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THE GENESIS

OF THE

TERTIARY SPECIES OF PLANORBIS AT STEINHEIM.

BY ALPHEUS HYATT.

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The Genesis of the Tertiary Species of Planorbis at Steinheim.

By Alpheus Hyatt.

The following work arose from the interest excited in my mind by the brief account of the Steinheim fossils, given by Dr. Hilgendorf, in the "Monatsbericht d. K. Preuss. Akademie d. Wissensch. zu Berlin," for July, 1866. My attention was attracted to this paper soon after its publication, because, if true, it was the only reliable statement of the theory of evolution, which could be considered a demonstration of the practical applicability of that doctrine to the life history of any considerable series of animal forms; and as by previous studies I had tried to prepare for the appreciation of such problems, it was with a feeling of most intense pleasure that, in 1872, I found myself in the neighborhood of this famous locality.

Through the introduction of Prof. Fraas, of Stuttgart, I was enabled to make my investigations and pursue my studies with every facility. During the first visit, as the time was limited, and it was somewhat late in the autumn, the work was confined almost wholly to the survey of the pits. A hole was dug in the Old Pit, down to the dark brown clay which forms the base of these deposits. Specimens were collected in abundance, by the bag-full, without regard to what they might be, and secured on the spot in paper bags and boxes containing labels, indicating, by a prearranged system of notation, the precise level from which they came. Not anticipating any new or original results from the work, I was simply careful to obtain unmixed samples from every stratum and the intermediate partings of limestone. After the return to Cannstadt, where I was then residing, a large part of my leisure during the winter was spent in sifting the material, picking out the shells, studying and drawing with a camera-lucida the different varieties, making one hundred and eighteen drawings in all.

The process of examination was conducted as follows: The bags were opened one at a time, according to their formations. The contents of each bag was sifted by a series of three graded and nested sieves, made for the purpose, over a large plate or basin. These allowed only the fine dust to escape into the dish. All of the four lots, thus divided according to their sizes, were examined at each operation, and the shells found secured in pill-boxes, marked with the same label as the bag; after each bag was finished a general examination was made, and the species of each separate bag compared with others, even if they came from a spot only a foot or a few inches removed.

In this way the greatest attainable security from any accidental mingling was obtained, and the contents of separate bags, even from the same formation, were never mixed until they had been thoroughly studied. The small size of the third sieve of the sifter also secured a very thorough examination of the sand, so that I think almost every one of the thousands of shells brought home, except some of those of very small size, such as young, etc., really passed once if not oftener, under observation.

In my opinion, this method, in such cases as that at Steinheim, is far superior to the ordinary one of examining formations and collecting therefrom such specimens as strike the eye. Such collecting is largely governed by the preconceived ideas of the collector and he cannot, however honest, avoid seeing by preference, and involuntarily selecting the things which are forecast in his own mind. There is also great danger that he will be content with any evidence which fills out his ideal, and stop short of the discovery of the exceptions, which, though few in number, are essential to the verification of his logical conceptions.

Illustrious examples in all fields of science are involuntary witnesses to the truth of these remarks, and show also, that even repeated observation and mechanical means cannot always correct the personal equation or eliminate the errors arising from this source. My effort has been to use such clumsy mechanical means as the present state of zoölogical science permits, and of the success of these, others must be the judges; in this case the writer can only appear appropriately as an advocate.

My studies led me to think either that Dr. Hilgendorf had made the most serious mistakes with respect to the stratigraphical position of the forms, or that I had collected them without sufficient care. Determined to leave as little risk of error as possible, in this respect, I again visited Steinheim early in the following spring, as soon as the snow began to leave the ground. Though this time, as before, almost continually suffering from adverse weather, I succeeded in collecting largely. The old hole was reopened in the Old Pit, widened, and specimens again collected. Another hole to the northward, but within the limits of the pit, was sunk to the Jura clay. A hole was also dug in the Little Pit, but not so successfully, owing to the rainy weather, which rendered the work of undermining the sand dangerous. In the East Pit, although a more persistent attempt was made in two places, the abundance of water rendered it too difficult to go beyond the limits shown in the section. The Cloister Pit was dry, but here I did not deem it necessary to go deeper than was essential for the development of the upper series of formations. The most exact measurements were made upon the face of every stratum, and quite a number of sketches showing the position and character of the limestone partings and sandbeds. In fact, every possible precaution was taken to insure accuracy, so far as the work went.[1] The plotting of the sections consisted of the reduction of the measurements to one one-hundredth part of those actually taken, and are approximately correct as shown in the table of the Geological Sections.

As remarks have been published which show that some importance is attached to the length of time actually spent by me at Steinheim, it becomes necessary to state, that it was about five weeks in all: once two weeks, and at another visit three weeks. Where such earnest controversy exists, as that to which the Steinheim shells have given rise,

[1] No collections were made from the limestone partings during the second visit, except where these contained additional forms. Such a collection would have been too bulky for transportation. and I found by careful examination of each limestone layer, that no additional information was obtainable, except in isolated instances.

such points as these are seized upon by one or the other of the contending parties, and magnified iuto importance. Short as my stay was, it was quite sufficient for the gathering of bags of sand, each containing hundreds of specimens from every layer which I saw, so that the positive facts stated were proved, some of them by repeated instances. This account is given principally in order to enable others to judge as nearly as possible how much weight theoretical opinions may have had in governing my results. For the same reason also, I have preferred photographs to drawings. The distinguished draughtsman, the late Mr. Sonrel, to whom Prof. Agassiz and others owed so many of their most beautiful plates, has assisted me by his advice, and has photographed the first three plates in a manner which will be appreciated by all who have attempted to deal with such difficult subjects. The remaining plates were made by Mr. Black of Boston, who took the greatest pains to produce good results. The shells were mounted upon pieces of slate with cement, and then enlarged by the camera. This, though not large enough in the first three plates to show all the characteristics of many of the smaller forms, is still sufficient for the immediate purposes of this memoir. The remaining plates are on a larger scale, and give the separate series and their theoretical relations more in detail. These contain true *Pl. levis*, from Undorf, sent me by Prof. Dr. Sandberger, and the closeness of the resemblances between these and the pit forms is thus shown. Those who cannot credit the evolutionary hypothesis, are advised to try to separate these out from the rest of the forms on plates 4–7, without previously consulting the names of the species, and then to compare results with the descriptions of the plates.

Useless repetition has been avoided, and the nine hundred and fifty-three specimens photographed, and twenty-eight drawn with the camera-lucida, a total of nine hundred and eighty-one, do not by any means exhibit all the variations. Each one was selected after having been handled, examined, and classed with its congeners many times. The principal varieties were all previously drawn by myself, with a camera especially constructed for the purpose, before the present plan of figuring by the wholesale was thought of, but none of these are reproduced in the plates.

In spite of previous experience, I had hoped to find a perfect demonstration in the concrete of the theory of the transmutation of species. That I was rightly and legitimately disappointed in this, I have endeavored to point out in the chapter on the geology of Steinheim. The Pit deposits certainly do exhibit the fullest, and perhaps one of the most complete series of genetically connected forms, which it is perhaps possible to obtain, but there is here, as well as in the adjacent limestones and in those on the rim of the basin, a deficiency of data, which no explorations can make absolutely perfect. It is my wish to be here fully understood, not as meaning that there is any deficiency of observable facts. On the contrary, the varieties are so abundant, that it becomes difficult for the impartial investigator to avoid becoming hopelessly confused, but notwithstanding this excess of riches, the record is and must ever remain exceedingly incomplete. An infinitude of details are necessarily absent, the animals themselves must ever remain unknown, and we are forced here as elsewhere to construct our genetic tables upon theoretical grounds, which must necessarily change from day to day as knowledge progresses.

The adoption of the name Planorbis, was made after due consideration of the different views advanced, but especially after a close study of the affinities pointed out by Prof'. Sandberger, in his renowned work on the "Land-und Süswasser-Conchylien der Vorwelt." The name of Valvata does not seem to apply, for two reasons; the entire absence of the least remnant of an operculum, although I searched for this part with a microscope in the loose sands as well as in the limestones; and the peculiar aspect of the striae of growth which are curved, even in the unwound forms, instead of being annular, as in the Valvata forms.

The affinity with Carinifex, which Prof. Sandberger insists upon for most of the series, does not appear to me so close as that with many species of Planorbis. His authority with regard to a matter of this sort would naturally and rightfully have more weight than mine, but he describes *Pl. Steinheimensis*, and some other forms, which I am entirely unable to separate from the carinated varieties or species, as members of the genus Planorbis, whereas the remainder appear under the generic name of Carinifex. The young of *Carinifex Campbelli*, the only form I have been able to obtain, either from the Smithsonian Institution, the Museum of Comparative Zoölogy, or any of my correspondents, is entirely distinct in form from most of the young forms of *Pl. discoideus* and *Pl. trochiformis*, though to others it bears a very close resemblance. I am not at all surprised that Prof. Sandberger should join the two in view of this similarity, but on account of the evident connection of *Pl. trochiformis* with *Pl. levis*, I cannot support him in this conclusion. In my opinion, it must be regarded as a similarity produced in the shell of distinct animals in widely separated localities.

The nomenclature adopted for the various forms, is similar to that of Dr. Hilgendorf's, in so far as the main forms are represented by distinct names, generally the same as those proposed by him, with the omission of the name "multiformis," and the intermediate forms are designated by two names placed one above the other, thus $\genfrac{}{}{0pt}{}{\text{tenuis}}{\text{Steinheimensis}}$. In this way the derivation of these forms and their intermediate character is conveniently expressed in one and the same term. I have used the binomial nomenclature instead of the trinomial, because the latter is clumsy; and I can see no reason for the prevalent practice of designating under the same specific name all forms which may be joined by intermediate forms or by the study of their development. It is evident, that all of the principal forms of the *Pl. trochiformis* series differ from each other quite as much as the universally recognized and distinct species of the main body of the genus. If they had been found in different localities, there would be no hesitation in describing them as species. A binomial nomenclature, therefore expresses exactly the sense which it is considered desirable to convey, namely, that the forms dealt with in this memoir are, as compared with others of their own group, of specific value, and ought, from a taxonomic point of view, to be so considered.

In conclusion, it seems essential to add, that, in spite of the great care taken at the time the explorations were made to render the evidence as perfect as possible, many things were necessarily neglected. Thus a fuller exploration of the Valley Rocks, especially with regard to the relations of the Cloister Ridge Rocks, and the Pit Deposits can only be attained by these or similar means. Doubtless Dr. Hilgendorf's forthcoming memoir will supply many of these deficiencies. Nevertheless, the existence of a Lower

Steinheim Period, underlying the sandy strata of the pits, can be approximately proved, and this renders the task of accounting for the origin of the forms in the pits less difficult. It removes the question of the origin from an ancestral form with equal umbilici, a single variety of a species, as figured by Hilgendorf, to that of evolution from several distinct varieties of one species with unequal umbilici, *Pl. levis* Klein, which is, after all, only a form of *Pl. oxystomus* ; and also gives a greater allowance of time for the production of the forms.

In order to enable the reader to contrast the theoretical views of Dr. Hilgendorf and those given in the first chapter of this essay, and on Plate 9, the following table is appended, copied from Dr. Hilgendorf's paper, above quoted.

0					supremus		
9			crescens		revertens		
8		costatus	crescens		oxystomus		
	denudatus						
7		costatus	minutus		trochiformis	elegans	pseudotenuis
6		costatus	minutus		trochiformis		pseudotenuis
5		costatus	minutus	triquetrus	discoideus	rotundatus	pseudotenuis
4			minutus		discoideus		Kraussii
3			minutus		sulcatus		Kraussii
2			minutus		tenuis		Steinheimen
1			parvus		Steinheimensis		
			æquiumbilicatus				

That Dr. Hilgendorf found these forms in these relations can hardly be doubted; his reputation and the thoroughness of his explorations I do not call in question at all, nor do I in any sense doubt that he and others found the *Pl. Steinheimensis* at lower levels than where I found them in my explorations. Our differences rest wholly upon a series of facts which have evidently been treated by two distinct methods of research, and have led to different results. But it will be observed that these differences are not irreconcilable. The fact being that I require more evidence than is found in the Pit Deposits to prove the genesis of the *Planorbis trochiformis*, out of *Pl.* *Steinheimensis* / *levis*, as far as the succession of the forms in time is concerned, and he has accumulated an immense mass of facts, going to show that the Pit Deposits are all sufficient, and contain the whole history of the series. This question, and others connected with it, are discussed in the following pages, and it only remains for me to express my earnest thanks to Dr. Hilgendorf for a valuable series of his type specimens and for his courteous frankness in sending me accounts of his work while in progress, and to regret that he has not yet published his last researches. Dr. Sandberger has also treated me with great kindness, and I have to thank him for material assistance, especially for specimens of *Pl. levis*, without which I could not have continued my work. The owners of the Pits in Steinheim were uniformly kind and obliging, as were all the persons with whom I came in contact at that place, and the accomplishment of my explorations rendered easier and much facilitated by them.

I. General Relations of the Series.

The genealogical series illustrated on Plate 9, are constructed in accordance with facts discussed in the chapter on the "Descriptions of the series," but they also possess certain peculiar characteristics of their own, which require explanation.

A glance will indicate what the main assumption is, that all of the forms found in the Pit Deposits are the direct descendants of four varieties of a species, which is taxonomically the normal form to which all the primordial forms of the four series can be referred. In other words this form, *Pl. levis*, stands at the focus of all the affinities of the four series, and is related to them in such a manner that we can only explain the arrangement of the facts by supposing that this is the ancestral form from which they sprang. The geological position of *Pl. levis* also justifies this conclusion with regard to all the series, since it is a common form in the adjoining Tertiary rocks, as is admitted by all authors.

These series, having been the result of no preconceived plan of arrangement as far as the author could judge, were considered to be approximately natural, and were assumed to be a reliable basis for working hypotheses, in spite of the fact, that no certain data with regard to succession in time were obtainable, except in the case of the supposed ancestral species. This assumption rests largely upon well known laws of heredity, such as these, that an animal found to repeat the stages of another animal of a closely allied species in the young, with the addition of new characteristics in the adult, may be considered to be either a lineal descendant of that species, or of some form common to both; that in such cases as these, whether the forms or species occur mixed on the same level, or on different levels, there is but one natural arrangement, which has been illustrated on Plate 9.

Such an arrangement in a diverging series can also, by varying the primal norm or starting point, be used to represent the relations of a brood of individuals, or a species, or a number of species; in fact it is precisely the same as Darwin's diagram of lines diverging from a point of origin; and after seventeen years of investigation I am entirely unable to propose any fundamental improvement in this mode of presenting natural affinities. It represents with the same accuracy the parallel succession of characteristics of the individuals, and also the parallel reproduction of similar forms in varieties, species and larger groups, having as approximately determined by their intermediate forms, embryology and structure a common origin. It represents also the relationship in time of groups upon different levels in geological history, and their parallelisms and differences. It represents these relations equally well for retrogressive, or progressive series according to the values we may assign to each line, and can be made to coincide with the true time ratio or relation in time of all the forms.

It seems, therefore, no improbable assumption that the four series, if they answer all the requirements, are natural series, and that the living forms they represent, once had the relations here approximately depicted, and that, though the relationship in time has not yet been cleared up, it is probable that these forms did originate from each other in the succession assigned to them in plate 9.[1] It will be understood by all intelligent readers, however, that this, like all other arrangements, is an intellectual generalization from the facts and only, as stated above, an approximation to the natural order in which the animal probably occurred, or was evolved. For example, the different series did not occur as they are placed upon the plate. If the geological succession had been confirmed as first laid down by Hilgendorf, then the true relations in time of the different forms would have been given. Thus instead of placing artificially the representative forms, nos. 10 and 5, on the same level as is here done with these and others, they would have probably been on different levels, representing corresponding differences in the time or formation in which they occurred. The representation or similarity of form, however, would have remained unchanged, and all the deductions here drawn from such comparisons.

I make no pretence of originating this method, nor can, so far as I know, any one else. It has grown with the science of Natural History, and nearly every naturalist uses it more or less, whether he recognizes the ultimate meaning of gradations in their serial arrangements, or ignores them.

Theoretically, then, the normal primordial form *Pl. levis* can be considered as having had four varieties before its migration into the Steinheim lake, and as having subsequently reproduced these, or their immediate descendants in this new field. These are as drawn on pl. 9, *Pl.* $^{minutus}_{levis}$, fig. 16, *Pl.* $^{parvus}_{levis}$, fig. 12, *Pl.* $^{oxystomus}_{levis}$, fig. 8, and *Pl.* $^{Steinheimensis}_{levis}$, fig. 1. These four principal series, shown on pl. 9, and numbered in sequence 1–7, 8–11, 12–15, 16–28, were developed from these four varieties after their migration into the Steinheim lake. While the original forms on the first line had the closest relationship with each other, their descendants gradually diverged, until finally no hybrids connected the different series with each other. This is a somewhat bold assertion to make with regard to such closely allied animals as these must have been, and it may possibly be forced to give way to more complete evidence than that at present possessed by the writer. It cannot, however, be refuted except by an absolutely perfect series of intermediate forms. Tested by the ordinary methods of comparison pursued, especially by paleontologists, every one of these forms are connected by hybrids, and the whole presents to the ordinary observer a chaos of similarities and differences. The hybridity must appear not only in the adults, but in the absolute identity of the young

[1] Since the above was written I have had the satisfaction of reading in a late work of Prof. Dr. Neumayer an unreserved confirmation of a precisely similar investigation with regard to the Arietes, a family of Ammonites occurring in the Lower Lias, which has been treated according to the same method. Prof. Neumayer followed the ordinary practical method of tracing the series by the graded resemblances of the adult forms, and connected the Arietes with the predicted ancestral species Fauna d. Untersten Lias. Abh. d. K. K. Geol. Reichsan'l. Bd. 7, hft. 5. Wien, 1875.

[2] This series is divided on the plate into three sub-series, 16-20, 18 to 21–24, 21 to 25–28. This last sub-series is also divided in the chapters on the " Descriptions of Series," into two sub-series, but here these are resolved into one, this plate having been finished before the two sub-series were distinguished. For all the general purposes of discussion in this chapter, they can however be treated as a united sub-series without confusion, since the differences are entirely those which arise from the greater or less prominence of the costae or ribs, as they are sometimes called.

forms, since it is frequently the case that the adults of two species are closely similar when the young are distinct.

The four main varieties, or species found in the Pit Deposits, figs. 2, 9, 13, 17, pl. 9, are not connected by hybrids, and are distinguished from each other by a practiced eye with less difficulty than would seem possible to any casual observer, however well trained in other fields.[1] The remaining representative forms, such as 4–19 and 5–10, are also not connected, and are quite distinct in the characteristics of their particular series. The First Series, as has been stated, is as represented on pl. 9, divided sufficiently for general consideration into three sub-series. The first sub-series leads up to *distortus*, fig. 28, a variety of *Pl. costatus*, fig. 26–27; the second to *denudatus*, a variety of *Pl. minutus*, fig. 21; the third to *turbinatus*, fig. 20, a variety of *Pl. triquetrus*, fig. 19. The Second Series is capped by *Pl. crescens*, fig. 15, the Third Series by *Pl. supremus*, var. *turritus*, fig. 11, and the Fourth Series by *Pl. trochiformis*. These four series and sub-series may be classified under three heads, according to the meaning of their ontological characteristics.

A, the purely progressive series, or those in which the special characteristics of the series are developed more and more decidedly, and new ones added in each successive species or form as in the Second, Third, and Fourth Series.

B, the purely retrogressive, or those in which the differences observed in the Pit forms, when compared with *Pl. levis*, are not maintained in the progressive sense, but in which disease interferes with progress, and leads to the production of distorted variations, as in the second sub-series 21–24.

C, the partly retrogressive and partly progressive series, in which the differences are increased by the addition of certain minor peculiarities, but the forms become nevertheless distorted by disease or decrease in size, as in the first and third sub-series.

The resemblances of the forms 1, 8, 12, 16, pl. 9, are of course due to their close affinity as varieties of *Pl. levis*, those of *Pl. Steinheimensis*, fig. 2, *Pl. oxystomus*, fig. 9, and *Pl. minutus*, fig. 18, belong, however, to a distinct species, and must be considered representative forms. They belong, in two cases, to 2 and 9, to progressive series, and 18 to the partly progressive and partly retrogressive third sub-series.

The representative forms, *Pl.* *tenuis* *Steinheimensis*, fig. 3, *Pl.* *crescens* *parvus*, fig. 13, *Pl. minutus*, fig. 21, and *Pl.* *costatus* *minutus*, fig. 25, have even closer resemblances in outline than the original four varieties of *Pl. levis*, and yet, on account of the absence of hybrids or intermediate forms, are unquestionably more easily distinguished from one another, than these four original varieties. The same observations apply to *Pl. tenuis*, fig. 4, and *Pl. triquetrus*, fig. 19; *Pl. discoideus*, fig. 5, and *Pl. supremus*, fig. 10; *Pl.* *trochiformis* *discoideus*, fig. 6, *Pl. supremus*, var. *turritus*, fig. 11, *Pl. triquetrus*, var. *turbinatus*, fig. 20.

[1] In justice to myself it ought to be remarked, that the method pursued in drawing the different figures on pl. 9, was as follows: Each series was picked out without reference to the formations, merely to show the zoological relations. After all were drawn with the camera-lucida, no transfers were permitted, therefore the shells are all reversed. This defect, however, was considered preferrable to the risk of errors sure to occur in any attempt at transfer by tracings, or otherwise. After all the figures of each series had been made, they were arranged upon a dark brown tablet. I had but a slight suspicion even of the remarkable nature of the ontological relations here described, until the final arrangement of the figures on the plate had to be considered and carefully studied, in order to show as many of the natural relations of the species and series, as possible.

Figs. 5–10 and 6–11–20, at first sight do not seem to be very close; but if we remember that *Pl. discoideus*, fig. 5, and *Pl.* $\frac{trochiformis}{discoideus}$, fig. 6, often have no carinations on the lower side, and if we compare these and such forms as are figured on pl. 2, line c, fig. 1–6, with the sulcated forms of *Pl. supremus*, the resemblances will be seen to be quite as close as in other representative forms. Here also there can be no doubt of the absence of hybrids.

Pl. trochiformis, fig. 7, stands alone in spite of its general resemblance to *denudatus*, fig. 24, because the similarities to the latter are not exhibited in the form and characteristics of the whorl itself, but are simply such as any spiral shell might have to any other allied form, with a similar spiral mode of growth.

This tendency reaches a climax in both the second sub-series and the Fourth Series, and thus, though *Pl. trochiformis* and *denudatus* (trochiform variety, pl. 9, fig. 24), have very distinct whorls, the general outline of the whole shell in each is similar. This is especially the case when we compare an old or distorted *Pl. trochiformis*, pl. 2, line r, fig. 10, in which the last whorl is partly unwound, with *denudatus*, in which the young whorls are also closely wound, and the last whorls only open. This peculiarity has a distinct meaning from that of the representative characteristics described above, and will be discussed farther on.

At present it will be better to concentrate attention upon the representative characteristics in the progressive series, (Second, Third, and Fourth Series). As has been said above, we can readily account for the production of representative forms on the lower lines, because these are really one and all but slightly different from the four original varieties of *Pl. levis*, and resemble each other necessarily on account of their close affinity, though not joined by hybrids. But how can we account for the fact that still more divergent forms, which follow and which have less affinity with *Pl. levis*, should resemble each other, species for species, with such remarkable closeness? New modifications are introduced in these species, which are not present in the original species. These new characteristics consist of alterations in the forms of the whorls, and the advent of sulcations, accompanied by a more decidedly asymetrical mode of growth. These modifications could not have been inherited from *Pl. levis*, since they did not exist in that species, nor in the lower representative forms, pl. 9, figs. 2–9–18.

These considerations enable us to separate the representation in the parallel series into two kinds, that which occurs by the inheritance of a similar form and characteristics from the parent form, *Pl. levis*, and that which results from the introduction of new characteristics in each series, which are similar to those produced in corresponding forms in other series, and which could not have resulted from intercrossing of the different species in the separate series.

Two of the progressive series, the Second and Third, present us no forms strictly parallel or representative to *Pl. tenuis*, fig. 40. This can be readily explained by the fact that these series retain with great pertinacity the characteristics of the varieties of *Pl. levis*, from which they sprang. The Second Series remains smooth and devoid of sulcations, though the outer side of the whorl becomes angulated in *Pl. crescens*. The Third Series retains the gibbous form of the under side of the whorl, and does not flatten the whorls at all, as in *Pl. tenuis*. Nevertheless, the general tendency to increase the asymmetry of the spiral, and to introduce decisive sulcations and carinations, finally asserts itself, and eventually produces representation. Thus, *Pl. supremus* becomes very similar to some of the varieties of *Pl. discoideus*, and *Pl.* $^{\mathit{trochiformis}}_{\mathit{discoideus}}$, particularly to those forms which either retain or revert to the smooth character of the under side first observed in *Pl. levis*. This Third Series also fails in producing any modification comparable with *Pl. trochiformis*, fig. 7, for the same reason, because of the preponderance of its inherited peculiarities. Thus, although the last whorl is very asymmetrical, and quite similar in shape to *trochiformis*, the young internal whorls are peculiar and always have an upper umbilicus, and are therefore enveloped by, rather than elevated above, the outer whorls. This condition is frequently excessive in *Pl. levis*, and is the natural result of the discoidal mode of growth during the early stages of the shell.[1]

These facts, when viewed as a whole, show that the progressive series are all more or less parallel, and may be said in general terms to have the following succession of form, First, a universal tendency to increase the spiral; equivalent to the deepening of the lower at the expense of the upper umbilicus, thus eventually producing more or less trochiform shells. Second, the forms are modified in the following succession in each of these series, starting from (1) the smooth forms, there occurs (2) a gradual increase in the flattening of the sides of the whorl, both above and below, accompanied by (3) the introduction of longitudinal sulcations and (4) carinations.

There is, then, in spite of the diversity maintained by the differences, which have arisen in the original progenitors, and which continue to be inherited throughout all the members of each genetic series, certain uniform tendencies which have led to the genesis of certain similarities in the form and even in the minor characteristics of the species in different series. Farther than this, it may also be said that these uniform tendencies, as expressed in the spirality of the growth and the introduction of new characterstics, have a certain uniform succession.

The phenomena, therefore, indicate the action of some general cause which controls the tendency to variation first observed in the varieties of *Pl. levis*, and brings about a certain uniformity in the production of forms and representative characteristics in each progressive series.

The First Series and its sub-series are also subject to the control of the same law so far as the tendency to increased spirality is concerned, but in other respects they deserve special consideration. The similarities of the lower representative forms, figs. 25, 21, 18, are evidently accounted for in somewhat the same way as those of the progressive, viz.: they are close to the point of origin. Unlike these, however, they are so nearly related, that the hybrids or intermediate forms are numerous. It will be observed that they possess the flat form of whorl also found in the Second Series. We are on this account able to compare figs. 25, 21, with 13, and *Pl. costatus*, fig. 26, with *Pl. crescens*, fig. 14. The representation of *Pl. major*, fig. 27, and *Pl.* $^{\mathit{denudatus}}_{\mathit{minutus}}$, fig. 22, is also evidently due to the close affinity of the two, and the tendency of the whorls to become uncoiled and to degenerate in outline generally, as may be seen by observing the apertures of the shells. Fig. 28, *Pl. costatus*

[1] There are, however, forms much more like *trochiformis* than fig. 11, see *Pl. oxystomus*, var. *rotundatiformis*, pl. 3, line 1, fig. 4–11, but of these no full grown ones seemed any closer than the one figured.

var. *distortus*, and *Pl.* $^{denudatus}_{minutus}$, fig. 23, can be explained in the same way. Var. *denudatus*, fig. 24, crowns one sub-series standing alone, as did also the remarkable *Pl. trochiformis*, the latter as the extreme of the progressive series, and the former as the extreme of the retrogressive series.

These sub-series are not all purely retrogressive. The second sub-series is almost wholly so, because it does not add a single new character to those observed in *Pl.* $^{minutus}_{levis}$, except the tendency to form a spiral. It goes steadily without a break, from the closest coiled, smooth, discoidal form of the latter, to the extreme spiral, trochiform, and partly uncoiled *denudatus*, and remains throughout diminutive in size, smooth and with a cylindrical and extremely embryonic form of the whorl. The first sub-series, however, while it agrees entirely with the second in the size and form of the whorl and shell, and the tendency to increased spirality, nevertheless adds a new characteristic, the enlarged transverse striations or ribs, and increases in size in some species, as in figs. 26 and 27.

Thus only the second sub-series is almost entirely retrogressive, and yet both the first and second have diminutive shells, and the first has also diseased forms, which present a tendency to uncoil the shell. This last characteristic is only observable in isolated instances in the species of the purely progressive series. Thus it occurs as figured on pl. 8, line a, fig. 1, to an incomplete degree in the extreme old age of *Pl. Steinheimensis*; and for a similar reason in a very large *Pl. tenuis*, pl. 1, line k, fig. 11; in *Pl. discoideus*, in different degrees, pl. 1, line g, fig. 10; line i, fig. 6; as a pathological condition of the individual either due to wounds, disease or premature old age; in *Pl. oxystomus* to a most extraordinary degree as figured by Sandberger, and to a less degree in figs. 7, 8, 9, line p, pl. 3. These instances, however, are very instructive, since in fig. 8, the scars of severe wounds are apparent on the shells, whereas figs. 7 and 10 exhibit no cicatrices, and are evidently the result of some weakness caused by disease in the animal; in *Pl. trochiformis*, pl. 2, line r, fig. 10, and other specimens as previously described, it occurs as the result probably of some disease. Pl. 8 is especially devoted to these senile and diseased specimens, which will be described more fully further on.

The uncoiling of the whorls must therefore be looked upon as a sign of weakness in the animal, and as the result of pathological conditions, whether these be normal as in the final retrograde transformations of advanced senility and disease of any kind affecting the adults and young; or traumatic and abnormal as in the cases cited where wounds and other accidents may have caused disease in the animal, followed by a weak condition in which the usual increase of the shell by growth could not be maintained. Therefore there is the strongest reason for calling the second sub-series a purely retrogressive series, and the first partly retrogressive, since not only do they show retrogression by the size of the species, and their failure to produce comparable series of new and varied forms with newly introduced characteristics, but they show common variations, which can be compared with the pathological variations and metamorphoses of the shells of individuals of the progressive series. It will be observed by all who read this memoir attentively, and study the plates especially, that these uncoiled forms do not occur, except in the cylindrical whorled forms which are transitional from *Pl. minutus* to *denudatus* and *distortus*, and this cylindrical characteristic is decisively retrogressive. It can occur only in those individuals which do not inherit the more flattened and more involute whorls of the full grown *Pl.* ${}^{minutus}_{levis}$, but retain throughout life with very slight changes, the cylindrical form of the very youngest stages of that shell. Like the uncoiling, it indicates the weakness of the animals, which fail in the power of growth and cannot continue even the normal rate of increase in the size of the shell which distinguished them in their later stages, and adult condition.

It is very evident, however, that all of these retrogressive characteristics cannot be considered as pathological in exactly the same sense as the results of individual cases of disease among the progressive species. They here affect three entire series of forms which exhibit their impaired natural powers in various degrees, in one series as has been shown, mingled with the advent of new characteristics, and in another, the third sub-series, so completely subservient to these new characteristics, that the forms become representative, notwithstanding their derivation from *Pl.* ${}^{minutus}_{levis}$ and decrease in size, with those of the progressive series.

The gradations and the numbers, and perfectly normal aspect of these shells as regards their thickness, external markings and so on, as well as the increase in size noted in first sub-series show that we must look to some cause which has affected their entire development and lessened their powers of growth, finally leading through heredity to evidently normal and general distortion. The retrogressive sub-series of the First Series, furnish therefore, a very sharp contrast with the picture presented as a whole by the purely progressive series.

In the Second, Third and Fourth Series, there is a purely progressive tendency towards increase in involution, in size, in spirality, and in the addition of new characteristics. In the retrogressive sub-series on the other hand, there is a progression in some respects, and a retrogression in others.

The progressive characteristics are, however, but feebly manifested. Thus the decrease in size from *Pl. levis* to *Pl. minutus*, fig. 18, is the most marked characteristic, and after that the increase in size is confined to the normal members of the *costatus* group, the finely costate and the coarsely costate shells, which are similar to fig. 26, and lines h and k, pl. 4. The distorted forms corresponding to these, figs. 22–24, 28, pl. 9, and lines d, e, f, g, k, pl. 4, are nearly all small, and these are more numerous in the first or costate sub-series, than the larger shells. In the third sub-series no increase in size can be truthfully predicated, as may be seen on pl. 4, lines a, b, c, though in these forms as has been stated, there are carinations and sulcations, and slightly turbinate forms produced, which are decidedly progressive in these characteristics. These facts seem to show clearly that each sub-series has a history of its own in which both progressive and retrogressive tendencies are active in different degrees.

The tendency then to produce forms steadily increasing in spirality, is the only progressive characteristic common to all the series shown in the table, and is evidently a prepotent characteristic of all the Steinheim species, as it is in fact of most of the divisions of the shell-bearing Lamellibranchiata, Gasteropoda, and Cephalopoda.

Eliminating this characteristic and laying it aside for future consideration, let us now turn to the very evident selection which has been exercised between the retrogressive and progressive characteristics of the different series and sub-series. It has been shown, that the retrogressive characteristics of the first and second sub-series could be compared with the pathological conditions, normal and abnormal, of occasional diseased and senile individuals of the progressive series, but that they were distinct as far as they showed that whole series were affected. They were therefore spoken of as the results of normal pathological conditions of the animal, which were inherited with ever increasing effect in successive species, occasioning distortions and retrograde metamorphoses, and finally leading to the extinction of the race.

In the same words we can formulate the life history of a diseased individual, since, as has been shown, a similar series of changes are produced in the forms and characteristics of the diseased individuals of the progressive series, and that these, though in a more confined field, are identical in their results, leading also to the death of the individual.

In the individual the effects are shown in the disturbance of the laws of growth producing abnormal or premature weakness; or in the natural exhaustion of the powers of growth, causing senility. A wound and its results, whatever they may be, can unquestionably be so classified, since it is primarily a severe shock to the system, which lays additional burdens upon the powers of growth, and is usually followed, if severe, by retrogressive metamorphoses, or premature old age.[1] Senility and its accompanying metamorphoses also fall under the same law, though here there is no accident, and we must refer it to the action of well known physiological laws. Thus, when the powers of incremental growth during the life of any individual reach that point at which actual increase in the size of its organs is no longer perceptible, physiology teaches us, that the organs are maintained in size and the performance of their functions by an adequate supply of nutriment; but that, after a time, the individual becomes unable to digest sufficient food to supply the waste occasioned by the performance of its functions. Then, that those peculiar transformations take place, consisting of the loss of functions and the gradual decrease in size and entire or partial absorption of parts and organs, which constitute what are called the retrograde metamorphoses of old age.

Senility, therefore, simply expresses the normal wearing out of the powers of vitalized tissue to sustain itself against the perpetual friction with the disintegrating, wasting, and ultimately unfavorable effect of existing physical surroundings. When we compare these effects of unfavorable environment in producing distortions and decrease in size of the individual, with the corresponding distortions and decrease in size of the retrogressive sub-series, there is a certain similarity which leads to the supposition that the latter are also probably due to an unfavorable environment. In other words, that the continuous action of unfavorable environment upon a race, eventually produces variations in form and characteristics in the successive but genetically connected species, which show that their growth not only as individuals is interfered with, but that the distortions and retrogressive characteristics thus produced tend to be inherited, and affect the whole series of forms.

We are justified, therefore, in assuming, that in all probability the sub-series were retrogressive, because the environment in the Steinheim lake was so unfavorable; that the

[1] The exceptions in which additional normal characteristics or abnormal ones are produced are very rare and can be disregarded.

physical causes represented by that term acted upon the organization of the animals unfavorably, occasioned a weak pathological condition leading to deterioration in size, and to the production of senile-like characteristics and deformities, and the final but gradual extinction of the different sub-species. In other publications I have used the term geratology, and shall employ that same term here to indicate such correspondences and such phenomena.

Having met the question of the general retrogression in size and form, by the hypothesis of an unfavorable environment, the question naturally arises, how shall we account for the progression of the progressive series? How then could this environment act upon such closely allied shells, in such an opposite way as to cause the decease of some races and be entirely healthy for others?

We habitually refer such questions among animals, and in man, to the innate strength or pliability of the constitution of the race or the individual, and account for the survival, growth, and development of races and individuals by this reference to their supposed ability either to resist change in their surroundings, or to become modified in accordance therewith.

This principle is one of the best established results of paleontological research. It is founded primarily upon the perpetual dying out of races in geological times, simultaneously with the close of formations and the incoming of closely-allied, but modified forms in later formations. It is sustained by the existence of persistent types which resisted change to such a degree, that they are but slightly modified through long periods of geological time, although passing through revolutions in the environment which destroyed the larger proportion of their allied forms. It is sustained by the advent and comparatively short life of those forms, which suffer greater modifications in each successive formation. Among living animals it is a matter of daily experience to find some races incapable of enduring variations in the surroundings, to which others readily accommodate themselves, and even thrive under. Precisely the same environment, therefore, may produce results diametrically opposed to each other, even upon different individuals of the same species or closely allied forms, provided there is anything in the constitution either directly acquired or inherited, which enables the organization of one to resist or fit itself to conditions which the other cannot healthfully endure. It being therefore a matter of fitness or unfitness of the organization, a question of inherited or acquired power and capacity, which we can refer to the constitution of individuals, species, or races, we must now inquire, whether there are any signs of greater strength to encounter, or ability to accommodate themselves to change manifested in progressive series. The facts already stated show this. The individual shells are larger, steadily increase in size in the successive species of each series, and show distortion only in isolated individuals as the results of disease, or only in the very advanced age of others equally exceptional. This latter fact is very curious, and would be puzzling if I had not already been familiar with the extraordinary fact, that many animals have no old age; *e. g.*, Amoeba, most of the Insecta, and probably most of the Crustacea. Old age, in fact, being the result of an exhausted or outgrown organization, it can only take place in animals which have complicated organs, and which also live so long, or use them so actively that they become worn out by perpetual effort to sustain the waste occasioned by their surroundings. The absence of well-marked old age metamorphoses in most of these large shells, is therefore another sign of the innate strength of the progressive series.

The progressive series are, therefore, not persistent but variable types, and consequently we can consider them as possessing a capacity of adjusting themselves to the changes in their environment, which affected the retrogressive series unfavorably. The reference of these matters to the organization itself as a primary standard is farther sustained by the behavior of each of these series.

Thus each series is distinct from every other in the amount of change which it exhibits, and in the partly retrogressive series we see the contention of two opposing tendencies. The representative characteristics, the sulcations and carinations, and increasing involution of the whorl, are equally with the increase in size and spirality, marks of strength. If so, the third sub-series exhibits most decidedly this battle of the tendencies, and assuredly the first sub-series, where the size is temporarily increased, is a still stronger instance of a similar kind.

Here we appear to have a display of energy or force which probably did not arise in the retrogressive species themselves, but was inherited from *Pl. levis*, and we see it in these races unsuccessfully resisting the deadly influences of the unfavorable environment. These races, therefore, present in this respect, as well as in their forms, changes which may be compared to those in the life of any individual of the progressive series, which passes through a full series of changes or metamorphoses; that is, one which has not only a series of young and adult progressive changes, but also a series of retrogressive or old age changes.

If we analyze the phenomena presented by such an individual, we find, first, that it is smooth, discoidal, and in a word similar to *Pl. levis*; then that the whorl shows a flattening taking place above and below, with an increase in the amount of involution, and in spirality; then sulcations begin to appear, and longitudinal carinæ, then as it passes its adult condition, and is affected by disease or by old age, there is a tendency to suppress the longitudinal carinations, and substitute more prominent costæ or transverse lines of growth, to decrease in size, and destroy the spiral. All of these last are changes attributable to weakness in the organization of the animal. The prominence of the transverse costæ is due to longer periods of rest in building up the shell, and the consequent accumulation of shelly secretions at intervals; the decrease of the size in whorl self-evidently to the same cause, and this also accounts well for the loss of symmetry in the spiral, which can only be maintained by a constant increase in the building up of the shell. Here we perceive the same contest of tendencies. There is the inherited strength of the constitution building up the organization in size, and in all its progressive characteristics, and resisting functional waste. There is then, in all outgrown specimens, though to an unappreciable degree in some, a retrogression, and in others a well marked retrogression, in which the functional waste overbalances the supply of nutriment, and the organization loses its progressive characteristics in a series of retrogressive changes. The contest is decided at last as it must always be, in favor of function, the representative of physical forces, which exhausts, conquers and kills by continuous friction. Thus, we can readily understand that each of these series, whether progressive or retrogressive, can so far as its collective life is concerned, be compared in the closest manner with the life of an individual, and similar correspondences be traced in both, and also that the tendencies exhibited are of two kinds in each, one towards a building up of the organization, and the other directly opposed to this.

We cannot understand these remarkable concordances between the changes shown in the succession of the forms in allied or genetic series, and the metamorphoses of the individual, unless we can attribute them to a similar cause. The fact, that during the growth of the individual, the increase in bulk, and all increments, whatever be their nature, must be due to an excess in the supply of nutriment over and above what is needed to repair the waste of the body, alone shows that there is a force at work within the organization. The action of this innate power of the organism therefore is fundamental, and lies at the base of all changes whatever, except the strictly retrogressive, and it becomes evident that the same force which causes growth also occasions all progressive changes.

It is sometimes the case that, as in the third sub-series, the force described produces a series of progressive characteristics without increasing the size; but this, and also the very frequent decrease in bulk of full grown animals when compared with their larval forms, as in many butterflies and moths, etc., and in some frogs, may be accounted for by the greater development of functional activity. The phenomenon is similar to the stunting of the growth of an animal by the too early and powerful use of its organs. The growth power is used up in the assimilation of the formative material for the new parts produced, and their functional waste is so great that there is no material for increase in bulk.

If we apply the presence of this unknown power or force within the animal to the explanation of the characteristics of the series, we are struck by the ease with which all the phenomena of parallelisms are resolved. By reference to the laws of growth and development the naturalist is able to explain why it is that all the forms and modifications on the progressive grades, show similarities to the metamorphoses of the growing individuals; why all the forms of the descending grades compare so closely with the senile metamorphoses of the individual; why it is that some series, like some individuals, have no perceptible and others have a very complete series of old age metamorphoses; why all the forms and characteristics of the progressive series succeed each other in similar order in every series, occasioning the reproduction in each series of an independent but similar parallel series of forms and characteristics; why it is that there is a similar succession in the development of the characteristics in each representative species; why it is that different tendencies, one towards the production of progressive, and the other towards the production of retrogressive characteristics, can appear in the retrogressive series in different combinations or quantities according to the series; why it is in fact that the whole series of modifications in the group and its series, can be approximately compared with the life of one individual. The uniformities of series of animals as compared with each other then become like the uniformities observable in the growth of closely allied individuals, like their parallelisms in growth and in old age or disease, all due to the force of the inheritable constitution, enabling the animal to take advantage of favorable surroundings for a time, or to resist the effects of its unfavorable environment more or less successfully. In all cases the individuals and its series must change by growth along certain lines of modifiation, which it is but reasonable to suppose we shall some day be able to map out beforehand for a series of forms with the same precision that we can now forecast the metamorphoses of any given individual in a given species.

The parallelisms of the species or forms in the different series are, however, produced by characteristics, which, as we have noted above, are not inherited from *Pl. levis*, and could not have been inherited from any previously existent species, since they originate independently in the forms of each series. This condition of affairs casts doubt upon these unqualified statements of the paramount influence of the forces of growth as stated above, and leads to the following questlon: Are these parallelisms adaptations, and can they possibly be attributed to the direct action of the uniform external environment upon the forms of the different series? This can hardly be answered in the Steinheim locality, but still there are indications that here, as in other groups, these parallel characteristics are not due to similar inorganic influences. The lower forms probably arose in the First Period if my observations are correct, and only a part of them, the *Pl. trochiformis* in the Fourth Series, the forms of the First Series and its three sub-series during the Second Period, in the pits, and those of *Pl. crescens* in the Second Series were evolved, during the same time. It does not appear, then, that the inorganic influences, which were probably very dissimilar, if we can judge by the deposits, during these two periods, could have been the cause of the representation. Fortunately, however, the phenomenon of representation is quite common in the animal kingdom, and we can look elsewhere for a solution of this question. I have described a large number of species of Ammonites, and in no case was it possible to attribute the independent production of similar forms in distinct series to the action of similar physical environment. On the contrary, the most remarkable cases of parallelism took place frequently in series occurring in different formations and distinct faunae, just as the remarkable parallelism of the Marsupials with the rest of Mammalia. The unquestionable case of the Marsupials of Australia, may serve as a means of estimating the effects of the environment. While this certainly cannot be said to determine either the growth of the individuals in parallel lines, or to be the cause of the production of the parallel forms, it may nevertheless be essential to the full exhibition of both phenomena.

It must be remembered that in the Marsupials we have, probably, the lowest mammalian type, as well as the oldest, and the greater number of representative forms which we now find in Australia, are characteristic of the present period, and they are not found in the fossil European, nor in the existing or fossil American forms. There is, then, something peculiar in the environment in Australia, which makes it possible at least for these forms, which represent Rodentia, Carnivora, etc., to be produced there. It is evident that, if the land had already been possessed by these classes of typical mammals, or if they had not belonged to the base of the mammalian stock, no such expansions of the marsupial type would have been possible. It required these two elements; the growth force of a basic mammalian type and room for it to grow and reproduce, or a free environment. This was the case also in the Steinheim lake. *Planorbis levis* is an immature or low form, the field into which it entered was free, and it developed all its latent growth force, in order to fill it with species. In the same way the Ammonites did not exhibit their greatest expansion until after the lowest competing type, Nautilus, having expended its growth force in the Carboniferous, began to die out.

This hypothesis then would attempt to account for the production of so many similar forms in distinct series, simply by the fact, that the series had room to expand, or to grow and reproduce to the fullest extent in this field; that they did so in precise accordance with the laws of growth, and the succession of characteristics in the individual. This is very evident from the fact that Planorbis exhibits no such tendencies in other localities where it is surrounded by competing forms. It has become plain probably to the "begeisterte Darwinianer" by this time, that this is in fact an application of the law of natural selection, but he will also see that it is accompanied by such important modifications, that it is reconciled with the laws of growth. Thus it may be said that the struggle for existence, and the survival of the fittest, is a secondary law grafted upon laws of growth, and governed by them in all its manifestations.

The law of natural selection, as generally understood, assumes in the first place the existence of an animal type, of its descendants, and of a tendency to variation (indefinite and unlimited) in every one and all of these descendants, from which (an indefinite and unlimited) selection may take place during the struggle for existence between competing forms, destroying the weak and permitting only the strongest and fittest of these variations to survive.

The truth is, as far as my studies have gone, that there is no such thing as indefinite or unlimited variations in any species. They may perhaps be considered innumerable, but they are not indefinite or unlimited. This obvious proposition, if admitted, leads at once to the question, what are the limits within which a species may vary? Making special studies for this purpose among the Ammonites, the limits of variation in the species have been found to correspond to the growth changes in an individual. Some individuals may retain a portion or a large part of their earlier developed characteristics (not embryological), some may make considerable modifications in their hereditary adult characteristics, amounting even to new additions in many instances; some may occupy the other extreme, and either as diseased individuals, or as individuals under circumstances very unfavorable to normal growth, show premature senile and retrograde metamorphoses and distortions. This also is a picture of the grander variations of any large or small group of Ammonites, and of the present group of Planorbis. *Pl. levis* may vary from the equiumbilicated discoidal form, to the unequiumbilicated form similar to *Pl. oxystomus*, or the more depressed whorls of *Pl.* $^{parvus}_{levis}$, and each of the varieties may have minor sub-varieties founded upon innumerable minor differences in the spiral, more or less angular outer sides, and so on, but there is evidently a well defined law in their development. The variations consist in the retention of the earlier or young form with no additional progressive characteristics, or if these are added they consist of modifications or exaggerations of some part, found more or less developed in other forms, whether these occur in the lakes of America or other continents.

It has already been shown that the representative forms were divisible into two kinds. Those whose similarities could be accounted for, because they differ very slightly from *Pl. levis*, retaining in part its form and smooth whorls, and those subsequently produced which were new in the Steinheim lake, and, that the former, which are due to the retention of ancestral characteristics, are replaced by the latter.

Thus the equiumbilicated discoidal form is lost entirely in *Pl. tenuis*, *Pl. triquetrus*, and *Pl. crescens*, except in the young of some specimens. In *Pl. discoideus*, it is not even found in the young which are asymmetrical at all ages, except perhaps the youngest zones of growth in the shell. This decrease is evidently brought about by the prepotency of the newly introduced tendency to increase the spirality, and develop the square form of the whorl and the sulcations and carinations.

The retrogressive series, as may be readily seen, have an increase in the adult retrogressive characteristics, which obeys the same law; the farther removed the species is from the original form the less it is apparent, either in the young or in any of the adult forms. Thus, in following up the series we find, that in any one form during the adult stages the representative characteristics displace the ancestral characteristics in inverse proportion to the affinity of the forms in which they appear for the ancestral form.

This law is applicable even to those resemblances occurring between the forms of the old and young, such as have been traced between the oldest and youngest stages of the individual among the Ammonites, by D'Orbigny and the author, and by many authors between Baculites and Orthoceras. These resemblances are accompanied in these cases, as in man, where there is considerable resemblance in the form of the body and the parts at the extremes of life, by entirely distinct structures, and are evidently due to the partial or entire absence of parts and organs. In the young this is found only before or during the stage of development in the parts; in the old however, only after or during the stages of absorption of the parts. The retention of the cylindrical or semicylindrical whorl in the adult of *denudatus* and *distortus*, are precisely comparable with such geratologous characteristics. The extreme young are closely coiled and similar to the young of *Pl. levis*, and the subsequent aspect of the shell is brought about by retrogressive changes counteracting the normal tendency of the growth. They are not arrests of development, but geratologous metamorphoses. True arrests of development and reversions, if the latter can really be separated from the former, are precisely the exceptions which are needed to show the uniformity of the law under ordinary conditions, and its subordination to unfavorable or extraordinary external conditions.

This law is equally applicable to the parallelisms of individuals of the same brood, same variety, species, genus, or family. The differences which appear in the individual adults, and which distinguish them at this stage from their own young, or their own embryos, are for the most part those which show their affinity to other individuals of the same brood, variety, species, genus, and family.

These new or differential characteristics replace those of the earlier stages, which, as is well known, are inherited from ancestors, who, with the exception of animals having the larval stages much prolonged, have first acquired them during growth in their adult stages. In fact, one cannot understand such series as are here shown, or as may be constructed from a study of the affinities of animals, when arranged with a due regard to the embryology, geological surroundings in different formations and occurrence in time, and their adult characteristics, without assuming continuity of descent. This being granted, all observations show that one and the same general law covers all series, whether retrogressive or progressive, namely, that the representative characteristics of the individuals and their differences in structure *at the adult stage* are inversely proportional to their relative removal in time, and the surrounding conditions or environment, from the egg or from some assumed or observed parent type.

It is impossible to construct a series and begin to investigate the causes of the origin of the forms without assuming continuity of descent, and the action of time and changed conditions in modifying the organization, as has been done by modern experimental zoologists.

If this position is the true one, then similar physical causes acting through similar periods in time, upon the same or different genetic series of animals, ought to produce results or modifications in which not only the action of time and the environment upon the animal, but also the reaction of the laws of heredity and growth, would be distinctly manifested. This has seemed to me to be the case among the Steinheim series, and among the Ammonites, and to account for the sudden appearance of geratologous resemblances, arrests of development and reversions, all of which are pathological; and due, like other pathological conditions, to unfavorable surroundings.

There are two extreme classes of cases which might be considered exceptions to such a law, one class embraces what paleontologists call persistent types, and another those curious parasites, which like the Epizoa and others among Crustacea, or the parasitic Vermes lose in the adult a portion or nearly all of their typical characteristics.

The persistent types are such animals and their fossils, as in Lingula, Nautilus; Myrmecobius among mammals; Ceratodus among fishes; and a host of other forms, which exhibit at the present day very nearly the same forms as those of the same genus found in Paleozoic or Mesozoic time. Even if this statement be doubted, as it may reasonably be with regard at any rate to the Lingulæ, as stated by Mr. Dall, and with the Nautili, there still remains the fact that these types are persistent, or do not present any modifications of their organization at all proportionate to the changes through which they passed. Paleontologists have noted these peculiar and remarkable instances, but failed to call attention to the fact that many groups present a greater or less number of species which can be classed in the same category with these more noted examples, and that, after all, this is not an uncommon phenomenon.

Almost every group of Ammonites contains such species, and I have tried to show in previous publications that all of these persistent species or forms were among the lower, or earlier occurring, members, or more embryonic forms of the groups to which they belonged. When taken in conjunction with the fact that none of the extremely persistent forms exhibited geratologous transformations, these facts appeared to show that the reason why time and changing conditions had no more effect, was due to the enormous power of reaction in the organism itself, its growth force, which enabled it to withstand the action of the shifting environment, and to adjust itself to these changes without materially modifying its own organization. Such a case is also presented here, and it is *Pl.* $\frac{parvus}{levis}$, *Pl. oxystomus*, and *Pl. Steinheimensis* which have the greatest range in time, and are found in all the formations.

If it be true that growth force has anything to do with the life of a series, as it has to do with the life of an individual, then there ought to be some common ratio between the power of reproduction in the series and in the individual, and between the life power of these persistent types and the point at which they sprang from the ancestral tree. In fine, if growth force has any meaning at all, and has, as is here claimed, an influence upon the life of a series in the same way that gravitation acts upon the heavenly bodies, determining the morphological cycle of their successive species, then types could only be persistent when they sprang from a point of origin near to the source of the whole group to which they belong. The instances of persistent types are all of this character, as far as I know them, and preëminently what Prof. Agassiz would call embryonic types, when comparing them with the higher organisms of their own group.

The greatest contrast with these is afforded by the parasitic types, which vary from those which are in the fully adult condition, still recognizable as Vermes, Crustacea, Mollusca, etc., to those in which all the type characteristics are obliterated in the adults, but still preserved in the young, and finally to those in which the type is difficult to recognize at any period. Of the first classes there are many examples, of the second fewer, and of the third very few illustrations.

A large portion of the Epizoa among Crustacea, Entoconcha among Mollusca, Linguatula among Arthropoda, are familiar illustrations of the second class; while Gregarina and Taenia, may possibly belong to the last, to which some of the males of several genera of the Cirripedia make a near approach.

It is difficult to escape from the conclusion, that the loss in the adults of the alimentary canal and other parts and organs, which are found in the young of the second class, must be attributed to the parisitic environment; no other adequate cause whatever has as yet been presented, and the losses take place in those parts which are especially affected, and become useless on account of the parasitic environment namely, the alimentary canal, limbs, the shell, etc. In these cases, we can only account for the second and third classes, by supposing that the differences arise from the greater or less completeness of the parasitic mode of living, which time and habit have increased, until the environment finally conquered the tendency of the growth, and of the laws of heredity to repeat in the young the inherited characteristics of the type. How fast, or how slowly this was accomplished in specific cases, is not the question, but simply whether there were two opposing forces at work, one represented by heredity and growth, and the other by physical causes or the environment, and I think this assumption is highly probable. With regard to the third class of cases, it would be difficult to determine whether they represented distinct types in the animal kingdom in some cases; but the gradation which is presented in the males of Cryptophialus among Cirripedia, where the young are almost as degraded in organization as the adults, shows that the environment has acted either throughout a long time or quickly and effectually, so as to destroy the type characteristics even in the earlier stages.

This would then be an extreme exhibition of the power possessed by physical causes to alter the primitive organization, and in fact I do not see how we can otherwise account for this result when we look at the results of modern research and the serious modifications produced by the experiments of Schmankewitch upon Artemia and Branchipus among Crustacea, of Carl Semper upon Lymneus among Mollusca, and of Siebold and others upon Batrachians.

But although this power be granted in the abstract, and as a corollary of all the relations of animals to their environment, the fact remains that under all but the most extraordinary conditions, animals maintain their type characteristics. They show this by growing through a series of stages in the young, which repeat more or less fully the adult characteristics inherited from their ancestors, and by producing series of new forms, more or less parallel with those of other congeneric series, which are also new, or in part the direct result of inheritance from the parental type form.

Thus, although it may be said that the environment, which here consisted of an unoccupied field, or one which may at least be inferred to have been unfavorable for the growth of other competing shells, was favorable to the fullest expansion of the type, nevertheless the precision with which the series were evolved, and their concordances cannot be explained by any hypothesis based solely upon these influences. Again, if this be doubted, and the uniform action of the uniform environment be assumed as possible, then how account for the manifest differences arising in the primary *Pl. levis*, and becoming hereditary in the series. These characteristics are not representative, but essentially differential, in fact the only ones which in the lower forms indicate affinity, and enable us to begin to thread our way through the complicated labryinth of representative characteristics. Thus, *Pl.* $^{minutus}_{levis}$, *Pl.* $^{parvus}_{levis}$, *Pl.* $^{oxystomus}_{levis}$, and *Pl.* $^{Steinhemensis}_{levis}$, are all more or less distinct and possess certain differences which are subsequently increased in each of the progressive and in some, but not all of the retrogressive series.

Thus, *Pl.* $^{parvus}_{levis}$ has the sub-acute outer side of the whorl less perceptible than in *Pl. parvus*, but it is a distinction constant in the series. Reversions to *Pl. levis* might of course, and probably would, occur, if we could know the facts by the actual experiment of hatching broods, but these would only add strength to the present proposition, since they would only be adults retaining the form of the young, which until a late stage, even in *Pl. crescens*, is identical with *Pl. levis*. *Pl.* $^{oxystomus}_{levis}$ has the narrow umbilicus and gibbous whorls in the lower side of some varieties of *Pl. levis*, and we have only to consult the plates to see how persistently this is maintained in *Pl. supremus*. *Pl.* $^{Steinhemensis}_{levis}$ has the form of whorl of the more angular and flattened varieties of *Pl. levis*, with a tendency to increase this to an excessive degree in *Pl. discoideus*.

But here a curious interference is observable. An apparently retrogressive or reversionary characteristic, the gibbous or rounded and smooth character of the under side of the whorls described in many of the *Pl. discoideus*, appears, and is increased in the successive forms causing so close a resemblance to *Pl. supremus*, that a derivation of that form from these was actually traced out by Hilgendorf. I have shown, however, that this is probably erroneous, and that they are in distinct genetic series.

All of the changes of form in the First Series as previously pointed out, are representative, so that the only characteristics which can be compared to the class now under discussion are the prominent costæ, and the small size of the whorls when considered as one series.

Having now this peculiar category of characteristics before us, it is easy to see that they represent the essential differences of the series, and are quite distinct in their nature. They are permanent when once introduced, and essentially progressive, or rather cumulative, in each series, except where they are modified by the introduction of some prepotent representative or reversionary characteristic, as in *Pl. trochiformis*.[1]

[1] Though even here they are present in the early stages of all forms with one exception (the variety with rotundatus like young).

They arise as differences and remain differences, and have at no time any value as representative characteristics. They, however, appear in the same forms as the representative or parallel characteristics; and the question now arises, can they also be reduced to the control of the same law of succession in the series and in the individual?

Evidently there is no such succession, for if we take an individual out of any of the series, and attempt to show this, we are met at once by the insuperable difficulty that there is nothing to compare it with in other series. These characteristics, therefore, present themselves with remarkable clearness, as increasing by heredity throughout the series, or as in the case of the Fourth Series increasing only in a certain number of species, and being then partly superseded by an evidently prepotent tendency in the remainder of the species to revert to the rounded form of the whorl, or they are absent as in the geratologous series, the second sub-series. Here, I think we have the key. The geratologous series, if the comparisons made above are approximately correct, owes its purely retrogressive character to the disadvantageous nature of the surroundings, and in these the differential characteristics are not developed, while in all others they are developed in precise proportion to their rank as progressive series. Thus in the first sub-series, the fine crowded costæ or the enlarged widely separated costæ or size, form alone the progressive characters of the series. In the third sub-series, the development of the third carination is decidedly progressive, as is also the serial difference of the Second and Third Series, and even the Fourth as far as it goes.

Not only do these differential characteristics as a whole progress, or increase, but they are progressive in the differences, which they present within each series. That is to say, that the gibbous underside of the whorl in *Pl. supremus* is only a little more gibbous in *Pl. supremus* than it is in *Pl.* $^{\textit{oxystomus}}_{\textit{levis}}$. The whorl of *Pl.* $^{\textit{parvus}}_{\textit{levis}}$ is more angular in *Pl. crescens,* the flattened lower side of *Pl.* $^{\textit{Steinhemensis}}_{\textit{levis}}$ still flatter in *Pl. tenuis* and *Pl. discoideus,* the costæ of *Pl.* $^{\textit{costatus}}_{\textit{minutus}}$ are largest in var. *major* of the largest size. There is then uniformity in the way in which these differences of the series act, they are all progressive, but their progress in each series consists alone in their increase in intensity of expression or size in each series. Thus their uniformities are in the strongest possible contrast to the uniformities of the representative characteristics. These do not agree with each other in the same series, but have their uniformities in the representative forms of different series, whereas the differential characteristics have all their uniformities in the same series, and do not agree with each other in different series. The increase of intensity in each series is, as above stated, directly proportional to the more or less progressive character of the series, being nothing in the exclusively geratologous series, and most intense in the most progressive or Fourth Series.

If, therefore, the absence of the differential characteristics can be accounted for by the action of disadvantageous surroundings in the second sub-series, it becomes evident that the existence and permanency of the same class of characteristics in other series must be due to the selective action of the same surroundings. This conclusion can be farther sustained by the great increase in size of the First Series, or most progressive or differential one, and the gradual decrease in size of each series towards the left of plate 9. Proportionate size and weight are acknowledged by physiologists as the most reliable basis of estimating relative health of individuals, and, other things being equal, the favorable or unfavorable character of their surroundings. These facts and the peculiar reversions of *Pl. trochiformis* in some of its characteristics, appear therefore to be perfectly well accounted for by Darwin's theory of natural selection. In no other way can we possibly account for the selection of but four out of the varieties of *Pl. levis*, and the continuous propagation and increasing intensity of the differences which they exhibit. An examination also of the figures of the nearest allied forms of *Pl. levis*, such as *Pl. Steinheimensis*, will show any one how many variations are lost in each form or species of the series, and how few are continued. This can only be accounted for upon the supposition that those which survived possessed in some way advantages indicated by their peculiar variations, which enabled them to propagate those variations, and suppressed their less fortunate neighbors.

It is impossible to imagine any uniform inorganic cause acting upon the comparatively constant organization of *Pl. levis*, and producing therefrom a number of radiating series, genetically distinct from each other, and with all the other marks of independent constitutional and hereditary traits above cited, unless we allow with Darwin a basis of original, constitutional differences indicated by the tendency of *Pl. levis* to vary. Then it is easy to see how the physical environment would cause a selection to take place in the differential characteristics of the varieties, and how the same causes continued, would permanently fix the favorable differences in the race or series, causing it even to increase in intensity until another change, as in *Pl.* $\frac{\textit{discoideus}}{\textit{trochiformis}}$, might cause selective alteration of the original differences, or even a reversion of these.

All of these considerations when taken together appear to show that the following propositions may be considered as reasonable:

(1.) The extraordinary modifications and series of shells found at Steinheim are in one way exceptional, and owe their existence to exceptional conditions.

(2.) These conditions appear to be the isolation of the modified descendants of *Pl. levis*, due to the absence of competing types, and the character of the environment.

(3.) This environment was suitable for the propagation and perpetuation of the distinctive peculiarities of three series, and unfavorable in various degrees to those of the sub-series of the First Series.

(4.) That while the perpetuation and survival of the differential characteristics can be thus accounted for, we must look to other causes for the production of the parallel forms and the regularity of succession of these forms, as shown in the arrangement in the different series, and in the development of the individual.

(5.) That this cause lies in some law of growth and heredity which reacts against the tendency of the physical environment to produce variations and differences, and produces parallelism in the development of different individuals of the same species, of different species in the same series, and in the succession of forms in the different series, and also limits the tendency to variation within definite boundaries in the species, especially in *Pl. levis*.

(6.) That while the influence of the environment must be admitted as paramount in exceptionable instances, it for the most part produces these exceptions in extreme cases of parasitism, and the Steinheim shells are not parasites, and cannot be assumed to have been under similar influences in respect to the laws governing the size and genesis of the series, they ought, therefore, to come under the same laws as other forms occurring in other localities.

(7.) That this appears to be the case except in so far as they are a very limited group, confined to a very limited field, a field free from competition, and extremely favorable to their growth for that and other reasons.

These conclusions being approximately arrived at our next inquiry is very naturally, what is this law of heredity and growth which maintains the type, causes parallelisms and constrains variation under ordinary conditions, but still, in certain cases, is forced to give way to physical influences.

Ruling out the lost or transient forms which are not perpetuated we see that the fundamental law here, as elsewhere, is that all the characteristics are inherited after they are once introduced.

Our first inquiry, then, must be as to the mode in which they are inherited. Is there any law which embraces this class of phenomena in some general statement?

In former essays, especially written for this purpose, I have tried to show that there was such a general law which is so plain and simple that I have wondered that no authors have made it the basis of investigation except Prof. Cope and myself.

In every series of animals which I have studied the same fact appears, namely, that in a given number of generations inherited characteristics of every kind tend to appear in the descendants at earlier stages than that at which they first occurred in the ancestral forms. Whether characteristics are normal or abnormal, provided they are fixed in the race either by the action of natural selection or by the direct working of physical causes, they are inherited according to this law.

Though led to this discovery, if it is such, by close observation of small series of Ammonoid forms, I have since applied it, with greater or less success, to every series of animals which have come under observation, and in fact it is a corollary of the doctrine of evolution.

The law of Biogenesis which is now quite generally adopted in Europe, though long since used habitually by the students of Prof. Agassiz[1] in this country, and regarded by them as an essential basis of investigation, leads naturally to a search for some such uniformity in the inheritance of characteristics as that described above. How can an animal in its transient stages of growth resemble the permanent adult characteristics of ancestral forms without the action of some such law?

A negation is not proof, though so often regarded in that light, nor is it proof that in some individual cases a disease or characteristic is inherited later in the life of that particular individual. These instances, and they are not very frequent, are exceptions, and this investigation simply shows that the ordinary action of this law, which has been called the law of accelerated development or *acceleration* by Cope and myself, has been interfered with by the action of external causes. The only proof against it must be of such a character as that upon which it is founded, namely, the investigation and published description of some genetically connected series of closely allied species, which do not develop in accordance with or verify its provisions.

[1] Prof. Agassiz did not give his law an evolutionary application nor a name, Hæckel did both, and it is now called "Hæckel's law" in Europe.

A general and confused conception exists that certain characteristics either appear "in utero", or tend to be inherited at earlier or later periods in the life of individual descendants, and, then becoming fixed in the organizations, are transmissible at corresponding stages, and also, that in some way, some of these characteristics become fixed in embryo, and thereafter are invariable for that particular division of animals.

The law of acceleration appears to me at present to show the manner in which characteristics, which are perpetuated, finally either disappear or become fixed in the young, or even in embryo. This conclusion may be followed out by any one who will arrange a series of animals or their shells, according to their adult affinities and their developmental characteristics. He will then see that adult characteristics which are introduced in ancestral forms, tend to reappear at earlier and earlier stages, as he travels along the series.

Though it is perhaps impossible for us to trace any type back to its beginning, and thus substantiate this law for the truly embryonic characteristics, the conclusion is inevitable that if it is a true expression for the mode of inheritance of any series of animals, it was probably also true for their ancestors.

Why, then, the invariability of the embryonic form and characteristics, as among the Ammonoids and Nautili? The explanation appears to me to present no great difficulty. All perpetuated characteristics when crowded into the younger stages, and tending to appear at younger and younger periods, must either replace the original embryonic form and characteristics, or be crowded out by the constant incoming of new characteristics, which are continually being originated and tending like them to be inherited by the law of acceleration.

Embryonic characteristics are subject to great variations, under the action of corresponding changes in the environment. Witness the different degrees to which parasitism has encroached upon the type characteristics of the males of Cirripedia and of the Epizoa, shortening the periods during which the young show their typical Crustacean forms and characteristics, and the inference becomes almost irresistible, that Taenia has lost its original type characteristics at all stages of development by the same process.

In what other way can we describe this as taking place, except by the law of acceleration, by the earlier and earlier inheritance in successive generations of differential characteristics first introduced in the adult stages of their ancestors by the influence of the parasitic environment?

It is evident that suitability to the parasitic mode of life determined the selection of these crustacean forms, otherwise we cannot understand their being found in such habitats, or the pliability of their organization, or the fact that their young are locomotive, and seek out the hosts in which we find them when full grown.

In the same way we cannot understand the disappearance of perpetuated characteristics in the young except on the hypothesis that they have become useless and are absorbed to make room for the new ones which are inherited from later ancestors. They are met on the one side by the embryonic type characteristics, which are the last to give way even in the parasites, and on the other by the action of the law of acceleration, and they must disappear or become embryonic. But room for them in the embryonic stages does not appear to be found, except perhaps to a very limited degree. This we know from the comparative uniformity of these stages wherever they have been observed, except in a few extreme cases above described, and their almost exact parallelism in different individuals of the same type, and by the observations of Barrande, Chalmas and the author among the embryos of fossil Trilobites, Ammonites and Nautili.

Why, then, are these embryonic characteristics usually so invariable,[1] and why do they resist even the efforts of the parasitic environment to crowd them out by the action of the same law of heredity by which they first became embryonic?

If they first became embryonic by the action of the law of acceleration upon the adult characteristics of some ancestral form, all traces of which are now lost, why did they not in their turn disappear?

An answer to this in detail must be deferred to a paper I am now preparing, an abstract of which will, I hope, in due time appear in the Proceedings of the Boston Society of Natural History. Here I shall try to show that this invariability rests not only upon the power of the earlier and more embryonic organisms to resist change produced by the environment, but also upon the greater protection from the working of physical causes afforded to the young during the earlier periods of its existence.

The environment is more uniform as regards temperature, food, and so on, in the egg, than at any subsequent period. Starting with the common origin of the ovum, I think it can be shown that the uniformity of the environment of the earlier stages, whether held "in utero" or cast out to take care of itself, whether carried and protected in pouches or at the breast, is not assumed without a sufficient basis of evidence. If it be granted, that there is a growth force in organisms, which is the basis of all heredity, and which resists the working of physical surroundings, tending to preserve the type and sustain the uniformity of the organization, which limits variations and produces parallelisms, the conclusion becomes inevitable, as in the Steinheim shells and the persistent and embryonic types, that the nearer an animal is to the point of origin of its type the stronger or more potent will be all of its uniformities, and the less subject to variation from changes in the environment.

If then we can join to this any general law of uniformity in the environment at early stages, we have two efficient causes working in unison to maintain the stability in geologic time, and the invariability in heredity of existing types, as shown by the characteristics of the embryo.

Deferring the proofs of this position to a future opportunity, it only remains to add by way of caution, that I recognize in the term growth-force an expression of a purely physical cause, which is shown by the fact that organic forms can and do habitually grow in opposition to the forces of gravitation, as well as exist and perpetuate themselves in spite of the action of physical forces of the environment, which even under the most favorable circumstances suffer them to exist but a very limited time, killing them off in inverse proportion to the innate powers of resistance, or growth force, manifested by them. I do not pretend to assume that this force is antecedent, correlative, or consequent upon the production of organic matter, I simply assume its active existence,

[1] Comparative invariability is here meant, for as I have shown, Fossil Cephalopoda, Bull. Mus. Comp. Zool., vol. 3, there is considerable variability in the earlier stages of Silurian Goniatites, as compared with the same stages in more recent descendant forms. See also H. J. Clark, "Mind in Nature," on the differences of the egg in different types, etc., and authors on the structure of the egg at early stages.

and use the word force as all of us are obliged to do for a cause, which we can recognize, but cannot see. This battle of a force from within, against a force from without, is perhaps the strongest argument for natural selection which can be adduced. But it also shows that natural selection, even if it is as general as is claimed, is the expression for a series of results caused by the action and reaction of these forces, one upon the other.

The views of Wagner upon the necessity of isolation for the production of new forms, have specially interested me in connection with the Steinheim shells, since they show certainly the effects of isolation in an extreme case. Although the Steinheim basin is an evident exception, and although it is much more difficult to apply the law of isolation in ordinary cases, still Weissmann has shown us how this can be done, and how the prevention of indiscriminate crossing, "amixie," may be called in to assist isolation in the production of new forms. This view appears to me to receive the strongest possible confirmation when applied to the differential characteristics of the Steinheim Series, since, as I have pointed out, the four species were selected from a number of varieties of *Pl. levis,* after these had migrated into this isolated basin where their surroundings were favorable, and the field unoccupied. But the uniformities presented by these series appear to me to indicate the existence of other causes, which must be taken into account if the phenomena presented by them are to be fully and correctly explained.

The law of acceleration in the inheritance of characteristics is very often difficult to recognize among shells, but not fortunately among the Steinheim species. The rounded whorl of *Pl.* *levis, Steinheimensis,* begins to be confined to the early stages in the *Pl. Steinheimensis,* and in those like figs. 4–19, line c, pl. 1, which have angular whorls in the full-grown, it is found at still younger stages, and finally disappears altogether in *Pl. discoideus,* with some exceptions, and is replaced in the young by a form like that of *Pl. tenuis,* fig. 4. This form is again replaced in the young of the extreme forms of *Pl. discoideus* and *Pl. trochiformis,* by a more spiral form resembling the adult of *Pl. elegans*, the whorl has the same flat, angular upper side, and rounded lower side. The increasing spirality of the adults is carried back into the easy stages in the same way and at the same time as the other characteristics. In *Pl. crescens,* this acceleration is less noticeable than in other forms, but even here the inheritance of the acute, angular, outer side of the whorl takes place much earlier in *P. crescens,* fig. 15, than in the transition form, fig. 14. In the young of *Pl. discoideus* and *trochiformis,* all traceable derivation from *Pl. Steinheimensis* is lost, being crowded out by the angular *sulcatus* or *elegans* form. This also occurs in *Pl. triquetrus* var. *turbinatus,* fig. 20, when compared with true *Pl. triquetrus,* fig. 19 and *P. minutus.*

The inheritance of striæ in the first sub-series proceeds according to the same law, but the presence of numerous hybrids makes it difficult to follow it out.

The small sac-like shell which occupies the apex, belongs to the later embryonic stages, and as such is present in nearly all Gasteropoda, except such as retain a still earlier and flatter or more open form, and all the Ammonoids and Belemnoids, and, though absent in the Nautiloids, its former presence is indicated by a scar which occupies the apex of the whorl.

I have not a sufficient acquaintance with the local peculiarities of the Planorbidæ in other habitats to determine whether there is any general modification in all of the shells, or even a majority of them, which may have been caused by the physical peculiarities of the environment, and which can be attributed solely to their action.

The tendency to increase the spirality in each series at first sight appears to be a uniform result which might be attributable to the habitat alone. But, as has been shown, this is a general tendency expressed without regard to locality in nearly all series of the Mollusca, and shows very forcibly what the author means by the tendency of growth-force to reproduce under the most diverse circumstances similar forms in similar succession.

The well-known researches of Mr. J. A. Allen [1] and other American naturalists among birds and mammals have shown that such general modification in the colors, bills, tail and wing feathers of birds, and in the pelage and size of ears and feet in mammals, do take place in given localities, and are attributable probably to certain well defined local causes, such as humidity, temperature, etc. My own similar results obtained from the commercial forms of the keratose sponges,[2] and Mr. Scudder's [3] in the insects, also seem to show that there are such general effects on the organization which may be separated from other categories of characteristics.

There is not the slightest reason for regarding any of the series, as purely scalariform and distorted, except the first and second sub-series. These also agree in form with the Planorbis found in the famous locality of Magnon, where the environment is evidently unfavorable to the race.

To these instances I can happily add another of peculiar interest which occurs in a marl bed at Lawlor's Lake, near St. John, New Brunswick. My attention was first called to this locality by the kindness of Prof. E. S. Morse, who sent me a lot of shells collected there by Prof. C. F. Hartt, late Director of the Geological Survey of Brazil, whose untimely loss was regarded here, as well as in the country of his adoption, as a public misfortune.

Since the receipt of these I have personally surveyed the locality in company with Mr. G. F. Matthews, a well known geologist of St. John, attached to the Canadian Survey. Residing several weeks in the vicinity, I gathered a large collection, which is now undergoing the process of sifting. The shells are all scalariform and distorted so as to resemble closely in form and aspect the third sub-series and the Magnon Planorbes, but they all belong to the genus Valvata (an unquestionable identification).

It is also worthy of remark, that a true Planorbis is found abundantly side by side with the distorted Valvatæ, so similar to *Pl. levis*, that I think it may prove to be identical. This is also distorted but to a less degree. It would be premature to attempt to give a description of the probable condition of the lake when the distortions were produced in Valvata, but I hope to be able to present, in course of time, a joint memoir written by Mr. Matthews and myself. It may be observed, however, that none of the distorted Valvatæ now exist in the lake itself, upon the banks of which, and in immediate contact with the water, lie the deposits of marl containing the extinct shells. In all these instances of pure distortion, as well as in others observed by me in speci-

[1] Bulletin Mus. Comp. Zool., Vol. 2.

[2] North American Poriferæ, Mem. Bost. Soc. Nat. Hist., Vol. 2, pt. 2, 1877.

[3] Revision of Oedipodidæ, Proc. Bost. Soc. Nat. Hist., Vol. 17, p. 482–83.

mens of Planorbis from this vicinity, or from the West[1] there is no difficulty in determining that they are the result of the unusual and unfavorable conditions to which the individuals or races were exposed. They all show one thing, namely, a disturbance of the regular growth of the spiral, resulting in some extreme cases in the complete unrolling of the whorls.

This enables us to separate them at once from such series as are presented in the third sub-series, and Second, Third, and Fourth Series on pl. 9, and adds considerably to the evidence here produced. This question undeservedly assumed great prominence in the discussion of the Steinheim shells, at the meeting of the Naturforschende Gesellschaft at Munich, several naturalists hastily adopting the view that most of these shells were distorted forms.

I must also be permitted to point out another serious error which the retrogressive sub-series illustrate. Many investigators evidently picture a retrogressive series as a departure from the normal form of any group, which can only be represented by a line running backwards, so that to them the fan-shaped arrangement of lines is not a true presentation of the affinities of any given number of series. They demand a series of radii emanating from a centre to all points of the periphery of a sphere. The utmost that can be granted to the graphic presentation of such an arrangement is a hemisphere of radiating lines. A centre of distribution being granted, that centre is a form or fixed point in geologic time, and from that we can only truthfully depart in lines of genetic descent, radiating in time upwards, or horizontally, perhaps, but never backwards.

This common sense view of the relations of affinity and time is farther borne out by the fact, that in no case are retrogressive series actual returns of forms really identicalwith those previously existing, unless they are the direct descendants of those forms. The Baculite is not an Orthoceras, nor is Bactrites, though they are all wonderfully similar. The Epizoa are never Protozoa, nor is Entoconcha a worm. Nor are the distorted forms of Magnon,[2] though Planorbes, identical with their distorted brethren of the Steinheim basin, though this is a case where identity could perhaps be found, if the environment was exactly similar, and they belonged to the same species. If the retrogressive sub-series can be represented by lines going backwards, where are the more ancient forms with which they are identical?

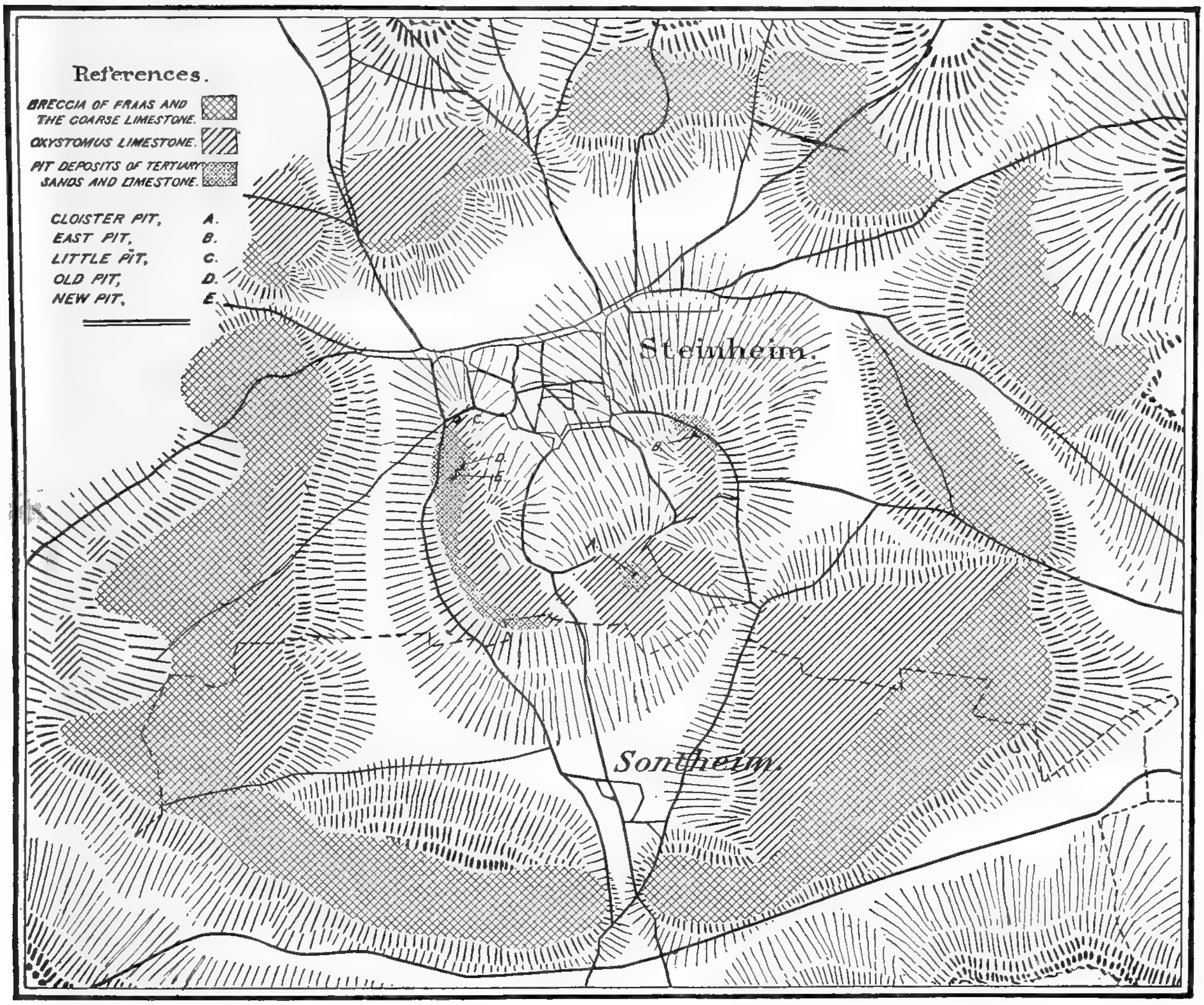
It cannot be claimed that the Magnon specimens should be graphically represented in this way, because they are similar to those of Steinheim; for it is evident that they are simply parallel forms. As compared with the normal Planorbis, they can be more truthfully represented by the extreme lateral line of a fan-shaped arrangement of lines having a centre, in some existing species of Planorbis.

The habit of representing affinities by the sphere of radiating lines is in direct opposition to all that we know about genesis, growth, and development, retrogressive or progressive, and the relations of these phenomena to time and the surfaces upon which animals live. I may add, also, that it is rarely employed by any, but mere zoölogists.

[1] U. S. Geol. and Geog. Survey of Colorado, Dr. F. V. Hayden, 1874. Report by Ernest Ingersoll, p. 402.

[2] M. Louis Piré. Planorbis complanatus (forme scalaire). Ann. Soc. Malacol. Brussels, vol. 6, 1871.

II. Geology of Steinheim.



GEOLOGICAL MAP.

The village of Steinheim in the kingdom of Wurtemburg, stands at the height of about 1867 Wg. feet above the level of the sea.[1] It is not far from Heidenheim on the eastern slope of the elevated plateau forming the Wurtemburger Alb. This village, from which the formations described in the following pages acquire their name, and the village of Sontheim, are situated in a valley which is circular in form, surrounding a central hill; Steinheim lying just to the north of this elevation, and Sontheim a short distance to the south. The valley externally, is surrounded by a circle of ridges more or less discontinuous where they have been cut through by the drainage of the surrounding highlands. The underlying formations of these ridges is the White or Upper Jura. Those of the central hill, where the overlying Tertiary limestones and sands have been removed by denudation, comprise representations of all the principal formations from the Lias to the

[1] Equal to about 1822.5 English feet, or about 555.5 metres.

White Jura, *A* and *B* included. Prof. Quenstedt and Prof. Fraas have given minute descriptions of the geology, and the map accompanying the official report of the latter to the government of Wurtemburg, is here reproduced with certain essential changes in order to illustrate this description. Though differing with regard to the structure of the underlying portions of the central hill or Cloisterberg, these investigators and Prof. Sandberger agree in considering the valley to be due primarily to a synclinal depression of the White or Upper Jura, which is the surface rock of the larger portion of the surrounding and more elevated parts of the Alb.

According to this view then, we start in our history with a more or less closed kettle shaped valley in which the Tertiary rocks, clays and sands, which form the subject of this memoir, were deposited. These belong, according to all authorities, to the Miocene, and according to Sandberger to the upper part of that formation.

Surrounding the entire edge or rim of the kettle is found a peculiar coarse breccia of the older or Jurassic rocks, cemented together by freshwater limestone. My visits to these rocks were directed wholly to the search for the beds described by Hilgendorf as containing *Pl. aequiumbilicatus* and its descendants, and therefore, the geological observations made were merely incidental. I first endeavored to find these rocks as directed by Hilgendorf on the west side of the basin, but did not succeed on account of the stormy weather and my uncertainty as to their exact position. Subsequently, and also in the face of a cold storm, I succeeded in finding two of the formations described by Fraas as occurring upon the Burgstall south of Sontheim, or "Die Landzunge zwischen dem Stubenthal und Steinheimer Thal." Prof. Fraas writes of this locality very fully, and the cursory observations made by me accord precisely with his descriptions. The Coarse Breccia lying externally, or next to the Jurassic rocks, I did not visit, but found the Coarse Fresh-water Limestone of Fraas in place. This rests immediately upon and passes into the coarser and underlying Breccia, and contained only poorly preserved fossils, but by careful comparison I have been able to ascertain that they unquestionably belong to the *oxystomus* series. The natural sections which are abundant leave no room for doubt that the larger number of the forms have a deeper upper umbilicus than is common even in *Pl.* $^{oxystomus}_{levis}$, and approximate more closely to the typical form of *Pl. oxystomus*. There are also several moulds of *Pl.* $^{supremus}_{oxystomus}$. The umbilicus is large above and deep, as in that species, and the upper ridge and sulcations plainly though slightly marked.

A fossil somewhat better preserved than others, showed in section a curious intermingling of characteristics. The last part of the outer whorl had the angular aspect of *Pl. levis* Klein as figured by Sandberger. The front part of the same whorl was of somewhat blunter aspect, like *Pl. levis*, as figured by Klein, the size being also about that of the specimen figured by Klein. The upper umbilicus was much shallower than in *Pl. oxystomus*, and the lower umbilicus wider. In fact it seemed to be a form combining characteristics of *Pl. levis*, *Pl. Steinheimensis*, and *Pl. oxystomus*. This specimen leads to the supposition that *Pl. Steinheimensis* should be regarded as a variety of *Pl. levis*, a view sustained by Hilgendorf's observations, and by fifteen authentic specimens of *Pl. levis* received through the kindness of Prof. Sandberger. They were collected at Undorf, near Regensburg, and contain several marked varieties.

Eight of the specimens have exactly the form and characteristics described and figured by Sandberger. *Pl.* $^{levis}_{oxystomus}$ is represented by one full-grown specimen, with rounder whorls in the young, and only the outer whorl angulated. This leads into one full-grown specimen exactly identical with Klein's figure of *Pl. levis*, with whorls somewhat flatter on the upper side, always rounded externally, and slightly stouter, so that the umbilicus is deeper. This last is supplemented by one in which the whorls become still stouter, and the umbilici on both sides perceptibly deeper, which is absolutely identical with *Pl. oxystomus* in the general aspect and characteristic outline of the whorl, but differs slightly in the more open character of the lower umbilicus.

Two young specimens were until a late period of growth absolutely identical with *Pl. Steinhemensis*, var. *œequiumbilicatus*, and one acquires an angular outer whorl when not quite half grown. This one and the *Pl. levis* forms with angular outer whorls in the adults cannot be distinguished from the typical specimens of *Pl.* $^{minutus}_{levis}$, part of *parvus* of Hilgendorf, such as are figured on pl. 3, line k, fig. 1–4, and many others, which a reëxamination of my Cloister Pit material has brought to light. The full-grown specimen described as having only the outer whorl angular, is not distinguishable in any way from the young shells described as transition forms between var. *parvus* and the *Steinheimensis* forms of the pits. The specimens mentioned as identical with Klein's figure and the one described similar to *oxystomus*, can be in no way separated from *Pl. oxystomus*, especially forms which can be readily picked out of any large number from formation *m*, of the Cloister Pit. In fact, these specimens show conclusively that *Pl. Steinheimensis*, *Pl. oxystomus*, etc., are varieties of *Pl. levis*, and explain the confusion of characteristics which must necessarily result as long as this is not recognized. All the gaps were not filled in the pits with intermediate forms, which would be so considered by an exacting judge opposed to all theoretical views of the transmutations of specific forms. This failure is here accounted for, and the gaps closed up by the forms found in the rocks of the Lower Steinheim Period, and the more ancient Tertiaries.

Other specimens, with rounded outer whorls, are not infrequent in the Coarse Limestone, which the receipt of Prof. Sandberger's specimens of *Pl. levis* have enabled me to identify as precisely similar to the stouter forms of the *Pl.* $^{oxystomus}_{levis}$. No specimens were found which could be said to have whorls identical in all respects with the angular whorls of *Pl. levis*, figured by Sandberger. *Gillia utriculosa* was also found.

Fraas' description states that the Coarse Limestone passes into regularly stratified fine grained limestone, his "Valvaten-Kalk," which I have called Oxystomus Limestone, to accord with the views taken here of the affinities of the fossils.

This contains according to Prof. Fraas' account of this locality only the discoidal forms found in the oldest layers of the Pits. "Die Valvaten gehören der neideren, flachen Form an, die in der Sandgrube von Steinheim im unteren, ältesten Lager sich finden."

The specimens of rock hammered out by me and apparently in place contained specimens of *Pl. levis*, var. *parvus* Hilg., *Pl.* $^{oxystomus}_{levis}$, and *Pl. oxystomus* with their young. *Pupa antiqua* and *Gillia utriculosa* were also found, but were rare. Remains of fishes were frequent as described by Prof. Fraas, but all fossils were less abundant than in the surface limestones next to be described.

The "schmieriger Sand," probably a deposit of clayey sand described as underlying the Oxystomus Limestone, was not visible at any point in my path in such a way that I could determine its relations to the surrounding rocks. A large number of loose pieces of a thin bedded limestone, slightly coarser in texture than the Oxystomus Limestone, were found lying scattered on the soil of the lower part of the hill from the junction of the Sontheim and Cloister ridge roads to the western end of the Burgstall. *Pl. supremus* is very abundant in these pieces, and one form also occurred, a variety with a slightly elevated spire, which I have described as *Pl. oxystomus* var. *cochleata.* This also occurs in formation *m* of the Cloister Pit in great abundance. Though we find this to be a turretted form with the whorls flattened on the upper side and so similar in the young to those of the adult of *Pl.* $^{oxystomus}_{levis}$, when seen from the same side, that no differences could be detected, nevertheless the lower umbilicus was deep, the increase of the whorls in size by growth exceedingly rapid, and the whole shell evidently similar to *Pl. oxystomus*, var. *cochleata.* Closer investigation showed that this view could be sustained by an almost uninterrupted series of intermediate forms, and by innumerable young shells, which covered the surface of the slabs. *Pl. levis* Sand. also occurred, but this was rare and I could not detect any specimens having forms intermediate between this and the former. *Gillia utriculosa*, *Gillia* sp. unknown and *Pupa antiqua* were also found. The fossils are not sufficiently peculiar to identify those fragments as belonging to any rock in place and I only mention them here because they contain the rare form of *cochleata.*

The formation next described by Fraas as occurring on the road to Neuselhalderhof, I did not visit, but the fossils are fully described by him, and differ from all hitherto mentioned. The rock itself he describes as succeeding the Coarse Breccia on the lower part of the hill, but he does not attempt to synchronize it with the formations just described on the Burgstall. The fossils consist of *Pl. solidus* Th., *Pl. declivis* Br., *Pl. platystomus* Klein, *Pl. exustus* Desh., *Pl. Hilgendorfi* Fraas, *Helix sylvestrina* Ziet., *Helix gyrorbis* Kl., *Lymneus socialis*, *Ancylus deperditus* Desh., *Neritina fluviatilis* Linn. Of all these it will be remarked that only *Lymneus socialis* and *Helix sylvestrina* are found subsequently in the neighborhood of the Cloisterberg, either in the rocks or in the Sand Pits, and that not a single one occurs in the formation on the Burgstall. To determine precisely the relations of this formation with regard to those on the Burgstall, would require a re-examination of the locality, but this is hardly necessary. Prof. Fraas has described it as lying within the Coarse Breccia, and considers the fauna as related to the older Tertiary Molasse of Teutschbuch. Hilgendorf describes the formation as a "hard, thick, yellowish-gray limestone," and besides the fossils enumerated by Fraas, says that it contains the *Pl. aequiumbilicatus* Hilgend. Steinberger refers this *Pl. aequiumbilicatus* to *Pl. levis* Klein, and says in his famous work so often quoted (page 579), that this species occurs in the Planorbis shale (Schiefern), over the limestone containing *Helix sylvana*, and mentions, as found with it, *Lymneus dilatatus* Noulet. Sandberger describes the whole fauna of the Neuselhalderhofer or Sylvana Limestone as older than the Cloisterberg deposits, and adds the following significant remarks:[1] "The enormous number of such species as *Carinifex multiformis, tenuis, oxystomus, Gillia utriculosa, Planorbis costatus,*

[1] *Op. cit.*, p. 654.

Kraussii, and so on, which until now have been found in no other Tertiary formation, astonishes one at first, and occasions one to overlook the manifold relations which exist between the Steinheim fauna, that of the Upper Freshwater Molasse, and that of the Sylvana Limestone, which (last) appears at Neuselhalder, under such circumstances that it must at any rate be considered as the next oldest Tertiary formation of the neighborhood." This opinion is supported by a long list of all the fossils found in this and other localities, and other remarks which will be quoted more fully hereafter. Prof. Sandberger is an acknowledged authority upon the Tertiary shells of continental Europe, and this opinion, therefore, is of the greatest weight, especially when it is accompanied, as in the present case, by a wealth of illustration, and a detailed text which most fully supports the position.

Again the same authority does not describe the Neuselhalderhof rocks, under the heading of Steinheim, but under that of the "Land und Süsswasser Conchylien des Kalkes mit Helix sylvana, und der oberen Süsswasser Mollasse der Schweiz Schwabens und Bayerns," and speaks of it as follows: "The Upper Miocene Limestone with *Helix sylvana* again appears to the north-west of Ulm, first at Neuselhalderhof" (one hour from Steinheim), and then describes its occurrence at a host of other places in various parts of Germany, in scattered detached masses, the remnants of the former deposits of an equally large number of fresh-water lakes of the Upper Miocene period.

Though none of these authors state distinctly the relationship of the Sylvana Limestone at Neuselhalder to other rocks or by what it is immediately underlaid, they all agree that it must be a remnant of a former period and it contains as stated by Hilgendorf the elements from which the shell fauna of the Steinheim lake-basin were in all probability directly derived. It is equally clear that it occupies according to Sandberger a position underneath the Planorbis bed, a formation in which he found *Pl. levis* var. *aequiumbilicatus* Hlg. on the Neuselhalderhof road.

These facts support the proposition advanced by Hilgendorf, that the ancestors of the Planorbis forms of the Pits are found in the *Pl. levis*, var. *aequiumbilicatus* of the Neuselhalder rocks. Though I cannot for reasons previously given trace all of the forms to this variety, it is evident, that in the main proposition, the descent of the Pit forms as a whole from the Neuselhalder and perhaps other Tertiary varieties of *Pl. levis*, Dr. Hilgendorf is amply sustained.

More or less doubt must of course hang about conclusions based upon anything but a series of close observations, and therefore I cannot at present do anything more than suggest the probability that this First Period really represents two, one including the Sylvana Limestone and the Coarse Breccia, and the other beginning with the Planorbis rocks. I am also bound to state certain alternatives by no means improbable, namely, that the remnants of an older fauna as shown in the Neuselhalderhof rocks may have lived side by side with the new fauna for a considerable length of time, or on the other hand, that the fauna of the Sylvana Limestone merely represents an unsuccessful migration from a neighboring fauna, which gained only a temporary foothold in the lake. Both of these alternatives appear to me to be unsatisfactory, but in such a locality nothing but the keenest exploration can settle such a question, and that has not yet been given to this point by any person, so far as I know.

To the east of the road to Heidenheim and on the low ridge crossed by the road, I took a sample of rock which I considered at the time to be identical with that occurring in the East Pit; the more massive character of the deposit struck me at the time, but being influenced by the conclusions of former authors I did not pay much attention to the locality. I supposed that it was nothing more than a fragment of the limestones from which I had already collected in the East Pit, and took only one hand specimen, and that only as a precautionary measure.[1] This is to be regretted since its connection with the Sylvana Limestone and the Cloisterberg rocks is very remarkable. The fossils show that the gradual character of the transition from one fauna to the other cannot be safely denied. *Pl. discoideus* is represented by a full array of varieties, but the flatter forms predominate such as are figured on pl. 1, line e, fig. 10–12; like these also the young in the few cases examined had the true discoidean character. The extreme varieties, the stout form similar to fig. 19, line f, pl. 2, or the thin form shown in figs. 10, 11, line h, pl. 1, are rarer than the normal forms, though the observer is very apt to think the latter very abundant until a close examination is made. *Pl. tenuis* was sought for, but not found.

Two forms occurred which are probably the young of *Pl.* $\substack{tenuis \\ Steinheimensis}$, but it is not possible to determine whether they were these or the young of *Pl. Steinheimensis*. The upper umbilicus was entirely wanting, and the whorls had the shape of *Pl. tenuis*, but without its angularity, or flatness on the lower side, or its narrow umbilicus.

Besides these there occurs a specimen of *Hyalina subnitens* Müll., and *Vitrina Suevica* Sand. Though casts, these are well enough preserved to give positive grounds for their generic identification. The second of these two species is described by Sandberger[2] as occurring in the Sylvana Limestone, on the west side of the valley, and the first as in the same formation at Möringen and Undorf. Both are very rare, and it is quite remarkable that they should occur in a single hand specimen of this rock taken at random from the first available point. *Lymneus socialis* of large size was very abundant.

The exposures of rock on the southern side of the Cloisterberg ridge are divisible into two portions. The lower part occupies the lower border of the ridge extending in places nearly to the top. Its structure, though finer than the Coarse Limestone on the Burgstall, is very similar, and it was evidently deposited under similar conditions. Both are evidently the product of speedy deposition in waters saturated with lime, as shown by their coarse, irregular, granular structure, and numerous cavities which have led to the frequent description of the latter as tufaceous.

I surveyed these rocks on every available occasion, and obtained many hand specimens without, however, being able to determine with certainty either that they were connected with the rocks to the eastward of the Heidenheim road, or what were their upper boundaries. All varieties of *Pl. discoideus* are abundant, except those with very deep sulcations on the lower or umbilical side; these are very rare, as are also the deep, thick-whorled forms like those on pl. 2, line f, fig. 19. The prevalent variety is similar to that described above, from the rocks in the valley to the east of the Heidenheim road. They differ, however, in the young, which is more immature in aspect and precisely resembles in a large number of forms the adult of *Pl. tenuis*. This is, therefore, an intermediate variety and must be designated as *Pl.* $\substack{discoideus \\ tenuis}$. Specimens of *Pl.* $\substack{tenuis \\ Steinheimensis}$,

[1] I have called this the Valley Rock, to distinguish it from other formations.

[2] *Op. cit.*, p. 602.

such as are described farther on are extremely rare, but still do occur occasionally, though they can only be determined when the young can be seen as in natural sections.

Pl. tenuis occurs quite frequently, and also a variety, which is slightly turretted. The young are a little flattened, and have narrow umbilici on the lower side, so that they can be at once distinguished. The upper side, and the form as a whole, resembles fig. 6, line c, pl. 1, but the lower umbiiicus is much narrower, and there are no marks of sulcations. There is one specimen of the young of this species with no umbilical depression in the upper side, a truly turretted variety, which resembles precisely the figure of *Pl. Lartetii* Noul., as figured by Sandberger, on the upper side, but is more rounded on the lower side.

Lymneus socialis, of large size, was very abundant in places, occupying the rock to the exclusion of other forms. *Gillia utriculosa* Sand., was present in considerable numbers, in the forms figured by Sandberger. Casts of the stems of Chara appear, but are rare.

The rocks which I have called the Upper Tier, form the summit of the crest, and like those of the Lower Tier are much denuded, the surface being worn out into pillars of fantastic shapes, and rough looking knolls. The composition is similar to that of the Lower Tier, but much harder and denser in places, though nowhere is the porous characteristic, formerly described, entirely lost. The fossils are much less numerous than in the Lower Tier with the exception of the Chara stems which are very abundant in some places.

Pl. discoideus is very rare, but *Pl.* $^{discoideus}_{tenuis}$ is of more frequent occurrence. *Pl. tenuis* is the most abundant fossil, but is almost wholly represented by the very flat form, which is quite rare in the Lower Tier. The slightly turretted variety, which is quite common in the Lower Tier, is found here also, but is much more infrequent. All the specimens are very small or young, with the exception of *Pl. tenuis*.

Several young specimens were collected, which were identical with those previously described in the Valley Rock as the young of *Pl.* $^{tenuis}_{Steinheimensis}$. These are here unquestionably the young of forms which in the adult have the characteristics of *Pl. tenuis*. Nevertheless these young have rounded whorls and open umbilici on the lower side, until a much later stage of growth than that at which the angular whorls, etc., are usually acquired in *Pl. tenuis*. One full grown specimen was similar to Sandberger's specimens of *Pl. levis*, to my *Pl.* $^{oxystomus}_{levis}$, and also similar to the specimens figured on pl. 1, line b, figs. 13–15. Its evidence makes the relation of the most extreme forms of *Steinheimensis* and *Pl. levis* very clear. It has the peculiar flattened aspect on the upper side and shallow umbilicus of many forms of *Steinheimensis* with the whorls on the outer and lower sides exactly like those of *Pl.* $^{oxystomus}_{levis}$. Besides these, several young specimens occurred, which were not separable from the young of *Pl.* $^{oxystomus}_{levis}$, and were undoubtedly identical with them.

Lymneus socialis of large size is present, but quite rare. In one hand specimen of a peculiar gray limestone on the lower border of the Upper Tier on the west side of the Cloisterberg, were found several specimens and fragments of *Pupa antiqua*, and a broken cast of a specimen of Helix. A fragment of a tooth with thick dark-brown enamel, like that of some small rodent, was also found.

No stratification was observed, and consequently it was not possible to determine whether the rocks dipped towards the valley or not. These characteristics indicate a continuous deposition, or rather precipitation of calcareous matter, since it is hardly possible to conceive that any metamorphic changes could have taken place sufficiently extensive to destroy the marks of stratification. It would seem a fact that these rocks must have been deposited under circumstances very similar to those which occurred when the brecciated limestones of the outer rim were formed.

This is evidently the view taken by Prof. Fraas, since he alludes to them in the following words: "Diesem Griesfels oder den Breccienkalk begegnen wir zum erstenmal bei Steinheim, das von einem solchen Schuttgebriges regelmässig umlagert ist."[1] And again, "Sobald man sich aber dem centralen Klosterberg, und den Dorf nähert, wiederholen sich gleich den Breccien Erscheinungen aus dem Ries: regellose Massen älteren Juras, die in tertiären Sand und Kalk drin stecken."[2]

Sandberger[3] describes these rocks under the name of "die klotzigen Kalke," and says, that though no stratification is found by which the superposition of the fossils can be definitely determined, they contain the same association of fossils as in the strata of the Pit, up to the introduction of "*Carinifex multiformis*."

The statements with regard to the geology, are entirely in accordance with my own observations, except the portion of Prof. Fraas' remarks which refer to the underlying structures of the Jura. With regard to these, I am not capable of judging between his and Quenstedt's views, nor has the question an important bearing upon the age of the rocks under consideration. Whether the Cloister ridge is an irregular mass, as stated by Fraas' or an anticlinal ridge, as held by Quenstedt, it is, according to both authorities, capped by the tertiary deposits here called the Cloister ridge rocks, and these alone are concerned in the present discussion. When we attempt to compare the fauna of the opposite sides of the valley, we are at once struck by the great differences between the fauna of the Cloister ridge and Burgstall rocks. *Pl. levis ? Pl.* $^{oxystomus}_{levis}$, and *Pl. oxystomus* in the rocks of the Burgstall present the characteristic association of forms found in the fauna of the Cloister Pit, formation "*m*," rather than what their geological position would lead one to expect, though, as has been shown, these species are really the direct descendants of *Pl. levis*, and their occurrence here ought not to surprise any one. On the other hand the rocks of the Upper Tier on the Cloister ridge, though they resemble the Coarse Limestone closely in texture, and may be of the same age, have a very different set of fossils. *Pupa antiqua*, *Lymneus socialis*, an unknown Helix, the tooth of a rodent; *Pl.* $^{tenuis}_{Steinheimensis}$, *Pl. tenuis*, *Pl.* $^{discoideus}_{tenuis}$, and *Pl. discoideus* are all distinct from those of the Coarse Limestone. *Pl.* $^{oxystomus}_{levis}$ alone represents the species of this last named formation.

The fossils of the Upper Tier are, as remarked by Prof. Sandberger, similar to those in the lowest of the Pit deposits. In the next or Lower Tier this likeness to the fauna of the Pits is increased, but the change consists more in the relative proportions of the species than in the introduction of new forms. *Lymneus socialis*, *Gillia utriculosa*, *Pl. tenuis*, *Pl.* $^{discoideus}_{tenuis}$, *Pl. discoideus*, are abundant, and *Pl.* $^{tenuis}_{Steinheimensis}$ very rare. The prevailing form is, however, as in the Pit formations, *Pl. discoideus*, except in places where *Lymneus socialis* excludes all other forms.

[1] *Op. cit.*, p. 13. [2] *Op. cit.*, p. 14. [3] *Op. cit.*, p. 630.

If the rocks to the east of the Heidenheim road had contained any Planorbis, Lymneus or Gillia it might have been said that the Cloister ridge and these rocks together, contained a fauna precisely intermediate in character between the Burgstall and the lower strata of the Pit Deposits. The presence of *Hyalina subnitens* and *Vitrina suevica*, however, both fossils of the Sylvana Limestone, may be perhaps explained in the same way as the reappearance of *Pl. oxystomus levis* in formation *m* of the Cloister Pit, namely by colonization from some neighboring part of the lake where they had continued to exist. With these exceptions, the fauna of these Heidenheim road rocks certainly presents a somewhat remarkable character and contains an association of species which appear to follow on very naturally after those of the Lower Tier, and fill the gap between these and those of the lower strata of the Pit Deposits. This rock is very similar, as remarked by Quenstedt, to the limestones of the Pit Period, and at first sight seems to be filled by the normal varieties of *Pl. discoideus*, to the exclusion of other forms, and has altogether a more recent aspect than the rocks of the Cloister Ridge.

The forms, however, do not indicate a geological transition, because it is in the Lower Tier that the predominance of *discoideus* occurs and not in the Upper. The Upper Tier appears to lie upon that here called the Lower Tier, though with regard to this the data are not such as would render this view unquestionable. The division between the two Tiers is uncertain and not sharply marked off by any line of stratification. It is possible that what now is the Lower Tier does not underlie the Upper Tier, but may have once covered the summit of the hill and been superimposed upon the rocks now exposed by denudation above. In this case the anomaly of the prevalence of "*discoideus*" in the lower bed instead of the higher, would be done away with.

Whatever results may flow from future investigations upon the relations of the rocks of the circular valley, it does not seem to me probable that the bearing of these facts upon the origin of the fauna of the Pits can ever be materially altered. The rocks contain a fauna, which is probably older than that of the Pits, and shows that the forms which here and there appear suddenly at the lowest levels in the Pits had their origin in a former period of which these rocks are the imperfect remnants. The richness and the sudden development of the forms of the lowest stratum of the Pits at the two places examined by me require an explanation, and that given by Hilgendorf does not seem to me wholly satisfactory. Granting that the spots examined by me were nearer to the shore line, and his farther out in deeper parts of the lake, and that he found only *Pl. Steinheimensis* and *Pl. parvus* in the lowest stratum of the Pit deposits, the fact remains that my explorations reached the bottom of the deposits in two places. If the fauna I found was not contemporaneous with that which he found, the shores must have been very steep, and have prevented the burying up of the shore-line faunas until all the deeper parts of the lake were filled. This, however, is a difficult matter to prove, in view of the fact that the strata have been more or less elevated since they were deposited.

The Cloister Ridge has suffered greatly from denudation, and standing on the summit alongside of one of the pillars or knolls, which still remain, the conclusion, that the entire valley or basin must have been originally covered by rocks of a similar kind, which have been, however, almost wholly removed, seems to be well supported.

Fraas and Quenstedt both attribute the formation of the circular valley and the superficial aspect of the Cloister Ridge largely to denudation, and I think the inference is very well founded that a considerable proportion of this must have taken place before the formation of the lower strata of the Pits. These partially consist in the lower part of the Little Pit of a peculiar coarse sand, containing fragments of rock, both resembling in color and texture the Cloister Ridge rocks, though in the small number of fragments examined no fossils were found. The dark, reddish-brown color of the sand in the lower strata of the Pits predominates, whereas, in the upper parts above *e* and *f*, this is not the case, and pure white shell sand is more abundant. Above these again comes in some of the sections a sort of rubble, like that of the basal strata, containing Lymnea again in abundance, whereas, in the intermediate deposits, it was but sparsely represented. I was under the impression when at Steinheim, that the Cloister Ridge rocks were considered older than the Pit Deposits, but nevertheless spent a considerable portion of time in studying the relations of the two, and made a series of observations, in order to find out their relations to each other, knowing that but little attention had been paid to this part of the field.

Dr. Hilgendorf, in reply to my questions, wrote me on the 13th of November, 1877, that in the Old Pit the massive Fresh-water Limestone of his Section 2 [1] was surely a tufa similar to the Cloister Ridge rocks. "'Der massige Süsswasserkalkstein' welcher die Grundlage des Profils M 2 bildet (p. 481) ist sicher ein Tuff gewesen æhnlich den Felsen, die den Klosterberg kronen." He also states that he found in one of his excavations a block of "Tenuis Tuffa," resting upon the Jura, which was four and one-half metres thick, and adds that they (the Cloister Ridge rocks) agree with the older layers of the pits. The view that the Cloister Ridge rocks and the lower Pit Deposits were formed at the same time is rendered inprobable by all the facts stated above; by the composition of the lower Pit Deposits; by the difference in the structure of the rocks, which show that conditions existed which made the lake at this period very different, a reservoir of lime-laden water unfavorable, either from this or some accompanying cause, to the existence of such vast numbers of shells as appeared in the purer waters of the Pit Period; by no signs of transition between the two, and by the position and inclination of the strata of the Pits, which dip away from the unstratified Cloister Ridge rocks, indicating a want of conformability, which, however, could not be proved because no contacts were exposed.

The influences which effected the deposition of the Cloister Ridge rocks, were independent of any periodical changes which could so materially alter the quantity of sediment held in suspension by the water at any season of the year as to produce regular strata of slight thickness. Whereas, within a few feet occur the Pit Deposits regularly stratified in such a way that we can say with certainty that there were periods of quiet waters for the limestones and clays, and periods alternating with these during which much coarse sediments were transported and deposited in the form of sands and rubble, etc.

I am aware that the deposits of water impregnated by mineral springs, may take place in very narrow and confined areas, but that such a thickness of rock exceeding that of the Pit Deposits, would have been deposited on the Cloister Ridge in the immediate vicinity of the Pit Deposits, in the middle of a lake, and yet been wanting in the larger number of

[1] See p. 44 of this Memoir.

the forms which are so abundant in the Cloister Pit, which is surrounded by them, appears highly improbable.

In fact the enclosed pieces of rock, the general composition and inclination of the strata, and the fossils of the lower Pit Deposits, all seem to indicate for them an origin later in time, and a partial derivation of the material from the Cloister Ridge rocks.

The uppermost Pit Deposit found by me on the hill immediately above the Old Pit, and containing *Lymnea socialis* and described as a rubble derived from the Cloister Ridge rocks, also indicates a similar origin.

The structure of the Cloister Ridge rocks indicates a contemporaneous origin with the lower rocks on the Burgstall, as noticed by Professor Fraas, but the fossils are not identical. No exposure of any rock under the Lower Tier was seen, although diligently sought for, and I was disappointed in this last hope of obtaining positive proof of identity between the rocks on the Burgstall and those on the Cloister Ridge. The impression made by the fossils and the rock structure was such that under ordinary circumstances, and in a less important locality, I should hardly, however, have hesitated to consider the Cloister Ridge rocks as belonging to a somewhat later, if not contemporaneous part of the same general deposit as those of the Burgstall.

The Pit Deposits do not extend far out into the valley, but are limited to remnants clinging to the sides of the central hill. The underlying clay, the White Jura β, has been described as occurring wherever wells or cellars have been dug in the village, and was found by Dr. Hilgendorf and the author in the Old Pit at the base of the deposits. According to Dr. Hilgendorf, however, the White Jura forms the base of the East Pit, and the *Opalinus* Clay, a much older formation of the Brown Jura, the base of the Cloister Pit. This last fact shows how great the denudation must have been which took place before the Pit Deposits began to be laid down on the south side of the hill.

It is very evident also from the singular want of exact agreement between the layers of adjoining localities, as for example in Sections 7 and 8, representing two nearly opposite sides of the New Pit, that the physical conditions varied considerably within a few yards, and that while limestone or clay was accumulating in one spot, sand was being laid down in another immediately adjoining, and the same for greater distances, and in a larger sense. As, for instance, the sands and limestones of the Cloister Pit are in direct contrast with the great prevalence of clay in the corresponding parts of the New Pit and East Pit. There must have been, therefore, very considerable variation in the state of the water in these different spots, though in such close proximity to each other. Nevertheless, with all this local variation, there is a regularity in any one section in the succession of limestones, clays, and sand, which strikes the observer at first as absolutely uniform. Thus though no great amount of uniformity exists such as would enable us to synchronize the strata with exactitude in different localities on the same level, there is great uniformity in the alternation of limestone and shell sand, or clay and shell sand, and this may be seen to be the governing fact in any one of the sections. These minor local differences of structure can not be used to explain the greater differences of the Cloister Ridge rocks, since in no case are the partings of limestone formed "in situ" of a similar structure. They are everywhere a shell limestone of greater or less fineness, but never vesicular, or similar to the limestones of Cloister Ridge rocks except in the lowest parts of the Pit Deposits.

M. Ami Boué in an article entitled "Les dépots Tertiaries et Basaltiques de la parti du Wurtemburg et de la Bavière,"[1] describes these Cloister Ridge rocks as a calcareous tufa deposited upon the strata of sands and clays. This hypothesis is, however, inadmissable, since no observer has seen any of the Pit deposits between the underlying Jura rocks and the Brecciated or Cloister ridge Limestones in any locality. The Cloister Ridge rocks are described as resting directly upon the Jura in all cases, and so also is the Breccia of Fraas, and they are both laid down in the official map of which a modified copy heads this chapter, in accordance with these views. The existence of the Lower Steinheim Period though advanced here in distinct terms for the first time, is really to be inferred from the writings of Quenstedt, Fraas, Hilgendorf and Sandberger. Every one of these authors allude either directly or indirectly in such terms to the Neuselhalderhof rocks containing a distinct and older fauna than that of the Upper Steinheim (or Pit) Period.

The Geological Map of Steinheim, page 33, shows the central hill with Steinheim to the north and Sontheim to the south. The Neuselhalder rocks are situated to the westward and are marked like the Breccia of Frass, as are also the Cloister Ridge rocks forming a half circle on top of the central hill, and also the rocks of the Burgstall, southeasterly from Sontheim. This was done to place clearly in view the association of rocks supposed to form together the strata of the Lower Steinheim Period.

III. Review of Geological Sections.

Hilgendorf gives five different and detailed sections in the Old Pit, which do not agree very closely, nor in view of the great disparity of even adjoining parts of the same pit, depart much from the sections here given. His remarks about the New Pit, however, show that here there was a very marked difference. He describes this as very deficient in limestone, whereas, a glance at my Sections 7 and 8 will show that the opposite condition occurs at the present time. This agrees also with the fact that for a long time previous to my visit this had been the pit preferred for the excavation of sand, and had been very much enlarged. The two following sections are quoted from the two, which were continued down to the base of the deposits, by Dr. Hilgendorf.

Dr Hilgendorf's First Section.

Limestone; formerly the floor of the pit.
Clayey sand.
?.4. Clay with three strips of shell-bearing sand.
3 { Shell-sand with *Pl. m. sulcatus.*
Clay.
Shell-sand with *Pl. m. sulcatus.* }
$\frac{3}{2}$ { Clay.
Shell-sand.
Clay.
Clayey-sand with *Pl. m. tenuis* and *sulcatus*, }
2 { underneath clay with a thin layer of *Pl. m. Tenuis* and below with large angular pieces of Jura-limestone. }

Dr. Hilgendorf's Second Section (lower part).

4 { Clay.
Shell-sand.
Clay.
Limestone.
Clay.
Shell-sand.
Clay.
Shell-sand.
Clayey-sand.
Shell-sand. }
$\frac{3}{2}$ { Clayey-sand.
Shell-sand.
Clay. }
2 Clayey-sand with two shell layers.
1 Massive Fresh-water limestone.

[1] Ann. des Sci. Nat. 1824. Vol. 2se, p. 5—12.

It will be observed, however, that, in the two holes sunk in the Old Pit, under my directions, the pieces of Jura limestone began to be thrown up as soon as the pick entered the dark clay layer. Dr. Hilgendorf, in none of his sections, found the dark clay layer, which forms the base of these two sections. Nevertheless, No. 2, in his First Section, consisted above of clay layers containing *Pl. tenuis*, and below the large angular fragments of Jura limestone, which show that he had here reached the bottom of the deposits. It seems as if no other inference was possible, since everywhere this indicates the same fact, and is accepted as the limit.

I cannot synchronize his sections and any of mine with success, as in fact might be anticipated from the great variation which occurs often within a few feet between the details of the stratification.

His second section, given on p. 480–81, is the most complete of all, since here he obtained his *Pl. m. Steinheimensis*. With relation to this there are some statements which have confused me in searching for the exact situation of this form. All of his sections described are in the Old Pit, and only a general description is given of one in the New Pit, and of the "dritte Grube" which is the Cloister Pit — the East Pit he does not mention. In the New Pit he distinctly states that he did not reach the *Steinheimensis* layer; and in the Cloister Pit he saw the *Steinheimensis* zone, but not "in situ," ("nicht in situ gesehen.")

This narrows the places in which this zone was first observed to one section, his second section.

On p. 492 in his account of *Pl. m. Steinheimensis*, and its genetic series, he writes as follows: "Die Zone (1), deren Schilderung den Anfang machen müsste, *ist mir leider nur mangelhaft bekannt*, da sie bei meinem letzten Besuch der Gegend unzugänglich war. Sie enthält die echten *Steinheimensis*; doch zeigen schon hier einzelne Exemplare eine Andeutung von *tenuis* — Kennzeichen; am Ende der letzte Windung tritt oben eine undeutliche Furche auf, und die Abplattung der Umgänge ist auf der Oberseite oft schon recht merklich. Doch kein einziges Exemplar würde mit einem *tenuis* verwechselt werden können. Dagegen kommt in der nächsten Zone, (*der untersten, zu der ich in der alten Grube gelangte*), ein *tenuis*-artiges Aüssere den meisten Exemplaren zu, nur die scharfe Kante auf der Unterseite ist bei keinem Exemplare ausgebildet, so dass ein eigentlicher *tenuis* (unter etwa 1000 Exemplaren) noch nicht zu finden ist. Diese erscheint erst in der nächsten Schicht in der Begleitung von echten, meist involuteren *Steinheimensis*; beide Zonen zusammen geben eine Reihe von Exemplaren die von der schönsten Rundung eines *Steinheimensis* zu der breiten scharf kanntigen Form des *tenuis* jede Abstufung zeigen, Doch scheint in den *tenuis* Zonen schon eine kleine Lücke zu sein, so dass aus ihr allein eine Reihe nicht mehr gut herstellbar ist. Man kann die 3 Schichten als *Steinheimensis*-zone, Uëbergangszone des *Steinheimensis* zu *tenuis*, and *tenuis*-zone bezeichnen."[1]

In this description he declares the second zone to be the lowest which he reached in the Old Pit, although the first zone is put down in his second section. This discrepancy however, disappears, when taken in conjunction with the fact that he describes zones 1 and 2 in the section, as two layers of shells contained in one

[1] The italics are all my own, except, of course, the names of the species.

layer of clayey sand. The lowest of these consisted of true *Steinheimensis* shells, and the upper of *Steinheimensis tenuis* shells. In this statement, then, we see that Dr. Hilgendorf did not find two distinct deposits, but one deposit with two distinct layers of shell. Unfortunately, the conditions of the problem demand that there should be a wider separation than this, or else there comes in the doubt that in this case, at any rate, there may have been the overlapping of local and contemporaneous colonies, so common in these deposits. This same section also assures me that in my sections in the Old Pit, the bottom of the deposits at that place was reached. I carefully kept separate [1] until after I had drawn and studied them, the samples of fossils gathered from pockets in the Jura clay itself, and these contained specimens of the *Pl. multiformis*, which were not only important in respect to being found in this position, but still more so from the fact that they were transported shells. This was the conclusion arrived at by comparing them with other specimens. They were encrusted with brown limestone, and otherwise roughened like rolled shells. They imply that *Pl. multiformis* existed before this lowest layer was deposited, and that the few specimens found were transported from some other locality where living specimens existed, and had been in the water long enough after the death of the mollusks to acquire their rolled aspect, and encrusted outer surface.

I farther assured myself from the owner of the pit before digging the hole, that the floor of the pit had not been disturbed since Dr. Hilgendorf's visit, and dug near the spot pointed out to me as the one where he had sunk a pit. This, however, proved to be a mistake, since the limestone was unbroken, and Dr. Hilgendorf claims that the section No. 6, of my digging, was nearer the hill, and not so deep as those explored by him, except his No. 4, and that I struck the Jura clay at a much less depth, so that in place of Nos. 1–2, I found only his bed 5, equivalent to his *discoideus* zone.

He states that the fish remains occurred in his zones 6 and 7, while they occurred much lower in my sections — namely in bed *c*. His zones 6 and 7, however, are the equivalents of *k. l.* in my sections, and the whole thickness of my sections were between 40 and 55 feet in the Old and New Pits. This is a very significant fact, since he states that the total thickness of all the strata were 45 Wurtemburg feet — about 42 English feet. "Die gesammte Mächtigkeit der beobachteten Schichten würde sich auf etwa 45 Fuss belaufen, wenn dieselben der nämlichen Stelle sämmtlich in günstiger weise entwickelt wären."

The number of zones which could be distinguished petrologically was, as stated by him, about 40 in all; but this I could not use for comparison, the number of layers differing so greatly, that no reliable comparison could be made. The total thickness, also, must have been considerably lessened in the Old Pit at the time of Dr. Hilgendorf's visits, since he did not find the *oxystomus* and *supremus* zones here, but in the Cloister Pit, whereas, these were well shown in the New Pit immediately adjoining the Old Pit, at the time of my explorations.

[1] It is of course understood in all these cases, that no pains were spared to make every sample perfectly reliable, and that in no case was a hole sunk except through unbroken limestone, nor was anything gathered from an exposed surface, or without digging under the limestone layers, etc. No one but a tyro would think of neglecting such precautions.

I am, of course, bound to believe Dr. Hilgendorf's explicit statement that he was obliged in order to reach the Jura, to dig much deeper than I did, and there are certain facts in my own sections which confirm this. He dug to the Jura in his Sections 1 and 2, before the Pits were opened so far into the side of the hill, and was therefore farther out in the valley, and this corëllates with the facts in my Sections 5 and 4, as compared with 6. In 6 the lowest formation *a* is really equivalent to *a*, 3 in No. 5, which was only a short distance to the northward, and is replaced by a layer of limestone in No. 4, which was a considerable distance to the north and east. This is shown by the position of the limestone immediately between the clays above, and the coarse layer below, in No. 4.

Thus all the layers found below *a*, 3 in No. 5, and the limestone just above *a*, 3 in No. 4, are absent in No. 6. The first of these is the coarse layer *a*, 2, in Section 5, and *a*, 3, in Section 4. The great increase in the thickness of this, is carried out in the Little Pit in the other beds also, so that it can safely be inferred that the beds grow deeper outwards in this direction, as well as probably to the westward where Dr. Hilgendorf dug. Thus *a*, 1, in Section 5, is shell sand and clay, becoming two layers and possibly more of clay, with at least three thick limestone partings in No. 4.

The conditions governing the deposition of the layers between these three places, therefore, must have been very different, though going forward at the same time, and at a short distance from each other, and two of them, 5, 6, in nearly the same depth of water. This conclusion is sustained also by the aspect of the layers containing fish remains, which occur in *b*, *c*, *d*, according to the observations made upon the adjacent Sections 3, 4, 5, and 6. The pit formations, in fact, show everywhere the exceeding variability of the conditions under which deposits took place in adjacent spots, for they cannot be dignified by the name of localities.

The fossils found in *a* of Section 6, comprised nearly the whole range of forms, and indicated also by the worn character of some of the *trochiformis* shells that they had colonized this locality from some other part of the lake. Those found in the lower part of *a* in contact with the Jura contained eight specimens of *Pl. trochiformis*, all in one spot together, with intermediate varieties $\frac{\textit{trochiformis}}{\textit{discoideus}}$, while at another place in the hole, only three feet distant, none were found of this species. No divisions were seen in this stratum, but the specimens were fewer in the upper part than in the lower. Fish remains occurred in a soft calcareous parting immediately between this and formation *b*.

This last fact is important, since it confirms the opinion that in all probability *a* in Section 6 is equivalent to *a*, 3, in Section 5.

Do the fossils differ in Section 5? The list given shows that in formation *a*, 3, only the following are found, *Pl. Steinheimensis, tenuis, discoideus*. If I had gone no farther, the absence of *Pl. trochiformis*, and the intermediate forms *Pl.* $\frac{\textit{trochiformis}}{\textit{discoideus}}$ might have been considered very significant in favor of Dr. Hilgendorf's view.

But the next lower formation *a*, 2, Section 5, at a lower level, contained the same general association of forms with the addition of *Pl. discoideus*, and $\frac{\textit{trochiformis}}{\textit{discoideus}}$. The lowest formation *a*, 1, contained even a more complete association of forms, and was not separable from *a* in Section 6, with which the specimens were finally mingled on plate 1 in order to complete the illustration of this stratum, which in both cases rested on Jura clay. But there was a much greater abundance of *Pl. sulcatus*, and the *Pl. trochiformis* was exceedingly rare, only one specimen being found, and that a rolled shell.

If we assume in accordance with the contained fossils, that these layers belong to the *Trochiformis* zone, the difficulties become greater instead of less, as we shall see farther on.

Dr. Hilgendorf in his communication "Neue Forschung in Steinheim," Zeitsch. d. Deutsch. geol. Gesellsch., 1877, p. 450, writes that he tried to find during his reëxamination of all these localities, single specimens of the higher varieties in the lower strata, but without success, and also that no less than five other competent observers failed in the same quest. This is very strong evidence, especially when taken in connection with the fact, that Dr. Hilgendorf, with a zeal which must make every one desire to agree with him, sunk no less than ten holes to the Jura, and took photographs and sections, going over all his observations again and again six times, with great care. Altogether the amount of time, trouble, and study he has expended is very remarkable, and worthy of the highest success, which I most heartily wish for him.

But although my observations cannot compare with his in these respects, there are certain facts which even the great mass of evidence he is able to bring to bear upon this subject, do not seem to make clear.

My two sections 5 and 6 reached the bottom of the deposits at the places where they were made. Whatever formations they represent, whether deposited in deep or shallow water, rest upon the original bottom of the lake. The *trochiformis* fossils are not only the remains of fresh, but also of rolled shells. These were found at a greater depth in Section 5 than in Section 6. Therefore, if bed *a* in Section 6 was the equivalent of Dr. Hilgendorf's *Discoideus* or *Sulcatus* bed, or even if *a*, 1 in Section 5, was so high, how was it, that on three occasions, and two different places, I found *Pl. trochiformis* there.

Dr. Hilgendorf's *Trochiformis* bed unquestionably lies immediately underneath *m*, the *Oxystomus* bed, in all my sections, and, if *a* in my section is part of the *Trochiformis* zone, then the *Trochiformis* bed would extend from *m*. to the Jura, a greater thickness, and a larger number of beds than could be included in that formation, and yet preserve the sequence of the forms as described by him, since under this again must come five out of the ten zones described by him.

His recent researches may possibly remove these doubts by showing how this can be accounted for, but there still remain other facts.

Unquestionable *Pl. oxystomus* occurred in the New Pit, much lower than *m*, the first true *Oxystomus* zone of the Old Pit and of the Cloister Pit, namely in *h*, Section 8, together with *P. crescens*,[1] which also ought not to have occurred until the *Oxystomus* zone was reached. *Pl. oxystomus* also occurred in Section 6, in bed *i* again in company with *Pl. crescens*.

Another point in this connection is the occurrence in *a*, 3, of Section 4, in a formation lower than *a* Section 6, and equivalent to *a* 2 in Section 5, of a specimen of *Pl.* $\frac{denudatus}{minutus}$. This is such an intermediate form as is figured on pl. 4, fig. 2, which does not occur until *e* is reached in the Old Pit, pl. 2, line *e*. This specimen was found when hunting

[1] This species also occurred in *f*, before *Pl. oxystomus*.

very carefully, by digging into the sides of the Pit, for the few specimens of *Pl. tenuis* which accompanied it.[1]

But what is more important, and to me most inexplicable in this matter, is that I failed to distinguish throughout any beds which could be considered as corresponding to those described by Dr. Hilgendorf as *sulcatus*, $\genfrac{}{}{0pt}{}{\textit{discoideus}}{\textit{sulcatus}}$, *discoideus*, $\genfrac{}{}{0pt}{}{\textit{trochiformis}}{\textit{discoideus}}$, *trochiformis* and *oxystomus*.

There were here and there beds, such as *a* 3, Section 4, which held only *Pl. tenuis*, but this had also $\genfrac{}{}{0pt}{}{\textit{denudatus}}{\textit{minutus}}$; *a* 2, Sect. 5, could have been $\genfrac{}{}{0pt}{}{\textit{trochiformis}}{\textit{discoideus}}$, but here was also *trochiformis*; and *a* 3, Sect. 5, could also have, but for this, been considered a true *Discoideus* bed.

Pl. minutus came in formation *d*, Old Pit — but how account for the earlier appearance of *Pl.* $\genfrac{}{}{0pt}{}{\textit{denudatus}}{\textit{minutus}}$ in *a* 3, Sect. 4, so much earlier, before the fish layers, and in what would otherwise have been a perfect *Pl. tenuis* bed. In the New Pit the same difficulty occurs with *Pl. oxystomus* and *crescens* which, as described above, put in an appearance too early, and spoiled the definition of the *Pl. trochiformis* formations.

So also, in the East Pit, formation *d*, *e*, otherwise a perfect *Pl. discoideus* formation, with *Pl. triquetrus*, and *Pl. costatus* and *minutus* as described by Dr. Hilgendorf, contained one or two *broken* specimens of *Pl. oxystomus*. Not much in themselves, but very significant when taken in connection with other facts, and also when it is considered, that to obtain these, I sifted considerable material taken from this very thick formation.

In this Pit, however, I could easily trace the kind of evidence brought forward by Dr. Hilgendorf, and from *d*, *e* to the true *Trochiformis* bed *h*, which would give a very perfect series from *Pl. discoideus* or *sulcatus* to *Pl. trochiformis*.

I can think of no way to account for these discrepancies, except the different results of different methods of research. My collections are much smaller, and my observations more limited than those of Dr. Hilgendorf, and therefore it may seem to some readers that it is presumptuous on my part to oppose his results, but from another point of view this only makes it more difficult to account for the exceptions which were found.

I feel myself, that the conclusions with regard to the Cloister Ridge rocks need more positive evidence than I have been able to bring forward, but the facts with regard to the occurrence of fossils in the Pit Deposits, are not in any case theoretical. The identifications are made after comparison with a set of types sent me by Dr. Hilgendorf, and after prolonged and repeated observations, and the discrepancies occur in species of marked characteristics, and easily identified. The method of research excludes error in any other respect as much as is possible in such investigations.

The theory also, which I have advanced, that the Cloister Ridge rocks really contained a more ancient fauna than the Pit Deposits, is substantiated by the geological facts, the fauna contained in them, the "*tenuis Tufa*," found lying on the Jura Clay, by Dr. Hilgendorf, and described by him in a letter to me, the structure of the lower beds of the Pit Deposits, and so on.

Again, the situation of the Cloister Pit, where Dr. Hilgendorf found a full series of beds near the highest elevation of the ridge, and which must be at least a hundred feet

[1] The sides of the Pit above in which the *Pl. denudatus* also occurs in formation *e* were removed well back, and this shell differs in color from them, and agrees with the bleached, dead white *Pl. tenuis* found with it.

higher than the Old Pit, seems to show that the relative depth to which one may dig in reaching the Jura does not count for much. The elevations which have taken place, and which of course primarily affected the Jura clay also, make it impossible to say that the strata represented in a hole, six feet deep in one spot, may not be of equal age with strata resting on the Jura, in a hole fifteen or twenty feet deep. The foldings of the formations and the broken aspect of the limestone layers above, show that restricted local and vertical movements in the formations have taken place, and that a general movement of the Cloister Ridge upwards has also taken place. This last would account for the greater thickness of the formations as a whole as we go outwards from the ridge, but not for the greater thickness of the same beds. If this is a fact, such formations as *a* 1, 2, Sect. 5, are older than *a* 1, Sect. 6; and *a* 1, Sect. 4, older than *a* 1, Sect. 5.

The great uncertainty in this problem is the variability of adjacent beds, as in *m–p*, of the two sections in the New Pit, or *d*, *e*, *f*, of the two sections in the East Pit.

Of course, if the fossils followed each other in regularly arrangeable series, as described by Dr. Hilgendorf, in a number of places, and throughout the entire series of formations from the Jura clay to *m* inclusive, in every pit and excavation, there could be no doubt, but, if they fail in a single section, it is fatal, provided the number of exceptions found are sufficient to eliminate errors of observation due to the accidental intermixture of higher occurring species in lower formations; and this appears to me to be the real state of the case.

The following section of Sandberger's is given in detail, because it was taken in the East Pit, which is likely to vary exceedingly with farther exploration, and also presents more difficulties than the others.

Sandberger's Section. No.		Metres.	Equivalents. Section 2, East Pit. No.		Formations.
1	Shell-sand	?			d
2	" "	1.10	2	Shell-sand	
3	Limestone	0.01	3	Limestone	
4	Shell-sand	0.20	4	Shell-sand	
5	Limestone	0.01	5	Limestone	e (2–7)
6	Shell-sand	0.22	6	Shell-sand	
7	Limestone	0.02	7	Limestone	
8	Shell-sand	0.30	8	Shell-sand	
9	Limestone	0.01	9	Limestone	
10	Shell-sand	0.08	10	Clay	
11	Limestone	00.2	11	Limestone	f (8–14)
12	Shell-sand	0.30	12	Shell-sand	
13	Clayey-sand	0.16	13	Clay	
14	Limestone	0.58	14	Limestone	
15	Shell-sand	0.45	15	Pocket shell-sand	
16	Clayey-sand	0.15	16	Clay surround'g 1st Pocket of shell-sand and also occupying centre.	g[1] (15–17)
17	Limestone	0.02			
18	Shell-sand	0.50	17	Pocket shell-sand	
19	Limestone	0.04	18	Clay	h (18–19)
20	Shell-sand	0.50	19	Shell-sand	

Sandberger's Section. No.		Metres.	Equivalents. Section 2, East Pit. No.		Formations.
21	Limestone	0.03	20	Limestone	
22	Shell-sand	0.12	21	Shell-sand	
23	Limestone	0.05	22	Clay	
24	Shell-sand	0.28	23	Shell-sand	
25	Limestone	0.02	24	Clay	i (20–28)
26	Shell-sand	0.09	25	Shell-sand	
27	Limestone	0.06	26	Limestone	
28	Shell-sand	0.14	27	Shell-sand	
29	Limestone	0.04	28	Limestone	
30	Shell-sand	0.12			
31	" "	0.03	29	Shell-sand	kl
32	" "	0.62			
33	Limestone	0.05	30	Limestone	
34	Shell-sand	0.97	31	Shell-sand	x1
35	Limestone	0.16	32	Limestone	m (32–33)
36	Shell-sand	0.85	33	Clay	
37	Limestone	0.09	34	Limestone	
38	Shell-sand	1.30	35	Shell-sand	n–o (34–37)
39	Limestone	0.25	36	Limestone	
40	Shell-sand	0.25	37	Clay-sand	
41	Limestone	1.20 (41–42)	38	Shell-sand	x3
42	Shell-sand				

My own Section 3, was not taken directly up the face of the cliff, but in two connected parts of the cliff, and Section 2, from a hole in the centre of the pit.

[1] The correspondence here is much confused on account of the distribution of the shell-sand in pockets in the midst of the clay.

It is quite curious that under these circumstances, such a close agreement could have been obtained as is exhibited in the preceding table. In this table, however, I have taken the liberty to transform the word sand into shell-sand, otherwise Sandberger's table is given literally. This was done, because in my own notes and sections all hard sand is put down as shell-sand, whether entirely composed of shells and their fragments, or largely made up of detritus.

The sections from 1–8 inclusive, were taken from the précipitous sides of the various pits, which are located on the Geological Map. The measurements were taken with a rule or tape in millemetres, from the face of the strata, and in no case estimated. Nevertheless, the thickness of the limestone partings are quite often exaggerated, in order to make them of an appreciable thickness in the printed sections, where, if reduced to $\frac{1}{100}$, they would in some cases be too thin to show the cross-bars which indicate their lithological character.

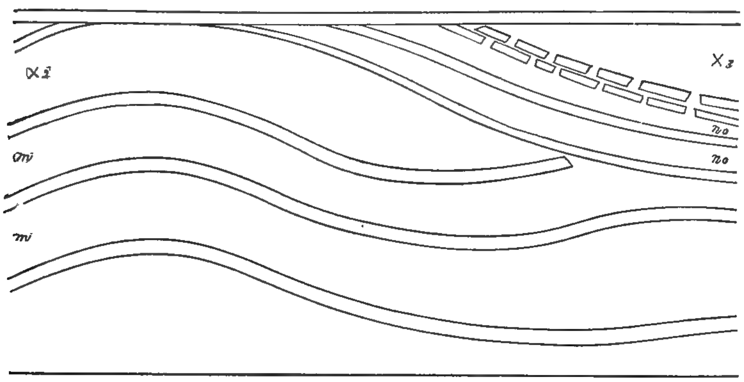
It may be said that there is general prevalence of the clay layers below in the lower parts of Sections 4, 6, and probably also in 2, 3, and 7, 8, if they had been penetrated sufficiently; and that these clay bands are for the most part destitute of fossil shells. Above the fish layers *c* the sand predominates until we reach formation *m*, when the clay again appears in excess. It will be observed that this coincides with the three great faunal groups which may be made, the period of the *Pl. Steinhemensis* which is rare above the fish formation *c*; of *Pl. trochiformis*, which is so abundant from formation *d* to *l*, inclusive; and of *Pl. oxystomus* which is equally characteristic of formations *m* to *o*, inclusive. This is apparently contradicted by the prevalence of clay in formations *f* to *i*, inclusive, in sections 3 and 4. We can, however, account for these as unfossiliferous partings between the layers of shell-sand, corresponding to the limestone partings of the the other sections.

Notwithstanding this apparent correspondence between the kind of bottom obtaining in the lake at any one time and the species of shells living at that time in the waters, there are many failures which prevent the application of this rule in detail. Thus, the *oxystomus* series, which is prevalent in the clays of formation *m*, in Sections 3, 7, and 8, are equally prevalent in the sands of the corresponding formations in the Cloister Pit, and in the Coarse Limestone of the Lower Period. *Pl. trochiformis*, also, which appears usually only in the shell-sands, is very abundant in the upper clays of Section 8, and the formation *p*, of Section 7. All species seem to be found in about equal abundance in the limestone partings, but are rarer and often entirely absent in the thin clay layers, or partings described above, and in some of the thicker beds.

Nevertheless, the general tendency of the observed facts, leads to the conclusion that the entire series of animals found below formation *m* preferred to inhabit localities in which sand was being deposited, or had sandy bottoms, and those from formation *m* upwards were either equally well fitted for clayey or sandy waters, which seems the most probable conclusion, or preferred to dwell in clayey localities.

This conclusion derives additional probability from the fact that the return of the *trochiformis* fauna, which occurred in formation *x*, in the East Pit, Old Pit, and New Pit, was accompanied by a deposit of shell sand.

The dip of the strata is quite irregular, considering the limited boundaries of the pits, varying from 10° to 30° of inclination outwards on all sides of the central hill. This elevation, to a certain extent, evidently took place before the formations of the pits were entirely completed. This is shown by the pocket containing the *Pl. multiformis* and *Pl. discoideus* shells in the New Pit, and also by a similar pocket in the East Pit.



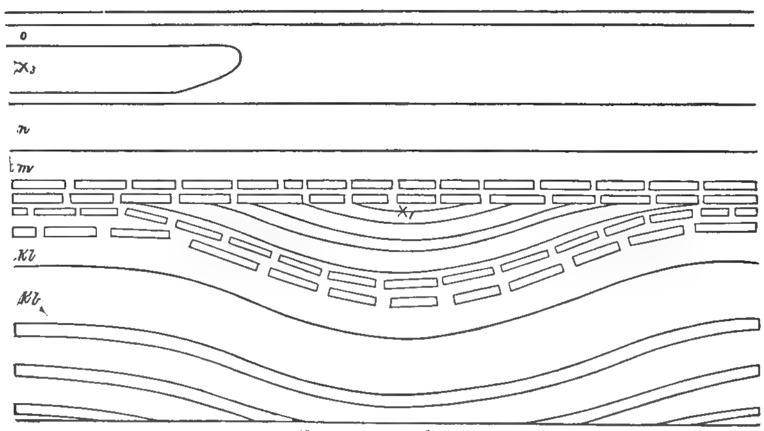
Section 9.[1]

Formations *m* and *x* 2 of Section 9 were evidently deposited one upon the other in the New Pit. The only way to explain the appearance of the wood-cut, after this, is to imagine that the folding took place along the lines of elevation. The wood-cut represents a section at right angles with the dip, so that the folds run across the strike of the layers.

Subsequent to the folding, a certain amount of denudation must have removed part at least of the bed *x* 2, and the upper part of the bed *m*, in order to permit the deposition of *n o*, and *x* 3.

Whether the same tendency to fold continued, caused by the resumption of the process of elevation on either side of *x* 3, and gave the basin-shape to *n o*, deepened the folds on either side, but did not alter them otherwise, leaving *x* 3 a symmetrical hollow, or saucer-shape, is doubtful. They seem to belong to the same system of folds as *x* 2 and the want of *x* above is probably due to local denudation. On the face of the pit on the north side of *x* 3, this is shown by the anticlinal bend in *m*, but even more perfectly by the fact that *n o*, and *m* become exactly parallel farther to the north.

Section 10 shows that somewhat similar conditions must have obtained in the East Pit at about the same time. Unfortunately I had confused the samples from *x* 1, with those from *k*, and consequently only rely on my notes made upon the detailed section. These speak of *trochiformis* in two places as prevalent, but not abundant; whether, therefore, other fossils occurred with this I cannot say.



Section 10.[1]

Here the bed *x* is in both cases a pocket—in one case in a fold, and in another evidently occupying a hollow in an undisturbed clay layer. It is very evident that formation

[1] These sketches are not drawn to any definite scale.

x 1 of Sect. 3, and Section 10 above, and of Sect. 6, is not the same as formation x 2 of Sect. 7, since they are separated by the clay bed *m*, and for the same reason formation x 3, of Sections 3 and 7, is not the same as x 2, since these are separated by formations *n* and *o*. There are really, therefore, three series of formation x, due to the colonization and re-colonization of the same spots by the persistent forms of *Pl. discoideus* and *Pl. trochiformis*. How is it possible for x bed fauna to alternate in this way with clay in pockets, or in folds, as the case may be, or with beds of pure shell-sand and shell, without recognizing their resemblance to the same mode of occurrence of similar pockets in many of the clay layers below? That they were ruins of the older *trochiformis* formations and were swept into these well defined local depressions is of course possible, but it is an assumption which an experienced collector would be slow to adopt. It is a well-known fact that deep holes in water-ways are usually more or less filled with dead shells of various kinds, but these usually exhibit decisive marks of the rough handling they have received from the currents.

This does not appear in the shells of the x beds so far as I have observed them, and even in such a small lake as Steinheim this must, I think, be asked for. Many shells are unquestionably water-worn and, if so, why not all in these beds if, as claimed by Dr. Hilgendorf, they are made up of wholly transported materials.

The upper layer of limestone in the Old Pit, and all the layers of limestone above formation *l*, in the East Pit are fragmentary. These fragments lie more or less closely together, and look very much like continuous layers broken up in place by the bending of the strata. Whether these may be taken as evidence that the strata lying upon them at the time of their last elevation was not of great thickness, it would be hazardous at present to say. One fact, however, seems to indicate something of this sort. The limestone above *l*, was probably free from any great pressure at the time the folds took place, which formed the pocket at x 1, in section 10, as also was that of *l* in the Old Pit. This suggests that the same condition of affairs probably occasioned the breaking up of the succeeding layers in the East Pit.

The formations seemed to have been disturbed in the East Pit, and in the Old Pit, at about the same time, that is after the deposition of x 1 upon *l*, or *k*, *l*. This did not seem to affect the strata in the New Pit, however, until after the deposition of clay beds containing fossils, which caused me to synchronize them with *m* and *n*, *o*, in the East Pit, and the bed x 2 which was deposited between them.

The broken aspect of the layers of limestones were not, when I saw them, similar to the descriptions given by Dr. Hilgendorf in "Neue Forschung in Steinheim," p. 452, but possessed in all the cases observed by me, a regularity which I could only account for as the result of the bending of the strata after deposition. It is well known in this country that not very dissimilar effects occur from the compression of gneiss occasioned simply by the removal of the superincumbent rocks. The upper layer relieved from the weight, in some spots forms miniature anticlinals and synclinals, and in others bursts with considerable violence in the quarries of Monson, Mass., where these phenomena have been observed by Prof. W. H. Niles.[1] I could not understand the reg-

[1] Proc. Bost. Soc. Nat. History, XIV, 80.

ularity which the upper layer of limestone in the pits presented, if the pieces were transported there, and thrown loosely together.

It will, however be observed, that formation *m*, of the Cloister Pit, presents a fauna closely similar to *m*, in the other pits, and that of *n o* above in all of the pits is quite as similar to *m*, as the fauna of *x* 3, above is to that of *x* 1, 2, below, wherever that bed occurs twice. There is, it seems to me, just the same reason for maintaining that *m* and *n o* are composed of drift, as there is for maintaining that *x* is made up in this way. In conclusion, I would say also, that there are the most positive reasons for the belief that *x* in Section 8, represents the upper and not the lower bed *x*, of Section 7. I find it so mentioned in my notes and sketches taken on the spot. I was, however, unable to say whether *m* in Section 8 represented *m* alone, or both *m* and *n o*, of Section 7, with absolute certainty, since the south-east corner of the pit was concealed by a recent and heavy fall of loose materials. One thing, however, can be said with certainty, that a bed corresponding to lower *x*, on the east side of the pit, as represented in Section 7, is not to be found on the south side, and the thickness of the clay on that side is very nearly equal to that of the two clay beds on the east side, and it has every appearance of being continuous with those two. If, therefore, lower *x* is drift, it had a very limited distribution, since it is certainly not found on the south side of the New Pit. This also corresponds with the unquestionably mere pocket-like aspect of the upper *x* deposit in the East Pit, and is evidently not in harmony with the supposition that this is a bed of detrital matter, as represented by Dr. Hilgendorf, spreading over the entire bottom of the lake.

I do not consider this point of any great consequence, or worthy of much debate, since it makes not the slightest difference with regard to the main question, whether *Pl. trochiformis* lived after the *Pl. oxystomus* bed was deposited, or not; though it is of vital importance to determine whether *oxystomus* preceded *trochiformis* in time.

One statement, however, of Dr. Hilgendorf's is of great importance, since it shows that very considerable changes likely to disturb the regularity of the deposits in very confined areas, as is claimed here, did occur in one case, whether they occurred in the latest *Trochiformis* bed or not. On p. 452,[1] he states that in the *Sulcatus* bed he found broken *Steinheimensis* clays "Platten," "*tenuis* Gesteinen," blocks of porous *sulcatus* tufa, clayey sand and Jura pieces, all mixed in the greatest confusion, and two metres thick. This mass evidently was of very limited extent and shows how great are the local peculiarities likely to be found in any one spot from the transportation of material.

As he says, these mixtures are apt to escape a careless observer, and I might add also, any one perhaps, not especially looking for them. In this extraordinary mixture, however, of the *Sulcatus* zone, he found no intermixture of the higher occurring forms. This fact he justly regards as very important to his hypothesis, since the rocks also are all older than the stratum or zone in which he found them.

The characteristics and situation of the bed *l* appear to make it very suitable as a standard for the comparison of all the formations above and below its level. It occurs immediately between the beds containing the *trochiformis* fauna, and those containing the *oxystomus* fauna, and it affords a strong contrast in its fossils and lithological characters, and is also apparently universal in its distribution. These reasons have induced me to

[1] Neue Forschung in Steinheim, Zeit. d. Deutsch. geolog. Gesellsch. 1877.

adopt it in the table as a fixed level through which I have drawn a dotted line. Departing from this in any section, it becomes possible to synchronize the different formations.

If we assume that the usual sedimentary matter held in suspension by the waters of the lake was clay, and that these waters were saturated with lime, we have an explanation of the rapid formation by deposition of the plates of limestone. This being the necessary consequence of the undisturbed action of the water, we should have the dense limestone layers deposited on the bottom wherever the currents were not disturbing it and spreading out the coarser sand derived either from the Cloister Ridge rocks or the adjacent surfaces of the Jura.

The constant shiftings of the local currents, due either to the obstacles they themselves had built up or other disturbing causes, would produce this aspect of regularity in each section of the layers, as well as the want of correspondence in the synchronous deposits of even adjoining sections.

The widely distributed formations could never be limestones, but might occasionally be composed of materials derived during floods from the surrounding country, that is of clay or sand. A glance at the sections will show that this is the case since *e* is of shell-sand, *m* of clay, and none of the limestone tables are continuous. The general changes, the predominance of shell-sand during the *Trochiformis* period, and of clay during the *Oxystomus* period, would also seem to be accounted for by a greater or less prevalence during a certain number of successive seasons of similar deposits, due to changes in the localities from which the greater part of the drainage was derived, or to other local causes.

In this condition the Steinheim deposits of the Pits assume the aspects which might be expected to arise in a land-locked lake with a central island. The deposits would be formed in some places from the debris washed off of the rapidly disintegrating surface of the island, and in others, even in close approximation, the ordinary formation of limestone or the precipitation of fine sandy material, or flocculent clay, might take place in quieter water, or farther from the shore. Any of our inland lakes present similar conditions wherever local streams empty into them. During heavy rains as at dffierent seasons of the year, the debris of the beaches and bottom is subject to noticeable variation within very short ranges.

Another fact in this direction indicates also that the amount of time represented by the Steinheim Pit Deposits must have been very limited. Strata slowly formed are marked off in exceedingly thin layers, since but a small amount of fine sediment is held in suspension by the water, and slowly deposited during a given period of time. The thicker layers result from a larger amount of sediment which has been held in suspension and falls with greater rapidity. This accounts for the finer bedding of the clays, fine grained sandstones, limestones and so on, as contrasted with the coarser rocks and rubble.

The strata and sometimes entire thick beds of shell-sand bear no marks of stratification, and must, therefore, have been built up by continuous and rapid deposition. The clay layers are of various degrees of thickness, but usually an inch or more, and very rarely of paper-like thinness, and this is true also of the limestones. The fish-layers of formation *c* are particularly instructive in this respect. The fishes being necessarily very destructible, testify to several things: first the rapid deposition of the layers, which are an inch or more in thickness; second, the prolonged continuance of conditions about equally favorable to the rapid formation of limestone, or of clay strata; and third, the unfavorableness of the waters, at this time, to the existence of the fish, which must have died in vast numbers.

None of these facts, so far as the Pit Deposits are concerned, are in favor of the vast periods of time which have been claimed by Darwinists, in order to account for the changes which are supposed to have taken place in the fauna of the lake during the Upper Period.

There is only one fact which would seem to interfere with this conclusion. Some of the "shell-sand beds" are mostly composed of broken shells, and it may be inferred that they are wholly made up in this way. This may possibly be so, in some instances, in the middle part of the deposits, but is of local occurrence, and not a general characteristic. The limestones would come under this head more than any other, as might have been anticipated from their chemical constitution, but even here in most cases the matrix is an even-textured argillaceous limestone, and is not invariably composed of shell fragments alone.

It is very evident that the formation of the strata, either by precipitation or deposition, was going on all the time, either as clay, limestone, or shell-sand, all over the area described. The apparently regular interruption of the deposition of the clays and shell-sands by beds of limestone are too local to indicate in any very positive way the constant recurrence of periods of time or seasons when the waters of the lake were generally affected, and contained so little transported sediment of any kind, that limestone layers could be formed on the bottom which would be continuous. These facts, the local distribution of the beds of shell-sand in some clay strata, as in Section 3, and in several instances not sketched in the section, in the East Pit and New Pit, the dark clay band *d*, Section 2, in the midst of shell-sand, all appear to show that the unstratified beds were swept into the spots where they are now found by currents of greater or less strength, and built up continuously during a period of time limited by the extra supply of water rushing down from the drainage of the island, or the neighboring hills, or both. This extra supply of water could only recur at certain seasons of the years; therefore the unstratified beds either represent rainy seasons, and the intermittent local currents which they would naturally produce, or constant currents shifting in position from year to year, or season to season.

If the latter theory is accepted it becomes exceedingly difficult to interpret the regularity with which the coarser beds were locally interrupted by the limestone layers, without assuming that there were years or periods of years, during which the currents flowed constantly bringing in shell-sand, and then shorter or longer periods of months or years of rest. These would occur at regular intervals during which the currents flowed somewhere else to return again by some inexplicable fatality directly over the same spot, begin to increase in volume, and move so fast that shell-sand could be again transported.

The latter hypothesis appears to me to present by far the greatest difficulties, besides being contrary to experience. If we adopt the former, the Steinheim Pit Deposits show a very limited thickness, for the most part of loosely aggregated materials which must have been heaped up in a shorter time than one would be led to suppose by the number of new fossil forms produced and by a cursory examination of the strata.

I cannot, of course, presume to say that the period of time represented by the Pit Deposits was or was not long enough to allow of all, and more than all the changes which took place in the fauna, but simply point out the fact, that no grounds exist for the assumption that they represent any very prolonged periods of time, such as have been habitually, and, in my opinion, erroneously claimed, by most naturalists, as essential for serious morphological changes in animal series.

Professor Cope's researches among fishes and reptiles, the author's among the Ammonites, and, at a later date, Mivart's work on the "Genesis of Species," have all given a large amount of evidence, which tends to show that vast periods of time are not necessarily essential to the production of new species, or even new generic or family forms. Nor is yet the converse true, that animals which have lived through great periods of time, and many geological changes, are necessarily and correspondingly altered in their organization. The testimony of all paleontologists bears witness to the last statement, but the first requires more proof, and for this I must refer my readers to the authors above mentioned.

In the chapter on the geology of Steinheim, an attempt has been made to show how great the denudation of the surface of the rocks of the Cloister Ridge must have been, and that a part of it probably took place before and during the deposition of the lower part of the Pit Deposits. The evidence that a great amount of denudation has occurred since the Pit Deposits were formed, would not need to be summed up to any one who had seen the locality.

The whole area of the circular valley must have been at one time covered to a considerable depth by stratified deposits similar to those of the Pits, either resting upon the denuded limestones of the Lower Period, or what is more probable, merely abutting against these remnants on the sides of the valley. These have almost entirely disappeared, since what is left adhering to the sides of Cloister Ridge can only be considered as the merest fragments of what the mass originally was. What the vertical height of these deposits must have been is of course wholly problematical. Sufficient evidence has been brought forward to show that, though the elevation of the Cloister Ridge took place before the Pit Deposits were formed, this elevation was continued certainly after their deposition was completed, and probably also went on more or less while they were being deposited. This of course, would be an element in the problem, as well as the determination of the extent to which the neighboring heights and the outlets, which once bordered and limited the depth of the waters of the lake, had suffered from sub-aerial denudation. This portion of the problem, therefore, can only be safely approached by a local geologist, and it would be idle for any one else to attempt an estimate. That the Pit Deposits were much thicker than they are at present, and that they present in every way only fragmentary evidences of what the fauna of the lake was, as well as of its geological history, can hardly be gainsaid, unless different conditions governed in former periods from those which we now find in similar localities.

It remains only to add that ample provision for the removal of any required thickness of deposits once probably existed in the drainage of the surrounding mountains. A proportion of this even now passes through the valley of Steinheim to the Steubenthal as described in Quenstedt's article previously quoted, and ample evidence of the former existence of a more powerful stream, may be found in the official geological map of Wurtemburg, "Heidenheimer Blatt," and its accompanying text by Prof. Fraas.

IV. Descriptions of Series and Sub-Series.

FIRST SERIES.

Planorbis minutus.

Planorbis multiformis minutus Hilg., Monatsber. d. Akad. d. Wissensch., Berlin, July, 1866, f. 15.

Pl. Zietenii (pars) Sand. Land und Süssw. Conchyl. d. Vorwelt., p. 645.

Pl. hemistomà Klein, Jahreshefte Ver. Naturg. Württemb. 2 vol. 1847, pl. 1, fig. 25.

This remarkable species seems to have in the aspect of the whorl, and the general thinness of the disc-like form a very close affinity for *Pl. crescens.* It differs, however, in the greater involution of the whorls in the healthy forms which precisely resemble *Pl. Kraussii,* in the aspect of the umbilici when viewed from above or below. This part is narrower, and the internal whorls less exposed than in *Pl. crescens.* It is plain that a flattened form of *Pl. Kraussii* would be precisely intermediate between these two. After much search, I found a specimen which was a trifle flatter than the usual square form, the outline being similar to that of *Pl. minutus*, but it was still considerably larger than the ordinary specimens of this species, and could not be considered a hybrid. A close comparison between the largest *minutus* and *Pl. parvus*, was more successful. The typical *minutus* forms have a narrow umbilicus, as compared with *Pl. parvus*, in any of its varieties, but this characteristic is exceedingly variable in the species, and many of the specimens have a wide umbilicus on the lower side. If we compare these with the young of *Pl. parvus*, as figured on pl. 3, line *a*, fig. 6, 20–22, they will be found to be almost identical.

Var. *minutus* can by no means be considered the ancestor of var. *parvus*, on account of closer affinity of the latter for *Pl. levis*, and Hilgendorf has also found it in company with *Steinheimensis* in the lowest formation. Both Hilgendorf and Sandberger decided that the affinity of this species was closer for *Pl. levis* than for var. *Steinheimensis*, and this is also my own conclusion. My observations agree also with those of Hilgendorf, in respect to the derivation of *crescens* from *parvus*, and with both his and Sandberger's, in tracing a close affinity with *Pl. minutus*. They differ, however, in preferring to trace a direct connection between *Pl. minutus* and *Pl. levis*, through the normal forms of both species, rather than through the aequiumbilicated varieties of *Steinheimensis*.

Again, if we compare a large *minutus* with the forms of *Pl. parvus* having an angular outer whorl, pl. 3, line *k*, fig. 1, this similarity strikes the eye very forcibly. Compare also the figures of *parvus* on pl. 3, with the those of *minutus*, line *a*, pl. 4. This connection with *parvus* settles the question of size, since this variety of *parvus* is certainly an intermediate species in this respect, between *minutus* and *Pl. levis*. I have, therefore, separated this angulated form of *parvus*, figs. 1–4 and 11, line *k*, pl. 3, under the name of $\frac{minutus}{levis}$, to distinguish it from the normal forms of *parvus*, which lead into *Pl. crescens*.

It only remained, therefore, to find some form of a full-grown specimen from Undorf, which would show the characteristics of *Pl.* $\frac{minutus}{levis}$. This, on the reception of Sandberger's specimens, was accomplished, and is figured on pl. 9, fig. 16.

Starting then with *Pl. levis*, we can trace this series through a variety found in the Pits which we call the ${}^{minutus}_{levis}$ (equal *Pl. m. parvus* Hilg. in part), into the more angulated varieties of *Pl. minutus*. This last figured on pl. 9, fig. 17, and line *e*, fig. 16, pl. 2, is the *Pl.* ${}^{triquetrus}_{minutus}$ of Hilg. Notwithstanding this name it will be found by comparison with such forms as have just been mentioned, as *Pl.* ${}^{minutus}_{levis}$, that it differs only in size. This leads into a variety of *Pl. minutus*, fig. 18, pl. 9, and fig. 1, line *e*, pl. 2, in which the breadth and angularity of the inner part of the aperture is still maintained, but the shell is otherwise a variety of *Pl. minutus*, and has the thinner proportions of the young whorls observable in this species. Both this and fig. 17, pl. 9 seem to fade by imperceptible gradations into fig. 19, *Pl. triquetrus*, also figured in nos. 1–3, pl. 4, line *c*. Or they may be traced into the less involute forms of *Pl. minutus*. These have exceedingly cylindrical whorls, and umbilici entirely open on both sides, and connect the more involute or *levis*-like *minutus* forms, with the uncoiled *Pl. denudatus*.

Remarks: On pl. 4 this genetic series is fully illustrated. Line *a* exhibits various varieties of *Pl. minutus*. These appear to be identical with the *Pl. m. minutus*, var. *β teres* of Hilgendorf in part, and in part are equal to his *Pl. m. minutus*, var. *α typus*.

I think that figs. 1, 3, 5, 7, line *a* would be considered as belonging to the first named. The figures on line *a*, however, are arranged with the view of exhibiting the varieties which tend to deflect the whorl by growth against the spiral. Fig. 7 is an extreme form in this respect. Figs. 2, 4, line *b*, are typical *minutus* forms, and connect directly with *Pl.* ${}^{triquetrus}_{minutus}$ figs. 7–8, line *b*. These have a closer umbilicus on the lower side (compare figs. 2 and 6, line *b*), and in this respect approximate to *Pl. triquetrus*. This last named species is figured on line *c*, figs. 1–5. *Pl. triquetrus*, var. *turbinatus* figs. 5 and 9, line *b*, the latter a section, exhibit very distinctly the tendency towards trochiform growth of the spiral, which is common in all the species and varieties at Steinheim. This also, is the proper place to notice the modes of variation among Steinheim shells.

It will be observed that the varieties of any one of the forms previously described fluctuate between two extremes so far as the spiral is concerned. As in the case before us these extremes are indicated by a tendency to reverse the spiral in some forms, and to increase it in others. This correllates with a widening of the umbilicus on the lower side in the former, and a narrowing of the umbilicus in the latter.

These two again correllate with more cylindrical whorls in the former, and wider or larger whorls in the latter. The latter correllation is important, since it enables us to draw one more important distinction between the healthy and unhealthy series, or the progressive and retrogressive, as I have called them. Thus on the Summary Plate, pl. 9, series 2–4, exhibit this in a marked manner, and so also does sub-series 3, which thus shows another progressive characteristic besides those previously enumerated.

If there is any truth in the assumption that health marks the favorable character of the surroundings, and that such correllations are signs of healthy growth, then the sub-series previously assumed upon other grounds to be diseased or unhealthy, might show the universal tendency to form a spiral, but ought to be deficient in healthy characteristics. I have already shown this to be the case in different degrees according to the character of the sub-series, and I now have to add, that they are in a measure exceptions to this law of correllation, since in sub-series second, the whorls become less in respect to their breadth, or more cylindrical as has been previously stated. It will also be seen by looking at pl. 4, that there is a decided increase in size in the costate sub-series, as was to be anticipated in correllation with the partially progressive characteristic of the well-marked costæ which appear in this sub-series. The contrast between the large and comparatively healthy specimens of this sub-series and the smaller distorted ones, is very well shown also on lines *h* and *k*, as contrasted with *g* and *i*. This tendency to such correllations as here described, show that the varieties of each species are quite closely parallel with the general progress or morphology of the most advanced group, the Fourth Series.

Thus not only does every species vary from a more or less aequiumbilicated to a more or less asymmetrical *rotundatus* or *trochiform*-like shell, but the whole series of changes in form of the Fourth Series is similar. See pl. 9, figs. 1–7.

To this I might add if space permitted, many other examples among the fossil Ammonites and living animals. In fact, in my experience, the general limits of variation are indicated in the range of form of almost any numerously represented species of a group. The difference between the morphological range in a species of this kind and the group to which it belongs being one of degree, one of quantity rather than quality,[1] or otherwise there could be no parallelism between the morphological variations of form in the species and the series of forms, which are comprised in the group to which the species belongs.

Planorbis triquetrus.

Planorbis multiformis triquetrus Hilg., *Op. cit.*, fig. 17.

Var. *typica.*

Fig. 18, pl. 9, leads into shells, fig. 9–23, line *g*, pl. 2, in which the upper side becomes slightly channelled, and sometimes the lower side also, as in Hilgendorf's figure. We are here presented with a remarkably close parallelism with the thinner forms of *Pl. tenuis*, but it is not very difficult to separate even large perfect forms of *Pl. triquetrus* from the young of forms which are figured in the two lines below on the same plate.

Var. *turbinatus.* This includes three specimens, which, as in figs. 20, pl. 9, or figs. 5, 6, 9, pl. 4, line *b*, become more trochiform than var. *typica.*

Planorbis denudatus.

Pl. multiformis denudatus Hilg., *Op. cit.*, fig. 19.

Hilgendorf's arrangement of the derivative forms which may be designated by this name, appears to be defective, in so far as he traces the uncoiled, smooth or "*denudatus*" variety, to the coiled and round whorled "*costatus*." My collection gives a perfect series, without break of any kind, from the perfectly smooth *Pl. minutus* to a completely asymmetrical shell, which differs but slightly from Hilgendorf's figure of *Pl. denudatus.*

[1] It must always, however, be understood that parasites do not come under this law, nor any range of forms however closely connected, which have been placed in exceptional surroundings. As previously stated, the environment is the supreme modifier, and the reaction of the organization against the environment, and the maintenance of the type by this reaction, cannot survive in the presence of continuously exceptional surroundings.

Thus, figs. 1–5, 7–8, 10–14, line *e*, 6–8, line *g*, pl. 2, show this series perfectly enough, though too slightly magnified to be convincing with regard to the smoothness of the shell. I have been unable to detect any costæ on any of these shells, and have seen much more turbinate forms than fig. 8, line *g*, almost completely uncoiled. I have, however, not yet succeeded in finding the exact equivalent of Hilgendorf's figure, which must be very rare.[1] The forms which have the young so completely *trochiform*, usually have the last-formed whorls widely uncoiled instead of being so contracted as in his typical specimen.

On pl. 4 this series is shown fully and may be followed from the *minutus* forms through such specimens as figs. 6–9, line *c*, and the more uncoiled forms on line *d*, to the completely trochiform and uncoiled shells photographed on line *e*. None of these show any costæ.

The decrease in the breadth of the whorl of the specimens on lines *d* and *e*, as compared with the specimens less uncoiled on line *c*, and the true *minutus* forms is also perceptible. The flat form of the young in figs. 10–11, line *e*, can also be perceived, though less perfectly because the minute size of fig. 11 threw the lower part out of focus.

This young is like the young of *Pl. minutus*, and of *Pl. levis*, but I failed in finding an adult of any of these forms which could be considered identical with it. This was not a surprising result, since any resemblance occurring at so early a stage with any adult form in the shell alone was not to be anticipated, especially with the adult of any proximate ancestor.

The law of accelerated development by heredity, which has been noticed in other series, is here also demonstrated. The uncoiling begins at earlier and earlier stages in the different species, and it is the same story with the increase in spirality. If any arrangement in series is in general terms a fair presentation of the natural accession of the forms, then this law must be admitted. It will be found to hold equally well when applied to any serial arrangement of species based on all the attainable evidences of affinity, in the identity of the extreme young stage, the resemblances of the succeeding stages to supposed or traceable ancestral forms, and the similarities of the adult, old age, and diseased forms.

I have already sufficiently traced the resemblances between these retrogressive uncoiled species and the partly uncoiled, diseased shells of the progressive series photographed. Figs. 4–5, line *a*, 4–5, line *b*, and 1–2, 6, line *c*, pl. 8, are particularly instructive in this connection, since figs. 4–5, line *a* are senile deformities, figs. 4–5, line *b*, the results of normal disease, and the remainder doubtful or due to wounds.

The series traced by Dr. Hilgendorf between this species and *costatus*, can undoubtedly be formed, but it seems to me perhaps more natural to consider the costate forms as a distinct sub-series. They can certainly be separated quite as easily as any other set of species, if we recognize the fact that the different series all have a tendency to reproduce similar series of forms, which may be arranged in parallel lines.

[1] This defect in my own collection has been most generously supplied by Dr. Hilgendorf himself, and I feel deeply indebted for the beautiful specimen of this form, which he has sent me.

This appears also to have been the result arrived at by Sandberger, though from his conclusion, I must also differ in part, on account probably of the opportunities afforded by a larger amount of material, which has enabled me to trace the connection of *costatus* with $^{minutus}_{levis}$.

Planorbis costatus.

Planorbis costatus Klein, *Op. cit.*, pl. 1, fig. 24.
Pl. multif. costatus Hilg., *Op. cit.*, fig. 18, 18 a.
Pl. costatus Sand., *Op. cit.*, p. 647, pl. 28, fig. 5.
Var. $^{costatus}_{minutus}$.

In order to understand what follows it becomes necessary to trace the relations of the striæ of growth, and the costæ of the shells. It will be observed that the striæ of growth are of various degrees of fineness and prominence in all the species of the Steinheim Planorbidae. Sometimes they are hardly observable, since they are not prominent enough to be seen with the unassisted eye, though visible with a magnifier of four diameters, as in *Pl. minutus* and *denudatus.* There are all degrees of this in *Pl. Steinheimensis* for example, until we find specimens in which they are plainly visible by the naked eye. In other species, such as *Pl. tenuis, discoideus, trochiformis, oxystomus,* and *supremus,* they are distinct enough in many specimens to catch the light, and be visible in the photographs, and in all specimens with the naked eye.

This is also an effect of old age, as in the older portions of the whorl of the senile specimens of *Pl. supremus,* fig. 1–4, line *d,* pl. 8. In these, and in many others, any cause which retards or arrests growth, causes an increase of shell deposits at the lines of growth, and a consequently greater prominence of the striæ. That these more prominent striæ may be also a hereditary characteristic in perfectly healthy shells is demonstrated by such series as *Pl. levis* to *Pl. crescens,* and others, and by *Pl. discoideus* var. *sulcatus,* etc.

In *Pl. crescens* they are visible under a magnifier, as in *Pl. Steinheimensis* and *Pl. levis,* and in none of these, or in equally finely preserved shells of *Pl. minutus,* is there any tracable difference except in point of fineness. This fineness also differs in different shells of the same species, precisely as it does between different species, being finer in some than in others, according to the rate of growth of the animal. Between each projecting ridge or striation there is a (usually, but not invariably) sunken smooth band of exceedingly variable width in the same shell. At intervals there are striæ, more elevated than the rest, more elevated than those on either side of them, which are the costæ proper. They are formed by an arrest of the growth at this point, occasioning a slightly greater thickening of the shell. The rim of the opening not being absorbed in these shells, when growth is resumed at the usual rate of increase, and the true striæ begin to be again formed, there remains a larger and more prominent ridge. These costæ will often occur is some specimens of a species, and not in others. They are quite rare in those species which, like *Pl. Kraussii,* have very fine striæ of growth, but can be distinguished in some specimens. Care must be taken in both this and *Pl. minutus* to obtain shells which have not been acted upon by any re-agent. The larger number of the shells of *Pl. minutus*, and a very large proportion of *Pl. Kraussii* appear to have been subjected to the action of an acid sufficiently powerful in many instances to cancellate the outer surface, and destroy the striæ. It is, however, easy to distinguish the perfect shells after a close examination, though sometimes the striæ are so fine and equal, that at first sight, even under a magnifier, the shell appears to be absolutely smooth.

The costæ are not found on some specimens of *Pl. Kraussii* or *Pl. minutus*, but in others they are distinct, though in the latter more difficult to see than in the former, on account of the size of the shell. The costæ in their turn are apt to be confounded with the still larger and more opaque ridges left by the building in of mouth rims, which have marked long periods of arrest of growth in the shell. I have not been able to reduce them to any law on account of the perfect way in which they are generally covered up when growth is resumed. In recent species of Planorbidæ it is quite possible to trace them occuring at regular intervals by their opacity and color, and they are evidently due to seasonal arrests of growth, but in the fossils they are too readily confounded with the striæ, though occasionally noticeable. When the shell attains its growth, however, the arrests of growth appear not to be wholly limited by the seasons. The building period appears to be shorter and more irregular, and in distorted specimens this is particularly noticeable. See, for illustrations of this, the figures of *Pl. supremus*, pl. 4, already described, and the following, fig. 9, line *g*, fig. 13, line *h*, pl. 1; figs. 2, 4, line *c*, fig. 5, line *m*, pl. 2; figs. 1, 7, line *g*, fig. 1, line *n*, pl. 3; figs. 3–5, line *a*, figs. 1–4, line *d*, pl. 8, all simple forms. A noticable case of distortion combined with senility is that of fig. 10, line *r*, pl. 2, which is repeated on line *e*, fig. 2, in a different position.

These were not specially selected to show these peculiarities, but are very good ordinary examples of the pathological conditions described. In any shell there may be every condition from that of the young or full-grown healthy shell marked with striæ, costæ, and permanent mouth-rims, to its old age form, in which the costæ are susperseded by permanent mouth-rims occurring at rapid intervals, and finally to the last stage of debility, in which the latest built mouth-rim projects only slightly beyond the former and greatly narrows the aperture, as in fig. 4, line *c*, pl. 8. The thickness of the permanent mouth-ring varies greatly in different adult individuals, even of species like *Pl. oxystomus*, which habitually have a very thick lip in the adult. As a general rule, however, the mouth-rims are thinner in the young shells of all forms, whether species, or varieties, or individuals, than in the adults; and especially so in those which thicken the lips or rims during their subsequent growth. This peculiarity aids in the concealment of the cicatrix or ridge of the permanent mouths during growth, so that these become apparent in most shells from the Steinheim Pits, only when the edges have been broken during the season of rest, or after the shell has reached the full adult size, and forms a thicker rim than is nsual in the young.

The first of the series of the costate forms are not distinguishable from the typical *Pl. minutus*, or from the varieties intermediate between that species and *Pl. denudatus*, except by the presence of distinct fine costæ. These do not occur in the young shells of the forms most closely allied to *Pl. minutus*, but only on the last whorl in the full grown adult shell. This point I have established by repeated observation, it being very important in its bearing on the law of acceleration. Thus figs. 8, line *k*, 1–2, line *f*, pl. 4, are shells in which they appear only on the last part of the last whorl, fig. 3, line *f*, at an earlier period on this same whorl, fig. 4, line *f*, at a much earlier stage, at least half a whorl sooner in the growth.

In all of these the costæ are closely approximate. Though there is very considerable variation in this respect, the differences between these and var. *major*, as shown on line *f*, pl. 4, and on lines *g*, and *i*, where they are of about the same size, being distinguishable by a practiced eye in almost all shells.

Line *g* shows a variety identical with Hilgendorf's var. *typica* of *Pl. costatus*, and figs. 1–5, line *i*, the equivalents of his var. *platystomus* of the same species. The costæ are very wide apart in the latter, which in my view are the young of the larger specimens of the coarsely costate forms on line *k* above, while the specimens figured on line *g* are the young of those shown on line *h*, in which the same peculiarities of the costæ are observable. The extremely uncoiled forms are in all cases, of course, regarded not as young forms, but as diseased shells, which as previously observed, would of course be undersized in comparison with more healthy individuals of the same species.

I have not succeeded in finding any hybrids or shells of an intermediate character between these and the corresponding uncoiled smooth forms of *Pl.* $\frac{\textit{denudatus}}{\textit{minutus}}$. The different forms may be in general terms distinguished into two varieties: 1st, Shells with sharply defined crowded costæ. 2d, Shells with widely separated costæ. These may have their variations in the costæ. (1), having either sharp, forward projecting, rim-like costæ; (2), thick, vertical lip-like costae; (3), thick costae overhanging, opposite to the direction of the growth of the shell. These modifications are due to the way in which the costae are built up. In the first place, the re-building of the shell is begun on the inside of the old whorl, leaving the edge of the mouth projecting forward like the free edge of a frill, fig. 9, line *g*, pl. 4. The second is accomplished by the curious way in which the new growth is begun, immediately along the flaring edge of the mouth so that the resulting costæ are of double thickness.[1] The third is occasioned by a slight overlapping of the old edge of the mouth by the new growth, so that the most abrupt portions of the costæ are the posterior sides, instead of the anterior, as in the first instance.

Varieties 1–2 may be subdivided in precisely the same way, but the peculiar ways in which the variations are occasioned in var. 2, are more easily observed.

Notwithstanding these facts, however, it is noticeable that the last two kinds, or abnormal costæ, are very rare in the finely costate series, and very common in the coarsely costate, or 2d variety.

The distorted varieties are precisely parallel with *Pl. denudatus*, so far as the form of the whorls and the spiral is concerned, but bear the most indubitable marks of their derivation from the various costate races above described. They are of all degrees of uncoiling except the absolutely uncoiled, that is, one in which the extreme young is not closely coiled. The whorls may not touch anywhere, after the first part of the first whorl is built, but this is invariably in close contact with little bag-like ovishell, due to the prepo-

[1] This variety is figured in the coarsely costate specimen, fig. 1, line *k*, pl. 4. See also for the next described variety, fig. 7, line *i*, pl. 4.

tent inherited tendency to form a closely coiled shell during the protected stages of the earliest period of growth. I failed to find any finely costate forms, with distorted or open whorls.

Line *h*, pl. 4, gives photographs of the variety *major* of Hilgendorf, and he probably also includes in this variety the coarsely costate forms on line *k*.

Var. *major* (*Pl. multiformis* var. *major* Hilg.), fig. 15, line *b*, pl. 3, is an exceedingly fine specimen of the largest size. It is comparatively rare even in formation *n* of the East Pit, where it was most abundant. It was, however, not difficult to ascertain that it was divisible into sub-varieties, having fine and coarse costae, but these are invariably more or less widely separated, and therefore belong to the coarsely costate series.

The following table depicts these relations diagramatically for the purpose of placing them in a clearer light.

Coarsely costate sub-series.	*Finely costate sub-series.*	*Smooth shelled sub-series.*
Pl. costatus var. platystomus.	Pl. costatus var. distortus.	Pl. denudatus.
Pl. costatus var. obtuso-costatus.	Pl. costatus var acuto-costatus.	Pl. minutus.
Pl. costatus / minutus.	Pl. costatus / minutus.	Pl. minutus.
	Pl. minutus.	

Pl. minutus and its immediate affinities are shown by three sub-series. Each of these have the cylindrical and less involute forms corresponding to *Pl. minutus*, and the completely trochiform and partly uncoiled cylindrical whorled forms, the equivalent of *Pl. denudatus*. Thus each of the three sub-series presents a similar succession of forms, the ancestral, or closely allied, the highly differentiated or distinct forms of the third line and the diseased and closely representative forms of the fourth line.

I do not think that the accepted limitation of a species to one or more series of forms connected by hybrids or intermediate varieties, is of any use whatever in estimating the value of the characteristics in cases like that under consideration. The value of these must be determined with reference to all the members of the group in which they occur; this alone can give their approximate taxonomic meaning. Thus, by reference to the Planorbidae generally, we can show that the modification represented by forms in the smooth and costate series, are really more distinct than most of the species of the genus Planorbis. If the intermediate forms were lost or destroyed, there would be no doubt on this point. If the word species can be used to mean anything at all, it must be restricted in given groups to certain limited series of modifications, having a certain approximately determinable value. If the term can be used at one time to designate so great a series as is included from *minutus* to *costatus*, or *Steinheimensis* to *trochiformis*, or even *discoideus* to *trochiformis*, I can see no reason why at another time it may not be used for all these forms together, as Hilgendorf has done.

Fig. 15, line *b*, pl. 3, has no costae on the last part of the outer whorl, and this represents the extreme old age condition of the costate series. This return of the smooth condition of the young shell is exactly comparable with the conditions attending senility, as observed first by D'Orbigny among the Ammonites, and subsequently by the author, among these shells, and also in other departments of the animal kingdom. It is apt to mislead the observer, since, although it occurs in the life of the same animal, and in the same organs, it belongs to a class of resemblances which are not generally understood, and have been neglected by all but a few observers. The absorption of, or more exactly speaking the failure of the animal to build up, the costae during the last stages of its existence, causes the whorl to revert to its early smooth condition, and while the latter is due to heredity, the former is evidently pathological in its origin. If a represents the young and its inherited characteristics, and b the new characteristics added during growth to n the adult stage, then $a+b+n=m$, the adult forms. The amount of resemblance between the senile stage and the young, therefore, depends upon how much or what parts of b and n are subtracted by absorption or decay during old age, and as it is never the whole $b+n$, which is destroyed by senile disease, the resemblance produced can never be identical, though they may appear so to the eye in some organs or parts.

Another way of explaining these phenomena is admirably illustrated by the numerous cases which have been cited of the sudden return of youthful and apparently long forgotten facts, songs, etc., in the memories of old people. They are evidently the survival and the sudden reappearance of youthful characteristics, which have been hidden under a mass of differential characteristics. These being removed the basal form becomes once more visible.

The foundations of a building are the first to appear, then become invisible under the superstructure, and become visible again only by the decay and destruction of that which they supported.

SECOND SERIES.

Planorbis parvus.

Planorbis Zieteni (A. Braun) Sandb., *Op. cit.*
Pl. m. parvus Hilg., *Op. cit.*, fig. 4.

The shells which represent this variety, pl. 3, line *a*, figs. 6, 20–22, have a defined upper umbilicus and closely resemble in all essential characteristics those young forms of *Pl. Steinheimensis*, which have the mouth deflected downwards and the third carina exceptionally well marked. Figs. 10, 11, line *b*, pl. 1, represent specimens of this class, which are a trifle stouter than the true *parvus* and are evidently the young of *Steinheimensis*, since at earlier periods than the one figured the whorls have all the peculiarities of *Steinheimensis*. The third carina, which is so prominent in figure 11, does not appear until the shell has attained a stage considerably older than that in which this carination usually makes its appearance in *parvus*. This is the case also in the more compressed forms of *Steinheimensis*, such as fig. 9, line *m*, pl. 1, though in some of these the resemblance of the nearly full grown shells to the young and adult shells of *parvus* is even closer than in fig. 11, line *b*, pl. 1. This is undoubtedly attributable to their more disc-like or flattened forms.

The specimens forwarded by Prof. Sandberger resolved the difficulties encountered in the Pit Deposits and explained admirably the close affinities above described between the young of *Steinheimensis* and the adult of *parvus* and the very evident differences between the full grown shells of each variety. They are both probably distinct varieties of *Pl. levis* derived directly from that species. Some of the specimens of one of the varieties of *Pl. levis* from Undorf are identical with *parvus* and have been previously described.[1]

Hilgendorf regarded *parvus* as intermediate between *minutus* and var. *aequiumbilicatus*, and also as in the same genetic series as *crescens*. Sandberger on the other hand joined *minutus*, *teres*, and *crescens* under the name of *Zieteni* Braun as a distinct species.

Planorbis crescens.

Pl. m. crescens Hilg., *Op. cit.*, fig. 16.

This species is perhaps the least variable of any of the Steinheim forms. The connection with the preceding is clearly made through some specimens slightly stouter than the norm, but these are exceedingly rare in my collection.

The mouth and last whorl may be central or turned downwards. I have so far seen none with these parts deflected upwards or against the spiral. Some of those with the mouth in the middle have nearly equal umbilici, but these are extremely rare forms. Those with the mouth turned downwards and the upper umbilicus only slightly marked, as in figs. 9–12, line *c*, pl. 3, and those with no upper umbilicus, as in figs. 13, 14, on the same line, are very numerous. Quite a trochiform variety ends the tendency to variation in this direction, of which I have found one specimen, pl. 9, fig. 15, but even in this one the whorls retain the same attenuated aspect and form. The third carina is prominent in all of these, and in some the fourth makes its appearance, especially in those like figs. 13, 14, line *e*, pl. 3. The striae of growth are particularly well defined in this variety, even at the earliest stages, and in all specimens.

Remarks. On pl. 5, the entire genetic series as here described, is figured. The four shells on line *a* are undoubtedly *Pl. levis*, from Undorf, and show the close relationship with *Pl. parvus* from the Pits, as exhibited on line *b*. *Pl.* $\frac{crescens}{parvus}$ is exhibited on line *c* and on line *d* the ordinary forms of *Pl. crescens*.

The angularity of the outer whorls resulting from the development of the third carination is evidently a mark of affinity with *Pl. levis*, in which this is a constant characteristic. The gradual flattening of the form of the whorl is shown in the right and left series of figures, and the close resemblance in form of the whorl to that of *Pl. levis*, in fig. 2, line *b*. Compare this with some of the forms of *Pl. levis*, on pl. 7, which are in the same position. This flattening of the angularity of the whorl, and the openness of the lower umbilicus, fig. 5, line *d*, are both low characteristics, and show that the series has altered but very little in the characteristics which were derived from *Pl. levis*. The increase in size is notable, and this must be classed with the progressive series. The progression in the flattening of the whorls and the angularity of the outer whorl which takes place in the adult also characterizes the young, and is inherited at earlier stages in each form, until, in fig. 2, the young begin to show the *crescens* form at a very early age.

[1] See p. 35.

No very decidedly diseased or aged forms were observed, but the spiral is often slightly irregular.

The peculiar gibbous aspect of the whorls in fig. 7, line *b*, is exaggerated by the photograph, as it is also in fig. 1, on the same line, and may mislead the observer into the belief that he is looking at specimens of $\frac{oxystomus}{levis}$. This, however, can be readily corrected by comparing them with true $\frac{oxystomus}{levis}$, on pl. 6, lines *a*, *b*.

The apparent contrast between the two figures above mentioned, on line *b*, pl. 5, and the two corresponding figures of *Pl. levis*, on line *a*, is hardly perceptible in the specimens themselves, which are really very large specimens of *Pl. parvus*.

THIRD SERIES.

Planorbis $\frac{oxystomus}{levis}$.

The shells figured on pl. 1, line *m*, figs. 10–14, approximate to, but are still readily separated from those figured on pl. 1, line *a*, figs. 12, 13. These last are slightly different from the *Pl.* $\frac{oxystomus}{levis}$, from Undorf, but figs. 14–16, which are of about the same size, would not be separated by the most conservative naturalist, if found at Undorf. The full-grown forms, figs. 12, 13, line *a*, pl. 1, are larger, and approximate to true *Pl. oxystomus*, pl. 3, figs. 8, 9, line *k*; in fact, they are so nearly identical with these that the young alone show their affinity to *Pl.* $\frac{oxystomus}{levis}$. The young have the shallower umbilicus on the lower side, and that side of the outer whorl is flatter at the same age than in true *Pl. oxystomus*. Fig. 12, line *a*, pl. 1, even shows the peculiar mouth-rim and general outline of *Pl. oxystomus*.

There is one noticeable characteristic in the shells of *Pl. Steinheimensis*, which may also be cautiously used in separating the varieties just described, from those of *Pl. oxystomus*. The striae of growth are not so decisively marked in *Steinheimensis*. Shells with striations as prominent or as deeply incised as is usual in *Pl. oxystomus* are rare. The surface of the former has a smoother aspect than that of the latter, and this is almost invariable in the young, while the young of many varieties of *Pl. oxystomus* have very distinct striae. But though rare, such shells do occur, and some of them are found in the intermediate varieties just described.

Planorbis oxystomus.

Pl. oxystomus Klein, Jahresh. Wurtt, Vol. 2, pl. 1, fig. 27.
Pl. m. oxystomus Hilg., *Op. cit.*, pl. fig. 7.
Pl. m. revertens Hilg., *Op. cit.*, pl. fig. 8.
Pl. m. supremus Hilg., *Op. cit.*, pl. fig. 9.
Carinifex oxystomus Sandb. *Op. cit.*, p. 643, pl. 28, fig. 3.

Variety *revertens* Hilg. = $\frac{oxystomus}{levis}$, pars.

After prolonged comparisons I am unable to find any characteristic by which this variety in some of its forms can be separated from the narrow umbilicated forms of *Pl.* $\frac{oxystomus}{levis}$. These, like those figured on line *k*, fig. 6, and line *p*, figs. 10–11, pl. 3, have shallower umbilici on the lower side, with whorls less gibbous than is usual, and a mouth which neither flares nor contracts, and has a very thin inner lip.

Variety *typica*.

The second variety, or true norm, which I take to be identical with Hilgendorf's figure, has the mouth and part of the last whorl considerably contracted, the lower umbilicus quite deep, and the lower sides of the whorls gibbous but rounded, figs. 12–18, line *k*, and fig. 12, line *b*, pl. 3.

The third variety, figs. 2–9, line *m*, pl. 3, has a mouth similar to the first variety in some specimens, but in others there is a lip of medium thickness on the inner side.[1] This form is an exaggerated repetition of that of figs. 12–16, line *a*, pl. 1. The closeness of the resemblance in form is due to the rotundity of the lower side, and the depth of and narrowness of the umbilici in both forms.

Planorbis supremus.

Pl. m. supremus Hilg., *Op. cit.*, fig. 9.

First variety.

This begins with a form precisely similar to the preceding, except in the upper umbilcus. This deepens by growth, and the first carina and sulcation begin to make their appearance. The lower side also, is sharper, and the fourth carina stands out quite prominently. The mouth is central. Figs. 6, 10–12, line *o*, figs. 7–9 same line, are intermediate between these and the last described form of *oxystomus* on line *k*, pl. 3.

Second variety.

This differs only in having the mouth bent downwards. The first carina and sulcation become very prominent, and the fourth carina also, as in figs. 1–7, line *n*, and 1, 5, line *p*, pl. 3.

Another form is represented by figs. 8–13, line *n*, and fig. 1, line *o*, pl. 3. In these the upper umbilicus becomes shallower, and in fact almost disappears. This is one of the nearest approaches to a turretted form observed in this variety, and it is accompanied in fig. 8, line *n*, by the development of a distinct sulcation on the upper side. A typical variety of *oxystomus* occurs on line *a*, fig. 14, pl. 3, in formation *h*, East Pit. This differs from the series just described in the upper umbilicus. This is shallower, and the inner whorls are therefore more exposed in the young. Almost without exception, these have the fourth carina strongly developed, but there are some in which the upper umbilicus is deeper than usual, and the whorls more cylindrical.

This variety leads by the closest gradation into the stouter form figured on line *b*, pl. 3, figs. 1–6, and line *l*, figs. 1–3. The next step is shown in figs. 9–10, line *b*, and 5–8, line *c*, in which the lower umbilicus may be either quite wide or very narrow, and the upper side begins to lose the umbilical depression.

In fig. 13, line *b*, fig. 1, line *c*, and figs. 4–7, line *l*, pl. 3, this tendency is consummated in a truly turretted form.

Variety *turrita*.

In figs. 9–11, line *l*, pl. 3, the whorls increase with great rapidity below the fourth carina, and narrow lower umbilicus, assuming a *trochiform* aspect.

I have one specimen of this last, considerably larger then the one figured, with a form similar to that of "*elegans*" Hilgendorf. It is noticable that although the first and fourth

[1] It should be noticed here that the specimen figured on line *a*, pl. 1, fig. 12, has a thickened inner lip, also a characteristic which is exceedingly rare in *Pl. Steinheimensis*, in which this portion of the mouth is usually represented by a very thin or almost imperceptible film, while in *Pl. oxystomus* the opposite is the case, the thin film being exceptional, and the thick deposit the rule.

carinae are distinctly indicated in fig. 1, line *c*, and the first, second, third, and fourth in some other specimens of the turretted varieties, there are no accompanying indications of sulcations on the upper sides of the whorls. These are usually round, but may become somewhat flattened, though in no case have I found sulcations. The limits here given for this species correspond quite closely to those given by Sandberger, since he also included under one name the three principal varieties described by Hilgendorf. The difference in our views is due to the intermediate forms, which in my opinion bridge the chasm between this and *Pl. levis*. With regard to the affinity with Carinifex, I have written elsewhere.

The whole series is given on pl. 6.

Figs. 1–3, line *a*, are *Pl. levis,* from Undorf. Compare fig. 1, line *a*, with fig. 1, line *b*; also fig. 2 with 4, line *a*, and fig. 3 with 7, line *a*. Line *b* is the *Pl.* $^{oxystomus}_{levis}$, from formations *l* and *m*, of the Cloister Pits. Thus it can be seen, that it is not necessary even to descend to formation *a* of the pits, in order to obtain forms showing the probably direct derivation of *Pl. oxystomus* from *Pl. levis*.

Fig. 3, line *b*, is important in this connection, because it shows very distinctly that a perfectly preserved shell of *Pl.* $^{oxystomus}_{levis}$ exhibits the bright and polished surface and striae which are common in *Pl. levis*.

The transition from *Pl. levis* to *Pl. oxystomus* is also still farther confirmed by the two young specimens, figs. 4–5, line *d*; fig. 5, being *Pl. levis,* from Undorf, and fig. 4, the young of a typical *Pl. oxystomus,* from the Cloister Pit.

Pl. oxystomus var. $^{oxystomus}_{levis}$ is shown in figs. 4–7, line *a*; these are even closer to *Pl. levis* than those on line *b*, which exhibit the transitions from $^{oxystomus}_{levis}$ to true *oxystomus,* occupying lines *c* and *d*.

Pl. supremus is represented by the figures on line *e*.

The series is roughly shown by the range of figures numbered 1 in each line, and these exhibit the general tendency to increase the spirality. The tendency in each variety to increase spirality of growth in some shells, is also observable. Thus, in *Pl. oxystomus,* line c, fig. 6 is quite trochiform, only inferior to fig. 1, line *d*, a specimen of the same variety.

This last is apparently quite as turbinate as fig. 1, line *e*, a specimen of *Pl. supremus*; but in reality it is not of the same species as this, since the umbilicus is more open, and wider.

The oxystomus-like widening of the whorl in course of growth, fig. 1, line *c*, is not observable in any of the forms of *Pl. levis*, in the youngest stages of growth, which have whorls like fig. 3, line *a*. In *Pl.* $^{oxystomus}_{levis}$, this peculiar widening, occasioning the angularity of the aperture on the lower side, is more pronounced in the adults, and appears earlier in the life of the individual. In *Pl. oxystomus,* line *c*, fig. 5, this is still more pronounced, and inherited at a still earlier stage.

In *Pl. supremus* the broad whorl occurs at a very early age, so that the young are often identical with the typical form of *oxystomus*; and subsequently the first carination, or the first and second with the sulcation between them, appears during the growth of individuals.

It is interesting, also, to note that some specimens which have no pronounced carinations or sulcation, but are smooth, like *oxystomus,* have to be classed with this variety on account of the peculiar shape of the whorls, as in the turbinate form, fig. 1, line *e*.

Another interesting peculiarity is the obliteration of the upper umbilicus in several turbinate forms, as in fig. 1, line *d*, and its approximate obliteration in figs. 2 and 6, line *c*. It must be understood, however, that even in fig. 1, line *d*, there is a minute upper umbilicus in the extremely young shell, as seen at the apex.

A very curious tendency in the whorl to depart from the regular mode of growth is apparent in figs. 6–9, pl. 3, line *p*. The whorl, either through a wound as in fig. 8, received at an earlier age, or through some weakness caused by sickness or unfavorable conditions, ceases to increase by growth according to the usual proportions. This contraction gradually leads to the distortion of the spiral. Sandberger figures one of this species much much more remarkable than any here. The mouth strikes off almost as a tangent to the curvature of the spiral, and extends out to a distance very much beyond that of any of the specimens seen by me, except perhaps fig. 5, line *b*, pl. 8.

The distorted forms to whose illustration plate 8 is devoted, are largely taken from *Pl. oxystomus*, and it will be observed that most of them are var. *revertens* Hilg. $= {}^{oxystomus}_{levis}$.

Figs. 3–4, and perhaps 5, line *a*, figs. 1, 6, line *b*, are from specimens of typical *Pl. oxystomus*, while figs. 2–5 line *b*, and all of line *c*, are taken from ${}^{oxystomus}_{levis}$. Some of these cases are evidently due to wounds, the effect being distinctly marked on the shell. That the wound in such cases affected the health of the animal is evident, because in other cases of shells similarly scarred, no distortions are observable in the subsequent building up of the shell. Figs. 3, line *a*, 2, line *b*, and all on line *c*, are undoubtedly due to such accidental causes. The other shells show no derangement in their striations or scars. These distortions may or may not have been due to diseases arising from other causes, but of one thing we can rest assured, that ${}^{oxystomus}_{levis}$ was more subject to such distortions than any other species or form belonging to any of the progressive series. If it is desirable to test the conclusions drawn from such diseased specimens in chapter 1, it can be readily done by comparing figs. 1–3, line *c*, and 4, 5, line *b*, with the uncoiled forms of the retrogressive sub-series, or better still by observing the close parallelism of fig. 5, line *b*, with fig. 23, of pl. 9.

Another remarkable result of disease, whether it may be from accident or otherwise, is a reversion to the peculiar angularity of form conspicuous in some varieties of *Pl. levis*. This is not very well shown in the plate on account of the positions of the specimens, but is partially shown in fig. 2, line *b*, which was especially intended to exhibit this peculiarity. It results from a perceptible flattening of the diseased portion of the whorl, as well as from a general diminution in size. The diseased specimens of *Pl. supremus*, figured on line *d*, are very large, and they are distorted only towards the latter part of the last whorl. The distortions consist of enlarged striae, and simultaneously the size of the whorl decreases, occasioning at once a deflection from the regular increment of the spiral, which tends to become turbinate.[1]

These phenomena appear to indicate the slow rate of growth consequent upon old age. This is also shown very well in fig. 1, line *n*, pl. 3, when the same enlarged striations are seen on the last part of the last whorl, and it is this part alone which is deflected to

[1] I do not wish to be understood as implying that the tendency to become turbinate is always a diseased or retrogressive characteristic. While this is often the case, it is equally unquestionable that *Pl. trochiformis* is a thoroughly healthy species, as are many other turbinate forms.

form the extreme spirality observable in another view of a precisely similar specimen in fig. 2, by the side of the first described.

FOURTH SERIES.

Planorbis Steinheimensis.

Variety *aequimbilicatus.*

Pl. m. Steinheimensis var. *aequiumbilicatus* Hilg., *Op. cit.*, fig. 1.

Forms which are aequiumbilicated are quite rare in the lower formations of the Pits. One is figured in section on line *b*, fig. 17, pl. 1, another on line *a*, fig. 2; almost all others only approximate to this condition and ought perhaps to be placed with the inaequiumbilicated forms. They are the true transitions from the latter, but also possess the more cylindrical or equal-sided and less involute whorls of the aequiumbilicated variety, such are those figured on plate 1, line *a*, figs. 1, 3, 4, line *c*, figs. 1, 19, and line *m*, figs. 1–7.

In the aequiumbilicated variety there are several sub-variations. Those with the mouth and last whorl or whorls turned upwards, those with these parts central, and those with these parts turned down as in fig. 7, line *m*, pl. 1.

In the inaequiumbilicated variety there are similar variations in the direction of the last whorls, but here the downward or spiral tendency is of course predominant. In the aequiumbilicated variety I did not find a tendency to flatten the upper or lower sides, but it must be taken into consideration that very few specimens of this variety were found.

In the inaequiumbilicated variety, especially in the sub-variety with the mouth turned upwards, there is a decided tendency to flatten the upper sides of the whorls and this is correllated with a corresponding tendency to angulate or produce a ridge-like angularity in the whorls on the outer side, both above and below and on the inner lower side near the umbilicus. For convenience sake I have called these ridges the second, third, and fourth carinae, reserving the designation of first carina for the innermost umbilical ridge on the upper side, which appears so prominently in *Pl. discoideus*. Forms may be picked out which show this tendency[1] in every way in the sub-variety with the mouth turned downwards, though the second carina is very rarely seen.

In some specimens only the third carina is seen, and these are remarkably similar to *Pl. levis* as figured by Sandberger. In others the fourth carina alone, or third and fourth carinae with a slight flattening of the lower side occur, and the second and fourth carinae, but in none did I find the third carina alone.

The forms united under this name have, besides the characteristics above given, the following: the whorls are more cylindrical, and the increase in the size of the whorls by growth is less marked than in *Steinheimensis* proper, and therefore the involution a trifle less.

Variety *Steinheimensis.*

Pl. Steinheimensis Hilg., Monatsb. K. Preuss. Akad. Wissensch., Berlin, July 1866, p. 485, fig. 2.

Pl. Steinheimensis Sandb., *Op. cit.*, p. 644.

[1] It must be observed that I here speak of a hardly perceptible angularity such as is shown in the outline of the mouth and lower side of fig. 5, line *m*, pl. 1.

This species or variety may be distinguished from the preceding, principally by the more rapid increase in the size of the whorls by growth, and the consequently slightly greater breadth and involution of the last whorls. The young are habitually asymmetrical, as in the section fig. 7, line *a*, pl. 1. No absolute line can, however, be drawn between this and the preceding. The varieties are very numerous, and I cannot pretend to enumerate all of them. The most significant, if it may be so expressed, are the following:

1. Those with the mouth turned upwards, or against the spiral; line *b*, fig. 3, pl. 1.
2. Those with the mouth central; line *a*, fig. 9, pl. 1.
3. Those with the mouth turned downwards; line *m*, fig. 13, pl. 1.

All three of these varieties may occur with perfectly rotund, smooth whorls, without the slightest indications of a carina-like angularity or ridge, in any light, or in any position in which they may be held. There is, however, this observable peculiarity: the larger number of carinated specimens have the mouth central or turned downwards, rarely deflected against the spiral.

All three of these principal varieties may also occur with the carinations described in the preceding form, and in one case a distinct third carina appeared, fig. 1, line *n*, pl. 1, which will presently be described in detail.

Specimens with the mouth turned upwards, have a tendency to flatten the upper side of the whorls. The second carina is very rarely indicated in these, but the third very often. Sometimes it is alone, but usually it is accompanied by a well defined tendency to flatten the lower side, and produce the fourth carina also, as in fig. 3, line *b*, pl. 1.

The same peculiarities, word for word, may be attributed also to those having the mouth central. Those figured on line *b*, figs. 6–10, pl. 1., have only one carina, the third, indicated as in the mouth of fig. 6, inside of which it is well shown, though rather too delicate and unpronounced to be shown in others. Figs. 4, 5, have the third and fourth carinae indicated, especially the specimen shown in fig. 4. Fig. 4, line *n*, plate 1, exhibits this peculiarity more markedly than it can usually be shown by photography.

In this variety also a sulcation makes its appearance as a faint depression on the upper side, as shown in fig. 2, 5, line *n*, pl. 1. The extraordinary form, figured on line *n*, pl. 1, fig. 1, not only has the third and fourth carinae, but shows a peculiarly broad, dorsal aspect, and has indications of the second carina, and a very slight depression or sulcation on the upper side, quite equal to that in No. 5, on the same line, though hidden by the flare of the mouth. These characteristics are well marked, according to the usual fashion in other specimens, on the last whorl, for about three-fourths of its length. A constriction occurs in this specimen, caused evidently by some accident to the shell, which was probably the immediate cause of the appearance of these unusual characteristics. After the repair of this injury, the third carina appears as a regular ridge with a definite linear depression on either side.

The old age of *Steinheimensis* is indicated in this and other large specimens by a slight decrease in the amount of involution of the last quarter of the last whorl, and this peculiarity is well marked in this shell, so that the distinct carination appears to arise in the old age of this form.

The variety with the mouth turned downwards, in the normal direction of the spiral, fig. 11, line *m*, pl. 1, has the third and fourth carinæ well developed. Fig. 13, line *h*, pl. 1, exhibits throughout its adult stage a form inseparable from that described above, on line *n*, fig. 1, but in old age the whorl is deflected in the normal direction. At the same time the sulcation appears, and with it the first carina is indicated, and the second carina becomes quite prominent and much better defined than I have seen it in any other specimen. The aspect of the whorl, the decrease in its involution, and the enormous comparative size of the shell show that these exaggerated features are the products of senility. A tendency to produce the second, third and fourth carinae is also observable in quite a number of specimens with a decided and symmetrical flattening of the upper, outer, and lower sides of the whorls, but no sulcations ; this is the case with fig. 16, line *b*, pl. 1, which can only be separated from *Pl. tenuis*, line *c*, fig. 2, by the absence of any linear sulcation or depression on the upper side.

Besides the above, there are still other modifications which it is necessary to mention. These consist of exceptionally flattened forms. All of those previously described are more or less stout, but there are some which do not partake of this characteristic, such as are figured on line *m*, pl. 1, figs. 8–9. All, including the above just described, have rather wide and open umbilici on the lower side, and cylindrical or flattened whorls, but there are some forms, with stout whorls, in which this is exchanged for a tendency to narrow the umbilicus, and these, though difficult to distinguish at first, are soon readily picked out after a little practice. They are then seen to be distinct, and by comparison with *Pl. levis*, are recognizable as the intermediate forms of *Pl.* $\frac{oxystomus}{levis}$, figs. 14, 16, line *a*, pl. .1.

Planorbis tenuis.

Planorbis tenuis Hilg., *Op. cit.*, fig. 3.
Carinifex tenuis Sand., *Op. cit.*

Variety $\frac{tenuis}{Steinheimensis}$.

Certain forms which I have included under this name are not distinguishable from certain forms of *Steinheimensis.* They nearly all have faint but unquestionable marks of a sulcation on the upper side, but so have some unquestionable specimens of *Pl. Steinheimensis*, and that this is an artificial line can be readily shown by the comparison of such specimens as fig. 16, line *b*, and fig. 2, line *c*, pl. 1. The latter I have often referred to *Pl. Steinheimensis*, when studying that species, because of its very faint sulcations, and also on account of the extreme smoothness of the shell and its close resemblance to true *Steinheimensis* forms, especially figs. 3, 4, line *a*, pl. 2. There is the same story to be recounted with any characteristic which may be selected.

First sub-variety.

This is represented by a flat shell with the first, third and fourth carinae indicated, but the second almost absent. They are not distinguishable from such forms as fig. 14, line *c*, pl. 1. They are rounded and smooth on the upper side, but flattened as in *tenuis* on the lower side, with the third and fourth carinae well developed. Some of these have also almost imperceptible sulcations on the upper side on the last whorl. These differences disappear in fig. 13, same line, which is really a flattened *Steinheimensis* form with intermediate form and characteristics. Fig. 13, line *n*, pl. 1 must also be joined to this sub-variety. The form has not a very close resemblance owing to the deflection of the mouth, but the third carina is well developed and the shell is intermediate to figs. 14 and 15 same line.

Second sub-variety.

It is not possible to arrange these varieties in a line with reference to *Steinheimensis*, and therefore the successive numbering of the sub-varieties means nothing so far as the genesis and relative rank is concerned. The forms figured on pl. 1, line *d'*, figs. 1–4, have both the first and second carinae, and the sulcation on the upper side is indicated. Fig. 16, line *e*, shows a passage form from these directly to *Steinheimensis*. The under sides of the whorls in this variety are rounder than in the first variety, stouter and not so involute.

Other sub-varieties might be described in the transition forms, such as fig. 1, line *b*, pl. 1. This is an extremely thin shell, more or less flattened on both the upper and lower sides of the whorls, and with the faintest possible sulcation.

Near the mouth or the upper side, it is evidently very closely allied to such flattened forms of *Steinheimensis* as fig. 9, line *m*, pl. 1, or intermediate between these and the still more flattened form on line *n*, fig. 8, which leads into forms figs. 9–12 on the same line, belonging to the true *tenuis* group. We must also add to this list fig. 6, line *n*, pl. 1, which fills the gap between fig. 7 of the *tenuis* group and *Steinheimensis*.

The specimens described in the Lower Steinheim Period, as occurring in the Cloister Ridge rocks show with considerable clearness that *Pl. tenuis* is really a derivative of *Pl. levis*, and that the transition forms here described between this and *Pl. Steinheimensis* must be accounted for either as hybrids or as descendants from Cloister Ridge species.

Variety *Kraussii*.

Planorbis Kraussii Klein, Jahresh. Würt., 1847, plate 1, fig. 28.

Pl. multiformis Kraussii Hilgend., Monast. K. Preu. Akad. d. Wissensch., Berlin, July 1866, pl., fig. 12.

Pl. Kraussii Sand., Conchyl. d. Vorwelt, Supp., p. 646.

This species at first sight appears to be separable from *Pl. Steinheimensis* on the one side and *Pl. tenuis* on the other. The close and thorough examination of the shells, however, gradually obliterates all distinctions. It can, therefore, if one chooses, be properly considered one of the varieties of *Pl.* $\overset{tenuis}{Steinheimensis}$.

If we compare the full grown shell with the young of *Pl. tenuis*, line *f*, fig. 1–7, pl. 2, we find that the young of certain forms are with difficulty separated from *Pl. Kraussii*, *e. g.*, fig. 4, line *f*, and fig. 3, line *d*, pl. 2. The young of the more immature of the *tenuis* forms are like the specimens of *Pl. Kraussii*.

This would answer very well for all the forms with flattened upper sides, figs. 1–8, line *d*, and figs. 13–16, same line, pl. 2, in which a triquetrus-like outline is attained by the flattening of both the upper and lower sides. This explanation, however, hardly applies to such forms as figs. 9–12, and 17, on the same line. These are almost purely Steinheimensis-like, so much like the latter that if they had been found in the same formation, I should have called them by that name.

The umbilicus on the lower side is narrow, and it will be observed that the young are quite stout in some specimens, as in figs. 11, 12, line *d*, pl. 2. Since the above was written, I have succeeded in finding in my collection true *Pl.* $_{\textit{Steinheimensis}}^{\textit{Kraussii}}$, in formation *a*, of the Old Pit, line *f*, figs. 1–3, pl. 1.

The prominence of the third carination in *Pl. Kraussii* is precisely what was previously observed in *Pl. Steinheimensis*, and besides this the adults of many develop the second carina and become flattened externally on the last whorl, as in the young of *Pl. tenuis*. Occasionally, also, as in fig. 2, line *d*, pl. 2, a faint sulcation becomes visible on the upper side.

It is possible that the specimens figured on pl. 2, from the higher formations of the Pits, are the survivors of the forms of formation *a*, and perhaps may be considered as somewhat dwarfed. Their resemblance to the specimen from formation *l*, figured on pl. 2, line *q*, fig. 12, as *Pl.* $_{\textit{Steinheimensis}}^{\textit{tenuis}}$, is apparent at a glance.

The specimens of *Kraussii* figured on line *d*, pl. 2, figs. 13–16 are similar to some of the more compressed young of *Pl. tenuis*, like those of figs. 7, 13, line *n*, pl. 1, and figs. 1–2, line *f*, pl. 7, and are identical with the more immature young, and some of the full grown shells of *Pl. tenuis* of the Cloister Ridge rocks. Sandberger appears to have been unable to separate this form in the Pits from *Pl. tenuis*, but there is no difficulty in doing this until the young of the *tenuis* forms are studied. The adults are quite distinct. Hilgendorf's opinion that this species is a direct derivative from *Pl. Steinheimensis* is amply sustained by the material I have examined, but whether this ought also to be considered intermediate between *Steinheimensis* and his *Pl. pseudotenuis* is more doubtful. This last I have had no means of studying, except through two specimens sent me by Hilgendorf. These are very minute, delicate, thin-shelled specimens, with the third carina only developed, which forms a sharp ridge on the lower side and outer edge of the whorl. The shell has the aspect of the young of *Pl. tenuis*, but I have unfortunately not the time now for a re-examination in order to test this question. If his material enables him to trace a close series of transmutations this can be established, but in the absence of this exact proof, I should certainly at once class it as the young of a variety of *Pl. tenuis*, traceable to such forms of *Pl.* $_{\textit{Steinheimensis}}^{\textit{tenuis}}$ as are figured on pl. 1, line *c*, fig. 14.

There is not a single specimen of *Pl. pseudotenuis* figured on my plates, and this shows the extreme rarity of the shell, a fact I was not aware of until the receipt of Dr. Hilgendorf's type specimens. If this series is finally established by Dr. Hilgendorf, then another distinct series of a retrograde character will have to be added to those described in these pages. The specimens of *Pl. m. Kraussii* received from him are of the true $_{\textit{Steinheimensis}}^{\textit{Kraussii}}$ type, and show none of the tenuis-like characteristics here described as varieties of this species. Fig. 9, line *f*, pl. 2, is identical with these.

Variety *tenuis*.

The sub-varieties appear to be almost wholly derived from forms of the preceding decribed varieties, either of *Steinheimensis* or $_{\textit{Steinheimensis}}^{\textit{tenuis}}$. Thus the first sub-variety which shows a tendency to become turbinate, such as that figured on line *c*, pl. 1, figs. 2–12, appears to be connected directly with the *Steinheimensis* forms, similar to fig. 16, line *b*, previously described.

The majority of this variety, however, have the square form of the whorl with the sulcations and carinæ well developed. The mouth in these may be deflected against the spiral slightly, as in fig. 16, line *c*, pl. 1, and perfectly flat on the upper side, as in figs. 15, 17, 18, on same line. They are inseparable from the preceding variety, though in many forms they tend to grow in a sub-turretted form, fig. 8, line *d*, pl. 1, and line *e*, figs. 14, 15, and line *o*, fig. 1–3, fig. 6, and line *f*, pl. 7.

These last lead without break into forms such as figs. 4–7, line *o*, which have an extraordinary development of the first carina with a sub-turretted shell, or with a flat shell, as in figs. 2–10, line *e*, pl. 1. Then a sub-variety, probably connected with the last, in which both the first and fourth carinæ are very prominent, as in figs. 11–13, line *e*, pl. 1.

The forms on line *n*, pl. 1, figs. 9–12, are much compressed, with sides flattened and convergent outwardly, showing a whorl, which connects them with the extremely flattened form, fig. 8, same line ; and also fig. 1, of line *b*, on same plate.

If one examines this last mentioned compressed form, and fig. 8, line *n*, there is in both a slight want of symmetry, which consists in the greater prominence of the zone which would be occupied by the third carina, if it were present.

This is perhaps one of the most curious of the genetic series traced out directly from specimens, which are identical with *Steinheimensis*, on account of the almost imperceptible changes of form by which it is accomplished, and by reason of the extreme variation of some of the varieties.

Planorbis discoideus.

Variety $^{discoideus}_{tenuis}$.

This transition form, when that term is used in its most conservative sense, as applicable to shells which exhibit characteristics which make it impossible to decide whether they belong to *discoideus* or to *tenuis*, is not found in the Pit Deposits. It is, however, found in the Cloister Ridge rocks and has been previously described.

These forms entirely fill the gap, since they meet the only objection which can be urged against the intermediate position of the Pit forms ; they have young which "precisely resemble the adult of *Pl. tenuis*." There is indeed so close an approximation to true transition forms that I have more than once had to alter the nomenclature of this series. Thus the gap which exists between the form of *Pl. tenuis* figured on line *e*, fig. 1, pl. 1, and those of *Pl. discoideus* figured on line *f*, figs. 4, 17, pl. 1, is so slight that hardly any naturalist would hesitate to unite the former with the latter. Nevertheless the young of the form figured on line *f* cannot be considered as similar to the adult of the form figured on line *e*, since it is stouter.[1]

For a precisely similar reason I have also been obliged to separate the compressed forms of *discoideus* figured on line *h*, figs. 10–12, and line *p*. figs. 1–2, pl. 1, from *Pl. tenuis*, though among these it is possible that farther search would detect *Pl.* $^{discoideus}_{tenuis}$.

[1] This would generally be considered as of no value, but it must be remembered that the basis of the reasoning here adopted is restricted to the most conservative basis of anti-evolutionism.

Variety *discoideus*.

The *sulcatus* form is simply a compressed variety of *Pl. discoideus* with a remarkably square mouth and whorl as in figs. 7–14, line *g*, line *h*, and 8–10, line *p*, pl. 1. The squareness and angularity of the under side is well depicted in figs. 2–3, and 7–9, line *h*. There is a prevalence of these forms in formation *a*, but they are accompanied by true *discoideus*, and every attempt to separate the two has been attended by great confusion in my own mind.

The typical forms of *Pl. discoideus involutus* Hilg. are shown in figs. 10–17, line *f*, and 1–6, line *g*. I have applied this name to still more involute and more easily distinguishable forms, the extremes of this variety.

Figs. 4–7, line *g*, show a still stouter form in which carinations and sulcations are more marked, but the mouth at an early age has not the angularity of *Pl. discoideus*; figs. 14–17, line *f*, the carinations are still more distinct, and the mouth is angular in the young. Figs. 10–13, line *f*, show a trifle stouter and more trochiform shell with perfectly developed carinae, and sulcations both above and below.

After this, the difficulty in following the series consists only in settling the affinities of the adults of the numerous varieties; the young remain quite similar in form, though differing greatly in being more or less carinated or sulcated. They accord in this respect usually with the adults, as for example, fig. 7–14, line *f*, pl. 1, and the various series of lines *d*, *e*, *f*, pl. 3. In this way it may be shown that the species really most closely related to *Pl. tenuis* are the somewhat flattened but trochiform and unconnected forms like fig. 7, line *l*, pl. 1, and not the deeply sulcated and carinated forms like *sulcatus*, however flat they may be.

The first variation is that cited above, in which the upper sides of the whorls have the first carina well developed, the second rounded off, with the third and fourth on the lower side prominent. This leads into a number of allied forms, such as figs. 9, 10, line *e*, pl. 1, which become very turretted, and on the other hand into exceedingly flat forms like fig. 4, same line, in which all four carinae are well developed, but the sulcations not well marked. Figs. 15–18, pl. 2, line *f*, shows a similar series of modifications, and these are evidently the young of the trochiformis-like varieties, on line *n*, figs. 3, 4, and line *m*, figs. 3, 4, and which lead in $\frac{trochiformis}{discoideus}$, same line, figs. 1, 2.

A series might also be formed with the variety *elatior* Sand. as a type, fig. 16, line *i*, pl. 2. This also, it seems to me, is not sufficiently described when included with the *discoideus* series, and placed as Sandberger places it among the transition forms from true *discoideus*, to his variety *intermedius*, sub-variety *communis*, figs. 1–2, line *m*. Though quite closely allied to this series, there is a certain outline to the mouth, and an aspect of the whorl, which is reproduced in *trochiformis*, figs. 6, 7, line *r*, pl. 1, and a series could be doubtless formed connecting the two.

Going back again we may take up almost any other line of characteristics, and follow them out to a similar result.

Let us take, for instance, the true *sulcatus* form, already studied in part. In this we find the flattened tenuis-like form, line *h*, pl. 1, figs. 10–12, and line *p*, figs. 1, 2, becoming stouter, 3–10, same line. On line *h*, figs. 2, 3, we can see them more trochiform, and on line *p*, fig. 12, so excessively altered, that it is difficult to recognize the same variety. But observe closely the shape of the inner whorl in this and in fig. 13, then it will be seen that these are flat on the lower side, and in all respects similar in shape to fig. 3, line *i*.

Still another form of this variety is shown on pl. 2, line *b*, fig. 1-4, in which the turretted forms are not so, and may be traced directly back to the thinner forms mentioned above, through fig. 6, line *i*, pl. 1.

Within the limits of these series, there are a great many varieties which appear to be simply individual, or else to obtain only in a limited number of individuals, and to have no special meaning. Such is the appearance of an anomalous carination, along the centre of the whorl, as in fig. 5, line *k*, pl. 1. The existence of this appears to me unaccountable, as a normal characteristic, and it is not perpetuated. The peculiar mode of growth shown in figs. 17–19, line *e*, and fig. 18, line *d*, pl. 1, in which the regularity of the spiral is abandoned, seems to be another characteristic equally unparalleled.

Besides these anomalies, there are numerous individual characteristics appearing with exceedingly limited range, which can be better accounted for. These are largely mere excessive developments of certain parts, as certain carinations, or suppression of others. Very often these have a meaning, which is very important. They are often really characteristic of a series, as the extraordinary development of the first carina in a large number of the *sulcatus* series. Again they may be of more limited application, but even more significant and instructive.

If we observe any series of square forms, such as 7–14, line *g*, pl. 1, there will be some with the upper and lower sides of nearly equal breadth, and others in which the lower side is narrower, *never broader*. In such extremely square forms as no. 19, line *f*, and fig. 11–14, line *i*, pl. 2, this is quite as well marked as in other series, fig. 10–11, line *c*, pl. 2, being the young of such forms, showing the the narrowness, as does also fig. 13, line *i*. Sometimes this tendency is accompanied by a tendency to suppress the carinations on the lower side. When carried to its extreme, as in the series figs. 1–6, line *c*, this produces a whorl, which is rounded and smooth on the lower side, as in fig. 6. If we now compare these forms with line *k*, fig. 6,[1] pl. 1, we shall see that this is one of those transitions to *Pl. trochiformis*, which are distinguished by having smooth lower sides.

In the same way, where the carinae are not atrophied, it will be observed that the narrowing of the lower side always takes place in the transition forms to *Pl. trochiformis* in proportion as they become more turretted.

I do not mean to trace out a series on this character, because no one can examine a series without seeing that the narrowing of the lower side and the sometimes correlative atrophy of the ribs is not characteristic of series, but is an individual variation, gaining in importance and represented in a larger number of individuals, as we approach the turretted forms. See also in this respect the transition forms, figs. 1–4, line *r*, pl. 2. We can say also, with approximate accuracy, that in any series there is a constant tendency

[1] The *Pl. elegans* of Hilgendorf.

to produce flattened forms with prominently developed carinations, but that this is counteracted by a still stronger tendency to produce turretted forms, with the carinations and sulcation of the lower side more or less depressed or atrophied, and that side correspondingly more or less rounded. It will be seen at once that these tendencies produce in one direction the squarest whorls and mouths, and in the other the triangular or trochiform shape of the whorl and mouth.

The specimen figured on line *o*, fig. 15, pl. 1, is the young of *discoideus*, with a very close resemblance to the var. *rotundatus*, Hilg., differing only in the greater angularity of the lower side. It is the young of a *Pl.* ${}^{trochiformis}_{discoideus}$ variety, and not of the true *Pl. trochiformis*. There is one remark of importance to be made in this connection, that this young form is intermediate between the flattest of the *rotundatus*-like young, next to be described, and the young of the immature forms of *discoideus*, figured below on line *l*, figs. 7–9.

Var. *rotundatus*, as described and figured by Hilgendorf, is equivalent to the young of several forms of *Pl. trochiformis*.

Sandberger alludes to it as a full-grown variety of his *intermedius*, distinguished by its smoothness, but in this sense it is not identical with Hilgendorf's figure, which relates to the young alone, as may be seen in the following remarks.

If we compare the young of *Pl. discoideus* displayed on pl. 2, line *i*, figs. 1–9, and line *h*, figs. 1–17, with the *tenuis* forms on line *f*, fig. 1–12, we shall first ascertain one very important fact, which has been stated before: that the young of *Pl. discoideus* differ in the smooth forms from the young of *Pl. tenuis*, in being stouter, even from a very early period, though in all other respects they are identical. The *discoideus* series is finished by the older specimens, figs. 13–17, line *f*.

The continuity is unbroken on line *h*, and fig. 18 makes an easy transition with its more or less rounded whorls, from *discoideus* to the forms of *rotundatus*.

These do not entirely abort the third carina which is still to be seen in fig. 23, line *h*. They do, however, inherit a tendency to become trochiform, at a very early age, and with this a tendency to round the lower side of the whorl, and suppress the third and fourth carinæ. If now we attempt to follow up the characteristics, we are led into such forms as figs. 4, 5, 6, line *p*, pl. 2, with a linear third carination, which are undoubtedly young of *Pl. trochiformis*, as figured on line *q*, fig. 18.

The *Pl. trochiformis*, fig. 8, line *n*, is tracable in all its stages down to the undoubted *rotundatus* forms, fig. 12, same line, and figs. 15–18, line *o*. Figs. 9–10, line *o*, are identical with *Pl. discoideus*, and at first seem really to belong to that species. They bear nearly the same relation to that species as fig. 6, line *c*, differing only in having the narrow umbilicus and peculiar sharpness of the lower whorls, which show that they are the young of the same varieties of *trochiformis* as *rotundatus*.

As a separate designation for a variety, the name *rotundatus* therefore has no existence, unless accepted as noted by Sandberger, but even then it is open to this difficulty, that very dissimilar varieties of *Pl. trochiformis* may be devoid of carinae. They may be as distinct as the transition form, fig. 4, line *r*, pl. 2, and the *Pl. trochiformis*, fig. 9, line *k*, pl. 1.

This study of the young forms, however, leads to the conclusion that we must look to the true *discoideus* line for the origin of the major portion of the trochiform varieties. That this is the case, will be established by looking at any large collection of specimens.[1]

In the majority of the varieties of *Pl. trochiformis*, the upper sides of the whorls of the young are exposed at the apex of the shell, and these are smooth, not sulcated, and have two carinae generally blunt, as in the true *discoideus*.

Others, however, equal to the variety *pyrguliformis* Sand., *Pl. trochif. turbinatus* Hilg., are more prominently carinated, as on plate 2, figs. 9–12, line *s*, and have flattened apices; and the young, as seen externally at the apex, seem to be identical with the young of such forms as are figured on line *n*, figs. 1–2, plate 2, which are flattened forms of *discoideus*, distinguishable from the true *sulcatus* variation by the absence of a deep sulcation on the upper side.

Occasionally, however, the apices of some true trochiform varieties are similar to those of the young of other varieties than *discoideus*. Thus, in the case previously pointed out, the young of the forms on line *r*, figs. 6–7, plate 2, indicates a descent from the variety *elatior*, fig. 16, line *i*, same plate, and to this might be added other similar forms like fig. 8, also on line *r*, plate 2, and also fig. 8, line *k*, plate 1. These appear to be identical with Klein's *V. multiformis*, var. *trochiformis*, and in part with Sandberger's *multiformis*, var. *trochiformis communis*.

Fig. 3, line *o*, plate 2, which is the young of the *Pl. trochiformis*, fig. 5, line *r*, has the flattened apex and some of the characteristics of *elegans* Hilg., but also resembles the *discoideus involutus*, and the *discoideus rotundatus* forms. From this, which often has prominent carinations, we are able to pass into *Pl. trochiformis turbinatus* Hilg., line *s*, figs. 9–12. These forms have the flattened and sharply carinated young like those of the less turbinate *elegans* Hilg., as shown on line *a*, fig. 15, plate 3, with a broken young specimen of *Pl. trochiformis* (fig. 16) for companion. Compare then again with selected forms of *Pl. discoideus* in which the young are remarkably flattened and sharply carinated above (as fig. 13, line *c*, plate 2, figs. 1–3), line *k*, figs. 12–14, line *g*, plate 1, and similar figures of *discoideus* on plate 3. The paucity of intermediate forms in this series is very marked, and caused Dr. Hilgendorf, as in the case of *rotundatus*, to invert the natural order of the series. He derives both of these forms from *Pl. trochiformis*, whereas in tracing them out as in the case of *revertens* it will, I think, be found that the young, which always indicate the true line of descent, show closer affinity with discoidean than with trochiform varieties. In this connection see figs. 6, 7, 8, line *k*, plate 1 (fig. 6 being very like *Pl. elegans*, though evidently intermediate between *discoideus* and *trochiformis*); also 5–10, line *b*, plate 2, and then compare fig. 15, line *a*, plate 3, with flat *discoideus* above. The resemblance of the young to these full grown forms will at once become apparent. So far as my experience goes the only retrogressions from *trochiformis*, which I have been able to find, are like those figured on plate 8, which are diseased forms showing, as previously described, a tendency to depart from the spiral as in fig. 10, line *r*, and fig. 11, line *s*, plate 2.

The conclusion from these observations seem to be that *Pl. trochiformis* arises from the almost simultaneous changes of a number of closely allied varieties. These are mostly

[1] The name of the species, *Planorbis trochiformis*, which ought to have been at the head of these remarks, has been accidentally omitted on p. 78, above third paragraph.

discoideus. The extremely flat and square whorled varieties with their prominent carinae and sulcations being, however, more rarely represented by true trochiform descendants, than those forms of *discoideus* in which these parts are less prominent, and the form from the beginning of the series more asymmetrical. These in the trochiform descendants appear in the young as the rotundatus-like form, by which the greater part of all the trochiform specimens are characterized. Thus the direct line of descent from *Pl. Steinheimensis* is shown to be prepotent, or to have a greater number of descendants than any other form.

It is useless to attempt to reduce these proportions to numbers, but it may be generally stated that in any formation the trochiform varieties with rotundatus-like young greatly outnumber all others; so much so that those with a distinct flattened form of the apex have to be sought for, and become rarer and rarer until the extreme is reached in sulcatus-like young of *elegans.*

The value of this statement has been tested by the revision of boxes of *Pl. trochiformis* from nearly all the formations, the results of the sifting of several samples from each formation in the New Pit, besides a mixed box containing thousands, and a similar review of material in the Old Pit and East Pit. There is, however, one notable distinction which is represented also in a measure in the plates. The forms with rotundatus-like young occur much more abundantly in the East Pit than in the Old or New Pit, where the forms with discoideus-like young, the *Pl. trochiformis,* as figured by Hilgendorf, appear to be equally, if not more abundant in some formations.

It will, however, be noted even in this connection that all of the rotundatus-like young as well as the larger forms with rotundatus-like young figured on plate 2, came from the Old Pit. The cases of distorted spirals also are much more frequent among the specimens with flattened discoidean apices than in those with normally formed or rotundatus-like apices. This fact correllates with another of equal importance, namely, that in some case a true elatior-like whorl may be caused by a wound. Thus in one specimen in my collection, of a *Pl. trochiformis* with a typical rotundatus-like young, very smooth and rounded on the apex, a wound has interrupted the deposition of the shell when nearly half grown. The new whorl, when growth was resumed, was not only begun considerably inside of the spiral projected by the earlier whorls, thus narrowing the spiral considerably, but a first carination was produced, and a form of the whorl similar to that of *elatior* instead of such a form as in plate 2, line *s*, fig. 6, which would have been produced in due time if no wound had taken place.

These facts and others mentioned previously, are very curious and appear to indicate less strength on the part of the prominently carinated forms to resist external or internal causes of disease, producing a lessened size of the whorl and distortions of the spiral, which are only very rarely found in those forms having the rotundatus-like young. Thus the descendants in the direct line of descent from *Steinheimensis* are not only more numerous, but healthier than those of other varieties. The largest specimens are those of the transition forms from the flat variety of *discoideus* to *Pl. trochiformis,* such as are figured on line *m*, plate 2, and others with the rotundatus-like young.

The descendants of the *sulcatus* and *elatior* varieties are generally smaller, especially when distorted, but when perfectly normal may be quite up to the average size of the direct line, except in the case of those of *Pl. trochiformis,* which have the discoidean young and are descended from those just referred to, as figured on line *m*, pl. 2. Thus the forms in the direct line of descent have the advantage in point of size, as well as in the other characteristics mentioned.

Besides these numerous varieties, there are still others which cannot strictly perhaps be attributed to disease or any definable cause. One of these is precisely similar to fig. 4, line *r*, plate 2, in the rotundatus-like characteristics of the apex, but is extremely attenuated or tapering. The whorls, however, are perfectly regular, and the external aspect of the spiral smooth and more regular even than in fig. 4. This seems to be the variety *vermetiformis* Sand.

Another variation, which may be the *trochiformis communis* Sand., is that represented by the peculiar stout-whorled spiral of figs. 4–9, line *k*; figs. 2–5 and 6–8, line *s*, on plate 2, have also rotundatus-like young.

The distorted specimens, line *r*, figs. 9–10, plate 2, also deserve special attention. These have rotundatus-like young, but the last whorl, as shown in fig. 10, has an excessively thick inner lip, and strikes off from the regular line of increment. In both cases, the coarseness and the crumpled look of the aberrant part of the whorl indicates a diseased condition to which doubtless the distortion must be attributed.

There are also extraordinary forms frequently found at the apex, showing that the young, as in fig. 1, line *s*, plate 2, must have presented a remarkable spiral during the two whorls, owing to the sharp projection of the second carina due to the contraction of the spiral. This was undoubtedly, I think, a pathological condition, because if it had been continued the adult would have been much distorted, perhaps even unrolled, as in *Pl. denudatus* Hilg. It will be perceived that these results agree only in part with those of Hilgendorf. That author traces *Pl. trochiformis* through *discoideus* and *sulcatus* in linear succession, to *Pl. tenuis*, then to *Pl. Steinheimensis*, and lastly to *Pl. aequiumbilicatus.*

The changes or variations from *sulcatus* and *discoideus* varieties into *trochiformis* were probably simultaneous or nearly so. At any rate, though this cannot be proved, there is a strong antecedent probability in its favor, owing to the sudden appearance of these forms in such great numbers, the precise parallelism of the different series, the frequency of hybrids and a parallelism so exact that it can only be explained by supposing that it was produced by the intercrossing of all the varieties.

This conclusion I find after a re-examination of the material to be substantially correct so far as the evidence as found in the Pits is concerned.

Throughout the preceding observations any reader can see by referring to the figures from what Pit and formation the different shells came, but in the following remarks no attention is paid to the formation, that not being considered important.

There are upon plate 7, six specimens of *Pl. levis* from Undorf; three of them are easily picked out, having been mounted on white paper, but can any reader distinguish the other three from the Pit forms of *Pl.* $^{\mathit{Steinheimensis}}_{\mathit{levis}}$, which are associated with them, before reading the following descriptions.

This series is arranged entirely with the view of showing the zoological affinities of the series, independent of their geological relations.

The shells are more magnified than in the first three plates, and carefully selected to show their affinities.

Line *a*, fig. 1, *Pl. levis*, from Undorf, compares with figs. 3, 5, *Pl. Steinheimensis*. The latter have peculiarly deep umbilici on the upper side, which is a characteristic of *Pl. levis*, and are otherwise just like fig. 1; the forms could not be separated if found together. Fig. 2 shows the typical form of *Pl. levis*, from Undorf. Fig. 6, also, from Undorf, exhibits the angular whorl of *Pl. levis*, and compares equally closely with fig. 7, *Pl. Steinheimensis* and fig. 8, a young specimen of the latter. Compare also fig. 2, line *b*, from the Pits, with *Pl. levis*, Undorf, fig. 3; fig. 1, line *b*, *Pl. Steinheimensis*, with fig. 4, *Pl. levis*, Undorf; figs. 5, 7, 8, line *b*, from the Pits, with figures on the line below, and fig. 6, from Undorf. It is observable, however, that while in *Pl. levis* a decided angularity is found in the outer edge of the mouth-rim, owing to the prominence of the third carination, this is not the case with *Steinheimensis*, as a rule. It is a rare exception in the last named, and none of the normal specimens examined by me, even though they had this third carination as strongly shown as in fig. 6, line *a*, plate 7, possessed an angulated aperture.

Fig. 3, line *c*, shows a remarkably fine specimen of *Pl. Steinheimensis*, which has the cylindrical form of the whorls common in var. *aequiumbilicatus* Hilg., but is not aequiumbilicated. It is decidedly asymmetrical, and shows the tendency to form a turbinate whorl, which is so common in all the forms. Line *c* exhibits forms of *Steinheimensis* intermediate with regard to the stoutness of the whorl, etc., between those in the three lower lines, and line *d*. These specimens also show, as dō those below, that in some specimens the same variations occur also in the young. Line *e*, figs. 1–4, are more or less symmetrical forms, all normal, healthy, full-grown, but not outgrown, or old specimens, as in fig. 13, line *h*, pl. 1. Fig. 7, line *d*, is *Pl.* $\overset{tenuis}{Steinheimensis}$, from the rocks of the Upper Tier of the Cloister Ridge; figs. 5–7, line *e*, are *Pl.* $\overset{tenuis}{Steinheimensis}$ from the Pits.

Figs. 1–3, line *f*, complete the transition to *Pl. tenuis*, figs. 4–5.

The asymetrical forms of *tenuis* are shown in fig. 6–7, same line, and on line *g*, all of which are *tenuis* forms. Fig. 6, line *g*, is the stoutest true *tenuis* form which I have been able to find in my collection, and it will be seen that a hair's breadth more and a shade more of prominence to the third carina would make it impossible to say whether it was *tenuis* or *discoideus*.

The remaining specimens on this plate exhibit the ordinary forms of *discoideus*, those having *rotundatus* young. Figs. 3–6, line *i*, are true *rotundatus* Hilg., and figs. 1, 2, same line, the transitions from *Pl. discoideus* to these.

It remains now only to trace the law of acceleration in this series. If we select any of the transition forms, *Pl.* $\overset{tenuis}{Steinheimensis}$, and examine the younger stages, we should find, as in fig. 1, line *b*, fig. 13, line *c*, pl. 1, that the only traceable resemblance to *Pl. tenuis*, the sulcation, occurs on the last part of the last whorl, or during the full grown adult condition only; that such shells as figs. 14–15, line *c*, exhibit the same at an earlier age, accompanied by carinae, and finally fig. 16, at a still earlier age; so that it is difficult to say whether the young is like *Pl. Steinheimensis*, except at a very early stage.

Finally in many specimens of *Pl. tenuis* it becomes difficult to recognize the form of *Pl. Steinheimensis* at all on account of the early period at which the flattened whorl, carina, sulcation and narrow umbilicus make their appearance, figs. 5–10, line *e*, pl. 1. The square form of the whorl as inherited by *Pl. discoideus* passes through a similar series of descendants, in which it becomes more pronounced and stouter in the young by degrees, until the young themselves from being similar to *tenuis* become stout whorled and discoidean, as well as the adults, fig. 16, line *b*, pl. 2, fig. 14, line *g*, pl. 1. The turbinated form of the shell is wholly an adult characteristic in many specimens of *discoideus*, figs. 2–3, line *h*, pl. 1, fig. 12, line *p*, and may be traced with all its accompanying characteristics through several series to *Pl. trochiformis*, where the different series culminate in shells which have young that are so trochiform-like at an early age, that only the very youngest periods retain any resemblance to *discoideus*.

In some of these it is easy also by breaking down the shell to see one of the common results of this mode of inheritance by acceleration. Namely, the *Steinheimensis* form is almost, and in some few cases entirely, unrecognizable. It is skipped by the development, and so also is the *tenuis* form, the *discoideus* form alone surviving in the young.[1]

With regard to the proper identification of these forms, and those described by Klein in Jahresh. d. Vereins für vaterland. Naturk. in Württ., 1847, p. 60, fig. 7, line *h*, pl. 1, seems to me identical with Klein's *V.*, *multiformis* var. *planorbiformis*, pl. 2, fig. 14.

Fig. 7, line *k*, pl. 1, seems to correspond with Klein's *V. multiformis* var. *intermedia*, pl. 2, fig. 15. Fig. 8, line *r*, pl. 2, is almost exactly identical except in size with Klein's figure of *V. multiformis* var. *trochiformis*, pl. 2, fig. 16. Fig. 7, line *l*, pl. 2, is equally close to Klein's figure of *V. multiformis* var. *turbiniformis*, pl. 2, fig. 17. Fig. 11, line *o*, pl. 2, is apparently identical in every respect with Klein's *V. multiformis* var. *rotundata*, pl. 2, fig. 18.

Feeling that it would be futile to attempt a revision of the names of the different varieties, I do not attempt here or elsewhere, to do anything more than assist those who may feel disposed to take upon themselves this thankless task, with such observations as I may have made.

Sandberger's diagnosis, in which he divides this group into three, is the best which has been devised, with the exception of *rotundatus*, which, as shown, is only a name for a young specimen, and is therefore placed in brackets.

First variety[2] A, *planorbiformis*; containing sub-variety *a*, *sulcatus*, sub-variety *b*, *discoideus*, sub-variety *β*, *elatior*.

Second variety B, *intermedius*; containing sub-variety *a*, *communis*, sub-variety *b*, *elegans*, [sub-variety *c*, *rotundatus*].

Third variety C, *trochiformis*; containing sub-variety *a*, *communis*, sub-variety *b*, *pyrguliformis*, sub-variety *c*, *vermetiformis*.

[1] This phenomenon was what led to the adoption of the name "acceleration."

[2] In place of "variety," I should have written *group*, and in place of "sub-variety" the word *species* in most cases, but this is merely a difference in taste.

V. Lists of Fossils by Sections.

Old Pit, Section 5–6.

Formation "a."

Stratum "a," 1, and a.

This, the lowest observed stratum, was explored in two places in the Old Pit by means of holes sunk through the fish layers, *c*, to the dark Jura clay beneath. At the lowest points fossils were carefully collected, which are figured on plate 1, lines *a–k*, and *k–l*. Lines *a–k* include the varieties obtained during the first visit to Steinheim, in the first hole sunk to the Jura-clay level, and also those collected during the second visit in a new hole at a short distance to the northward and still within the limits of the Pit. Lines *k–l*, include a selection of the varieties obtained in the lowest stratum during the reopening and reëxamination of the first hole dug and described above, in order to establish the fact that *Planorbis trochiformis* occurred in the Old Pit associated at the lowest level with *Pl. Steinheimensis*, var. *aequiumbilicatus*.

The descriptions and plates show that the following species, with many intermediate forms, were obtained from the lowest part of the deposit, in contact with the Jura or dark-brown clay.

Pl. Steinheimensis, var. *aequiumbilicatus.*
Pl. Steinheimensis.
Pl. oxystomns/levis.
Pl. Kraussii/Steinheimensis.
Pl. tenuis/Steinheimensis.
Pl. tenuis.
Pl. discoideus.
Pl. discoideus, var. *involutus.*
Pl. trochiformis/discoideus.
Pl. trochiformis/discoideus, similar to var. *elegans* Hilg.
Pl. trochiformis.

Stratum a2, Old Pit.

This consisted, like the first stratum, of a brownish colored, coarse sand, but was devoid of clay, and contained also stones or small boulders. The following species were found, and are figured on plate 1, lines *m–p*:

Pl. Steinheimensis var. *aequiumbilicatus.*
Pl. Steinheimensis.
Pl. oxystomus/levis.
Pl. tenuis/Steinheimensis.
Pl. tenuis.
Pl. discoideus.
Pl. trochiformis/discoideus.

Stratum a3, Old Pit.

This consisted of sand of a similar coarse quality and color to that of *a*2, but contained no large stones. The fossils were as follows, and are figured on plate 2, line *a*, and line *b*, figs. 1–4.

Pl. Steinheimensis, var. *aequiumbilicatus.*
Pl. Steinheimensis.
Pl. tenuis/Steinheimensis.
Pl. tenuis.
Pl. discoideus.

Summary of Formation "a."

The geological characteristics of the lowest observed stratum in each of the two holes sunk to the level of the bottom clay differed. In the first hole, at the base of Section 6, it was almost entirely shell-sand, but in the second hole, at the base of Section 5, the sand was largely mixed with clay. The strata *a*2 and *a*3, in Section 5, both contain the typical forms of stratum *a*1, but not quite so fully represented in *a*2 as in *a*1, or in *a*3, as in *a*2. They seem, therefore, to be diminishing at the end of this period, in this part of the lake. The deposits of *a*2 are distinct from *a*1; they consist of masses and granules which resemble in character the adjacent porous limestone, or the older rocks described previously as forming the mass of the Cloister-ridge. Without the contained fossils it would not have been possible to have synchronized the two formations, namely, the single stratum at the base of Section 6, and the three strata at the base of Section 5. The fossils, however, include a similar association of forms. *Pl. Steinheimensis*, *Pl. tenuis* and *Pl. discoideus* are abundant, and *Pl. trochiformis* is comparatively rare.

Formation "b," Old Pit.

This contains no fossils, but was situated immediately under Formation *c*, in both of the holes dug in the Old Pit. It contained shell-sand, and a considerable proportion of clay, in Section 6, and was almost wholly of clay in Section 5.

Formation "c," Old Pit.

This consisted, in the first hole dug, of 250 mm. of clay, in layers, and 250 mm. of limestone layers, all more or less filled with fish remains; in Section 5, however, in the second hole, the limestone occurred in layers regularly divided thoughout by layers of clay. No shells were found associated with the fish fossils. The general distribution of this Formation and its peculiar fossils makes it very valuable as a fixed level, from which to estimate the relationship of other formations.

Formation "d," Old Pit.

This consisted, in the locality first explored in the Old Pit, of clay and sand mixed, 300 mm. in thickness, and in the second place, Section 5, of sand exclusively, the thickness being approximately 270 mm. The fossils were scarce and difficult to gather, because this formation formed the floor of the Pit in both sections.

The following fossils were obtained:

Pl. discoideus.	*Pl. trochiformis.*	*Pl. minutus.*

They are figured on pl. 2, line *b*, figs. 5–16.

Formation "e," Old Pit.

This consists of shell-sand 1 m. in thickness, and abundance of fossils, especially of the smaller forms. The color differs somewhat from this ordinary shell sand, and it appears of darker or brown color, as if made up of the debris of darker limestones on the hill.

The following fossils were obtained:

Pl. discoideus.	*Pl.* $\frac{denudatus}{minutus}$.	*Pl* $\frac{costatus}{minutus}$.
Pl. trochiformis.	*Pl. denudatus.*	*Pl.* $\frac{minutus}{levis}$.
Pl. minutus.	*Pl. costatus.*	*Pl. tenuis*, var. *Kraussii.*

They are figured pl. 2, lines *c*, *d*, and *e*, figs. 1–17.

Formation "f," Old Pit.

This consisted of the usual quality of white shell-sand, and contained the following fossils:

Pl. tenuis.
Pl. discoideus.
Pl. $\genfrac{}{}{0pt}{}{denudatus}{minutus}$.
Pl. denudatus.
Pl. $\genfrac{}{}{0pt}{}{costatus}{minutus}$.
Pl. costatus.
Pl. triquetrus.

Plate 2, line *e*, figs. 18–27, line *f*, line *g*, figs. 1–16.

Formation "g," Old Pit.

This is composed of the common white friable shell-sand, but contained no fossils.

Formation "h," Old Pit.

This consisted of the ordinary white, friable shell-sand, and contained the following fossils:

Pl. discoideus.
Pl. discoideus (*rotundatus*-like young).
Pl. discoideus (var. *elatior*=*Pl. triquetrus*. Sand).
Pl. trochiformis.

Plate 2, line *g*, figs. 17–23, line *h–l*.

Formation "i," Old Pit.

This consisted, where examined, mostly of the debris of broken shells, but contained numerous fossils in good preservation, but very few species.

Pl. discoideus.
Pl. $\genfrac{}{}{0pt}{}{trochiformis}{discoideus}$.

Plate 2, line *m*.

Formation "k," Old Pit.

This consists of the common quality of white, friable shell-sand, and contained the following fossils:

Pl. tenuis.
Pl. discoideus.
Pl. trochiformis.
Pl. trochiformis (*rotundatus*-young).

Plate 2, lines *n*, *o*, and *p*, figs. 1–13.

Formation "l," Old Pit.

This consisted of white shell-sand, and contained:

Pl. $\genfrac{}{}{0pt}{}{tenuis}{Steinheimensis}$.
Pl. tenuis.
Pl. discoideus.
Pl. $\genfrac{}{}{0pt}{}{trochiformis}{discoideus}$.
Pl. trochiformis.
Pl. trochiformis (var. *pyrguliformis* Sand).
Pl. minutus.
Pl. $\genfrac{}{}{0pt}{}{denudatus}{minutus}$.
Pl. denudatus.
Pl. costatus.

Plate 2, line *p*, figs. 14–20, and lines *q*, *r*, *s*.

Formation "x," Old Pit.

This has the admixture of broken shells and perfect specimens which is very often found in other formations, and I cannot see why it should be necessarily considered as entirely composed of transported materials, as described by Hilgendorf.

Pl. discoideus, *Pl. trochiformis*, and one well-preserved specimen of *Pl. oxystomus* were obtained.

Formation "l." (Uncertain.)

The absence of the upper or clayey formations from "*m*" upwards, in the Old Pit, had attracted my attention from the first.

In order to ascertain whether this had been due to denudation, I ordered a hole to be dug on the top of the hill at some distance from the Old Pit, and a little to the north of a line connecting the Old Pit and the East Pit. This was sunk about eight feet; the first two feet or so through a bed of rubble, containing large specimens of Lymnæa; the remaining five feet, through a bed corresponding more to Formation *l* of the Old Pit, than to any other. *Pl. trochiformis* of the same varieties as those figured on plate 2, lines *r*, *s*, were very abundant, but distinguished by the almost invariable absence of the carination on the lower side.

Pl. costatus and *minutus* were also quite abundant, especially the latter; in both also the specimens were large, and the ribs in the latter very coarse and prominent, as in the variety *major* Hilgend. Var. *Kraussii* was also found, but of rare occurrence.

The bed could not be said to be continuous with *l* in the Old Pit, although in all probability it was synchronous, and bed *x* was entirely absent, its place being occupied by the rubble, which occurs frequently just under the surface soil on the hill, and appears to be composed of drift from the Cloister-ridge rocks.

This result was interesting, in so far as it confirmed the conclusions attained elsewhere, that the beds often differ so essentially, although but a short distance removed from each other, that it is not possible to determine whether they are exactly synchronous. One fact is worthy of special remark. The rubble had also occurred at the very highest point known, the top of the Cloister Pit, Section 1, but the *oxystomus* layers were absent, and the rubble on the north side of the hill rested directly on the *trochiformis* beds, which agree in their fossils with formation *l* of the Old Pit more than with the higher beds *x*; which, however, have similar fossils.

New Pit, Section 8, South side.

This section was made on the south side of the New Pit, where the formation differed somewhat from those on the east side, as shown in Section 7. It would have been idle to repeat the figures of the usual *Pl. discoideus* and *trochiformis* shells of the Old Pit, and other species which have been already so fully given. These occurred abundantly in some of the strata, and more rarely in others, until in Formation *m*, they gave way to the usual fauna of the *oxystomus* zone. I have accordingly only figured those forms which were not previously found at what have been considered as corresponding levels in the Old Pit, or which seemed to require special consideration.

Formation "f," New Pit, South side.

This consisted of the usual shell-sand, but many of the specimens were incrusted with lime, and had the aspect of transported shells. *Pl. crescens* makes its appearance, but is rare.

Pl. tenuis. *Pl. discoideus.* *Pl. trochiformis.*

Pl. 3, line *a*, figs. 1–3.

Formation "g," New Pit, South side.

This also consists of shell-sand and fossils, but not so abundant as in *f.*

Pl. discoideus and *Pl. trochiformis.*

Formation "h," New Pit, South side.

This consists of shell-sand, and contains :—

Pl. parvus. *Pl. oxystomus.* *Pl. discoideus.*
Pl. crescens. *Pl. minutus.* *Pl. trochiformis.*

Pl. 3, line *a*, figs. 4–14.

Formation "i," New Pit, South side.

Pl. parvus. *Pl. oxystomus.* *Pl. trochiformis* var *elegans*,
Pl. crescens. *Pl. trochiformis.* (Very rare).

The absence of *Pl. discoideus* is a fact worthy of remark.

Pl. 3, line *a*, figs. 15–23, line *b*, figs. 1–11.

Formation "k," New Pit, South side.

This consists of shell-sand and contains :—

Pl. oxystomus. *Pl. costatus* var. major. *Pl. trochiformis.*
Pl. crescens. *Pl. discoideus.*

Pl. 3, line *b*, figs. 12–17.

Formation "l," New Pit, South side.

This consists of shell-sand, and contains : —

Pl. oxystomus. *Pl. minutus.* *Pl. trochiformis.*

Pl. discoideus was not found.

Pl. 3, line *c*, figs. 1–4.

Formation "m," New Pit, South side.

This consists almost wholly of clay, and contains :— *Pl. oxystomus*, *Pl. crescens*, but no *Pl. discoideus* ; and *Pl. trochiformis* becomes exceedingly rare.

Plate 3, line *c*, figs. 5–16.

Formation "x," New Pit, South side.

This consisted of the usual shell-sand and broken shells with *Pl. trochiformis* and *Pl. discoideus*, well preserved and very abundant.

Formation "p," New Pit.

This consisted of alternate thin layers of clay and limestone, containing remains of *Pl. oxystomus*, *Pl. crescens*, and *Pl. trochiformis*, the last very abundant in the lower part, and very rare in the upper part of the formation.

New Pit, Section 7, East side.

The species of the formations in this section did not seem to require figuring. The beds are remarkably distinct in aspect from those of the more regular layers on the south side of the same pit, as shown in section 8.

Formation "g," New Pit, East side.

This formation was made up of alternate layers of limestone and shell-sand, containing the usual *Pl. trochiformis* and *discoideus*, but no other forms were present, or represented in my collection.

Formation "h," New Pit, East side.

This narrow streak of shell-sand was perhaps one of the most remarkable deposits which it was my good fortune to find. It was an almost solid bed of shells, consisting largely of the transition form, *Pl.* $\frac{\textit{trochiformis}}{\textit{discoideus}}$. Quite a number of the *Pl. discoideus* and *Pl. trochiformis* were also present in all varieties and some very remarkable forms, produced by distortion of the spiral, arising from wounds.

Formation "i," New Pit, East side.

The lower part of this formation presented a very close resemblance to Formation "*n*," of the East Pit, Section 3. It contained lumps of limestone, in a fine sandy clay, and it is not improbable that these show the mode of formation of the numerous dividing layers of limestone, since they are of all degrees of hardness and exhibit frequently no definite outlines when in place.

Pl. parvus was found, but not very abundant. *Pl. crescens* was more abundant than the preceding. *Pl. oxystomus* was quite rare. *Pl. trochiformis* was abundant, but not so frequent as in the upper part. Var. *Kraussii* was also found, and *Pl. minutus*, but not abundantly.

Formation "k," New Pit, East side.

This consists of a thin layer of shell-sand between two layers of clay, and was evidently of very limited extent. The clay on either side contained no fossils.

Pl. $\frac{\textit{oxystomus}}{\textit{levis}}$ = var. *revertens*, and the turbinate and flat forms were very abundant. *Pl. crescens* was also abundant. *Pl. trochiformis* and *Pl. oxystomus* were the most characteristic and numerous of all others.

Formation "l," New Pit, East side.

This consisted of shell-sand. The usual list of shells were found, *Pl. trochiformis* being perhaps the most abundant form.

Pl. minutus.	*Pl. crescens.*	*Pl. tenuis* var. *Kraussii.*
Pl. oxystomus.	*Pl. trochiformis.*	

Formation "m," New Pit, East side.

The clay bed in this section was by no means so thick as in Section 8, though it probably only corresponds to the lower part of Formation "*m*" in Section 8. The collections made from this bed are particularly favorable to the views taken by Hilgendorf of the genesis of *Pl. oxystomus* from *Pl. trochiformis*.

They appear in my collection labelled as transition forms, and would without other evidence be considered sufficient to prove his position. A most perfect series can be built up between *Pl. trochiformis* and the extreme *discoidal* variety of var. *revertens*, which I think would be considered sufficient even by the most sceptical person, if no other evidence was forthcoming.

The confusion arises from the number and variety of the *Pl. trochiformis* with *rotundatus* young, and the close resemblances of these young forms to certain varieties of *Pl.oxystomus*, which were also present in considerable numbers.

Pl. crescens was abundant and of large size.

Formation "x2," New Pit, East side.

This consisted of the ordinary materials of the shell-sand filling a lenticular pocket, which disappeared on following it a short distance towards Section 8.

Formation "n, o," New Pit, East side.

This was a bed of clay of the usual fine texture, and containing specimens of *Pl. oxystomus* and *Pl. crescens*, but no other species.

Formation "x3," New Pit, East side.

This consisted of the usual materials, and was apparently continuous with *x*3, in Section 8, and just above it laid the layers of limestone and shell-sand of

Formation "p," New Pit, East side.

This bed is directly traceable into formation *p*, of Section 8, and contained the same species of fossils.

Little Pit, Section 4.

Formation "a," Little Pit.

This was situated considerably to the northward of the Old Pit, on the first road to the eastward. It was only a small excavation, but I employed a laborer to open it to the depth of about ten feet. The weather, however, was very unfavorable for such work, and the digging difficult on account of the thickness and frequency of the limestone. I therefore abandoned it before reaching the Jura clay, but succeeded in ascertaining the fact that the layers increase in thickness to the northward.

Above the two clay layers respectively marked 1 and 2 of Formation *a*, occurred a thick deposit of drift material, often very coarse, and exactly resembling the porous limestone drift of Section 5, formation *a*2, but much thicker. Here shells were more abundant, and I obtained a few specimens of *Pl. tenuis*, and one uncoiled specimen of

Pl. denudatus. This last was very carefully collected, and there is no doubt in my own mind, that it came from this formation, but though I sought diligently for specimens, I could not find another. Above this we find Formations *b*, *c* and *d*, running together, and consisting of layers of clay containing the fish remains.

Formation "e," Little Pit.

The lower part of this formation consisted of the same brown porous limestone drift as formation *e* in the Old Pit, and the fossils of the lower part also agreed very closely with those of that formation. The upper part contained a large admixture of the ordinary friable shell-sand, and a somewhat distinct fauna.

Lower Part.

Pl. minutus, *Pl. costatus*, and *Pl. denudatus* were particularly abundant, with *Pl. discoideus*.

Upper Part.

Pl. discoideus, and *Pl. trochiformis* are abundant, and with them numerous specimens of the form of the young, known as *rotundatus*.

Formation "f," Little Pit.

The prevailing fossils here, as elsewhere, were *Pl. trochiformis* and *Pl. discoideus*.

East Pit, Section 3.

This section was taken on the south side of the Pit, and continued as far down as possible by a hole dug to the fish-layers of formation *e*. Any attempt to penetrate this, though made here in two places, was frustrated by the influx of water.

Formation "c," East Pit.

This consisted of clay in layers containing the usual fish fossils, but no shells.

Formation "d, e," East Pit.

This is very thick, and consists of layers of shell-sand of greater or less density, but otherwise not distinguishable. They have the same lumpy character and brown color of the corresponding formations in the Old Pit. *Pl. discoideus* was abundant.

Pl. minutus and *costatus* were also abundant. *Pl. triquetrus* was also found. A broken specimen or two of *oxystomus* was found, a fact which was carefully ascertained.

Formation "f," East Pit.

This formation is naturally divided into three parts just in the southwest corner of the sandpit, where one hole was dug, by streaks of clay interpolated between the three thicker layers of shell-sand. *Pl. discoideus* is particularly fine in the lowest, but generally not very large. The usual spiral transition forms are not very abundant, the large majority being of the deeply channelled *sulcatus* form. A few also are smooth, but none of them approximate very closely to *trochiformis*. *Pl. sulcatus* had the same peculiarities in the middle bed. In the upper bed, however, nearly all the forms, without approximating very closely to *Pl. trochiformis*, showed the trochiform tendency in being more or less spiral, either throughout life, or only in the adult; only a very few of the flat sulcatus form were found in this part. *Pl. minutus* occurred but very rarely in the lower part, while in the middle part it was much more numerous, and also associated with *Pl. costatus*. In the upper part they were even more numerous, and associated with *Pl. costatus*. One specimen had the tunnelled form, but the whorls were not open. Var. *Kraussii* follows nearly the same rule, being scarce in the first, quite numerous in the second, and still more abundant in the third part.

One broken specimen of *Pl. oxystomus* was found in the middle part in which only a portion of the centre, and an outer whorl is left unbroken.

Formation "g," East Pit.

This consists of clay, but has two pockets or layers of shells. *Pl. discoideus* was very abundant, with numerous specimens of the rotundatus young of *Pl. trochiformis* in all varieties, *Pl. minutus* and *costatus*, and *Pl. parvus*, and rarely *Pl. crescens*.

Formation "h," East Pit.

This consists of shell-sand. *Pl. discoideus*, and *Pl. trochiformis*, with all the intermediate forms were very abundant. *Pl. minutus* and *Pl. costatus* were also very abundant, and uncoiled forms of both species. Var. *Kraussii* and *Pl. crescens* also occur, but not so frequently.

Formation "i," East Pit.

This consists in the lower part of two strata of clay, with three of shell-sand, and in the upper part of one layer of shell-sand between two of limestone. The shells were not abundant, and much thinner than in the preceding formations. *Pl. trochiformis* most frequently occurred, but not in good preservation. *Pl. minutus*, *Pl. costatus*, and *Pl. crescens* were also found. A specimen similar to *Pl. pseudotenuis Hilg.*, probably the young of *Pl. tenuis*, occurs for the first time in these formations.

Formation "k, l," East Pit.

This consisted of shell-sand and could have been divided into two parts according to the fauna, but this hardly seemed essential since the deposit was continuous. The lower part contained *Pl. minutus*, *Pl. costatus*, and a large proportion of the uncoiled or costated denudatus-like varieties. *Pl. crescens*, and *Pl. oxystomus* also occurred, the latter in great plenty. *Pl. trochiformis* was also abundant, but the most interesting form zoölogically, though not frequent, was the pseudotenuis-like species, which seems to be the young of the *Pl. tenuis* figured on line *f*, figs. 1–6, plate 2.

The shells of *Pl. minutus*, in the upper part, were whiter and more fragile than in the lower, and *Pl. oxystomus* was almost entirely absent; otherwise the fauna presented the same characteristics.

Formation "xl," East Pit.

This formation occurred in a pocket of limited extent.

Formation "m," East Pit.

The lower part of this formation was divided by a layer of broken pieces of limestone. Both parts consisted of clay. Specimens of *Pl. trochiformis*, *Pl.* $^{oxystomus}_{levis}$ var. *revertens*, and *Pl. oxystomus*, *Pl. crescens*, *Pl. tenuis*, *Pl. minutus* and *Pl. costatus* var. *major* were also found. The upper part contained the same forms with the exception of *Pl. costatus* and *Pl. trochiformis* in one spot, while in another, almost adjoining, these were also found.

Formation "n," East Pit.

This consisted also of two parts. The lower of an argillaceous shell-sand, and the upper of an exceedingly fine sand filled in the border with nodules of the same material, but of lithographic fineness, and very soft. The lower portion alone contained fossils.

Pl. trochiformis, *Pl. crescens*, *Pl.* $^{oxystomus}_{levis}$ var. *revertens*, and *Pl. costatus* var. *major* occurred, but none very abundantly.

Formation "o," East Pit.

This consisted of clay more or less permeated by reticulated veinings of limestone, arising from percolation from above, giving the whole a loose tufaceous aspect, reminding one of the limestone on the surface of the hill. Only a few specimens were found. *Pl. oxystomus* var. *revertens*, *Pl. oxystomus*, *Pl. crescens*, and *Pl. costatus* var. *major*.

Formation "x3," East Pit.

This appeared to be similar in character to what was found in the Old Pit, but contained *Pl. oxystomus* in considerable abundance.

East Pit, Section 2.

It is not necessary to describe in detail the formations shown in this section. It is taken from an excavation in the centre of the Pit. Three such excavations were examined, and an attempt made to sink this one deeper, which was unsuccessful on account of the influx of water. It is evident, however, here, that the strata are apt to become thicker, as we progress outwards from the hill. The fossils were about the same as in the corresponding formations of Section 3.

Cloister Pit, Section 1.

This pit, which had become filled with debris, was reopened to a depth sufficient to uncover the beds containing abundance of the *Pl. discoideus* and *trochiformis*. None of these formations compare very closely with those of the other pits, and it is to be regretted that I did not continue the excavations to the base.

Dr. Hilgendorf in his last exploration, however, has repaired this omission. He found that the base of the section rested upon Opalinus clay, an older formation of the Jura than those which are at the bases of the other sections. He also ascertained that the lowest beds contained only *Pl. Steinheimensis*, a fact of the greatest importance to his theory. This, however, does not seem to me to be conclusive, even though confirmed in other sections, for reasons given elsewhere. In fact, the occurrence of the true *Pl. Steinheimensis* bed in these elevated deposits makes it very difficult to account for the absence of this bed in lower situations, such as those represented by Sections 5, 6.

Formation "k," Cloister Pit.

This consists of shell-sand and contains the following fossils in the lower part:—*Pl. discoideus, Pl. minutus. Pl. discoideus* was the only fossil Planorbis found in the upper part.

Plate 3, line *c*, figs. 17–19, and line *d*.

Formation "l," Cloister Pit.

Consists of layers of shell-sand, with the usual limestone partings, and contains *Pl.* $^{minutus}_{levis}$ = *parvus* (pars). *Pl. crescens, Pl.* $^{oxystomus}_{levis}$ var. *revertens, Pl. oxystomus, Pl. oxystomus* var. *cochleata, Pl. supremus* var. *turrita, Pl. supremus, Pl. discoideus, Pl.* $^{trochiformis}_{discoideus}$, *Pl. trochiformis.*

Plate 3, lines *e–k*, and line *l*, figs. 1–14.

Formation "m," Cloister Pit.

This is like "*l*," lithologically, and contains:—*Pl.* $^{oxystomus}_{levis}$ var. *revertens, Pl. oxystomus, Pl. supremus* var. *turrita, Pl. discoideus, Pl. trochiformis.*

Plate 3, line *l*, figs. 15–17, and lines *m–p*.

Formation "n, o," Cloister Pit.

This consisted of sand layers with limestone partings like formation *m*, but contained no fossils. Above this occurred a bed of rubble consisting of disintegrated rock, apparently derived from the Cloister-ridge rocks and resembling in character that previously encountered on the north slope of the hill, but containing no fossils.

VI. Lists of Species by Formations.

Lower Period, or Period of Rock Deposits.

Neuselhalder Rocks.

Pl. solidus.
Pl. declivis.
Pl. Larteti or *conulus.*
Pl. platystomus.
Pl. exustus.
Pl. Hilgendorfi.
Pl. levis.

Coarse Limestone.

Pl. oxystomus / levis.
Pl. oxystomus.
Pl. supremus / oxystomus.

Oxystomus Limestone.

Pl. oxystomus / levis.
Pl. parvus.
Pl. oxystomus.
Pl. supremus / oxystomus.

Valley Rock.

Pl. tenuis / Steinheimensis.
Pl. discoideus.

Cloister-Ridge Rocks.

(Lower Tier.)

Pl. tenuis / Steinheimensis.
Pl. discoideus.
Pl. tenuis.
Pl. discoideus / tenuis.

(Upper Tier.)

Pl. oxystomus / levis.
Pl. discoideus.
Pl. tenuis / Steinheimensis.
Pl. tenuis.
Pl. tenuis, turreted variety.
Pl. discoideus / tenuis.

Upper Period, or Period of Pit Deposits.

Formation a.

Pl. Steinheimensis var. *aequiumbilicatus.*
Pl. Steinheimensis.
Pl. oxystomus / levis.
Pl. Kraussii / Steinheimensis.
Pl. minutus.
Pl. tenuis / Steinheimensis.
Pl. tenuis.
Pl. discoideus.
Pl. discoideus var. *involutus.*
Pl. trochiformis / discoideus.
Pl. trochiformis / discoideus var. like *elegans* Hilg.
Pl. trochiformis.
Pl. denudatus.
Pl. tenuis, turreted variety.

Formation d.

Pl. discoideus.
Pl. trochiformis.
Pl. minutus.
Pl. costatus.
Pl. triquetrus.
Pl. oxystomus.

Formation e.

Pl. discoideus.
Pl. trochiformis.
Pl. minutus.
Pl. denudatus / minutus.
Pl. minutus / levis.
Pl. denudatus.
Pl. costatus.
Pl. costatus / minutus.
Pl. triquetrus / minutus.
Pl. trochiformis (rotundatus-like young).
Pl. triquetrus.
Pl. oxystomus.

Formation f.

Pl. discoideus.
Pl. denudatus / minutus.
Pl. denudatus.
Pl. costatus / minutus.
Pl. Steinheimensis.
Pl. costatus.
Pl. triquetrus.
Pl. tenuis.
Pl. crescens.
Pl. trochiformis.
Pl. Kraussii.
Pl. minutus.
Pl. oxystomus.
Pl. pseudotenuis.

Formation g.

Pl. discoideus.
Pl. trochiformis.
Pl. trochiformis (rotundatus-like young).
Pl. minutus.
Pl. costatus.
Pl. parvus.
Pl. crescens.

Formation h.

Pl. Steinheimensis.
Pl. discoideus.
Pl. discoideus (rotundatus-like young).
Pl. discoideus var. *elatior.*
Pl. trochiformis.
Pl. trochiformis var. *pyrguliformis.*
Pl. trochiformis / discoideus.
Pl. triquetrus.
Pl. parvus.
Pl. crescens.
Pl. oxystomus.
Pl. minutus.
Pl. costatus.
Pl. denudatus.
Pl. costatus var. *distortus.*
Pl. Kraussii.

Formation i.

Pl. Steinheimensis.
Pl. discoideus.
Pl. tenuis / Steinheimensis.
Pl. trochiformis / discoideus.
Pl. parvus.
Pl. crescens.
Pl. oxystomus.
Pl. trochiformis.
Pl. Kraussii.
Pl. minutus.
Pl. oxystomus / levis.
Pl. costatus.
Pl. tenuis.

Formation k.

Pl. tenuis.
Pl. discoideus.
Pl. trochiformis.
Pl. trochiformis (rotundatus-like young.)
Pl. Steinheimensis.
Pl. oxystomus.
Pl. crescens.
Pl. costatus var. *major.*
Pl. oxystomus var. *revertens.*
Pl. tenuis / Steinheimensis.
Pl. minutus.
Pl. costatus.
Pl. costatus var. *distortus.*
Pl. tenuis.
Pl. pseudotenuis.

Formation l.

Pl. tenuis/Steinheimensis.
Pl. tenuis.
Pl. discoideus.
Pl. trochiformis/discoideus.
Pl. trochiformis.
Pl. trochiformis var. *pyrguliformis.*
Pl. oxystomus/levis.
Pl. minutus.
Pl. denudatus/minutus.
Pl. denudatus.
Pl. oxystomus.
Pl. Kraussii.
Pl. crescens.
Pl. parvus.
Pl. costatus.
Pl. oxystomus/levis var. *revertens.*
Pl. oxystomus var. *turritus.*
Pl. supremus.
Pl. pseudotenuis.
Pl. supremus/oxystomus.
Pl. Steinheimensis.

Formation x.

Pl. oxystomus.
Pl. discoideus.
Pl. trochiformis.

Formation m.

Pl. Steinheimensis.
Pl. oxystomus/levis.
Pl. oxystomus.
Pl. crescens.
Pl. trochiformis.
Pl. trochiformis (rotundatus-like young.)
Pl. oxystomus/levis var. *revertens.*
Pl. tenuis.
Pl. minutus.
Pl. costatus.
Pl. costatus var. *major.*
Pl. supremus.
Pl. supremus var. *turritus.*

Formation n.

Pl. crescens.
Pl. oxystomus.
Pl. trochiformis.
Pl. oxystomus/levis var. *revertens.*
Pl. costatus var. *major.*

Formation o.

Pl. crescens.
Pl. oxystomus.
Pl. trochiformis.
Pl. costatus var. *major.*
Pl. oxystomus/levis var. *revertens.*

Formation x bis.

Pl. discoideus.
Pl. trochiformis.
Pl. oxystomus.

Formation p.

Pl. oxystomus.
Pl. crescens.
Pl. trochiformis.

APPENDIX I.

On page 27 I have written, that I wondered no authors except Prof. Cope and myself had made the law of acceleration an object of investigation.

This statement is not wholly correct, since I find in a work just received, "Studien über die Stammes-geschichte der Ammoniten," by Leopold Würtenberger (Leipzig, Ernest Gunther, 1880, 8vo., pp. 110, with four Stammtafeln), that the author has used this law of heredity, though evidently misunderstanding its fundamental character, as one of the laws of heredity, and explaining it as the result of the action of the law of natural selection. It becomes interesting, also, to observe how closely his statements and facts agree with those previously made in my publications; for example, on page 28, he writes as follows: "Wenn nämlich eine Veränderung welche für die ganze Gruppe eine wesentliche Bedeutung erlangt, zum erstenmal auftritt, so ist dieselbe nur auf einem Theil des letzten Umganges angedeutet. Gegen jungere Ablagerungen hin tritt diese Veränderung immer deutlicher hervor und schreitet dann, dem spiralen Verlaufe der Schale folgend, nach und nach immer weiter gegen das Centrum der Ammonitenscheibe fort; d. h. sie ergreift allmählich immer mehr auch die inneren Windungen, je höher man die betreffende Form in jungere Schichten hinauf verfolgt."

"When, for instance, a variation which attains a substantial importance for the whole group, makes its appearance for the first time, it is exhibited only upon a part of the last (outer) whorl. This variation comes out ever more distinctly as the strata are younger, and advances, following the spiral trend of the shell, step by step, towards the centre of the spiral: that is to say, they (the characteristics) strike gradually more and more towards the inner whorls, as one follows the forms from the older into the younger (later formed) beds."

This statement is an exact transcript of what I have repeatedly written in various essays upon the Ammonites, and also gives the fundamental facts upon which all my investigations have been based for fourteen years.

Compare the above, for example, with the following sentences from p. 203, of my memoir in Vol. 1st of the Memoirs of Bost. Soc. Nat. Hist., read Feb. 21, 1866, and published in 1867.

"The young of higher species are thus constantly *accelerating* their development, and reducing to a more and more embryonic condition, (or entirely passing over) the stages of growth corresponding to the adult periods of *pre-existing* or lower species."

"In other words, there is an unceasing concentration of the adult characteristics of lower species in the young (or inner whorls) of higher species, and a consequent displacement of other embryonic features (in these inner whorls), which had themselves, also, *previously belonged to the adult periods of still lower forms.*"

With reference to the characters of the Ammonitoid shells, on p. 94, he says: "dass die Veränderungen an den Sculpturen, sowie an den übrigen Charakteren der Ammonitenschalen sich zuerst auf dem letzten (äussern) Umgange derselben bemerklich machen, und dass dann eine solche Veränderung bei den nachfolgenden Generationen sich nach und nach immer weiter gegen den Anfang des spiralen Gehäuses fortschiebt, bis sie den grössten Theil der Windungen beherrscht."

"That the variations of the sculpture, as also those of the other characteristics of the shells of Ammonites first make themselves visible upon the last (outer) volution, then such a variation advances in the following generations step by step always nearer to the beginning of the spiral, until it covers the greater part of the (inner) whorls."

The difference between our statements[1] is that Würtenberger speaks of the inner whorls and I use the word "young" in place of the word "inner whorls," because the inner whorls of all shells represent the first formed or younger stages of growth.

I also in the first quotation use a phrase "entirely passing over" which has been included in parentheses because it refers to the skipping of characteristics in development, a phase of the law of quicker inheritance, or acceleration in heredity, which Herr Würtenberger also mentions, but which is not included in his first statement. I might also refer if I chose to similar quotations from Prof. E. D. Cope of Philadelphia, showing that he, simultaneously with me, discovered the same law though giving it a somewhat different application than either Würtenberger or myself.

Now we have only to understand, that the outer whorls are built during the full grown or adult period, and the inner by the animal during the younger stages, in order to perceive that this is a statement that the Ammonites inherited the adult characteristics of their ancestral forms at earlier and earlier periods in successive generations.

This is the law of acceleration, and it is specifically given by Herr Würtenberger in various places in his book, notably on p. 98, where he attributes the preservation of any characteristic differences which may arise, to natural selection, and says that they may be inherited earlier or later in the life of individual descendants.

Then as the earlier inheritance of these characteristics would be of advantage to the individual in the struggle for existence, Herr Würtenberger thinks that successive generations would tend to inherit them at earlier and earlier periods. The objections to this seemingly simple and straightforward explanation are numerous. Animals do not inherit the new characteristics which their parents may have acquired at later periods than those in which they appeared in the parent, but at the same time, or earlier in the immediate descendants, and eventually always earlier in the more remote descendants. I have as yet seen no evidence that the descendants inherit a characteristic at a later period than that at which it first appeared in an adult ancestor.

Even if this assumption should be proven it would still remain necessary to establish the nature of the characteristics inherited, whether they really were advantageous or not.

Nothing can exceed the confidence with which the strict Darwinist assumes, without any appeal to observation, that all characteristics which are inherited are necessarily advantageous. Exactly the reverse is very often true. The disadvantageous, the advantageous, the parallelisms and the differences, are all subject to the law of acceler-

[1] In order to see how closely we have followed the same path it is also necessary to compare the statements on pages 27 and 28 of this Memoir, and in the following essays: "Development of the shells of Ammonoids and Nautiloids." Proc. Bost. Soc. Nat. History, Vol. 14, p. 398. "This is the law of acceleration, or the perpetual reduction of adult characteristics to earlier and earlier periods in the growth of the later existing individuals, until finally many characteristics altogether disappear." "Cephalopods of the Museum: Embryology." Bull. Mus. Comp. Zool., Cambridge, Mass., Vol. 3, No. 5, p. 70-71. "Evolution of the Arietidae." Proc. Bost. Soc. Nat. Hist., Vol. 17, p. 238. "Genetic relations of Stephanoceras," in same, Vol. 18, p. 379, last paragraph, p. 382.

ation described above, whereas the law of natural selection can only act when there is a choice of characteristics, and where those characteristics are differences, variations newly introduced, not yet fixed in the organization, and unquestionably advantageous. Animals or plants must act and react upon each other, and then and not before then, can we have any law like that of natural selection, and it is exceedingly questionable whether natural selection applies at either extreme of life. Man is certainly by his own acts capable of modifying and perhaps controlling the result of the battle of life, and it is very probable that the action and reaction of the first beginnings of life in the past history of the world, was no more than could be accounted for by the known action of physical forces upon the simplest of organisms.

Natural selection certainly has nothing to do in the embryo, nor yet in the extreme old age of the individual. If, as I have constantly tried to prove, the individual life is a true exponent of the life of the group to which it belongs, the embryo to the progressive past, the adult to the present, and the old age to the degraded or retrogressive future of an exhausted or diseased type, then it may with approximate certainty be assumed that natural selection acts at neither of the extremes of the variation of a given group, neither upon the phenomena of their first appearance, nor upon those indicating their decline and leading to their disappearance.

Natural selection, in fact, is simply one of the transient conditions of the physical surroundings, having no value as a cause of origin of characteristics, but simply acting on certain categories of these characteristics, after they have originated, and helping to take them out of the list of transient characteristics and fix them in the organization. Once fixed they are inherited, and, unless as described above, interfered with by a reversal of the ordinary physical conditions, by extreme parasitism, etc., they become a part of the younger stages of growth in accordance with the law of acceleration, and are either finally skipped, crowded out altogether, or become embryonic and part of the type form.

Herr Würtenberger has, also, observed this peculiarity of the skipping or omission of accelerated characteristics, which originally caused the use of the name acceleration as applicable to these phenomena, and used also in this respect words which are almost identical with those which I have employed in describing the same phenomena in previous essays.

"Denn es ist leicht einzusehen, dass die fortgesetzte Wirkung der frühzeitigeren Vererbung der fortwährend im Lebensalter auftretenden Abänderungen dahin führen muss, die früheren Entwickelungsstadien näher zusammenzudrängen, zu verwischen oder zum Theil ausfallen zu lassen, wenn die der eigentlichen Entwickelung der Organismen nicht über alle Massen hinaus verlängert werden soll."

"For it is easy to perceive, that the prolonged working of the earlier transmission[1] of the changes which are perpetually appearing in older life[2] must lead the earlier stages of development[3] to shorten up, to disappear wholly or partly, or else the individual development of the organism would be prolonged beyond all just measure."

[1] In successive individuals, forms or species.

[2] Of the more ancient or ancestral individuals or species.

[3] Of descendant individuals, forms or species.

I have endeavored in this memoir to explain these accelerations or skippings from which the theory took its name, on pages 28, 29, 30, and the importance of this law in explaining the partial or total obliteration of type characteristics in the embryos of some parasites, as well as in the ordinary cases which occur in every group of animals.

Herr Würtenberger deals with the Planulatus, Amaltheus, and Pettos groups, on all of which I have published papers, and since he has quoted Waagen, who cites my work, and since Herr Würtenberger also knew of my work on the "Embryology of the Cephalopods," as is shown by his allusion to my name at the foot of page 35, it would be very interesting to know how he escaped noticing that I had discovered and formulated the law which he justly considers an important law of heredity, and to the exposition of which he had devoted his book.

In a note to page 35 he gives Branco the credit of having done in 1879 the work which I had done in 1872 in my treatise on the Embryology of the Cephalopods, and casually mentions that I had already done something of the same sort on the Goniatites, a small sub-division of the Cephalopods.

Here, unfortunately, he did one of his own countrymen an injustice, since this was one of the parts of my work which was not original, it having been copied almost bodily out of Guido Sandberger's previous researches. I can, however, congratulate Herr Würtenberger upon his recognition by full quotations of that much abused naturalist, Haeckel, who, notwithstanding his great offences against the conservatism of reasoning in science, has given a better analysis than any other living naturalist of the laws governing the relations of animals to their surroundings and to each other. His critics, whose name is legion, do him a monstrous injustice in allowing themselves to dwell wholly upon the errors and the faults they can find, forgetting themselves, and blinding others to the substantial services to science of this justly celebrated naturalist. My own indebtedness to him and to his works is very great, as must be that of all those who strive to get some idea of fundamental laws.

Though differing from him on essential points, still in his Generelle Morphologie der Organismen he has given substantially the same view of the action of heredity in preserving the type, and of the relations of growth to heredity and of heredity to the modifications produced by the direct action of physical influences, as has been set forth in this memoir. The differences lie principally in the estimate of the importance of the law of natural selection, which he considers as of wider application than I think is at all justified by any proofs which have so far been produced.

APPENDIX II.

On page 14, in paragraph next to the last, and again on page 31 in the first paragraph, I allude to the general tendency to spiral mode of growth in all shells.

I had in this memoir no opportunity to enlarge on this subject, and when the remarks were written had not yet published any observations on this interesting subject. Since then, however, in an evening lecture given before the American Association for the Advancement of Science during the meeting of 1880, at Boston, I gave some account of the facts as they stand throughout the Mollusca, and attempted to prove, so far as the absence of experiment would permit, the hypothesis that the spiral forms of all shells, whether Cephalopods, Gasteropods, or Lamellibranchs, and their peculiar shapes, can be accounted for by the different ways in which the attraction of gravitation would act upon the excreting border of the mantle through the weight of the shell itself, or by the natural growth of this part when freed from the weight of the shell.

Thus the oyster, pecten, etc., show during the adult stages distortions and a peculiar horizontal growth which can only be accounted for by the support they receive, either from permanent attachment, or by resting on one valve.

The evidence here seems to show that the shell must grow in the direction resulting from the action of the two forces, the movement and growth of the tissues and the opposing force of gravitation. The extraordinary shapes and combinations of asymmetry and symmetry in different parts of the same animal as exhibited in the mollusca, all seem to be resolved when we can account for the influence of gravitation upon a fixed or moving organism, allowing for the reactions occasioned by growth and heredity.

APPENDIX III.

The remarks on p. 76, with regard to *Pl. pseudotenuis*, are misleading. Since this page was printed I have undertaken with the help of two assistants to revise and re-arrange my collection. This has led to the finding of several specimens of *Pl. pseudotenuis*. These show that *Pl. pseudotenuis* is a form which is genetically connected with *Pl. minutus*. It has all the characteristics and peculiar aspect of that species in the young, and is never so stout at any period as *Pl. Kraussii*. The latter has a shell which resembles it in color and general aspect but not in its proportions, and is also approximate to *Pl. pseudotenuis*, very closely in some specimens which have a prominent thick carination. These are very closely similar to *Pl. pseudotenuis*, and I think led Dr. Hilgendorf to trace *pseudotenuis* into *Kraussii* instead of into *Pl. minutus* with which it seems to be connected. There have also been found two specimens of *Pl. pseudotenuis* with a sulcation on the upper side of the whorl, which confirms this conclusion; as any one will see, even from an examination of Hilgendorf's own figure, that such a sulcation would render even the extreme form of *Pl. pseudotenuis* very similar to *Pl. triquetrus*, which Hilgendorf himself considers a member of the minutus series. Var. *Kraussii* p. 89, fifth paragraph, is *Pl. pseudotenuis*. One specimen of *Pl. pseudotenuis* has been found in Formation *f*, New Pit, one in *k*, *l*, East Pit, one in *x* same Pit, and one in *l*, Old Pit.

This revision of the collection has also led to the discovery of several diseased forms of *Pl. trochiformis*, which are very interesting. They are dwarfed. The spiral is partly unwound and then closed up again in course of growth, but is even then much contracted. In fact a very slight increase in the characteristic tendency of the growth, as shown by our specimen would make a whorl larger, but not very unlike *Pl. denudatus* in general appearance.

APPENDIX IV.

In revising the collection my assistants have also succeeded in finding in Formation *d e*, referred to on page 49, line 18, as containing only "two broken specimens of *Pl. oxystomus*" and also on p. 93, line 22, two well preserved young specimens and one nearly full grown.

APPENDIX V.

The Geological Map on p. 33, does not exactly represent the views of the strata given on the subsequent pages, it having been copied from the official geological map of the Steinheim locality, sometime before the text was written.

Thus the Cloister-ridge Rocks near Steinheim are represented as the equivalent of the Oxystomus Limestone near Sontheim, whereas they more nearly resemble the Coarse Limestone. The rocks on the west side of the amphitheatre, and the two spots of rock also shaded like the Oxystomus Limestone, and lying the west of these, again, are the Neusel-halder rocks, and not at all like the Oxystomus Limestone, which contains a much younger fauna.

CORRECTIONS.

Page 9, line 8, read *animals* for *animal*.
Page 11, line 39, read *fig.* 4 for *fig.* 40.
Page 12, note, line 2, read *var. cochleata* for *var. rotundatiformis*.
Page 14, line 30, read line *i* for line *h*, omit line *f*.
Page 28, line 28, after *last*, insert the words *a large part of*.
Page 30, line 24, after *fig.* 4, insert *pl.* 9.
Page 30, line 28, read *early* for *easy*.
Page 32, line 25, read *immediate* for *direct*.
Page 35, line 2, *Pl.* *oxystomus levis,* in place of *Pl.* *levis oxystomus*.
Page 39, line 6, read *umbilicus* for *umbiicus*.
Page 49, line 22, read *trochiformis* for *Trochiformis*.
Page 62, line 11, read *to* for *by*.
Page 63, line 19, read *pl.* 8 for *pl.* 4.
Page 63, line 22, read *pl.* 8 *line e fig.* 2 in place of *line e*, *fig.* 2.
Page 67, line 21, read *line c* for *line e*.
Page 75, line 22, read *Steinheimensis* for "*levis*."
Page 75, line 31, read *sub-varieties* for "*varieties*."
Page 77, line 7, after "*line o*," insert *Pl.* 1.
Page 78, line 2, after "*line h*," insert *except fig.* 13.
Page 78, line 14, insert Pl. trochiformis as title in centre of page.
Page 78, line 36, read *pl.* 2 for "*pl.* 1."
Page 80, line 33, read *traceable* for "*tracable*."
Page 94, line 24, the *Pl. pseudotenuis* Hilg. there mentioned is not a true *pseudotenuis*.

EXPLANATION OF THE PLATES.

Plate I.

Magnified 2 diameters.

List of Species.

Pl. Steinheimensis var. *aequiumbilicatus*, line a 1–4, b 17, c 1, 19, m 1–7.
Pl. Steinheimensis line a 5–11, b 2–16, d 5, f 18, h 13, m 8–11, n 1–5.
Pl. *oxystomus/levis,* line a 12–16, m 12–14.
Pl. *Kraussii/Steinheimensis,* line f 1–3.
Pl. *tenuis/Steinheimensis,* line b 1, c 13–14, d 1–4, e 16, n 6, 13.
Pl. tenuis, line c 2–12, 15–18, d 6–17, e 1–15, k 11, n 7–12, 14–15, o 1–7.
Pl. discoideus, line f 4–17, g 1–14, h 1–12, i 1–12, k 1–5, 12, l 1–10, o 8–14, 16 (named specimen), p1–13.
Pl. discoideus var. *involutus*, line d 18, e 17–19.
Pl. *trochiformis/discoideus,* line k 7, line o 15.
Pl. *trochiformis/discoideus* (var. *elegans* Hilg.), line k 6.
Pl. trochiformis (= *trochif.* typus Hilg.), line k 8–10, l 11–12.

Check List by Lines.

Line a, figs. 1–4 *Pl. Steinheimensis* var. *aequiumbilicatus*, 5–11 *Pl. Steinheimensis*, 12–16 *Pl.* *oxystomus/levis,*
Line b, fig. 1 *Pl.* *tenuis/Steinheimensis,* 2–16 *Pl. Steinheimensis*,[1] 17 *Pl. Steinheimensis* var. *aequiumbilicatus*.
Line c, fig. 1 *Pl. Steinheimensis* var. *aequiumbilicatus*, 2–12 *Pl. tenuis*, 13–14 *Pl.* *tenuis/Steinheimensis,* 15–18 *Pl. tenuis*, 19 *Pl. Steinheimensis* var. *aequiumbilicatus*.
Line d, figs. 1–4 *Pl.* *tenuis/Steinheimensis,* 5 *Pl. Steinheimensis*, 6–17 *Pl. tenuis*, 18 *Pl. discoideus* var. *involutus*.
Line e, figs. 1–15 *Pl. tenuis*, 16 *Pl.* *tenuis/Steinheimensis,* 17–19 *Pl. discoideus* var. *involutus*.
Line f, figs. 1–3 *Pl.* *Kraussii/Steinheimensis,* 4–17 *Pl. discoideus*, 18 *Pl. Steinheimensis*.
Line g, figs. 1–14 *Pl. discoideus*.
Line h, figs. 1–12 *Pl discoideus*, 13 *Pl. Steinheimensis*.
Line i, figs. 1–12 *Pl. discoideus*.
Line k, figs. 1–5 *Pl. discoideus*, 6 *Pl.* *trochiformis/discoideus,* var. *elegans*, 7 *Pl.* *trochiformis/discoideus,* 8–10 *Pl. trochiformis*, 11 *Pl. tenuis*, 12 *Pl. discoideus*.
Line l, figs. 1–10 *Pl. discoideus*, 11–12 *Pl. trochiformis*.
Line m, figs. 1–7 *Pl. Steinheimensis* var. *aequiumbilicatus*, 8–11 *Pl. Steinheimensis*, 12–14 *Pl.* *oxystomus/levis.*
Line n, figs. 1–5 *Pl. Steinheimensis*, 6 *Pl.* *tenuis/Steinheimensis,* 7–12 *Pl. tenuis*, 13 *Pl.* *tenuis/Steinheimensis,* 14–15 *Pl. tenuis*.
Line o, figs. 1–7 *Pl. tenuis*, 8–14 *discoideus*, 16 *Pl. discoideus* (named specimen), 15 *Pl.* *trochiformis/discoideus.*
Line p, figs. 1–13 *Pl. discoideus*.

Check List by Sections and Formations.

Formation a.

Stratum a 1, Second Hole, and a, First Hole,[2] Old Pit, Sections 5, 6.

Pl. Steinheimensis var. *aequiumbilicatus*, line a 1–4, b 17, c 1, 19.
Pl. Steinheimensis, line a 5–11, b 2–16, d 5, f 18, h 13.
Pl. *oxystomus/levis,* a 12–16.
Pl. *Kraussii/Steinheimensis,* line f 1–3.
Pl. *tenuis/Steinheimensis,* line b 1, c 13–14, d 1–4, e 16.

[1] Figs. 10–12 are very similar to *Pl. m. parvus* Hilg.
[2] Lines a–k show a mingling of forms from both holes; lines k–l, a special suite from the First Hole, Sect. 6 taken during my second visit to Steinheim.

Pl. tenuis, line c 2–12, 15–18, d 6–17, e 1–15, k 11, o 8–10.
Pl. discoideus, line f 4–17, g 1–14, h 1–12, i 1–12, k 1–5, 12, l 1–10.
Pl. discoideus var. *involutus*, line d 18, e 17–19.
Pl. *trochiformis discoideus*, line k 7.
Pl. *trochiformis discoideus* (var. *elegans* Hilg.), line k 6.
Pl. trochiformis, line k 8–10, l 1–12.

Stratum a 2, Second Hole, Old Pit, Section 6.

Pl. Steinheimensis var. *aequiumbilicatus*, line m 1–7.
Pl. Steinheimensis, line m 8–11, n 1–5.
Pl. *oxystomus levis*, line m 12–14.
Pl. *tenuis Steinheimensis*, line n 6, 13.
Pl. tenuis, line n 7–12, 14–15, o 1–7.
Pl. discoideus, line o 8–16, p 1–13.
Pl. *trochiformis discoideus* line o 15.

Plate II.

Magnified 2 diameters.

List of Species.

Pl. Steinheimensis var. *aequiumbilicatus*, line a 1–2.
Pl. Steinheimensis, line a 3–4.
Pl. Kraussii, line d 1–17, f 9.
Pl. *tenuis Steinheimensis*, line a 7–8, q 12.
Pl. tenuis, line a 5–6, 9–12, e 18–27, f 1–8, 10–12, p 9–13, q 5–11.
Pl. discoideus, line a 13, b 1–6, 16, c 1–13, f 13–19, h 1–18, i 1–14, k 1–2, m 3–4, 6–9, n 1–7, q 13–16.
Pl. discoideus (var. *elatior* Sand.), line i 15–17.
Pl. *trochiformis discoideus*, line m 1–2, 5, q 17–18, r 1–4.
Pl. trochiformis, line b 7–10, d 18–19, k 3–11, l 1–11, n 8–12, o 15–18, r 5–10, s 1–8.
Pl. trochiformis (var. *pyrguliformis* Sand.), line s 9–12.
Pl. discoideus (young with forms similar to *rotundatus* Hilg.), line h 19–23.
Pl. trochiformis (young of normal varieties identical with *rotundatus* Hilg.), line o 1–14, p 1–8.
Pl. minutus, line e 1–5, 7–8, g 1–2, 4, p 14–20, b 11–15.
Pl. *denudatus minutus*, line e 10–12, g 6, q 1.
Pl. denudatus, line e 13–14, g 7–8.
Pl. *costatus minutus*, line e 6, g 5.
Pl. costatus, line e 9, g 3, q 2–4.
Pl. *minutus levis*, line e 15–17.
Pl. triquetrus, line g 9–23.

Check List by Lines.

Line a, figs. 1–2 *Pl. Steinheimensis* var. *aequiumbilicatus*, 3–4 *Pl. Steinheimensis*, 5–6 *Pl. tenuis*, 6–8 *Pl.* *tenuis Steinheimensis*, 9–12 *Pl. tenuis*, 13 *Pl. discoideus*.

Line b, figs. 1–6 *Pl. discoideus*, 7–10 *Pl. trochiformis*, 11–15 *Pl. minutus*, 16 *Pl. discoideus*.

Line c, figs. 1–13 *Pl. discoideus*.

Line d, figs. 1–17 *Pl. tenuis* var. *Kraussii*, 18–19 *Pl. trochiformis*.

Line e, figs. 1–5 *Pl. minutus*, 6 *Pl.* *costatus minutus*, 7–8 *Pl. minutus*, 9 *Pl. costatus*, 10–12 *Pl.* *denudatus minutus*, 13–14 *Pl. denudatus*, 15–17 *Pl.* *minutus levis*, 18–27 *Pl. tenuis*.

Line f, figs. 1–8 *Pl. tenuis*, 9 *Pl. tenuis* var. *Kraussii*, 10–12 *Pl. tenuis*, 13–19 *Pl. discoideus*.

Line g, figs. 1–2 *Pl. minutus*, 3 *Pl. costatus*, 4 *Pl. minutus*, 5 *Pl. costatus/minutus*, 6 *Pl. denudatus/minutus*, 7–8 *Pl. denudatus*, 9–23 *Pl. triquetrus.*

Line h, figs. 1–18 *Pl. discoideus*, 19–23 *Pl. discoideus* (rotundatus-like young).

Line i, figs. 1–14 *Pl. discoideus*, 15–17 *Pl. discoideus* (var. *elatior* Sand.).

Line k, figs. 1–2 *Pl. discoideus*, 3–11 *Pl. trochiformis.*

Line l, figs. 1–11 *Pl. trochiformis.*

Line m, figs. 1–2 *Pl. trochiformis/discoideus*, 3–4 *Pl. discoideus*, 5 *Pl. trochiformis/discoideus*, 6–9 *Pl. discoideus.*

Line n, figs. 1–7 *Pl. discoideus*, 8–12 *Pl. trochiformis.*

Line o, figs. 1–14 *Pl. trochiformis* (rotundatus young), 15–18 *Pl. trochiformis.*

Line p, figs. 1–8 *Pl. trochiformis* (rotundatus young), 9–13 *Pl. tenuis*, 14–20 *Pl. minutus.*

Line q, fig. 1 *Pl. denudatus/minutus*, 2–4 *Pl. costatus*, 5–11 *Pl. tenuis*, 12 *Pl. tenuis/Steinheimensis*, 13–16 *Pl. discoideus*, 17–18 *Pl. trochiformis/discoideus.*

Line r, figs. 1–4 *Pl. trochiformis/discoideus*, 5–10 *Pl. trochiformis.*

Line s, figs. 1–8 *Pl. trochiformis*, 9–12 *Pl. trochiformis* (var. *pyrguliformis* Sand.).

Check List by Sections and Formations.

Formation a.

Stratum a 3, Second Hole, Old Pit, Section 5.

Pl. Steinheimensis, var. *aequiumbilicatus*, line a, figs. 1–2.
Pl. Steinheimensis, line a, figs. 3–4.
Pl. tenuis/Steinheimensis, line a, figs. 7–8.
Pl. tenuis, line a, figs. 5–6, 9–12.
Pl. discoideus, line a, fig. 13, b, 1–4.

Formation d, Section 5.

Pl. discoideus, line b, figs. 5–6,16.
Pl. trochiformis, line b, figs. 7–10.
Pl. minutus, line b, figs. 11–15.

Formation e, Section 6.

Pl. discoideus, line c, figs. 1–13.
Pl. trochiformis, line d, figs, 18–19.
Pl. Kraussii, line d, figs. 1–17.
Pl. minutus, line e, figs. 1–5, 7–8.
Pl. denudatus/minutus, line e, figs. 10–12.
Pl. denudatus, line e, figs. 13–14.
Pl. costatus, line e, fig. 9.
Pl. costatus/minutus, line e, fig. 6.
Pl. minutus/levis, line e, figs. 15–17.

Formation f, Section 6.

Pl. Kraussii, line f, fig. 9.
Pl. tenuis, line e, figs. 18–27, f, 1–8, 10–12.
Pl. discoideus, line f, figs. 13–19.
Pl. minutus, line g, figs. 1–2, 4.
Pl. denudatus/minutus, line g, fig. 6.
Pl. denudatus, line g, figs. 7–8.
Pl. costatus/minutus, line g, fig. 5.
Pl. costatus, line g, fig. 3.
Pl. triquetrus, line g, figs. 9–16.

Formation h, Section 6.

Pl. triquetrus, line g, figs. 17–23.
Pl. discoideus, line h, figs. 1–18, i 1–14, k 1–2.
Pl. diseoideus (rotundatus-like young), line h, figs. 19–23.
Pl. discoideus (var. *elatior* Sand.), line i, figs. 15–17.
Pl. trochiformis, line k, figs. 3–11, l 1–11.

Formation i, Section 6.

Pl. discoideus, line m, figs. 3–4, 6–9.
Pl. trochiformis / discoideus, line m, figs. 1–2, 5.

Formation k, Section 6.

Pl. discoideus, line n, figs. 1–7.
Pl. trochiformis, line n, figs. 8–12, o 15–18.
Pl. trochiformis (rotundatus-like young), line o, figs. 1–14, p 1–8.
Pl. tenuis, line p, figs. 9–13.

Formation l, Section 6.

Pl. minutus, line p, figs. 14–20.
Pl. denudatus / minutus, line q, fig. 1.
Pl. denudatus, line q, figs. 2–4.
Pl. tenuis, line q, figs. 5–11.
Pl. tenuis / Steinheimensis, line q, fig. 12.
Pl. discoideus, line q, figs. 13–16.
Pl. trochiformis / discoideus, line q, figs. 17–18, r 1–4.
Pl. trochiformis, line r, figs. 5–10, s 1–8.
Pl. trochiformis (var. *pyrguliformis* Sand.), line s, figs. 9–12.

Plate III.

Magnified 2 diameters.

List of Species.

Pl. discoideus, line c, figs. 17–19, d 1–11, e 1–12, f 1–14, g 1–9, h 1–10, i 5–9, l 15–17.
Pl. trochiformis / discoideus, line i, fig. 1.
Pl. trochiformis, line a, figs. 16, i 2–4, m 1.
Pl. trochiformis var. *elegans*, line a, fig. 15.
Pl. minutus, line a, figs. 8–13, c 2–4, d 12–16.
Pl. costatus (var. *major* Hilg.), line b, fig. 15.
Pl. parvus, line a, figs. 6–7, 20–22.
Pl. minutus / levis (*parvus* Hilg. pars.), line k, figs. 1–4, 11.
Pl. crescens, line a, figs. 1–5, 17–19, 23, b 16–17, c 9–16, i 10–14.
Pl.. oxystomus / levis (var. *revertens* Hilg.), line k, figs. 5–10, m 10–14, p 6–14.
Pl. oxystomus, line a, figs. 14, b 1–14, c 1, 5–8, k 12–18, l 1–3, m 2–9, o 2.
Pl. supremus, line l, figs. 12–14, n 1–7, o 3–12, p 1–5.
Pl. oxystomus var. *cochleatus*, line l, figs. 4–11.
P , o, 1.

Check List by Lines.

Line a, figs. 1–5 *Pl. crescens*, 6–7 *Pl. parvus*, 8–13 *Pl. minutus*, 14 *Pl. oxystomus*, 15 *Pl. trochiformis* var. *elegans*, 16 *Pl. trochiformis*, 17–19 *Pl. crescens*, 20–22 *Pl. parvus*, 23 *Pl. crescens*.

Line b, figs. 1–14 *Pl. oxystomus*, 15 *Pl. costatus* var. *major*, 16–17 *Pl. crescens*.

Line c, fig. 1 *Pl. oxystomus*, 2–4 *Pl. minutus*, 5–8 *Pl. oxystomus*, 9–16 *Pl. crescens*, 17–19 *Pl. discoideus*.

Line d, figs. 1–11 *Pl. discoideus*, 12–16 *Pl. minutus*.

Line e, figs. 1–12 *Pl. discoideus*.

Line f, figs. 1–14 *Pl. discoideus*.

Line g, figs. 1–9 *Pl. discoideus*.

Line h, figs. 1–10 *Pl. discoideus*.

Line i, fig. 1 *Pl. trochiformis discoideus,* 2–4 *Pl. trochiformis*, 5–9 *Pl. discoideus*, 10–14 *Pl. crescens*.

Line k, figs. 1–4 *Pl. minutus levis,* (*parvus* Hilg. pars.), 5–10 *Pl. oxystomus levis* (var. *revertens* Hilg.), 11 *Pl. minutus levis,* (*parvus* Hilg., pars.), 12–18 *Pl. oxystomus*.

Line l, figs. 1–3 *Pl. oxystomus*, 4–11 *Pl. oxystomus* var. *cochleatus*,[1] 12–14 *Pl. supremus*, 15–17 *Pl. discoideus*.

Line m, fig. 1 *Pl. trochiformis*, 2–9 *Pl. oxystomus*, 10–14 *Pl. oxystomus levis.*

Line n, figs. 1–7 *Pl. supremus*, 8–13 *Pl. supremus* var. *turritus*.

Line o, fig. 1 *Pl. supremus* var. *turritus*, 2 *Pl. oxystomus*, 3–12 *Pl. supremus*.

Line p, figs. 1–5 *Pl. supremus*, 6–14 *Pl. oxystomus levis.*

Check List by Sections and Formations.

New Pit, South side.

Formation f, Section 8.

Pl. crescens, line a, figs. 1–3.

Formation h, Section 8.

Pl. parvus, line a, figs. 6–7.
Pl. crescens, line a, figs. 4–5.
Pl. oxystomus, line a, fig. 14.
Pl. minutus, line a, figs. 8–13.

Formation i, Section 8.

Pl. trochiformis var. *elegans*, line a, fig. 15.
Pl. trochiformis, line a, fig. 16.
Pl. parvus, line a, figs. 20–22.
Pl. crescens, line a, figs. 17–19, 23.
Pl. oxystomus, line b, figs. 1–11.

Formation k, Section 8.

Pl. oxystomus, line b, figs. 12–14.
Pl. crescens, line b, figs. 16–17.
Pl. costatus var. *major*, line b, fig. 15.

Formation l, Section 8.

Pl. oxystomus, line c, fig. 1.
Pl. minutus, line c, figs. 2–4.

Formation m, Section 8.

Pl. oxystomus, line c, figs. 5–8.
Pl. crescens, line c, figs. 9–16.

[1] This species is erroneously referred to as var. *rotundatiformis* on p. 12.

Cloister Pit.

Formation k, Section 1.

Pl. minutus, line d, figs. 12–16.
Pl. discoideus, line c, figs. 17–19, d 1–11, e 1–12, f 1–14.

Formation l, Section 1.

Pl. $\substack{\textit{minutus}\\ \textit{levis,}}$ line k, figs. 1–4, 11.
Pl. crescens, line i, figs. 10–14.
Pl. $\substack{\textit{oxystomus}\\ \textit{levis,}}$ line k, figs. 5–10.
Pl. oxystomus var. *cochleatus*, line l, figs. 4–11.
Pl. supremus, line l, figs. 12–14.
Pl. discoideus, line g, figs. 1–9, h 1–10, i 5–9.
Pl. $\substack{\textit{trochiformis}\\ \textit{discoideus,}}$ line i, fig 1.
Pl. trochiformis, line i, figs. 2–4.
Pl. oxystomus, line l, figs. 1–3.

Formation m, Section 1.

Pl. $\substack{\textit{oxystomus}\\ \textit{levis,}}$ line m, figs. 10–14, p 6–14.
Pl. oxystomus, line m, figs. 2–9, o 2.
Pl. supremus, line n, figs. 1–7, o 3–12, p 1–5.
Pl. supremus var. *turritus*, line n, figs. 8–13, o 1.
Pl. discoideus, line l, figs. 15–17.
Pl. trochiformis, line m, fig. 1.

Plate IV.

Magnified 8 diameters.

Line a, figs. 1–7 *Pl. minutus*.
Line b, figs. 1–4 *Pl. minutus*, 5–6, 9 *Pl. triquetrus* var. *turbinatus*, 7–8 *Pl.* $\substack{\textit{triquetrus}\\ \textit{minutus.}}$
Line c, figs. 1–3 *Pl. triquetrus*, 4–5 *Pl.* $\substack{\textit{triquetrus}\\ \textit{minutus,}}$ 6–9 *Pl.* $\substack{\textit{denudatus}\\ \textit{minutus.}}$[1]
Line d, figs. 1–5 *Pl.* $\substack{\textit{denudatus}\\ \textit{minutus,}}$ uncoiled in various degrees, 6–10 same, but more turbinate.
Line e, figs. 1–5 *Pl. denudatus*, uncoiling excessive, but turbination slighter than in 6–8; 9 broken adult, whorl of, 10, the young of the same shell perfectly flat and in part closely coiled, 11, young stage of another broken out. This, though not a distinct figure shows that the coiling is in the same plane in the young.
Line f, figs. 1–8 *Pl.* $\substack{\textit{costatus}\\ \textit{minutus.}}$
Line g, fig. 1, *Pl. costatus*, 2 *Pl. costatus* var. *distortus*, 3–10 *Pl. costatus*.
Line h, figs. 1–7 *Pl. costatus* (*Pl. costatus* var. *major* of Hilg.), var. *acuto-costatus*.
Line i, figs. 1–5 *Pl. costatus* var. *platystomus*, 6–12 *Pl. costatus* (=*major* Hilg. pars.), var. *obtuso-costatus*, much distorted.
Line k, figs. 1–7 *Pl costatus* var. *obtuso-costatus* (=*Pl. major* Hilg. pars.), 8 *Pl.* $\substack{\textit{costatus}\\ \textit{minutus.}}$

Plate V.

Magnified 5½ diameters.

Line a, figs. 1–4, *Pl. levis* from Undorf.
Line b, figs. 1–7, *Pl. parvus*.
Line c, figs. 1–6, *Pl.* $\substack{\textit{crescens}\\ \textit{parvus,}}$ 7 *Pl.* $\substack{\textit{crescens}\\ \textit{parvus,}}$ turretted variety.

[1] The different forms of *Pl. denudatus*, *Pl. costatus* var. *distortus* and *Pl. costatus* var. *platystomus* would probably have been more clearly understood if I had given them separate specific names and called them respectively *Pl. denudatus*, *Pl. distortus*, and *Pl. platystomus*, but having neglected doing this, and even in one place on page 10, spoken of *Pl. denudatus*, as variety *denudatus*, I thought it best to make no alterations in the nomenclature used in the text, p 65.

Line d, figs. 1–7 *Pl. crescens.* Fig. 2 line d shows a specimen of the young, which at a very early age begins to show the compressed form of the whorl, which distinguishes the adult of *Pl. crescens.* In fact the three young specimens on this line form a series in this respect, fig. 2 being the most compressed, fig. 6 next, and fig. 4 the least, although figs. 2 and 4 are of the same age and fig. 6 a little older. The adults of all of the three would have been about equally compressed in form.

Plate VI.

Magnified 5½ diameters.

Line a, figs. 1–3 *Pl. levis* from Undorf, 4–7 *Pl.* $^{oxystomus}_{levis,}$ (=*revertens* Hilg.).

Line b, figs 1–6 *Pl.* $^{oxystomus}_{levis,}$ (=*revertens* Hilg.), somewhat stouter than the normal forms of *Pl. levis*, even in the young, fig. 5.

Line c, figs. 1–5 *Pl. oxystomus* with extremely stout whorls even in the young. In this variety the young are very similar to the rotundatus-like young of *Pl. trochiformis*, see pl. 2, line o, figs. 1–14, line p, figs. 1–8. They, however, are distinct in the aspect of the upper umbilicus, in the carinations and shell, and outline of the opening of the whorl, especially in the younger stages. Compare also figures on lines o and p, pl. 3, with figures of young of *Pl. oxystomus* var. *cochleatus*, pl. 3, line l, figs. 4–11, which also have extremely stout whorls in the young. Fig. 6 is a fine specimen of the transition from the normal variety to the turretted form, variety *cochleatus* of *Pl. oxystomus.*[1]

Line d, fig. 1 *Pl. oxystomus* var. *cochleatus*, full grown shell,[2] figs. 2–4 *Pl. oxystomus*, normal variety, showing the identity of a young shell, fig. 4, with a shell of the same size of *Pl. levis*, from Undorf.

Line e, fig. 1 *Pl. supremus* var. *turritus*, figs. 2–4 *Pl. supremus.*

Plate VII.[3]

Magnified 4 diameters.

Line a, figs. 1–2 *Pl. levis*, Undorf. Figs. 3–5 are deeply umbilicated forms of *Pl. Steinheimensis* which are similar to fig. 1 in this respect and in the form of the whorls. Fig. 6, *Pl. levis*, Undorf, to compare with figs. 7–9 *Pl. Steinheimensis*, adult and young with a similar form of whorl. Fig. 10 an unusually turbinate form of *Pl. tenuis.*

Line b, figs. 1–2 *Pl. Steinheimensis* for comparison with figs. 3–4 *Pl. levis*, Undorf. Fig. 5 *Pl. Steinheimensis* with sub-angular outer whorl for comparison with fig. 6 *Pl. levis*, Undorf. Figs. 7, 8 *Pl. Steinheimensis*, younger stages of same variety as fig. 5.

Line c, figs. 1–3 *Pl. Steinheimensis* with very slight unsymmetrical and cylindrical whorls, figs. 4, 5 *Pl. Steinheimensis* normal variety (see specimens) with cylindrical whorls, figs. 6, 7, normal variety with unsymmetrical whorls and a deeper, narrower umbilicus on the lower side than in the preceding. Fig. 8 *Pl. Steinheimensis* var. *aequiumbilicatus* ?

Line d, figs. 1–6 specimens of *Pl. Steinheimensis* with stouter whorls transitional to those of line c. Fig. 7 *Pl. tenuis*, from the rocks of the Upper Tier of the Cloister Ridge. This has young like the adult of *Pl. Steinheimensis.*

Line e, fig. 1 *Pl. Steinheimensis* with an extremely turbinate tendency expressed in the last whorl. Figs. 2–4 are large fine specimens of the normal unsymmetrical varieties, figs. 5–7, are *Pl.* $^{tenuis}_{Steinheimensis,}$ for comparison with these and others below, for example compare the umbilicus of fig. 7, with fig. 6, line c.

Line f, figs. 1–3 *Pl.* $^{tenuis}_{Steinheimensis,}$ somewhat more advanced stage of transition, figs. 4–7 *Pl. tenuis.*

Line g, *Pl. tenuis.*

Line h, *Pl. discoideus*, figs. 1–4 flatter variety with acute carinations, figs. 5–7 stouter varieties with generally less acute carinations.

Line i, *Pl. discoideus* with rotundatus-like young, showing transitions to the varieties of *Pl. trochiformis* having similar young.

[1] See in this connection remarks on page 70.

[2] This shell has a much shallower umbilicus than the one figured on pl. 9, fig. 11, and described on p. 12.

[3] See for discussion of figures on this plate, p. 83.

Plate VIII.

Magnified 4 diameters.

Line a, fig. 1 *Pl. Steinheimensis*, same as fig. 13, line h, pl. 1, an aged specimen of extraordinary size, showing the deflection and contraction of the last formed or oldest part of the outer whorl; fig. 2 *Pl. Steinheimensis*, also very large and beginning to show senile changes, same as fig. 18, line f, pl. 1. Figs. 3–5 *Pl. oxystomus*; fig. 3 has the spiral deflected as the result of a wound, possibly also in part as the result of old age; figs. 4–5 are probably both distorted solely by senile or geratologous metamorphoses.

Line b, figs. 1–6 *Pl.* $^{\text{oxystomus}}_{\text{levis,}}$ (=*revertens*, Hilg.); figs. 1 and 6 are normal forms with spiral deflection probably due to old age; fig. 2 shows a cicatrix which has produced a precisely similar effect upon the size and direction of the last part of the last whorl; fig. 3, probably distorted from some normal disease or old age; figs. 4, 5 are undoubtedly weak or diseased specimens in which the spiral is very greatly deflected as in *Pl. denudatus*.[1]

Line c, figs. 1–6 *Pl.* $^{\text{minutus}}_{\text{levis,}}$ These specimens are all distorted apparently from the results of wounds or injuries received during the building of the last whorl.

Line d, figs. 1–4 *Pl. supremus*; all are more or less deflected, and the striae enlarged as the result of geratologous changes.[2]

Line e, figs. 1–3 *Pl. trochiformis*, fig. 1 shows a deflected spiral probably due to disease. Fig. 2 is a front view of fig. 10, line r, pl. 2. The distortion or deflection of the whorl is evidently caused by the age and perhaps also, diseased condition of the specimen, as may be seen from the enlarged striae and thickened shell. Fig. 3 is distorted on account of a severe wound.[3]

Plate IX.

Magnified 4 diameters.

Figs. 1–7 *Fourth Series* showing transformations from *Pl. levis* var. $^{\text{Steinheimensis}}_{\text{levis,}}$ Undorf, fig. 1(=fig. 1, line a, pl. 7), to *Pl. trochiformis* fig. 7. Fig. 2 *Pl. Steinheimensis*, 3 *Pl.* $^{\text{tenuis}}_{\text{Steinheimensis,}}$ 4 *Pl. tenuis*, 5 *Pl. discoideus*, 6 *Pl.* $^{\text{trochiformis}}_{\text{discoideus.}}$

Figs. 8–11 *Third Series* showing transformation from *Pl. levis* var. $^{\text{oxystomus}}_{\text{levis,}}$ Undorf, fig. 8 (=fig. 1 pl. 6), to *Pl. supremus* var. *turritus*, fig. 11. Fig. 9 though spoken of in the text p. 10 and elsewhere as *Pl. oxystomus*, is really a specimen of *revertens* Hilg.= *Pl.* $^{\text{oxystomus}}_{\text{levis,}}$ out of the Sand Pits, Steinheim, and ought to have been supplemented by a figure of true *Pl. oxystomus* such as fig. 1, line c, pl. 6, but this plate was already finished before I became aware of the need of another figure. Fig. 10, *Pl. supremus*, is the flat and sulcated variety of this species.

Figs. 12–15 *Second Series* showing transformations from *Pl. levis* var. $^{\text{parvus}}_{\text{levis,}}$ Undorf, fig. 12 (=fig. 1 pl. 5), to *Pl. crescens*, trochiform variety, fig. 15.

Fig. 13 *Pl.* $^{\text{crescens}}_{\text{parvus,}}$ The gap here which should have been filled by a figure of *Pl. parvus* was left unfilled purposely on account of the number of figures necessary, see pl. 5, lines b, c. Fig. 14, *Pl. crescens*, normal variety.

Figs. 16–28 *First Series*, figs. 16–20, third sub-series includes *Pl. levis* var. $^{\text{minutus}}_{\text{levis,}}$ Undorf, fig. 16 (=fig. 2, line a, pl. 7), *Pl.* $^{\text{minutus}}_{\text{levis,}}$ fig. 17, also *Pl. minutus*, fig. 18, which has cylindrical whorls showing one of the transition forms from *Pl.* $^{\text{minutus}}_{\text{levis,}}$ to the normal *Pl. minutus*, fig. 21 at the base of the next sub-series,[4] also fig. 19, true *Pl. triquetrus*, and fig. 20, *Pl. triquetrus* var. *turbinatus*.

Figs. 21–24, second sub-series includes *Pl. minutus*, fig. 21, normal smooth form, which leads into *Pl.* $^{\text{denudatus}}_{\text{minutus,}}$ figs. 22, 23, and *Pl. minutus* var. *distortus*, fig. 24. The intermediate forms, etc., are given on pl. 4 and described in the text on pages 59 to 66.

[1] See also description on p. 13, of other forms, and discussion on pp. 15, 17.

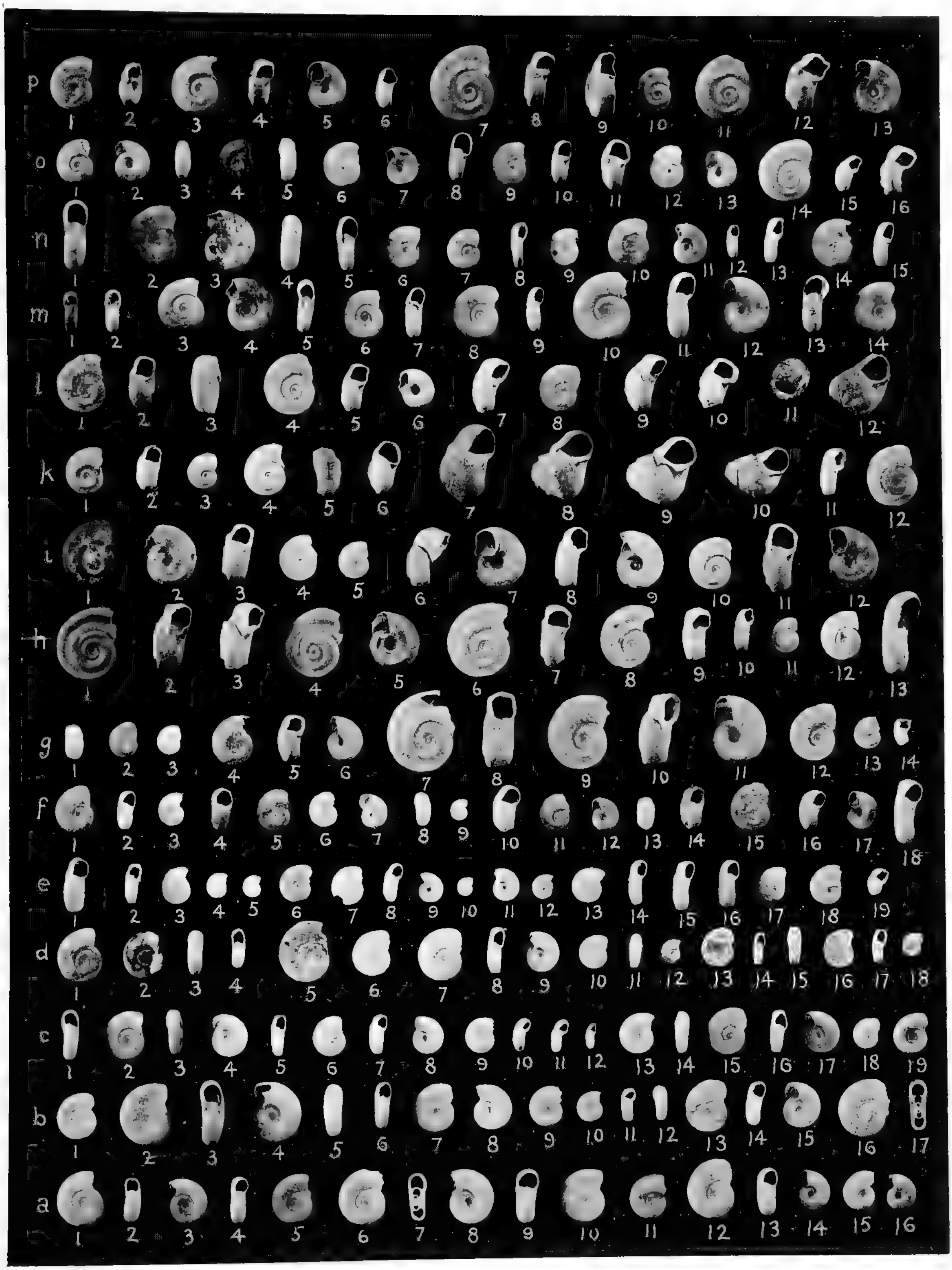
[2] Compare, also, pl. 3, figs. 1–2, line n, 5, 6, line g, 4, line h; pl, 2. figs. 2, 3, line h, fig. 6, line i.

[3] Compare, also, fig. 11, line s, pl. 2.

[4] The transition forms from *Pl. minutus* to *Pl. triquetrus* are photographed on Pl. 4.

Figs. 25–28, first sub-series includes as previously mentioned p. 65, two sub-series, the acuto-costate and the obtuso-costate, but as they are both exactly parallel in the production of the distorted varieties, *platystomus* and *distortus*, it was not considered necessary to go to the expense of making up and photographing another plate. Fig. 25 *Pl.* *costatus minutus*, fig. 26 *Pl. costatus*, the costae are coarser in these figures than in the specimens and so also are those of *Pl. costatus* var. *distortus*, figs. 27, 28, but they show accurately the forms of this sub-series.

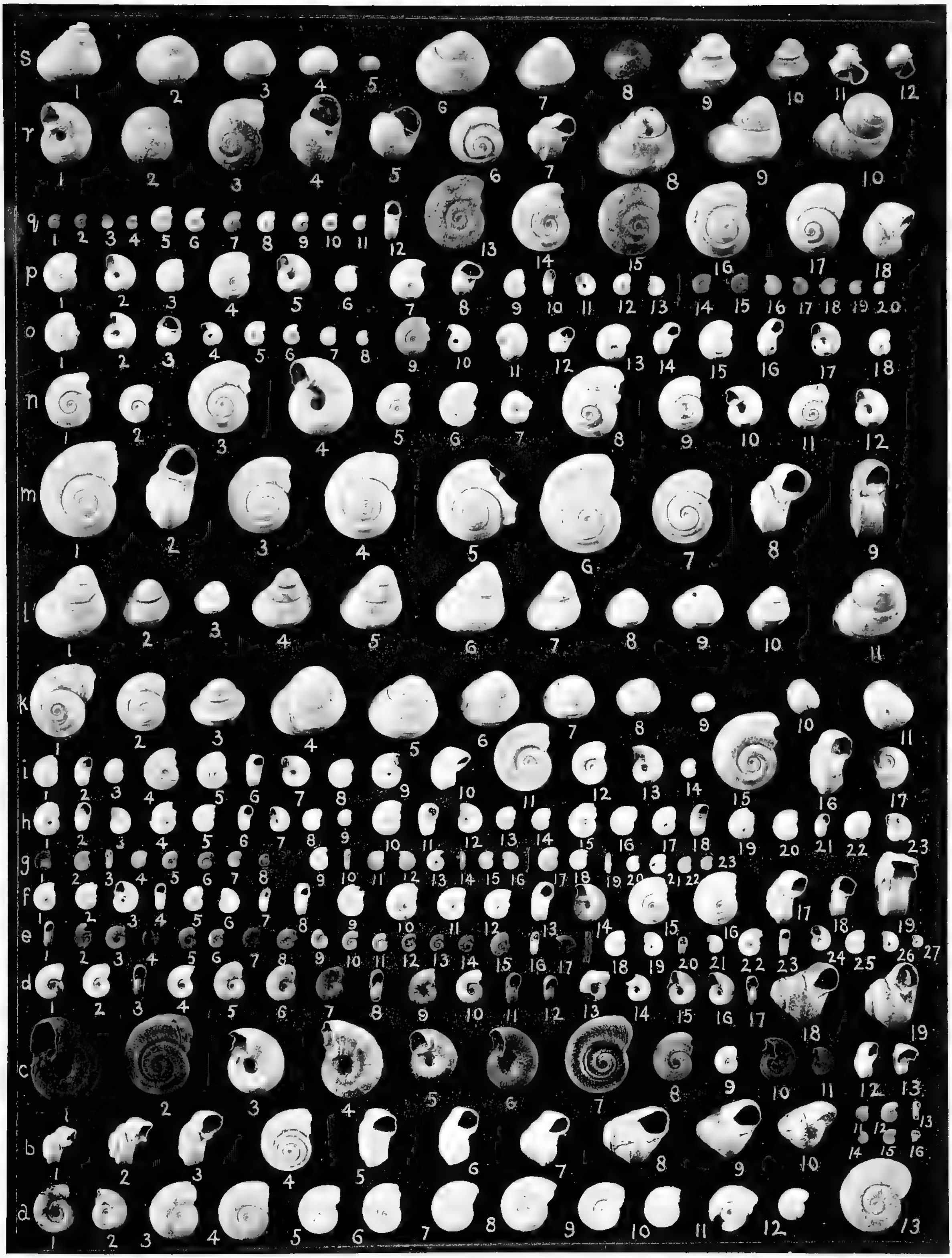
NOTE. These plates are described in the text as having been photographed by Sonrel and Black, but the negatives prepared by them could not be used by the Heliotype Company, and the whole were successfully rephotographed by the latter.



...CIES OF PLANORBIS AT STEINHEIM.

Formations $a-a^1-a^2$.

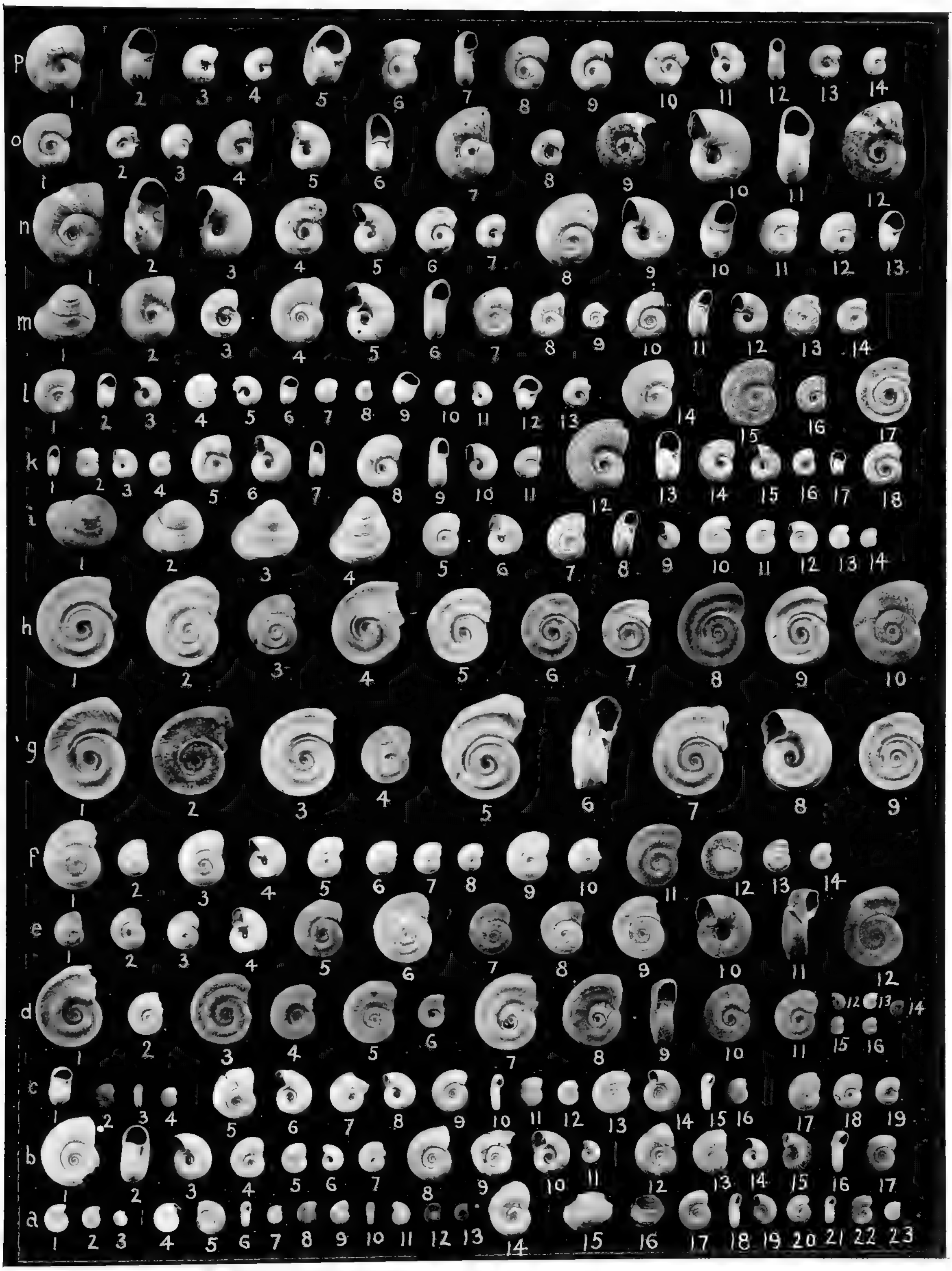
The Heliotype Printing Co. ... Tremont St. Boston



[illegible]CIES OF PLANORBIS AT STEINHEIM.

Formations a^3—l.

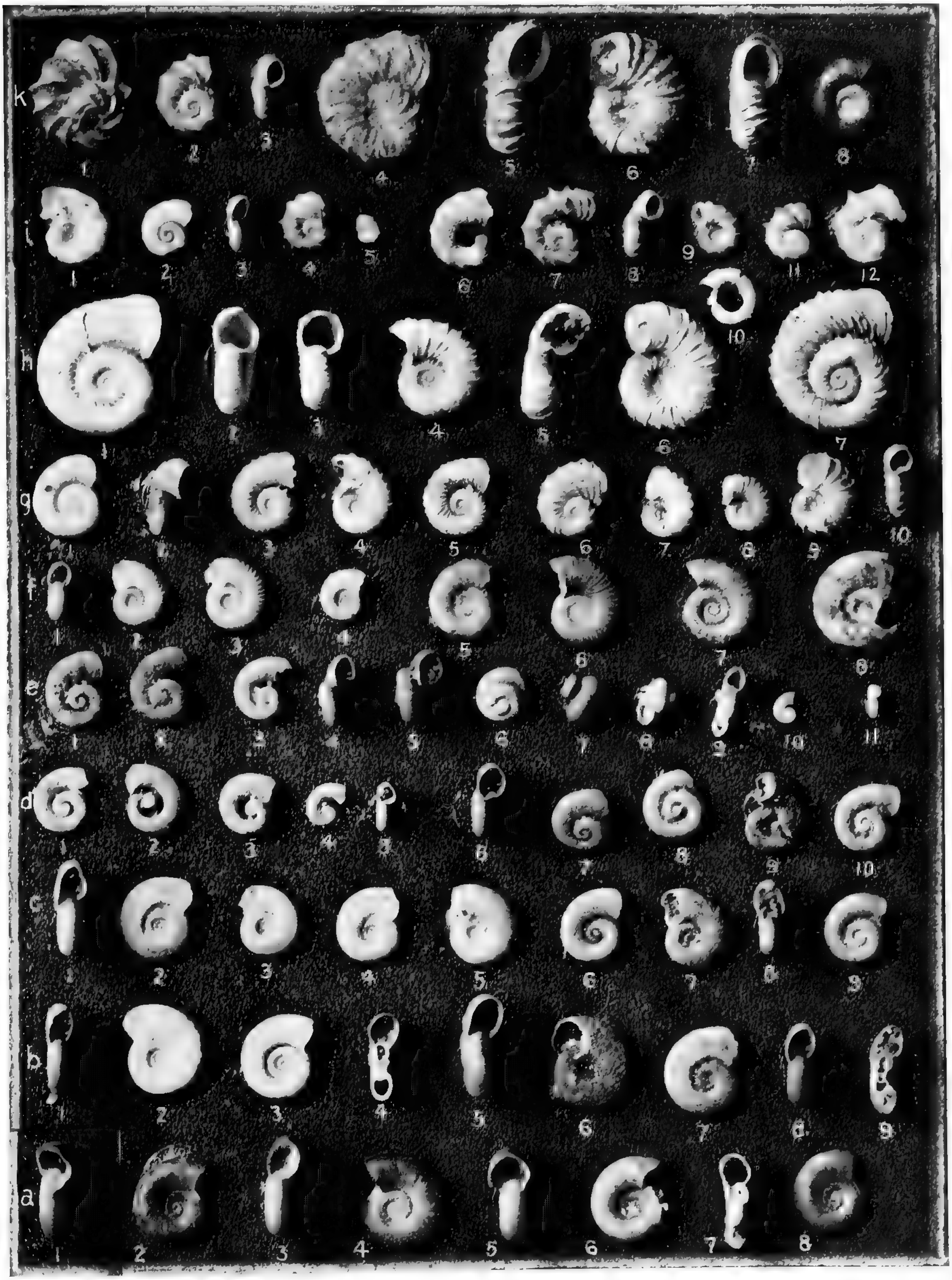
The Heliotype Printing Co. 211 Tremont St. Boston



CIES OF PLANORBIS AT STEINHEIM.

mations f—m.

The Heliotype Printing Co. 211 Tremont St. Boston.



CIES OF PLANORBIS AT STEINHEIM.

Zoological Series 1.

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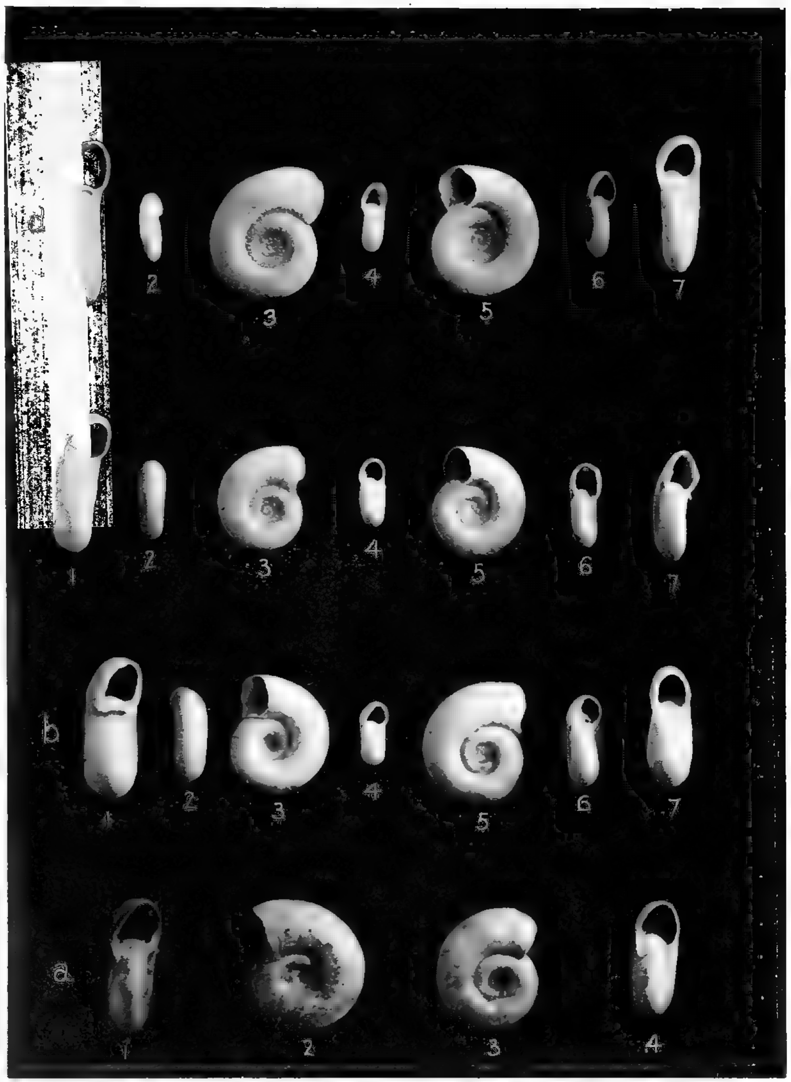
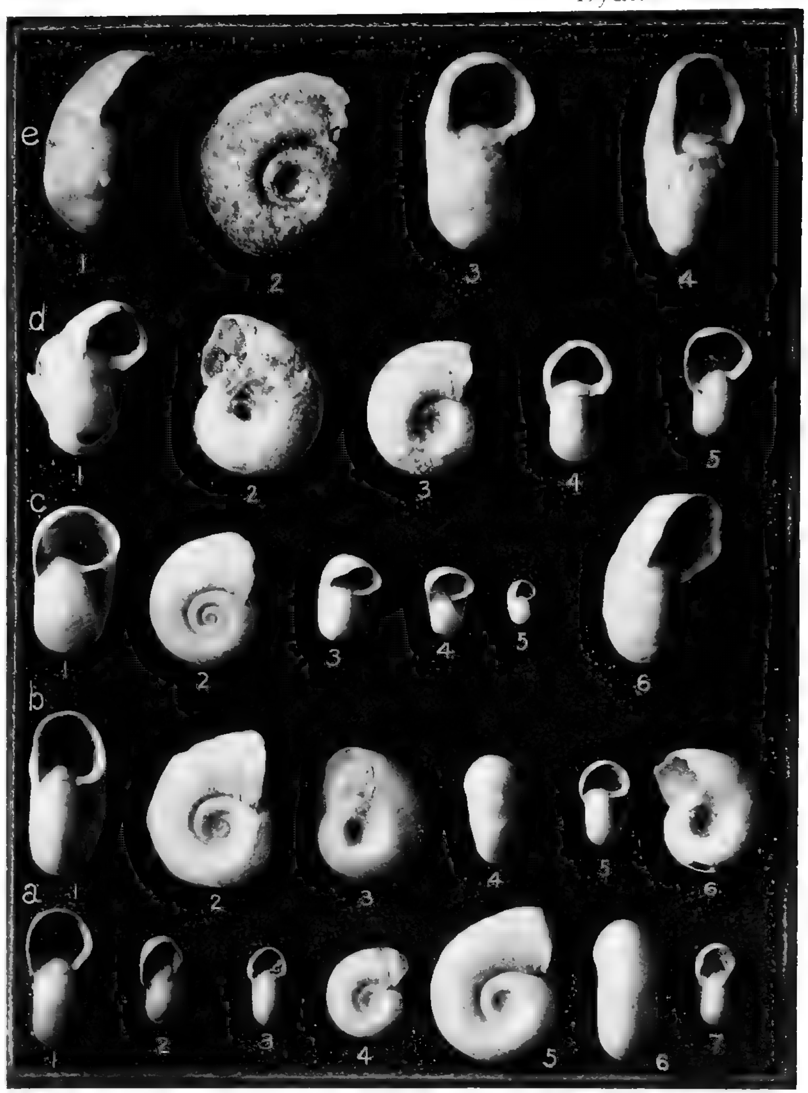
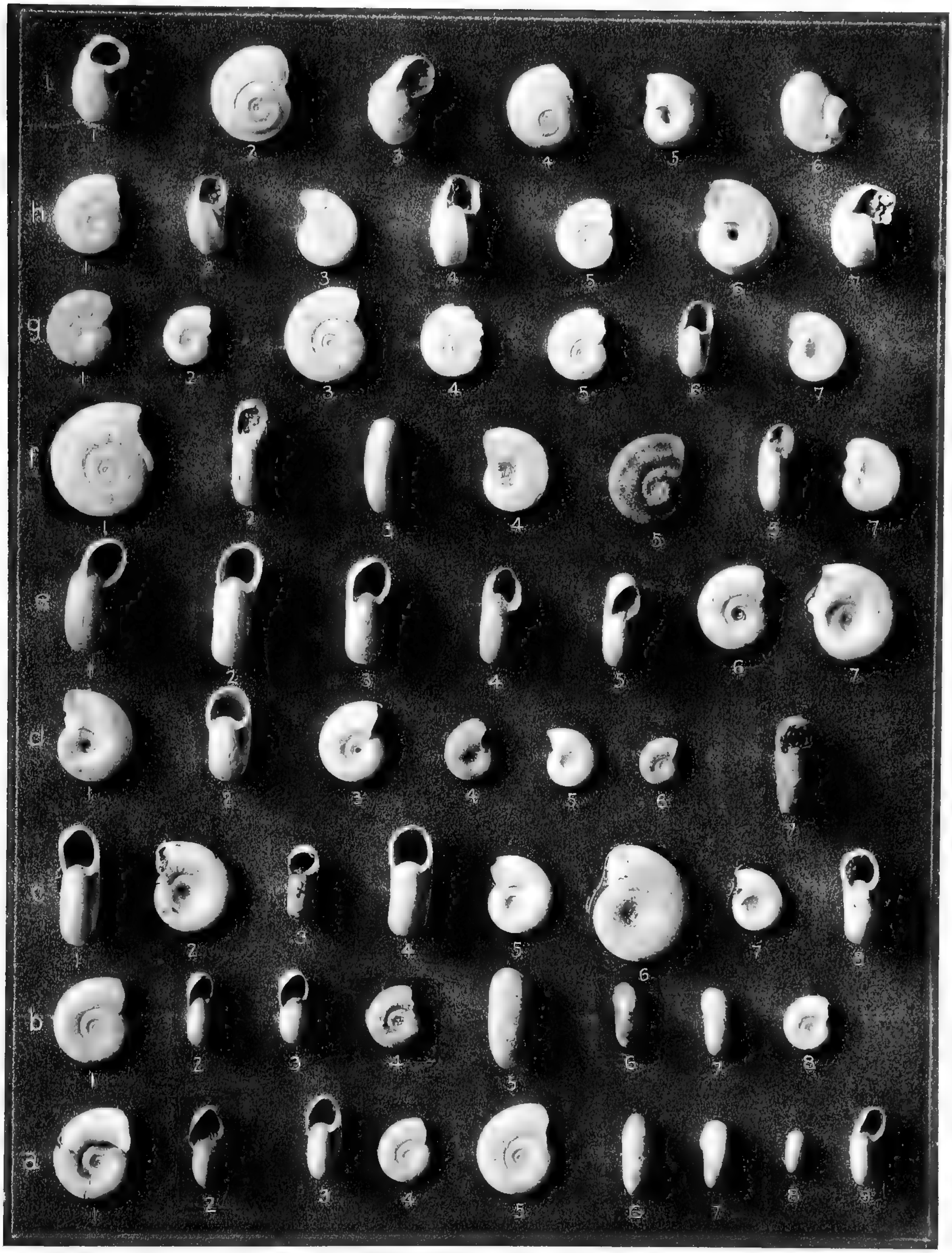




THE TERTIARY SPECIES OF PLANORBIS AT STEINHEIM.

Zoological Series. II.

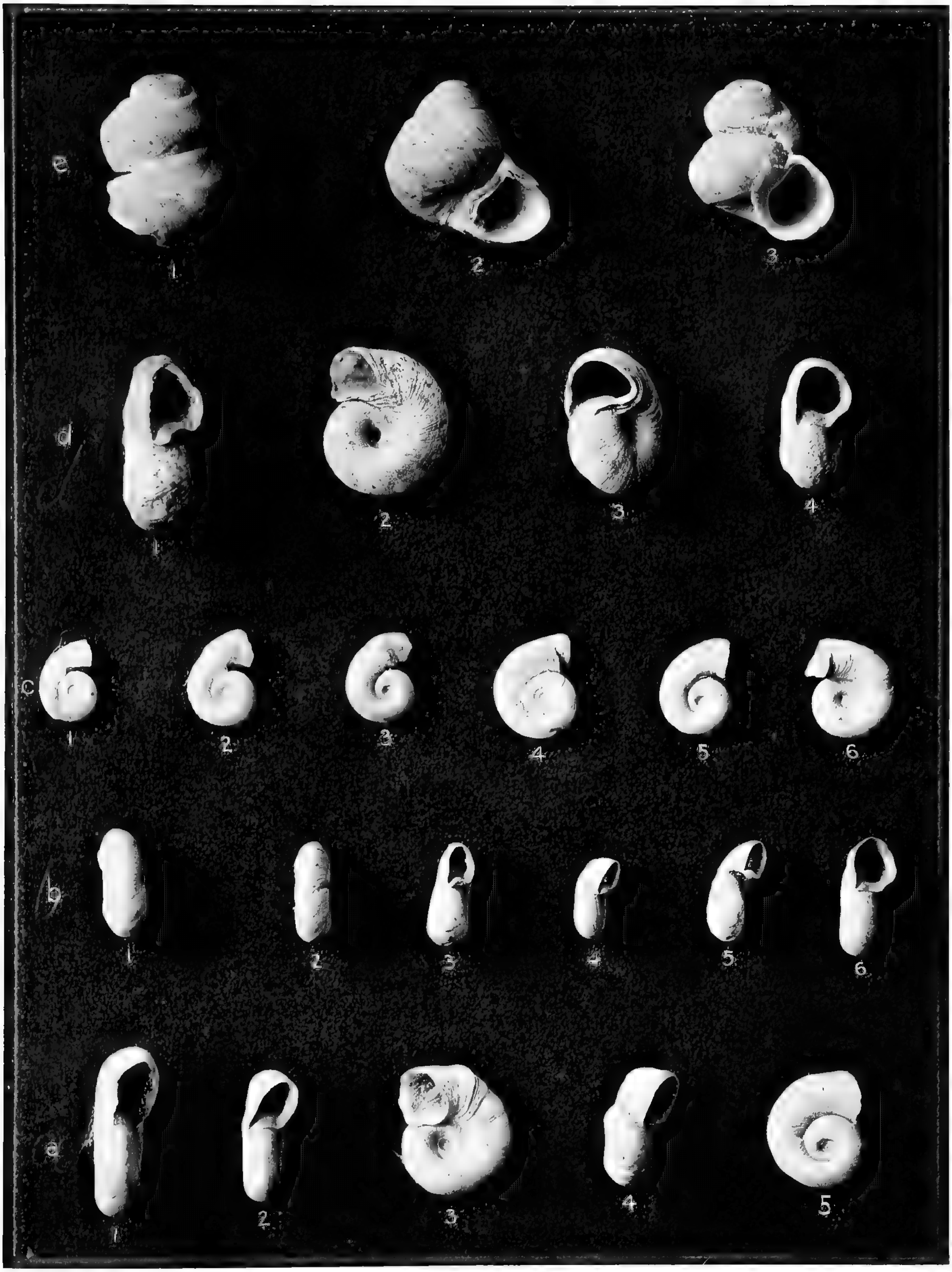
The Heliotype Printing Co. Boston.



CIES OF PLANORBIS AT STEINHEIM.

Zoological Series IV.

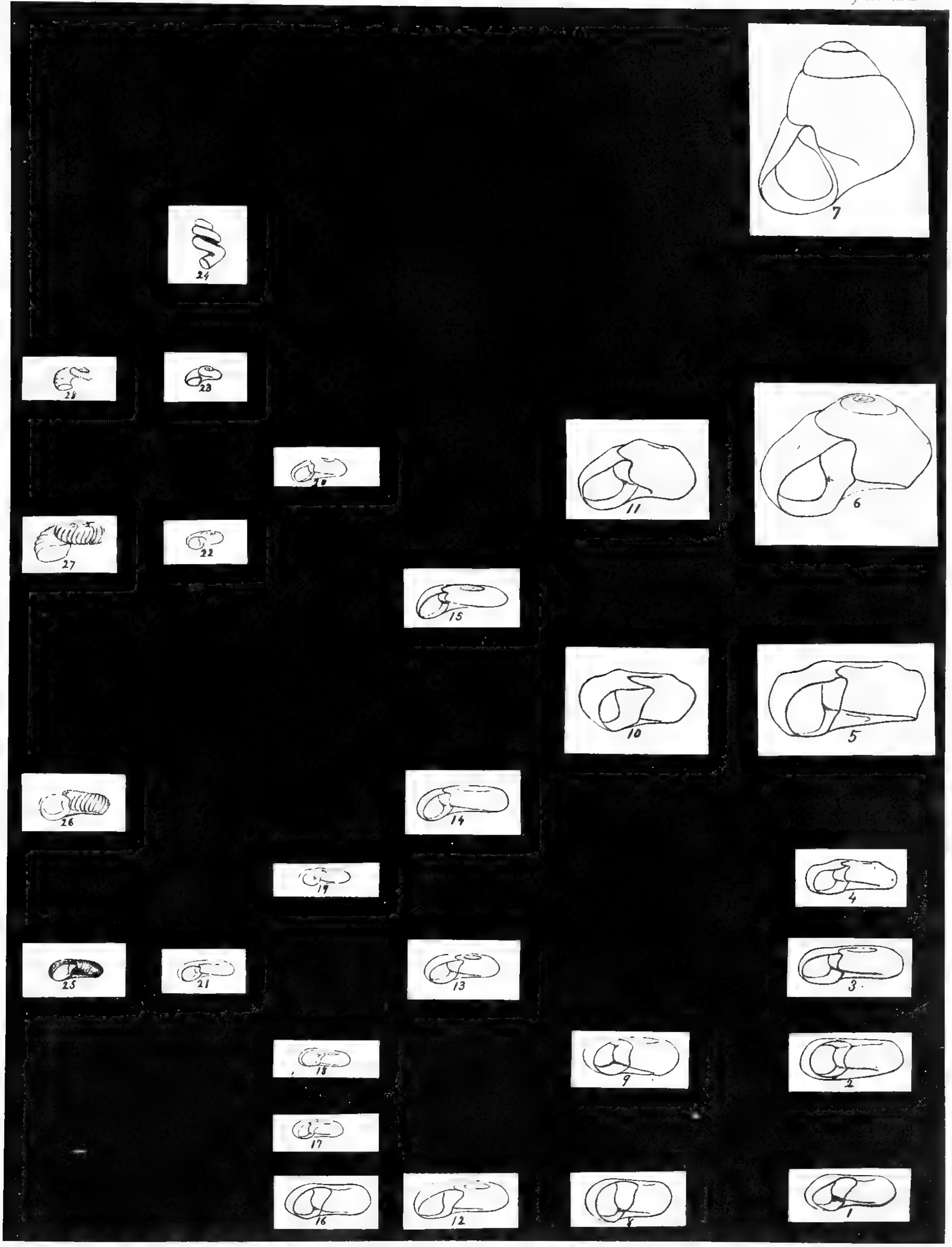
The Heliotype Printing Co. 211 Tremont St. Boston



THE TERTIARY SPECIES OF PLANORBIS AT STEINHEIM.

Distorted Forms.

The Heliotype Printing Co. 211 Tremont St. Boston.



Series I II III IV

THE TERTIARY SPECIES OF PLANORBIS AT STEINHEIM.

Summary of Zoological Series.

The Heliotype Printing Co. 211 Tremont St. Boston.