ZOOLOGY.

THE MOUNTAIN LEPIDOPTERA OF BRITAIN: THEIR DISTRIBUTION AND ITS CAUSES.

By F. BUCHANAN WHITE M.D., F.L.S.

THE distribution of species, either of plants or of animals, is of a twofold character,—firstly, as regards space, and secondly, as regards time, the former of these being again capable of subdivision into latitudinal and longitudinal distribution, and altitudinal distribution; but between the latitudinal and altitudinal distributions a close relationship exists.

In ascending a high mountain and observing the various degrees of temperature and climate, with the accompanying vegetation, that are successively experienced as we pass from the base to the summit—the olive-trees and vines, myrtles and oleanders, that occupy the lowest parts; the chestnuts and oaks that perhaps come next, followed in succession by fir-trees, open pastures, moss and lichen covered soil; and, finally, at the summit, by eternal snow—it does not require any great stretch of the imagination to fancy that the terrestrial globe resembles in many aspects two great mountains cohering by their bases at the equator, and culminating at the poles in summits covered with eternal ice and snow. As we proceed from the equator to either pole, we pass through zones of climate and vegetation similar to what we did in ascending the mountain, and find that each has sufficiently well-marked limits characterised by special forms of animals and plants.

But many mountains have more than one summit or peak, not so high or so extensive as the real or central peak, and on each of these secondary summits we find repeated, though possibly on a smaller scale and in a less degree, the features of vegetation presented by the whole mass. And so it is with the two imaginary hills that form the terrestrial globe. They have many smaller peaks (in other words, mountains), each of which pre-

sents in miniature and in some degree the botanical or zoological phenomena of the whole terrestrial mass. Each of these summits is a facsimile on a very small scale of the north or south pole, and the base of each is, *in comparison* to the apex, a tropical region. Near the arctic (or antarctic) circle a hill of moderate height will present these features, but as we go southwards an ever-increasing altitude is necessary. Thus we find that plants or animals which at the arctic circle are found at the sea-level, do not, in middle Europe, descend below one or more thousand feet above sea-level; in the Alps or Pyrenees several additional thousands of feet are necessary; and on hills south of the latitude of Europe a still greater altitude. So with species that inhabit the sea-level of northern (but not arctic) Europe; they, too, when existing further south, keep above a certain altitude, always increasing as the tropics are approached. Some species are very exorbitant in this respect, but others are better able to accommodate themselves to altered conditions, and hence have many advantages in the fight for existence.

From all this we may gather the intimate relations existing between latitude and altitude in the distribution of species.

From the zones of latitude or altitude inhabited by them, species may be classed in groups. Some are confined to the region within or near the arctic circle, and hence may be called *arctic* species; others are confined to the great mountain chains (including the Alps, Pyrenees, and other ranges north, south, east, or west of them), and are termed *alpine* species; others occur in both these regions, but not on the intervening lower ground, and to them the title of *arctic-alpine* species may be given.

To one or other of these groups all the species about to be treated of belong.

Of the 2000 species of Lepidoptera known to inhabit the British islands, not more than about fifteen can be considered as mountain species—meaning thereby species confined to the higher mountain ranges, and not usually descending below an altitude of about 1500 feet above sea-level. The majority of the species alluded to do not descend as low as 1500 feet, but some, at least in the far north of Scotland, descend much lower. Many other species of Lepidoptera may be frequently found at high altitudes, but as they descend to the low grounds, they cannot be considered as mountain species proper; whilst

some others which are confined to mountain districts do not as a rule live at a high altitude, so that they also cannot be included in this class.

The Lepidoptera which seem to merit the title—in Britain—of mountain species are the following. (The words within brackets show to which of the above-mentioned groups each species belongs.)

Erebia Epiphron, Kn. (alpine);
Zygæna exulans, Hchwh. (arctic-alpine);
Pachnobia hyperborea, Zett. (arctic-alpine);
Anarta melanopa (arctic-alpine);
" *cordigera* (arctic-alpine);
Psodos coracina (arctic-alpine);
Scopula uliginosalis, Stph. (alpine);
Scoparia alpina, Dale (? alpine);
" *gracilalis*, Dbld. (? alpine);
Crambus furcatellus (arctic-alpine);
Penthina Staintoniana, Brrt. (alpine);
" *Grevilleana*, Curt. (? alpine);
Swammerdamia nanivora, Stt. (alpine);
Zelleria saxifragæ, Stt. (alpine);

and possibly one or two species of *Nepticula*, which I will omit.

The distribution of these species in Britain and Europe is as follows :—

Erebia Epiphron occurs in the north-west of England, in the north-east and north-west of Scotland, and in the west of Ireland. It inhabits grassy places on the sides of the mountains, and seems to be very local, as I have gone over many parts of the Scottish Highlands which seemed well suited for it, without observing it—as, *e.g.*, in Aberdeenshire, eastern Inverness-shire, and Ross-shire. Its most northerly localities in Britain are—so far as our present knowledge goes—Rannoch and western Inverness-shire. Several varieties of this butterfly have received names, and on the Continent these varieties have a rather distinct distribution. *Epiphron* proper has a more decided band of rufous spots, and in the female the eye-spots have white centres. It is found on the mountains of the Black Forest and of Silesia, and, as far as I can judge, is the form that occurs in Rannoch and elsewhere in Scotland. The var. *Cassiope* F. has the rufous spots less distinct, and the eye-spots without white centres. This is the most widely distributed form, occurring on the mountains of Central Europe so far east as Hungary, and also in Britain. The var. *Pyrenaica*, H.S., is larger, and

has larger eye-spots. It is the Pyrenean form, but some of our Perthshire specimens resemble Herrich-Schäffer's figures very much.

In Scotland, *Epiphron* does not seem to descend lower than 1500 feet above sea-level, at which elevation I have found the larva.

Zygæna exulans inhabits grassy places on the mountains of Aberdeenshire, at an elevation of 2200 feet and upwards. On the Continent two forms occur—*exulans* proper, which is found on the higher Alps and Pyrenees, and is more or less suffused with ochreous; and the var. *vanadis* Dalm., which has scarcely any ochreous tinge, and is restricted to the Scandinavian mountains and to Lapland. Our form seems to be intermediate between these two, and I have proposed for it the name of var. *subochracea*.

Pachnobia hyperborea occurs on some of the higher mountains of Perthshire and Aberdeenshire—usually on the ridges of the hills. On the Continent it ranges from Lapland to the Swiss Alps, and eastwards to Carinthia (var. *carnica*) and Hungary. It is a very variable and beautiful insect, and does not in Britain probably descend below 2500 feet or thereby.

Anarta melanopa inhabits the higher parts of some of the mountains of Perthshire, Aberdeenshire, Sutherland, and Zetland, and has been reported from the west of Scotland. It generally does not descend below 2000 feet, but in Zetland has been taken at about 400 feet. Out of Britain it is almost confined to Lapland, though also occurring in Labrador, and a variety (which I have also seen alive) on the Swiss Alps.

A. cordigera is scarcely a true mountain species (as defined above); for though it occurs on the hills up to 2200 feet or upwards, yet it is frequent at as low an elevation as 1000 feet, or even lower, in Perthshire, Aberdeenshire, and Morayshire. On the Continent it occurs in central and north Europe, going as far south as the Alps, and as far east as the Ural. It also inhabits Labrador.

Psodos coracina (the *trepidaria* of British lists) is—so far as my experience goes—confined to the ridges of the higher mountains of the north-east and the north-west of Scotland, not descending below 2000 feet. In Europe it ranges from the mountains of Lapland to the Pyrenees, going east to the mountains of Galicia, and perhaps reaching east Siberia and the Amur. In Scotland I have almost invariably found it associated with *Azalea* (or

Loiseleuria) *procumbens*, and thought that that plant might be its food, since I have found the spun-up larvæ in close proximity to it; but as the *Azalea* is not a Pyrenean species, there must be another food-plant.

Scopula uliginosalis (the *alpinalis* of British lists, and perhaps a variety of the true *alpinalis* Schiff., which is apparently not a British species) inhabits grassy places on the sides of the mountains of the north-east and north-west of Scotland, occasionally, but rarely (as in Braemar), descending to 1200 feet, but usually not found under 2000 feet. On the Continent it occurs on the Alps, and on the mountains of Hungary and Galicia.

Scoparia alpina frequents grassy and mossy places—often on the ridges—of the higher hills of Perthshire and Aberdeenshire, usually not descending below 2000 feet. It has not yet been found out of Britain.

S. gracilalis occurs on the mountains of Perthshire and of Norway; but as it is the only one of the species of which this paper treats, which I have not personally observed, I cannot give any information as to its habits.

Crambus furcatellus most usually occurs on the grassy or mossy ridges of the higher hills of Scotland, north-west England, and Wales; but, like the other mountain species, it is very local. The lowest altitude at which I have noticed it is about 2300 feet. On the Continent it occurs on the Alps and Norwegian mountains, and in Lapland.

Penthina Staintoniana has been as yet found only in Scotland, where it occurs very locally, in sheltered places on the hills, at or above 2000 feet.

P. Grevilleana is also known only as a Scottish species, and one of very great rarity. Though I have taken it, I regret that I am unable to give any account of its habits.

Sericoris irriguana is sometimes considered to be a variety of *metallicana* Hb., but is more of a mountain species than that insect. In Britain it occurs very locally on the higher parts of mountains in the north-east and north-west of Scotland. On the Continent it inhabits the Alps, Norwegian mountains, and polar Norway, as well as the Altai.

Swammerdamia nanivora was, till lately, only known from a single specimen found, in the larval state, by me, in east Inverness-shire, at an altitude of about 2000 feet. It has lately been taken in Esthonia.

Zelleria saxifragæ is not uncommon, but rather local amongst

saxifrages, on the Perthshire and Aberdeenshire mountains, descending as low as 1000 feet. It also occurs on the Alps.

An examination of the distribution given above in detail will show that all the species occur in Scotland; one (*Erebia Epiphron*) in Scotland, England, and Ireland; and one (*Crambus furcatellus*) in Scotland, England, and Wales; and regarding their exotic distribution, eight species are found in North Europe (seven, if not all, reaching the arctic circle); seven are both arctic and alpine; three are alpine, but not arctic; and three occur on the Pyrenees (two of these being also arctic); two are found in America; and of four the distribution is imperfectly known.

The distribution may be presented in tabular form, thus:—

British distribution	Scotland,	all.
	Scotland, England, and Ireland,	1
	Scotland, England, and Wales,	1
Exotic distribution	Arctic and alpine,	7
	Arctic or northern only,	1
	Alpine but not northern,	3
	Imperfectly ascertained,	4

We are now in a position to inquire, Whence, when, and how did these insects come to Britain? for I do not suppose that any one entertains the opinion that they (or at least the majority of them) originated in this country. Some conspicuous Lepidoptera are nearly or quite restricted to Britain, and have possibly been evolved from other and allied species within or near our borders; but the species under consideration, which seem to be confined to this country, probably only *appear* to be so, because, from their small size and close relationship to other species, they have as yet been overlooked elsewhere.

Whence, therefore, or from what direction, did these mountain Lepidoptera come?

When or at what period, relatively to the great mass of the native Lepidoptera?

How or by what agency and route were they brought in?

These are all questions easier to ask than to answer, and may be best considered together. To them we will add still another, What causes have governed and restricted the distribution?

Britain, as every one is aware, did not—apart from the changes wrought by man's agency—always present the same physical features that it does at the present day. There was once a time,

and that, from a geological point of view, not very remote, when the greater part of the country was covered by an immense ice-sheet. During that period there was probably no vegetation in any part of these islands, and hence we may be sure that there were no Lepidoptera. This state of matters had existed for many ages before the time I speak of, but not with uninterrupted severity. Warm periods occasionally occurred, when the icy shroud of the country was removed, and the land was clothed with vegetation, varying in its nature according to the character of the climate. Sometimes the plants belonged — as may be learnt from the vegetable remains still preserved in the east of England and elsewhere — to the alpine and arctic groups, including such species as *Betula nana* and *Salix polaris;* and we may be pretty certain that Lepidopterous larvæ were there to feed on the leaves. It is true that Lepidoptera have not, I think, been found in association with the plant remains, nor, from their fragile and perishable character, could we well expect them to be; but the remains of Coleoptera, both herbivorous and carnivorous, have been found, and it is not likely that other insects were absent. Therefore, though we cannot prove it, it seems very probable that some of the species treated of in this paper were then inhabitants of Britain. But, as I have already said, arctic conditions returned and destroyed all the plants and animals, and those whose descendants we see at the present day must have had a more recent introduction.

Two views have been advanced as to the condition of this country during the final stage of the icy or glacial period. The older view was, that most of the country was submerged, and that only the hills remained above water. To these island-hills icebergs drifted, and deposited their burdens of stones, earth, and other *débris,* including seeds of the various arctic-alpine species, which now form part of the flora of many of the high hills. Admitting that the same vehicles might have brought the mountain Lepidoptera, and that they were able to survive the dashing to and fro, the intense and prolonged cold, and the probable submergence in salt water, and that, moreover, there were localities whence it was at all likely that they could be brought, the proofs are wanting that such a condition of the country existed, while many incontestable proofs have been advanced in favour of the other and more modern view, set forth so admirably by Dr James Geikie in his 'Great Ice Age,' to which work I refer those desirous of examining into it for themselves.

This was the state of Britain during the final stage of the glacial period. All Scotland, and the northern half of England, were covered with a thick sheet of ice, pouring down from the mountain-ranges and concealing all the low ground; from the Welsh mountains another ice-sheet descended and joined the northern one; all the north as well as the centre of Ireland was also covered with ice, and in the mountainous south-west portion of that island were large local glaciers; the rest of England and Ireland was covered with thick snow, partially melting in summer, and giving rise to great floods; certainly no animal, and probably no vegetable life, existed anywhere in the whole country.

On the continent of Europe the same arctic climate existed. All the northern half was covered with an ice-sheet coming from the north, and which, in addition to overrunning the land, filled the bed of the German Ocean, and impinged upon the British ice-sheet. Then from the mountains of central Europe, from the Alps and Pyrenees, great glaciers descended, and spread for hundreds of miles over the low country. Where the ice-sheet did not reach, snow covered the ground in winter and heavy floods inundated it in summer. No plants, no animals anywhere except in the far south, and even there the climate was more of an arctic or sub-arctic than of a temperate nature, as we know from the remains of the plants and animals (including such species as the reindeer, musk-ox, lemming, &c.).

But at last a temperate climate began to predominate over a sub-arctic one; the ice-sheets began to melt and retreat to the north or up the mountains; the snow-fall was less heavy; and the plants and animals seized the ground vacated by the snow and ice, and occupied the territory from which their ancestors had been driven by the ice-sheet in its southward march.

In course of time the altered condition of things would be felt in Britain, but the English Channel would as yet cut it off from the advancing tide of life. Still it is probable that the winds and sea-currents would carry thither the spores of mosses, lichens, and other cryptogamic vegetation, and perhaps even the seeds of some of the higher plants, which would find suitable resting-places out of reach of the great floods which continued to sweep over much of the low ground.

Finally, after several variations in the relative heights of the land or sea (the latter being at one time 100 feet higher on our shores than it is at present [1]), the land rose so much that the bed

[1] About 80,000 years ago.

of the German Ocean became dry land, and afforded a passage for the great mass of our plants and animals. That they did not cross all at once we may be sure. In the first place, it would be a long time before the soil of that wide plain would be in a fit condition to support plant-life. Probably the great floods that would frequently inundate it—for a large river flowed through it—deposited mud and gravel on which, as it became drier, plants could grow.

(*To be continued.*)

NOTES ON THE BIRDS OF THE BASIN OF THE TAY AND ITS TRIBUTARIES.

By Colonel H. M. DRUMMOND HAY, C.M.Z.S., B.O.U., &c.

(*Continued from page* 62.)

19. Caprimulgus europæus, Linn. (Night Jar or Goatsucker.)

In the lower parts of the district the Night-Jar is now much less abundant than in former years. In the Highland quarter, however, it is still to be found fairly represented; but from its decidedly nocturnal habits, few opportunities occur of its being observed in broad daylight. Occasionally, however, and especially in autumn, solitary individuals are not unfrequently to be met along the moor-side or other exposed spots, squatted lengthwise on some dyke or rail, or perhaps seated on the ground motionless — resembling, in this peculiar position and colour of plumage, so much some natural excresence, as not to be easily detected from surrounding objects—till, suddenly rising on the wing, the passer-by is startled by its unexpected appearance from almost under his feet. Having always observed these autumn birds to be those of the season, I have been led to believe that the parent birds, though late in their arrival (about the end of May), are among some of the first of our summer visitants to take their departure, leaving their young to follow as best they may. Though never fortunate enough in this district to have come across the two eggs, which the female invariably deposits on the bare ground, without any form of nest, or to have obtained any information as to their breeding in any of the upper parts, yet, I think, from the fact of the young being found in autumn, and the peculiar churring note of the old birds being constantly

ZOOLOGY.

THE MOUNTAIN LEPIDOPTERA OF BRITAIN: THEIR DISTRIBUTION AND ITS CAUSES.

By F. BUCHANAN WHITE, M.D., F.L.S.

(*Continued from p.* 105).

THE very earliest of the higher plants would be those arctic or north temperate forms which grow in the immediate vicinity of salt water, on the sea-shore,[1] or in salt marshes; and it may be noted that some of these inhabit mountains also.[2] Conversely, some of the mountain plants occur on the sea-shore, especially in the north. A saline element is necessary for the species restricted to the vicinity of the sea, but those common to sea-shore and mountain inhabit these localities, not entirely by choice, but because they have been driven out of the more favoured intermediate ground to less crowded situations, or at least into situations in which their constitutions enable them to hold their own against other plants. For the same reason some of the mountain plants descend and some of the maritime plants ascend along the shingly or sandy margins of rivers, where they have usually less of a crowd to contend with. This is one of the reasons why we find some of the so-called maritime plants high up on the mountains, their presence having been at one time considered to afford a proof of the theory that these mountains were once islands in an iceberg-laden sea.

Amongst the first plants to occupy the dry bed of the German Ocean would be the various species that followed closest on the retreating ice-sheet (viz., the arctic and arctic-alpine), but they, at least in the southern part, would soon be crowded out by the plants that followed. We may have some idea of the order in which the species would grow if we study the sequence in which our wild plants occupy any portion of ground recently made

[1] *E.g.*, *Mertensia maritima*, *Psamma baltica*, and, in a less degree, *Juncus balticus*.

[2] Such as *Armeria*, *Plantago*, and *Silene*, *maritima*, *Carex incurvata*, &c.

bare,—as, for example, a moor from which the turf has been pared, a drained lake, or a slope uncovered by a landslip on the hills. Perhaps the latter will show us something of what may, in part, have actually happened at the time of which I treat. Examining such a place, we will notice how, in course of time, one set of plants, and frequently those that are rarest in the immediate vicinity, begin to dot the surface of the unoccupied ground. In a year or two they are joined and jostled, as it were, by others before whom they gradually disappear, and then perhaps the second set are joined by others before which some of them too vanish. So it is easy to imagine how the arctic and arctic-alpine plants, which seem less fitted than others to live in a crowd, would first occupy the German Ocean plain, gradually cross it and invade Britain, spread over perhaps a great part of the country, be pursued and crowded by other plants, and be finally driven up the mountains, where the conditions of life would place them more on an equality with their pursuers (not all of which could live on the mountains), and where they could hold their own.

But to return to our insects. Whenever plants had become established, herbivorous insects would follow, each pursuing the food plant or plants of its larva. The first insects would likely be those attached to cryptogamic plants, such as mosses or lichens; and it is possible that if the *Crambus* and *Scopariæ* in the list given above have larvæ which feed on such plants—at present their food-plants being unknown — they were the first to cross the Germanic plain. Of the higher plants, those which are not so dependent as others upon insect agency for the fertilisation of their flowers would possibly be first in possession of the ground, and the insects which use them as food would thus get a start in the race, and by their presence assist in the spread of the plants depending on their assistance for fertilisation.

Thus *Erebia Epiphron* is a grass-feeder, and grasses being wind-fertilised, are independent of insect agency. The *Erebia*, consequently, would find food before *Pachnobia*, the *Anartæ*, &c., which are attached to the Ericaceous plants, which are usually fertilised by insect agency.

These are the known or probable food-plants of the insects treated of in this paper:—

Erebia Epiphron—Grasses.
Zygæna exulans—Low plants (Trifolium? Empetrum? &c).
Pachnobia hyperborea—Vaccinium myrtillus.

Anarta melanopa—Vaccinium and Arctostaphylos.
" *cordigera*—Arctostaphylos uva-ursi (&c. ?).
Psodos coracina—Calluna ?
Scopula uliginosalis—
Scoparia alpina—Mosses ?
" *gracilalis*—Mosses ?
Crambus furcatellus—Grasses? mosses?
Penthina Staintontiana—Vaccinium myrtillus.
" *Grevilleana*—Arctostaphylos?
Sericoris irriguana—
Swammerdamia nanivora—Betula nana.
Zelleria saxifragæ—Saxifraga aizoides, &c.

Of these plants, the grasses and *Betula nana* are wind-fertilised; *Vaccinium*, *Arctostaphylos*, and *Saxifraga* are generally insect-fertilised.

It may be argued that the insects in question, being furnished with wings, were not dependent on a land-connection with continental Europe for their introduction into Britain; and it is quite possible that some of them may have found their way across the narrow seas. Whether in that case they would make good their footing, would depend on whether their own peculiar food-plants had become established. That some plants had reached this country before the land-connection took place is very likely, but that the majority of the plants crossed by land (or at least when the water-barrier was much narrower) seems more probable. Another objection to a theory of passage across the sea is that most of the insects in question seem to be—now, at least—of a very unmigratory disposition; and unless their habits in former times were different, they would not be likely to venture across the sea. On the mountains there are many places, which appear as suitable as those inhabited by the various species, which remain untenanted; and though it would be very rash to say that these spots will remain untenanted, yet if the insects in question had been of a roving disposition, they would probably have colonised or recolonised them. As for involuntary migration, by means of the wind-currents, these mountain insects seem to have a wholesome dread of wind, and will not as a rule venture out in a breeze unless compelled by dire necessity, either concealing themselves in the scanty herbage or taking shelter under stones, as I have seen *Psodos* do. Many of the lowland insects get caught by the wind and blown on to the mountains, as I observed by finding large quantities of them scattered on snow-fields on one of our hills. I was at the time especially

struck by the fact that none of the mountain Lepidoptera had been caught in this manner. Of course it is quite, and perhaps extremely, probable that this habit of avoiding wind-currents may have been acquired since these insects colonised their present mountain homes, and that they were in former times as incautious as the lowland species. Moreover, even supposing that they were cautious, a single female of each of the species may have been carried by the wind and founded a colony.

On the whole, however, I think the probabilities are in favour of the passage by land, or rather by land only slightly interrupted here and there by very narrow water-barriers; and if we can judge from the present distribution of the species, we may hazard a guess at the sequence in which they came. I say the "present distribution," for we cannot tell of course what changes may have taken place—such as the extinction of species in localities once frequented by them—during the many thousand years that have elapsed since their first arrival.

But, first of all, what kind of a country did the dry sea-bed make, and what were its physical features? It might be thought that some idea of these might be obtained by studying the Admiralty charts of the various depths at present existing round our shores and in the German Ocean; but geologists think that many of the great banks which occur in the southern reaches of the German Ocean probably consist, in large measure, of glacial deposits, and their presence tends to obscure the physical features that obtained in pre-glacial and inter-glacial times. Were one to judge from the present depths, the first dry land lay between Holland and North Lincoln or South Yorkshire, and the Rhine, Thames, and other rivers ran west through the English Channel; the Elbe and other rivers north of the Rhine running, on the other hand, northwards. But geologists incline to believe that the Rhine flowed northwards, and was joined by the Elbe, Thames, and other rivers. However that may be, it is pretty certain that great plains, intersected by rivers of varying breadth, occupied the present bed of the German Ocean, and that all parts of that sea of less depth than one hundred fathoms were then dry land. The hundred-fathom line (beyond which the depths increase suddenly) reaches from Denmark to the north of the Zetland Islands, but does not touch Norway, which is cut off by a deep channel. From beyond the Zetlands it passes outside the Hebrides, Ireland, and the south-west of England, and gradually approaches the coast of France in the extreme

south-west. Between England and Ireland was a large lake reaching from opposite Wales to beyond the north of Ireland.

Assuming that *Crambus furcatellus* is (as is most probably the case) a grass or moss eater, we may regard it as one of the earliest of our mountain Lepidoptera to arrive. In the first place, because of its probable food-plant, which, as already said, would be one of the first to be established; and in the second place, because it is the only one of the species known to inhabit Wales. When the plants and animals began their northward march the arctic-alpine species would, as already remarked, follow closest on the retiring ice-sheet, and close behind them would come the more numerous species that inhabit the lower and less arctic localities. As these seem to be stronger, they would occupy all the ground behind, where, moreover, the climate would be becoming somewhat unfavourable to the mountain and arctic species. There would therefore be no possibility, on the part of the latter, of turning back, and they would be driven either up the hills or to the north. Some of the *Crambus furcatellus*, therefore, we may imagine, were pressed up the Welsh hills, where the then still existing local glaciers would afford a climate suitable to them and adverse to their pursuers; others would be driven northwards, and find resting-places on the hills of the north-west of England and of Scotland, on which, doubtless, the species had once a wide range. Another view of the possible history of the arrival and spread of *Crambus furcatellus* may be taken—namely, that it managed to get across the sea to the south of England, and thence gradually spread northwards, taking Wales on its way.

Perhaps the next—if not as early an—arrival would be *Erebia Epiphron*, which we know is a grass-feeder. It does not occur in Wales, and perhaps never did, but entering England on the east has left colonies on the north English and Scottish hills. From Scotland it probably reached Ireland by the north of the great lake, which, as we have seen, occupied a large part of the Irish Sea, and which to such a weak flier as the *Erebia* would prove an obstacle to direct migration from England. Ireland, or at least the north and west of it, not having been in all probability fully colonised, would not present such obstacles to a southward march as would the more accessible sister country.

The insects most likely to be next in succession would be *Zelleria saxifragæ* and *Swammerdamia nanivora*.

The *Zelleria* feeds on various species of saxifrages, especially (in this country) on *Saxifraga aizoides*, but also on *S. oppositi-*

folia, and (in Switzerland) on *S. aizoön*. *Saxifraga aizoides* must have been a very widely-spread species in this country before it was crowded out by other plants, as, though it is chiefly confined to the mountains, it yet occurs in various low-lying localities to which it cannot have been brought by water from the hills. It also descends the rivers. A curious fact in its distribution is that, though common in Ireland, it has not been found in Wales. We may therefore suppose that it entered England on the east, and reached Ireland by way of Scotland. The *Zelleria* doubtless followed it, and, though as yet only noticed (in Britain) in a few localities in Scotland, is probably of much wider distribution than is imagined. I am led to suppose this by finding it in every suitable locality in which I have looked for it. Against this theory of its line of migration must be set the fact that *Saxifraga oppositifolia*, on which it also feeds, does occur in Wales. The plant *par excellence* to which it is attached is, however, *S. aizoides*.

The *Swammerdamia* had better be considered with the remaining insects. The latter, so far as their food-plants are known, feed on ericaceous plants—species which mostly affect a peaty soil, and which, perhaps, would scarcely cross to Britain, or at least spread widely there, till a suitable soil had been prepared for them.[1] Some of these plants will scarcely flourish except when there is a large amount of peat in the soil; but others, though mostly found on such soils, will grow well enough where there is no peat, and probably only occupy the peat because they find on it less of a struggle for existence—or, in other words, they can flourish on it, while other plants which, on a different soil would overgrow them, cannot. Be this as it may, this kind of soil results from the previous growth and decay of other plants, more especially such as love a damp situation or climate. Now we have good reasons for believing that after the close of the glacial epoch great alternations of wet and dry periods of climate took place. During the wet periods moisture-loving and marsh-plants would find conditions most favourable for their existence and spread, and consequent on their growth and decay peat and peaty soil would be formed. During the dry periods the reverse would happen, and the vegetation would consist of plants that prefer a

[1] I need scarcely remind my readers that wherever the ice-sheet had spread (and that was over the greater part of the country), the peaty soil which had accumulated in the pre-glacial or inter-glacial periods was, except in a few sheltered places, swept away by the grinding ice, and replaced or overlaid by the boulder-clay or till.

drier soil and climate—as, for example, many of our forest trees. That such alternations of climate took place we may learn from a study of deep sections of peat, where—with greater or less distinctness—the succession of wet periods, characterised by marsh plants, and of dry periods, characterised by forest trees, may be seen. Of course there was no sudden change from one period to another, but a gradual one from wet to dry, and *vice versa*. In those intermediate periods—neither very wet nor very dry—the plants that affected an intermediate condition would grow and spread, and the insects that feed on such plants would be sure to follow them.

Betula nana is one of the plants that like a moderately damp situation, such as is afforded by a spongy sphagnum-covered morass. The ericaceous plants (*Arctostaphylos*, *Vaccinium*, and *Calluna*) prefer drier ground, and though lovers of a peat soil are not dependent on it. They are, however, species that probably spread during the wet or intermediate periods. Except the *Arctostaphylos*, these plants are of wide distribution in this country, and hence the range of the insects is not restricted by that of the food-plants, even supposing that they were (or are) always confined to these plants, which there are grounds for believing not to be entirely the case.

Judging, however, from the present distribution in Britain of these insects (namely, their being confined to the northern half of Scotland), it seems quite possible that they were never inhabitants of England, but that spreading along the shore (extending, as has been pointed out, between the Continent and Scotland) of the North Sea they reached Scotland, and ascended to the mountains when these were sufficiently free of snow and ice, and when the low grounds could be no longer held. In this manner the Zetlands were reached by *Anarta melanopa*. Of course, on the other hand, it is equally possible that they did inhabit England, but did not succeed in maintaining their position.

The reason already suggested for the non-persistence of those alpine species in lowland localities, once necessarily occupied by them, and which reason may be briefly defined by the now classical expression, "survival of the fittest," would be brought about by various agencies, more or less obscure or imperceptible to us in their action, but not the less efficacious. None of the Lepidoptera in question seem to be less protected from the attacks of enemies (such as birds, carnivorous or parasitic insects, &c.) than the majority of other species, though such enemies are

decidedly less numerous in the high-lying localities inhabited by these insects. Their want of success in holding their own must therefore, in part at least, be due to other causes. It is probable that their vital constitutions are different from that of the species which have supplanted them, and some of which even contest with them their present habitats. In one respect their constitutions must be hardy enough to sustain life at all in alpine and arctic districts; and it is probably not entirely (though in some degree) the greater summer heat of low-lying localities that makes such unsuitable for them, but the less severe and shorter-lasting cold of winter. In the high altitudes or high latitudes which they inhabit there is a continuous frost all through the winter, and none of the alternate frosts and thaws, accompanied by damp, that forms the winter of the northern lowlands, and which we know is so much more destructive to insect-life than a continuous low temperature. They are, moreover, protected at this season by a thick covering of dry snow.

Climate, therefore, is likely to have been an important factor in the distribution of these species. It must be remembered, however, that *Anarta melanopa* inhabits low elevations in the Zetlands, whose climate is pre-eminently an "insular" one, and where the mean winter temperature is comparatively high and the summer temperature low. In Zetland, however, the competition between species is much less than that in Britain. With this exception of *Anarta melanopa*, most of the species appear to prefer a "continental" climate to an "insular" one; and this is possibly the reason why more of them do not occur in Ireland, where the influence of the Atlantic Ocean is greatest. While the connection of Britain with continental Europe across the floor of the German Ocean lasted, our climate was much more continental[1] than at present, when we have what is termed an "insular" climate, reaching its maximum on our western shores. It is to this insular climate that, I believe, the poorness of our fauna, compared with parts of continental Europe situated much further north of us, is partly due. For example, compare the Butterflies of Finland with those of Scotland. Finland has 89 species, Scotland only about 36 (Britain altogether only 64); and though Finland is situated to the north of any part of Britain, yet many of its species are those which are—in Britain

[1] That is to say, the summer heat was greater and the winter cold more severe and continuous,—both due to a less humid atmosphere, caused by the less near proximity of the sea.

—only found in those parts which have a more continental (or a less insular) climate, and are insects which do not reach Scotland or the north of England.[1]

That many species, now confined to a few localities in the south of England, had at one time a much wider range in Britain, is extremely probable; and it is equally probable that perhaps many other European species once inhabited this country, but failed to survive the change to a more insular climate. On the other hand, we possibly owe to our insular climate (and situation) many of the curious varieties of Lepidoptera that are found only in Britain.

One more point in connection with our mountain Lepidoptera merits attention, and that is, their comparative age as species, as well as the probable place where they originated.

There seems great reason to believe that the countries of the north temperate hemisphere, and even the north circumpolar lands, were the regions where many of the species of plants and animals at present in existence were evolved, and that the last and other glacial periods were very instrumental in dispersing these species over the earth's surface. We have proofs that many species now only existing in a living state in the warmer temperate regions once flourished near the North Pole, in company with other species now extinct, but which seem to have been the more immediate ancestors of certain living species. Probably very many other species (including many living now) once flourished along with these, but from their more fragile nature have left no remains.

To go no further back than the last glacial period, it is easy to understand how the change of climate of that epoch acted as a dispersing agent, driving the plants and animals before it step by step, and, doubtless, utterly destroying many species that failed to make good their escape to more genial climes. We must not think of this change of climate, and its accompanying phenomena of ice-sheets and heavy snows, as having occurred suddenly. It would happen gradually—probably very gradually—and possibly, had any naturalists been then existent to study the change induced in the fauna and flora, it would have required the observations of many generations before such changes became established—or, rather, admitted—facts.

[1] Amongst other species may be noticed *Papilio Machaon*, *Thecla betulæ* and *pruni*, *Melitæa cinxia*, *Argynnis Latonia*, &c. &c.

All the same, slowly but surely the changes were taking place. The species at one time abundant in the suppositious locality under observation would become rarer and rarer, till they had ceased to live in that locality at all; but their places would be supplied by other—more northern or mountain—species, which, mingling with the others, would gradually supplant them, but would in their turn be supplanted by still more alpine or arctic species. And what would happen in one locality would happen in all to which the phenomena of the glacial period extended—the more northerly or more alpine suffering first, the southerly and low grounds at a later period.

Moreover, there were times in which the change in the climate (and consequent alteration in the fauna and flora) would not only not alter for the worse, but, to a greater or less extent, for the better. And in these periods ("inter-glacial periods") the species driven out would return, though perhaps not all of them, and perhaps others would come which had not previously inhabited the locality, all however to be again driven out or supplanted when that inter-glacial period came to an end.

At last, however, the great glacial period would reach its maximum intensity, and the climate would gradually (but, as before, interruptedly) become better, and would be accompanied by similar phenomena of a changing fauna and flora.

In short, there were during all this long period—extending over many thousand years—great but gradual oscillations of climate, and consequent shiftings in the component parts of the fauna and flora, which could not fail to make immense alterations in the species.

From all this we may gather that it is probable that the species whose distribution at the present day is widest are the more ancient, and that those of a less wide range have possibly had a later evolution.

Of the species discussed in this paper, *Anarta cordigera* is the most widely distributed, and *A. melanopa* ranges nearly as far. These are the only species (amongst our mountain Lepidoptera) which occur in America, and therefore probably existed as arctic species before the glacial period. In America they have been reported from Labrador only, so that apparently they are not circumpolar.

European (or palæarctic) species had two routes by which they might have gone to America (the nearctic region). One was by a broad land-connection, reaching south of Greenland, that united

North Europe and North America, which geologists suppose to have once existed; the other is across Behring's Straits or by the Aleutian islands. As, however, these species of *Anarta* do not occur in the eastern palæarctic region (*i.e.*, Siberia, &c.) nor on the western side of North America, the route seems more likely to have been by Greenland or polar lands north of it. It is quite possible that the species originated in these polar lands, and when driven southwards colonies were sent both to Europe and America.

Of the other species under discussion, the macro-lepidoptera (the *Erebia*, *Zygæna*, *Pachnobia*, and *Psodos*), all range pretty widely, but, with the exception of *Psodos* (a doubtful inhabitant of Siberia), are confined to Europe. I expect that some of these species may, like many of the arctic-alpine plants, inhabit the Himalaya, or even some of the African and other mountains, but I have not been able to find any evidence of this. These species may be as ancient as the *Anartæ*, or they may not. Their absence from America is slightly suggestive of the latter.

Some of the micro-lepidoptera in question are also likely to be of ancient origin; but some of them may be, if they are confined to Britain—a fact possible, but not probable—of comparatively recent evolution.

In conclusion, the facts and suggestions put forward in this paper may be thus summed up :—

1. The British isles being at one time subject to extreme arctic conditions, had no fauna or flora.

2. At the close of the last glacial period they were peopled by plants and animals from continental Europe.

3. Most of these plants and animals reached Britain across the dry or nearly dry bed of the German Ocean.

4. Plants necessarily arrived before animals; and of the former, certain classes of cryptogamic plants, and the maritime and wind-fertilised species of the higher plants, were the first comers.

5. The arctic and arctic-alpine plants and animals, being those that followed closest on the retreating ice, were amongst the earliest arrivals, and had a wide range through the country.

6. From their present distribution in Britain it is probable that all the species (in question) did not enter Britain at the parts nearest continental Europe, but that they reached it at various points on the present east coast.

7. The distribution of the species (treated of in this paper) is not co-extensive with that of their food-plants.

8. Climate has been a chief factor in producing the present distribution.

9. Ireland derived some of its insects from Scotland.

10. At least some of the British mountain lepidoptera existed as species previous to the last glacial period.

The answers, therefore, to the questions asked at the beginning of this paper are briefly these :—

Whence did our mountain Lepidoptera come?

From continental Europe south of the latitude of Britain, or at least south of all except the south of England.

At what stage (or time) relatively to the majority of the Lepidoptera?

Amongst the very first, or at least before most of the others.

By what route were they brought?

By a continuous or nearly continuous land-passage across the bed of the German Ocean.

What causes have produced the present distribution?

Climatic conditions and other agencies which, separately or conjointly, result in causing the survival of the fittest.

Notes on Lepidoptera.—Three months ago, when I sent to you a few notes on Lepidoptera, lovers of that study had a gloomy looking forward to. The general belief was, if there could be got a few to replace some of the decayed ones it would be all; but as the old saying is, "There is nothing surer than disappointment:" and such has been the case with moth and butterfly collectors this summer. At least so far my experience has been. I have taken this summer 162 species within two miles round about this place; and Berwickshire, as far as I know of, contributes amongst the *Diurni*, *Nocturni*, *Geometræ*, and *Noctuæ*, 314 species to the list of Lepidoptera.

Moths and butterflies have been more numerous this summer than for the few past years, and instead of the extreme severity of the last winter destroying insect-life it has saved it. In species whose larvæ bury themselves in the earth in order that their pupæ may be protected from birds and atmospheric influences, let the pupa be ever so hard frozen, as long as it is covered, it will take no harm. I have tried a few, and I find that pupæ which are buried in the earth, if exposed in fresh weather to the air for a while, some may become perfect insects; but I never could succeed in rearing insects from pupæ which were removed from the earth in frosty weather, although they were replaced in the earth a short time afterwards. Pupæ whose nature is to hang on grass, palings, &c., can stand any amount of frost. Last autumn I put a few pupæ of the Fox Moth (*Bombyx rubi*), the Emperor (*Saturnia carpini*), and the Light Knot Grass (*Acronycta menyanthidis*), on the outside of the window, exposed to all the frost and rain: I took them into cover in the beginning of May, and without exception every one became a beautiful moth. Can it not be the case with the snow protecting them from the frost, the