also covered with forest. Elsewhere the park is grass-covered. It is nowhere luxuriant, except in a few localities where there is natural meadow land, as in the northeastern part. There is some sage land in the lower portions of the park.

The valley of the Upper Arkansas is comparatively narrow and the part about the head of the river and the bench land everywhere are covered with forests. The open country is mainly sage land, with more or less grass.

The region of the Elk Mountains, including the narrow valleys of the upper branches of the Grand and Gunnison Rivers, is heavily timbered.

In the southern portion of Colorado, the mountain belt attains a still greater development. The Front Range, which, from Southern Wyoming, has formed the shore to the vast sea of the plains, after rising to a great height in the Pike's Peak group, suddenly falls, and disappears, while the Sangre de Cristo range, the continuation of the Park Range, comes to the front and for several degrees of latitude through Southern Colorado and most of New Mexico forms the immediate boundary of the plains. For a few miles south of the cañon of the Arkansas, a short range, known as the Wet Mountains, standing in front of the Sangre de Cristo Range, seems to form a continuation of the Front Range, the interval between this and the Sangre de Cristo being occupied by the Wet

Mountain Valley and Huerfano Park. West of the Sangre de Cristo Range lies the large valley of San Luis, beyond which is the broad and complex group known as the San Juan Mountains. These ranges are all covered with forests to the timber line. The Wet Mountain Valley is timbered except in the lower part near the Arkansas River, where the plateaus, into which it develops, are well grassed. The Huerfano Park has a very similar vegetation, being timbered near the divide and on the minor ridges, while grasses cover the lower parts.

The San Luis Valley, which contains the upper course of the Rio Grande, is a long valley, extending from Poncho Pass down into New Mexico. It has a length of about 140 miles, a maximum width of fifty, and an average width of 35 or 40 miles. Its area is not far from 5,300 square miles, of which about two thirds is in Colorado and the balance in New Mexico. Its surface is almost as level as a billiard table. In the northern part the growth is bunch-grass. As we proceed southward it changes very gradually to sage, which in turn becomes more and more stunted, and in the southern part of the valley the vegetation is very scanty, excepting at the bases of the ranges on the sides. The soil, too, undergoes a corresponding change from a gravelly soil at the northern end and at the bases of the mountains on the sides. Farther down the valley, about Sawatch Creek, the soil becomes a stiff adobe clay, and yet farther down the valley it becomes very sandy. In some places along the eastern side of the valley the sand has heaped up in drifts or dunes. This is notably the case near the Music and Mosca Passes. The sand begins near the latitude of the point where the Rio Grande enters the valley, and extends down to its southern end.

There is quite a large area of marsh and semi-marsh in the northern portion of the valley. San Luis and Sawatch Creeks entering the valley near its northern end, join and flow down the valley near its eastern border, and sink in the San Luis Lakes, near Mosca Pass. Their course in the valley, and especially below their point of junction, is sluggish and accompanied by a broad belt of marsh and of land naturally irrigated. About the lakes this area is much enlarged.

The San Juan Mountains contain no valleys of any extent. Baker's Park, an area of possibly half a dozen square miles, is the only bit of flat country to be found among them, except among their lower spurs, which will be noticed farther on, under the head of the Plateau area.

Proceeding southward into New Mexico, we find the lower limit of timber crowded higher and higher up on the mountains, so that, on the lower ranges of the southern part of the State, there is no timber whatever.

The low range of the Ratons on the boundary between Colorado and New Mexico is well timbered, though grasses extend well up its slopes. The Sangre de Cristo Range is covered with forests to its end, near Santa Fé, and the Sandia Mountains, a short group which continues its course for a few miles southward, are also well timbered. East of the latter, on the headwaters of the Canadian, there are several small areas of timber on the plateaus, and farther south, between the Pecos and Rio Grande, the minor ranges of the Guadelupe, Sacramento and Jimenez.

The country between the latter ranges and the Rio Grande is a sage barren, depreciating in some places to a desert, excepting that close to the river, which is covered with good grass.

On the west of the Rio Grande, the mountains are timbered, with the exception of a few small ranges in the south, such as the Burro and Miembres Ranges. The country is mainly an undulating plateau, and is in most localities covered with short but abundant grass. In the northwestern corner of the Territory, however, conditions of greater aridity prevail, and the prevalent growth is sage.

The Plateau Area.

This region may be roughly defined as the area drained by the Colorado River and its tributaries. The principal of these head in the mountains, yet their courses are almost entirely in this peculiar region. Exception should be made, however, of the Gila and Williams Rivers, of Arizona, which drain a region resembling that of the Great Basin in Nevada, of low, isolated, parallel ranges, separated by desert valleys.

The plateau region includes the western portion of Colorado, the eastern and southern parts of Utah, and most of Arizona. Most of it consists of plateaus, horizontal or inclined, differing widely in elevation and in degree of natural fertility. The streams, as a rule, flow in cañons far below the surface, though in a few cases they are in broad valleys.

The Green River Basin, one of these broad valleys, has already been treated of in detail. South of this, and separating it from the characteristic plateau region to the southward, is the Uinta Range, a broad, heavily timbered mountain mass, trending east and west. This range is well timbered, the forests extending nearly to the base everywhere.

On the east and west borders of the plateau region the table lands are high, reaching along the borders of the mountains proper nearly or quite to timber line. These plateaus are heavily timbered. Among them may be mentioned the following: On the east, in Colorado, the White River Plateau, at the head of the river of that name; the Grand and North Mam Plateaus, between the Grand and Gunnison Rivers; and on the west, in Utah, the Aquarius and other high table lands, which continue the direction of the Wahsatch Range and the Kaibab Plateau, through which the Colorado cuts its Grand Cañon.

The Roan or Book Plateau, and the inclined steppes north of it, which extend across the whole region from east to west, having heights ranging from 6,000 to 8,000 feet, have considerable range in natural productions near; their crests producing mainly grasses, with occasional groves of timber, and in the lower portions sage only.

The Uinta Valley, at the south base of the Uinta Range, is described as being a very fine valley, with luxuriant grasses in the upper part, degenerating into Artemisia near Green River.

The Grand River, after emerging from the Middle Park, flows through a region of high broken table lands, most of the way in a cañon, only occasionally emerging into a narrow sage-brush valley, nearly to its point of junction with the Gunnison. The latter stream has a somewhat more open course, with several large valleys. The uppermost of these, Taylor's Park, near the head of the stream, is pretty well covered with forests. Then follows a short cañon, from which the river emerges into the Gunnison Valley, a meeting place of several considerable streams, and of a number of valleys of greater or less width. The lower part of this compound valley is sage-covered, while the upper parts and the plateaus in the neighborhood are covered with luxuriant grasses and cottonwood.

Below this valley the river is in cañon for a long distance, while the plateaus bordering it, which rise gradually on the north to the Elk Mountains and on the south to the San Juan Range, are grassy, with groves of quaking aspens. At the foot of this, the Grand Cañon, the river emerges into daylight at the foot of the Uncompahgre Valley and flows across its lower end. This valley extends northward from the base of the San Juan Mountains, the Uncompahgre River flowing down its center. It is about 50 miles in length and 15 to 20 miles wide. It contains but little grass, except at its upper end. The growth is sage, the soil a heavy, cold clay. The bottom lands of the river are broad—one-half mile to a mile—and overgrown with bushes of various species, with quite an extensive growth of cottonwood and willow. At the foot of this valley it joins the Gunnison, which in the valley has bottom lands one to two miles in width, with a fine growth of willows.

Below the mouth of the Uncompahgre the Gunnison flows in a cañon on the left-hand side of a broad valley which produces but very little vegetable growth; and the same remark holds good, in a still more marked degree, concerning the broad valley which extends down the Grand below their junction, lying at the south base of the Book Cliffs. It is an utter desert, without possibility of amelioration save by a change of climate.

West of the Uncompahgre and Gunnison is a high plateau inclining toward those valleys and breaking off abruptly toward the southwest. It has the form of an immense spur from the San Juan Mountains, trending to the northwest. Its crest has an elevation of 8,000 to 9,000 feet; its higher part, near the crest, is well timbered, but contains many open grassy parks. Lower down on each slope the plateau is covered with sage, interspersed with piñon pine.

Farther to the westward are lower plateaus falling one below another and passing by gradations, according to altitude, into a more and more desert country. In the lowest and worst of this region the Grand and Green join, forming the Colorado.

West of the San Juan Mountains stretches the Great Sage Plain, which extends westward to the Sierra Abajo, and south to the Rio San Juan, a broad expanse fully justifying the name, which was given to it by Professor Newberry. Here and there on this plateau are patches of piñon pine and cedar, the only tree-vegetation to be found in these arid regions. Beyond the Abajo Mountains the country presents the aspect of a plateau, arid and waterless, and almost without vegetation.

On the other side of this great plateau basin, the plateaus sloping eastward from the Wahsatch present features, in general, almost identical with those on the eastern side—the same succession of steps from the higher to the lower plateaus, the same gradation in the vegetation. There are, rising out of these plateaus, a few groups of volcanic mountains, such as the Sierras la Sal and Abajo, the Henry Mountains, and El Laté, which are partly clothed with timber, and around whose bases are belts of fine luxuriant grass, resembling oases in a desert.

The San Juan River rises in the San Juan Mountains, in a number of branches, which, flowing southward from the mountains, unite in the plain at their base, and thence pursue a general westward course to the Colorado. Among the lower spurs of these mountains, the streams have narrow grassy valleys, interspersed with timber. Away from the mountains, however, the omnipresent sage asserts proprietorship again. The river has a narrow flood plain, with groves of willows and cottonwood, but here, as everywhere in this region, grass is scarce. South of the river, however, near the boundary between New Mexico and Arizona, is an extensive group of mountains, known as the Carrisos and Tunichas, the latter name being applied to the southern portion of the range.

These mountains contain some timber near their summits, and are everywhere well grassed, while the valley of the Chelly west of the range, which forms the principal part of the Navajo Reservation, is covered with exceptionally fine grass. Beyond this region, to the westward, the country north and south of the river goes from bad to worse, a country fit only for the habitation of the rattlesnake, tarantula, and coyote.

The Colorado Chiquito heads in the western part of New Mexico, and, flowing at first westerly and then northwesterly over the Colorado Plateau, empties into the Colorado River. The plateau over which it flows has an elevation of 5,000 to 6,000 feet, terminating in a well-defined edge on the south and southwest, where it is much higher than the country beyond. In Western New Mexico and Eastern Arizona the southern border is crowned by the Datili Range. Northward the plateau stretches, a desert-like expanse, into the country above described. The greater part of this plateau, and especially the northern portion, is barren and uninviting. About the course of the river it is less arid, while the immediate valley is described as grassy and fertile, but with very little timber.

West of the river is the volcanic group known as the San Francisco Mountains, rising to a height of 12,500 feet. These mountains are densely timbered, as is also the plateau about their bases, while the timber extends westward over the plateau to its edge and down the slopes. The whole edge of the plateau is covered with forests from the mountains in New Mexico westward and northward nearly to the Colorado. This timber belt is accompanied on its northern side by a strip of varying width of pasture land, extending in some places nearly to the Colorado Chiquito.

From the edge of the plateau, the country falls rapidly towards the Gila and the deserts of Lower Arizona. About the heads of the Gila there are many groups of mountains, most of which are timbered, while the valleys and plains are well grassed. All along the slope of the Colorado Plateau the country is broken, timber occupying most of the mountains, while the valleys are grassy. As the elevation diminishes, the vegetation changes and decreases, and when we reach the lower levels, we meet with the system of narrow, parallel ranges and valleys, most of the former being grass-covered, or possibly crowned with a few scattering trees, the latter mainly barren. Of this description is the country along the Lower Gila, and its branches, the Colorado and Williams Fork. The country along the Mexican boundary in Arizona is nearly all of this description, though improving to some extent from the longitude of Tucson eastward.

The Great Basin Area and the Wasatch Mountains.

This region, which finds no outlet save evaporation, comprises portions of the following States and Territories: Oregon, Nevada, Utah, and California—itself one great basin, it comprises a number of smaller ones, which may be classified comprehensively into three, namely: that of Harvey's Lake, Oregon; of Salt Lake, Utah, and of Carson-Humboldt Lakes, Nevada.

The characteristic surface feature is that of narrow, parallel ranges, trending nearly north and south, separated by narrow, partly-filled valleys.

The most fertile regions of the basin are among the ranges in the drainage area of tributaries to Great Salt Lake, in Utah, and in the northern parts of Utah and Nevada.

Proceeding now to the drainage area of Bear River, one of the largest tributaries of Great Salt Lake, we find that its valleys, with the single exception of the upper one of all, that which extends from the base of the Uinta Mountains down to the mouth of Smith's Fork, can easily be burned over; that the ranges of hills and low mountains which separate these valleys are grass-covered, while the higher ranges, such as the Bear River and Wasatch Ranges, are covered with a somewhat sparse growth of timber.

The upper valley of the Bear, extending, as was said above, from the base of the Uinta Range northward to the mouth of Smith's Fork, with a few minor interruptions, is clothed only with a sparse growth of stunted Artemisia. The soil is a heavy clay, and the valley is not likely to be used by the locusts as a breeding-ground.

The narrow valley of Smith's Fork of the Bear, which extends up that stream for about 20 miles, has an average width of two or three miles. This valley, with the hills on either side, is well grassed, and can easily be burned over.

A few miles below the mouth of Smith's Fork, a second large branch from the right joins the Bear. This is known as Thomas' Fork. On this stream is a large, fine valley, covered with sage and grass.

The valley of the Bear, between these streams, though not as broad as it is above, is much less inhospitable, containing more grass, and a more luxuriant growth of sage.

Between the Bear and Bear Lake lies a group of hills, which toward the south flatten out into a rolling country, which separates the valley of the Bear from the drainage of the Weber. Near the railroad, this belt of country is poor in everything except Artemisia, and even that is not sufficiently luxuriant to support a conflagration. Indeed, from the Platte Valley westward, the Union Pacific Railroad runs through one of the most forbidding sections of the whole West. North of the railroad, as this rolling country rises and becomes defined as ranges of hills, its natural productions improve, so much so that in August, 1877, nearly the whole mass of hills east of Bear Lake were burned over by fires set by Indians.

Bear Lake Valley, which may be considered to extend from the head of the lake northward as far as the Soda Springs, is a fine valley containing much grass among the omnipresent sage. This entire area, excepting that covered by the lake and swamp, can be burned over, as well as the mountain slopes on either side for at least a thousand feet above the valley, that is, to the base of the timber.

The Bear River Range separates Bear Lake Valley on the east from Cache Valley on the west, and rises to a height of about 9,000 to 10,000 feet above the sea. Above a certain elevation, which may be set roughly at 1,000 feet above the valleys, it is well, but not densely, timbered. Below the timber is an abundant growth of grass on a soil generally gravelly. South of the latitude of the head of Bear Lake this range breaks gradually down into bare hills, covered with sage and grass, which are crossed by the Weber in its westerly course to Great Salt Lake. These hills I should judge to be burnable.

The valley of the Weber, which is, for the most part, merely a notch cut in high hills, widens out at the east base of the Wasatch Range into a large fertile basin, well settled by Mormons. This valley is easily burnable.

Returning to the Bear, at Soda Springs we find that it makes an abrupt turn back upon itself around the north end of the Bear River Range. Below this bend the river flows first through Gentile Valley, a small valley between the Bear River and Portneuf Ranges. This, like most of the valley country in this region, is covered with sage and grass.

Then, after a short cañon, the Bear flows out into Cache Valley, the "Garden of Utah." This beautiful, fertile valley is about 50 miles in length in a north and south direction, by 12 miles in the opposite direction. It lies between the Bear River and the Wasatch Ranges, and has an area of about 600 square miles.

The Bear flows half-way down this valley, then, turning west, it cuts its way through a low ridge, which here represents the Wasatch Range, and thence flows off southward to Great Salt Lake.

The surface of the valley slopes gently inwards from the base of mountains or hills which limit it. Near the river, and extending for two or three miles on each side of it, is fine meadow land, sufficiently moist to admit of cultivation without artificial irrigation. The natural productions of this part of the valley are coarse marsh grasses, while the drier parts of the valley are covered with bunch grass, with a due admixture of sage; though it must be said that in this case there is much less than the ordinary proportion of this latter staple. The whole valley, with the lower slopes of the mountains and hills surrounding it, can easily be burned over.

Cache Valley is well settled. The population, which in 1870 amounted to 8,229, are nearly all of the Mormon persuasion, and are almost exclusively engaged in agricultural pursuits. A very considerable part of the arable area of the valley is now under cultivation. The cultivated areas extend in strips from the base of the mountains down nearly or quite to the river, and are irrigated mainly from the large lateral branches of the Bear.

The Wasatch Range forms the eastern wall of the Salt Lake Valley. This range, which in its middle and southern part is broad and very complicated, in its northern part, *i. e.*, north of the gap of the Weber River, is very much narrowed, being reduced to a single ridge; and just south of the Gates of the Bear it practically disappears, being represented at the Gates only by a low ridge. Farther north this ridge develops suddenly into a high range, known as the Malade Range, which forms a part of the western wall of Cache Valley. West of it lies the valley of the Malade River, stretching southward to the northern shore of the Great Salt Lake. This valley is somewhat more arid than that east of it, but yet supports a very good growth for pasturage. Meadow land is found in considerable amount near the streams in the northern part of the valley and along the shores of Great Salt Lake. As in Cache Valley, these are covered with coarse marsh grasses. The whole valley is burnable.

The hills west of Malade Valley, the Blue Spring Hills, are almost entirely devoid of timber, and are covered with excellent grass, with a slight admixture of sage. They can easily be burned over. Such is also the case with the valley next west, known as the Blue Spring Valley. This valley resembles that of the Malade in most essential features of vegetation.

Thence westward, the country in Northern Utah and Nevada and Southern Idaho and Oregon consists of a similar succession of narrow ranges and valleys, the former grassy, or containing a sparse growth of inferior timber, while the latter are poorer in grass and richer in sage-brush.

Along the Central Pacific Railroad the vegetation is very scanty as far as the head of the Humboldt, and grows still worse to the southward. This is the country which formed a part of the bed of the fossil lake Bonneville, and, while the water has departed, the solid portions, in the form of saline incrustations, remain in immense amount, covering thousands of square miles with a white, shining floor of alkali. Of course, here it is impossible that vegetation should grow. Even on the few groups of mountains, which rise here and there like islands from a placid sea, there is little vegetable growth.

The country along the western base of the Wahsatch Range, extending thence to the Great Salt Lake, is a fertile, well settled region. The inhabitants are Mormons, and their occupation farming. At the base of the mountains a continuous line of springs breaks forth, which, with the Weber and Ogden Rivers and Box Elder Creek, water nearly the whole of this strip.

The lower slopes of the mountains produce a fine growth of bunch grass, while on the flat below sage becomes a component to some extent of the vegetation. Along the shore of the lake there is much marshy land, producing reeds and coarse grasses. All this strip of land can be burned over easily.

The valley of the Jordan was originally an expanse of sage, bordered at the base and on the lower slopes of the Wahsatch Range by fine pasturage. The grass improves southward, among the valleys on the tributaries, to the Utah Lake, and on Sevier River, while the mountains and higher plateaus are timbered.

On the eastern slopes of the Wahsatch Range there are several fine valleys, where the plateaus break off against the base of the mountains. One of the largest of these is known as Castle Valley.

Comparatively few of the ranges of Nevada are timbered, and most of those are but sparsely covered by a stunted growth of desert species, such as Piñon pine and cedar. Of these the Toano, Goshute, East Humboldt, Diamond, Piñon, Snake, Antelope, and Cedar Ranges in the eastern part, the Pancake, Hot Creek, Monitor, Toyabe, Desatoya, and West Humboldt in the center, and the Walker River, Sierra Nevada, and Pyramid Lake Ranges in the western part contain nearly all the timber of the State. The other ranges are grassy, or, in the south, covered with Artemisia, or are barren.

Few of the valleys contain grass enough to be of economic value, except in the northern part. Most of them are waterless and covered with stunted sage, or are barren. It is unnecessary to go into details regarding them, as the accompanying map expresses them better than any description could do it.

There is a plainly marked gradation southward in the vegetation.

Of the Mojave Desert, of Southeastern California, little need be said, save that it is almost without vegetation, excepting at a few isolated spots, where springs break through to the surface, forming small oases, and the narrow belt along the Mojave River. On the borders of the San Bernardino Range, however, there is a narrow belt of grass, while the higher portion of the range is well timbered.

PREVENTIVE MEASURES IN THE PLAINS AREA.

From the foregoing account of the topographical and botanical characteristics of the different areas in the Permanent Region, taken in connection with what we have said both in this and our previous report, it is obvious that the plains area transcends in importance all the other areas here considered, from the locust point of view.

The surface conditions under which *Caloptenus spretus* breeds in the greatest abundance are a loose, warm, gravelly soil covered by a tolerably luxuriant growth of grasses, such as are found in most river bottoms; in the northern part of the plains of British America, along the bases of the mountain ranges, and in the high mountain valleys. Such areas are of greater extent in the northern portion of the region which we have described, becoming very much more limited in the Southern States and Territories.

While it is quite possible that the insects may breed anywhere on the plains, it is certain that, as shown in our first report, the more fertile portions of this area, and especially that great fertile belt between the two Saskatchewans, in British America, is the principal source of the swarms which at times sweep down upon the prairies. The extent of these breeding grounds in British America may be approximately estimated at about 100,000 square miles.

In Montana there is a broad belt at the eastern base of the Missouri Range, extending down the branches of the Missouri River for long distances. The country about Sun and Teton Rivers is very luxuriant, even as far as their mouths. The Gallatin Valley is luxuriantly grassed. The lower slopes of the Judith and other neighboring groups of mountains, the country about the base of the Yellowstone Range, the valleys of the Jefferson and its branches, with the hills in their neighborhood, may also be looked upon as breeding places of the pest. On the western or Pacific Slope, the valleys of the Deer Lodge, Bitterroot, and Hellgate, and of several of their branches, fall into the same category, as also the valleys of the Kootenai, and of Flathead Lake.

The bottom lands of many of the streams of the plains, though comparatively narrow, afford probable breeding grounds. Those of the Missouri are quite narrow, but on the Yellowstone they have an average breadth of more than a mile. These bottom lands are fertile and, where not covered with cottonwood and willow timber, are clothed with luxuriant grasses. The total area of the more fertile portions of Montana may be roughly estimated at 26,000 square miles.

In Washington Territory, all of that portion represented on the map, with the exception of that occupied by forests, is covered by luxuriant grass. Its area may be set down at about 7,000 square miles.

In the eastern part of Oregon the more fertile portions consist principally of comparatively small valleys in the Blue Mountains, such as the Grand Ronde. They sum up about 2,000 square miles.

In Idaho the more fertile grass lands are very widely scattered, consisting mainly of more or less narrow belts about the bases of the Bitterroot, Cœur d'Alêne, and Salmon Mountains, and in the mountains in the southeast corner. Altogether they sum up about 10,000 square miles.

In Western Dakota the most fertile grass regions are on the north, east, and south of the Black Hills. Luxuriant grass extends northward for many miles from their base, and eastward covers nearly all the country between the forks of the Cheyenne. The area may approximately be estimated at about 5,000 square miles.

In Wyoming the principal breeding grounds are probably the following localities: The plains east of the Laramie Range, the Laramie Plains, the country about the base of the Park Range, the borders of the Wind River Valley and the Green River Basin, the valley of the Sweetwater and the Granite Hills just north of it, the eastern base of the Yellowstone Range, and the Big Horn Mountains. The total area of the Territory may be roughly estimated at 12,000 square miles.

In Colorado the following regions are the most fertile: The plains at the eastern base of the Front and Sangre de Cristo Ranges—this fertile region extends eastward to a varying distance in different latitudes and altitudes; the Parks, North, South, and Middle, with the northern end of San Luis Valley; the plateaus about the cañon of the Arkansas and the Gunnison Rivers, the Wet Mountain Valley and Huerfano Park, and also many small areas among the mountains, which cannot be specified, but which, in the aggregate, swell the total considerably. The total area is probably about 15,000 square miles.

Proceeding southward, the area of luxuriant grasses becomes markedly less. In New Mexico it probably does not exceed 5,000 square miles, or about one-third that of Colorado. This is found at the east base of the Sangre de Cristo Range, and about the Raton Hills, along the Rios San José, Puerco, and Vaca, in the Valles Mountains, and on the plateaus about the head of the Colorado Chiquito.

In Utah the area is about the same. It is located mainly in Cache Valley, on the narrow ranges of mountains west of it, in the narrow strip of land between the Wahsatch Mountains and Great Salt Lake, in the upper valleys of the Sevier River, the Uinta, Castle, and Grass Valleys, and about the bases of the Henry Mountains and Sierra la Sal.

In Arizona the fertile area is still farther circumscribed, being not more than 3,000 square miles. It is found only on the higher plateaus, the Uinkaret, the Paria, and Sand Dune, in the valley of the Rio de Chelly, and in Nine Mile Valley.

In Nevada the area is about the same, and is nearly all confined to the mountain ranges in the northeast and a few valleys on the northern border, such as that of Quinn's River.

It would seem, therefore, that of the 400,000 square miles embraced in the Permanent Region, but about 177,000, or about one-third of the whole, is of such a character as to permit excessive multiplication of the locust. Some 19,000 are contained in Washington Territory, Oregon, and Idaho, where the movements of the locusts are neither so regular nor controlled by the same laws as are those of the hordes which breed in the Northwest, east of the mountains. It is noticeable also that in British America there is more land favorable to permanent breeding and excessive multiplication than in all the rest of the Permanent Region, and that the country in Montana just south of the boundary line furnishes the next largest amount.

We will therefore at once consider in how far each of the preventive measures is practicable in this plains area, and the results that may be expected from liberal government support of either.

1. ENCOURAGEMENT TO SETTLEMENT.—That every encouragement to the settlement of the Northwest should be given we have endeavored to show in Chapter II. Aside from the fact now generally conceded, and which the experience of the last quarter of a century seems to demonstrate, that the climate is materially modified and rendered more humid by settlement and cultivation, it is also a self-evident fact that in proportion as the farming population increases and pushes into the region where the locust permanently breeds, in that proportion will the extent of those permanent breeding grounds be reduced by man's necessary efforts in self-protection.

Compared to the excessive injury from locusts which formerly prevailed in Central Europe, there has been great freedom from their ravages during the past century, a fact evidently due in large part, if not entirely, to the increase of population and settlement. With a dense population it is easy to adopt preventive measures by destroying the eggs and young of invading swarms. So also in Utah the injury and fear of injury on the part of the Mormons have decreased in proportion as population and settlement increased.

The belief is very general among those who have studied the subject that the planting of tree belts and forests tends greatly to ameliorate a dry climate by causing rain precipitation where otherwise the clouds would pass over and away, as well as by more nearly equalizing the normal annual rainfall, which, on our plains, is generally borne to earth in torrential storms, which do comparatively little good. We have no doubt but that the belief is well founded, for careful researches carried on by M. Fautrat in France, and recently recorded in the *Comptes Rendus* of the French Academy, strongly confirm the belief and the position generally maintained, and well set forth in Marsh's "Man and Nature"; but it would seem equally true, from some of the most careful researches that have been made on the subject, that the breaking and cultivation of the soil and planting of other forage and cereal crops have also a marked effect, probably as great as the cultivation of trees, in producing the same effect. This is the experience of M. Tisserand,[341] and has been strongly confirmed recently by Mr. H. R. Hilton, in a paper read before the Kansas Academy of Science, on Rainfall in its Relations to Kansas Farming. He maintains that the actual amount of rain which falls in a given district is not the measure of the ability of that district to withstand drought, but rather the amount absorbed by the soil and held for the use of plants. The gulf winds which blow over Kansas are as humid as those which reach farther east, but the rainfall in that State is less because the soil offers less favorable conditions for precipitation. He shows clearly that the cultivable area is increasing with the advance of settlement, and in proportion as the soil is plowed deeply and the area of ponds of water and the cultivated fields of growing crops extends. Settlement, therefore, providing it be not purely pastoral, will not alone cause a decrease in locust injury by virtue of the number of locusts, whether in or out of the egg, that may be slain, but indirectly, by causing an increase in the moisture of the country, since the migratory locust is essentially a denizen of arid regions. In a recent trip to the Northwest, Professor Thomas was so deeply impressed with the important bearing which the settlement of Dakota had upon the locust question in Minnesota that he communicated to Governor Pillsbury the following views, which we give at length, because the same views are equally applicable to much of the rest of the plains area:

According to promise, I give here my reasons for believing that in time Minnesota will be comparatively free from locust invasion. As stated in my verbal communication to you, no one acquainted with the history and habits of these insects, and who has witnessed their flights as in 1874 and 1876, expects or hopes to find any means of suddenly exterminating them or stopping their flights. If this is ever accomplished it must be done gradually and by making use of such natural forces as may be partially within man's control.

The facts ascertained by the commission in reference to the long series of invasions from 1873 to 1877 led me to believe that there was but little hope that your State would ever be relieved of this fearful pest. This opinion was based upon the fact of their apparent stronghold upon and long continuance in the southwestern portion of the State; and the belief I then entertained, that a large portion of Dakota east of the Coteau of the Missouri could never be made an agricultural section on account of its supposed arid condition.

A fact then suspected, which will hereafter be explained, and what I have seen and ascertained the present year in reference to the agricultural capacity of Eastern Dakota have served to materially modify my former opinion and to cause me to hope and, I may say, believe, that the day is not very far distant when Minnesota will no longer have reason to fear the invasions of the locusts.

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[341] *Cf.* Conclusions of M. Tisserand, as given in the report by John P. Reynolds on the State of Illinois at the Universal Exposition of 1867 at Paris, p. 124.

By reference to the map of your State, prepared by your Geological and Natural History Survey, showing the locust areas therein for the years 1873-'76, it will be seen that the southwestern portion of the State was the part most continuously affected. Other facts ascertained by the commission indicated some peculiarities in this respect in reference to this section not observed in other parts of the State or in the States south. These facts attracted my attention and induced me to seek and, if possible, to find out the cause for these peculiarities; in other words, to find why the locusts hung longer and more continuously around this section than in other portions of the State. This, I now believe, is to be found in the elevated region called the Coteau of the Prairies, which affords topographical and climatic conditions more nearly adapted to the continual existence of the locust than other portions of the State. If I am correct in this opinion we have here one factor which must be taken into consideration in the discussion of this locust problem so far as it relates to your State and the adjoining section of Dakota.

As before intimated, I had formed the idea that the more elevated portions of Eastern Dakota, for instance, those lying along and bordering the valley of James River, were too sterile and arid ever to be used for agricultural purposes; that in fact but a narrow strip alone along the James River could be made productive by means, in part at least, of irrigation. The facts seen and ascertained the present year have in a large measure dispelled this unfavorable opinion. I am aware the present year is a very favorable one, and one that cannot be considered as a type of the seasons in that section; but it shows, I think, conclusively, that a very large portion of this section of Dakota can and will ultimately be made to sustain a large agricultural population. For even allowing quite a heavy discount on the present crop there would still be sufficient to justify farming in this region; and wherever this is the case, and the process of farming is so easily carried on as here, the section will ultimately be settled up.

In this fact I think we find a second important factor to be considered in discussing this problem.

A third possible factor is the supposed climatic change believed by many to be going on. Although I have not included this item in the present consideration, and cannot say that I have been converted to that view, but look upon these changes rather as cyclical, yet there are some reasons for believing that an unusual change of some kind is now going on in the seasons in the Northwest; what the ultimate result will be I am wholly unable to predict, but so far, at least, it is favorable.

Leaving the last item out of the discussion let us see what hope is to be based on the other items.

It is reasonable to believe, in fact we may assume as evident, that the farther west settlements are pushed continuously, that is without extensive breaks, and the denser they become, the greater will be the tendency to hold back, so to speak, the locust swarms; that is to say the advanced cultivated fields will bring them down, in part at least, and, supplying their appetites, prevent them from advancing further eastward; their temporary nesting grounds will also be disturbed, and thus their advance retarded.

While this is true theoretically, the experience of the years 1874-'77 may cause many to doubt its correctness in reality. It is true that swarms drive on southeast in their invading flights over broad and extensive settlements, as, for example, over Nebraska into Iowa and Kansas, and occasionally even into Missouri and Texas; but after all, though not brought to public notice, the fact is that Northern or Northeastern Nebraska often receives the smaller invading swarms and suffers the injury when the central and southeastern parts are entirely exempt. Other facts might also be cited to prove that the statement above made is true as a general principle. But Minnesota is somewhat peculiarly and favorably situated in this respect. The locust swarms, as a very general rule, sweep down from the northwest in a south and southeast direction, and, as it requires a much less opposing influence to turn them slightly away from their course than to stop them directly, the chances are much more in favor of localities thus situated than if placed directly in the line of their usual course.

As bearing upon this point and tending to confirm the opinion here advanced, I refer you to the chapter on chronology in the first report of the commission. In this it will be seen that the great invasions of 1876 passed southward along the west side of Manitoba not entering that province and not entering Minnesota (that is depositing eggs) north of Clay County, whereas in 1856 they penetrated eastward in this latitude to Cass County.

By reference to the map of Minnesota before alluded to you will see that the areas of egg-deposits in 1873-'74 and 1875 were in the extreme southwestern part of the State.

From these facts, and from many others which might be mentioned, I conclude, and, as I believe, correctly, that if (with the conditions hereafter mentioned) the eastern part of Dakota, from the west line of the James River Valley to the eastern border of the Territory, can be settled to a moderate extent with a farming population, the locust invasions will be largely diverted from your State. The farther these settlements extend northward, and the more extensive and dense they become, the greater the benefit.

In this connection I may add that while in Winnipeg I was informed that the Souris or Mouse River section is proving to be a better agricultural area than was supposed; that coal has been found there, and that land is now being surveyed preparatory to settlement. If this is found to be correct, and the settlement should become extensive, it will aid in the direction indicated.

The benefit to be derived by Minnesota from the settlement of Eastern Dakota does not by any means consist wholly in the fact that it will then offer the first attractions to the invaders. Dakota, east of the Missouri, has evidently long been a kind of camping-ground for the locusts. Not simply a stopping place for a few days of invading swarms that then passed onwards, but a temporary breeding ground, where the invaders of one season would deposit their eggs, the young from which, if the next season proved favorable, would pass onward to the southeast or east. I am fully aware that invading swarms from Montana and even British America sometimes extend their flights in a single season to Iowa, Nebraska, and Kansas; but I am also aware of another fact, not so generally known, that, in what are considered non-locust years, the shorter movements—as from Montana into Dakota, from British America into Dakota, and from Western to Eastern Dakota—are going on, to a greater or less degree, according to the seasons, and that for a season or two preceding the great invasions they are more than usually active in these movements. For proof of this I refer you to our First Report, pp. 82 to 92, and Appendix, pp. 243, 244.

A settlement of this section of Dakota will have a tendency to interrupt these movements and prevent the insects from using it as a temporary breeding-ground. That this portion of the Territory could be considered a truly permanent breeding-ground of the Rocky Mountain locust I now consider improbable, for I do not believe they can remain permanently in any section where farming can be carried on continuously without any aid from irrigation, unless it be far northward in British America, or in some very elevated section. But, possessing largely the topographical and climatic characteristics adapted to the life, habits, and perpetuation of the locusts, they retained their hold here much longer than in the more truly temporary regions of Central Minnesota and of Iowa, Nebraska, Kansas, &c. As before stated, the elevated and treeless character of the Coteau of the Prairies has evidently furnished the pests with a temporary breeding-ground, and will explain the reason for their hanging so long in the southwestern part of the State.

Is it possible to do anything to this coteau that will render it less adapted to this purpose? If it is possible to clothe it with timber, I answer, emphatically, yes. Cover it with a forest and it will cease to be a rendezvous of the pests, and the influence of this changed condition will be felt in this respect down to the extremity of the long and gentle slopes extending into the southwestern counties of Minnesota. No one supposes that any artificial forest that can be placed here will form such a barrier as to stop the flight of a locust swarm; but it will prevent it from being a nesting-place.

From all I could ascertain during my short visit to that section I think that by beginning with cottonwood the elevated ridges and plateaus of this coteau might ultimately be clothed with timber, but this is a question that must be decided by the horticulturists. If it can be done, and the settlement of Eastern Dakota goes on as rapidly as at present, I am thoroughly satisfied that locust visitations to Minnesota will grow less and less frequent, and the numbers decrease. In other words, the battle with the armies of these little foes will be transferred to a great extent to the valleys and plains of Eastern Dakota.

It is therefore to the interest of Minnesota that the settlement of this part of Dakota be pushed forward as rapidly as possible; that the numerous lines of projected railroad through this area be completed at as early a day as possible. Nor will this be less beneficial to this portion of Dakota, for the more extensive and more dense the settlements become, the less difficult will the contest be.

But in order to obtain the full benefit of this settlement there are three conditions which I think it will be necessary to observe.

First. The clothing of the higher portions of the Coteau of the Prairies with timber, and I think it would be well for Dakota and Minnespta to apply to Congress for this purpose. It is the only assistance in this respect they will have to ask of the government, and whether the result so far as the locusts are concerned be as anticipated or not, any reasonable appropriation made for this purpose will not be uselessly spent if the work is properly carried out, for the timber will render the land more valuable, and it is more than probable that it will have at least a slightly beneficial effect upon the climate. It is proper that I should remark, in this connection, that the present Commissioner of Agriculture, General Le Duc, suggested this some two years ago for another purpose than that now proposed.

Second. Tree-planting should be carried on as extensively as possible in all the settlements.

Third. The lakes, ponds, and even marshes scattered over Western Minnesota and Eastern Dakota should be carefully preserved. This is an essential item in the future prosperity of this entire region. Drain these or dry them up, and the day will surely come when this entire section and Northern Iowa will be as arid and barren as the great plains of the West. Every pond, swamp, or marsh drained is to that extent an injury to your State.

From whence comes the moisture that supplies your prairies? From the great lakes that lie along your northern border from Superior to Winnipeg. Arising from these it falls first into or feeds the lakes and marshes of your northern timbered section; thence by another step it spreads southward over the prairie region, feeding the numerous lakes and ponds of that section. The evaporation from these not only assists in drawing down the moisture which would otherwise be dissipated, but assists in spreading it farther southward and southwest. Drain the latter and all this beneficial influence will be lost, and step by step the water area will be diminished and the amount of rainfall lessened.

The broad and extensive marshes of the Red River Valley, between Saint Vincent and Saint Boniface in Manitoba, are of great value to the lands bordering the upper or southern portion of that valley, and if drained will certainly tend to lessen the rainfall over the beautiful and productive plains between Red and James Rivers.

I urge this matter upon your consideration because the history of the world shows that in this respect man has generally acted with consummate folly. In all the writing and discussions in reference to rainfall and supply of moisture the all important item—area of evaporating surfaces—seems to have been overlooked. Preservation of forests, planting of trees, &c., have been urged, and properly too, but maintaining or enlarging the area of water or evaporating surface seems to have been entirely forgotten. It is possible perhaps to accomplish this, in part at least, by appropriate State legislation. But simply refraining from draining is not sufficient. These little bodies of water should be surrounded by fringes of shrubbery and trees which should never be removed. If even the little streamlets flowing here and there through the prairies were generally fringed with thick shrubbery so as to partially protect the surface from the sun, this would aid much more than is supposed in retaining and distributing the moisture.

It would require too much space for me to attempt to give in full here the reasons and arguments bearing on this point.

In conclusion, allow me to say that I feel confident that if proper measures are taken and proper efforts are made in the directions indicated in this communication, the citizens of Minnesota may feel assured the day is not far distant when the grasshopper will no longer be "a burden" upon the agricultural prospects of their beautiful State. That there will be occasional visitations is to be expected, but I believe the day of severest trial has passed; the long and severe visitation of 1873–'77 will probably never be repeated unless, through want of care, your country is allowed to become arid and dry, or some climatic change over which you can have no control should bring about this condition.

I might add something in reference to the system of farming which I think would be advantageous in reference to the locust problem, but this communication is already long; and moreover I am well aware that farmers are not much disposed to listen patiently to suggestions in reference to their particular profession from one they consider a mere theorist. I therefore refrain.

I am glad I can speak thus hopefully of the future of your State. I have written conscientiously and not for the purpose of flattery. The views here given have been formed after a somewhat lengthy and careful study of the subject in all its bearings.

2. ENCOURAGEMENT TO RAILROADS.—Many persons believe that the building of railroads through almost rainless regions—the breaking of soil, laying of rails, stretching of wire, and consumption of fuel incident thereto—has a beneficial effect in ameliorating the climate in one way and another, but particularly in causing more frequent precipitation of moisture. They cite, in confirmation of this belief, the constant extension of settlement and of the cultivable area westward along the lines of the Kansas and the Union Pacific Roads; for the country is now settled along these roads far into what was formerly called the "American Desert," or into regions which but a few years since were considered uninhabitable from the fact that farming was supposed to be impossible there. The results are doubtless more due to the breaking and cultivation of the soil as above explained (p. 303); but whether or not railroads have this supposed influence, it is certain that they greatly benefit such a country in many other ways, and they should be encouraged as much as possible, not only because they conduce to the settlement of the country they traverse, but because they also facilitate communication between sections, and, in the country under consideration, will render more complete the system of warning, which we shall presently consider. We believe, therefore, that it is to the interest of the Government to encourage the building of railroads in this sparsely settled region and would emphasize what has been said on page 21.

3. IRRIGATION.—It is well known that in most of the country west of a line passing through Dakota, Nebraska, Kansas, Indian Territory, and Texas irrigation is almost universally necessary for success in agriculture. The eastern boundary of this "arid" region consists of a broad

belt of *debatable* land, which has a width of perhaps two degrees of longitude. In favorable seasons this belt may be cultivated without irrigation, while in dry seasons the whole area may require artificial watering. This belt traverses the eastern part of Dakota, gradually moving westward as it nears the southern border. It passes across Nebraska nearly in its center, and continues nearly due south, crossing Kansas slightly west of its middle line. It crosses the western part of Indian Territory, and in Southern Texas gradually trends to the eastward, reaching the Rio Grande not far from its mouth.

From this arid region must be excepted the greater part of Washington Territory, especially the western portion, that part of Oregon lying west of the Cascade Range, and the northern half of California lying west of the Sierra Nevada. Within the region thus excepted the rainfall is sufficient to insure crops.

Within the area designated as "arid" there are small districts which, owing to the conformation of the local topography, enjoy sufficient rainfall for the needs of agriculture. But these cases are too few and limited to be considered in this connection.

Here, then, is an area of 1,400,000 square miles, or nearly one-half the area of the country, exclusive of Alaska, in which the important industry of agriculture is dependent entirely upon irrigation. Without water the land is of value only for its sparse covering of grasses; is useful only to the stock-raiser; its productive capacity is reduced to about one-hundredth. The question of irrigation, therefore, is one of paramount importance, inasmuch as the future of nearly one-half of the country depends in a great measure upon it. It is a subject of State and national importance. Throughout the greater part of this region the extent of the arable land is purely a question of the amount of water available for irrigation. The area of land suitably situated in other respects for agriculture is several times as great as can be supplied with water. Probably not a hundredth part of the water which flows in the streams of the West need run to waste for want of land fit for receiving it; while, on the other hand, it is probable that, using all the water to its utmost capacity in irrigation, not one-fifth of the land which is suitably situated for it can ever be irrigated.

It becomes, then, a question of water rather than of land. Of the two the former is all-important; the latter has the smallest actual value. Without water the land cannot be given away; with it, it becomes as valuable as the rich prairies of Iowa. The measure of success already obtained in the endeavors to reclaim the Arkansas Valley to profitable agriculture, as the Hon. F. G. Adams has shown in a recent paper before the Kansas Academy of Science, is a sufficient warrant for much more careful surveys by the government of the river valleys of our Western plains with the object of increased irrigation.

There are two sections of the country which urgently require the protection and assistance of the national government for their agricultural interests. One, the great West, we have already treated of at length. The other is the low lands of the Mississippi Delta. Every flood in the great branches of the Father of Waters carries destruction to thousands of plantations in the South, destroys hundreds of thousands of dollars' worth of property, and leaves in its path deadly miasmas for the destruction of human life. A system of levees, constructed at an expense of millions, affords but partial protection, and costs large sums each year for repairs.

These levees can be regarded, in the light of modern engineering science, but as a temporary auxiliary in the great work of protecting this rich alluvial region. The true way of solving the difficulty of curbing the violence of this great river is to strike at the root of the matter, and *prevent the floods.* The only way to effect this is by the construction of reservoirs wherein the flood waters shall be gathered, and whence they shall be allowed to flow in a quiet, orderly manner. This is no new idea. It was proposed many years ago by Ellet, but at the time was buried beneath the ponderous arguments of the Engineer Corps.

Not long ago it was revived under their own auspices, and the experiment of controlling the Upper Mississippi by reservoirs in the lacustrine region of Northern Minnesota is now being tried. It will be, measurably, a success.

This work should be extended to the Missouri, the Plattes, the Arkansas, and the Red Rivers, and it should be combined with the irrigation interest in such a way as to serve the latter as perfectly as possible. These streams and their upper branches should be turned into reservoirs at or near their points of exit from the mountains. These reservoirs should be, collectively, of sufficient capacity to hold all, or nearly all, the vast amount of water brought down by the melting of the winter's snows. The construction of a series of small, rather than one or two large reservoirs, will probably prove most beneficial, both as costing very much less, and also because the water would be placed more conveniently for use, thus lessening the length and consequent expense of the irrigating mains and secondary ditches. There are, on or near the course of every considerable stream, among the swells and billows of the plains near the base of the mountains, an abundance of hollows suitable for reservoirs of greater or less magnitude. No great canals need be constructed, as sufficient reservoir capacity can be obtained on or near the streams, and all the water can be used by a comparatively narrow belt of land in close proximity to the rivers, where the land is more level and consequently better suited for irrigation than near the divides. Other things being equal, the water should be used on land near the mountains rather than on that far away, in order to avoid loss by evaporation and sinking, or "seepage," as far as possible.

As the land is placed under irrigation, it might be sold by the government with the water-right attached, *i. e.*, the right, in perpetuity, to the use of sufficient water for the irrigation of the land, at the rate of a certain number of cubic feet per second for each section of land. An annual tax, also, should be levied for the maintenance of the works. This would be a mere trifle compared with the original cost of the water-rights.

By thus taking the matter in hand, the general government will not only promote the welfare of the country by largely increasing its productive capacity, but will increase its own returns from the public lands immensely. It might, if properly managed, be an extremely profitable speculation for the government.

The cost of irrigation per acre differs materially in the various sections of the West, owing to the greater or less expenditure required for bringing the water to the land, and also, of course, according to the amount of water used. The general range is from $1 to $3 per acre annually, and the average is not far from $2. As a general thing, the water is supplied to ranchmen by ditch companies, who charge them a fixed price per year. The unit of measurement is commonly the "miner's inch," though this is gradually giving way to the simpler unit of the "second foot." Many companies, however, charge by the acre, ranging their rates with the different crops cultivated.

We have already laid stress on the importance of increased settlement and cultivation of the Northwest as a means of checking locust increase and of preventing the disastrous incursions of these devouring pests into the more moist and fertile Mississippi States; but as irrigation is, in the larger portion of the region, absolutely indispensable to this settlement by an agricultural population, its importance cannot be overestimated. As will be seen from our First Report, irrigation has not only this important indirect bearing on the locust question: it has also a direct bearing, for it affords one of the chief and most satisfactory means of destroying the young locusts, either by drowning them out, as in submersion, or by killing them with kerosene floated down the ditches. It is therefore by encouraging and extending irrigation that the national government can most satisfactorily act so as to permanently lessen the locust evil, and we cannot too strongly urge upon Congress the desirability of wise and patriotic action in the matter. So important, indeed, do we deem this question of irrigation that we have endeavored to get at some approximate estimate; first, of the amount of land redeemable by it; second, of the cost of redeeming said land; third, of the best plans to be pursued. Upon these and other points we have obtained the following report from Henry Gannett, E. M., whose experience adds weight and importance to his views:

To illustrate the great value of water in the arid region, we may say that a continuous flow of one cubic foot of water per second, throughout the growing season, means 200 acres of land saved from the desert; it means, also, 30 bushels of wheat per acre, a total of 6,000 bushels, worth perhaps $4,500. The utmost economy in the use of water is, then, the great desideratum, as every cubic foot saved insures to agriculture 200 acres, more or less, of the best of land. It is perhaps unnecessary to say that the system, or rather want of system, at present in vogue in this region is decidedly the reverse of economical. It partakes of the prevalent western spirit, by which the cream is skimmed from every source of natural wealth, which is then abandoned. "After us the deluge." In Colorado, irrigators use five times as much water as is needed, in Utah two to three times as much, and in the great valley of California it is used as wastefully. But in the arid regions of Southern and Southwestern California, where the ranchmen are Mexicans, who have had centuries of experience, and where the water supply is very limited and is all used, the utmost economy prevails, and probably the "duty" of water is carried to the highest possible extent.

But it is not alone the lavish use of water which should be criticised. The want of a general plan for the distribution of the contents of the larger streams will inevitably, in the near future, cause great waste of arable land. The let-alone policy is the only one in practice at present. By it each ranchman, or each ditch company, helps himself to water wherever he may find it. The only rights are those of priority of possession. The result of this happy-go-lucky mode of procedure is that the water is distributed to the land by no means in the most economical manner. As a general thing, the lands immediately adjacent to the streams—the bottoms—are first taken up, and they, monopolizing the water, render valueless all the land back of them, although the contents of the stream may not be by any means all used.

The general and the State governments are perfectly cognizant of this condition of things, yet practically nothing has been done by them. With the easy indifference of the optimist, the government has watched this waste going on for the past two or three decades, and has done nothing to correct it. A move in the right direction was made in 1873, when Congress authorized a commission, under a small appropriation, to make an examination of the Great Valley of California, with a view to forming a general plan for irrigating it. The commission made as full an examination as was possible with the limited means at its command, made its report—a very able, though by no means an exhaustive one—and there the matter ended.

In 1874, Prof. George Davidson, of the Coast Survey, was sent, under the auspices of the general government, to study the irrigation systems of foreign lands. He made a brief study of the methods in use in India and several European countries, and the results of these studies were embodied in a report to the Secretary of the Treasury, constituting Ex. Doc. 94, Forty-fourth Congress, first session.

The Geological Survey of the Territories, under Dr. Hayden, has made an examination, not by any means exhaustive, however, of the irrigable lands of Colorado, bringing out, as a net result, that 7 per cent. of the area of the State, or a little over 7,000 square miles, can be irrigated at once from the streams without having recourse to the reservoir system.[342]

The survey of the Rocky Mountain region, under Maj. J. W. Powell, made a similar examination of the Territory of Utah. The result of this work showed that but 2.8 per cent. of the Territory could be irrigated.[343] This, in the opinion of the writer, is too small, owing to some conclusions of Major Powell, to be hereafter noticed, which are believed to be erroneous.

The above embrace practically all that has been done by the general government touching this important subject. Fugitive articles upon the subject have been published here and there in government reports, but they have little permanent value.

State and Territorial governments have done quite as little. Indeed, not one has, so far as we are aware, touched the subject, excepting California. During the past year, this State has had a large engineering force at work, under the supervision of its State engineer, Mr. W. H. Hall, examining the southern half of the great valley, and the valleys of Los Angeles County, on and near the coast, with a direct view to drainage and irrigation. The present extent and character of the irrigation now carried on has been thoroughly canvassed. The nature of the surface of the land as regards

[342] Annual Report Geological Survey of Territories, 1876. Paper on "Arable and Pasture Lands of Colorado," pp. 311–347.

[343] Lands of the arid region.

irrigation has been studied, and all the large streams with most of the minor ones have been gauged at proper intervals throughout the year, giving a fair approximation to the amount of water which may be calculated upon. The work of Mr. Hall forms an admirable basis upon which to commence a well-devised system of irrigation for this area.

As to the total amount of land which can be reclaimed by means of irrigation, but the merest estimates can be made. It is, as was shown above, almost purely a question of the amount of water available. In the first place, we have but few measurements of the capacities of streams; and, except in the case of California, they are but single measurements, and simply represent the state of the stream at the time of gauging. The next day, or the day before, the stream may have carried a very different amount of water. In California, as was stated above, a number of streams have been gauged at short intervals throughout one year. From these measurements with the areas of the drainage basins, it may be possible to make rough estimates of the capacities of the streams of other parts of the country.

But there are other factors entering to complicate the subject. The first, and most important, is the question, What is the "duty" of water, *i. e.*, the amount required to irrigate a unit of land, or the number of acres which one cubic foot per second, throughout the season, can serve? This is not a fixed quantity, but differs with different crops, with different soils, and a variety of other circumstances. Corn requires less water than almost any other crop, while oats and grass require the most. Clayey lands need less than sandy soils, for very obvious reasons. Very level land requires more water than sloping land, as it absorbs more while under irrigation. Crops which are sown broadcast, like wheat or oats, require more water than those planted in drills, as the more expensive mode of flooding must be resorted to for irrigating them. Early sown or planted crops require less water than those planted late, as there is more rainfall in the early part of the season, and evaporation is not as rapid. Land that has been irrigated requires less water than new land. The reason probably is that the soil and subsoil become thoroughly soaked in time. Some even go so far as to say that a piece of land, after being irrigated for a number of years, requires no further watering. It is possible that this may be true for a season or two, but as soon as the water disappears from the subsoil, irrigation will again be necessary.

Major Powell, in his able report on "Lands of the Arid Region," states that the practice in Utah allows from 80 to 100 acres to the cubic foot per second, which is as high a duty as would be expected in Utah, where irrigation is not carried on intelligently or economically. In the San Joaquin Valley, of California, where irrigation is carried on by Americans, and where there is an abundance of water, we naturally find a very low duty, ranging from 50 to 150 acres per second-foot. In the counties of Los Angeles and San Bernardino, however, where most of the ranchmen are Mexicans, who have practiced irrigation for centuries, and where there is a great scarcity of water, nearly all the streams and springs being used up to their full capacity, we find the duty ranging from 300 to 1,500 acres per second-foot. To account for this difference between two sections of the State, Mr. Hall writes as follows: "The explanation undoubtedly lies in the greater experience acquired by the irrigating communities of Los Angeles and San Bernardino Counties, where the art has been practiced longer than in other parts of the State, resulting in the acquirement of more skill in the use of water; in the measures which nature has compelled the irrigators to take for the conservation and economical distribution of water, and to some extent to the character of the crops produced, * * * and last, though by no means least, we find in Los Angeles and San Bernardino Counties better irrigation organizations than in the San Joaquin Valley, which tends to harmonize interests and prevent waste."

A few statistics from the practice in foreign countries will be instructive in this connection. In Algeria the average duty for cereals is reported as 420 acres per second-foot. In the sub-Himalayan districts of India, the practice is to allow one second-foot for 218 acres. In Granada cereals and vines are irrigated at the rate of 240 acres per second-foot; in Valencia, above 200 acres per second-foot, and in Elche, where water is very scarce, a second-foot is made to do duty for 1,000 acres. Of course such crops as rice require much more water, giving a very low duty.

Hon. G. P. Marsh, in his well-known work, "Man and Nature," after discussing this question thoroughly, comes to the conclusion that 200 acres to the second-foot is a safe allowance. The United States commissioners, referred to above, who made an examination of the great valley of California, came to a similar conclusion. Mr. W. H. Hall, State engineer of California, concludes by saying that this duty, at least, can be reached. Indeed, it seems to be a generally accepted conclusion, that, with the average of crops and soils, and without considering the rainfall, the duty should reach 200 acres per second-foot. In Utah, the practice is, as was above stated, but 80 to 100 acres. In Colorado it is much less, probably 40 or 50 acres.

To arrive at any definite knowledge concerning the amount of arable land in the West, it will be necessary in the cases of nearly all the streams to institute a system of gaugings, to be made at intervals not greater than once a week, to extend throughout the year at least. The simplest way to carry this out would be to have a section made of the river channel at the point selected for the measurements, the section to extend to the marks of the highest floods on the banks. A gauge-rod, suitably placed, and read at the designated times, with measurements of current velocity at the periods of high, medium, and low water, would give data for the computation of the capacity of the stream. Until this is done, we can have but very loose ideas regarding the capacity of our public domain for supporting human life.

As the result of a tolerably careful examination, but not a thorough survey, it has been estimated that, without the use of reservoirs, Colorado contains 7,323 square miles of irrigable land, or 7 per cent. of the area of the State. By storing the surplus water from the spring floods this area can be increased to 10 per cent. at least.

Of the area of Utah, Major Powell estimates that 2.8 per cent. are irrigable without reservoirs. This estimate is based upon an assumed duty of but 100 acres per second-foot. Believing that this duty is but one-half of what can be reached, we are inclined to increase his estimate to nearly double this amount, and to place it at 5 per cent. The use of reservoirs will not greatly increase this amount, as most of the available land can be served by the streams directly. It is probable that not more than 6 per cent. can be irrigated by the employment of reservoirs.

In California it has been shown by survey that practically all of the great valley can be brought under irrigation. Add to this area of 15,000 square miles the numerous valleys of the Coast Range, and of the San Bernardino Mountains, and the total arable area of the arid portion of the State will exceed 20,000 square miles.

Judging from the character and size of the streams and the surface of the country, about 5 per cent. of the area of New Mexico is irrigable, and of Arizona about the same proportion. Wyoming, fully as well watered as Colorado, and having an immense area of plains, should have as great an area of irrigable land in proportion to its size.

Montana has probably very nearly the same proportion, though the great stretch of arid plains in its eastern half would reduce it somewhat. A safe estimate of its arable area would be 8 per cent. Idaho has a slightly smaller proportional area than Montana, but greater than Utah. Probably 7 per cent. is a safe estimate. Nevada has comparatively little water, it is safe to say not more than enough to irrigate 3 per cent. of its area.

Of Oregon, east of the Cascade Range and south of the Blue Mountains, which is the portion requiring irrigation, probably 6 per cent. can be watered. It is claimed that irrigation is unnecessary in any part of Washington Territory. Whether this be true or not, will soon be determined. We are inclined to doubt whether the eastern part can be cultivated, with safety, without water at hand to supply the deficiencies of the heavens.

Of that portion of Dakota lying within the arid region, probably not more than 5 per cent. can be irrigated. Of the arid portions of Nebraska and Kansas, it is difficult to make an estimate, as the rainfall will undoubtedly aid very materially, and the line of the arid region moves from east to west over a considerable distance, from one year to another. If entirely dependent upon irrigation it would be very small, as there are few small streams, and the large ones would be quite fully used in Colorado.

Of Western Texas but a very small proportion can be cultivated, probably not more than 3 per cent., as the whole area of the Staked Plains is irredeemable.

Tabulating the above figures, we arrive at the following results, as the possible arable area of the arid region:

ARABLE LAND

	Per cent.	Square miles
Colorado	10	10,450
Utah	6	5,070
California	15	20,000
New Mexico	5	6,060
Arizona	5	5,465
Wyoming	10	9,780
Montana	8	11,500
Idaho	7	6,040
Nevada	3	3,360
Oregon	6	3,000
Dakota	5	5,000
Texas	3	3,750
Total of irrigable land in the arid region	6.4	89,475

That is to say, about one acre in sixteen can be redeemed.

The amount of land at present in actual cultivation in the Western States and Territories is estimated at 8,000,000 of acres. Of this fully one-half is in California, and of this area of 4,000,000 of acres, nine-tenths is cultivated without irrigation, leaving 400,000 acres, or 625 square miles, as the total amount of land in the State under irrigation. The last are the figures for 1879, from the report of the State engineer. Of the remaining 4,000,000 of acres, about 1,000,000 are in the State of Oregon and the Territory of Washington, and of that portion in Oregon nearly all is in the Willamette and other valleys, where the abundant rainfall precludes the necessity of irrigation. There is at present but very little irrigation in this State.

The lands under cultivation in Eastern Dakota, in the Red River Valley, and the valleys of the Missouri, Dakota, Big Sioux, and other streams in the southeastern part of the Territory, may be estimated at 1,000,000 acres more. In this part of Dakota irrigation is not needed. The remaining 2,000,000 acres, or 3,125 square miles, are distributed among the remaining States and Territories in about the following proportion:

	Per cent.
Colorado	30
Utah	20
New Mexico	20
Montana	10
Idaho	6
Nevada	6
Arizona	3
Dakota (arid portion)	2
Wyoming	2
Texas (arid portion)	1

It is unnecessary to say that these are but very rough estimates made in default of any definite information upon the subject.

Out of a possible arable area, then, of nearly 90,000 square miles in the arid region, there is at present an extent of but 3,750 square miles under actual cultivation—a proportional area of but 4.2 per cent. The area yet remaining is equal to that of New York and Pennsylvania combined, or that of Illinois and Indiana. The best of the land and that situated most conveniently to water is included in that already taken up.

A great deal has been said and written upon the subject of irrigation by means of artesian wells, and many hundreds of thousands of dollars have been literally sunken in vain attempts to bring water from the bowels of the earth. It has been a pet idea with many theorists that the great extent of the plains can be fertilized by the promiscuous boring of wells. They seem to have an idea that water is omnipresent beneath the surface, and is only waiting for an opening to be made, to pour itself upwards. They do not reflect that it is only under very peculiar conditions of dip and character of strata, that water having an upward tendency can be found.

If nothing else will stop this senseless clamor for artesian wells surely it would appear that the history of the failures which have attended such attempts should effect it. The Union Pacific Railroad has bored five or six between Fort Steele and Green River City. They are, on the average, about 1,000 feet deep, and cost about $15,000 each. Most of them were at first flowing wells, while in the rest the water rose to within 10 or 15 feet of the top. After a year or two most of them stopped; perhaps two are still running. These were sunken in a locality very favorable for the purpose. The United States Government sunk a well at Fort Russell, Wyo., to a depth of 1,100 feet, at a cost of $10,000, without success. At Denver a well was bored to a depth of 800 feet when the attempt was abandoned. The Kansas Pacific Railroad has also expended a large amount of money in the same fruitless quest.

In Los Angeles and San Bernardino Counties, in California, irrigation by means of artesian wells is carried on to a considerable extent. In this part of the State the soil and climate are exceptionally fine, the crops, very largely fruit and wine-grapes, are very valuable, while water is extremely scarce, and is used with the utmost economy. In these counties there are about 1,000 artesian wells, which irrigate altogether 18,000 acres, an average of 18 acres to each. They are used mainly for small vineyards, gardens, and orchards. Their depth ranges from 40 to 600 feet, while the average is 150 to 200 feet. Success has been had in sinking them only in a few limited localities. Their average cost has been about $400, and the average amount of water brought to the surface by each is about one-tenth of a cubic foot per second. In other words, each second-foot of water has cost $4,000. At the present duty of water in vogue in Colorado, *i. e.*, 40 acres per second-foot, it will be seen that it would cost no less than $100 per acre for a water-right. This is without taking into account the vast amount of money which has been spent in useless borings. Truly, as the State engineer of California says, in concluding his remarks upon this question, "it will be seen that the luxury is a somewhat expensive one." Many people, however, still pin their faith to artesian wells as probable sources of large supplies of water, and scarcely a session of Congress passes without attempts being made to pass legislation looking toward an expenditure of money for boring them. During the last session an appropriation was made for "examining into the needs of the arid region," and for boring two artesian wells "on the plains east of the Rocky Mountains," the appropriation to be at the disposal of the Honorable Commissioner of Agriculture. Fortunately the amount is small, being only $5,000, and it is to be hoped that this amount will serve to demonstrate the utter hopelessness of the scheme. If so, it will not be expended in vain.

There are four general methods of irrigation in use, viz:

1st. Flooding, or downward filtration, by which the surface of the soil is covered with water, which is then allowed to stand and settle into the earth.

2d. Ditching, where the ground is supplied with water from lateral percolation from ditches placed at short intervals.

3d. Subsoil irrigation, where the water is conducted underground and supplies the soil by capillary attraction.

4th. Sprinkling, in imitation of nature's method.

The first method admits of several variations, as follows: If in motion, it may be in a very shallow layer, applied continuously for a considerable period of time, or in a deep layer for a short period.

If the flooding take the form of a standing sheet of water, it may be quite deep, and be allowed to stand until it all settles into the ground and evaporates. A fourth method is to combine the standing sheet with the flowing one, allowing the water to stand for a short time; then draw it off to some other portion of the field. This process is more applicable to large farms than any other method. It costs less, generally speaking, to prepare land for irrigation by this process, and the work can be done more quickly. But it is applicable only to lands of gentle, even slopes, and a soil which does not cake after being soaked. A large volume of water, comparatively speaking, is required, and there is danger of great waste, unless the irrigator be a man of experience and the ground be well prepared. There are, however, many crops for which this method is not the best.

The second method—by ditching—is also varied, to a considerable extent, in practice. It may be carried, flowing constantly, between the rows of plants, whence it percolates laterally through the intervening soil, or the water may be kept standing in ditches between the rows. In this case the ditches should be larger and further apart than in the previous case. In the case of very open, sandy soils, ditches may be led along the divides, or ridges, at greater or less distances apart, the lateral percolation, or seepage, being sufficient to carry the water over the whole ground.

The ditching method has great advantages over the flooding method in some respects. It costs, in general, very much less to prepare the land and to apply the water. On the other hand, it is ordinarily less economical of water, and requires more time in the application of it.

The third and fourth methods are not, and probably never will be, in use on any considerable scale, for reasons too obvious to mention.

It is impossible to form any estimate whatever of the amount of money at present invested in irrigation works, as there are very few and very scattering statistics on this subject, and it is not a subject upon which inferences can be drawn from the known to the unknown. Still less can any estimate be made of the amount which would be required to construct works which would utilize all the water flowing in the streams and thus bring the maximum of land under cultivation. Such an estimate, even in the roughest form, must await the result of detailed surveys, and the development of definite plans.

During the past few years fertile brains have been busied very extensively in devising ways and means for spending money to no purpose on grand schemes of reservoirs and ditches. These schemes have come from all grades of authority, from an ex-President of the United States, who knew nothing about it, down to a county surveyor, who ought to have known better.

None of the streams of the West carry sufficient water, or command land in sufficient amount, to warrant the construction of any single great work in the form of reservoirs or irrigating canals. The fall of those streams is, almost without exception, sufficiently great to allow the water to be taken up to the bluff lands by a very few miles of ditch. As the primary and almost sole object of a long canal, parallel to the stream is to save fall, so as to command the country, it will be seen that such canals are doubly unnecessary in this region.

When the arable lands of the arid region are developed to the utmost capacity of the streams, they should be distributed in the following general way. Along the base of each mountain range should be a strip of land parallel to the range, more or less continuous, and of greater or less width, in proportion to the amount of water flowing from the mountains. Down each stream of any consequence would follow a belt of cultivated land. If the stream has a rapid fall the belt may be broad, and extend a comparatively short distance down its course. If its current be sluggish, the strip should be narrow, confined, perhaps, to the bottom-lands merely, and may extend down the stream a long distance. The details would depend upon local circumstances.

4. PRESERVATION OF THE FORESTS AND ENCOURAGEMENT TO TREE PLANTING.—Without entering into a discussion as to the value of forests in ameliorating climate, and fully conscious that they must succeed rather than precede such amelioration; in other words, that it is impossible, as a rule, to cultivate forests or extend them successfully in arid regions without first supplying the requisite conditions of moisture; we nevertheless fully appreciate the great importance of preserving as far as possible the timber already sparsely existing in the regions we are considering, and also the desirability of extending it, as a sequence and valuable outgrowth of the increased irrigation we have just been advocating. There are also many sections of the West, especially near the limit line of the distribution of the Locust, where timber growth is spontaneous whenever the prairies are protected from the annual fires which usually sweep over them and hinder forest extension. These facts add weight to all efforts looking either to increased irrigation or judicious restriction and use of fire.

5. JUDICIOUS BURNING.—In this connection we find little occasion to materially modify our views expressed in our first report and repeated on page 272, *ante*. In order not to overestimate the practical benefits that may arise from judicious burning Mr. Thomas has brought together in Chapter II (pp. 16–18) the strongest possible arguments against its practicability, and, after giving these due weight, it yet remains true that in thus burning we have one of the most, if not the most, inexpensive ways of temporarily checking locust increase in many parts of the country where the insect freely breeds. No amount of theoretical objections or of unsatisfactory results, often due to imperfect or injudicious burning, can offset the beneficial results that may be obtained with care and under favorable circumstances. The writer himself has personally witnessed the slaughter of myriads of locusts in this way, and this mode of reducing the numbers of the destructive hordes in their natural habit at once forces itself upon the attention of all who have had experience in that country. The fact that locusts are not destroyed in very great numbers in the Temporary region is due to the fact that the eggs are not laid in this region in the ground covered with dense, long or prairie grasses. The insects would be destroyed by burning were they there. In the more humid prairie country, bare dry spots are preferred for oviposition; but in the Permanent region the insects will abound most where the vegetation is rankest and most succulent. A study of Map I will give an approximate idea of the amount of land in the plains area, the vegetation of which is susceptible of being burned over, and will also show that it includes all the more arable and valuable land for settlement—a fact of great importance.

In the plains area proper there is little or nothing to prevent wholesale burning of the vegetation late in the spring, after the bulk of the locusts have hatched out, beyond the expense of preventing such burning the previous fall. The only practical way in which this could be done would be by a system of fire-guards where there are no natural streams or other barriers to prevent the spread of the flames. We repeat, that any extensive system of guarding the vegetation in the fall so as to fire it the ensuing spring would only be warranted at government expense in those particular areas where it is absolutely known that eggs have been thickly laid and that the insects from such eggs will swarm the following year. Such a condition will occur only at irregular intervals and the government should take some steps to provide for annual observations that will lead to a knowledge as to when and where such conditions prevail. Systematic firing should then be carried on from the circumference of such area or areas after the bulk of the insects are known to have hatched and before they are able to escape by flight. That such work can profitably be performed in large portions of the permanent region, we have little doubt, and that the expense in such instances would be warranted is made manifest by the terrible losses which the insects are capable of occasioning.

In many sections a system of fire-guards will be absolutely necessary to judiciously carry out any such scheme, in order to prevent the destruction of timber.

6. A PERMANENT SYSTEM OF OBSERVATIONS AND WARNINGS.—In order to carry out the plan just considered, and, in fact, to enable the government to take any intelligent action looking to the direct destruction and decrease of the Locust in the region under consideration, systematic observations made and reported from year to year are absolutely essential, and we cannot too strongly urge upon Congress that provision be made for such continued observations. There is no reason why it should not be made part of the duty of the Signal Bureau to obtain the desired information, and to report the situation to the country from time to time. The source of these destructive insects is no longer an utter mystery, and every year is adding to the facilities for making the desired observations.

With an increasing population; with the near completion of projected roads through Montana and adjoining Territories; with the completion of the Canadian and Northern Pacifics now assured, the means of establishing a system of locust signals and warnings, and of making more complete and accurate observation, will be far greater than they have been. Information as to the situation and extent of egg-deposits; the time of hatching of the young locusts; their movements both on foot and on wing, can and should be as rapidly obtained and disseminated as possible. The local press will be but too ready to disseminate it. The course of flights from day to day should be traced and published in the maps issued and now generally posted at available points, as post-offices, depots, etc. In many instances such warnings would enable the farmer to cut and save his crops before the swarms reached him, that would otherwise, unheralded, swoop down upon him and in a few hours destroy the labor of a year. Tracts which it would pay to guard against fire in autumn and then burn the ensuing spring, as we have just set forth, could also be mapped out and the maps published for the general good and as guides to Congressional action, while an annual report on the locust condition and prospects, to be made part of the report of the Signal Bureau, could not fail to greatly interest and benefit the people most concerned, and indirectly through them the whole country.

A limited appropriation to the Signal Bureau for this special purpose, that would enable the Chief Signal Officer to begin at once the work here suggested, under the direction of some competent person or persons, would, we have no doubt, directly tend to immensely increase the practical usefulness of the bureau to the farming community dwelling in the vast regions subject to locust injury. Even the observations of the individual commissioners and their agents, limited as they have necessarily been as compared with those which the Signal Bureau could make, have been of great service in permitting, since its organization, annual statements and prognostications that have proved correct to a remarkable degree; while, in the event of a repetition of the scenes of 1873 to 1877, no one would question the value of daily bulletins, such as the Signal Bureau might publish with the increased power we have indicated, as to the movements and flights of destructive swarms. We therefore strongly recommend an appropriation to the Signal Bureau for this special purpose.

7. CO-OPERATION WITH THE DOMINION GOVERNMENT.—That efforts in any schemes for the protection of the western farmer from locust injury should be made as far as possible with the co-operation of the Dominion Government is too apparent from the facts presented in this and our previous report to need any special emphasis or argument.

PREVENTIVE MEASURES IN THE MOUNTAIN AND PLATEAU AREAS.

The measures to be adopted to prevent locust injury in the more mountainous area must be essentially the same as those we have recommended on the plains; but, as shown in Chapter II (p. 24), there is in the intermontane area less land adapted to agricultural pursuits than in the plains area, and the chief industry in the former section will always be that of mining. Dr. Packard, who has more particularly studied the problem in the mountain and plateau areas, gives the following report of his views and experience as to the best means of counteracting and lessening the injury in the mountains:

"The arable lands are the bottom lands among the Rocky Mountains, the Uintah and Wahsatch Ranges, which lie for the most part between the altitudes of about 4,000 and 8,000 feet. Above this height, owing to summer frosts and cold nights, as well as cold storms, the locusts do not flourish in great numbers nor arrive at maturity until two or three weeks after those which have hatched out in the regions below have become fledged and flown away.

"It is evident then that the breeding grounds of the locust are in those regions of the Rocky Mountains which will ultimately be taken up by settlers as farming and grazing lands; hence, when this region is settled, the prevention of locust injuries will be a problem much easier of solution than at present.

"The effect of putting this large area under more or less thorough cultivation, either as irrigated farms or cattle and sheep ranges, will be to render the country less liable to great and prolonged drought, and thus cause the climate to be more equable. All this will tend ultimately to keep the locust within its normal limits, so that it will not in certain favorable years multiply to so great an extent as to lead to extensive migrations into adjoining or remote regions. The locusts will be restrained within their natural and original limits. Hence the best means of protection will be to destroy the eggs and to fight the young when they hatch, and to exterminate them by all the methods fully described in the First Report of the Commission. The greater the number of eggs and young destroyed within the Permanent Region year after year, over a period of 25 or 50 years, the more will the number of individuals throughout the whole area be lessened.

"The settlement of Montana and the western border of Dakota will ultimately have a great effect in lessening the extent of the breeding grounds of the locust; and thus diminish the numbers of those which swarm into Utah on the one hand, and Minnesota, Iowa, and Nebraska on the other.

"The State of Colorado is invaded by swarms which originate west of the range about the White and Bear Rivers, and north and northwest from the Wind River Valley and the Laramie plains of Wyoming, so that these regions are the tracts which need to be occupied, and where an unremitting warfare, pursued with combined effort year after year by the farmers, will ultimately tend to keep the locust within comparatively harmless bounds.

"To this end the replanting of the forests, now being recklessly cut down by the settlers of the Western Territories, will have a favorable effect, both tending to reduce the extremes in the seasons, and to break up and diminish the breeding grounds of the locust. Moreover, the construction of railroads and the settlements which spring up along them will have their effect in reducing the extent of the breeding grounds.

"The settlement also of the wild lands of the Rocky Mountain plateau will in a measure tend to keep the locusts from migrating eastward. If there were a sufficiency of food in the plateau region, there would be no inducement for them to take flight for regions situated five hundred to a thousand miles eastward, for without much doubt the main cause of their migration is the desire for food; for if the broad, extended plains of the region between the mountains and the Mississippi Basin do not afford them sufficient food, they will pass on to the prairie region of the western edge of the Mississippi Basin.

"While, therefore, we do not see how any special means of exterminating the native locust in the Rocky Mountain region can be systematically and extensively applied beyond locally burning over tracts and destroying the freshly-hatched young, we may with confidence predict that even in ten or twenty years from now, when the rich grazing and farming territory of Montana will sustain a much denser population than at present, the locusts may be in many places locally exterminated, their numbers in general diminished, and their ravages be greatly lessened.

"As is well known, the greater part of the injury done by the locusts is accomplished by the voracious young working in fields of young wheat. The winged adults swarm in after the wheat is harvested or about the time of harvest.

"What the farmer of Colorado and Utah wants in the middle and latter part of July is certain, reliable, and detailed information respecting the presence or absence of locusts west of the Rocky Mountain Range or in Wyoming northward, if he live in Colorado; or, if he be a Mormon farmer, whether the locusts are flying from Montana into the region of Idaho lying north of Cache or Malade Valleys. He may then be able to tell whether to expect the locusts late in August or early in the autumn in his own country. At the present time the western border farmers pick up in a desultory and haphazard way information of this sort, but as the Far West becomes more densely populated and increased care and diligence are observed, as they will have to be exercised in the future when the struggle for existence becomes more intense among agriculturists and wheat-growers, all the means we have referred to of obtaining, classifying, and disseminating a knowledge of the movements of the locusts will be more or less fully adopted. When this result is attained the battle with the locusts is more than half won. A tolerably complete knowledge of the habits and movements, direction and time of flight, &c., over a series of years will also (as it already has in Utah) tend to clear up the mystery hitherto attending the migrations and ravages of locusts. This will have the effect of making the agricultural community less subject to wild panics, and more bold, determined, and combined in endeavoring to exterminate the locusts.

"A large proportion of the money losses resulting from the locust invasions of 1867, '69, '74, and '76 was the result of a panic, of uncertainty as to the future; this resulted in disheartenment, in the abandonment of large tracts of the best of farming lands to nature and the locusts. This will probably never again happen in the West. The knowledge already disseminated, the extent of the population now pouring into the Northwest, the rapid settlement of the Territory of Montana, and the completion of the Northern Pacific, Canadian Pacific, the Utah and Northern Railroads, and the consequent change in the surface of the country due to human agency will so essentially modify the locust situation that we believe the West will never again suffer as in the past. It remains for the people of the Rocky Mountain Plateau to use such local and general means as their own experience and this Commission have suggested in the first and present reports; for the State and Territorial and county governments to make and execute laws for combined and persistent action during times of general local invasion and for the prevention of others. If this be done in the plateau region in the future the invasions of the western border Mississippi States will tend to become more and more feeble, inconsiderable, and harmless, until, we venture to predict, the time will come when the losses from locusts will be only local and comparable with those inflicted by locusts and grasshoppers in the eastern Atlantic States. At any rate, the western locust has already ceased to be a bugbear and object of dread; familiarity with its habits and history has already taught the pioneer farmers of Utah, Montana, and Colorado that with energy its ravages can be lessened if not entirely overcome, and no one intending to migrate west from the Atlantic States or from Europe need to be deterred by the fear of such alarming invasions as have occurred in former years."

APPENDICES.

APPENDICES.

APPENDIX I.

MISCELLANEOUS DATA AND REPLIES TO CIRCULAR NO. 1.

The following data in reference to the Rocky Mountain locust, collected chiefly in 1877 by Mr. Thomas, was omitted in the former report, partly for want of space and partly because it was impossible to get the material ready in time. A few extracts were made, which will be found in Appendices XXII, XXIII, and XXIV of the former report. The dates of flights for 1877 mentioned therein were collated and arranged as given in Appendix XXIII; but the communications and the large amount of valuable information they contain were left out for the reasons mentioned.

It has been thought best to arrange this data by States and Territories rather than by date.

In order that these communications may be understood, it is necessary to state here that most of them are in answer to the questions in the following circular issued by the commission early in 1877, as stated in our first report (p. 2):

CIRCULAR No. 1.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE UNITED STATES ENTOMOLOGICAL COMMISSION,
——, ——, 187 .

Mr. —— ——.

DEAR SIR: The Commissioners are desirous of collecting, as soon as possible, all ascertainable facts in reference to the migrations of the Rocky Mountain locust (*Caloptenus spretus*), and also regarding its appearance, habits, and devastations in your section.

We present below a series of topics upon which we shall be glad to receive data from your locality. We expect you to dwell only on those topics upon which you have positive information, and shall be glad to receive any facts or views not suggested by this circular. Some of the subjects cannot be reported on till toward the approach of winter, while others can be considered earlier. In responding, therefore, we ask our correspondents to couple their answers with the number of the circular and of the inquiry.

We shall be glad to receive and will determine any of the different species of locusts that occur in your locality, and particularly specimens of their different parasites and natural enemies. These are best forwarded by mail, packed in cotton, moistened with alcohol, and placed in secure tin or wooden boxes. Living specimens may be sent in tin boxes, and are preferred, where they will not be too long on the way.

The inquiries have reference more particularly to the present year 1877, and when facts are communicated that have reference to other years, correspondents will please be careful to specify the particular year.

The Commissioners will refund whatever expense may be incurred for postage in replying to this circular, or in forwarding specimens, should correspondents so desire.

Copies of documents published by the commission will be sent to correspondents who forward data in accordance with this request. Communications may be sent to either of the Commissioners.

CHAS. V. RILEY.
A. S. PACKARD, JR.
CYRUS THOMAS.

TOPICS ON WHICH DATA ARE REQUESTED.

1. Date and time of day of the arrival of swarms.
    1*a*. Direction and force of the wind at the time.
    1*b*. Temperature and character of the weather at the time (clear or cloudy).
    1*c*. Direction of the flight, density, height, and extent of the swarms.

2. Date and time of day of the departure of swarms.
    2*a*. Direction and force of the wind at the time.
    2*b*. Temperature and character of the weather at the time.
    2*c*. Direction of the flight, density, and extent of the swarms.
3. Date when the first eggs, if any, were deposited the present year.
4. Date when the eggs were most numerously hatching the present year.
5. Date when the eggs were most numerously hatching in previous years.
6. Proportion of eggs that failed to hatch the present year, and probable causes of such failure.
7. Nature of the soil and situations in which the eggs were most largely deposited.
8. Nature of the soil and situations in which the young were most numerously hatched.
9. Date at which the first insect acquired full wings
10. Date when the winged insects first began to migrate.
11. Estimate the injury done in your county and State.
12. Crops which suffered most.
13. Crops most easily protected.
14. Crops which suffered least.
15. The prevailing direction in which the young insects traveled, and any other facts in relation to the marching of the young.
16. The means employed in your section for the destruction of the unfledged insects, or to protect crops from their ravages, and how far these proved satisfactory.
17. The means employed in your section for the destruction of the winged insects, or to protect crops from their ravages, and how far these have proved satisfactory.
18. Descriptions, and, if possible, figures of such mechanical contrivances as have proved useful in your locality for the destruction of either the young or the winged insects.
19. If your section was not visited in 1876, please state this fact.
20. If visited any previous years, please give the dates.
21. To what extent have birds, domestic fowls, and other animals, domestic or wild, been useful in destroying these insects?
22. State the ratio of prairie to timber in your section or in your county.
23. State all you know about the habits of the young or full-grown insects during the night, *and especially whether you have ever known them to march or continue to fly after the sun is down, and, if so, how long into the night.*
24. The amount of damage to fruit and shade trees, and the most satisfactory means employed in your section to protect them.
25. Furnish copies of all the records you can obtain, which were made at the time of the visitations of the grasshoppers, whether written or printed.
29. State all you may know in reference to eggs hatching in the fall.
27. What plants, cultivated or wild, appear to be preferred by the young, and what by the full-grown insects?
28. What plants, cultivated or wild, appear to be least relished?
29. State to what extent the invading swarms have been observed to injure the native grasses, and to what extent the young have been observed to injure them.
30. What animals, such as quadrupeds, birds, and reptiles, have been observed feeding upon the young or full-grown insects or their eggs?
31. State what measures for destroying the eggs have been tried, and how far they have proved effectual.
32. State the ratio of prairie to timber in your section.
33. State all you know in reference to the habits of the young or grown insects during the night: where they remain; whether they ever march, continue to fly, eat, &c.
34. At what rate do swarms move during flight?

NEBRASKA DATA.

HOOPER, DODGE COUNTY, *May* 14, 1877.

The first time I noticed the Rocky Mountain locust in this locality was June or July, 1859. They have since then, up to the year 1866, made short visits, never doing any damage to the crops, nor did they at any time leave any eggs behind them. About the middle of September of the year last mentioned they came upon us from the northwest in full force, and their numbers were legions; they came, too, to stay until the first slight frost in October finished their earthly existence, seemingly all dying in one night; not until, however, they had left us a large crop of eggs and destroyed fully one-third of the corn crop. The eggs hatched the following spring, numerously in April, and the young pest seemed to outnumber the old swarm, living for a time, as it were, to devour everything tinted green, avoiding, after all, the tender corn blades. But plenty of moisture and fine growing weather checked their voracious appetites, and the damage done was confined only to narrow strips of wheat. We were visited by them time and again, sometimes from the south, sometimes from the north, once destroying the oat crop, another time the corn crop, but have never, as yet, seriously injured the wheat crop.

Question 1. In 1876, wind northwest, fresh breeze. The first swarm arrived here August 15, 4 o'clock p. m.

1 *b*. Clear, warm, with occasional flying dark clouds. The swarms were seen for three hours in the distance; mistaken by some for banks of clouds.

1 *c*. Covering a breadth of 30 miles; from northwest; dense enough to darken the sun perceptibly; 500 feet in depth.

Question 2. In 1876; on every dry day; when the wind was favorable, from the northwest or west; for some ten days; swarms were leaving each day to the south and southeast, others arriving from the west and northwest, and for two weeks longer deposited their eggs, leaving as soon as the work was completed. Those which are hatched in the north have uniformly gone to the southeast, while the eggs which were deposited when hatched as uniformly move in the direction the parents came from. The *Caloptenus spretus* has such a spread of gauzy wings that it can neither fly when the air is damp nor against the wind; it rises only when the dew is off, 10 to 11 a. m., 4 to 5 p. m., and with no wind move about five miles an hour, or faster with the breeze, and high or low as the air is more or less dry, and highest at noon.

Question 3. The eggs in 1877 hatched very uneven, owing, as is supposed, from being deposited in more varied soils; most of the eggs hatched between the 10th and 20th April.

Question 5. From the 10th to the 30th of April.

Question 6. One-third. First, because of mild winter weather. Moisture is the only condition that will spoil the eggs; cold will not do it, neither before nor after development has begun. Second, because it is claimed, and correctly too, that some of the eggs were hatched last fall; have seen eggs hatched two or three years ago in the middle of August that were dropped about three weeks before, but the young 'hoppers so hatched were not nearly as numerous as their parents were.

Question 7. Dry, sandy, naked, hard, or compact soil, in the sod of new breakings and on roadsides; it is on or near these places where the damage is now committed and where the insects are now congregated in flocks of untold millions, while there are also large spaces of prairie and cultivated spots intersecting where there is not a grasshopper to be found.

Question 9. An average of 50 days after hatching, being about June 25 to 30, as formerly.

Question 10. A period of not less than ten days will elapse after full wings are grown, to all appearance, before they will actually marshal their hosts; which will bring it, as in 1867 and 1874, to the last days in June, and before which there is no hope of being rid of them in this locality.

Question 11. Up to May 13; about one-sixth of wheat and one-third of gardens.

Question 12. Wheat and gardens.

Question 13. All small grain.

Question 14. Last year there was none but corn, flax, potatoes, tobacco, and late gardens in 1875; they came from the south in August, about the 1st, again, injuring the corn crop most.

Question 15. Those hatched here invariably go northwest; they go in no definite direction before their wings are of full length, and then spend some ten days in exercising their muscle in short flights, increasing from ten feet to twenty rods. In damp weather and nights they huddle and lie still on clods, weeds, trees, corn and wheat stalks.

Question 16. A few have been burning them by stringing out straw, and in cool nights, when they seek the straw for shelter, it is set on fire, leaving the ground covered with red-burned 'hoppers; some have bought or made machines or traps, and have used them with good success, sufficient to establish the fact that hereafter no crops will be destroyed by the young 'hoppers if all will take hold, burn, ditch, and catch them; and last, but not least, protect the birds; also turning under deep the eggs on cultivated soil before putting in crops.

Question 17. None.

Question 18. The essential features of these machines or traps are: 1st, a platform that runs on the ground, on runners or wheels; 2d, a canopy meeting the platform at an angle; 3d, a reservoir at the junction of the two, containing water or coal-oil, either or both. The 'hoppers jumping up strike against the canopy while the machine is in motion and will fall into the reservoir.

Question 20. About every other year.

Question 21. Nearly all birds, domestic or wild, limit their work of destroying the insects by their capacity, such as blackbirds, snowbirds, prairie-chickens: and, finally, machines or traps, are capable of saving the crop in the worst grasshopper year if bred here, and the birds, if as plenty as they should be, will take care that the infliction be not permanent.

Question 24. By the young, the tender blades of wheat; by the old, corn; and when the oats are about ripe they seem to relish or prefer to cut off kernels of oats between the kernel and the straw.

Question 25. Broom-corn and sugar-cane.

Question 26. Never injured them worth mentioning.

Question 28. Scarcely any.

Question 29. From 5 to 10 per cent.

Question 30. They eat and eat during the daytime, and in 1867 would eat off a strip of wheat, and, if grown again, return to the original place. During rainy days they lie still and do not eat; during cold they seek shelter behind clods and rubbish; they never move at night unless disturbed.

Question 31. From 5 to 20 miles an hour.

C. F. EISELEY.

PLEASANT HILL, SALINE COUNTY, *May* 21, 1877.

Question 1 *a*. North; light.

Question 1 *b*. Clear and dry.

Question 1 *c*. As far as the eye could reach, and dense enough to partially obscure the sun.

Question 2. Kept coming and going from 9 a. m. to 2 p. m.

Question 2 *a*. Northerly and light.

Question 2 *b*. Warm and dry.

Question 2 *c*. Southeast; density and extent moderate.

Question 3. None the present year.

Question 4. May 19, 1877. Came out in vast quantities.

Question 5. About the same time in 1855; not as numerous. None in 1876.

Question 6. About half; cause, blowing off of covering by wind and exposure to the elements.

Question 7. On naked, hard, dry ground, such as well-fed pastures, old roads, &c.

Question 8. Dryest and hardest ground.

Question 9. In 1875 got wings about June 1.

Question 10. About June 10.

Question 11. Nothing yet this year.

Question 15. I think they have no given direction of travel. Their line of march depends on the surface of the ground and proximity of crops.

Question 16. There has been no means tried by us yet except burning. Several farmers have scattered straw along the edge of their fields. The young 'hoppers collect in the straw in great quantities. Some farmers claim to have destroyed five or six bushels at one burning.

Question 17. Nothing of that kind has yet been attempted.

Question 18. We have as yet nothing of the kind.

Question 19. We had no locusts at all in the spring of 1876. In the fall they came in on us from the northwest.

Question 20. In 1874 they came in from the northwest about August 10; the season was exceedingly hot and dry, thermometer reaching 114° in the shade. The locusts were very ravenous, eating everything before them, but deposited eggs sparingly. Last fall they ate but little, but deposited eggs in enormous quantities in many places, as many as three hundred to the square inch.

Question 21. All our domestic fowls eat them in vast quantities; our little chickens just hatched live on the young ones without other food. All wild birds prey upon them, especially the prairie-chickens and quails. It is believed that a prairie-chicken eats one pint per day; quails about one-half that quantity. The bird which has done us the best service is a blackbird with a yellowish-white head and wings; never noticed it here until this season. They came in great quantities, probably a thousand in a flock; they marched over the field like a band of soldiers, cleaning the ground clean where it was actually black with 'hoppers; on a pasture field of about eighteen acres they destroyed about five bushels a day. If these birds remain with us, we will have no full-fledged 'hoppers this year, or very few at most.

Question 22. Have none.

Question 23. I heard a great deal about eggs hatching in the fall, but have no evidence that any did.

Question 24. They take everything but sorghum and pumpkin vines, and have a particular regard for tobacco and onions.

Question 26. Have never injured the native grasses as far as I know. Are particularly destructive to timothy, but don't seem to relish blue-grass. We have not enough clover in this county to give an estimate.

Question 27. I know no quadrupeds or reptiles (except snakes) that eat them.

Question 28. Nothing of the kind has been done in this section of the country.

Question 29. Timber very scarce, probably not one-fiftieth.

Question 30. The young insects are quiet during the night, crawling under old rubbish and into the ground. The large full-fledged ones collect on shrubs and trees in quantities sufficient sometimes to bend the trees. When on the wing, I think they fly night and day. In June and July, 1875, there was an uninterrupted flight about 50 days, moving continually in a northerly and westerly direction.

Question 31. Owing to the force of the wind, from 4 to 30 miles per hour.

E. S. ABBOTT.

FARMERS' VALLEY, HAMILTON COUNTY, *May* 24, 1877.

Question 30. This spring the young insects toward night went to the high grass or stalks in the field for shelter, and would remain there during a storm; when it was again pleasant they emerged, to continue their devastation. They will eat, when full grown, during the night. I had a field of corn, in 1874, that was standing, and not seriously damaged, when night commenced; the next morning it was only corn-stalks, leaves and ears having been eaten as early as daybreak. When the insects drop on us in swarms, they remain only as long as the wind is unfavorable to their apparently desired course; but as soon as the wind changes to suit, they depart.

J. VOSBURGH.

STEELE CITY, JEFFERSON COUNTY,
August 24, 1876—10 a. m.

Question 1*a*. The wind had been south for three or four days, changed to the north about 9 or 9.30 a. m., and the 'hoppers soon came with it.

1*b*. The morning had been hot and sultry; the north wind brought the 'hoppers. The sky was clear, no clouds.

1*c*. South with wind. Density: As we looked toward the sun we could see them floating with the wind as high as the eye could reach, till they looked like tiny snow-flakes, so high above us—I should think nearly half a mile; and they were probably as thick to a much greater height. They were flying thickest at noon, and by six o'clock they had mostly quit flying. About nine the next morning they commenced rising and flying again about as thick as on the previous day, some leaving and others coming to take their places. The 26th the wind was south all day. They rose as on the previous day, as if they were uneasy, but could not go against the wind, nor did they show any inclination to take the back track and go with it. The 27th the wind was still south, and they appeared more contented, commenced coupling, and laying eggs.

Question 2. They commenced leaving on the 31st, flying about the same as when they first came. After this I kept no record of their movements, but there was more or less coming and going every time we had a clear day and north wind, though there was more left than came, so that by frost the most were gone.

Question 4. The eggs began to hatch about the 20th of March in large quantities. One old gentleman said that he was on a wheat-field in the Blue Valley the day before, and they were nearly as thick as they could be. About one-eighth to one-fourth of an inch in length, and at least half an inch thick on the ground. This was on a sandy soil, near timber. I think the eggs were most numerously hatching in April.

D. T. GANTT.

NEBO, PLATTE COUNTY, *June* 16, 1877.

The 14th, the wind being strong from the southwest, clear and warm, the locusts were on the wing, the air was full, bearing a little west of north. Now and then a straggler came down. About three o'clock they had all passed. I suppose they were a Texas delegation. Our own hatch is about half-grown.

JOHN WISE.

NORTH PLATTE, LINCOLN COUNTY, *June* 1, 1877.

The *Caloptenus spretus* has been passing this place since the 27th instant, going north 30° west in immense swarms. They are very high, 1,000 to 3,000 feet; only a few have stopped here.

In 1873 saw a swarm, July 6, in latitude 40°, longitude 100° 15′ west, passing southeast, but saw none in the settled part of the State.

In 1874 they came from northwest, June 27 to August 6, then traveled northwest to October 3, but did no damage in this locality.

In 1875, May 20, latitude 42°, longitude 103°, saw large swarms going north 30° west. June 6, at Camp Sheridan, saw them every day until the 10th go northwest. June 21 latitude 41° 30′ north, longitude 101° west, saw them go southeast; continued to go southeast each day when wind was favorable until August 5, then they began to go southwest and continued to October 1. This is the first season that they have done much damage here; they took all the crops. They lodged against the snowy range of the Rocky Mountains in immense numbers and perished in the snow. A friend of mine says they were six inches deep on the snow.

In 1876, June 20, flew southeast to July 25, then drifted every way the balance of the season; did but little damage west of longitude 100° 30′ west. Laid their eggs south of latitude 41° from Colorado at least east to 100th meridian. None north of this line.

In 1877, April 25, parties coming in from Republican Valley say that the country is full of young 'hoppers from the bluffs south of the Platte to south line of the State; April 12, I started for Niobrara River, returned April 25; saw none on the route. May 12 went to Republican River, then up to the White Man's Fork; saw very few young 'hoppers; the people said that the heavy rain had destroyed them.

J. W. LA MUNYON.

CHAPMAN, MERRICK COUNTY, *May* 18, 1877.

Question 19. Our section was most severely visited in 1876.

Question 20. Was visited in 1873, about May 15, and did considerable damage to the wheat, the only crop we had at that date; staid about forty-eight hours; was cool and damp while they stopped; they traveled from southwest to northeast; again in 1876 (in wheat harvest), probably about July 15; came from northwest; injured the late wheat, destroyed the entire corn crop, potatoes, melons, and garden truck in general.

Question 31. They always travel with the wind, *i. e.*, the same direction; of nearly a calm day they travel as fast as the wind; but when the wind is strong they right-about face, letting the wind carry them. They always stop when the wind changes. In 1876 they came from the northwest, nearly covering the ground and all vegetation. It was a bright clear day; they staid fourteen days, eating everything but native grasses and plants most repugnant to them; they, for the first time, deposited eggs with us, and they hatched out this spring by the millions, but did not grow any, and consequently died when a few days old. At the present writing—five weeks from the first hatching—there is scarcely one to be found, and at no time were they any larger than when first hatched. We think the cool, wet weather is the probable cause of their dying.

H. M. COX.

PONCA, DIXON COUNTY, *August* 9.

August 9, 1872.—The 'hoppers (a small flight) came down upon us, remaining about three and a half days, doing very little damage.

May 28, 1873.—At about noon to-day we were visited by any amount of Mormon grasshoppers; they went to work immediately depositing their eggs, doing but little damage to vegetation.

June 5.—The 'hoppers about all left to-day. In the spring of 1874 the eggs hatched early and in abundance; they destroyed some fields of small grain entirely, and some fields were only slightly injured. Our small grain was good, notwithstanding.

They left us as soon as they could fly; but on July 17, 1874, was our terrible suffering. Legions came upon us, destroying our entire crop of corn, potatoes, cabbage, and all gardens without exception unless smoked day and night; some saved their cabbages in this way; everything they could light on was covered; sheds, trees, and the earth could not be seen for them; even the cottonwoods and soft maples suffered considerably, the leaves being eaten off; they killed several soft maple trees by gnawing the bark off; box elder they did not trouble; on July 21, after staying with us five days and six nights, they left. I forgot to say they began to light down upon us at four o'clock in the afternoon and quit at half past six. When they left, on the morning of the 21st, the sun was partially obscured, so dense was the cloud of 'hoppers.

August 6, 1876.—A day long to be remembered by us. Millions of 'hoppers lit down upon us, partially destroying our corn, totally destroying our gardens and potatoes, doing immense damage.

On the 13th this first flight left for the south. Between the 13th and 17th two more flights lit down, leaving on the 18th towards evening, as our vegetation was all gone, seeking for something to eat southward.

J. ROCKWILL.

FREMONT, *May* 11, 1877.

Question 23. Have not had eggs hatch here in fall. In 1873 the Texas 'hopper deposited eggs here in June; these hatched in about two weeks, I think.

OGALALLA, KEITH COUNTY, *June* 13, 1877.

Swarms were observed passing northward over this place on the 26th, 27th, and 28th of May. They were flying high, did not appear to be very dense, and I have no knowledge of their extent. They were going with a light wind from the south, moving northward varying slightly to the westward; weather moderately warm and nearly clear; were passing or noticed from 9 a. m. to 3 p. m.

The large swarms have never stopped long in this section, there being no farming done here. They do not appear to do much harm to the grass.

W. P. P. ST. CLAIR.

ALBION, BOONE COUNTY, *May* 17, 1877.

We have been visited by the flying locusts four out of the five last years, yet in one of the four years very little damage was done to crops. In 1874 they were flying in a southerly direction, commencing their ravages here about the middle of July; corn crop entirely destroyed, and small grain about half. The following fall Southeastern Nebraska,, Southwestern Iowa, Missouri, and Kansas were literally filled with eggs. The next year (1875) they were flying in the opposite direction, towards the north. In 1876 it was again reversed, and they returned south, entirely destroying the corn crop, but were too late to do much harm to other grain; gardens, however, were destroyed. Commenced flying about the middle of August.

My observations of their movements and habits in the year I have named have led me to the following conclusions:

First. That they fly north and south (or nearly in that direction) in alternate years over this section of country.

Secondly. That there is no particular time of day in which they alight or rise, depending entirely and absolutely on the course of the wind, either favorable or unfavorable for the course in which they are moving. I have seen fields literally covered with them in almost all kinds of weather, clear, cloudy, and rainy.

I have seen them flying very thick just before a heavy shower and immediately after it, and yet did not come down, which has suggested the idea that they may rise above the rain during that time. If not, they certainly must fly through it.

Again, during the season of their migration, either north or south, the wind blows from the south, or say from between the points, southeast and southwest.

In 1874 and 1876 they were moving from north to south (and only move with favorble winds), destroying our crops each year, in consequence of the almost continual south wind detaining them sometimes a week at a time.

In 1875 they were fully as numerous, and commenced their ravages fully as often as in either of the other years I have mentioned, yet the wind being favorable nearly all the time for flight in the direction they were pursuing, their stay was very short at all times during the season.

I have never known them to alight while a favorable wind was blowing, neither have I ever known them to remain an hour after a favorable wind commenced blowing.

I do not wish to be understood to mean that they are confined to a particular or exact point of compass, but that, when they are going south, it may range from southeast to southwest.

LORAN CLARK.

PLATTSMOUTH, CASS COUNTY, *June* 7, 1877.

Question 1. *July* 2, 1867.—General southerly to northerly direction on gentle breeze (Signal-Office nomenclature of winds) from south. First noticed about 9 a. m., continued on the 3d in a heavy body, as also on the 4th till 3 p. m., when a heavy rain of 1.60 inches in 1½ hours obscured (?) them. A very few were found on the ground after the storm, but not .0001 of what were seen before the clouds obscured them. What became of them? Frequent observations since have shown that when flying with a wind which brings a storm they simply disappear from view as the clouds obscure the sky. But if a wind reverse to their course meets them they come down in large numbers. The 2d, 3d, and 4th, up to 3 p. m., were nearly or quite clear, and wind continued southerly.

August 8, 10, and 11, 1868.—Each day much the same, calm and but few clouds in the forenoon, and immense swarms passing from south to north, but each day from 1 to 3 p. m. a northwesterly to northerly wind from strong to fresh brought them down like a hail-storm.

Many memorandums were made of flights and arrivals from 1868 to 1875, too lengthy to copy, but all to this general effect. They were invisible when passing overhead till near 9 o'clock a. m., or in the afternoon much after 3 p. m. They must be nearly in a line with the sun to be visible, and the sun falling below this angle of some 45°, leaving untold myriads of them in the air. Yet I never knew them to come down after that time, unless driven down by an opposing wind. Again, in June, 1875, from the 13th to the 24th, on every day, if the sun shone out, they were passing over, but none were seen descending at night. The locusts rarely move much in the morning, till the sun warms up the air as also the locust, and I have no record or recollection of their rising till from 9 a. m. to 11. a. m., yet the mass above would be seen by or before that time high up on their regular course. Such immense masses could not descend each night without literally covering and burying the ground. Does the main army continue its march night and day, only dropping a few stragglers as they become too weary or hungry to keep up?

Question 1 *b. August*, 1868.—On the 8th, 18th, 19th, and 20th days of flight the thermometer ranged from 57° to 86°.

July, 1875.—From the 13th to the 22d the maximum temperature was from 70 to 94°, the minimum from 52° to 66°.

June 14 *and* 16, 1876.—(Flight from northeast to north on northerly winds); temperature 57° to 79°.

August 24 *to* 28.—Northeast wind; temperature 59° to 86°.

August 29.—Wind south; immense numbers; temperature 74° to 86°.

I do not think they rise to join the crowd above. I never knew them to rise unless there were swarms passing over at the time, in cloudy weather. Still, when in regular flight, I do not think clouds stop them, although it obscures them from view. As the sun has appeared through broken clouds I have often seen them passing, while when the sun was obscured they were invisible.

Question 1 *a and c*. Invariably in the direction of the wind, be its force more or less.

Question 1 *c*. By arranging the focal distance of a spy-glass to fit objects at a known horizontal distance, and comparison of appearance and size of locusts, I think the passing swarms are generally from one-half to one mile high, varying at times, probably seeking currents of wind or greater or less velocity. In case of sudden and heavy rains, when the air was full of them, none of consequence came down with the rain. It seems impossible that they could fly through the storm. Do they rise above it? In heavy swarms my glasses show them as dense as they can move without interference. The extent of the swarms it is difficult to ascertain, as the observer can only see a small belt. They may extend indefinitely right or left. During the flight from June 15 to 25, of 1875, I telegraphed east and west, and found a continuous line moving northward of 110 miles, and then somewhat broken 40 miles further. The movement of the wind for five days (15th to 20th) averaged about 10 miles per hour; and the locusts evidently moved considerably faster than the wind, at least 15 miles per hour. The swarm I estimated at from one-quarter to one-half mile deep. It seemed like piercing the milky-way of the heavens; my glasses found no limit to them. They might have been a mile or more in depth. They were visible from six to seven hours each of the successive five days, and I can see no reason to suppose their flight was checked during the whole five days. If so, the army in the line of advance would be 120 hours × 15 miles per hour = 1,800 miles in length, and say at even 110 miles in width an area of 198,000 miles! and then from one-quarter to one-half mile deep. This is utterly incredible. Yet how can we put it aside?

Question 2. According to all my records and recollections they rise to depart between 9 a. m. and 12 m., and never unless there is a swarm in motion overhead.

Question 2*a*. *June* 13 *to* 15, 1868.—Toward northwest on a southeast wind.

June 20, 1869.—After a four days' southerly wind, they came down largely on a north wind.

June 13 *to* 22, 1875.—The air was full of them nearly every day, the wind generally from south or southeast. The locusts went with it; two short changes to northeast brought them to the ground.

June 24.—During the forenoon the wind was light from the north and locusts came with it (a rare case). At noon a full calm and progress stopped. They circled round and round, and many came down.

June 25 *to* 28.—Wind southeast. Locusts went on it to northwest.

July 2, 1875.—With an east wind flew westward.

July 7.—Southeast wind, and to the northwest.

June 14 *and* 15, 1876.—To the southward on northerly winds.

August 10.—No wind and no general course.

August 24 *and* 25.—Northwest and northeast winds brought a few. On the above times the wind was generally light, from 5 to 10 miles per hour; the weather fair, of course, where the locusts were visible, for they are invisible in cloudy weather.

Question 2*b*. The temperature at the time of rising has ranged from 70° to 90°. Cold or cool weather renders them sluggish.

Question 2*c*. The direction always corresponds with the flocks they join, of which I have spoken above. I have rarely seen a large number rise at once. The lower air will be very full of them, but at least four-fifths of them rise, take long horizontal flights, but, seemingly unable to rise, come to the ground again. I presume they have to make several efforts before they succeed.

Question 3. August 24, 1876, I first noticed them.

Question 7.—A compact earth, as a path or firm, solid, bare ground, with fair exposure to the sun. It must not be too hard, as the central part of a road or path beat very hard.

Question 8. Warm sunny exposures, not beaten too hard.

Question 9. June 5, 1875.—A neighbor reports that a few came down June 6, 1877.
Question 10. From June 12 to 20.
Question 12. Wheat, oats, corn, and garden vegetables.
Question 13. I know of no effectual protection.
Question 14. Potatoes, pease, and sorghum.
Question 15. I have no knowledge of any course except toward food.
Question 16. Firing prairies and straw piles, and some machinery, have been tried. As eggs are rarely deposited on the prairie sod, burning it is useless, except as it borders cultivated grounds, where it may catch some who have traveled from the bare fields to the bordering grass for food.
Question 17. None.
Question 18. Of machinery, three or four have been used, but, as far as I can learn, with no very desirable effect.
Question 19. We were heavily visited in 1876.
Question 21. 1857, 1858, 1861, 1864, 1867, 1868, 1869, 1873, and 1875.

Domestic fowls, so far as garden lots, home lots, &c., are concerned, are of much value; if in sufficient numbers but few eggs or locusts will escape them.

With regard to birds, my residence is largely surrounded by shrubbery and trees, which draw large numbers and varieties of birds. I have closely watched them for years, and, although they may be of service against the locusts, I cannot testify to much in their favor. I protect them from all enemies as far as possible, but it is a very rare case to see any one of them in evident pursuit of the young locust.

Question 23. I *know* nothing. I have reports that different persons saw a few last fall, but I doubt the fact.

Question 24. Cabbage, turnips, and wheat—the young plants—seem to be universally a favorite food, but circumstances or tastes seem to vary in most other plants. In one field certain plants are entirely devoured and others close at hand untouched, while in others it is exactly the reverse. My neighbor on an adjoining lot had his lettuce and pease entirely destroyed, while his other plants were untouched. In mine nearly all are gone but my lettuce and pease, which are unharmed. Many like cases have come to my knowledge, both with the young and the old.

I know nothing of any marching or traveling except as they march across a field of grain or other food and leave a bare plain behind them. When on the wing I am inclined to think they fly all night.

Their movement must be regulated largely by the wind they are on, and this they out-travel, according to my observation, at least one-half.

Yesterday, July 22, about noon, I noticed they were passing over in very large numbers; a light southerly wind bore them northward. I gave my entire attention to them, and watched them, assisted with a spy-glass. The swarm was of great depth, at least one-fourth mile; how wide I had no means of determining—through some peculiarity of the atmosphere, probably aided by a lower flight than usual. (The barometer indicated from 30.019 to 30.062 inches pressure.) I kept them in view till after 7 p. m. with no perceptible diminution of numbers. Careful observation in the evening and again this morning shows not a single one on the ground.

At 8½ a. m. this morning I succeeded in getting sight of them again overhead, and as the sun rose higher developed numbers about the same as yesterday. (Query: Was the line continuous through the night?)

For several years I have observed the locust and have seen no exception to the general rule that it is very sluggish in the cool of the morning, *i. e.*, on the earth. It does not leave its perch, roost, or bed, voluntarily until the air is warmed up from 8 to 10 a. m. Supposing this swarm had descended somewhere, it must have literally more than covered the ground. Yet, in violation of their general habit of late rising here, they are at 8½ a. m. in regular flight overhead. The thermometer at 9 p. m. (last night) was at 68°, at 7 a. m. this morning 64°. A minimum thermometer fell during the night to 55°, altogether too cool for them to have risen from the earth to recommence their flight this morning. But, on the other side, if cold renders the locust sluggish, how does it succeed in keeping on its way in the upper strata of air, which must be much colder than on the earth? Does its action evolve sufficient heat to enable it to keep up its flight?

When met by opposing winds, I have seen them come down in large numbers, but by common consent to descend *en masse;* I have no knowledge of it. I see no way to avoid the conclusion that they fly all night.

A. L. CHILD. *M. D.*

GRAND ISLAND, HALL COUNTY, *May* 12, 1877.

Question 4. April 13 and 14, 1877, the eggs were most numerously hatching on my farm (bottom land), while I learn that on higher and dryer locations they hatched in great numbers about one week earlier.

Question 5. Probably one-fourth of the eggs originally deposited failed to hatch the present year. I frequently found a smallish white maggot occupying the egg-sack, which was emptied from the original contents. I believe the failure to hatch was owing partly to the warm weather during winter and early spring, which caused early deposited eggs to approach the period of hatching so near that subsequent hard freezing caused them to addle.

Question 7. In warm and sandy, well-settled soil; such as cornfields, orchards, and pasture land where the grass had been eaten off by stock rather close, and where bare spots were frequent.

Question 16. The means effectually employed in this section of the country to destroy the young insects is principally the so-called "*Canfield Grasshopper Exterminator.*" I have killed four nail-kegs full* within three days.

Question 18. Coal-oil, used to the depth of about one-fourth of an inch in the machine, is the medium by which millions of young 'hoppers are killed in a very short time by dragging the machine over the ground infested by them. In sowing the killed 'hoppers along the border of grain-fields I have kept the living ones from entering the grain-fields and also have driven them away from spots in the orchard and grove where the young 'hoppers could not be caught on account of the trees and shrubbery.

We settled in this county (Hall) in July, 1857, and we did not notice any grasshoppers until August 1862. The swarm appeared then and came with northwest wind. Weather clear.

August 1, 1864, the hoppers made their appearance again.

July 15, 1875, all the buckwheat in the county was destroyed by them, but no other crops.

July 8, 1866, grasshoppers came in large swarms, doing a great deal of harm: northwest wind brought them; weather clear.

In 1868, appeared again but did no damage.

In 1869, came in the early days of August and destroyed nearly all the corn crops in Hall County.

In 1873, May 22, came in large swarms with southwest wind; damage light. They left with southwest wind.

In 1874, July 20, 21, and 22, also August 5 and 6, came in swarms which at times darkened the sky. Wind north and northwest; weather clear. Nearly all the crops, in particular corn crops, in Hall County were destroyed, but hardly any eggs were deposited by them here. They left before depositing their eggs and went into the southeast part of Nebraska, into Kansas and Iowa.

In 1875, June 24, appeared again in this county with southwest wind; August 8, and 10, with northwest wind, and the damage done in August was considerable. The greater number of them, however, in 1875, were diseased and fell dead frequently when flying.

Maggots numbering from one to eleven in each 'hopper were feeding on them in their bodies. Also little red parasites were frequently noticed fastened to the wings or bodies of them.

In 1876, August 5, first swarm seen here, at 3 p.m., with northwest wind, weather clear. This swarm, however, was not very large. August 10 and 12, at noon, large swarms of them arrived with northwest wind, weather clear, and commenced depositing eggs about August 13 or 14. On the 14th some left, but at the same time more and still larger swarms arrived; weather clear and northwest wind prevailing. I worked hard with ten hands for ten days to save my corn crop, vegetable garden, and orchard, by smudging fires, adding freely pulverized sulphur, but eventually had to abandon one field after another, thus leaving the 'hoppers the victors. They stripped every fruit tree of its foliage and took even the bark off the large limbs. They continued depositing their eggs until the 23d and 24th of August, when the wind which ever since the 15th had blown from the south and southwest changed to the north and northwest, which carried all those that were able to fly south and southeast.

The extent of country devastated by them—coming from north and northwest—reached from about the western boundary line of Nebraska to the Missouri, as far as the State of Nebraska is concerned, and from the Platte bottom toward the northern boundary of the State; while farmers 25 miles south of here got fair corn crops on account of the grasshoppers reaching them from ten to fourteen days later than they reached us.

In Hall County nearly all vegetables were destroyed by them—the early potatoes excepted.

The full grown 'hoppers relished, of fruit-trees, the foliage of apple trees more than of crab-apple, pear, peach, cherry, or plum trees; still all were more or less damaged. Plum and crab-apple the least. Of forest trees, the coffee-bean tree, ash-leaf maple or box elder, soft maple, honey-locust, elm, beach, willow, Rocky Mountain evergeen, red and white cedar were injured and eaten by them but little; while the black locust, white and gray willow, white ash, catalpa, cottonwood, silver poplar, black and white walnut, European larch, American larch, Scotch pine, white pine, Norway

* Mr. Thomas was at the house of the writer when he was fighting the young locusts and saw one keg full of the very young insects.

spruce, were eaten off and injured a great deal more than those trees enumerated first. The grape vines—the cultivated as well as the wild—were let alone until the apple trees all were stripped.

Question 26. The native grasses were injured but very little, while timothy, blue grass, red-top, and clover were eaten off clean by the full-grown 'hoppers.

Question 27. Wild as well as tame pigeons are feeding as well on grasshopper eggs as on the young 'hoppers, but I never saw them touch the grown insects. Domestic chickens and turkies, as well as prairie chickens, grouse, and quails partake of them at any time and in any state of development. Soon after you left here, large flocks of various kinds of black birds appeared, and have been feeding upon the young 'hoppers ever since. These birds have destroyed a fabulous number of the young 'hoppers, and are still at it.

Question 28. Deep plowing last autumn, so far it seems, with a good and satisfactory result.

Question 30. The young 'hoppers, soon after they are hatched, on mild days, will, towards evening, climb bushes, poles, sticks, small trees, and the dead stalks of grasses and corn. On wet and cold days they seek shelter and refuge in dry grass near the ground, under litter and rubbish or dead leaves; in fact, anything that will shield them best against the cold and wet. I have noticed them to work a hole with their hind legs and cover themselves with earth immediately previous to cold and wet weather, where the soil would permit them to do so. This led many farmers to believe them destroyed in consequence of a hard snow and rain storm of several days' duration, while experience proved that where the least shelter was offered them but few of the young 'hoppers died in consequence of snow and cold.

WM. STOLLEY.

GENOA, PLATTE COUNTY, *August* 1, 1877.

The movements of the locusts for the past month have been as follows:

From the 5th to the 13th the flight was to the north, the wind being generally from the south and southwest, then an intermission; then another flight from the 21st to the 25th in the same direction. On the 29th these insects commenced going south, and descended in considerable numbers though without doing much injury, the wind from the west at the time. On the 30th they went north, while the wind was fresh from southwest. On the 31st they again went south and southwest, while the wind was from the northeast. The time of moving was from 11 a. m. to 2 p. m.

SEPTEMBER 1, 1877.

During the past month the movements of the locusts from the 1st to the 21st have been towards the south and southwest, favored by winds from the north and northeast, the only exception being on the 19th, when, the wind being south, they were observed going towards the north. The 21st, date of the last observation of them, I presume to be the end of them for this season. From what I have seen, I infer that under favorable circumstances the locusts go north from the middle of June to the middle of July, varying a day or two from one season to another, and under similar circumstances they go south from the middle of July to the latter part of August, but whether it be the same flocks or not will be difficult to determine; but of this I feel satisfied, that, with favorable winds at the time of such migrations, the people of Nebraska need have no fears of them,

GEO. S. TRUMAN.

SUNLIGHT, CASS COUNTY, *May* 1, 1877.

Question 1. 1874, 2 p. m., July 26.
1*a*. Wind from northwest; light breeze.
1*b*. Clear.
1*c*. To southeast in clouds, low, flying, and lighting all the evening.
1875. First saw flying ones 11 a. m., June 3, but few, most on 19th.
1*a*. From south; light breeze.
1*b*. Clear.
1*c*. To the north, but few, quite high.
1876. August 24, 10 a. m.
1*a*. Light breeze from northwest.
1*b*. Clear.
1*c*. Southeast, but few, quite high (following day alighted thick).
Question 2. 1874, September 4, 2 p. m.
2*a*. From northwest to southeast; breezy.
2*b*. Clear.
2*c*. To southeast; all got away that day.
1875. Flew northwest and north from June 3; very thick on 16th.
1876. About 30th August.

2*a*. From northwest; gale.

2*b*. Clear.

2*c*. To southeast, part going and part remaining, till they perished by cold and starvation.

Question 3. No eggs deposited.

Question 4. 15th ultimo.

Question 5. May 10, 1875.

Question 6. But few failed.

Question 7. Soil, with a clay tendency and well drained.

Question 8. Same as above.

Question 9. 1875, about June 3. Haven't wings the present year.

Question 10. Same as above.

Question 11. In county, 1874, 125 per cent.; 1875, 50 per cent.; 1876, 10 per cent.

Question 12. 1874. Corn and vegetables.

1875. Wheat, barley, and vegetables.

1876. Corn and vegetables.

Question 15. They march for some field of grain, and stay there until fledged, if good picking.

Question 16. Burning prairie grass, placing straw or hay where thick and burning; satisfactory.

Question 19. Visited in 1876.

Question 20. 1874, July 26; 1875, from 3d till last of June. Also hatched.

Question 21. Very useful.

Question 23. Never known any to hatch.

Question 24. Radishes, cabbage, onions, rhubarb, tansy, wild and tamebuck wheat.

Question 25. Peas, tomatoes, sweet and Irish potatoes, vines of all kinds.

Question 26. No damage yet.

Question 27. Hogs, squirrels (prairie, gray, and striped), chickens, and wild birds of different kinds.

Question 28. Fall plowing.

Question 29. 98 to 100.

Question 30. Only saw the grown ones fly up to roost in the evening. The young, of a dry evening, crawl up on stubble or weeds cast off by the machine, but of a wet, get under shelter. Saw first 'hoppers hatching this year, April 15. (Some of our natives have been flying a number of days.) A large majority have hatched mostly last ten days; they are dying, I think, as fast as they hatch; cause, wet and cold. I find dead ones under stalks and grass where they have sheltered. I find but few larger than when first hatched.

T. N. BABBITT.

FALL CITY, RICHARDSON COUNTY, *May* 21, 1877.

Perhaps I ought to state at the beginning that I have lived here on the same 80 acres of land since the fall of 1865 (nearly twelve years), and have kept a journal all the time, so that data I give are not from memory, but from records made when there could be no mistake.

We have seen the locusts come in here five times, and at present the fifth swarm is being hatched. The first time we ever saw them they came in large numbers from the west, on September 7, 1866, and consequently the first hatch here was in the spring of 1867 (ten years ago). The season was wet and the eggs hatched late, as they are doing now, and I think there were quite as many eggs here then as now. Nearly all the wheat, oats, potatoes, and garden vegetables were ruined, except pease, which were not injured. The corn, which was thinned out in places by them before they left, made a good crop. In 1867 the first swarm that hatched here began leaving on June 28, and kept leaving, flying north and northwest, every day, when the weather was suitable, so that on the 4th of July but few were left here.

They came back again from the north in large numbers, but not so many as the year before (in the fall of 1867). In the spring of 1868 they hatched out early, so that they began leaving June 20, but they were not numerous enough to do us any serious damage.

In the fall of 1868 a swarm came back, but smaller than either of the others, and our crops suffered but little from the hatch of the spring of 1869. From the time that swarm left we were not visited again till August 9, 1874, when the swarm came in from the southwest. The eggs laid by them caused a total destruction of crops the next spring, and, as a consequence, nearly one-half of the farms in this county are mortgaged to-day.

In 1875 we saw a great many hatched on a south slope on the 19th of April. The weather was dry, and almost every egg seemed to hatch by the latter part of May. Almost every farm in the two counties, Nemaha and Richardson, were as bare as in mid-winter. After killing 200 apple-trees for me, they began to leave on the 11th of June. Then we planted our corn again; but when it came up it was again destroyed by a flying swarm that came down in a shower of rain. We planted our corn the third time the last of June and the first of July, so of course we had no ripe corn. What we put in cribs, most of it, began to heat, and we hauled it out for manure.

Last fall, it seems, we were favored; the 'hoppers did not get here till September 14. They had been near, both north and west, for several weeks, but a steady south wind kept them back, so there were not so many eggs laid as in 1874, and the season has been so wet that I have no doubt one-half of the eggs are rotten. Since May 9 it has rained every day except two. Very few 'hoppers are alive now, most of them being either picked up by the birds or drowned by the rains. I am glad to see you recommend plowing and harrowing in the Bulletin. We began to plow our roads in February, and our club has been planning and working to try to save our crops ever since, and it encourages us to know that our example has been followed nearly all over the county.

In 1876 the first eggs were deposited here September 15.

The eggs were most numerously hatching this year May 8, on the roadsides, abandoned roads, &c.

A neighbor saved his garden in 1875 by ditching around it 2 feet wide and 2 feet deep. Another saved his young apple-trees by whitewashing often.

GEORGE HUTCHINGS.

FRIEND, SALINE COUNTY, *June* 1, 1877.

The time that swarms of locusts arrive vary in accordance with the wind.

In 1873 the locust, in passing from the northeast, encountered a southwest wind, which caused them to alight in great numbers (August 27), at about 4 p. m. On the following day, the wind having changed to the north, a considerable number of them passed on towards the southwest.

In 1876 the first appearance of the locusts was August 25, at 3 p. m.; they came from the northwest, the wind being favorable to their general course. They evinced no inclination to migrate farther, but deposited their eggs and remained until the cold finally put an end to their existence.

Their descent has been either during clear warm days or upon the approach of sudden storms.

The general direction of swarms are alternately from north to south, going south, where they deposit their eggs, and when the young are sufficiently large to fly going north the next season. The departure varies according to the amount of dew on the ground. When there is no dew their departure will date as early as 7 to 8 a. m., and in other cases when the dew is sufficiently gone to allow them to become dry. They always fly with the wind, and in case the wind is adverse they patiently wait for a favorable breeze.

They began to deposit eggs about September 1, and continued until the frosts put an end to it.

Eggs hatched most numerous from May 1 to 15. The date of hatching previously was May 1. The hatching was late this year on account of long cold rains.

Eggs are usually deposited in hard ground sloping toward the south. 1st. New breaking being the most preferred. 2d. Early fall plowed land.

The young were most numerously hatched on sod land (or what is termed in Nebraska new breaking).

The insects are full fledged about June 25, and take their flight about July 1.

This section was visited in 1876. Visited in 1874 and 1858.

Birds and domestic fowls have been very useful in destroying the full grown' hoppers In the fall of 1876 the prairie hen was so impregnated with the locust taste as to be unpalatable. Quails, prairie chickens, snipe, blackbirds, &c., have been killed in this vicinity with their crops filled with the eggs. At present Nebraska is trying to protect her birds by a law imposing heavy fines for the killing, robbing of nests, or having in possession any recently killed bird at any season of the year, and the probabilties are that it will be enforced. During the fall of 1876 my garden, 50 by 100 feet, was literally filled with eggs. Upon close examination I found 100 eggs to the square inch, and the running of a spade or hoe through the ground about one inch below the surface made a noise like distinct skirmishing, so numerous were the eggs. At that time I had seven of the common chickens, and I noticed that they were scratching up the ground along the margin of some old onion beds for two or three mornings; after that I raked up one square rod with the garden rake, and by this time the fowls understood the business well enough to need no further assistance and in this manner went over the central plot.

This spring I have kept close watch, but not to exceed a dozen young insects have hatched. Suffice it to say that seven domestic fowls in about three weeks have entirely cleared about one-fourth of an acre of as thickly nested ground as Nebraska ever had.

No eggs are known to have hatched in the fall except by artificial means.

The young insects prefer onions, strawberry, wheat, oats, and barley. The old ones prefer onions, corn, and beyond that are not particular as to diet. Peas and sweet-potatoes are the least relished by both old and young locusts. Native grasses have not been injured by old or young insects to a degree so as to be visible.

The young and growing insects remain during the night in old grass, fallen weeds, piles of dry hay or straw, or under clods of earth, but never under the latter when the former is convenient.

E. WHITCOMB.

REPUBLICAN CITY, HARLAN COUNTY, *July* 31, 1877—3.15 p. m.

The locusts are passing over here to-day in vast numbers. Course from northeast to southwest. Temperature 89° in shade; have been flying since nine o'clock. The wind has been brisk until 12 m. Since that it is light. 'Hoppers are flying high and fast, wavering but little. Weather clear, was cloudy this morning, cleared about 8 a. m.

B. D. MILLS.

PLATTSMOUTH, CASS COUNTY, *June* 7, 1877.

The locust eggs have been hatching with us ever since early in April, and are still doing so in shaded cooler places, as also where turned under by the plow and less exposed to the heat of the sun. A few warm days in succession have repeatedly covered the ground with the newly-hatched insects. But one peculiarity has been observed and generally commented upon by all observers, viz, but a very small per cent. of the insects increase in size. They are still small, but just hatched; and, further, each successive hatching did not seem to increase the sum total. A very few are occasionally seen from one-half to three-quarters grown: while it is time (with former experience) that the earlier hatching should have wings and arrive at full growth, as the small swarm from the south yesterday also indicated.

We have, during May, had much rainy weather. Some severe storms that washed the ground somewhat severely, and some dead have been found on margins of streams; hence the general reply, although quite unsatisfactory, has been "drowned," "washed away," &c. Now a farmer, William B. Porter, a thoroughly reliable man, tells me to-day that yesterday he went over his wheat-field, and finding but few 'hoppers, where there had been many a few days before, he got down to the ground and carefully examined it, when under the *débris*, clods, &c., he found millions dead and many largely decayed. He could discover no insect or parasites upon them or other cause of death. The ground was not rolling enough to wash them off, supposing the rains have caused this destruction. My own experiments show that it is almost if not impossible to drown or freeze them to death, *i. e.*, at a single operation. But continued repetitions or series of rainy days (and we had ten successive days of rain) may wear them out at last.

A. L. CHILD, M. D.

SEPTEMBER 17, 1877.

The locust has been seen during many days since August 15 flying over, moving with the wind, generally in a westerly direction. None of consequence descending to the earth.

A. L. CHILD, M. D.

NORTH PLATTE, LINCOLN COUNTY, *June* 15, 1877.

I saw grasshoppers flying over (north) last week; think it was the first of the week. Have inquired of a number of persons, and so far have found no person that has seen any flying except on that day. I have been over on the north side of the North Platte River twice since the day they flew over, and saw very few; and, unless a person was looking for grasshoppers, they would not notice any. Last week was on south side of South Platte as far east as Warren; saw none that day.

Have lived in North Platte five years, and during that time, in the month of June, the country here has never been as free from grasshoppers as now.

J. H. McCONNELL.

FALLS CITY, RICHARDSON COUNTY, *May* 28, 1877.

Your opinion expressed in the Prairie Farmer that nearly all the eggs in Nebraska would hatch seems correct regarding this section. In the fall of 1874 the young 'hoppers or many of them formed in the eggs and hatched about the middle of April, 1875, a month earlier than this season. The flying 'hoppers came to this section about the 9th of August, in 1874, and began to deposit eggs at once. Last fall they came about the middle of September, which accounts for the lateness of the hatch this spring. Deep plowing under of the eggs is thought here the best plan as regards managing them. The nearer the time of hatching the plowing can be done is considered the best.

Eggs are deposited in many places where plowing is impracticable, and hence where the 'hoppers hatch out numerously in such places, unless destroyed, they will travel to and destroy crops. It is difficult to say here what crops or vegetation they prefer, as when here in 1875 they ate everything about clean as they went, except prairie grass and forest tree leaves. They are bound to eat and live even if they have to become cannibals. In this section they ate last fall all the early fall sowing of grain and grass seed.

C. C. SMITH.

PLEASANT HOME, POLK COUNTY, *August* 11, 1877.

The grasshoppers are flying in the air to-day, and have been for the last eight or ten days. They are not traveling in any particular direction, sometimes north, sometimes south, just whichever direction the wind is blowing. A good many alighted in my wheat field yesterday, and commenced cutting the heads off the wheat; they have not done any damage to amount to anything. The air has been full of them, but they have not traveled in swarms as they did last summer.

W. W. ELLIOTT.

G. M. Dodge's record of locust flights in Nebraska in 1877.

GLENCOE, DODGE COUNTY, NEBRASKA.

June 22.—*Spretus* has done little injury yet. During the last week a large number of the insects have pupated. The young appear to be moving north.

June 14.—Wind southwest; clear day; many grasshoppers flying, and some alighting; flying with the wind as they invariably do here.

June 16, 17.—Wind southwest and grasshoppers flying; few alighted.

June 22.—Wind southeast: grasshoppers flying; few or none alighted. Native grasshoppers (*Cal. minor* Lc. and *Gomph. clepsydra* Lc.) are just getting their wings; being ahead of *C. spretus*, but behind their usual season.

July 15, 18, 21.—Flying southwest abundantly; some alighted.

August 2.—Flying southwest; wind changed and they alighted, but were only thick on small areas.

August 5.—Wind light from northwest; *spretus* flying over and alighting; wind freshened in afternoon, and the new arrivals and those of August 2 all left.

August 7.—Clear. Flying southeast all day.

August 9.—Flying a steady stream all day southwest; some alighted.

August 11.—Flying southeast; arrivals of the 9th mostly left.

August 12.—Some flying northwest.

August 14, 15.—Flying southeast in great abundance.

August 16.—Flying abundantly southwest.

DATA FOR MINNESOTA.

MARSHFIELD, LINCOLN COUNTY, *August* 4, 1877.

Invariably since last communication, when the wind was in the east, north, or west, locusts have been flying over. The heaviest swarms when the wind was north, none flying with wind south or southwest, their general course to the southeast; none seen on the wing till about 11 o'clock a. m.; continue flying till sundown, how much longer impossible to tell.

Our county has suffered less from locusts than counties further east. Only one year in the last six have they deposited any eggs with us (last summer), and then but few. We have suffered most from migratory swarms. Perhaps this may be the reason: Our county is on the "dividing ridge" between the Mississippi and Missouri, nearly 2,000 feet above sea level, and is rather wet, nearly one-quarter of the area being lakes and meadow. Altogether a country for stock raising. The upland prairie this season covered with a blue joint grass nearly two feet high; soil black, sticky.

Two or three days the locusts alighted in large numbers in places a few rods across, perhaps ½ to 1 mile apart, seemed sickly, covered with red parasites.

M. L. WOOD.

[The following record of flights from Worthington, Nobles County, Minnesota, has been furnished us by Lieut. R. B. Platts, U. S. N.]

1877.

July 1.—High up is quite a flight going west and northwest on a southeast wind. Wind hauled from northeast since 9 a. m. Yesterday wind was very strong, a gale from south and southwest moderating to the northwest by sunset, and not much during the night. None light here at night.

July 3.—To-day, with a brisk east-southeast wind at noon, and, after quite a heavy flight going northwest, none are alighting now.

July 4.—'Hoppers flying high and thick to-day, though none light, or at least very few. Am told by a number that all that alight are infested with the mites.

July 10.—Since Saturday the wind has been north and northwest. On Sunday a great many 'hoppers were flying, but none lit to do damage that I have heard of. None flew yesterday or to day so far.

July 11.—(Wednesday) wind from southeast and going northwest all day, none stopping that I have heard of. Large numbers passing.

July 12.—Wind from southeast strong, quite a heavy flight to northwest; none lit that I know of.

July 13.—At writing, 10 a. m., it is cloudy and wind from south-southwest. I think none are moving.

July 14.—Rained very heavily last night till about midnight. Wind variable this morning, settling to brisk in the southeast; many flew over to northwest.

July 15.—Wind northwest, quite a good many flew to-day, seemingly going as near south as possible.

July 16.—Brisk wind from the west; none.

July 17.—Wind from west and change to northwest; scarcely any flying at all.

July 18.—Wind from northwest, cloudy; cool this morning. None flying.

July 19.—Wind northwest, cool. No 'hoppers flying.

July 20.—Wind north tending east. Quite a good many flying as near west as the wind will permit.

July 21.—Wind south-southeast. Quite a good many flying high to the northwest.

July 22.—Wind southeast. Good breeze and heavy flight; high to the northwest.

July 23.—Wind strong south-southeast. Heavy flight from about 10 a. m. till late, and to the northwest; flew high.

July 24.—Wind south-southeast at noon. Some were flying and flew late, to the northwest.

July 25.—Wind south-southeast; good breeze. Not many flying.

July 26.—Wind strong south-southeast; none flying.

July 27.—Wind varying from south-southeast to northwest, cloudy part of the day and none flying.

July 28.—Wind northwest; cool and none flying at 10 a. m.

July 29.—Wind from south-southeast; a very few 'hoppers flying.

July 30. Wind from south-southeast, backing up to north northeast. After noon a great many flying.

July 31. Wind from northwest to northeast. Rained a little this morning. After dinner wind northwest, and a good many flew.

August 1. Wind light from west to northwest. Quite a heavy flight.

August 2. Almost a calm this morning. About 11 a. m. 'hoppers were circling in the air, and about 1 p. m. a breeze from the southeast, and all moved off in a body, flying very late. None lighted.

August 3. Wind southeast nearly. Very few flying.

August 4. Wind from southeast. Scarcely any flying

August 5. Wind from south and southwest. No 'hoppers.

August 6. Quite a rain last night. Wind northwest. Quite a heavy flight; none lighting.

August 7. Light wind from southeast. None scarcely flying.

August 8. Wind brisk north-northwest. About noon a heavy flight going very high to the south and flying late.

August 9. Wind northwest nearly. Heavy and light again, but none lit.

August 10. Wind from southeast and none flying.

August 11. Wind from southeast very light. Cloudy part of the time, and could not notice any flying.

August 12. Wind from northwest. Cloudy somewhat, could not notice any flying.

August 13. Wind northwest. Cool; very few 'hoppers flying high.

August 14. Wind variable. None flying.

During all this time and all the flying, no damage done in the county that I can hear of, nor have any eggs been laid as yet.

MARSHALL, LYON COUNTY, *August* 2, 1877.

Locusts flew southwesterly in great numbers all day, and on July 27 and 28, and August 1 southeasterly.

August 1, a good many dropped down in this vicinity; none to speak of in this village, but north and south of it. They are said to be eating greedily. I fear they are a healthy lot, fresh from the great plains and will breed. Those which have been here before this year do not couple or lay eggs or eat much, or act lively.

D. F. WEYMOUTH.

AUGUST 6, 1877.

Grasshoppers flying southeast in great numbers; none lighted here. Those that were here have all disappeared.

For the last month the 'hoppers have been flying every clear day when the wind was northerly. One night they were flying in great numbers as long as we could see them and none fell down; they were also flying the next day. We feel sure they flew all that night, which was warm and without dew.

D. F. WEYMOUTH.

SAINT PAUL, RAMSEY COUNTY.

June 28, a considerable movement southeast, but none lighting heavily anywhere that I now recollect.

July 1–8, heavy flights northwest, and considerable numbers lighting from Big Stone Lake northward, especially around Morris.

Since the 8th, particularly the 10th and 11th, heavy swarms flying south or a little east of south, and considerable numbers lighting here and there as far east as Chaska, in Carver County.

In general, they have been flying every day with the wind, and as freely one way as another; no tendency to move in any particular direction.

Locusts were passing Morris for nearly a week, some coming down, others rising, but when the wind was in from the north they all started southeast (or nearly south), and left Morris clean. When the northerly wind struck up there was a south movement (a heavy one, too) seen as far east as Big Lake, up in Sherburne County. As a great many have flown southwest across Rock and other south counties, I think it likely that many have gone off into Dakota that will not get back again. So far as I can see, the swarms have moved hither and thither, regardless of direction, wherever the wind carried them.

Large numbers of dead locusts are being found everywhere. They are in the full grown and pupa states. In some cases, at least, it is due to the red mite.

ALLEN WHITMAN.

GRAFTON, SIBLEY COUNTY, *July* 2, 1877.

July 1, 1877, at noon, 'hoppers in great numbers fill the air from 20 rods high to just as high as the eye can see them; seem to be going southwest, as the wind is northeast; the flight at all times just the way the wind blows; the weather is very warm; the upper current of air is very mild; 'hoppers moving very slow, while the lower current is a little stiffer, and consequently the lower 'hoppers are moving much faster than the higher ones. 'Hoppers hatched much most numerously this year (1877) the last of May; in 1875 nearly the same time. I think there was not more than one out of every thousand of eggs deposited here but what hatched. They were deposited in breaking most numerously, and very many on the raw prairie. They like hard, compact soil to deposit their eggs in best. The first insect acquired full wings about the 20th of June, 1877. Some were seen rising up and going off the 24th of June.

Coal tar and sheet iron have been used very extensively, and other devices, such as sacks and burning of straw and of the prairie grasses—all to no avail.

We have had the 'hoppers with us since 1874, when they lit down on us, deposited their eggs, and in 1875 they hatched out. There was no emigration here that year. In 1876 they lit down upon us again, deposited their eggs, and from those eggs we have 'hoppers this year (1877).

GEO. R. GARDNER.

EXCELSIOR, HENNEPIN COUNTY, *July* 8, 1877.

Wind has been from the southeast for a week till to-day. 'Hoppers were flying to-day from 11 a. m. till 3 p. m., with the wind from northwest; did not see any alight; must have been a swarm rising from a whole district which passed wholly over.

Ours are yet of all sizes; some still hatching; crops all uninjured, but the larger ones are beginning to climb on the wheat ears; suppose you have heard of their moving to the northwest these few days past.

T. BOST.

BURNHAMVILLE, TODD COUNTY, *August* 24, 1877.

The young insects generally traveled in the direction of the wind, but when once on their way, a change in the direction of the wind would not induce them to change their course. They also liked to follow roads and paths. They seemed to be more inclined to travel shortly before they enter the winged state than at any other period of their development.

ALBERT RHODA.

JACKSON, JACKSON COUNTY, *June* 7, 1877.

Grasshoppers are not so numerous in this locality as was anticipated when they first commenced to hatch. The unprecedented heavy rain that fell May 20 must have destroyed myriads of them.

The eggs were deposited by two different swarms that lit here in the latter part of July and fore part of August last.

The ones nearest the surface commenced to hatch about the middle of April, and as late as May 24 cones turned up (while plowing) and would burst from five minutes' exposure to the air and the sun, until the plowed ground was covered with the little struggling pests. The yellow-headed blackbirds, in the meantime, were enjoying a carnival upon that plowed ground glorious to behold.

The 'hoppers, true to the instinct with which they are endowed, invariably deposit their eggs in solid bare ground, as the hatching process depends entirely upon the action of the sun and air.

Were it not for the migratory swarms liable to settle down upon my farm from time to time, the task of annihilating grasshoppers upon my own premises might be easily done: First, by preserving the grass upon pasture and meadow until the 'hoppers were all hatched and the dead grass real dry, and then fire it on the windward side during a rousing wind. The tilled land I should plow with a breaking plow, such that would scour, with a device attached to the fore part of the beam to skim the surface, so as to convey all the eggs snugly into the bottom of the furrow and turn up subsoil enough on top that neither drill nor harrow would disturb them while seeding in the spring.

Besides destroying many of the pests, such a thorough stirring of the soil would well repay for the extra power needed to draw the plow. Thence highly cultivated and thickly settled regions need not lose but one crop, the one that the pests might alight upon. But in these parts where so many farms have been vacated, and the few settlers that remain being generally miles apart, with every atom of energy and enthusiasm within them, so to speak, being smothered during the long siege, the question at once assumes a magnitude beyond conception, and the only safe course for us to pursue under present circumstances, is to till less ground and raise more live stock, for the native grasses, which are never devoured enough to speak of by grasshoppers, cannot be excelled in any part of the world for fattening stock.

There is a substance, which appears and tastes like saleratus, found in streaks through all the soils in these parts; the rains wash it from the knolls until the hollows are white with it, and I am inclined to think the 'hoppers have a tendency to subsist upon vegetation impregnated with it.

JOHN DAVIS.

DATA FOR IOWA.

TABOR, FRÉMONT COUNTY, *April* 11, 1877.

Your letter to President Brooks was handed me. I shall be ready to do all I can to assist in the work of studying and exterminating grasshoppers.

A few experiments I perhaps might give now as well as later.

About the middle of last February, after considerable pleasant weather, I dug a lot of eggs and kept them about ten days on the window-sill (a south window) in my recitation-room, in a crayon-box, when they commenced hatching and so continued for about ten days more, when I tested the effect of cold upon them, some of them having already shed their skins once.

I first placed some in a dry test-tube and plunged it into a freezing-mixture cooled to 10° F.: after keeping them one hour, all (20) were dead, and I have no doubt half that time would have been sufficient.

I then placed the box with the rest upon a stone out-doors and left it over night. In the morning the thermometer was at 15° F., and placing one in the box, it soon fell to 18°. I left the box in this position till noon, to avoid sudden changes of temperature. The day was pleasant, and at noon I found one or two (out of probably 15 or 20) moving, but I saw nothing of them after. It evidently killed them. However, I found on bringing the box to the warmer air of our living room, that about a dozen new ones came out, readily distinguished by their lighter color.

I have observed, also, that those just emerging from the egg are liable to be killed by their elders. I saw this done repeatedly. It may have been owing to lack of food at first.

I have the opinion that most of our eggs are dead, but have not satisfied myself fully by observations. This opinion is based on the fact that many eggs are dried up; many examined seem no further along than in February. Again, those in exceptionally dry places hatched, although they have been more exposed during the winter.

JAMES E. TODD.

NEVADA, STOREY COUNTY, *July* 2, 1877.

You will pardon me for volunteering a few suggestions on the locust pest.

In your report of June 15 to Governor Garber, of Nebraska, you use the following language, which appears to me to be erroneous: "Heretofore the swarms moving from the south northward toward their native habitat have not, so far as we are aware, done any injury;" and again, "Hence, that the race must run out here, and that it can only be continued by repeated invasions from its habitat in the far Northwest or Rocky Mountain region." I have observed the locust in this and the Rocky Mountain region for a number of years, and have come to the conclusion, partly from observation and partly from theory, that their native habitat is not in the far Northwest, but that they migrate there through natural causes; that when they migrate they never return to their native habitat, which is in a warm, dry soil, where there is but little winter and slight rainfall. They are very sensitive to heat and cold, and therefore when the full-fledged insect gets ready to migrate the warm south wind invigorates them; they rise up in the air and are carried north until they reach a climate which is not congenial, and where forage is scarce; they then, or their progeny, next season or perhaps both, change their course to a southeastern direction. Some swarms first migrate from their native habitat east and others west, but I think by far the most migrate in a northern direction. The locusts that came to this part of the State last fall (1876) were the progeny of those that left their native habitat in 1875 and are now becoming extinct. I think they will not survive the present season. I think by observation it can be known whether the insect is in its native habitat or not.

I suggested these thoughts in a communication to Professor Riley last winter.

J. S. FRAZIER.

DATA FOR DAKOTA.

SIOUX FALLS, LINCOLN COUNTY, *May* 21, 1877.

I have seen a willow grove in Iowa stripped of foliage and a field of corn adjoining it not injured. I have been also informed by reliable parties that a farmer living adjoining some timber has supplied Canton with a large amount of garden vegetables during fall and winter, when his neighbors had not enough for their own wants. From this it would appear that if we had a larger acreage of timber our crops might be to a great extent, if not entirely, saved from the ravages of the locusts.

B. C. JACOBS.

WAHPETON, RICHLAND COUNTY, *June* 27, 1877.

Question 4. Commenced hatching about May 10. Most numerously hatching about May 25. Still hatching in moderate numbers.

Question 6. Uncertain, very small, possibly one egg-cell out of 100 failed; cause, small worm entering cell and devouring eggs; also small red bug doing same thing.

Question 7. In the most thoroughly packed sandy soils.

Question 8. Same as No. 7.

Question 11. In the country, up to present time, owing to splendid growing weather, crops have kept well ahead of 'hoppers, until within the past week their ravages are showing in many localities; a very few fields almost ruined in past few days; others slightly; many not at all, but the pest is increasing so rapidly in size, number, and voracity that gravest fears are felt.

Question 12. Wheat, because it is the principal crop. Pease as yet have escaped.

Question 13. Pease, for the reason that thus far they have protected themselves.

Question 15. Generally south and southeast, occasionally in opposite directions.

Question 16. The sheet-iron "'hopper dozer" at first with strong hopes of saving crops, but when ten came to look after each one captured, farmers despaired but kept using the machine until the grain was too high and the 'hoppers to agile.

Question 18. The sheet-iron "dozer," as described in Saint Paul Pioneer Press: A strip of sheet-iron, 12 or 14 feet long, turned up at back and ends 6 or 8 inches, in front 1 inch; the pan covered with tar, kerosene, soft-soap, &c., the whole drawn by wires or cords.

Question 20. In 1875 and 1876.

Question 21. After careful observation several of us have concluded that if the prairie was packed seven feet deep over its entire surface with grouse, prairie chickens, and domestic fowls, and they could get no other food, they might make some slight impression on the hordes. In 1865 I rode 113 miles one day on the railroad from Wilmar, Minn., to Breckenridge, Minn.; the whole distance was through one continuous cloud of flying 'hoppers filling the air as with snow-flakes as far above the earth as a powerful field-glass could distinguish them: how much farther west the cloud extended is unknown, as the railroad and my trip ended at Breckenridge. The noise was as of bees swarming, so great was the number of wings in motion.

Question 23. Very few eggs hatched here in the fall. In February, 1877, I placed earth containing egg-cells in my office and hatched out a large number, placed them out doors over night with thermometer 20° below zero; next day replaced them in office, and in a few hours one-third had recovered; next night placed them out doors, 18° below zero; next day only about one in five of the survivors of the first experiment recovered.

Last summer we put about one bushel of the grown 'hoppers in a gunny sack placed the sack in a barrel of water and kept it under water with weights. The next day I took them from the barrel and emptied them out of the sack, when, to my astonishment, I discovered a large number, perhaps one in forty or fifty, still alive.

Question 24. Garden truck, oats, barley, wheat, potatoes, buckwheat, and, when well grown, apparently anything an ostrich would digest; coats or other clothing, saddles, leather, whips, &c., left on the ground a few hours would be ruined.

Question 26. Here they do not seem to have made much impression on native grasses.

Question 27. Our domestic fowls. I have also observed my tame crane gathering them in.

Question 28. Plowing in fall and early spring where they were known to have laid eggs in great numbers seems to have almost entirely spoiled the hatch.

Question 29. Almost entire prairie; small clumps of timber occasionally along the streams.

Question 30. Our nights being almost universally cool the 'hoppers, towards sunset, congregate, when small, in piles or windrows, in the ruts in the roads, and along the sides of houses or other elevations, sometimes two or more inches deep. Where they lack these accommodations, I observe they climb on small shrubs, literally covering them. I think they neither march, fly, nor eat with us at night.

Question 31. Apparently about the same rate of speed as the wind.

D. WILMOT SMITH.

SPRINGFIELD, BON HOMME COUNTY, *June* 5, 1877.

The first appearance of locusts was in the morning of August 3, 1872. I think they must have come from northeast, as I met them while traveling in that direction. I recollect it was very hot, but did not record the direction of the wind; think it was a still day. The next noon, the wind being in the northwest, they moved a little to southeast and remained until about noon of the 5th, when they left in a body, wind being southeast. During their stay they spoiled some pieces of corn and late oats; others but slightly.

Their next visit was in 1874. I think it was July 18. They rose in the form of clouds in the south and southwest, about 1 p. m., and commenced settling about 2 p. m., ravenously devouring every green thing in garden and field, so that in two hours hardly a vestige was left in gardens; nothing in ours except young peach-trees; but the next day, between 9 a. m. and 12 m. the wind blowing gently from the north, they left for the south. The result was, very few men harvested an ear of corn or dug a potato, very few oats gathered, and wheat turned out less than 5 bushels to the acre. About two weeks later vast hordes passed over from the north, and thus ended the campaign for that year.

June 17, 1875, the wind being south, the 'hoppers came in untold numbers, and about 11 a. m. began to settle, but in a few minutes a cloud being in the north, the wind commenced blowing gently from the north; they came slowly but steadily all day from the south, settling mainly on fields of corn, remaining until noon of the 8th, when they left, leaving about three-quarters of a crop.

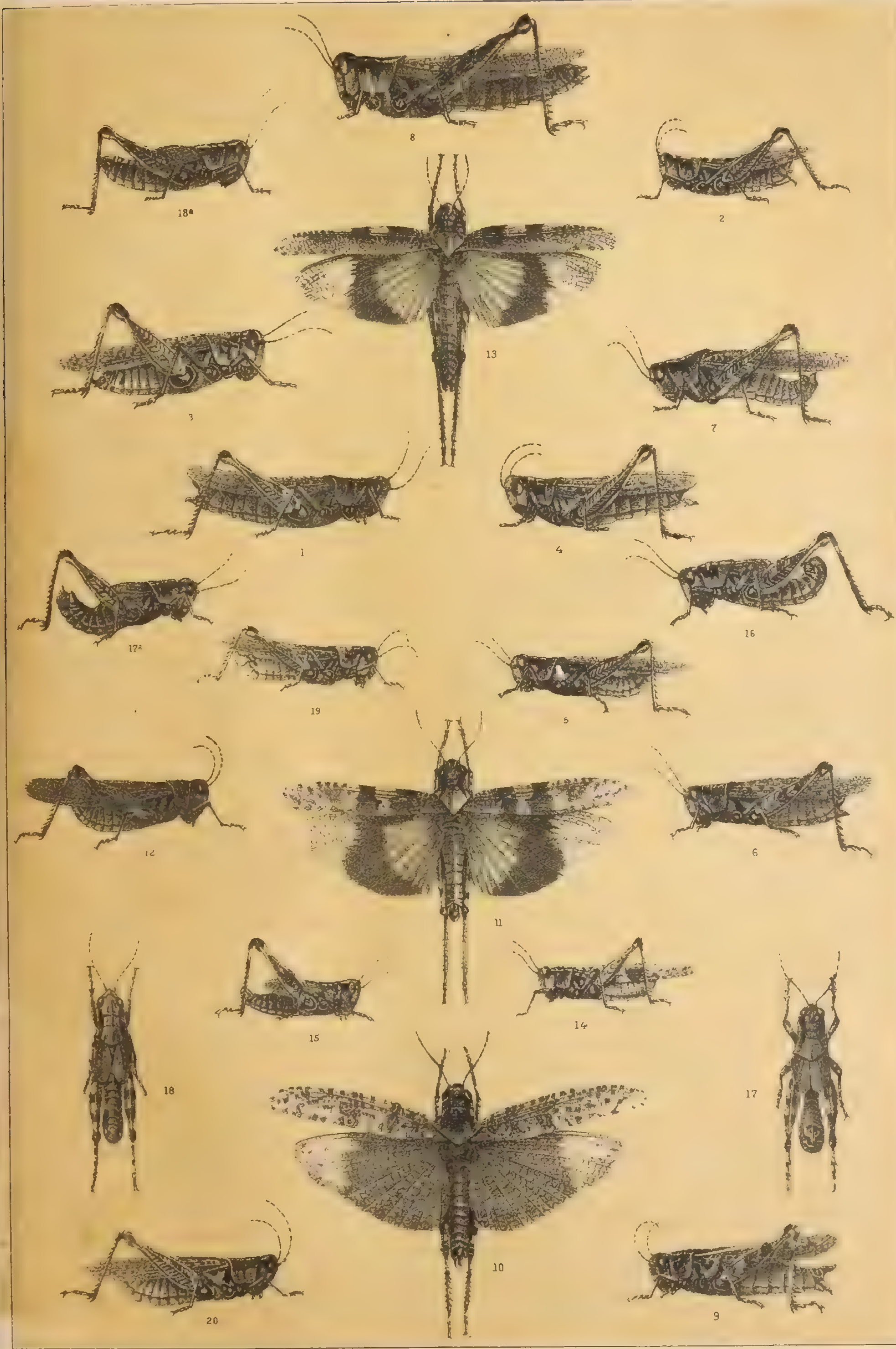
July 20, 1876, the wind having been in northeast for several days, they came in force from that direction, but did not appear to be very hungry; soon after they settled, the wind veered to the south and remained there almost constantly for a month, so they could not get away, they trying two or three times when the wind would change to north for a few minutes, so they merely changed neighborhoods two or three times till August 18, when the wind being north, with a clear sky and but gentle breeze, they took their final flight south, occupying about two hours passing a single point. I can't learn that there have ever been eggs of any amount laid in this part of the Territory since 1866 till last year, and then only in small patches in some locations. I have heard of but very few in our county, no one apprehending any danger from them; the first discovered was about the first of May, small patches, generally in sandy or gravelly locations, facing the south.

S. HITCHCOCK.

PLATE XVII.

Fig. 1. *Melanoplus cinereus* Scudder. Female; Wallula. (This and all the other figures of natural size.)

2. *Melanoplus devastator* Scudder. A small female; Reno, Nevada.
3. *Melanoplus devastator* Scudder. A large female; Redding, California.
4. *Melanoplus cinereus* Scudder. Female; Reno, Nevada.
5. *Melanoplus cinereus* Scudder. Male; Reno, Nevada.
6. *Melanoplus atlanis* (Riley). Female; Victoria, Vancouver's Island.
7. *Melanoplus packardii* Scudder. Male; Wallula, Washington Terr.
8. *Melanoplus packardii* Scudder. Female: Wallula, Washington Terr.
9. *Camnula atrox* Scudder. Female; Vancouver's Island.
10. *Circotettix maculatus* Scudder. Female; summit Sierra Nevada.
11. *Trimerotropis vinculata* Scudder. Sissons, base of Mount Shasta, California.
12. *Arphia frigida* Scudder. Male; Helena, Montana.
13. *Psinidia wallula* Scudder. Female; Wallula.
14. *Psinidia wallula* Scudder. Male; Sissons, base of Mount Shasta.
15. *Gomphocerus shastanus* Scudder. Mount Shasta, California.
16. *Pezotettix pacificus* Scudder. Male; California.
17. *Pezotettix borckii* Stål. Portland, Oregon.
18. *Gomphocerus shastanus* Scudder. Female; Mount Shasta, California.
19. *Melanoplus devastator* Scudder. Male; Colorado, 1879.
20. *Melanoplus devastator* Scudder. Male: Fort Keogh, Montana, 1880.



NEW SPECIES OF WESTERN LOCUSTS.

APPENDIX II.

LIST OF THE ORTHOPTERA COLLECTED BY DR. A. S. PACKARD IN THE WESTERN UNITED STATES IN THE SUMMER OF 1877.*

By SAMUEL H. SCUDDER.

GRYLLIDES.

GRYLLUS sp.
Vancouver's Island.

GRYLLUS sp. alt.
Salt Lake Valley, early June.

OECANTHUS sp.
Wallula, Wash.

LOCUSTARIAE.

XIPHIDIUM ENSIFERUM Scudd.

Specimens were obtained at Glen Brook and Reno, Nev., which agree with the ordinary type, excepting in the length of the wings, which surpass the tip of the tegmina.

XIPHIDIUM BREVIPENNE Scudd.

Sissons, Strawberry Valley, base of Mount Shasta, Cal. August 23.

XIPHIDIUM FASCIATUM Serv.

Portland, Oreg. None of the above Locustarians have before been recorded from points so far west. The latter two (which are probably dolichopterous and brachypterous forms of a single species) are thus shown to extend across the continent.

ANABRUS sp.

A large number of specimens of this genus, collected by Dr. Packard, are reserved for a future paper.

UDEOPSYLLA ROBUSTA (Hald.) Scudd.
Colorado; received from Mr. H. Edwards.

TROPIDISCHIA XANTHOSTOMA Scudd.
Mendocino, Cal.; received from Mr. J. Behrens.

ACRIDII.

(Acridiidae.)

ACRIDIUM SHOSHONE Thom.

Specimens taken at Reno, Nev., August 18, must be referred to this species, as a comparison with the types kindly lent me by Mr. Thomas shows, but they have a dis-

* A number of the species mentioned or described here are represented in Plate XVII at the end of the report.

tinct dorsal yellow stripe, probably effaced in Mr. Thomas's specimens from too long immersion in alcohol.

HESPEROTETTIX VIRIDIS (Thom.) Scudd.

Salt Lake Valley, August 13.

MELANOPLUS BIVITTATUS (Say) Scudd.

Salt Lake Valley, August 13.

MELANOPLUS FEMORATUS (Burm.) Scudd.

Wallula, Wash.

MELANOPLUS PACKARDII Scudd. Pl. xvii, figs. 7, 8.

Wallula, Wash.

MELANOPLUS CINEREUS Scudd. Pl. xvii, figs. 4, 5.

American Fork Cañon, Utah, August 5; Reno, Nev.; Wallula, Wash.

MELANOPLUS DEVASTATOR Scudd. Pl. xvii, figs. 2, 3, 19, 20.

Salt Lake Valley, Aug. 14; Reno, Glen Brook, and Lake Tahoe, Nev.; Sissons and the Shasta district, Cal.

MELANOPLUS FEMUR-RUBRUM (De Geer) Stål.

Salt Lake Valley; Glen Brook, Nev.; Sissons, Cal.; Portland, Oreg.

MALANOPLUS ATLANIS (Ril.) Scudd. Pl. xvii, fig. 6.

Glen Brook, Nev.; Wallula, Wash.; Portland, Oreg.; Victoria, Vancouver's Island.

MELANOPLUS SPRETUS (Uhl.) Scudd.

Numerous localities.

BRADYNOTES OPIMUS nov. sp.

Closely allied to *B. obesus* (*Pezotettix obesus* Thom.) General color blackish griseous, more or less flecked with brown; face and genae below the eyes varying from pale to pinkish livid, punctate, especially below, with black, and divided by black stripes following the edges of the frontal costa and the lateral carinae of the face, and also, generally, the arcuate posterior carinae of the genae, and an oblique line of punctures subparallel to it below the middle of the genae; summit of head with a median and a pair of arcuate, lateral, narrow black stripes, the former the darker; antennae testaceous near the base, blackish beyond. Anterior lobe of pronotum with a large central blackish spot, inclosing a pair of testaceous dots, laterally disposed; lateral lobes lighter below than above, speckled, with a broad, somewhat broken, black median band crossing the anterior lobe; tegmina wholly wanting. Abdomen varying from grizzly to blackish, the posterior edges of the segments dotted with minute longitudinal spots, and some of the posterior segments marked with a central, triangular, testaceous spot, seated on the posterior border. Hind femora with the outer face generally altogether black, occasionally lighter and marked with a central, oblique, pale dash above; upper and lower faces pale testaceous, the inner side of upper face with a pair of black bars; hind tibiae deep purplish at base (with the basal outer tubercle deep red), passing into deep red beyond the middle, the under surface clay-yellow; the spines on basal half pale, on apical half reddish, all black tipped. Anal cerci nearly straight, subcompressed, but convex exteriorly, broad at base, tapering throughout more rapidly on the basal than on the apical half to a bluntly-pointed tip.

Length of body, ♂ 23^{mm}, ♀ 24^{mm}; of antennae, ♂ 9.5^{mm}, ♀ 10.5^{mm}; of pronotum, ♂ 5.5^{mm}, ♀ 5^{mm}; of hind tibiae, ♂ ♀ 10.5^{mm}.

This species differs from *B. obesus* in some of its markings, in the lighter punctuation of the posterior lobe of the pronotum, and especially in the anal cerci of the male, which are much stouter and coarser, not so strikingly divided into a rounded basal and slender, almost linear, apical half, as in *B. obesus*. Like it, it comes from high elevations. Baron Osten Sacken brought home specimens taken in the Sierra Nevada between July 17–22, some of them immature; and Dr. Packard took 1 ♂ 2 ♀ at the forest line on Mount Shasta, Cal. A single specimen, damaged by too long preservation in alcohol, and brought by Mr. W. G. W. Harford from Oregon City, appears to belong here.

PEZOTETTIX BORCKII Stål. Pl. xvii, fig. 17.

Portland, Oreg.

PEZOTETTIX PACIFICUS nov. sp. Pl. xvii, fig. 16.

Form and appearance of *P. Borckii*, Stål, but slenderer. Fastigium of vertex and frontal costa continuously and shallowly sulcate, approaching flatness at the upper extremity of the latter; front and genae yellowish livid, flecked with brown; antennae castaneous, pale at base; summit of head testaceous, flecked, especially in the middle, with black; a broad piceous stripe extends from the eye to the posterior border of the upper half of the deflected lobes of the pronotum. Lower portion of these lobes of the color of the genae; disk of pronotum testaceous, flecked with black dots, and a pair of small black spots lying on either side of the middle line on the posterior division of the anterior lobe; anterior lobe distantly, coarsely, and shallowly punctate; posterior lobe profusely and less coarsely punctate; transverse sulci of anterior lobe very distinct; median carina sharp and distinct on posterior, obsolescent on anterior lobe; posterior margin of pronotum nearly straight, scarcely angulate. Tegmina shorter than the pronotum, broadly rounded, not at all produced at tip, testaceous, with dark veins, the inner area paler. Hind femora compressed, outer surface blackish, under surface pale sanguineous; hind tibiae very dark bronze-green; hind tarsi castaneous, infuscated in spots. Abdomen yellowish, the sides with a narrow, tapering, longitudinal piceous band. Anal cerci strongly compressed, very broad and rounded on basal half, with marginal borders, and a little tumid in the middle, the apical half subcylindrical, slender, tapering, pointed, not one-third the width of the base, the whole not more than half as long again as broad.

Length of body 17^{mm}, of antennae 6^{mm}, of tegmina 3.75^{mm}, of hind femora 10^{mm}.
1 ♂. Sissons, Cal.

(*Truxalidæ.*)

STENOBOTHRUS CURTIPENNIS Harr.

Lake Tahoe and Glen Brook, Nev.

STENOBOTHRUS PROPINQUANS Scudd.

Salt Lake Valley.

CHRYSOCHRAON sp.

Lake Point, Utah.

GOMPHOCERUS SHASTANUS nov. sp. Pl. xvii, fig. 15, 18.

Front of head brownish testaceous, faintly flecked with fuscous, excepting in a clear livid stripe in front of the lateral carinae, passing from between the antennae and the eyes to the outer base of the mandibles; genae bluish livid below, becoming infuscated above, and deepening to black behind the eyes; summit fusco-testaceous, with an arcuate dusky or blackish line from the front edge of the eyes to the posterior border, where the upper limit of the black stripe behind the eyes is edged above with a lighter more or less yellowish color. Antennae about as long as the hind femora in the male, fusco-testaceous or castaneous, subdepressed, equal throughout in both sexes. Eyes separated above by as much as the outer bases of the antennae, the front of the fastigium bent at a right angle, slightly margined, the lateral foveolae straight, equal, meeting in front, sulcate, many times longer than broad; frontal costa perfectly flat, expanding and fading below the ocellus. Pronotum brownish, the lateral carinae generally marked distinctly with a dull yellow stripe, the lateral lobes mostly black or blackish above, usually deepest on the middle of the front lobe, its anterior margin often marked with yellow and with a central, very short, longitudinal, pale-yellow dash; median and lateral carinae equally distinct and rather slight; the front and hind margin slightly angled. Tegmina ovate-sublanceolate in the female, shorter than the head and thorax together, oblong-obovate in the male, much longer than the head and thorax together, rounded apically; in both obscure dark fuscous, with blackish flecks. Hind femora black on the outer face, but the lower carina and inferior face pale yellow, the superior face brown, with two oblique dark transverse stripes, which also cross the yellow interior face; apex black. Hind tibiae black at base, followed by a broad pale yellow and then a fuscous belt, the apical half sanguineous, the spines black tipped. Abdomen brownish fuscous above, yellow below, the two inter-digitating on the sides.

Length of body, ♂ 16^{mm}, ♀ 21^{mm}; of antennae, ♂ 11^{mm}, ♀ 10^{mm}; of pronotum, ♂ 3^{mm}, ♀ 4^{mm}; of tegmina, ♂ 7.5^{mm}, ♀ 5.5^{mm}; of hind tibiæ, ♂ 10^{mm}, ♀ 11.5^{mm}.
5 ♂, 5 ♀. Mount Shasta, among the firs.

(*Oedipodidae.*)

CHIMAROCEPHALA PACIFICA (Thom.) Scudd.

Mann County, Knight Valley, Skaggs Springs, Cal.; received from Mr. Edwards.

CAMNULA ATROX Scudd. Pl. xvii, fig. 9.

San Francisco, Sauzalito, Cal.; Reno and Glen Brook, Nev.; and Victoria, Vancouver's Island.

ARPHIA FRIGIDA Scudd. Pl. xvii, fig. 12.

Virginia City, Mont., June; Helena, Mont., June 21.

HIPPISCUS CORALLIPES (Hald.) Scudd.

Salt Lake, June 9.

HIPPISCUS LINEATUS Scudd.

Franklin, Idaho, June 12. The tegmina differ slightly from the type.

HIPPISCUS sp.

Helena, Mont., June 21.

SHIRAPLEURA DECUSSATA Scudd.

Helena, Mont., June 21.

DISSOSTEIRA CAROLINA (Linn.) Scudd.

Portland, Oreg., Vancouver's Island, September 8. Abundant at Sissons, Cal.

CIRCOTETTIX CARLINGIANUS Thom.

Reno, Nev., August 18.

CIRCOTETTIX MACULATUS nov. sp. Pl. xvii, fig. 10.

In surface, sculpture of the head and thorax closely resembling the species last mentioned, but with the median carina of the pronotum more distinct, and a heavier pile upon the head and thorax. Whole head below the lower level of the eyes varying from cinereous to chalky white, flecked on the posterior border and on the frontal costa with black specks; upper part of head dark cinereous, mottled with black, with a narrow black stripe behind the eye. Thorax cinereo-testaceous, with a large central blackish spot on the disk, and a heavy quadrate black blotch over the front portion of the upper half or more of the deflected lobes, followed beneath by whitish. Tegmina cinereous, heavily flecked with blackish fuscous, especially collected on their basal half into two transverse bands, one in the middle and the other at the base of the second quarter; on the apical half the spots are quadrate and more or less clustered into short oblique bars. Wings varying from entirely dark fuliginous, with a faint hyaline cloud near the apex of the costal margin, to dark fuliginous, with the apical third hyaline but containing a few dusky flecks. The wing differs from that of the typical species in that the middle of the anal area is not so ample, and that the spurious veins lie closer to the branches of the anal vein and do not extend so far toward the base, this species approaching closer to *Trimerotropis;* the cross-veins, also, are more distant and not so distinctly scalariform, so that some of the characteristic features of *Circotettix* are here much weakened. Hind femora cinereous, with two transverse bands of black flecks; hind tibiae yellowish cinereous, blackish at extreme base, and infuscated beyond a basal yellow band.

Length of body, 25mm; of tegmina, 25mm; of wings, 22mm; breadth of same, 14mm; length of hind tibiae, 10mm.

A single male from the summit of the Sierra Nevada was given Dr. Packard by Mr. Henry Edwards. Baron Osten Sacken also gave me two males from the same place, taken between July 17 and 22.

TRIMEROTROPIS LATIFASCIATA nov. sp.

Brownish cinereous, the vertex darker than the rest of the head, all the sculpturing of the head sharply defined; antennae yellowish brown, deepening apically. Posterior half of anterior lobe of pronotum rather strongly corrugated, the median transverse sulcus very deeply impressed; surface of anterior lobe otherwise smooth, posterior lobe delicately but distinctly rugulose; median carina rather prominent and heavy on anterior lobe, slight but sharply defined and posteriorly obsolescent on posterior lobe. Tegmina marked with two obscure, narrow, transverse belts of dark fuscous flecks, one in the middle and one beyond the basal fourth; a similar but faint third band appears before the base of the apical fourth, and beyond it a few obscure quadrate fuscous flecks in the diaphanous part of the tegmina, caused by the infumation of single cells and the nigrescence of their bordering veins. Wings very pale yellowish or milky, with a diaphanous tip, on which the veins are black and the cross-veins yellowish or partly yellowish and black, and with an unusually broad, very dark, almost piceous middle band, occupying about one-third the length of the wing on the middle of the costal margin, and curving around to the inner angle; its outer border straight or even slightly concave until just before it reaches the outer margin, which it avoids by bending inwards a short distance; the inner border of the band is strongly and pretty regularly arcuate, scarcely tending toward the base above. Hind femora with faint traces of a pair of dusky transverse bands on the outer face; hind tibiae pale reddish, with black-tipped spine.

Length of body, 29mm; of antennae, 11.5mm; of pronotum, 6 mm; of tegmina, 32mm; of hind tibiæ, 12mm.

2 ♀. Wallula, Wash., September 1; Lake Point, Utah, August 14. The specimens were preserved in alcohol.

TRIMEROTROPIS FONTANA Thom.

American Fork Cañon, 7,500 feet, August 5. This species is closely allied to if not identical with *T. Juliana* Scudd.

TRIMEROTROPIS SIMILIS nov. sp.

This species, of which only a single male was taken, at Wallula, Wash., appears to differ from the preceding species simply in the coloration of the wings, which are pale yellow at base, hyaline at apex, where the principal nervures are brown and the cross-veins whitish, and are marked by a moderately narrow but *distinctly defined* blackish fuliginous band, which follows the posterior border to the inner angle, and sends a shoot along the discoidal field half way to the base; beyond it the costal edge is blackish nearly to the tip of the wing.

Length of body, 18.5^{mm}; of pronotum, 4.4^{mm}; of tegmina, 22^{mm}; of hind femora, 9^{mm}.

TRIMEROTROPIS CAERULEIPES nov. sp.

Very dark brownish cinereous, sometimes with a slight hoary bloom. Lower part of head varying from white to livid, heavily flecked with black punctures; frontal costa flat or nearly flat above the ocellus, deeply sulcate below; fastigium flat, with sharp and rather elevated lateral carinae, the lateral foveolae elongate, triangular; antennae blackish fuscous. Front lobe of pronotum rather small tuberculate, the median carina sharp and rather elevated at this point, but on the granulate and rugulose hinder lobe sharp and slightly elevated. Tegmina marked with blackish fuscous flecks, which cluster into more or less distinct bands (the middle one the most distinct) at the end of successive quarters, the outer a little nearer the middle one, besides faint dusky dots which follow the principal black nervures on the apical third. Wings pale greenish at base, hyaline or slightly infumated at apex, where all the veins are black, with a narrow, arcuate, obscure, fuliginous, median, transverse belt, scarcely extending at all along the outer margin, shooting almost to the base of the wing below the costal margin, where also it is deepest in tint; beyond it the costal margin is also deeply fuliginous. Hind femora grayish cinereous, with a pair of obscure dusky or blackish transverse belts on the outer face, most distinct above, and a blackish apex; hind tibiae with the base heavily mottled with black and yellowish brown, beyond deep blue, the spines tipped with black.

Length of body, ♂ 19^{mm}, ♀ 25^{mm}; of antennea, ♂ 11.5^{mm}, ♀ 9.5^{mm}; of pronotum, ♂ 4.5^{mm}, ♀ 5^{mm}; of tegmina, ♂ 21.5^{mm}, ♀ 26^{mm}; of hind tibiae, ♂ 10^{mm}, ♀ 12^{mm}.

1 ♂. 2 ♀, Portland, Oreg.; Sissons, Cal.

This species, which resembles *T. fontana* Thom. in the character of the band on the wings, seems to be very distinct from any *Trimerotropis* heretofore described.

TRIMEROTROPIS VINCULATA Scudd. Pl. xvii, fig. 11.

Sissons, Cal., Aug. 23; Wallula, Wash.

TRIMEROTROPIS SUFFUSA Scudd.

Berkeley and Shasta District, Cal.

PSINIDIA WALLULA nov. sp. Pl. xvii, fig. 13, 14.

Closely allied to *P. sulcifrons* Scudd., but with even deeper sulcations on the head, and with considerably shorter organs of flight. Fusco-cinerous; head gray from a mottling of minute brown and livid spots, darker on vertex, paler about the mouth; a rather narrow blackish fuscous stripe runs from behind the eye over the anterior lobe of the pronotum, on which it is followed beneath, on the middle of the deflected lobes, by a small quadrate black spot, the darker markings rather heavier in the female than in the male. Fastigium of vertex deeply sulcate, closed or almost closed behind, opposite the posterior half of the eye, by faint walls which curve inward and backward; sides of fastigium sharply carinate, connecting directly with the frontal carinae, and in the female incurved next the antennae; frontal costa very deeply sulcate, in the male elevated nearly to the carinae at the extreme summit and punctate; in both sexes the frontal carinae are punctate in black. Antennae of male as long as the hind tibiae, testaceous, infuscated toward the tip. Median carina of pronotum distinct throughout, but scarcely cristate on anterior lobe; disk of pronotum more or less rugulose, with a tendency to a transverse disposition of the rugae, especially on the posterior part of the anterior lobe, where it is heaviest. Tegmina fusco-cinereous, the apical third partially diaphanous, the costal half or less with two distinct, broad, quadrate or roundish, blackish bars in the middle, and in the middle of the basal half, besides brownish flecks along the middle of the tegmina, and scattered flecks apically—the latter having a tendency to follow the veins and especially to mark their tips. Wings pale citron-yellow at base, pellucid, with dark and sometimes thickened veins at tip, with a broad arcuate fuscous median band, more distinct in the female than in the male, sending a shoot inwards in the median area fully half way to the base, and terminating below at or before the fifth superior* anal ray; the costal edge at and beyond the band is black, and the row of cells beneath it infumated. Hind femora dark cinereous, with three very oblique faint fuscous stripes; hind tibiae pale red, pale at base.

Length of body, ♂ 16^{mm}, ♀ 25^{mm}; of antennae, ♂ 9^{mm}, ♀ 8.5^{mm}; of pronotum, ♂ 3.15^{mm}, ♀ 5^{mm}; of tegmina, ♂ 17 ♀, 25^{mm}; of hind tibiae, ♂ 9^{mm}, ♀ 11.75^{mm}.

5 ♂, 3 ♀. Reno, Nev., August 18; Sissons, Cal., August 26; Wallula, Wash.; Dallas, Oreg., September 3.

AULOCARA DECENS Scudd.

Lake Point, Utah.

(*Tettigidae.*)

TETTIX GRANULATUS (Kirb.) Scudd.

A single specimen from Vancouver's Island is provisionally referred to this species; the pronotum is shorter than in Eastern specimens.

BLATTARIAE.

PHYLLODROMIA GERMANICA (Linn.) Serv.

A single specimen from California was given to Dr. Packard by Mr. Behrens; it has recently been described by Mr. Thomas as a new species, under the name *Ischnoptera bivittata.*

PANCHLORA sp.

Perhaps *P. hyalina* Sauss. Also received from Mr. Behrens. Probably imported into California.

*By "superior" is here meant a ray which lies at the upper level on the folding of the wing.

APPENDIX III.

REPORT OF JOHN MARTEN.

Dr. CYRUS THOMAS,
Of the United States Entomological Commission:

SIR: I have the honor to report that, in obedience to your instructions, I have visited personally Northwestern Iowa, Southeastern Dakota, Southwestern Minnesota, and Northwestern Nebraska.

My investigations, under your letter of instructions, were confined to portions of the months of July and August, 1879.

I started from Carbondale, Ill., July 22, passing up the Iowa Central Railroad to Ackley, Iowa. The grasshoppers flying here last year were not numerous enough to cause any serious alarm. They came from the north and northwest. No eggs were deposited by them, and no 'hoppers have been seen this year.

At Fort Dodge no 'hoppers were found this year. In 1876 the Des Moines Valley was visited in this vicinity by numerous swarms coming from the west and northwest and depositing eggs, which hatched in the spring of the following year, also, a few came in, but altogether there were not enough to do any serious damage.

At Marcus, July 26, I saw the first locusts; they were full fledged.

July 25. at Le Mars, I found the locusts quite thick. In 1873, eggs were deposited here in June, and returning swarms came from the south in August; was again visited in August, 1876, when eggs were deposited, which began hatching in March, 1877.

In August and September of 1877 swarms came from the northwest and deposited eggs, which hatched in the spring of 1878, and full-fledged locusts were seen June 28.

From September 15, for a period of twenty days, eggs were deposited, generally in sandy, compact soil, free from vegetation, and preferably on a southern or eastern slope. These eggs hatched from April 1 to June 10 at intervals. The early and irregular hatching was supposed to have been caused by the dry weather and the deep plowing done by some of the farmers.

The young 'hoppers moved in various directions; some were seen going northwest, others east, and still others south. They attacked the wheat, barley, and flax most voraciously; other small grains did not suffer so severely. Corn was not damaged materially, although there were a few instances in which a second planting was made of a few outer rows.

The estimate of damage given me for Plymouth County was 90 per cent. for wheat and 50 per cent. for other small grains, but from observation I think this rather large.

Swarms were departing from June 14 to July 7 or later, the first going to the north and west with the wind, a few straggling swarms going south after the wind changed and blew in that direction.

At Sioux City, July 28, a few full-fledged 'hoppers were noticed. Swarms came about September 1 from the north and northwest, and remained all fall depositing eggs, which hatched June 18, 1879, at which time Dr. W. R. Smith, to whom I am indebted for aid, reported his wheat, corn, and garden all devoured.

From June 25 to July 1 the 'hoppers disappeared very notably, going south with the wind. The estimated damage in Woodbury County shows that the western part suffered most severely, wheat being damaged 75 per cent., oats and other small grains 50 per cent., while in the eastern part the estimate is placed at 20 or 25 per cent. for all small grains. Corn was damaged considerably, but there will yet be a fair crop. Sorghum, broom-corn, and pease generally escaped.

No means of destruction have been used extensively. A few coal-tar pans and other machines used in previous years have been employed.

The young 'hoppers, before obtaining their wings, have no particular direction of travel, some broods going in one direction and some in another; but when a brood starts in a direction it generally maintains it until wings are obtained.

In Sioux County locust eggs were deposited in June, 1873, the locusts coming from the south, there being a south wind at the time, and in the latter part of July they came from the north. In the fall of 1876 eggs were deposited, and in 1877 the 'hoppers hatched and flew south.

September, 1878, eggs were deposited in vast numbers, principally in the western and southern parts of the county. These hatched during May and began flying about June 25, 1879.

July 30 and 31, was in Sioux Falls. The locusts visited that vicinity in August, 1878, depositing eggs from the 15th instant to middle of September. These eggs hatched most numerously from April 25 to May 15. The young 'hoppers have no particular direction of travel, going wherever they could find anything to eat. The amount of damage done by them this year was comparatively small, as much being attributed to the drought as to the locusts, 25 per cent. being the estimate of damage for Minnehaha County this year. Full-fledged 'hoppers were seen May 20, and swarms were flying northwest with the wind June 11 to July 7, and were seen flying over to the south July 28, but none have stopped here.

Union and Lincoln Counties, parts of which I passed over, have suffered very much. Wheat was almost all destroyed; oats had suffered severely, as had all other small grain. Corn was looking well, but in some places a second planting had been made.

Scarcely any means have been employed for destroying the locusts this year, a few of the farmers using coal-tar pans and muslin-bag machines. Several farmers "backset" their fall plowing, and this undoubtedly destroyed great numbers of eggs, as there were not so many 'hoppers noticed on such fields as on those not backset. More eggs were hatched on the bottoms than on the higher lands.

July 31, at Worthing, Minn., a few locusts were yet to be found. For information obtained here I am indebted to Mr. R. B. Potts, who very kindly gave me what notes he had collected.

Swarms came in August and September, 1878, from the northwest, and deposited eggs in new ground, and preferably in low places, and in the beds of sloughs and ponds. About one-third of the eggs deposited hatched, beginning early in April and hatching in batches until the latter part of May. Full-fledged locusts were noticed the last week of June, and swarms began departing about July 1, going in a northwest direction as near as possible, the wind being favorable. 'Hoppers have since then passed over on a northwest wind going southeast, flying very high. This season the young 'hoppers traveled to the northwest, but this is not their usual habit.

All the wheat and about one tenth of other crops except sorghum, broom-corn, and pease were destroyed. A portion of the failure of this wheat crop is attributable to poor seed.

Crops on sod-land were injured; most of those on old, well-cultivated ground escaped with not much injury.

Many 'hoppers died about the time of the last molt. The dead bodies had a decayed appearance just back of the thorax shield—no grubs were formed in the bodies.

The silky mite destroyed numbers of the eggs and also preyed upon full-grown locusts when in its more mature state. Dragging and harrowing the ground in the fall and winter exposed the eggs to birds, and the action of the weather which by alternate freezing and thawing destroyed them.

Farmers have employed no means of destroying the young locusts this year.

August 1, 1879, I arrived in Yankton, Dak., and am greatly indebted to Mr. A. W. Barber for information and assistance.

From September 15 to 20, 1878, the locusts arrived here and immediately began depositing eggs, preferably in the cultivated porous soils of the bottoms along streams. Very few eggs were placed in grassy or woody places.

April 11, 1879, young 'hoppers were first seen in sunny places. From this time until the latter part of May they were hatching in batches, caused by the deep plowing of some of the farmers.

Full wings were obtained from about June 15 to the latter part of July. They commenced flying during the first week of July, going to the south with the wind. Other swarms were noticed flying over, going to the south and west. The prevailing winds, as noted by the United States Signal Service at Yankton, for June, July, and August were as follows: June, to the southeast; July, to the south 70 times, to the southeast 44 times, out of 217 observations; August, to the south, but nearly evenly distributed among the different directions.

Crops damaged most are wheat, of which about 50 per cent. is destroyed; oats, 25 per cent.; and corn to a considerable extent.

Three miles north of Yankton, on the farm of Mr. Cribbs, the damage was not so great, while on the farm of Mr. Peter Huber, 15 miles north, the damage was very extensive. Mr. Huber said he had sown 200 bushels of wheat, and expected to harvest about 50 bushels.

Sorghum, broom-corn, and pease escaped injury; onions and tobacco were mostly eaten.

In 1876 the locusts hatched very numerously, but did not do a great amount of damage. The red mites and wet season, with other causes, prevented their eating extensively.

In 1877 the eggs were destroyed by silky mite and chickens. Mr. A. W. Barber found about 1,200 eggs to the square foot in 1877.

The means of destruction used in this vicinity was the coal-tar pans. Crops were saved to some extent by dragging ropes across the fields and by smoking them.

August 5, 1879, I went from Yankton to Firesteel, Dak., on the stage. The locusts had visited Baldwin, Ramsey, and other places along the route, but had done only slight damage to all crops and less damage on the prairies than in the James River bottom.

At Firesteel, locusts were first noticed in 1874, July 13 or 14, and staid two days. July 25 they came from the northwest in large numbers, and August 1 another flight, small in numbers, came. These departed to the southwest. They did no damage, as there were only a few fields of sod corn in the valley. In 1875 locusts came in July, about the first week, and destroyed oats, wheat, and barley. In 1876 no 'hoppers to speak of. In 1877 locusts came July 5. The gardens were all destroyed. In 1878 no damage was done to small grains. Corn only slightly. Eggs were deposited for the first time.

In 1879 locusts have been flying toward the southeast, but none have stopped.

Eggs hatched in the James River bottom at Fire Steel, and in the bottom six miles north of there. The hatching commenced in May, and the latter part of June the 'hoppers began flying to the southeast.

From Firesteel I went to Fort Thompson. I went in a buggy. Full-fledged locusts were seen nearly all along the route.

August 8, near the Wessington Hills, locusts were seen flying to the southeast, and on the 9th, at Fort Thompson, they were flying to the southwest; both days they were very high. No damage was done at Fort Thompson this year; as to previous years I could learn nothing positive.

August 13, 1879, I visited Yankton Agency and found a few locusts, but could gather no facts concerning them. Being referred to Rev. John P. Williamson, who was absent at the time, I wrote to him for information. His answer I give in full:

"My first acquaintance with Yankton Agency was in 1868. Most of the time since I have had a little Indian paper here, and from that and some other memoranda I gather the following:

"A. D. 1868.—Grasshoppers arrived August 1 in such clouds as to cast a shade, and as they lit their wings made a roar like a flock of pigeons. They came from the northwest, went southeast. They mostly left in two or three days, but a few remained and deposited eggs along the roadside, and bare places, and in fields. No small grain sowed here then, but the corn and potatoes were entirely destroyed. Along the creeks many bushes were divested of leaves, especially ash.

"A. D. 1869.—A few hatched out in early spring and ate off some fields of corn as it came up. 'Hoppers left for the north when their wings grew in June.

"A. D. 1870.—No damage by grasshoppers.

"A. D. 1871.—Ditto.

"A. D. 1872.—Ditto.

"A. D. 1873.—Grasshoppers passed going northwest for several days, the last of June and first of July. A few lighted, but left without doing any damage to mention. They covered a field of wheat one night, but did not eat the wheat.

"A. D. 1874.—Grasshoppers came from the northeast during the last of July and remained a week or more, not in such numbers as in 1868, but injured corn badly, destroying probably half of the crop on the reservation. They came too late to injure small grain, though but little was sown at that time. No damage by grasshoppers since 1874. I can remember that some years a few have been seen passing over, and almost every year we have heard of them injuring crops in neighboring counties, but they did not reach us on this reservation. You will see from my notes that early in the season they moved north, and later south."

August 13, 1879, at Ponca, Nebr., a few locusts yet remain. They began hatching April 15, and hatched until May 20. They began flying June 12 toward the north and northwest. From the editor of the North Nebraska Journal I learned that two-thirds of the wheat, oats, and barley were destroyed. Corn was not damaged much. Sorghum and pease not eaten.

Coal-oil pans were used to kill young 'hoppers. Ropes were dragged across the fields to scare the old ones away. Smoke was also used to drive them away. Domestic fowls destroyed a good many.

For flights of locusts I give a list as furnished by Mr. James Rockwill:

"*May* 16.—Light wind from south; mercury at 58° morning, 78° noon. A heavy flight of 'hoppers go north nearly all day.

"*June* 16.—'Hoppers fly north by countless millions. Light winds from the south; mercury 78° at noon. Also the young 'hoppers are destroying the small grain, and some fields of corn suffer badly.

"*July* 5.—Myriads of 'hoppers fly north. Light wind from the south.

"*July* 11.—A prolonged flight of hoppers; go south. Light wind from northwest; mercury at 70° in morning, 92° at noon.

"*June* 26.—A very heavy flight goes south. Light wind from northwest; mercury 84° at noon. Besides these, several small flights, nearly all going south.

"*July* 15.—Terrible storm of wind, accompanied with lightning, thunder, and some rain, doing considerable damage to growing crops, blowing down fences, chimney-tops, &c."

The North Nebraska Journal reports locusts flying into Dakota County, Nebraska, June 5. Of this county the western part suffered severely. Of the eastern part only a few farms near Covington, opposite Sioux City, Iowa, were visited.

Very respectfully,

JOHN MARTEN.

CARBONDALE, ILL., *October* 11, 1879.

APPENDIX IV.

BIBLIOGRAPHY OF SOME OF THE LITERATURE CONCERNING DESTRUCTIVE LOCUSTS.

BY B: PICKMAN MANN.

Since I received a request to prepare an account of the various books and articles treating of destructive locusts on this continent and the continents of Europe, Asia, and Africa, circumstances have prevented me from devoting to the task enough time to do it any manner of justice. If I offer this very imperfect sketch it is only because I am warned that whatever is to be used must be furnished soon.

It will be noticed that I have made especial use of two books containing bibliographical material: the Bibliotheca Entomologica of Dr. H. A. Hagen (1862) and the article Ueber die Heuschrecken in Südrussland of F. Thdr. Köppen fil. (1865); also, that I have taken some citations from Gerstäcker's pamphlet, Die Wanderheuschrecke (1876). I have designated my extracts from these works by citing the names of the authors.

References to works upon a subject like the present may be classed as general and particular. Under the latter division I would place the citation of passages concerning destructive locusts in books of travel or other works not treating generally of the locusts. The number of such citations here given is small, and it is so mainly because most of the citations which I could make were already included in a few general works upon destructive locusts, viz., in the works by Ludolf (1694), Eiselt (1836), Keferstein (1843), and Köppen (1865), and, to a great extent, all the information contained in the passages so cited is transferred to the pages of one or more of the four works last mentioned. As far as I could, I have given a complete list of the works which have for their general subject the consideration of destructive locusts. I am far from having exhausted the subject, however, especially for works later than the Bibliotheca Entomologica, and I would point out, as an especially fertile field of research for any one who may wish to supplement my list, the annual reports upon entomology made by Burmeister (1834–1835), Erichson (1836–1848), Schaum (1848–1852), Gerstäcker (1853–1866), Brauer (1867–1870), and Bertkau (1871–1874), in the Archiv für Naturgeschichte, edited by Wiegmann (v. 1–6, 1835–1840), Erichson (v. 7–14, 1841–1848), and Troschel (v. 15–44, 1849–1878); also, the Record of Zoological Literature and Zoological Record for 1864–1873 (10 v., 1865–1875), and the Catalogue of Scientific Papers for 1800–1863 (6 v., 1867–1872), by the Royal Society of London.

For recent and future North American entomological literature, see the Bibliographical Record published in PSYCHE, the organ of the Cambridge Entomological Club, v. 1 (1874–1877), v. 2 (1877–1879), and subsequent volumes.

Titles which I have compared with the originals are designated by an asterisk (*) placed before them; titles thus verified by Dr. Hagen are preceded by a dagger (†).

ON THE DESTRUCTIVE LOCUSTS OF EUROPE, ASIA, AND AFRICA.

1. **Ant: Ruyschet.** Wahrhaftige Zeitung in Schlesien, geschehen 1542, von unerhörten Heuschrecken, wie viel der gewesen und was sie Schaden gethan haben. 1542. 4°.
   [Hagen, ii, 100.]

2. **Jodocus Willich.** Dialogus de locustis. Argentorati, 1544. 8°.
   [Hagen, ii, 290.]

3. **François Valleriola.** Verwüstung durch Heuschrecken um Arles um 1555. < Valleriola, Curations medicales, livr. ii, obs. 1.
   [Hagen, ii, 234.]

4. W. Strauch? Natürliche Conterfeyhung des gewaltigen Fluges Heuschrecken, welcher gefangen worden ist zu Mailand 1556. Nürnberg.

["Perhaps Strauch is only the printer." Hagen, ii, 201.]

5. Jul: Caesar Scaliger. De locustis. < Exotericarum exercitationum [liber xv de subtilitate ad H. Cardanum. Lutetiae, 1557. 476 folios. 4°. ——— Basel, 1560. 8°. ——— Francfurt, 1592. 8°. ——— Francfurt, 1607. 8°. ——— Hanaeviae, 1634. 1076 p. 8°]. fol. 192, p. 625.

[Hagen, ii, 112.]

6. Ant: Bersandier. Discours sur le dégât que les sauterelles firent en Provence 1613–1614. Paris, 1614. 12°.

[Hagen, i, 46.]

7. † Bartolomeo Ximenes Paton. Discorso de la langosta, que en el tiempo presente aflige, y para el venidero amenaza. Dedicado a Don Ivan Coello de Contreras etc. Con licencia en Baeça por Pedro de la Cuesta. [Villa nueva de los Infantes.] 1619. 22 leaves, without pagination. 4°.

[Hagen, ii, 31.]

8. † Juan de Quinones. Tratado de las langostas muy util y necessario, en que se tratan cosas de provecho y curiosidad para todos los que professan letras divinas y humanas, y las mayores ciencias. Madrid, por Luis Sanchez, 1620. 86 leaves + 22 p. Preface + 25 p. Index, without pagination + title-vignette. 4°.

[Hagen, ii, 57.]

9. † Anonym. Some observations of swarms of strange insects and the mischief done by them. < Philosophical Transactions. 1665. v. 1, no. 8, p. 137–138.

[Hagen, ii, 339.]

10. J: Dan: Major. Dissertatio de myrrha et locustis. Resp. J. F. Moller. Kiliae, 1668. 40 p. 4°.

[Hagen, i, 515.]

11. † Thdr: Kirchmaier. Dissertatio de locusti. Resp. G. Henr. Ursinus. Wittenberg [1680?]. 16 p. 4°.

[Hagen, i, 417.]

12. † Gotthilf Treuern. Die Heuschrecken, wie sie in der heiligen Schrift in ihrer Vermehrung und Vertilgung, in ihrer natürlichen Eigenschafft, in Historien und Sprüchwörtern betrachtet werden, beschrieben. Franckfurt a. O., Eichorn, 1681. 48 p., without pagination. 4°.

[Hagen, ii, 227.]

13. † Joac: Hopp. De edaci locustarum pernicie. Dissert. Resp. G. Martini. 2d ed., Jena, 1682. 5 sheets = 40 p. 4°.

[Hagen, i, 382.]

14. † H: Justell. An extract from a letter written from Aramont in Languedoc near Avignon giving an account of an extraordinary swarm of grasshoppers in those parts. < Philosophical Transactions. 1686. v. 16, no. 182, p. 147–149.

[Hagen, i, 407.]

15. Jean? Gallois. Observations sur les sauterelles qui ont ravagé la Pologne et la Lithuanie en 1689. < Mémoires de l'Académie des Sciences de Paris. v. 2, p. 88.

[Hagen, i, 261.] [Köppen, p. 194.]

16. Jan G: Swalbach *or* **S. Ussans.** Particularités remarquables des sauterelles qui sont venues en Russie. Paris, 1690. 5 p., 2 pl. 4°.

[Hagen, ii, 208 + 234 + 339.]

17. † J: Bilberg. Dissertatio: Locustae. Resp. P. Salonius 5. Juli. Upsaliae, 1690. 20 p. 8°.

[Hagen, i, 53.]

18. ——— Tenzel. Ueber Heuschrecken aus Ludolf. < Monatl. Unterred. 1691, p. 527; 1693, p. 838.

[Hagen, ii, 213.]

19. † Ludwig Chr: Crell. Dissertatio de locustis non sine prodigio nuper in Germania conspectis. Resp. J. F. Hauptvogel. Lipsiae, Coler, 1693. 3½ sheets = 26 p. 4°. ——— [Program]. * Disputationem historico-physicam de locvstis, non sine prodigio in Germania nuper conspectis, Dei auxilio & Superiorum indultu favente d. 28 Sept. M.DC.XCIII. publicè habebunt Praeses M. Ludovic. Christian. Crellius, Neostad. ad Erycas Franc. Et respondens Johannes Fridericus Hauptvogel. Lipsiae, Colerianus, 1693. 28 p., without pagination. 4°.

[Hagen, i, 146.] History, description, devastations, origin, and migrations of the locusts. Why do they come? What do they signify? How can they be got rid of?

20. G: Wolfg: Eberlin. Oratio de prodigioso locustarum agmine quod in diversis Pannoniae et Germaniae tractibus obumbravit solem, terrasque opperuit, an. 1693. Altdorf, Meyer, 1693. 16 p. 4°.

[Hagen, i, 204.]

21. G. E. Fesken. Gottes bedenkliches Heuschrekken-Heer, welches sich hin und wieder neulicher Zeit in ungewöhnlicher Menge sehen lassen. Leipzig, 1693. 4°.

[Gerstäcker (1876), p. 60.]

22. *Melissand Fichtelbergen. Heu! Schrecken! Von Heuschrecken, so dieses anno 1693. Jahr im Augusto, erstlich im Egrischen Creyss der Cron Böhmen, dann auch andern Orten, Wolcken-weisse eingefallen. St. Annaberg, Dav. Nicolai, 1693. 32 p., without pagination. 4°.

[Hagen, i, 232.] Accounts of invasions of locusts in all times.

23. *†J: Paul Hebenstreit. De locustis, immenso agmine aerem nostrvm implentibvs, et qvid portendere putentvr, numine æterno adspirante in Academia Jenensi sub praesidio J. P. H. [etc.], d. xxvi. Aug. M DC XCIII. publicè disputabit Christianus Prange [etc.]. Jenae, Schmid, 1693. 65 p. + 1 copper-pl. 4°.

[Hagen, i, 351, and ii, 52, cites both Hebenstreit and Prange as authors, but mentions one copy which bears the name of Prange "auctor" upon the title-page. Krebs seems to have been the printer and Schmid paid the bill.] Name, anatomy, qualities, and ravages of the locusts; means against them.

†J: Paul Hebenstreit. De remediis adversus locustas, imprimis Pontificiorum methodo expellendi eas per excommunicationem. Resp. B. G. Lippoldt. Jenae, 1693. 36 p. 4°.

[Hagen, i, 351.]

24. G: Caspar Kirchmaier. De locustis insolitis, tergemino examine et portentoso numero e Thracia Daciaque in Pannoniam inferiorem perque Austriam in Germaniae regionibus plures sese infundentibus, et pabula, quo transitus ferebat depascentibus ad virum Dr. Ch. Fr. Paullini dissert. epistolica. Wittenberg, Schroedter, 1693. 16 p. 4°.

[Hagen, i, 417.]

25. Abr: Klesel. Bericht von dem 1693 geschehenen Durchzuge der Heuschrecken. 1693. 4°.

[Gerstäcker, p. 60.]

26. Christoph H: Loeber. Mit Gott! Eigentliche Beschreibung des entsetzlich grossen Heuschrecken-Heers, welches im August A. 1693 bei und unweit Jena etc. erschienen. Jena, Bielcke, 1693. 47 p. 4°.

[Hagen, i, 488.]

27. J: Ph: Treuner. Dissertatio phaenomena locustarum praecipue nuperrimarum. Resp. Arnold Richerz. Jena, Müller, 1693. 32 p. + 1 pl. 4°.

["*Locusta migratoria.*" Hagen, ii, 227.] ["Gives historical notices especially." Gerstäcker (1876), p. 59.] [Gerstäcker, l. c., cites Richertz (sic) as the author.]

28. †G: And: Wollenhaupt. Dissertatio locustas et portentosam earum nubem etc. das ungewöhnliche Heuschrecken Heer. Resp. Johann Nicolas Oberländer. Erfurt, Grosch, 1693. 24 p. 4°.

["*Locusta migratoria.*" Hagen, ii, 295.] [Gerstäcker (1876), p. 60, cites Oberländer as the author, and gives as the title: Diatribe zoologica locustas etc.]

†Anonym. Eine Heuschreckliche Schreckruthe so zu Plauen im Voigtlande am 15. und folgenden Tagen Augusti dieses laufenden Jahres 1693 sich merklich blicken gelassen etc. Dresden [1693]. 4 p. 4°.

[Hagen, ii, 339.]

Anonym. Heerzug der Heuschrecken. Leipzig, 1693. 1 sheet. 4°. fig.

[Hagen, ii, 339.]

29. N: Hoepfner von Wetterstral. Die neue böse Pest der grossen und ominösen Fliegenschwärme. Jena. 4°.

Diptera or Orthoptera? [Hagen, i, 372.]

N: Hoepfner von Wetterstral. Abhandlung über die Sturmwinde und Heuschrecken. Gera, 1694. 4°?

[Hagen, i, 372.]

Christoph H: Loeber. Beschreibung des Heuschreckenheeres. Orlamünde, 1694.

["*Locusta migratoria.*" Hagen, i, 488.]

30. †**Jo. Hiob Ludolf.** Appendix secunda ad historiam Aethiopicam continens Dissertationem de locustis anno praeterito immensa copia in Germania visis cum Diatriba, qua sententia autoris nova de selavis, sive locustis, cibo Israëlitarum in deserto, defenditur, et argumentis contrariis viri docti respondetur etc. Francofurti ad Moen., Zunner, 1694. fol. 6 p. + p. 1–88 + pl. on p. 20; fig. on title and on p. 14.

"†Historia Aethiopica, published at Francf. ad Moen., 1681. 4 lib. fol. ——— †Commentarius. Francf. a. M., 1691. fol. ——— Appendix I. Francf.. a M., 1693. fol. ——— French translation, abridged: Nouvelle histoire de l'Abyssinie. Paris, 1684–1693. 12°. Also, English, Dutch, German, and Russian translations." [Hagen, i, 507.]

31. †**E: Floyd.** A letter giving an account of locusts lately observed in Wales. <Philosophical Transactions. 1694. v. 18, no. 208, p. 45–47. ——— †Badd. 1739. v. 3, p. 99–100.

[Hagen, i, 241.]

32. †**G: Owen.** Extract from his history of Pembrokeshire. <Philosophical Transactions. 1694. v. 18, no. 208, p. 48.

"Locusts in Wales." [Hagen, ii, 24.]

33. **Caspar Neumann.** Donnerwetter und Heuschrecken, beide im Jahr Christi 1693 zu Breslau gesehen. Breslau, 1694. p. 26–53. 4°.

"Penitential sermon." [Hagen, ii, 4.]

34. †**C: Rayger.** De locustis volantibus. <Ephem. Acad. Nat. Curios. 1694. Dec. 3, ann. 2, obs. 22, p. 29–31.

"*Gryllus migratorius.*" [Hagen, ii, 63.]

35. †**J: Christoph Ortlob.** Dissertatio de praesagiis locustarum incertis et falsis. Resp. Maurit. Castens. Vratisl. Auctor. Lipsiae, Titius, 1713. 32 p. 4°.

[Hagen, ii, 22.]

36. †**Paul Jetzen.** Conjecturae de ominosis locustis quae aestate superiore Silesiam depopulatae sunt etc. Sedini, Dahlius, 1713. 8 p., without pagination. 4°.

"Program." [Hagen, i, 398.]

37. †**Paul Jetzen.** Muthmaassungen von den wundersamen Heuschrecken welche im vorigen Sommer in Schlesien grossen Schaden gethan etc. Stettin, Dahlen, 1713. 14 p. 4°.

"New Year's gift. Probably the same as the preceding." [Hagen, i, 398.]

38. †**S: Chr: Loeber.** Epistola de locustis. <Ephem. Acad. Nat. Curios. 1715. Cent. iii et iv, Append., p. 137–146. ——— Valentini Amphitheat. Zootom. P. ii, p. 182–186.

[Hagen, i, 488.]

39. **Giu: del Papa.** Relazione delle diligenze usate con felice successo nell'anno 1716 per distruggere le cavallette, le quali avevano stranamente ingombrato una gran parte delle Maremme di Pisa, di Siena, di Volterra, e tutte le campagne di Piombino, Scarlino, e Sovvereto. Firenze, 1716. 48 p. 4°.

[Anonymous. Also ascribed to Tommaso Buonaventuri? Hagen, ii, 28 (Papa), 51 (Popa).]

40. †**Tommaso Buonaventuri.** Relazione delle devozioni ed opere di pietà che si son fatte nell'anno 1716 per ottenere da Dio la grazia di discacciare le cavallette che infestavano le Maremme di Pisa, di Siena e di Volterra. Firenze, 1717. 55 p. 4°.

[Hagen, i, 102.]

41. †**Francesco Scufoni.** Osservazione intorno alle cavallette. (Locusta migratoria.) Romae, Rossi, 1718. 24 p.; fig. 4°. ——— Latin translation: †Observationes circa locustas. <Ephem. Acad. Nat. Curios. 1722. Cent. ix et x, Append., p. 485–508, fig. ——— Extract: <†Giornale de letterati d'Italia, 1721. v. 33, pt. 1, no. 8, p. 411–425.

[Hagen, ii, 148.]

42. † **J: G: Siegesbeck.** Von der vermeintlichen Ankunft der Heuschrecken aus dem Mond. < Breslauer Natur- und Kunstgeschichte. 1723. vers. 23, p. 291–292.

[Hagen, ii, 163.]

43. † ——. Von dem sogenannten wandelnden Blatte. < Breslauer Natur- und Kunstgeschichte. 1723. vers. 25, p. 304–309.

[Hagen, ii, 339.]

J: Jac: Scheuchzer. Dissertatio physicae sacrae specimen de locustis. Resp. Maagius et Cellarius. Tiguri, 1724. 2½ sheets + 1 pl. 4°.

[Hagen, ii, 122.]

44. † **J: Leonh: Frisch.** Beschreibung von allerley Insecten in Teutschland, nebst nützlichen Anmerkungen und nöthigen Abbildungen von diesem kriechenden und fliegenden inländischen Gewürme, zur Bestätigung und Fortsetzung der gründlichen Entdeckung, so einige von der Natur dieser Creaturen herausgegeben, und zur Ergänzung und Verbesserung der andern. Berlin, Nicolai, 1720–1738. 13 v. 4°.

† v. 9. 1730. Sammt einer Vorrede, darinnen ein Auszug aus des Hr. Franc. Redi Buch von der Erzeugung der Insecten enthalten ist. Wie auch einer Beschreibung der Strich-Heuschrecken, welche in diesem Jahr grossen Schaden gethan, etc. 6 p. Vorrede + 38 p. + 22 copperpl. —— † [Review, on the locusts.] < Commerc. Norib. 1731. p. 103.

[Hagen, i, 254.] [Köppen, p. 266.]

45. † **C: H: Rappolt.** E generali contemplatione emolumentum e creaturis noxiis capiendi subnata quaestio; an damnum per locustas agris illatum earundem beneficio compensari possit. Berolini, Haude, 1730. 2½ sheets. 4°.

"Description and anatomy of three locusts." [Hagen, ii, 60.]

46. † **J: Jac: Rembold.** Historisch und physikalischer Tractat von Heuschrecken oder kurze Beschreibung von deren Benennung, Arten, Eigenschaften, Vermehrung, Wiederkunft, grossen Land-Schaden, Vorboten noch grösseren Unglücks, verschiedenen Anschlägen, Vortheilen auch in unterschiedl. Provintzien angewandten Mitteln selbige zu vertreiben u. völlig auszurotten, Zurichtung zur Speise, nützl. Gebrauch in Arzteneien-Kunst, nebst anderer curieuser Anmerk. berühmter Natur-Kunst- u. Welterfahrener Scribenten. Berlin u. Leipzig [autor, 1730]. 64 p. + 1 pl. 8°.

"*Locusta migratoria.*" [Hagen, ii, 71.]

47. † **Anonym.** Edict wegen Vertilgung der Heuschrecken oder Sprengsel: sub dato Berlin 13. April, 24. Octbr. 1731. < Corpus constit. Marchic. 1740. v. 5, pt. 3, p. 381–386, no. 41–42. fol. —— Reimpr.?: Königsberg, Hartung, 23. Mai 1805. 2 sheets. fol.

[Hagen, ii, 339.]

48. **V. Ludwig.** De locustis. < Hall. Wochenbl. 1731.

[Hagen, i, 507.]

49. * † *Conte* **Giu: Zinanni.** Delle uova e dei nidi degli uccelli libro primo. Aggiunte in fine alcune osservazioni, con una dissertazione sopra varie specie di cavallette. . . . Venezia, Antonio Bortoli, 1737. title + [6] + 130 + 55 + p., 18×12.5. frontispiece, 21×13.5. [3] + 22 + 8 pl., 18×12.

Contains:

* † Osservazioni giornali sopra le cavallette . . . . con una dissertazione in fine intorno alle medesime [including: Dissertazione delle cavallette, p. 35–50, and explanation of the plates of locusts, p. 51–55]. title + 55 p.; 8 pl.

"Biology and anatomy of the locusts." [Hagen, ii, 304.]

50. † **J: F: Weidler.** Narratio de erucarum et locustarum, quae agros Vitembergae vicinos aliquot abhinc annis vastarunt, interitu. < Philosophical Transactions. 1734. v. 38, no. 432, p. 294–296. —— † Badd. 1741. v. 9, p. 512–514.

[Hagen, ii, 263.]

51. † **J: Gottf: Buechner.** De rarioribus quibusdam animalibus in Voigtlandia quondam natis, ac degentibus. < Acta Natur. Curios. 1737. v. 4, p. 261–271.

"*Locusta migratoria.*" [Hagen, i, 100.]

52. **Justus Christoph Dithmar.** Relation von Heuschrecken, welche sich etliche Jahre jenseits der Oder aufgehalten, sammt den Anmerkungen von solchem Ungeziefer. < Oekonom. Fama. St. 2, p. 57.

[Hagen, i, 174.]

53. **Anonym.** A true representation of the locusts that fell in England the 4. Aug. 1748. 1 pl.

[Hagen, ii, 338.]

54. **Anonym.** Kaiserliches Mandat wegen der Heuschrecken, wie auch Beschreibung der 1747 und 1748 in Ungarn eingedrungenen Heuschrecken. < Natur- u. Kunsthistorie von Obersachsen. v. 2, p. 208.

[Hagen, ii, 339.]

55. ***† J: Chr: Kundmann.** Anmerkungen über die Heuschrecken in Schlesien von dem Jahre 1748. Auf Verlangen den Druck überlassen. Breslau, Korn [1748]. 39 p. + 1 pl. 4°.

[Hagen, i, 440.]

56. ***Ein Liebhaber der Natur-Wissenschaft.** Die Heuschrecke in ihrem Heer-Zuge, als ein wahrer Schrecke-Gast in Betrachtung gezogen. Mit einer Kupffer-Tabelle, darauf die mancherley und ganz besondern Arten der Heuschrecken vorgestellt werden. Leipzig, Schönermarck, 1748. 38 p.; 1 pl. 8°.

Description, classification, reproduction, swarms, food, injury and uses of locusts; means against them, history of their invasions. [Review: < Neue Hamburg. gel. Zeit. 1748. St. 7.] [Hagen, ii, 338.]

57. ***Ern: Ludewig Rathlef.** Akridotheologie oder historische und theologische Betrachtungen über die Heuschrekken, bei Gelegenheit der ietzigen Heuschrekken in Siebenbürgen, Ungern, Polen, Schlesien und Engelland. Nebst einer Muthmassung, dass die Selaven, welche die Israeliten zweimahl in der Wüsten gegessen, weder Wachteln, noch Heuschrekken, sondern die Vögel Seleuciden gewesen. Hannover, Richter, 1748. 12 + 36 + 233 p.; 1 pl. 8°.

History of locust invasions in all times in Asia, Africa, and Europe. Structure, descriptive characters, various species, habits, abundance, native countries, and migrations of locusts; their destructiveness and the use that can be made of them. [Hagen, ii, 61.] [Hagen, l. c., cites a Dutch translation of either this, the following, or both, by P. A. Verwer. Amsterdam, 1750. 176 p. + 1 pl. 8°. ——— Review: < Hamburg. Berichte. 1750. St. 58. ——— Review: < Erlang. Beitr. 1750. p. 482.]

58. **Ern: Ludewig Rathlef.** Akridotheologie, oder historische, physikalische und theologische Betrachtungen über die Morgenländischen Heuschrekken, bei Gelegenheit ihrer Züge in Europa in den Jahren 1747, 1748, 1749. Hannover, 1750. 340 p. 8°.

"Gives historical notices especially." [Gerstäcker (1876), p. 60.]

59. **† Anonym.** Beschreibung der Heuschrecken, sonderlich der heurigen. Dresden, Harpeter, 1748. 70 p.; 1 pl. 8°.

"*Locusta migratoria.*" [Hagen, ii, 338.]

60. **† A: J: Roesel.** . . . Der monatlich herausgegebenen Insecten-Belustigung zweiter Theil, welcher acht Classen verschiedener sowohl inländischer, als auch einiger ausländischer Insecte enthält; alle nach ihrem Ursprung, Verwandlung und andern wunderbaren Eigenschaften, grösten theils aus eigener Erfahrung beschrieben und in sauber illuminirten Kupfern nach dem Leben abgebildet, vorgestellet. Nürnberg, beim Verfasser, gedruckt bei J. J. Fleischmann, 1749. 50 + 550 p. + index + 94 col. pl. (on 76 pl.) + 1 title-pl.

Heuschrecken und Grillen, 200 p. + 30 pl. (on 29 pl.). [Hagen, ii, 84.]

61. **† Anonym.** An account of the locust which did vast damage in Walachia, Moldavia and Transilvania in the years 1747–1748 and of some swarms of them, which in the months of July and August 1748 came in to Hungary and Poland. < Philosophical Transactions. 1749. v. 46, no. 491, p. 30–37. ——— < † Hamburg. Magazin. 1751. v. 7, p. 546–554.

[Hagen, ii, 338.]

62. **Anonym.** Nachrichten von den landverderblichen Heuschrecken. Frankfurt a. M., 1750. 8°.

[Hagen, ii, 339.]

63. **† Anonym.** Sammlung merkwürdiger Nachrichten von den Heuschrecken, welche 1747 und 1748 aus der Türkey in Siebenbürgen, Ungarn, Polen eingedrungen, und von da 1749 durch Oestreich, Bayern etc. ausgebreitet. Frankfurt a. M., Cronau, 1750. 110 p.; 1 pl. 8°.

"*Locusta migratoria.*" ["Also in Kundmann's writing upon Silesian locusts." Hagen, ii, 339.]

64. **Christoph Gottlob Grundig.** Nachricht von allerley Insecten, sonderlich den Heuschrecken. < Natur- u. Kunsthistorie von Obersachsen. 1750. v. 1, p. 545.

[Hagen, i, 307.]

65. **Gottf: Schuster.** Schulabhandlung von den Insecten, besonders von den Heuschrecken. Königsberg, 1750. 7½ sheets. 4°.
[Hagen, ii, 144.]

66. † **Anonym.** Nachricht von denen Heuschrecken und wie selbige auszurotten. < Stuttgart. select. Phys. Oecon. 1751. v. 1, st. 4, p. 311–323.
[Hagen, ii, 339.]

67. † **Anonym.** Geschichte der Heuschrecken, darinnen under andern gezeigt wird, wie man dieselben wo nicht gleich vertilgen doch gar bald so dünne machen kann, dass ihre Anzahl dem Lande nicht mehr so empfindlich sein wird. Nürnberg, Zimmermann, 1753. 77 p. 8°.
[Hagen, ii, 339.]

68. † **J: Gottlieb Gleditsch.** Abhandlung von Vertilgung der Zugheuschrecken und den eigentlichen Hülfsmitteln, die sich auf richtige Erkenntniss dieser Thiere gründen. Berlin u. Potsdam, Vosse, 1754. 71 p. 8°.
"*Gryllus migratorius.*" ["Also in his Forstwissenschaft. ——— Act. Reg. Soc. Berol. 1752. pl. 4, p. 83–101. ——— † Mylius physik. Belustig. 1755. St. 26, p. 1192–1217. ——— Nürnberg, 1753. 8°. ——— Berlin, 1754. 8°. ——— † Gleditsch., Phys. bot. ök. Abhdl. v. 3, p. 228–311."] [Hagen, i, 286.]

69. **Anonym.** Supplément aux réflexions sur le désastre de Lisbonne avec un journal des phénomènes etc. en 1755 et des remarques sur la plaie des sauterelles. 1757. 8°.
[Hagen, ii, 339.]

70. **Jos: Gottlieb Koelreuter.** Razsuzhdenie o sarantshe s pokazaniem nadezhneïshikh sposob k iskoreneniiu onoï. < Sotshineniia i perevodi, k pol'ze i uveseleniiu sluzhashtshiia. 1758., p. 150. ——— [German translation.] † Abhandlung von dem Strichheuschrecken, nebst einer Anzeige der zuverlässigsten Mittel, dieselben zu vertilgen; übersetzt aus der russischen Monatsschrift, welche zu St. Petersburg unter der Aufsicht des Hrn. Prof. Müller heraus kommt. < Hamburg. Magazin. 1760. v. 24, pt. 2, p. 186–216, fig.
[Köppen, p. 196.] [Hagen, ii, 338.]

71. **Anonym.** Remedia quibus in regno Neapolitano locustae earumque ova destruuntur. < Histoire de l'Académie des Sciences de Paris. 1765.
[Hagen, ii, 339.]

72. **Gottf: A: Gruendler.** Beobachtungen über einige Heuschrecken. < Naturforscher. 1775. St. 5, p. 19–22.
"*Gryllus migratorius.*" [Hagen, i, 307.]

73. † **J: S: Schroeter.** Von den Heuschrecken, ihrer Naturgeschichte und den Gattungen, welche sich in Thüringen aufhalten. < Schroeter Abhandlungen über verschiedene Gegenstände der Naturgeschichte. 1776. v. 1, p. 258–316. ——— < † Berlin. Samml. 1772. v. 4, p. 496–541.
[Hagen, ii, 142.]

74. **G: F: Moeller.** Die Heuschrecken als ein Landwirth betrachtet. < Oekonomische Nachrichten [? der Gesellschaft in Schlesien. 1779]. v. 7, p. 48; p. 438.
[Hagen, i, 545.]

75. † **Don Guillermo Bowles.** Historia natural de la langosta de España. Madrid, 1781. 40 p. 12°.
[Hagen, i, 80.]

76. **Anonym.** Zur Kunde fremder Völker und Länder; aus französischen Missionsberichten. Leipzig, 1781. 8°. > v. 1, p. 19–22, contains: Heuschreckenschwärme aus der Reise eines Missionairs von Constantinopel nach Haleb.
[† Füessly neues Magazin, v. 1, p. 185–187.] [Hagen, ii, 339.]

77. * † **J: Roskoschnik.** Nachricht von den nach Bontzhida in Siebenbürgen gekommenen Zugheuschrecken, ihrem Aufenthalte daselbst, und ihrer Ausrottung; nebst einigen die Naturgeschichte derselben betreffenden Bemerkungen. Pressburg, Löwe, 1782. 14 p.; 1 copperpl. 8°. ——— Ungarische Magazin. 1782. v. 2, p. 389–399, fig.
"*Gryllus migratorius.*" [Hagen, ii, 93.] Treats of three or more species.

78. * † **A. Baron.** Recherches sur les sauterelles et sur les moyens de les détruire. < Journal de Physique. 1786. v. 29, p. 321–330. Q°. 4°. t 17 × 11.
"*Gryllus migratorius.*" [Hagen, i, 29.]

79. **A. Baron.** Rélation des ravages que les sauterelles ont fait dans quelques cantons de Languedoc et de Provence. < Journal de Languedoc. 1787. no. 1.

[Hagen, i, 29.]

80. † **Don Ignacio de Asso y del Rio.** Discurso sobre la langosta y medios de exterminarla. 1785. 32 p. 8°.

[Hagen, i, 15.] [See the following.]

81. * † **Oluf Gerhard Tychsen.** Des Don Ignacio de Asso y del Rio Königlich-Spanischen General-Consuls in Holland &c. Abhandlungen von den Heuschrecken und ihren Vertilgungs-Mitteln, aus dem Spanischen übersetzt, und mit einem Anhang von den Biblischen Heuschrecken begleitet. Rostock, Koppen, 1787. 16 + 104 p.; "1 pl".

Description of the three injurious genera of Spanish locusts; causes of their increase; means against them at all stages of their growth. Interpretation of biblical references to locusts.

["The appendix occupies p. 41–104, tab. ——— Extract: Jenaische Allgemeine Litter. Zeitung. 1788. v. 2, p. 163–165."] [Hagen, ii, 231; i, 15.]

82. **J: G: Kruenitz.** Oekonomisch-technologische Encyclopädie. 1790. v. 23, p. 377–503.

"The article 'Heuschrecke' gives historical notices especially." [Köppen, p. 91.] [Gerstäcker (1876), p. 60.]

83. **J: Bapt: Baron Rougier de Labergerie.** Ravages causés par des sauterelles dans un canton du Département du Gard. < Annales de l'agriculture française. An VI [1798]. ser 1, v. 1, p. 322–326.

[Hagen, ii, 95.]

84. † **P: Sim: Pallas.** Bemerkungen auf einer Reise in die südlichen Statthalterschaften des Russischen Reiches in den Jahren 1793–1794. Leipzig, 1799, 1801. 2 v. 4°. 25 + 26 pl.; 3 maps. ——— † [French transl.] Paris, 1801. 2 v. 8°. ——— [Completer ed.] Leipzig, 1803. 2 v. 8°.

[Hagen, ii, 25.] [Köppen, p. 248 and p. 258, quotes from v. 2, p. 376–382 and p. 487, concerning *Caloptenus italicus*.]

85. † **J: Gottlieb Georgi.** Geographisch, physicalische und naturhistorische Beschreibung des Russischen Reichs. Königsberg, Nicolovius, 1797–1802. 3 v. in 4 v., nebst Nachtrag. ——— [Notice (by Hagen).] Stettin. entomol. Zeitung. 1859. v. 20, p. 101–102; p. 204.

[Insects, v. 3, p. 1983–2167, and Nachtrag, p. 331–343. Hagen, i, 272 and 331.] [Köppen quotes frequently from p. 2057–2060.]

86. **J: Barrow.** An account of travels into the interior of southern Africa in the years 1797 and 1798; including cursory observations [etc.] London, Cadell, 1801. 419 p. 4°. ——— German translation: Leipzig, 1801. 8°. ——— French translation by L. Grandpré: Paris, 1801. 2 v. 8°. ——— Extract: < † Illigers Magazin für Insectenkunde. 1805. v. 4, p. 220 [upon flights of locusts]. ——— † Voigts Magazin für den neuesten Zustand der Naturkunde [etc.]. 1801. v. 3, p. 169.

[Hagen, i, 29 and 399; ii, 246.]

87. † **B. P. Kofod.** Om Höeskraekker i Almindelighed betragtede; isaer deres Oedelaeggelser; og tillige om de vigtigste Bibelsteder, hoor Höeskraekker omtales. Kjöbenhavn, Tikjobs, 1802. 8°. 159 p.; 1 pl.

"*Acridium migratorium.*" [Hagen, i, 428.] On locusts in general, their ravages, and passages in the Bible where they are mentioned.

88. **Cas: Rostan** *et* **Lyle Saint Martin.** Extrait d'un rapport fait à l'Académie de Marseille sur les sauterelles qui en l'an XII [1804] ont ravagé divers quartiers du territoire de cette ville et sur les moyens employés pour detruire ces insectes. < Mém. Acad. Marseille. II (1804). ——— < Annales de l'agriculture française. 1807. v. 29, p. 398–424.

[Hagen, ii, 94.]

89. ——— **Oloffson.** Etwas über die seit einigen Jahren in der Ukraine und Kleinreussen wüthenden Zugheuschrecken und die Mittel zu ihrer Vertilgung. < Oekonomische Repertorium für Liefland. 1809. v. 4, p. 708–718.

"Upon locust-invasions in the years 1794, 1804, 1805, 1806." [Köppen, p. 196.]

90. † **E: Dan: Clarke.** Travels in various countries of Europe, Asia and Africa. London, 1810–1823. 6 v. 4°. ——— Also 1816–1824. 11 v. 8°. ——— French translation: [Voyages en Russie, en Tartarie et en Turquie. (Traduits de l'anglais.)] † Paris, Arth. Bertrand, 1813. 3 v. 3 maps; 2 pl. 8°.

[Hagen, i, 132.] [Köppen quotes from v. 2, p. 293–296 and p. 440 of the French.]

91. *†**Gaetano de Lucretiis.** Sulle locuste, dette volgarmente Bruchi. < Atti del Reale Istituto Incorrag. alle Scienze naturali Napoli. 1811. v. 1, p. 233–269. Q°. 4°. t 17 × 12.

[Hagen, i, 506.]

92. †**Pomponio Senni.** Raccolta di osservazioni sulla propagazione delle locuste mezzi per imperdirne lo sviluppo e per la loro estirpazione. Roma, Mordachini, 1811. 35 p. 8°.

[Hagen, ii, 152.]

93. †**Giu: Mar: Giovene.** Delle cavallette pugliesi (Acrid. migratorium). < Mem. Soc. Italiana. 1813. v. 16: 2, p. 188–211.

[Hagen, i, 282.]

94. **Luigi Doria.** Origine, propagazione e danni delle locuste. Roma, 1816. 4°.

[Hagen, i, 178.]

95. **Ivan Martos.** Sposob istrebliat' sarantshu + < Trudi Vol'nago Ekonomitsheskago Obshtshestva. 1817. pt. 68, p. 133–166.

Means of destroying the locusts. < Transactions of the Free Economic Society. 1817. pt. 68, p. 133–166.

[Köppen, p. 197.] How to extirpate the locust.

96. **Anonym.** Note sur les sauterelles qui se sont propagées dernièrement dans le territoire d'Arles et sur les moyens employés pour leur destruction. < Annales de l'Agriculture française. 1819. ser. 2, v. 8, p. 357–363.

Extract from Journal de Marseille. [Hagen, ii, 339.]

97. †**Baron L: A:in d'Hombres-Firmas.** Notice sur les sauterelles d'Arles. < Journal de Physique. 1820. v. 90, p. 210–212. ——— < Isis, 1820, p. 913–914.

[Hagen, i, 378.]

98. †**Anonym.** Ueber Heuschrecken-Schaden in der Krim. < Froriep Notizen. 1824. v. 8, p. 292. ——— < Morgenblatt. 1824. no. 224.

[Hagen, ii, 339.]

99. ***Luigi Metaxà** *e* **Seb:o Rolli.** Osservazioni naturali intorno alle cavallette nocive della Campagna Romana. Roma, Poggioli, 1825. iv + 52 + p. Q°. 4°. t 19 × 13. 1 col. pl., 24 × 17. ——— †[Same.] Terza ediz. italiana. Roma, Magnoz, 1839. 72 p.; 1 col. pl. 8°.

[Hagen, i. 537; ii, 339.]

100. **Athanasii Stoïkovitsch.** O sarantshe i sposobakh istrebleniia eia. Sanktpeterburg, 1825. 4°.

On the locust and means of destroying it. St. Petersburg, 1825. 4°.

"On *Pachytylus migratorius* and how to extirpate it." "Almost complete, and in part a literal translation from the article Heuschrecke in the Oekonomische Encyclopädie of Krünitz (1790), which the author does not say." [Köppen, p. 90 and p. 92.]

101. **Anonym.** Ueber die italienische Heuschrecke. < André Oeconom. Neuigkeit. u. Verhandl. 1826. v. 2, p. 593–595.

"*Acridium italicum.*" "Translated from Bibl. Italiana, 1825, Oct." [Hagen, ii, 339.]

102. ——— **Gamba.** Voyage dans la Russie méridionale. Paris, 1826. 2 v. (In 1820–1824.—C. T.)

[Köppen cites p. 226–231 of v. 2, frequently.]

103. **G. Playfair.** On the appearance of locusts in the Doab. < Transactions of Medical and Phys. Society of Calcutta, v. 1, p. 306. ——— †Brewster Edinb. Journal. 1828. v. 8, p. 149–151. ——— Froriep Notizen. 1828. v. 20, p. 167–168.

[Hagen, ii, 47.]

104. †**J: Smirnove.** A communication on the locust (Gr. migratorius L.) which lately devastated the Crimea and the southern provinces of Russia. < Transactions of Linnæan Society of London. 1827. v. 15, p. 507–509. ——— †Froriep Notizen. 1828. v. 22, p. 264–266.

[Hagen, ii, 168.]

105. *†**F:z Körte.** Die Strich-, Zug- oder Wander-Heuschrecke ihre Beschreibung, Verheerung in jetzigen und frühern Zeiten, und die Mittel zu ihrer Vertilgung. Berlin, Rücker, 1828. 52 p.; 1 col. pl. 8°.

[Hagen, i, 428.]

106. ***F:z Körte.** Die Strich-, Zug- oder Wander-Heuschrecke vom Eie an beobachtet und beschrieben. Mit einer colorirten Abbildung. Berlin, Rücker, 1829. 103 p.; 1 col. pl. 8°.

[Hagen, i, 428.] "Contains the best and most thorough description of *Pachytylus migratorius*, so far as I know." [Köppen, 1865, p. 92.]

107. * **Vinc: Kollar.** Über die Zug- oder Wander-Heuschrecke. Acrydium migratorium. (Latr.); Gryllus migratorius. (Lin.) Mit besonderer Rücksicht auf ihre, in Sommer 1828 in Siebenbürgen angerichteten Verwüstungen, und die Mittel zu ihrer Vertilgung. < Wiener Zeitschrift für Kunst, Literatur, Theater und Mode. 1829. no. 15, p. 113–116; no. 16, p. 121–125; no. 17, p. 130–137; 1 col. pl.

Describes *Pachytylus migratorius* and the related species.

108. **Jul: Thdr: Chr: Ratzeburg.** ——— < Mittheilungen der k. k. mährischen Gesellschaft zur Beförderung des Ackerbaues. 1829.

[Köppen, p. 173.]

109. **Alex: Lefebure.** [Stauronotus cruciatus.] < Annales de la Société entomologique de France. 1833. v. 2, p. 338.

[Köppen, p. 265.]

110. † **E: Dan: Clarke.** The locust. < Zoological Magazine, or Journal of Natural History. London, 1833. v. 8, p. 139.

"Extract from Clarke's Travels in Tartary" (1810——). [Hagen, i, 132.]

111. * **Paolo Zanghi.** Delle cavallette e del modo di distruggerle. Opera in circostanza della invasione avvenuta nella Provincia di Caltanissetta nel 1832. Palermo, Virzi, 1835. 176 + 171 p. O°. 5 fig.

112. † **Ant: Jos: J: Solièr.** Note sur des apparitions d'Orthoptères dans les environs de Marseille. < Annales de la Société entomologique de France. 1833. v. 2, p. 486–489; Bull., p. 49. ——— † L'Institut. 1833. v. 1, no. 21, p. 183–184. ——— Froriep Notizen. 1834. v. 39, p. 81–84. ——— Isis. 1846. v. 7, p. 496.

[Hagen, ii, 173.] [Köppen, p. 266.]

113. † **Biagio Crescimom.** Osservazioni sulla vita delle cavallette e sui mezzi per distruggere. Calatagirone, Montalto, 1833. 64 p.; 1 pl. 8°.

[Hagen, i, 146.]

114. **Anonym.** Sepia hexapodia Molina als ein Orthopteron erkannt. < Froriep Notizen. 1835. v. 45, p. 273–275.

[Hagen, ii, 339.]

115. † **Giu: Alessi.** Sul metodo di distruggersi le cavallette. < Atti Accademia Gioënia. 1835. v. 9, p. 329–353.

[Hagen, i, 7.]

116. † **J: Nepomuk Eiselt.** Geschichte, Systematik und Literatur der Insectenkunde von den ältesten Zeiten bis auf die Gegenwart, als Handbuch für den Jünger und als Repertorium für den Meister der Entomologie. Leipzig, Hartmann, 1836. 8 + 255 p. 8°.

[Hagen, i, 209.] "Long list of writers upon the journeys of *Pachytylus migratorius*, p. 240–245." [Fischer Fr., Orth. eur. (1853), p. 291.]

117. † **Jul: Thdr: Chr: Ratzeburg.** Die Forstinsekten oder Abbildung und Beschreibung der in den Wäldern Preussens und der Nachbarstaaten als schädlich oder nützlich bekannt gewordenen Insekten: in systematischer Folge und mit besonderer Rücksicht auf die Vertilgung der schädlichsten. Berlin, Nicolai, 1837–1844. 3 v. 4°. With woodcuts and black and colored pl.

[Hagen, ii, 61–62.] [Köppen cites this work, v. 3, p. 262–275, frequently.]

118. † **C: Darwin.** Narrative of the surveying voyages of H. M. S. Adventure and Beagle between the years 1826 and 1836, describing their examination of the southern shores of South America. London, Colburn, 1839. 3 v. 8°. ——— [German transl. by E. Dieffenbach.] Naturwissenschaftliche Reisen. ——— † Erichson Bericht, 1841, p. 9. ——— Froriep Notizen, 1841, p. 385.

[Hagen, i, 162.] [Köppen, p. 121, p. 129, p. 130, p. 165, cites v. 1, p. 180–181, and v. 2, p. 95.]

119. **L: A:in d'Hombres Firmas.** Notice sur les dégâts commis aux environs d'Aix par Locusta ephippiger. < Annales de la Société entomologique de France. 1839. v. 8; Bull., p. 30–32.

[Hagen, i, 378.]

120. † **Edwin Brown.** A specimen of Locusta migratoria captured at Mickleover, near Derby. < Annals and Magazine of Natural History. 1842. v. 10, p. 157–158.

[Hagen, i, 93.]

121. ——— **Tschernevskii.** O sarantshe. < Posrednik. 1842. nos. 2 and 3. On the locust. < Umpire. 1842. nos. 2 and 3.

"Interesting observations on habits of *Pachytylus migratorius*, especially at the mouths of the Danube." [Köppen, p. 91 and 92.]

122. Pierre Marcell Toussaint de Serres. Mémoire sur les causes des migrations de divers animaux et particulièrement des oiseaux et des poissons. [Couronné.] < Natuurkund. Verhandelingen van de Holland. Maatschap. der Wetenschap. te Harlem. 1842. 321 p. 4°. ——— † [Notice.] Isis. 1844. v. 4, p. 302–304.
[Hagen, ii, 154.] [Köppen cites p. 43–44, and p. 529.]

123. † Jos: Alph: Rion. Relations des ravages causés en Valaise par les sauterelles en 1837, 1838 et 1839. < Actes de la Société helvétique des sciences naturelles réunie à Lausanne, 1843, p. 118–131.
[Hagen, ii, 77.]

124. † Adolph Keferstein. Ueber die schädlichen Heuschrecken. < Stettin. entom. Zeitung. 1843. v. 4, p. 167–191, p. 213–224, p. 232–241.
["With rich literature." Hagen, i, 411.] ——— ["Gives historical notices especially." Gerstäcker (1876).] [He and Ritter (Erdkunde) treat the chronology of locust appearances most extensively. Köppen, p. 92.]

125. † K: Henrik Boheman. Om grässhoppståg i Östergöthland. < Oefversigt af Kongliga Vetenskaps-Akademiens Förhandlingar, 1844, p. 105–106.
[Hagen, i, 62.]

126. Alex: Nordmann. Mittheilungen aus der Gebiete der Ornithologie Süd-Russlands. < Bulletin de la Classe phys.-mathématique de l'Académie Impériale des Sciences de St.-Pétersbourg, v. 4, nos. 6 and 7.
[Köppen, p. 256.]

127. † J: Levaillant. Sur une invasion des criquets voyageurs. < Compt. rend. 1845. v. 20, p. 1041. ——— † L'Institut. 1845. v. 13, no. 589, p. 131.
[Locusts invading Algeria. Hagen, i, 475.]

128. † M. Guyon. Apparition des sauterelles en Algérie. < Compt. rend. 1845. v. 20, p. 1499–1500. ——— † L'Institut. 1845. v. 13, no. 595, p. 181–182.
[Hagen, i, 327.]

129. † F. W. Oligschlaeger. Naturhistorische Miscellen. Gryllus migratorius; Coccus radicum. < Verhandlungen des naturhistorischen Vereins für Preussischen Rheinlände. 1845. v. 2, p. 64.
[Hagen, ii, 20.]

130. Ant:o Villa. Notizie intorno agli insetti dannosi. 1. Le locuste o cavalette. Milano, 1845. 8°. ——— Extr. from: Spettatore industriale. ——— † Translated by A. Senoner in: Hammerschmidt Allgemein. Oesterreich. Zeit. für Landw. 1847. v. 1, p. 17–19.
[Hagen, ii, 241.]

131. C:o Ag:o Bassi. Degli insetti carnivori adoperati a distruggere le specie dannose all'agricoltura. < Giornal. agrar. Lombard. Venet. ——— Also separate: Milano, 1845. 8°.
[Hagen, i, 32.]

132. Angelo Bellani. Sul mezzo di prevenire il danno che arrecano gli insetti al frumento. < Ann. d'agric. r. d'Italia, v. 19.
[Hagen, i, 39.]

133. * † Ant:o Villa. Rivista analitica delle obiezioni publicate dai Signori Bassi e Bellani sulle memorie intorno gli insetti carnivori e le locuste. < Spettatore, v. 3, no. 27. ——— Also separate: Milano, Valentini, 1846. 23 p. O°. 6°. t. 18 × 10.
[Hagen, ii, 241.]

134. † P. F. Wahlberg. Om Sträckgräshopper. < Oefversigt af Kongliga Vetenskaps-Akademiens Förhandlingar. 1846. v. 3, p. 214–215.
"*Gryllus migratorius.*" [Hagen, ii, 250.]

135. † H: Scholtz. Ueber Gryllus migratorius in Schlesien. < Arbeit. schles. Gesellschaft für vaterländ. Kultur, 1846, p. 100.
[Hagen, ii, 137.]

136. Jona: Couch. Notice of the occurrence of the locust (Gr. migratorius) in Cornwall. < Rep. Royal Instit. Cornwall, 1846, p. —.
"*Gryllus migratorius.*" [Hagen, i, 145.]

137. Gotthelf Fischer v. Waldheim. [Description of the Russian Orthoptera.] < Nouveaux Mémoires de la Société Impériale des Naturalistes de Moscou. 1846. v. 8, p. 293–294.
[Köppen, p. 97, 168.]

138. Gotthelf Fischer v. Waldheim. [Description of Oedipoda vastator.] < Nouveaux Mémoires de la Société Impériale des Naturalistes de Moscou. 1846. v. 8, p. 312–313.

139. J: Demole. Les sauterelles dans la Rossie méridionale. [In Russian.] < Odesskiï Vestnik. 1846. no. 3. ——— [Reprint ?] < Zhurnal Ministerstva Gosudarstvennikh Imushtshestv. 1846. pt. 20; Sovremennaia Letopis, p. 22–25. ——— [Transl. ?] < Archives des sciences phys. et natur. de la Bibliothèque universelle de Genève. 1856. v. 31, p. 218–229. ——— [Notice.] † Gerstäcker Bericht, 1856, p. 107.

. . . < Odessa Courier. 1846. no. 3. ——— . . . < Journ. of Ministry of Crown Domains. 1846. pt. 20; Contemporary Annals, p. 22–25.

[Hagen, i, 167.] [Köppen, p. 91, 220.]

140. Mikhail Kanischtschev. Zametshaniia ob istrebleniï sarantshi. < Zemledel'tsheskaia Gazeta. 1846. no. 33.

Observations on the destruction of the locust. < Agricultural Gazette. 1846. no. 33.

[Köppen, p. 217.] Remarks upon the extirpation of the locust.

141. A. Arkhipoff. Zametshaniia o sarantshe. < Zemledel'tsheskaia Gazeta. 1846. nos. 42–46.

Observations on the locust. < Agricultural Gazette. 1846. nos. 42–46.

"Some original observations, made in the Government of Stavropol." [Köppen, p. 91, p. 92.]

142. J: G: Kohl. Reisen in Südrussland. 1847.

[Köppen quotes frequently from this work, p. 153–170.]

143. Evgeniï Han (Eug: v. Hahn). O poriadke i posledstviakh istrebleniia sarantshi v Bessarabskikh Bolgarskikh koloniiakh, v 1847. < Zemledel'tsheskaia Gazeta. 1848. no. 21. ——— < Zhurnal Ministerstva Gosudarstvennikh Imushtshestv. 1848. pt. 27, p. 178–185.

On the arrangements for and results of the destruction of the locust in the Bessarabian Bulgarian colonies, in 1847. < Agricultural Gazette. 1848. no. 21. ——— < Journal of the Ministry of Crown Domains. 1848. pt. 27, p. 178–185.

[Köppen, p. 178.] Report upon the destruction of locusts in the Bulgarian colonies of Bessarabia, in the year 1847.

144. † **F: Boie.** Ueber das Vorkommen von Gryllus migratorius (in Schleswig). < Stettin. entom. Zeitung. 1848. v. 9, p. 90.

[Hagen, i, 64.]

145. † **C. Cornelius.** Vorkommen von Gryll. migratorius; Aphidenzüge. < Stettin. entom. Zeitung. 1848. v. 9, p. 91.

[Hagen, i, 139.]

146. † **Jac: Poeschl.** Notizen über die Wanderheuschrecke. < Haidinger Berichte. 1848. v. 3, p. 436–438.

[Hagen, ii, 48.]

147. † Baron **Michel Edmond de Selys-Longchamps.** Sur la sauterelle voyageuse observée en Belgique. < Bulletins de l'Académie de Bruxelles. 1849. v. 16, pt. 2, p. 626–628. ——— † L'Institut. 1850. v. 18, no. 843, p. 71. ——— † Froriep Tagsberichte. 1850. v. 1, p. 119–120.

[Hagen, ii, 151.]

148. † **Vinc: Kollar.** Beiträge zur Kenntniss des Haushaltes und der geographischen Verbreitung einiger in ökonomischer und technischer Hinsicht wichtigen Insecten. < Sitzungsberichte der Akademie Wissenschaft. Wien. 1849. v. 3: 9, p. 317–323. ——— Separate: † Wien, 1849. 7 p. 8°.

"*Bostrichus, Oedipoda migratoria, Cynips calicis.*" [Hagen, i, 431.]

149. † **Hip: Lucas.** Note sur la Tryxalis procera et Acridium migratorium. < Annales de la Société entomologique de France. 1849. ser. 2, v. 7; Bull., p. 70.

[Hagen, i, 500.]

150. † ——— **Genin** *et* ——— **Bonjean.** Note sur des sauterelles qui ont paru près de Saint Pierre d'Albigny. < Compt. rend. 1850. v. 31, p. 452–453.

"*Oedipoda migratoria.*" [Hagen, i, 270.]

151. A: Le Jolis. Note sur l'oedipode voyageuse ou sauterelle de passage trouvée à Cherbourg. 1851.

[Hagen, i, 403.]

152. † **L: Imhoff.** Die Wanderheuschrecke in Basel. < Bericht über Verhandlung. der naturforschenden Gesellschaft in Basel. 1851. v. 9, p. 64.

[Hagen, i, 401.]

153. † **C: Vogt.** Zoologische Briefe: Naturgeschichte der lebenden und untergegangenen Thiere, für Lehrer, höhere Schulen und Gebildete aller Stände. Frankfurt, Literarische Anstalt, 1851–1852. 2 v. 8°. fig. v. 1, p. 1–719; v. 2, p. 1–640.

Insects: v. 1, p. 514–703. [Hagen, ii, 245.] [Köppen, p. 113, p. 134, cites v. 1, p. 537, fig. 630, and p. 578, fig. 697 (mucus glands); v. 2, p. 574 (migrations).]

154. Anonym. Das Forstgesetz für das Königreich Bayern. München, 1852.

[Köppen cites art. 46 and 76.] Laws for the destruction of locusts.

* † **Leop: H: Fischer.** Orthoptera europaea. Lipsiae, Engelmann, 1853. xx + 454 p., t 22 × 16; 18 pl. (1 pl. partly col.) 23 × 17.

p. 321–324, pl. 16, fig. 13. *Stenobothrus pratorum.*
p. 352–353, pl. 17, fig. 11. *Stauronotus cruciatus.*
p. 368–369, pl. 15, fig. 19–20. *Pezotettix alpina.*
p. 369–371, pl. 15, fig. 17–18. *Pezotettix pedestris.*
p. 377–381, pl. 15, fig. 25–26. *Caloptenus italicus.*
p. 393–395, pl. 18, fig. 12. *Pachytylus migratorius.*
p. 395–397, pl. 18, fig. 13. *Pachytylus cinerascens.*
and much more in general.
[Hagen, i, 238.]

155. ——— **Skarzhinskiĭ.** Skazanie o sarantshe. < Zapiski obshtshestva sel'skago khozhiaĭstva iuzhnoĭ Rossii. 1853. pt. 3.
Account of the locust. < Memoirs of the Society of Rural Economy of Southern Russia. 1853. pt. 3.

[Köppen, p. 156.]

156. **Vct: v. Motschulsky.** Études entomologiques. Helsingfors, Soc. Liter. Finn., 1853–1860. 9 v. 8°. ——— Dresde, 1861–1862. v. 10–11. 8°.

[Hagen. i, 552.] [Köppen cites v. 1, p. 74.]

157. L. v. Roenne. Die Verfassung und Verwaltung des Preussischen Staates. Das Domainen-, Forst- und Jagdwesen des Preussischen Staates. Berlin, 1854.

p. 614–638. A collection of the special orders, issued from time to time to meet particular cases, for the destruction of injurious insects in the royal forests of Prussia, and for assigning corresponding duties to private proprietors of woods. [Köppen, p. 238.]

158. † **Alfr: Edm: Brehm.** Reiseskizzen aus Nord-Ost-Afrika oder den unter egyptischer Herrschaft stehenden Ländern Egypten, Nubien, Sennaar, Rosseeres und Kordofahn, gesammelt auf seinen in den Jahren 1847–1852 unternommenen Reisen. Jena, Mauke, 1855. 3 v. 8°.

[Hagen, i, 86.] [Köppen, p. 106, cites v. 3, p. 219–220.]

159. Anonym. [Description of Wedel's machine for crushing locusts.] < Unterhaltungsblatt für deutsche Ansiedler im südlichen Russland. 1856. nos. 2 and 3. ——— Also: < Zemledel'tsheskaia Gazeta. 1856. no. 23. 1859. no. 98.

[Köppen, p. 221.]

160. * † **Vkt: Motschul'skiĭ.** O vrednikh i poleznikh nasekomikh. Sanktpeterburg, 1856. 134 p., 21 × 12, t 16 × 10. 8°. ——— Separate from: Mittheilungen der Kaiserlichen freien ökonomischen Gesellschaft zu Petersburg.
On injurious and useful insects. St. Petersburg, 1856. 134 p., 21 × 12, t 16 × 10. 8°.

Contains preface, 4 p.; on *Cecidomyia*, 20 p. + 1 pl., 1852; on *Oedipoda* (o sarantshe), 80 p. + 1 pl., 1853; on *Bruchus*, 20 p. + 1 pl., 1854; on *Hyponomeuta padella*, 14 p., 1856. [Hagen, i, 553.]

161. Vkt: Motschul'skiĭ. O sarantshe i sredstvakh k eia istrebleniiu. Sanktpeterburg, 1856. 32 ? p. 8°.
On the locust and remedies for its extermination. St. Petersburg, 1856. 32 ? p. 8°.

Upon the locust and the means of extirpating it. "Derived principally from the writings of Stoïkovitsch (1825), Tschernevsky (1842), and Keferstein (1843), mostly without citation of sources." [Köppen, p. 91, p. 92.] [Gerstäcker (1876), p. 64.]

162. * **Vct: Motschulsky.** On the means of destroying the grasshopper. Translated from the Russian by Professor W: W. Turner. < Annual Report of the Smithsonian Institution for 1858, 1859, p. 214–228, fig.

Probably a translation of the preceding.

163. † **Ant:o Villa.** Le cavalette o locuste. < Milano. Giornal. Fotografo. 1856. ann. 4, no. 3. 4 p.; 1 pl.

[Hagen, ii, 241.]

164. † **Al. Doenkingk.** Uebersicht periodischer Erscheinungen aus dem Thierreiche der Umgegend Kischinews. < Bulletin de Moscou. 1857. v. 30, pt. 3, p. 249–254. ——— † Gerstäcker Bericht, 1857, p. 37.
[Hagen, i, 174.] [Köppen, p. 107.]

165. † **G. Waga.** Leptinus testaceus parasite des Musaraignes; note sur les insectes nuisibles de la Pologne. < Annales de la Société entomologique de France. 1857. ser. 3, v. 5; Bull., p. 125–129.
[Hagen, ii, 249.] [Köppen, p. 265.]

166. **Anonym.** Die Forstverwaltung Badens. Karlsruhe, 1857.
p. 154. Laws for the destruction of locusts. [Köppen, p. 238.]

167. † **Rud: Tuerck.** Ueber die in Oesterreich unter der Ens bis jetzt aufgefundenen Orthopteren. < Wiener entomologischen Monatsschrift. 1858. v. 2, p. 360–381.
[Hagen, ii, 230.] [Köppen, p. 145.]

168. † **Vinc: Kollar.** Beitrag zur Geschichte schädlicher Heuschrecken. < Verhandlungen der Wiener zoologisch-botanischen Gesellschaft. 1858. v. 8, p. 321–324.
[Hagen, i, 432.] [Köppen, p. 265.]

169. † ——— **Audé.** Pluie d'insectes aux herbiers. < Compt. rend. 1858. v. 46, p. 1055.
"Orthoptera" dans la "Vendée". [Hagen, i, 17.]

170. † **F: Haberlandt.** Die Wanderheuschrecken in Hanság. < Verhandlungen des Vereins für Naturkunde zu Pressburg. 1858. v. 3, p. 5–9.
[Hagen, i, 328.]

171. † **Alex: Yersin.** Note sur le Pachytulus migratorius. < Archives des sciences phys. et naturelles de la Bibliothèque universelle de Geneve. 1858. v. 3, p. 267–286.
[Hagen, ii, 298.] [Köppen, p. 92.]

172. † **E. W. Janson.** Swarms of locusts in China. < Transactions of Entomological Society of London. 1858. ser. 2, v. 4; Proc., p. 87.
[Hagen, i, 396.]

173. ——— **Dor.** ———. < Annales de la Société entomologique de France. 1858. ser. 3, v. 6; Bull., p. 224–225.
[Köppen, p. 172.]

174. † **Andreas Johannes Jaeckel.** Ueber die Wander-, Zug- oder Strich-Heuschrecke in Bayern. < Correspondenzblatt. zool.-mineral. Verein Regensburg. 1859. v. 13, p. 160–171.
"*Oedipoda migratoria.*" [Hagen, i, 395.]

175. * † **F: Thdr: Koeppen.** Die Heuschrecken in der Krym im Jahre 1859. Auszug aus einem Briefe an den Ersten Secretär, Dr. Renard. < Bulletin de Moscou. 1859. v. 32, no. 3, p. 296–300.
[Hagen, i, 428.] [Köppen, p. 108.]

176. † **Pater Montrouzier.** Lettre entomologique de l'île Lifu (Chabrol), Nouvelle-Calédonie. < Annales de la Société entomologique de France. 1859. ser. 3, v. 7; Bull., p. 145–149.
[Hagen, i, 547.] [Köppen, p. 209.]

177. Dr. **W: Hamm.** Mitten in den Heuschrecken. < Gartenlaube. 1859. January.
[Köppen, p. 100.]

178. **Anonym.** Rukovodstvo dlia istrebleniia sarantshi, sostavlennoe osobim Komitetom, ytshrezhdennim v 1859 godu v g. Odesse, po rasporiazheniiu Ego Siiatel'stva, G. Novorossiïskago i Bessarabskago General-Gubernatora, General-Adiutanta Grafa Strogonoffa.
Guide to the destruction of the locust, compiled by a special committee established in 1859 in the government of Odessa, by direction of His Illustrious Highness Adjutant-General Count Strogonoff, Governor-General of New Russia and Bessarabia.
[Köppen, p. 241.] Manual of locust-extirpation.

179. † **E: Eversmann.** Orthoptera Volgo-Uralensia. < Bulletin de Moscou. 1859. v. 32, pt. 1, p. 121–146; pl. 1.
[Hagen, i, 218.] [Köppen cites p. 138–139.]

180. G. Belke. [Letter to Renard.] < Bulletin de Moscou. 1859. no. 4, p. 581-583.
[Cited by Köppen, p. 201, p. 206.]

181. Dr. **Const: W. L. Gloger.** [Locust ravages in the district of Schlochau.] < Beilage zum preussischen landwirthschaftlichen Intelligenzblatt vom 4 Juli 1860, no. 27.
[Köppen, p. 266.]

182. † **J. Schatiloff** *und* ——— **Borsenkow.** Mittheilungen über die Wanderungen des Gryllus migratorius auf der Taurischen Halbinsel im Jahre 1859 und über das Vorkommen einer Species von Gordiaceen in den Bauchhöhlen derselben. < Bulletin de Moscou. 1860. v. 33, no. 1, p. 294-297. ——— [Extract.] < Berliner entomologische Zeitschrift, 1860, p. 12.
[Hagen, ii, 117.] [Köppen, p. 125, p. 181.]

183. † **Al. Doenkingk.** Die Wanderheuschrecke und ihre Verheerungen im Jahre 1860. < Bulletin de Moscou. 1860. v. 33, p. 531-542.
[Hagen, i, 174.] [Köppen, p. 91.]

184. † **Alex: Yersin.** Sur les dégâts produits par les sauterelles dans la vallée du Rhône. < Bulletin de la Société Vaudoise des sciences naturelles. 1860. v. 6, p. 244-254.
[Hagen, ii, 298.]

185. H. Kawall. Die Orthopteren und Neuropteren Kurlands. < Correspondenz-Blatt des naturforschenden Vereins in Riga. 1861? v. 14, no. 11.
[Köppen, p. 143, p. 178.]

186. G: Ritter v. Frauenfeld. Der Aufenthalt auf Manila während der Weltreise der k. k. Fregatte Novara. < Verhandlungen der k. k. zoologisch-botanischen Gesellschaft in Wien. 1861. v. 11, p. 275-276.
[Köppen, p. 122.]

187. Anonym. O posledstviiakh mere k istrebleniiu sarantshi v iuzhnom krae Rossii v 1859-1860 godakh. < Zhurnal Ministerstva Gosudarstvennikh Imushtshestv, pt. 78, p. 175-194.
On the results of measures for the destruction of the locust in the southern district of Russia in 1859-1860. < Journ. Ministry of Crown Domains, pt. 78, p. 175-194.
["Seems to be an official report." Köppen, p. 201, p. 206.] The results of measures taken for the extirpation of the locust in Southern Russia in 1859-1860.

188. K: Brunner v. Wattenwyl. Ueber die von der k. k. Fregatte Novara mitgebrachten Orthopteren. < Verhandlungen der k. k. zoologisch-botanischen Gesellschaft in Wien. 1862. v. 12 [? p. 88-94].
[*Pachytylus migratorius*, *P. cinerascens*, *P. obtusus* n. sp.] [Köppen, p. 95.]

189. Dr. **W: Hamm.** Südöstliche Steppen u. Städte nach eigener Anschauung geschildert. Frankfurt a. M., Sauerländer, 1862. 349 p. 8°.
"Locust swarms, p. 179-196." [Hagen, i, 336.] [Köppen.]

190. * Dr. **Herm: A: Hagen.** Bibliotheca entomologica. Die Litteratur über das ganze Gebiet der Entomologie bis zum Jahre 1862. Leipzig, Engelmann, 1862-1863. 2 v. xii + 566 + 512 p. O°. 4°. t 18 × 11.
Collects the literature of all entomology, up to 1862, mainly from personal examination of the works cited.

191. F: Thdr: Koeppen *fil.* [Results of own observations of locusts.] < Zhurnal Ministerstva Gosudarstvennikh Imushtshestv. 1863. June.
. . . < Journ. Ministry Crown Domains. 1863. June.
[Köppen, p. 92.]

192. Ad:ph Keferstein. Einige Bemerkungen über Insecktenzüge. < Zeitschrift für die gesammten Naturwissenschaften. 1863. nos. 10 and 11, p. 249-275.
[Köppen, p. 180.]

193. Al. Petzholdt. Reise im westlichen und südlichen europäischen Russland. Leipzig, 1864.
p. 256-258. "Most exact description and figure of Wedel's locust-crushing machine." [Köppen cites frequently p. 253-258.]

194. E. L. Taschenberg. Naturgeschichte der wirbellosen Thiere, die in Deutschland schädlich werden. Leipzig, 1865.
[Köppen, p. 101.]

195. C. Cornelius. Die Zug- und Wanderthiere. Berlin, 1865.
p. 278-299. [Köppen, p. 90, p. 137.]

196. K. Skatschkoff. ——— [In Russian.] Horae Societatis Entomologicae Rossicae. 1865. v. 3, p. 24.

Extirpation of locusts in China. [Köppen, p. 110.]

197. * **F: Thdr. Koeppen** *fil.* Ueber die Heuschrecken in Südrussland. Nebst einem Anhange über einige andere daselbst vorkommende schädliche Insekten. < Horae Societatis Entomologicae Rossicae. 1865–1866. v. 3, p. 81–294. O°. 8°. t 18 × 11.

Collects the Russian literature and compares his own observations with those of other persons. Treats of the distinction of species and names of destructive locusts, and of the development, nourishment, reproduction, habits, movements, seasons, localization, abundance, subjection to atmospheric influences, enemies, periodicity, diseases, geographical distribution, and devastations of *Pachytylus migratorius*. Treats briefly, in a similar way, of *Caloptenus italicus*, and still more briefly of other injurious locusts. The appendix treats of the South-Russian fauna and of a few injurious insects of several orders.
References are made to innumerable passages in general works.

198. * Oberst v. **Malinowski.** Beiträge zur Naturgeschichte der Wanderheuschrecke (Acridium migratorium L.). < Verhandlungen der zoologisch-botanischen Gesellschaft in Wien. 1865. v. 15, p. 67–76.

199. * **Ant:o Villa** *e* **Gio: Batt: Villa.** Notizie sulle cavallette o locuste. Relazione. Milano, Redaelli, 1867. 12 p. 8°.

Notices of European and other invasions by locusts; use of locusts and other insects as food.

200. Vossische Zeitung, 7 Jul. 1875. Erste Beilage, p. 4.

[Gerstäcker (1876), p. 59.]

201. Sitzungsbericht d. Gesellsch. naturf. Freunde zu Berlin vom 20. Juli 1875, p. 106.

[Gerstäcker (1876), p. 59.]

202. * **Dr. A. Gerstaecker.** Die Wanderheuschrecke. (Oedipoda migratoria Lin.) Gemeinverständliche Darstellung ihrer Naturgeschichte, Lebensweise, Schädlichkeit und der Mittel zu ihrer Vertilgung. Im Auftrage des königl. preuss. Ministeriums für die landwirthschaftlichen Angelegenheiten verfasst. Berlin, Wiegandt, 1876. 67 p.; 9 fig. on 2 col. pl. O°. 8°. t 17 × 11.

History, characters, development, reproduction, nourishment, and migrations of the locusts; means against them.

203. * **Alb: Mueller.** Ueber das Auftreten der Wanderheuschrecke am Ufer des Bielersee's. < Verhandlungen der schweizerischen naturforschenden Gesellschaft in Andermatt, Sept. 1875, p. 188–190. Luzern, 1876. t 15 × 10.

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[The passages cited in the following magazines treat of locusts. These passages are compiled from quotations, so that others may exist beside them without being noticed here.]

204. Breslauische Sammlungen v. Jahre 1728.

[Gerstäcker (1876), p. 61.]

205. Gazeta Lesovodstva i Okhoti. 1856. no. 13, no. 14.
Gazette of Arboriculture and Hunting. 1856. no. 13, no. 14.

[Köppen, p. 189.]

206. Zhurnal Ministerstva Vnutrennikh Del. 1845. pt. 11. ——— 1848. pt. 23, p. 60, p. 66, p. 361. ——— 1849. pt. 27, p. 465–467. ——— 1850. pt. 31. ——— 1851. pt. 34, p. 510. ——— 1856. pt. 21; Sovremennaia Letopis, p. 20. ——— 1860. pt. 41; Letopis, p. 15. ——— 1860. pt. 42; Letopis, p. 30. ——— 1861. pt. 49; Letopis, p. 49.
Journal of the Ministry of Internal Affairs. 1845. pt. 11. ——— 1848. pt. 23, p. 60, p. 66, p. 361. ——— 1849. pt. 27, p. 465–467. ——— 1850. pt. 31. ——— 1851. pt. 34, p. 510. ——— 1856. pt. 21; Contemporary Annals, p. 20. ——— 1860. pt. 41; Annals, p. 15. ——— 1860. pt. 42; Annals, p. 30. ——— 1861. pt. 49; Annals, p. 49.

[Köppen, p. 92, p. 138, p. 139, p. 160, p. 166, p. 179, p. 189, p. 201, p. 207, p. 230, p. 264.]

207. Zhurnal Ministerstva Gosudarstvennikh Imushtshestv. 1843. pt. 8, p. 360. ——— 1846. pt. 21. ——— 1851. pt. 40. ——— 1852. pt. 42. ——— 1856. pt. 59. ——— 1860. pt. 73; Miscellen, p. 67–68. ——— 1861. pt. 78, p. 175–194. ——— 1863. June (Köppen). ——— 1864. Sept., p. 56 (Nowizky). ——— 1865. April, p. 433 (Brandt); Aug. (Kuschakewitsch).
Journal of Ministry of Crown Domains. 1843. pt. 8, p. 360. ——— 1846. pt. 21. ——— 1851. pt. 40. ——— 1852. pt. 42. ——— 1856. pt. 59. ——— 1860. pt. 73; Miscellen, p. 67–68. ——— 1861. pt. 78, p. 175–194. ——— 1863. June (Köppen). ——— 1864. Sept., p. 56 (Nowizky). ——— 1865. April, p. 433 (Brandt); Aug. (Kuschakewitsch).

[Köppen, p. 92, p. 107, p. 130, p. 179, p. 189, p. 194, p. 201, p. 206, p. 228, p. 243, p. 251.]

208. Landwirthschaftliche Mittheilungen für das Kurländische Gouvernement. 1855. no. 11.
[Köppen, p. 178.]

Morgenblatt. 1824. no. 224. ——— 1827. no. 45.
[Köppen, p. 198, p. 207.]

209. Odesskiï Vestnik. 1846. no. 3 (Demole). ——— 1850. ——— 1861. no. 65, no. 71, no. 72, no. 83, no. 91, no. 131. ——— 1862. no. 68.
Odessa Courier. 1846. no. 3 (Demole). ——— 1850. ——— 1861. no. 65, no. 71, no. 72, no. 83, no. 91, no. 131. ——— 1862. no. 68.
[Köppen, p. 142, p. 166, p. 188, p. 220, p. 237, p. 240, p. 249.]

210. Polnoe Sobranie Zakonov. [Full Collection of Laws.] v. 12, no. 9507, June 23, 1748. ——— O merakh dlia istrebleniia sarantshi.
Measures for extirpating the locust. [Köppen, p. 195.]

. . . v. 13, no. 9624, June 6, 1749. ——— O sposobakh k iskoreneniia sarantshi v Belogorodskoï gubernii.
Means of extirpating the locust in the government of Belogorod. [Köppen, p. 195.]

. . . v. 27, no. 20333, July 17, 1802. Ob istreblenii sarantshi i o plate za sobiranie eia semian.
Extirpation of the locust and payment for the collection of its eggs. [Köppen, p. 196.]

. . . v. 27, no. 20392, Aug. 28, 1802. ——— O rasporiazheniiakh k istrebleniiu sarantshi.
Arrangements for the extirpation of the locust. [Köppen, p. 196.]

. . . v. 38, no. 29577, Aug. 8, 1823. ——— O merakh k istrebleniiu v Novorossiïskom krae sarantshi.
Measures for the extirpation of the locust in the district of Novorussia. [Köppen, p. 199.]

. . . v. 39, no. 29731, Jan. 14, 1824. ——— O sposobakh k istrebleniiu sarantshi.
Means of extirpating the locust. [Köppen, p. 199.]

211. Russische St. Petersburg. Zeitung. 1850. no. 191, no. 210. ——— 1852. no. 272. ——— 1860. no. 156, no. 247. ——— 1861. no. 36, no. 124, no. 159, no. 192, no. 208.
[Köppen, p. 158, p. 188, p. 233, p. 235, p. 237, p. 249, p. 262.]

212. Deutsche St. Petersburg. Zeitung. 1861. no. 185.
[Köppen, p. 188.]

213. Svod Zakonov. v. 13. Ustav o nar. prodov.
[Code of laws.] [Köppen, p. 239.]

St. 91. Obiazannost' Palat Gosudarstvennikh Imushtshestv donosit' Ministerstvu Gosudarstvennikh Imushtshestv o poiavlenii sarantshi.
The courts of the crown-domains must report to the ministry of the crown-domains the appearance of the locust.

St. 267. Obiazannost' gubernskago natshal'stva donosit' Ministru Vnutrennikh Del o poiavlenii sarantshi.
The authorities of the governments must report to the minister of internal affairs the appearance of the locust.

Prilozhenie k st. 267. Pravila ob istreblenii sarantshi.
Rules for the extirpation of the locust.

214. Stettin. entomologische Zeitung. 1847. no. 12.
[Köppen, p. 177.]

215. Vedomost'. Moskva, 1712. Oct. 20. ——— 1855. no. 93; suppl.
Gazette. Moscow, 1872. Oct. 20. ——— 1855. no. 93; suppl.
[Köppen, p. 189, p. 195.]

216. Zapiski obshtshestva sel'skago khoziaistva iuzhnoï Rossiï. 1853. pt. 3. ——— 1861.
Memoirs of the Society of Rural Economy of Southern Russia. 1853. pt. 3. ——— 1861.
[Köppen, p. 157, p. 237.]

217. Zemledel'skaia Gazeta. Odessa, 1837. no. 45, no. 46. ——— 1838. no. 29 (Jensch). ——— 1846. no. 13, Beilage; no. 33 (Kanischtschev). ——— 1847. no. 64. ——— 1848. no. 27, p. 178–185 (Hahn); no. 58. ——— 1850. no. 74. ——— 1851. no. 64; no. 90, p. 718. ——— 1852. no. 37. ——— 1853. no. 44, no. 73. ——— 1855. no. 104 (Kudriavzev). ——— 1856. no. 36, no. 43. ——— 1858. no. 39, p. 310 (Strukow). ——— 1859. no. 98. ——— 1863. no. 16. ——— 1864. no. 11, p. 169. ——— 1865. no. 30–31, July 24–31, p. + 470–474 + (Kuschakevitsch).

Agricultural Gazette. Odessa, 1837. no. 45, no. 46. ——— 1838. no. 29 (Jensch). ——— 1846. no. 13, Beilage; no. 33 (Kanischtschev). ——— 1847. no. 64. ——— 1848. no. 27, p. 178–185 (Hahn); no. 58. ——— 1850. no. 74. ——— 1851. no. 64; no. 90, p. 718. ——— 1852. no. 37. ——— 1853. no. 44, no. 73. ——— 1855. no. 104 (Kudriavzev). ——— 1856. no. 36, no. 43. ——— 1858. no. 39, p. 310 (Strukow). ——— 1859. no. 98. ——— 1863. no. 16. ——— 1864. no. 11, p. 169. ——— 1865. no. 30–31, July 24–31, p. + 470–474 + (Kuschakevitsch).

[Köppen, p. 92, p. 99, p. 110, p. 128, p. 138, p. 140, p. 160, p. 185, p. 188, p. 199, p. 200, p. 201, p. 211, p. 214, p. 217, p. 221, p. 222, p. 227, p. 231, p. 235, p. 242, p. 243, p. 247, p. 248, p. 249, p. 256, p. 262.

[The date of publication of the following works is unknown to me.]

219. **Anonym.** Anmerkungen von Heuschrecken- und Raupenfrass. < Zink. Leipzig. Samml., v. 1, p. 379 (1742?).

[Hagen, ii, 338.]

220. **Anonym.** Beiträge zur Geschichte der Heuschrecken. < Wasserberg. Samml., v. 1, no. 18 (1773?).

[Hagen, ii, 338.]

221. **Anonym.** De la figure des sauterelles. < Erreurs populaires, v. 2, lib. 5, cap. 3, p. 121.

[Hagen, ii, 338.]

222. **Anonym.** Historia natural y descripcion de la langosta y modos de destruirla. Madrid, Cuesta. 8°.

[Hagen, ii, 339.]

223. **Ch. H. Cottrel.** Sibirien. ——— Deutsch von M. B. Lindau.

[Köppen, p. 209, cites v. 2, p. 91.]

224. **K. Ritter.** Die Heuschreckenplage der Länder der alten Welt, nach ihrer geographischen Verbreitung. < Ritter Erdkunde, pt. 8, p. 789–815.

"Beside Keferstein (1843), treats the chronology of locust appearances most extensively." [Köppen, p. 91, p. 92.]

225. **J. Russegger.** Reise in Egypten, Nubien und Ost-Sudan, pt. 2, p. 242.

[Köppen, p. 125.]

[For citations respecting enemies of locusts, see Köppen, p. 151–167.]

SUPPLEMENTARY LIST.

The following list of authorities was made out by Mr. Thomas during the preparation of Chapter IV of this report, concerning the habits and characteristics of locusts in all countries in relation to their movements, and consists chiefly of travels and descriptive works in which mention is made of locust movements, locust ravages, &c. A few works and papers relating wholly to locusts and omitted by Mr. Mann are added. Most of the authorities here mentioned are quoted directly or indirectly in the present report, all found in the Congressional and Department libraries, and a few also not found in these, having been consulted.

1. **M. Adanson.** "A voyage to Senegal, the isle of Goree, and the river Gambia" (1749–1754). Trans. into English. London, 1759. p. 159.

2. **Frances Alvarez.** "Voyage into the court of Ethiopia." In Purchas's Pilgrims, 1625, vol. ii, ch. xxxii, p. 1026.

3. **Alfonso Andreozzi.** Sulle cavallette; considerazioni estratte dal NUN-CEN-ZIUEN-SCIU, &c. From Bulletino Societa entomologica Italiana, ch. ii, 1870. Art. ii: "Disastro delle cavallette Nella China," p. 77.

4. **Anonym.** Gesichte der Heuschrecken. Nürnberg, 1753. p. 77. 8. Abhandlung von den Strichheuschrecken aus dem Russischen. Hamburg Magaz., Band xxiv, p. 186–216. (From Dryander's Catalogue.)

5. **Aristotle.** Hist. Anim. vol. v, p. 29.

6. **Ed. Phil. Asmuss.** "Verzeichniss der Orthoptera des Gouvernement Kaluga." (Verh. zool.-bot. Ges. Wien, 1857.) Band vii, p. 147.

7. **Archiv** für Naturgischte, 1845, Band ii, § 128; 1847, Band ii, § 59. (Weigmann.)

8. **Baldanus.** "Locustae majores quibus Johannes in deserto vitam tolerasse dicitur." (Comment Bannon, tom. v).

9. **John Barrow, Esq.** "An account of a journey in 1801 and 1802 to the Booshuna Nation, Southern Africa." (Travels.) 4th ed. London, 1806. p. 429.

10. **Beauplan.** "A description of the Ukraine." In Churchill's Voyages, vol. i, p. 541.

11. **Bochart.** Hierozoic. P. ii, l. iv, c. 5, p. 474, 475, and c. 6, p. 485.

12. **Karl Henrik Boheman.** In Öfvers af Kongl. Vet.-Akad. Forhandl., 1847, p. 250.

13. **M. Bolivar.** In Annales de la Sociedad Española de Hist. Nat., 1876, vol. v, pt. ii, p. 297. Also, same periodical and same number, "Actas," p. 47. Also, same periodical, tom. v, pt. 3, "Actas," p. 91, 355. Also, "Synopsis of the Orthoptera of Spain and Portugal," printed separately.

14. **M. Preudhomme de Borre.** In Comptes-rendus Société Entomologique Belgique, 1871–'72, p. xviii.

15. **Brace.** Miscellen. aus der neuestens auslandischen Literatur. Jena, 1834. Heft x, p. 107.

16. **Herm. Burmeister.** Handbuch der Entomologie. Berlin, 1832. vol. ii, p. 600.

17. **R. F. Burton.** In "Pilgrimage to El Medinah and Mecca, 1856." London ed. vol. iii, p. 91.

18. **Cantor.** Geschichte der merkwürdigsten Naturbegebenheiten auf unserer Erde. 1804. Band ii, p. 104, 226.

19. **Joa Cederhjelm.** Faunae Ingricae prodromus. Lipsiae, 1798. p. 128.

20. **Georgius Cedrenus.** Compendium historia, a mundo condito usque ad, &c. Eleventh century. In Corpus Scriptorum historiae Byzantinae (1828), vol. v, p. 31–321.

21. **Jean Chardin.** Journal du voyage du chevalier Chardin en Perse et aux Indes orientales par la mer Noire et par la Colchide. London ed., 1711 and 1735. Paris, 1811.

22. **Toussaint de Charpentier.** "Horae Entomologicae." Wratislaviae, 1825. p. 131–137.

23. **Chesney.** "Expedition to the Euphrates." London, 1850. vol. i, p. 362, 537.

24. **E. D. Clark, LL. D.** Travels in Russia, Tartary, and Turkey. 4th ed. London, 1816. vol. i, ch. iii, p. 133.

25. **M. Come.** In Annales Société Entomologique France, 4th ser., vol. vii, 1867, Bull. x–xiii. (See Girard below.)

26. **Coquerel.** Orthoptères de Bourbon et de Madagascar. In Ann. Soc. Ent. France, 1861.

27. **Vivant Denon.** Travels in Upper and Lower Egypt. Engl. trans. London, 1802.

28. **S. Joannis Dlugossi.** "Historia Polonica." tom. i, lib. ix, p. 1035; tom. ii, p. 535.

29. **Paulus Draconus.** (In Purchas.)

30. **Dryander.** Catalogue de Banks. vol. ii, p. 241–244.

31. **W. F. Erichson.** In Wiegmann's Archiv für Naturgeschichte, 1839, Band ii, § 348; 1845, Band ii, § 128; 1848, Band ii, § 59.

32. **P. Forskal.** "Descriptiones animalium quae in itinere orientali." Observant Forscal. Ed. Niebuhr Hanniae, 1775. p. 81.

33. **Captain Charles C. Frankland.** Travels to and from Constantinople in 1827–'28. vol. i, p. 264.

34. **Rev. T. H. Gallaudet.** Scripture Biography for the Young. Moses. vol. i, p. 114.

35. **M. Girard.** In Ann. Soc. Ent. France, 4th ser., 1864, vol. vii, Bull. x–xiii; 1867, Bull. x–xii.

36. **Paul P. De la Gironière.** "Twenty years in the Philippines." New York, 1854. p. 229.

37. **Rev. Saml. Gobat.** Journal of a three years' residence in Abyssinia. p. 392.

38. **Gregorius Turonensis.** Historia ecclesiastica Francorum. lib. iv, ch. xx.

39. **James Hamilton.** "Sinai, the Hadjaz, and Soudan." London, 1857. p. 297.

40. **Dr. F. R. Hasselquist.** "Voyages and Travels in the Levant, 1749–'52." Eng. trans. London, 1766. p. 444. Also: "An Locustae ab Arabicis cibi loco adhibeantur." Swedish trans. 1752.

41. **Irby** *and* **Mangles.** "Travels in Egypt and Nubia, Syria and the Holy Land." Murray's ed. London, 1847. ch. viii, May 27, p. 136.

42. **J. G. Jackson.** "An account of Marocco, &c." 2d ed. London, 1811. p. 103.

43. **F. Jagor.** Travels in the Philippine Islands. p. 273.

44. **Richard Jobson.** "Voyage to Gambora, Africa." 1620. In Purchas's Pilgrims, vol. ii, p. 1046–1047.

45. **John Macdonald Kinneir.** "Geographical Memoir of the Persian Empire." London, 1813. p. 43.

46. **Dr. Herman Krauss.** "Orthoptera von Senegal." Akad. Wissench. Wien, June and July, 1877, p. 33. (Also printed separately.)

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APPENDIX V.

DATA CONCERNING LOCUSTS IN TEXAS.*

GALVESTON, TEX., *August* 13, 1877.

To the Chief Signal Officer of the Army:

SIR: Agreeable to your letters of May 17 and June 9, I have the honor to submit the following data in regard to the habits and depredations of the Rocky Mountain Locust or Grasshopper in this State during the present year.

The data have been collected principally from the files of the Galveston Daily News, which has proved to be the only practicable means at my disposal for obtaining information on this subject, all requests for information addressed to the interior portions of the State having, with a single exception, been ignored.

The portion colored red on the accompanying map shows the section of country injured by the insects, which is nearly identical with the region in which they originally hatched. No information of their having appeared in the counties of Blanco, Comal, Burleson, or Karnes, located in the interior of this section, has been obtained.

A careful inspection of the herewith inclosed data enables the following answers to be given in answer to Circular No. 1 of the Entomological Commission. The answers, for convenience, are numbered to correspond with the questions.

1. The insects generally developed from eggs deposited in the ground last fall, and did not arrive in swarms from a distance.

2. In Caldwell County they were traveling northward about March 10; Milam County, going north about March 10; Fayette County, going westward about March 10; Hill County, diminishing about March 10; Bell County, diminishing about March 15; De Witt County, disappearing from Deer Creek about March 15; Milam County, jumping northward about March 15; Victoria County, leaving as soon as hatched, about March 15; De Witt County, hopping northward about March 20; McLennan County, moving northward about March 20; Milam County, going northward about March 20; Gonzales County, traveling northward about March 30; Colorado County, traveling a little north of west about April 3; Comanche County, diminishing in numbers about April 3; De Witt County, disappearing in spots about April 4; Comanche County, disappearing about April 10; Robertson County, hopping north about April 10; McLennan County, hopping north about April 6; Hays County, decreasing in numbers about April 12; Caldwell County, leaving by the million about April 15; De Witt County, disappearing about April 19; Fayette County, disappearing about April 20; Grimes County, going south about April 20; Waller County, disappearing fast about April 20; Grayson County, jumping northward on April 25; Montague County, moving northward about April 20; Gonzales County, flying northward about April 15; Washington County, gradually disappearing about April 20; Ellis County, passing northward slowly on April 26; Washington County, moving northward on April 26; Colorado County, rapidly disappearing about April 16–23; Fayette County, going northward on April 15; Johnson County, going off about April 25; De Witt County, flying off about April 25; Robertson County, disappearing about April 25; Waller County, disappearing on April 30; Bastrop County, rapidly disappearing about April 28; Hays County, going north about April 26; McLennan County, going north, flying high, on May 2; Travis County, heavens clouded with them, going north, wind south, on May 2; Austin County, heavens clouded with them, going north, wind south, about April 30; Washington County, air full of them, going north, about April 30; Bastrop County, moving northward about April 30; Bell County, nearly gone by April 30; Fayette County, heavens alive with them, going north, about April 30; Lee County, emigrating on May 5; Denton County, disappearing rapidly about May 1; Fayette County, going northward throughout week ending May 2; Leon County, rapidly disappearing about May 1; Lampasas County, passing north about May 2; Colorado County, emigrating in large numbers about May 1; Caldwell County, myri-

* The following notes were omitted from the First Report for want of space. They were furnished the Commission by the late Bvt. Brig. Gen. A. J. Myer, U. S. A., Chief Signal Officer.

ads of them traveling northward about May 2; Falls County, millions passing over, flying northward, about May 2; Gonzales County, nearly disappeared by May 2; Hays County, disappearing about May 2; Live Oak County, nearly all gone by May 2; Washington County, emigrating northward rapidly on May 8; Brazos County, almost entirely disappeared by May 5; Colorado County, flying northward about May 5; Lampasas County, millions flying northward during week ending May 10; Navarro County, departing about May 12; Navarro County, disappearing rapidly on May 16; Limestone County, left about May 15; going northward, wind south.

3. No eggs were deposited during the present year.

4. Hatching began about January 25, and ended about March 10. The eggs were hatching most numerously between February 15 and March 1.

5. In the visitation of 1858 hatching occurred between January 16 and February 27; the period of maximum hatching is not known.

6. No information was received that the eggs failed to hatch during the present year.

7. Open places, such as fields or prairies, free from bush and with but little grass, were generally selected by the insects to deposit their eggs. They seem to have been deposited in all sorts of light, loose soil.

8. Hatching began earliest in warm, sandy soil, in sheltered localities, but progressed without interruption wherever the eggs had been deposited.

9. First insect acquired full wings in Gonzales County about April 5; in De Witt County about April 8; in Colorado County about April 12; rapidly in Gonzales County about April 20.

10. The winged insects began to migrate from Gonzales County about April 20; from Washington County on April 26; from Colorado County about April 20; Fayette County on April 15; Johnson County about April 25; De Witt County about April 25; Robertson County about April 25; Waller County on April 30; Bastrop County about April 26; Hays County about April 26.

11. While the ravages were progressing the damages were reported as severe from nearly all of the central counties of the State, but their effect has since proved to be less permanent than was at first apprehended, many of the devastated grain-fields having entirely recovered since the departure of the insects; some, however, had to be replanted in Lavaca County. The damage was estimated after the departure of the insects as 5 per cent. of the crops; in Colorado County at less than 3 per cent.; in Bastrop County the damage was finally reported as not material, except to gardens; in Lee County it is reported that little damage was done; in Denton County damage reported as not general; in Leon County damage reported as not enough to materially affect the crop; in Navarro County damage estimated at less than 5 per cent. of crops; in Kendall County damage reported as not material; in Llano County the insects reported to have done but little harm; in Wilson County have interfered but little with corn and cotton; in Lampasas County injury to wheat not so great as was expected; in Burnett County reported to have done but little damage; in Williamson County reported to have done no damage of serious consequence.

From the preceding, which I take as fair examples of the remaining devastated counties, I conclude that the damage to the grain crops in the 64 counties visited cannot exceed 5 per cent. Gardens everywhere appear to have suffered to a much greater extent than the grain crops. They are reported as having been entirely destroyed in a large number of cases, and were badly damaged wherever visited. Assuming that a large percentage recovered from the ravages of the insect, as in the case of the grain, I will estimate 25 per cent. as totally lost. Taking the population of the 64 devastated counties for the year 1870 as a basis, and dividing it by 5, to get the approximate number of families, and we have for the latter 84,304. Assuming that one-half of these families possess gardens worth $75 each, and that an average of 25 per cent. of all were destroyed, and we have $790,350 as the approximate damage to gardens.

12. Wheat, oats, corn, and cotton were the crops most affected, the first-named sustaining the greatest and the last-named the least injury.

13. Fruit crops were more easily protected from the unfledged insects than cereals, and suffered less. Of the latter no comparisons can be given.

14. Crops which suffered least were fruit, corn, and cotton.

15. In almost every instance the young insects commenced hopping northward as soon as hatched. Their progress was necessarily very slow until after they had acquired wings, when they rose in immense swarms high into the air, and taking advantage of a warm south wind rapidly disappeared, always pursuing a northerly course. When meeting contrary currents of air from the north they were obliged to alight and wait for favorable winds.

16. Mr. Sears, residing on the Bosque River, McLennan County, poisoned myriads of the insects with corn-meal and strychnine. Many citizens of Brazos County saved their peach crops by applying tar to the body of the trees, thus preventing the insects from ascending. Liberal use was also made of fire, boards, carbolic soap, tar, kerosene, and turpentine, it is said with good success.

17. No information of any means having been employed to destroy the winged insects, or to protect crops from their ravages, they having left as soon as their wings were developed.
18. No information of any.
19. This immediate vicinity, as well as the entire coast country of the State for a breadth of from twenty-five to seventy-five miles, has never been visited by the insects.
20. This State was visited in 1858.
21. Blackbirds and meadow-larks destroyed large quantities of both the eggs and the young insects, but without apparent effect on their numbers.

C. A. SMITH,
Sergeant Signal Service, U. S. A.

U. S. SIGNAL STATION OF OBSERVATION,
Eagle Pass, Texas, July 1, 1877.

To the Chief Signal Officer of the Army, Washington, D. C.:

SIR: In obedience to instructions dated Office Chief Signal Officer, Washington, D. C., June 9, 1877, I immediately upon my arrival at this station began using all available means of collecting the information requested by the United States Entomological Commission.

This section being sparsely settled, and only few persons of superior intelligence having observed any of the facts in reference to the appearance and habits of the "Rocky Mountain locust," I am unable to forward as complete a report as I would wish to render, I having only arrived here a short time ago, but all the data collected are embodied in the following:

PREVIOUS YEARS.

In September, 1873 (no specified date), there appeared at this place, suddenly, immense swarms of locusts, coming from a northerly direction. The direction of their flight followed the Rio Grande River for about 30 miles in its course to the Gulf. For about five days the multitudes kept traveling over this place, descending to the ground at sundown, and remaining below until shortly after sunrise the next morning, when all would rise in a body and resume their flight.

The weather during this visitation was very dry and sultry, and the prevailing wind northerly; the damage done immense.

These locusts left an immense amount of eggs behind, which at the beginning of spring, *i. e.*, the latter part of January in this section, began to hatch. Then it was discovered that the eggs had been laid over a tract of country nearly 2 miles wide, having the Rio Grande River for its center, and following its course, but to what distance I am unable to ascertain. The wingless insects were harmless in the early stages of their growth, but as their development proceeded the work of devastation began. In the first part of May, 1874, they began to move, not flying, but crawling. The fact has been observed that the movements of these swarms of young locusts were in exactly the opposite direction to which their progenitors had traveled. They seemed to retrace the steps of their ancestors. Those hatched on this side of the Rio Grande River moved north towards the settlements, and on their way everything in the shape of vegetation was totally consumed. Those hatched on the Mexican side of the Rio Grande took a direction west of north, and the work of devastation was equally great in the parts of Mexico they passed over. I am assured on good authority that, when leaving this section, they were too young to fly, and their march was carried on crawling and hopping.

Towards the latter part of May, 1874, all had left and planting was begun.

Now, these young locusts before leaving had deposited eggs, but the eggs of the young ones are not very plentiful and sparsely distributed. The people of this section, while this occurs, do not mind it much, as the damage done by this not very numerous offspring is never considerable.

In September, 1875, another large swarm of locusts made its appearance, coming from the same direction, *i. e.*, north, but their numbers were not as formidable as those of the previous year. These insects deposited their eggs, who were hatched the ensuing spring, *i. e.*, latter part of January, 1876. The numbers of the young ones coming forth was comparatively insignificant, and having in their turn deposited their eggs, they left about first half of May, 1876, in a northerly direction.

1877.

The only locusts that appeared in this locality in the present year are those that were hatched from the eggs deposited by the insects mentioned as having departed from here in May, 1876. Their numbers are insignificant, and they are about full grown; they remain in this locality.

Answers to inquiries in Circular No. 1, Department of the Interior, Office of the Entomological Commission.

(NOTE.—As the Rocky Mountain locust has not arrived at nor departed from this section in swarms during the present year, and the inquiries have reference particularly to the present year, I am only able to answer a few.)

4. At the opening of spring, *i. e.*, latter part of January in this section.

5. At the opening of spring.

6. It is supposed that a severe cold would seriously interfere with the hatching process.

7. In low places and valleys, especially in black soil, where little or no sand is found.

8. In low places and especially in black soil, where little or no sand is found.

9. During May.

11. Injury done slight.

12. Garden vegetables; most of all, lettuce.

13. None that I could name.

14. Muskmelon.

15. It has been observed that the prevailing direction in which the young ones travel is in the direction from whence their progenitors come. They commence their march before they are able to fly, and the masses move crawling and hopping.

16. The means employed in this section for the destruction of the unfledged insects were only rude attempts at burning them. To protect crops from their ravages close brush fences are used, and are said to prove very satisfactory.

17. To protect crops from the ravages of the winged insect fires have been kindled and a dense smoke to cover gardens; but this is of almost no use whatever. Flowers and garden plants have been wrapped up and covered, which was partly successful.

19 and 20. Answered in paragraph headed "previous years."

21. Chickens, turkeys, partridges, snipes, mocking-birds, red-birds, blackbirds, crows, swallows, ducks, eat locusts with great avidity; but I am informed that domestic fowls after a few days tire of this food.

I am, sir, very respectfully, your obedient servant,

FREDERICK BELFORD,
Private Signal Service, U. S. A.

LAREDO, TEX., *December* 7, 1877.

To the Chief Signal Officer, U. S. Army, Washington, D. C.:

SIR: I have the honor to transmit herewith the report called for in letter from the Chief Signal Office, June 9, 1877, relative to the United States Entomological Commission circular.

The data inclosed are very meager in details. The circular was received too late to make any observations, as the young grasshoppers were hatched and disappeared long before the circular reached this station. The figures denote answers to the questions similarly numbered in the United States Entomological Commission Circular No. 1.

1, 2, 3, 4, 6. Grasshoppers did not make their appearance here this year.

5. No observations taken.

7. Nature of soil within a radius of 60 miles light loam.

No observations taken on distribution of eggs.

8. No observations taken.

11. Very little damage done in this county. Amount of damage in State not known.

12. In the early spring, in the few gardens in the vicinity, tomatoes, radishes, corn, and garden stuff generally suffered about equally from the young grasshoppers. Gardening is carried on by irrigation. In the surrounding country nothing grows but a stunted mesquite and the cactus.

13. Farming is not carried on on a sufficient scale in this vicinity to tell the crops that suffer most.

15. No observations taken.

16, 17, 18. No attempt made to destroy them.

20. This section was visited in 1875 and 1876. They made their appearance in those years about the beginning of November. No observations were made at the time.

21. Chickens, guinea-hens, and turkeys devoured them greedily. In the county wild turkeys, chaparral cocks, mocking-birds, cardinal birds, and a bird called by the Mexicans "one-tacoches," were particularly fond of them.

Respectfully submitted.

JNO. McGLONE,
Sergeant, Signal Service, U. S. A.

UVALDE, TEX., *November* 29, 1877.

To the Chief Signal Officer of the Army, Washington, D. C.:

SIR: Referring to Circular No. 1, United States Entomological Commission, I have the honor to report that, owing to no mention in Daily Journal of the Rocky Mountain locust, I can answer the interrogatories only in a general way, and from information from reliable residents.

This section was visited by small numbers of these insects in the spring and autumn of 1873 and 1875, and from October 1 to 15, 1866; none the present year, 1877. They come in the fall with the northwest wind, and as soon as hatched in the spring commence hopping northward, even before fledged.

The soil in which eggs are most numerously deposited is hard clay and in low location.

As this is not an agricultural country, very little damage has resulted from their visitations, and the numbers of "tree-larks" in this county, especially useful in destroying the eggs, "chaparral fowl," black hawks, and wild turkeys, devourers of the insects, prevent any large number arriving at age to migrate in the spring.

Respectfully, your obedient servant,

WM. NORRINGTON,
Private, Signal Service, U. S. A.

DATA CONCERNING LOCUSTS IN INDIAN TERRITORY, 1877.

FORT GIBSON, IND. T., *November* 20, 1877.

To the Chief Signal Officer of the Army, Washington, D. C.:

SIR: I have the honor to forward the following data as called for by Circular No. 1, United States Entomological Commission:

This vicinity has been free from visits of the Rocky Mountain locust during the summer past.

From April 13 to May 1 the young were hatching out in great numbers. Probably not more than one-eighth of the eggs hatched.

The disappearance of the young locusts and the failure of so large a proportion of the eggs to hatch is attributable to the long-continued cold rains occurring shortly after the eggs began to hatch. The eggs were deposited in sandy loam. They hatched most numerously in the black, sandy loam having a good southerly exposure. No young locusts were seen after the 14th of May. None of the locusts arrived at maturity, neither were any seen off their hatching grounds.

Large flocks of pewees hovered around the hatching grounds, feeding on the young locusts. This was especially the case if near any shelter.

No efforts were made in this vicinity to destroy them.

Very respectfully, your obedient servant,

GEO. H. CRANE,
Sergeant, Signal Service, U. S. A.

APPENDIX VI.

ON THE FLIGHT OF LOCUSTS.

[From the Atti del Real Istituto d'Incoraggiamento alle Scienze Naturali di Napoli, tomo I, pp. 233-269, Naples, 1811.]

Translated by F. P. SPOFFORD.

[Part of a memoir presented to the Institute November 5, 1809, by Gaetano de Lucretiis.]

Among the innumerable injuries to which the industries of the country are subject, one of the most destructive is the incalculable multiplicity of little animals and insects, the most pestilent element in animated nature, each of which, taken separately, is but a feeble and despicable thing, but which, through their excessive multiplication and surprising voracity, become a most pernicious pest, and a real public scourge, capable of rendering uninhabitable an entire canton. The extraordinary mildness of the winters, and the absence of that rigor of cold which belongs to that season, unhappily favor the generation and development of little animals, and especially of insects; so that in some places their multiplication much exceeds the limits of the ordinary year. But these insects are by no means all equally noxious. The great swarms of bees, of hornets, of wasps, and the clouds of gnats and midges and other similar insects, are rather annoying than injurious. Nearly the same may be said of the legions of ants, of butterflies, and of beetles which make their appearance in spring and autumn. But desolation is brought upon agricultural industry by the ravages of gnawing mice, of devouring worms, consuming the buds of the vine, of mites or weevils, destroying both grains and vegetables, and of so many other noxious animals and insects which spring up in the heart of our country and lay waste the wheat, oats, barley, vines, leguminous plants, and esculents. Italy suffers also the calamity of seeing countless legions of foreign insects, which abandon from time to time the deserts of Tartary and of Arabia, cross swiftly over to the shores of Italy, and, like hordes of invading armies or barbarous conquerors, despoil the earth over which they march, rob it of its fertility, leaving desolation in their track, and reducing whole populations to the horrors of misery and of famine. Thus they devour the produce both of sown ground and of meadows, and render the country a sterile waste, incapable of sustaining men or domestic animals with necessary food. Thus the locusts, vulgarly named *Bruchi*, have for years invaded the most fertile provinces of our kingdom. This is no new calamity for Italy, as Pliny records similar visitations in his day.

The cradle of the locust (*Grillus migratorius* Lin.), according to French naturalists, was Tartary and Arabia; but sometimes they abandon their native *habitat*, and come in swarms of emigrants to carry desolation and terror over Europe, and especially in our southern latitudes. The east winds appear to favor the flight of these exterminating hordes, composed usually of an incalculable number of individuals, which is confirmed by the testimony of that accurate observer Adanson in his voyage to Senegal, who records the following concerning the emigrations of this insect near the river Gambia, in Africa.* He says:

"At about eight o'clock in the morning, in the month of February, a dense cloud suddenly came up over us, darkening the air, and even shutting out the rays of the sun. I observed that this phenomenon was caused by a swarm of locusts rising about 180 feet from the earth, and spreading over an extent of many leagues; finally, an immense quantity of these insects came showering down with a rattling noise upon the earth, devouring whatever of verdure was found, and then resuming their flight. This swarm was blown along by a strong, gusty wind from the east, continuing all day, and spreading over the whole country adjacent."

These regions suffered the last great devastation from this source in the year 1758. Their arrival is heralded by a dull sound produced by the agitation of their wings, and the obscuration of the sun announces their impending fall upon the fields; and woe to the land where they light for repose from the fatigues of their journey, which frequently comprises 30 miles a day. The most fertile country after one of their visits exhibits the aspect of a melancholy desert.

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* The insect Adanson saw was evidently *A. peregrinum* and not *P. migratorius*.—C. THOMAS.

In their native regions, where the summer is hot and the herbage abundant, their multiplication is excessive, and a fair and dry season is best adapted to their emigrations; sometimes they fly even to the borders of Switzerland; which puts me in mind of the fact that the troops of the renowned Charles XII, when they traversed Bessarabia, believed themselves overtaken one day by a hurricane, accompanied by a terrible hail-storm, when a vast swarm of locusts, which darkened the sun, began to fall, covering men and horses and arresting the whole army on its march.

Their voracity is most surprising. Grundler placed some locusts under a globe of glass, in which some freshly-plucked stalks of barley had been placed. They first cut the stalks in two, then devoured from top to bottom all that remained at their feet, and then consumed every vestige of what fell on either side, with their greedy jaws, and all this with an avidity and agility that cannot be described. * * *

And yet I think that the damage produced by each locust would scarcely merit the attention of the agriculturist, if they only came, like other species of insects, in small numbers. But when their swarms are composed of innumerable legions, similar to dense clouds, falling from the sky by their own weight, and accompanied by the most active powers of devastation and a surprising agility, they carry with them the disastrous advantage of their exorbitant numbers, which sometimes baffles all calculations, falling upon a certain country and in the twinkling of an eye devouring all the plants in their pathway. Their first fury is discharged upon the delicate plants more abounding in juice; but soon finding these giving out, and lacking their coveted food, they attack the leguminous plants, the leaves and the bark of trees, and, generally, all classes of vegetables, without sparing those whose odor or sap has something acid, sour, astringent, bitter, and even poisonous, and devouring equally coverlets of wool and the clothing of the people of the country worn for protection from the rain or the frost, and finishing with stuffs of flax and of silk

Upon the emigration of locusts, certain circumstances, as common as they are unheeded, merit the attention of the observer. Their flight is more certain and at a greater altitude whenever the atmosphere is of a heated temperature and the air clear and calm. On the other hand, when the atmosphere is charged with mist or with rain, or pervaded by a chilly element, or even about the rising or the setting of the sun, they move more slowly, exhibiting a certain rigidity, moving their wings with difficulty, and not rising to any great height. And when they attempt to continue their raids in a rainy season, or one tending to cold, they begin by agitating their wings and exciting all their strength to rise; but, not finding themselves in a condition to sustain a long journey, they at first droop, and then fall precipitately to the ground, and are compelled to continue their journey on foot.

The Irish writer William Bowles, in his "Introduction to the Natural History and Physical Geography of Spain," published and annotated by d'Azara, speaking of the locusts which devastated various provinces of that kingdom from 1724 to 1757, maintains the theory that the ardor of perpetuating their species is not equal in the male and female locust, observing that the male is restless and solicitous, while the female shows herself cold and always intent upon feeding. Whence it comes that the males, during the fresh hours of the morning, are for assaulting the females, while the latter are fleeing and hiding; but in the first two hours of midday the females begin to free themselves from the importunity of the males, who are continually pestering and pursuing them, and in this exercise mounting into the atmosphere to the height of 400 or 500 feet, the first legion taking always the route which the wind favors, and going perhaps two leagues; and whenever the sky is serene and the air not agitated by winds their flight is very brief. From this cause, it is said, results the migration of the locusts. As declared by a Spanish countryman who saw his fields devoured by these pests: "If those accursed females would not act so prudishly, and if they would suffer the males to enjoy them in the country where they were born, I should not have to undergo this damage; but the vermin fear extinction, and seek to prolong life like ourselves, because they know that conjunction means nothing else than to impregnate and die."

One would need to be very easily impressed by the marvelous in order to adopt the credulous belief of the Spanish countryman, and to persuade himself that the locusts forsee the consequence of copulation as fatal to them, and to attribute to the chastity and rigor of the females the migration of those innumerable colonies which come from the farthest east to the west of Europe. But wherefore should we not attribute this migration rather to a cause both simple and natural, as well as founded upon an instinct of all organized beings—of gathering their own nourishment? Having consumed in one place all nutritious substances, why should they not seek out another where food abounds? And this is, without question, the first of the three principal causes that determine the migrations of living species, commencing with man and continuing through quadrupeds, birds, some reptiles, zoophytes, gnats, and other insects; and to which have been due the immense reflux of barbarian tribes which have abandoned their northern boundaries to pour their inundations into the warm and fertile regions of the south. In fact, all those swarms of Goths, Huns, Vandals, Cimbri, Borgognoni, Alani, which overflowed the vast provinces of the Roman Empire to find those means of sustaining life which were denied them in their own sterile countries, and the frequent invasions of Southern Asia by the Tartars, of which history is full, besides many other invasions buried in the obscurity of antiquity, all point to the same conclusion. Just like the wandering bands of foxes and wild boars from the north, which scattered themselves over vast spaces to gather prey in greater abundance, so much more naturally have those terrible swarms of locusts taken up their course from Tartary and Arabia to inundate the plains of India, of Palestine, of Poland, of Spain, and of Italy, devouring all vegetation in their path. Traveling in such countless masses, destroying vegetable sustenance throughout an entire region, and the need of alimentation compelling them to go to new places to find fresh food, they thus migrate from land to land.

* * * * * * *

All the governments of Europe strive to protect their people from the famine and pestilence which these insects cause, living or dead; and Spain especially, whose southern provinces appear to be permanently infected, has always promulgated standing orders to gather boxes full of eggs, and cause them to be consigned to commissions charged with burying them in deep ditches. And in the "*Récréations tirées de l'histoire naturelle des insectes*" we read that upon the passage of the locusts into France in 1613 they swept completely over fifteen arpents of grain in the environs of Arles, and even penetrated the granaries, when many hundreds of birds, and especially of starlings, as if commissioned by Divine Providence, began to labor for their diminution; notwithstanding which happy event, orders were issued by the government requiring that their eggs should be collected, of which more than three thousand measures were gathered, each one of which was estimated to be capable of producing nearly two million locusts.

At another migration of locusts, which took place in a portion of Bautzhida, in Transylvania, in 1780, with the view of preventing the terrible consequences which might ensue, orders were issued to fifteen hundred persons, each of whom was required to gather a full sack of locusts, which were in part crushed, in part burned, or buried; and yet the diminution of their numbers would have been scarcely noticeable but for a sharp frost that supervened. In the following spring there were millions of boxes of eggs disinterred and destroyed by the people, who gathered, as it were, *en masse* for this operation; and yet, in spite of all this, there were very extensive districts in which the soil was covered with young locusts so completely as not to leave a single spot bare.

The desolations sometimes occasioned by locusts in our Puglia Daunia at different epochs are very remarkable. Omitting the more remote periods of antiquity, and passing by the less destructive ravages, we come to the year 1231, in which these most pernicious insects compelled the wise Emperor Frederick II to promulgate a special law, by which it was ordained that every agriculturist, during the invasion of these little animals, should collect every morning, at the rising of the sun, four measures, and present them to the magistrate, who was required to have them burned. Of the year 1541, wrote Rovero Pontano: "In the summer of this year a great army of locusts flew through Germany into Italy towards our region. Wherever this swarm extended it devoured everything in its path, for the locusts were very large and numerous."

So great were the injuries caused in 1571 in this country by the locusts, that the Vice-Duke of Alcalà, D. Perafante de Ribera, was obliged to put forth, by the vote and advice of the Royal Council, on the 8th of October, 1572, the first pragmatic decree, *De Bruchis*, Title 23, by which it was ordered that the communes should appoint experts and practical men to explore their territories, and to search out all the places in which the locusts had deposited their eggs; and when found they were to dig trenches in the months of September and October, through which operation the eggs might be destroyed. And in the month of April the swine are turned loose to devour the locusts, of which they are very gluttonous. The housewives also spread sheets or pieces of cloth at convenient times, long and large, upon which the locusts alighting are folded up and entrapped.

The province of Puglia was inundated in the year 1662, and all the cultivated fields destroyed; insomuch that Vicerè, the Count of Peneranda, not only accorded to the tenants of the soil a general release from the rents due that year, but also deducted a portion of that of the year following, an indulgence which it became necessary to grant for several subsequent years. Puglia Daunia was again invaded in the year 1727, and the whole country ravaged. And, finally, they appeared again in this country in 1759, when D. Antonio Belli was governor of the customs; and on the 14th of August of the same year appeared orders similar to those of the Duke of Alcalà, above referred to, to which was added a command to burn the straw in all places infested by the locusts.

In the years 1770 and 1771 they frequented the provinces of Bari, Matera, and Lecce, and the governor ordered that the magistrates should adopt the most efficacious measures for their extirpation, and especially those prescribed by the president, Belli, and that handsome rewards should be paid to those who should use the greatest diligence for the destruction of the eggs. And similar provident regulations had such an effect that these pestilent insects not only did not then penetrate into our Puglia Daunia, but were entirely destroyed in the provinces adjacent.

As the result of all these experiences, it may be said that the means of exterminating these most pernicious insects may be reduced to the following:

1. In the first period, and particularly in the months of September and October, the ground in which the eggs may be deposited should be turned up with the plow or the spade, and the eggs collected and buried in trenches:* and there should be introduced into the ploughed fields a number of swine, who will devour a surprising quantity up to the third period.

2. The second important thing to do, when the eggs are about to expand, is to crush as many as possible under the feet of the peasants and with heavy wooden instruments; and during the whole period in which they have not the use of their wings, and are incapable of taking flight, but only of hopping, let them be surrounded with straw in the morning, and towards the evening, when found in great numbers over any extent of territory, attack them with fire on all sides, so that they cannot escape being burned.

3. When they have later unfolded their wings, which were at first enveloped, as it were, in two buds upon their backs, use should be made of the spread sheets and the deep trenches. And wherever it is attempted to drive them from a cultivated field into a neighboring wood or into some untilled region, let a loud noise be made by beating upon instruments of copper or other metallic substances, striking blows of steel, and making a clamorous sound. And, finally, as soon as the season of their copulation arrives, and the first swarm of locusts disperses, to wing its way into new territory, rising in enormous multitudes, the condition of turbulence in which they are then found furnishes to the peasants the most favorable occasion to destroy an immense quantity of their progeny by active and quick assault.

When the means above indicated are judiciously employed at various periods of their life, they will unquestionably produce the most advantageous effects.

OF THE LOCUSTS WHICH DESOLATED VARIOUS PROVINCES OF SPAIN FROM THE YEAR 1754 UNTIL 1757.

[From Bowles's (William) "Introduzione alla Storia Naturale e alla Geografia Fisica di Spagna; pubblicata dal Cao. D. G. N. D'Azara. Tradotta da F. Milizia." Parma, 1783. Tomo ii, pp. 1–24.]

Translated by F. P. SPOFFORD.

The locusts of which I am about to speak are found constantly in the southern regions of Spain, and especially in the uncultivated lands of Estremadura; but they ordinarily excite no attention, because they are found in moderate quantities and live upon the wild herbs, without touching the sown fields or the gardens, or penetrating into the houses. The countrymen see them hop about with indifference and feed upon the grass of the meadows; and their indolence causes them to lose the favorable occasion of exterminating them every year, a neglect which they vainly seek to repair when the mischief becomes without remedy.

The progeny which these insects leave every year is not very great, because the number of their males infinitely exceeds that of the females;† and if for ten years the generation of the two sexes should be equal their multiplication would be so prodigious that they would devour the entire vegetable kingdom; the birds and quadrupeds would die of famine, and the men would have to make their last meal of the locusts. In the year 1754 such a quantity of female locusts was bred that, in the following year, they inundated La Manche and Portugal, bringing with them all the horrors of dearth and of misery. The same calamity spread quickly over the neighboring provinces, carrying with it terror and desolation into Murcia and Valencia, and into the four kingdoms of Andalusia. * * *

The locusts always deposit their eggs in uncultivated ground, and have need of a certain degree of heat in order to hatch them; whence it may be inferred that they cannot propagate in cold and cultivated regions, which are only subject to certain passing invasions of such legions as are transported by the winds.

The locusts, which upon issuing from the egg are black and no larger than a small fly, swarm about the clods of earth and among a species of rushes, leaping one upon another, and occupying a space of three to four feet in circumference and two inches in height, so that a body of them resembles a black object which moves along the ground. The first opportunity which presented to me the view of such a spectacle surprised me from a distance of ten to twelve paces, because it conveyed the mournful

† Why not destroy them effectually, as by burning?

* We have not found this to be the case with *C. spretus*.—C. T.

idea of a funeral pall; and as these little animals live only upon dew, they raise and lower themselves continually one upon another to gather it.

The locusts move but a little space from the place of their birth during the first days of their lives, because their legs are always weak, their wings not yet well formed, and their teeth not sufficiently hard to eat the herbage. In the course of fifteen to twenty days they begin to eat the most tender stalks of the plants, and in proportion as their limbs grow stronger they break away from the society of the colony and spread over the adjacent fields, intent, day and night, without sleeping, upon devouring whatever presents itself to them, while their wings grow to their perfection. It is not to be wondered at that they consume the tender, juicy, and sweet plants, like the melons, citrons, pumpkins, and other green things, and the leguminous plants, and not less the aromatic shrubs, whose perfumes attract them from afar, like the thyme, the mint, the rosemary, the sage, the southernwood, which so abound in Spain that in many parts they serve to furnish aromatic fires, and in the north they are cultivated as choice plants in gardens. What seems strange, they devoured also the mustard plant, onions, and garlic, as well as poisonous plants like the *Stramonium ferox*, the *Solanum lothale*, the hemlock, and other fetid and poisonous plants; in short, the locust consumes everything, without distinction of flavor, of odor, or of virtue—good or bad.

The singularity about these locusts, which during four consecutive years desolated all the southern provinces of Spain, was a fact notorious to all the world, namely, that in the midst of so many plants greedily devoured they never touched the leaves and the flowers nor the fruit of the tomato (or love apple), the only privileged plant which was respected by this voracious insect. * * *

The locusts pass the months of April, May, and June near the place of their birth, at the close of which latter month their wings assume a beautiful rose color, and acquire all the strength and management of which they are capable. They now begin to unite in colonies for the second and last flight, and then begins in their youth to kindle in them the passion and desire of perpetuating their species. This is manifested in their movements; but it is observed that this ardor is very unequal in the two sexes, because the males become restless and solicitous, while the females remain cold and occupied continually in feeding. The one approaches, the other flies and hides, so that the whole early morning is passed in assaulting on the one part and fleeing and feeding on the other. Toward two o'clock in the afternoon, when the heat of the sun has dried all the dampness of the night from their wings, so that they assume their elasticity, the females begin to free themselves by jumping about, and fly from the importunities of the males who pursue them, in which exercise they begin to rise little by little into the air, and finally to the height of 400 to 500 feet, forming a cloud which intercepts the rays of the sun. The clear and serene sky of Spain is obscured, and becomes, in the midst of summer, more dark and gloomy than that of Germany in the spring. The rustling of so many millions of wings forms a dull roar similar to that which a sudden blast of wind produces in a forest full of trees. The route which the first formidable swarm takes always follows the wind, and this first flight is usually prolonged about two leagues; but if the weather is calm and serene the length of their flight is less. In these fatal pauses the locusts commit the most frightful ravages. By their exquisite sensibility to odors, they scent from a great height in the air a field of grain or a garden. I have seen them turn from the course of their march more than half a league, obliquely, to destroy a field of grain, and after they had devoured it rise again and resume their first direction which they had left. The destruction is accomplished in an instant. Each insect has four arms and two legs, and all the extremities of each of these members have three [two] claws for grappling. I have seen the males ascend the branches of the trees on which they feed, as sailors climb by the yards and ropes of their ship, cutting off only the most tender of the twigs and letting them fall to the earth, so that the females who are below may eat them. I will not venture to say what cause influences the males to be so complaisant, since the instinct is not revealed; and this gallantry being but ill reciprocated by the ungrateful females, leads the males to descend from the shrubs, taking flight and pursuing them. With frequent similar pauses they finally come together in some uncultivated ground, when the males give vent to their desires, and the females deposit their eggs in the manner already referred to.

What a terrible spectacle it must be for a poor husbandman to look upon his fields when these insects have devoured the whole harvest. A countryman of judgment, as many are in the regions of Spain, finding himself present with me at such a scene of destruction, and seeing his fields left without a stalk of grain, and only with a little chaff, exclaimed: "If these accursed females were not so prudish, and if they would suffer the males to possess them in the country where they were born, such a calamity would not have befallen me; but the rabble fears death, and strives to prolong its life like ourselves because it knows that after uniting nothing remains to it but to lie in and die."

All history and tradition declare that the apparition of locusts is a pest which has afflicted the southern provinces of Spain from time immemorial; and I remember to have read in an ancient Spanish romance this question: "What animal is that which resembles all the animals? Answer. The locust; because he has the horns of a stag, the eyes of a cow, the face of a horse, the talons of a stork, the tail of a serpent, and the wings of a dove." The tracing out of these resemblances proves that the locust has been for a long time known and observed in Spain. Many old men have assured me, when questioned upon the locust plague of 1754, that that was the third which they had seen in their day, and that they existed always in the uncultivated lands of Estremadura, whence they wandered from time to time to lay waste other regions. Certainly they must be indigenous in Spain, because these are of a very different species from those which are found in the north and in the Levant,* as can easily be seen by comparing them with the insects of those countries which are preserved in the cabinets of natural history. The locust of Spain is the only one which has wings of rose color. Besides this, it is not possible that he should come from other regions, because he certainly has not come from the north, as the observation of so many ages demonstrates; nor can he have come from the south without crossing the sea, which is impossible for him to have done because of his short flight; and this passage can be observed like that of the quails and of other migratory birds. I have seen a troop of locusts pass through Malaga and enter for a quarter of a league over the sea; but when the people began to take pleasure in the hope that they would disappear and be drowned, they gave a sweep toward the left, flew straight to the earth, and paused to deposit their eggs in an uncultivated field surrounded by vines, such as they usually choose for their nests. The great number of dead bodies of the locusts which are observed floating on the shores of the Mediterranean, and which are drowned in rivers, which transport them into the sea, afford familiar examples of their troops or swarms which are precipitated into the sea on their journeys.

I have referred to the injuries which this insect occasions. I may now anticipate the remedy which the superintendents and the magistrates of Estremadura and of La Mancha enjoin upon the countrymen, and especially upon the shepherds: to discover the places where they have deposited their eggs, and unitedly to join in destroying them, without waiting for the time when they have developed and have begun to hop. However great may be the number thus destroyed, there remains always an immense army. But it were better to annihilate this horrible scourge where it is produced, and where it always exists in a greater or less degree, by exterminating it from the roots. I have seen in San Clemente multitudes of locusts destroyed in two months, which, perhaps, left only in all Estremadura a few who were not able to fly; and nevertheless the effect was like taking a drop of water out of the sea, nor was there observed in the following year any diminution in the number of locusts. It appears that it would be attended with less labor and expense if the end were aimed at of making war upon them in their own country and preventing their fatal eruptions.

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*It is very important not to confound the locust of Spain with those described by other authors. These furnish a fine occasion to display erudition upon the species of known locusts, of which we find mention in Exodus, and which St. John the Baptist fed upon in the desert, like the people called "*Acridofagos*" or locust-eaters; but all this is not to our purpose, and can be found in the books of the naturalist.

APPENDIX VII.

NOTES OF A JOURNEY MADE TO UTAH AND IDAHO IN THE SUMMER OF 1878, BY A. S. PACKARD, Jr.

August 14, 1878.—I left Salem, Mass., for Omaha, accompanied by Mr. Leslie A. Lee, instructor in zoölogy, &c., of Bowdoin College, Brunswick, Me., as special assistant. We reached Omaha on the 17th, taking the overland train that day for Cheyenne.

August 18.—The day following we saw, for the first time after leaving Omaha, the sage-brush and the characteristic appearances of the "plains" at Big Springs, Nebr. At Potter we collected along the railroad track both sexes of *Caloptenus femur-rubrum*, and also several specimens of the genuine Rocky Mountain locust (*Caloptenus spretus*). In the evening we arrived at Denver, Colo.

August 19.—We made an early start for Georgetown, arriving there at 12.30, and after lunch took horses for Mrs. Lane's "log cabin," situated near the Argentine Pass, at the foot of Gray's Peak. Along the road, five or six miles above Georgetown, *Caloptenus spretus* was not uncommon at an elevation roughly estimated at about 9,000 feet above the sea.

August 20.—The ascent of Gray's Peak was made in a storm of hail, thunder, and lightning. The insects native to the extreme summit, found by turning over stones, were a species of Phalangium or harvest-man, a spider and mite, together with Poduræ. Specimens of *Caloptenus spretus* also occurred under stones, benumbed with the cold. The workmen building the summit-house told us that they had seen a few locusts flying over the peak in clear weather.

Upon the "Alpes," or green, flower-strown slopes of Gray's Peak, above timber line, about 12,000 feet altitude, *Caloptenus spretus* was found in abundance.

While in Denver Mr. A. J. Bell informed us that August 14, while in the South Park, he saw a swarm of locusts flying east for an hour or two; he also said that they bred in Snake and Bear River Valleys nearly every year, but that none were seen this year in Snake Valley.

Mr. Wright told us that locusts were abundant August 12 and 13 in Estes Park at Ferguson's Hotel. He saw them flying in the air in "enormous numbers," so that it was feared that they would lay their eggs, the ground being "covered" with locusts.

Captain Jenness told me that locusts had bred this summer in small quantities in Gilpin County, especially on the Bear Mountains.

August 23.—We left Denver for Cheyenne and Ogden. At the station of "Summit," on the Union Pacific Railroad, we were told that the Rocky Mountain locust had bred in the "bottoms" near the station this year and last in sufficient numbers to answer for bait in trout fishing.

At Laramie City a person told us that locusts were seen about the 6th or 8th of the month in the air flying towards the southeast. At Rock Creek Station we were informed by freighters that no locusts had been seen this season between the station and Fort Kinney, about 200 miles northward, and that in general they were less numerous this year than in 1877. No locusts had been seen about Bridger, nor in the region north of Cooper's Lake this season.

August 24.—While locusts had not been seen by us in passing through Wyoming they were abundant at Evanston, and from there to Echo. We left the train at Echo Station and drove to Coalville, enjoying the hospitality of Bishop Clough for two days. He informed us that nearly one-half the wheat crop in Summit County had been destroyed this year by the unfledged locusts, which hatched out in the wheat fields. The swarms which flew into the county late in the season in 1877 laid their eggs in the cultivated wheat fields, not on the hillsides as usual, so that the young when hatched could not be kept out of the wheat. When winged they flew back (contrary to the usual rule) in a northerly course into Morgan County, whence their parents came in the previous year. In former years the locusts, on becoming winged, took flight in a southeasterly course. We learned that at the Dairy, three miles south of Wasatch, locusts were very thick August 24 of this year.

August 26.—Returning to Echo we took the train to Ogden. We found locusts (*C. spretus*) to be abundant at Ogden in the vicinity of the railroad station, though they had not been destructive to crops this year in the vicinity of Ogden.

August 27.—From Ogden we took the Utah Northern Railroad to Franklin, Idaho. At Logan locusts were abundant, flying some twenty feet high in the air, and at Smithfield and Richmond a few were to be seen.

At Willard, Cache County, no locusts were reported this year, though they were said to have recently entered Malade Valley from the northeast.

From passengers on the train we gathered the following miscellaneous information: July 29, "eclipse day," a swarm of locusts passed over, flying from the west and west southwest, crossing Ryan's Cañon, the Stinking-water River, and devastated or "cleaned out" a few farms, eating off the heads of the oats. The moment the eclipse took place the locusts settled on the ground as if nightfall was coming on, and never were to be seen afterwards.

At Richmond we saw them jumping about on the ground and also flying at an elevation of perhaps 500 feet in the air, in a general southwesterly course, down the valley. These locusts were said to have come from the northeast, over the mountains, about the 1st of August, none having hatched out in the spring. The locusts extended from Logan to Franklin, and had destroyed one-third of the oats and a third of all the garden stuff at Richmond and Logan.

At Smithville, the year previous (1877), the farmers had, in consequence of the depredations of the locusts, raised but half a crop of wheat, the young having hatched out from eggs laid in 1876. They generally fly southward, toward Salt Lake, from Smithville as well as other points in Cache Valley.

August 28.—Locusts were found to be abundant, scattered over the ground in and about the town, and for several miles away from the village. They were coupling by the roadsides, though I could not see that any eggs were laid, and no females were seen engaged in boring holes in the earth preparatory to egg-laying. They were also abundant in plowed lands from which the wheat had just been harvested, and were on the willows eating the leaves, and on the wild roses and golden rods.

At 7.30 a. m. numbers of them were seen flying and sailing about in the air in various directions, there being no steady breeze.

They were reported to have been abundant in Gentile Valley about the 18th of August, the locality being situated between Franklin and Soda Springs.

According to the statements of Mr. Alexander Stalker they arrived here from the north, probably Portneuf Cañon, reaching Franklin between the 15th and 30th of July.

Mr. Stalker told me that locusts hatched out at Franklin in the spring of 1877, and when fledged, contrary to the usual rule, departed to the northeast. Those now here he supposes to be their progeny which have come from the breeding grounds to the northeast.

At Franklin some late wheat was damaged, and all except early oats; the early wheat was not hurt.

I learned from Mr. Stalker that locusts were pretty thick at Virginia City, Mont., August 2 or 3, and appeared to be flying northeast towards Madison River.

At Bozeman they had occasionally been destructive this summer, but no damage had been done by them at Beaver Head, Red Rock, Rattlesnake Creek near Argentine, Big Horn Prairie, Jefferson Fork, Big Hole, and none at Stinking-water River or in Ruby Valley, and none at Snake River Crossing (Taylor's Bridge), at Blackfoot, or at Portneuf.

A great many crickets were observed at Portneuf.

Mr. Stalker told me that the black cricket (*Anabrus simplex*) will in early summer eat young wheat and then leave it. Farmers do not fear them if the grain is irrigated, as then they are said to do no harm. They are pretty abundant about Franklin (though I saw none while there); the young crickets will eat the tender grass and grain and when adult will leave it. They are very particular to select the young grain. The best means of destroying the crickets is to herd the sheep in the grain, keeping them compactly herded, as the sheep will do little harm to the grain when young, and they trample the crickets to death.

Locusts were reported by passengers on the stage from Montana as abundant all the way from Pleasant Valley to Oneida; but though those seen by us at Franklin had evidently flown from Southern Montana, no damage was done by them in Montana this summer, as already stated. Between Helena and Fort Benton no locusts were heard of.

On our return to Salt Lake City, on the evening of the 28th, locusts were seen flying low at Brigham.

August 29.—From various sources we ascertained that the locust had not occurred this season south of San Pete, and then they were not abundant and appeared late. For a month or six weeks they have been passing in scattering numbers over Salt Lake City. They were particularly observed July 29, the day of the eclipse.

August 30 *and* 31.—At Lake Point the Rocky Mountain locusts were frequently caught in recently harvested wheat fields.

September 1.—For considerable valuable information regarding the distribution of the locust, obtained in Salt Lake City, we were indebted to the editor of the Salt Lake Herald, to the United States signal observer, and especially to Mr. Lawrence Bruner. He had, August 31, seen *C. spretus* at York, 70 miles south of Salt Lake City, and had this day returned from Provo, where he observed a few individuals.

September 2.—We left Salt Lake City for the East. Upon the train, after leaving Ogden, a scout with the pseudonym of Navajo Bill informed us that locusts were seen the past summer between McDowell's Ferry and the Blue Mountains, in Eastern Oregon, flying and also upon the ground. At Evanston, just east of the town, *Caloptenus spretus* was very abundant, both flying in the air and hopping about on the ground.

September 4.—At Como we stopped for two days. Mr. William Carlin, the station agent, whose hospitality we enjoyed, informed us that July 29, the day of the eclipse, he saw a large swarm of *Caloptenus spretus* passing to the east by south from about 10 a. m. to 4 p. m. He thinks they bred in the Wind River Valley. Mr. F. F. Hubbell told us that he saw a swarm three or four days after the eclipse going in an east by north course.

September 5.—In the course of a walk of five or six miles south of the station I saw only three *Caloptenus spretus*, and they were on the ground.

September 6.—We took the cars for Omaha. Mr. W. B. Scott, of the Princeton College expedition in search of fossils, whom we met on the train, gave us the following information regarding the distribution of the locust in the regions visited by him during the past season. He stated that grasshoppers were seen locally in a few places in abundance on Bitter Creek, 100 miles south of the Union Pacific Railroad, but usually there were not enough to serve as bait for fishing. They were also seen at the base and on the summit of Gilbert's Peak, at about 11,000 feet elevation. The last of August locusts were observed at Twin Creeks, on Ham's Fork, Wyoming.

We were told by a person on the train that *Caloptenus spretus*, or the locust, was not seen at Boise City, Idaho, this summer, but that crickets (*Anabrus simplex*) had been abundant.

We reached Salem September 10th. During our journey we gathered many other facts regarding the appearances, distribution, and ravages of the locust in former years in the Territories of Wyoming, Utah, Idaho, Montana, and the State of Colorado.

Our thanks are due for passes and other favors to the officers of the Lake Shore and Michigan Central Railroad, the Northwestern, Rock Island, Burlington and Quincy, Union Pacific, and Utah Northern Railways.

APPENDIX VIII.

YERSIN'S RESEARCHES ON THE FUNCTIONS OF THE NERVOUS SYSTEM OF THE ARTICULATE ANIMALS.

[Compare with chapter XI on the Brain of the Locust.]

In our chapter on the Brain of the Locust we omitted to record Yersin's* opinions as to the functions of the nervous system of crickets. We translate from H. de Saussure's "Notice sur la Vie et les Écrits de Alexandre Yersin," 1866, the following abstract of his researches on this subject.

The author followed two different methods in his researches; first, by making sections of the nervous chain; second, by endeavoring to isolate the ganglia.

The results attained by means of sections were quite varied. In performing on some crickets the section of the two nervous cords in the head, between the supra-œsophageal and infra-œsophageal ganglia, there resulted as a consequence of this operation a series of physiological phenomena. After a moment of stupor, the insect rose on the extremities of its feet while carrying its head directed forwards. Then the cricket turned in a circle to the right, while rubbing its head with the left foot, or *vice versa*.

When the section of the two commissural cords is performed between the head and the thorax, as, for example, when we decapitate a Blatta, the insect can still live ten or twelve days; the body continues to bend itself in such a way as to carry the posterior feet towards the head, which is wanting, as if to clean them with the mandibles. When the insect thus mutilated is excited it endeavors rather to defend itself than to escape, as an uninjured individual would. If the section is performed on crickets between the second cephalic ganglion and the first thoracic, without decapitation, it will be found that we have isolated the community of action in the head and body, which move independently of each other; the animal constantly tries to extend its feet as if to clean them with the mandibles, but the maxillæ do not recognize them. These are almost the only movements which the insect makes. Exposure to the sun reanimates it, and it leaps about a little; forty days after the operation it sometimes becomes suddenly aroused from its torpor. The act of coupling can be performed, even with a female operated upon, but the latter is incapable of laying eggs. The insect still eats a little, but while only the head eats, the trunk does not perceive it, and continues to extend the feet towards the mouth as if to rub them; so that the head eats, without perceiving the fact, its own feet as well as the food; the mutilation of the feet causes the insect to tumble about, which seems to prove the presence of pain. The reflex movements are very easy to provoke in this particular case, and the voluntary movements either of the trunk or of the head are exercised with a remarkable facility, although in an independent way. Thus the insect is capable of leaping; if it is stimulated too long it gives some symptoms of anger; if it is placed on its back it promptly turns over. The crickets operated upon live as long as those which are uninjured.

In making two sections of the cords of the ganglionic chain, so as to completely isolate one of the ganglia, we likewise isolate the functions of the nerves which are distributed from this ganglion, but without interrupting them. The reflex actions become in this case very pronounced. They are always of long duration; for example, when we excite the valves of the ovipositor, they continue to open and shut persistently; in exciting a foot belonging to the third pair we obtain an immediate reflex action on the one corresponding to it. The feet of the second pair seem, however, to be an exception to the rule, and only react with great difficulty on each other. If we isolate several ganglia collectively from the rest of the chain, we obtain analogous and naturally more varied reflex actions.

Yersin followed up his experiments by afterwards producing some lesions in the

* Alexander Yersin was a Swiss naturalist, who wrote several important and fruitful essays on the habits and physiology of the locusts and crickets. His essay on the nervous system of insects was the following: Recherches sur les fonctions du systéme nerveux dans les animaux articulés. Société Vaudois des Sciences Naturelles, et Académie des Sciences de Paris, 1856–'57.

ganglia themselves by cutting them apart in a longitudinal as well as transverse direction. These lesions produced phenomena which were quite varied, and which succeeded, from moment to moment, in an order more or less determinate. A longitudinal section, dividing unequally the subœsophageal ganglion, gave rise to some lateral movements; the insect turned as if rearing up like a horse (*en manége*), at first momentarily from the side of the wound, then definitely from the opposite side; it fell over on its back from the side opposite the wound, and, in rising, made a complete revolution. It lost the power of leaping. The transverse section of the same ganglion produced some accidents much more grave. The cricket raised the right foot, as if to find a point of support, and tumbled over often to the left; while on the other side we could not succeed in reversing it. The reflex actions were sufficiently pronounced.

The section of a single cord of the chain does not produce cross effects. It introduces a disturbance in the equilibrium of the functions of relation of the two sides of the body, and is always indicated by the insect's walking in a circle, the feet on one side functioning more rapidly than those on the other, &c.

In combining the different sections which precede, or in cutting simultaneously the two cords on a point of their tract, and a single one between them on some other point, we obtain some complementary information as to the mode of transmission of nervous actions.

The result of these experiments establishes the fact that the transmission of the will is always made directly, and without a transverse effect, while the reflex actions, although they are transmitted more easily by a direct course, take place, though with less intensity, by a transverse effect. Another general fact that Yersin has inferred from his experiments is that the maximum of intensity of the movements which he has observed after the operation has always occurred on the side on which the operation was made. This is why in its rearing gait (*marche en manége*) the insect turns in a circle from the opposite side. So when we make the section of the right cord between the head and thorax, the animal begins at first to turn to the right, but at the end of a moment it changes and turns to the left. It is, indeed, immediately after the section of the right cord that the right feet cease to be submitted to the action of the will, while those of the left side continue to obey the will, acting with more activity, and thus causing the insect to turn to the right. But at the end of an instant, the reflex action setting in motion the right feet, this impresses upon them a more lively movement than to the left feet, which act under the direct impulse of the will, and they consequently turn the insect to the left. For the same reason, the insect placed on its back will recover itself on the wounded side.

As the result of later experiments, read before the Société Helvétique des Sciences Naturelles, at Lausanne, in 1851, Yersin stated that each ganglion can become the point of departure of spontaneous movements and a center of distinct perceptions.

The following is an abstract of his memoir to the French Academy, the observations having been made in 1856, and relating to the effects of the section of the cords or commissures connecting the ganglions of the nervous cord:

1. The co-ordination of movements is not disturbed by the section of two cords at a time at any point whatsoever of the chain.

2. On the contrary, locomotion becomes abnormal, (1) every time we cut a single cord at a point from the anterior chain to the ganglion of the metathorax; (2) every time we make two or several sections, each on a single cord, between different ganglia, one at least of the sections being situated on a point anterior to the metathorax.

3. In the vertebrate animals the nerves properly so called have all their roots in the elongated medulla and in the spinal marrow. In the articulates almost all the nerves arise from the ganglia. Anatomical analogy leads us to compare the ganglia of the chain to a marrow.

4. The experiments here given in résumé seem to us to establish the fact that it is the ensemble of the cephalic and thoracic ganglia which preside over the co-ordination of locomotive movements without its being possible to ascertain whether this function resides in one of these organs to the exclusion of the others. Thus this marrow represents at the same time the cerebellum of the higher animals.

5. It is very probable that it is therefore in the reunion of the ganglia that we should seek the analogy of the brain of vertebrates.

INDEX.