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Editor:

CHARLES LANE POOR

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VOL. XIV PART I

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The Academy will meet on Monday evenings at 8.15 o'clock, from October 7th to May 19th, in the rooms of the Chemist's Club, **108 West 55th Street.**

* Deceased.

[Annals N. Y. Acad. Sci., Vol. XIV, No. 1, pp. 1–52, June 5, 1901.]

REPORT ON THE HEXACTINIÆ OF THE COLUMBIA UNIVERSITY EXPEDITION TO PUGET SOUND DURING THE SUMMER OF 1896

J. Playfair McMurrich

[Plates I–III; text figures I–II.]

(Read November 14, 1898)

In presenting this report I must testify to the pleasure I experienced in studying the collection, a pleasure due both to the admirable preservation of all the specimens and to the careful notes and drawings which accompanied them. The credit for both belongs to Dr. Gary N. Calkins. The method employed for the preservation was a preliminary immersion in magnesium sulphate as suggested by Tullberg, followed by fixation and preservation in formalin. Nearly all the specimens were beautifully expanded and the histological preservation was excellent. The only disadvantage presented by the method, probably due to the formalin, was the failure of preparations to stain with the ordinary carmine stains, such as Grenacher's borax carmine; hæmatoxylin stains acted admirably, however.

I wish also to express my thanks to Mr. Alexander Agassiz for his kindness in loaning me, for comparison, a number of drawings of West Coast forms prepared from livings specimens several years ago.

The manuscript of this paper was originally completed in April, 1898, but I have taken advantage of the long delay which has occurred in its publication to introduce some references to papers which have appeared more recently, and also to correct a grievous misapprehension into which I had fallen with regard to the systematic position of *Epiactis prolifera*. The nature of this misapprehension is explained in the description of the species.

HEXACTINIÆ

Actininæ

Family SAGARTIIDÆ

Actininæ with adherent base; with a mesoglœal (rarely a weak endodermal sphincter); and with acontia which are emitted either through the mouth alone or also through special openings (cinclides) in the column wall.

The family Sagartiidæ, since its first establishment by Gosse in 1858, has undergone certain changes which have for the most part been fully discussed by various authors. Within recent years there has been introduced a subdivision into subfamilies. The family Phellinæ of Verrill ('68) has been added as a subfamily and the remaining forms assigned to the subfamilies Sagartiinæ or Metridiinæ according as they possessed more than six pairs of perfect mesenteries or only that number (Carlgren '93); a subfamily Chondractininæ had previously been proposed by Haddon ('89); Simon ('92), recognized two subfamilies Aiptasiinæ and Sagartiinæ, the former characterized by possessing an endodermal sphincter or none at all; and, finally, Haddon accepts all the proposed subdivisions, admitting the existence of no less than five subfamilies.

It seems to me that the subdivision proposed by Carlgren is that to be preferred. I do not think the recognition of a subfamily Aiptasiinæ is advisable since several undoubted Aiptasias are known to possess a mesoglœal sphincter, as, for instance *A. pallida* (Ag.), *A.* sp. (from the Bermudas, McM.) and *A. lucida* (Duch. & Mich.) Duerden. In all these, it is true, the muscle is exceeding weak, but it nevertheless is present, and its absence in certain species is merely the fulfillment of the reduction of it which is characteristic of the genus. A separation of the forms with no mesoglœal sphincter would be an act of violence, and, if this be avoided, the genus *Aiptasia* is properly referable to the Metridiinæ.

In the second place, it does not seem to me that a recognition of the Phelliinæ and Chondractiniinæ as distinct subfamilies is necessary. Both lack cinclides, have a coriaceous column wall provided with an epidermis, a distinct mesoglœal sphincter and only 6 pairs of perfect mesenteries. Haddon makes the distinction rest upon the occurrence of gonads in the mesenteries of the first cycle which he has found in certain Phellias. It does not seem to me that this peculiarity deserves the importance that Haddon has assigned to it, and I may again refer to the genus *Aiptasia* as providing ammunition for use against my friend's proposition. In *A. pallida* and in *A.* sp. (Bermudas, McM.) gonads occur in the mesenteries of the first cycle, and yet I imagine that no one would therefore suggest the assignment of these species to a different subfamily than that which shelters *A. annulata*, etc. We may, apparently, find occasionally an infringement of the right of sterility usually enjoyed by the first-cycle mesenteries, but it does not seem to me that we should at present legitimize the infringement by granting it the rank of a subfamily characteristic.

In the present collection I have found no representatives of either the Sagartiinæ or Phelliinæ, but a representative of the Metridiinæ occurred.

Subfamily Metridiinæ, Carlgren.

Sagartiidæ in which the column wall is perforated by cinclides and in which only the mesenteries of the first cycle are perfect.

1. Metridium dianthus (Ellis) Oken.

Synonyms.—Actinia dianthus, Ellis, 1767.
Actinia plumosa, Müller, 1776.
Metridium dianthus, Oken, 1815.
Actinoloba dianthus, Blainville, 1830.
Actinia marginata, Lesueur, 1817.
Metridium marginatum, Milne-Edwards, 1857.
Metridium fimbriatum, Verrill, 1865.
? Actinia priapus, Tilesius, 1809.

(For a more complete synonymy see Andres, '83.)

As may be seen from the above synonymy, I have united into a single species three forms which have been usually regarded as distinct, though several authors have recognized the possibility of their identity. I wish it to be understood, however, that in employing the specific term *dianthus*, I do not desire to imply any prejudice to the claims to priority of two other terms, namely the *felinum* of Linnæus and the *pentapetala* of Pennant; I have not access at present to the works in which these terms were first used, and cannot, therefore, decide as to their validity.

Habitat.—I find in the present collection several representatives of this species, the majority of which were collected in shallow water principally from the piles of wharves or from stones, two specimens only coming from deeper water, one from 9.5 meters, where it was adherent to a deserted clam shell, and the other from 13.7 meters.

External Form.—Allowing for differences plainly due to size and degree of contraction, the external form is essentially the same in all the specimens. The base is adherent and the column is essentially cylindrical and smooth, except for, in some cases, fine longitudinal or transverse ridges, evidently due to contraction. A short distance below the margin there is a well-marked circular fold or collar, above which the wall is considerably thinner than it is below, and scattered over the surface below the collar, cinclides may be observed.

The margin is distinctly lobed and is tentaculate, the tentacles being very numerous and closely crowded in many cycles. They are rather short, and acuminate and entacmæous; I do not find, however, that the relative length and thickness of the tentacles is the same in all the specimens, differences of contraction causing them in some cases to be rather conical in shape, while in others they are much more slender and almost filiform. The disk is smooth and slightly concave, the mouth being somewhat prominent. The lips appear to be tuberculate, this appearance being due to the continuation upon them of the longitudinal ridges which occur upon the stomatodæum. In all the specimens in which the mouth is visible two gonidial grooves can be distinguished, except in one specimen in which there seemed to be only one.

Color.—Dr. Calkins' notes of the various specimens show that they can be arranged in three groups according to the prevailing color. Thus there is a group (I) in which the column is of a *brown* color, the tentacles being of the same color, while the lips are usually yellowish or orange. Dr. Calkins' description of one of the members of this group is as follows: "Light brown with long feathery tentacles of still lighter color. The extreme tips of the tentacles are white. The mouth parts are almost an olive green" and the disk is "transparent from mouth to margin."

In a second group (II), the column is of an orange or salmon color. Four representatives of this group occur in the collection: one of these Dr. Calkins describes as being of a "bright orange" color, and the other three as being "yellowish pink."

The third group (III) has but two representatives in the collection and these are described by Dr. Calkins as being "pure white."

Size.—The specimens belonging to the brown variety are on the whole smaller than the others. Some of them are, however, considerably contracted, measuring, in this condition, 1.3–1.5 cm. in height, the base being broadly expanded and measuring 1.8–3.5 in diameter, while at the upper part of the column the diameter is only 1.3–1.2 cm. One specimen, which was well expanded measured 3 cm. in height and had a diameter at about half way up the column of about 1.5 cm., while the base measured about 2 cm. Another specimen, also well expanded is about 4 cm. in height and about half way up the column has a diameter of 2.3 cm.

The specimens belonging to the orange variety have a greater average size. Three specimens measured 2.3 cm., 1.5 cm., and 3.5 cm. in height, with a column diameter of 2.3 cm., 1.3 cm., and 2.5 cm. respectively. Another specimen, taken at a depth of 13.7 meters, was much larger, measuring in its present condition, 12.5 cm. in height, the base having a diameter of 4.5 cm. and the column about its middle measuring 3.7 cm. in diameter. These figures do not, however, represent the original size of the specimen, since Dr. Calkins states that soon after it was placed in formalin its dimensions were "seven inches from base to mouth, five inches across the crown and three inches in diameter."

The two white specimens are of about the same size and measure 8 cm. in height and about 4 cm. in diameter.

As stated above, considerable variation occurs in the length of the tentacles. Thus in a brown individual measuring 4 cm. in height the inner tentacles measured 3.5 mm. in length, while in another individual of the same variety, measuring only 1.3 cm. in height, the inner tentacles were 5 mm. long. In the large orange specimen the inner tentacles measured about 4 mm.

Structure.—Considerable differences in the structural details are found in the various individuals, but these seem to be correlated, in part at least, with differences of age, that is to say of size. A comparison of the structure of the smallest individual with that of the largest would almost lead one to regard the two as distinct species; intermediate conditions, however, occur and it seems clear that the differences are growth differences associated with some tendency to variability.

The mesoglœa of the column wall has a fibrillar structure, or is even distinctly fibrous, especially in the region of the sphincter. Above the level of the collar the wall is much thinner than below, the difference being due to a difference in the thickness of the mesoglœa. The circular musculature of the column is well developed and in the smaller specimens, its mesoglœal processes are clearly marked off and show a tendency to branch slightly. In the larger forms, however, they are sometimes stout, with rounded extremities and may contain muscle cavities imbedded in their substance.

The sphincter is always well developed and is imbedded in the mesoglœa in the collar region. In different individuals, however, it presents decided differences in its minuter structure and I give on Pl. I three figures (Figs. 1, 2 and 3) showing some of the variations observed in the present collection. In Fig. 1, which is from an individual measuring 1.5 cm. in height, the muscle cavities are more or less circular and are scattered irregularly in the mesoglœa, being separated by a narrow band from its endodermal surface. In Fig. 2, which represents only a portion of the sphincter of an individual of the white variety measuring 8 cm. in height, the muscle cavities are much more numerous and extend quite up to the endodermal surface of the mesoglœa, even the processes found on that surface containing numerous cavities. In Fig. 3, finally another arrangement is shown. The preparation from which the drawing was made was from a brown specimen which measured 3 cm. in height, and the peculiarity which it presents lies in the band of mesoglœa destitute of cavities which traverses the muscle longitudinally, dividing it into an outer and an inner portion, the latter being separated from the endodermal surface by a distinct interval as in Fig. 1. This last condition recalls the arrangement figured by Carlgren ('93) for the European *M. dianthus* and may be termed the "layered" condition.

The occurrence of a band of mesoglœa, destitute of muscle cavities, between the inner surface of the sphincters and the endoderm is probably to be regarded as leading to a layered condition of the muscle. If, in a specimen similar to that from which Fig. 1 was taken, the inclusion of muscle fibers within the mesoglœa were to occur again with the continued growth of the individual, an arrangement would be found similar to that seen in Fig. 3, and an alternation of periods of growth during which inclusion went on with periods in which it ceased, would result in the arrangement figured by Carlgren. It may be presumed that in the larger specimens of *M. dianthus* a layered arrangement of the sphincter will be the most frequent, but cases like that represented in Fig. 2 show that it is not an invariable arrangement for the species.

I have examined the structure of the cinclides in one specimen of the collection and find that it agrees with what Carlgren has described for the European individuals, the canals being lined by endodermal cells, so that the cinclides may be regarded as endodermal evaginations. The same is true with regard to a specimen from our eastern coast (the *M. marginatum* Auct.), and this mode of formation may probably be regarded as typical for *Metridium dianthus*, though further observations are necessary to determine whether it can be regarded as characteristic of the entire subfamily.

The longitudinal musculature of the tentacles, and the radial musculature of the disk is ectodermal and but moderately developed. The stomatodæum is provided with well-marked longitudinal ridges, and in all the six specimens which were examined with regard to this point *two* siphonoglyphes were present.

In all the specimens examined, with a single exception, there were six pairs of perfect mesenteries, two of these being directives. In the majority of the specimens there were altogether five cycles of mesenteries, that is to say ninety-six pairs, but in some there were only four cycles and occasionally the fifth cycle was only imperfectly developed. In the exceptional specimen referred to above, there were only four pairs of perfect mesenteries. Two of these were directives, and between these two pairs on one side there were two pairs of perfect mesenteries, but none on the other. In other words, the irregularity affected only one-half of the specimen. In the normal half there were five cycles of mesenteries represented, the mesenteries of the fifth cycle, as is usual, lacking mesenterial filament. In the irregular half the various cycles could not be determined accurately, but judging from the relative breadths of the mesenteries the arrangement was D-iv-iii-iv-ii-iv-iii-iv-iii-iv-D, the mesenteries of the fifth cycle being omitted in this count.

The longitudinal muscles of the mesenteries were fairly well developed, forming a moderate thickening upon the inner portion of the primary mesenteries as represented in Fig. 4. Occasionally the pennon was somewhat narrower and more prominent, this condition being apparently normal for the directive mesenteries, the pennon in these having the form represented in Fig. 5. Parieto-basilar muscles are hardly at all developed (Fig. 4), and the basilar muscles have the form described by Carlgren, though not usually as large as those he has figured.

In only two specimens of those examined were reproductive organs present; in these they were borne upon the mesenteries of the second, third and fourth cycles. Acontia occurred and both the inner and outer stomata were found in the perfect mesenteries.

The specimens here described are undoubtedly identical with those described by Verrill ('65 and '69) as *Metridium fimbria-*

tum. Verrill founded this species ('**65**) on a specimen from San Francisco, but later ('**69**) gave a more complete description based on additional specimens from Puget Sound. In both papers he states his belief that the species is closely allied to the *M. marginatum* of the Eastern Coast of America, differing from it, however, "chiefly in having longer and more slender tentacles, with the parapet further from the margin of the disk." He further suggests that *M. marginatum*, *M. fimbriatum* and *M. dianthus* "will eventually be found to belong to one very variable and widely diffused species.

Andres ('**83**) considers *M. fimbriatum* a synonym for *M. marginatum*, accepting Verrill's suggestion to this extent, and though retaining *marginatum* distinct for *dianthus*, states his belief that it may be identical with that form.

We have here two questions of synonomy to consider : (1) Is *M. fimbriatum* identical with *M. marginatum?* (2) Is either of these species identical with the European *M. dianthus?* To the first of these questions I would answer in the affirmative. I have carefully compared specimens of *M. marginatum* from the coast of Massachusetts (Woods Holl) with the Puget Sound specimens, and, allowing for the variability which seems to obtain even in specimens from the same locality, I see no reason for regarding the two as distinct. It may be well however to compare in some detail the specimens from the two sides of the Continent, that my conclusions in the matter may not be merely *ex cathedrâ* statements.

1. As to the coloration. It has been stated above that three principal color varieties occur in the Puget Sound specimens. The same three varieties are readily distinguishable in the Woods Holl individuals, and, in connection with this, two points of some interest may be incidentally referred to. So far as I have seen in the examination of several hundred specimens of the east coast form, the smaller individuals are always brown, the individuals of a salmon or white color being invariably large and one is tempted to suppose that the salmon and white varieties are not distinct from the brown variety from the beginning, but that the brown color is characteristic of all younger individ-

uals and is, in some cases, after the individuals have obtained a considerable size, replaced by salmon color or by white. In support of this idea it may be stated that individuals are frequently found whose color is chiefly salmon or white, but whose column is splashed with irregular bands, spots or dots of brown. This fact seems to be true also of the Puget Sound forms according to the description given by Verrill ('69). Of course all individuals do not necessarily undergo a change from the brown color with advancing age, since brown forms may frequently be found quite as large as the individuals of the other colors.

The second point to which I wish to call attention receives a simple explanation from the conclusion just stated. Salmon-colored individuals blotched with brown are not uncommon and white individuals similarly marked are also found, but, never as far as I have seen, do individuals of a salmon color blotched with white, or *vice versâ*, occur. In other words the salmon-colored and white varieties never merge into one another while both merge into the brown variety.

2. As to dimensions the specimens which I have collected at Woods Holl agree in size fairly well with those of the present collection, except that I have never found any East Coast specimen as large as the largest Puget Sound specimen. Verrill, however, states ('64) that the more northern forms, especially those from the Bay of Fundy, are larger than those from more southerly localities.

3. As to external form I have not been able to distinguish any constant differences in the external form of the individuals from the two localities. The differences which Verrill considered to exist in the slenderness of the tentacles and the distance of the collar from the margin cannot be regarded as of much importance since they are apt to be due to contraction ; I find indeed as much difference in both these respects between different specimens from Puget Sound or Woods Holl as between specimens from the two localities.

As to internal structure. Making due allowance for the variability in the details of the internal structure shown to exist in the Puget Sound specimens, and for the similar variability occurring in the East Coast specimens, I can see no reason for considering the two distinct. In nearly all essential peculiarities there is practical similarity, the striking differences being in the apparent absence of variation in the number of siphonoglyphes and directives in the Puget Sound specimens. This difference will, however, be discussed later.

One other point may be mentioned. *M. marginatum* has been described from the coast of New Jersey to as far north as Labrador, *M. fimbriatum* from San Francisco and Puget Sound and Dr. Calkins informs me that it also occurs at Sitka. There is no record however of its occurrence in more northerly regions, the report from the American Station of the International Polar Expedition at Point Barrow (Murdoch '85) making no mention of any species which can be considered a Metridium. If, however, the East and West Coast species are identical it is probable that further observation will reveal their presence in the Arctic regions.

The specific identity of the East and West Coast forms being regarded as established, the question as to their identity with the European *M. dianthus* may now be considered. As pointed out above, suggestions as to their identity have been made, and, indeed, the American form has been actually identified with *dianthus* by some authors. Thus Couthouy ('38) speaks of the occurrence in the Charles River at Boston of *Actinia plumosa* Müller, and Dawson ('58) describes specimens from the Gaspé basin " which appear identical with the *A. dianthus* of the British Coast."

Certainly the two forms resemble one another closely both in external form and in coloration, three of the color varieties of *dianthus* recognized by Gosse ('60) being identical with those recognized for *M. marginatum*, while the fourth, the yellow, also occurs in the American species, but has been considered above as belonging to the salmon-colored variety. Of the internal structure of *dianthus* several more or less complete accounts exist, the most recent and most thorough being that of Carlgren ('93), and on comparing this point by point with what occurs in the American forms, the similarity is so great that there can be no doubt, I think, as to the identity of the two forms.[1]

I have not in the above discussion considered the variability in the number of the siphonoglyphes and directives, which is so pronounced in the European and American East Coast forms, and which might be regarded as of sufficient importance to be regarded as a specific characteristic. Sufficient data are not available to determine definitely whether this variability also occurs in the American West Coast forms, but in the six specimens I examined it was not observed. But even granting that no variability in this respect occurs in the *fimbriatum* forms, it does not seem that this would be sufficient for considering these specifically distinct from the *marginatum* and *dianthus* forms. No one has suggested that the *dianthus* forms with the siphonoglyphe and one pair of directives should be separated from those with two siphonoglyphes and two pairs of directives, and it would be even less reasonable, it seems to me, to separate *fimbriatum* forms from *marginatum* or *dianthus* forms with two siphonoglyphes and two pairs of directives, other structural characteristics being so similar.

There are not at present sufficient data at hand for determining accurately the relative frequency of the monoglyphic condition in the European and *fimbriatum* forms. To judge, however, from the statements of Thorell ('58), Gosse ('60), and Carlgren ('93), among others, the monoglyphic condition is by far the most frequent in the European specimens; the thorough observations of Parker ('97) show that it occurs in somewhat over one-half of the total number of *marginatum* forms which he examined; while, as stated above, it would seem to be much less frequent in the *fimbriatum* forms.

At the close of the list of synonyms of the species I have

[1] To judge from certain statements made by Gosse ('60) I should imagine that the relations of the different color varieties described above for *M. marginatum* do not hold for *M. dianthus*. What the physiological causes may be which produce the different varieties is at present unknown, but a fact quoted by Gosse is of interest in this connection. It is to the effect that on a water-logged board brought in by a trawler there were between four and five hundred specimens of *M. dianthus*, and all the individuals "*on one side the board were white, all on the other orange.*"

added *Actinia priapus* of Tilesius. The description which Tilesius gives of this Kamtchatkian form, though given at some length and accompanied with numerous figures, leaves one in considerable doubt as to its actual affinites. The figures of the entire animal given in his Pl. XIV, certainly resemble very greatly large specimens of *M. dianthus*, especially those contained in the present collection, and I should have little hesitation in identifying with that species were it not for Fig. 1, of Pl. XV, which suggests a Thalassianthan character for the tentacles. Andres has accepted this figure as representing the true structure of the tentacles and has assigned the form to a new genus Dendractinia, placing it however among the *Actiniae incertae sedis.* It seems to me quite probable however that the structure of the disc shown in Pl. XV, Fig. 1, is not natural but has been made by dissection, the figure being of a dissected specimen. In the text (p. 407) Tilesius says that the disk "in quinque vel sex ramos, ramulos et surculos papilliferos villiferosve divisus et subdivisus est, ita, ut periphèria disci a numerosissimis tentaculorum fasciculis formetur." This might be taken as confirming the accuracy of Fig. 1, but earlier in the paper (p. 396) be divides Actiniæ into two groups, of which the first contains "actinias disco diviso, scilicet in ramos ramulos et surculos tentacula efformantes" and includes *Actinia plumosa*, Müller, *Priapus polypus* Forskål, *Actinia effocta* Baster and *Actinia priapus.* The same description then which he applies to the tentacles of *A. priapus* serves also for *A. plumosa*, and this, taken in connection with the figures in Pl. XIV, seems to me to render exceedingly probable the identity of *Actinia priapus* with *Metridium dianthus.* It may also be mentioned that from what we now know of the distribution of *M. dianthus* there is reaaon to expect its occurrence on Kamtchatkian shores, while, on the hand, the occurrence of a Thalassianthid is not to be expected, since, so far as at present known, such forms are essentially tropical in their distribution.

Finally I may add, that if the identification of *A. priapus* be correct, it is possible that Brandt's *A. farcimen* ('35) may also be a synonym.

Family CRIBRINIDÆ.

Synonyms.—Bunodidæ. Gosse, 1858.
Tealidæ. R. Hertwig, 1882.
Bunodactidæ. Verrill. 1890.

Actiniinæ with adherent base, with a strong circumscribed endodermal sphincter; usually with the column more or less verrucose and frequently with acrorhagi at the margin, these, however, never being ramose or frondose. Perfect mesenteries usually numerous and gonophoric. No cinclides or acontia.

I have ventured to employ a new term for the family to which Gosse originally applied the name Bunodidæ. The change I have regarded as necessary on the ground that the family name should be a derivative from the name of the typical genus; my reasons for adopting Cribrina as the name for the typical genus are based upon a strict interpretation of the rules of priority and are as follows:

The family Bunodidæ was instituted by Gosse ('58) with the genus Bunodes (established in 1855) as its type, though previously Milne-Edwards had separated all actinians with verrucose column wall to form his group of actinines verruqueuses. Gosse took as the type of his new genus *B. gemmacea*, a form which had long been known and has been referred by Ehrenberg in 1834, to the subgenus Cribrina. An interesting question of priority here arises. The first species mentioned by Ehrenberg under the genus Cribrina, is this very one, and following the rule, it would be taken as the type of the genus. Haddon, however, has adduced reasons ('89) for believing that Ehrenberg regarded the fifth species which he included under Cribrina, namely, the *Priapus polypus* of Forskål, as the type, and for this reason retains Gosse's genus. The genus Bunodes certainly cannot be retained, since, as Verrill has pointed out ('99), the term had already been applied in 1854 to a genus of Eurypteroidea, and it seems better under the circumstances to consistently apply the rule and disregard Ehrenberg's possible or one might even say probable intention rather than introduce an entirely new term, such as Bunodactis, proposed by Verrill

('99). The genus Bunodella established by Verrill ('99, p. 43) has already been withdrawn by him ('99, p. 146) and need not be considered here, and the genus Evactis, also established by Verrill, is discussed later, and I need merely state here that after an examination of the type species, *E. artemisia*, Pickering, I see no reason for regarding it as distinct from Cribrina.

In 1834 Ehrenberg established a subgenus Urticina with the *A. crassicornis* of Müller as the type and later Gosse ('58) established for the same form the genus Tealia. The priority of Ehrenberg's term is generally admitted and consequently the use of Hertwig's name Tealiidæ for the family is inadmissible since Tealia is a nomen delendum.

I shall have occasion later to discuss another group of generic terms namely Anthopleura Duch. & Mich., Aulactinia Verrill, Ægeon Gosse and Bunodosoma Verrill, and may state here simply my belief that they cannot be separated but must all be included under the title Anthopleura.

The genus Phymactis M. Edw. ('57) has usually been regarded as a Cribrinid (Bunodid), Haddon, I believe, being the first to suggest that it might possibly be more correctly referred to the family Aliciidæ. Carlgren in a recent paper ('99) has published the result of his studies of *P. clematis* (Drayton), of which he finds Milne-Edwards' type species *P. florida* (Drayton) to be a synonym, and shows that Haddon was correct in his suggestion. I may add that I can confirm Carlgren's conclusions both as to the reference of the genus to the Aliciidæ and as to the synonymy of the two species mentioned, but may point out that one species, *P. cavernata*, which in the past has generally been referred to the genus Phymactis, must be removed from this genus and referred to Anthopleura. Verrill has practically already ('99) made the transfer, since he has included the species in his genus Bunodosoma.

With regard to the remaining genera which have been referred to the family little may be said, as for the most part too little is known of them to allow of certainty as to their true positions. I have already ('97) suggested the reference of Gyractis Boveri, to the Bunodidæ a suggestion which has been accepted by

Haddon. Carlgren's Isotealia ('99) must be allowed to stand for the present on account of the imperfect information in our possession concerning Hertwig's Leiotealia ('82) with which it is possibly identical, and Haddon's Ixalactis ('98) and Klunzinger's Thelactis ('77) will also stand as somewhat aberrant members of the family though it must be confessed that at present we are entirely in the dark as to the true systematic position of Thelactis as we are also to that of Physactis Verrill ('69), the last named genus being quite probably really an Aliciid, somewhat similar to Haddon's *A. rhadina* ('98). The genus Epiactis (Verrill '69) is considered further on.

Finally there remain to be considered Pseudophellia Verrill ('99), Tealiopsis Danielssen ('90) and Epigonactis Verrill ('99). Danielssen refers his *Tealiopsis polaris* to R. Hertwig's Tealidæ without however giving any definite evidence of its possessing the qualifications necessary for admission to that family; it may possess a circumscribed endodermal sphincter but neither in the text nor figures is there any indication of the existence of such a structure. If it does occur, then there seems to me a probability of Verrill's Pseudophellia being identical with Tealiopsis; it is impossible at present to speak with certainty on this point, however. Verrill's Epigonactis was established quite recently ('99) for two species which closely resemble each other and are not a little suggestive of *Urticina crassicornis* from which they are distinguished however by possessing on the surface of the column depressions which serve as "brood-pouches." With regard to the systematic value of this peculiarity I am exceedingly sceptical and believe that judgment on the admissibility of the genus must be suspended until a more detailed description accompanied with figures showing the structural details has appeared.

My views as to the relationships of the various genera mentioned above may be briefly expressed thus:

Cribrina, Ehr.—Synonyms, Bunodes Gosse, Evactis Verrill, Bunodactis Verrill, Bunodella Verrill.

Urticina, Ehr.—Synonyms, Tealia Gosse, possibly Epigonactis Verrill.

Anthopleura, Duch. & Mich.—Synonyms, Aulactinia Verrill, Ægeon Gosse, Bunodosoma Verrill.

Leiotealia, Hertwig.
Isotealia, Carlgren—possibly a synonym of Leiotealia.
Epiactis, Verrill.
Gyractis, Boveri—possibly a synonym of Cribrina.
Ixalactis, Haddon.
Pseudophellia, Verrill—possibly a synonym of Tealiopsis.
? Tealiopsis, Danielssen.
? Thelactis, Klunzinger.
? Physactis, Verrill.

Representatives of the first three of these genera occur in the collection.

Genus Cribrina Ehr.

Cribrinidæ without true acrorhagi; usually with numerous perfect mesenteries which are in some cases arranged on other than a hexamerous plan; sphincter strong; ectodermal musculature of the disk and tentacles not imbedded in the mesoglœa; column wall destitute of an epidermal covering and provided with verrucæ arranged more or less distinctly in vertical rows; tentacles simple.

Rather too much attention has been devoted in the past to the arrangement of the verrucæ, in members of the Cribrinidæ, whether they were arranged distinctly in vertical rows or not and whether these rows extended all the way down the column or only part of the way down. I plead guilty to such a misunderstanding of the value of the verrucæ in an earlier paper ('89) in which, basing my identification on this feature I described as an Aulactinia (*A. stelloides*) a form which is really a Cribrina and as a Bunodes (*B. tæniatus*) a form which is really an Anthopleura (*A. granulifera*).

It seems now that the presence of verrucæ, without regard to their arrangement, is sufficient for the genus, distinguishing it at once from Leiotealia, Epiactis and Isotealia. The absence of true acrorhagi, characterized by a marked development of nematocysts, distinguish it from Anthopleura, while the ectodermal situation of the longitudinal muscles of the tentacles and of the radial muscles of the disc may serve as a distinction from Urticina.

From Ixalactis and Pseudophellia it is readily separated by the simplicity of the tentacles and by the absence of an epidermal covering to the column wall.

2. *Cribrina elegantissima* (Brandt)

Synonyms.—Actinia (Taractostephanus) elegantissima, Brandt.
? Urticina crassicornis, Verrill.

The identification of the species here described with Brandt's *A. elegantissima* is necessarily somewhat uncertain, since the original description is not as complete as could be wished. So far as the description goes, however, the agreement is sufficiently close to warrant the identification.

Habitat.—" A very common form on the rocks and piles" in Puget Sound. (Calkins.)

External form.—The base is circular and adherent. The column is almost cylindrical (Figs. 7 and 8) and in its upper part is provided with vertical rows of verrucæ, which become obsolete towards the base. Some of the rows extend much farther down the column than others, and according to their length, about four sets can be distinguished, of which the third and fourth sets are much shorter than the other two. The lower part of the column is ridged transversely probably as the result of contraction. A well-defined margin is present, and a distinct interval exists between it and the bases of the outermost tentacles.

These are short, rather blunt at the apex and all finely ridged longitudinally. They appear to be arranged in about five cycles, though their total number does not agree with what would be expected from such an arrangement; as will be seen later there are irregularities in the arrangement of the mesenteries which probably explain the irregularities of the tentacles. The disk is marked by fine radiating furrows and is slightly concave, the peristome being prominent. In two of the specimens the stomatodæum is somewhat evaginated and it can be seen that its walls are longitudinally ridged. Two siphonoglyphes seem to be present as a rule, though sometimes irregular in position, and in one individual there were three, and in another only one.

Color.—The specimens when I received them were in formalin and showed a distinct green coloration in the upper part of the column, while the lower part was a dingy white. On transferring them to alcohol the green coloration gradually disappeared, the pigment to which it was due being evidently soluble in that medium. In life the coloration, according to Dr. Calkins' description, was quite brilliant. He says, " The ground color is bright green while rows of bright red vary it. Each tentacle is colored in the middle by a ring of brown and the tip is of the same color. They are very gorgeous " (**Fig. 8**).

Brandt's description of the coloration of his *A. elegantissima* is as follows: " Red, green, blue or fuscous, or even green spotted with purple. Disc olivaceous, striated with white. Tentacles white, purple at the tips and marked at the middle by a purple band." Comparing this with Dr. Calkins' description a decided similarity is noticeable, Brandt's account, however, indicating considerable variation in the color of the column. The markings of the tentacles Calkins describes as brown, while Brandt states that they are purple, a discrepancy perhaps due to variation, or perhaps to the uncertain way in which the term purple is frequently used. In both descriptions the arrangement of the markings is identical.

Size.—The three specimens sent me were all apparently small, measuring 3, 1.8 and 2.5 cm. in height, and 3, 3, and 1.5 cm. in breadth, respectively. Dr. Calkins in his notes says that some individuals " are of large size, five or six inches long and three or four in diameter, and Brandt's statement regarding the size is " Corpus magnum." The inner tentacles have a length of about 0.4–0.5 cm., while the outer ones seem to be slightly longer.

Structure.—The verrucæ are hollow outpouchings of the column wall (**Fig. 9**). The circular musculature of the column is well developed in the intervals between the verrucæ and is supported upon branched mesoglœal processes, which are frequently grouped together in bunches arising from a common base. The walls of the verrucal outpouchings are, however, almost destitute of musculature, except at the very summit of the pouch. Here a small number of muscle processes may be seen projecting from the inner surface of the mesoglœa, which is here slightly thickened. The ectoderm over the summits of the verrucæ is similar to that described for the verrucæ of *Cereus pedunculatus* by von Heider ('**77**) and for those of *Phymanthus crucifer* by myself ('**89**), the layer of cells at the base of the epithelium in the latter form being also present here. Indeed, the only difference between the structure of the verrucæ of the present species and those of Phymanthus is the existence of a special musculature on the endodermal surface of the summits of the papillæ in the former.

The sphincter, which occurs below the fosse intervening between the margin and the bases of the outermost tentacles, is of the circumscribed pedunculate bipinnate variety[1] (**Fig. 10**), and is strong. The ectodermal musculature of the disc is well developed, the processes of mesoglœa which support it anastomosing somewhat to form a reticulum, a condition intermediate between the typical ectodermal and the mesoglœal arrangements being thus produced (**Fig. 11**). Transverse sections of the tentacles show that their ectodermal musculature is also well developed, but no anastomoses of the mesoglœal processes occur (**Fig. 12**).

The walls of the stomatodæum are thrown into well-marked longitudinal ridges and are richly supplied with glands, except

[1] It seems advisable that certain terms should be agreed upon for the description of the principal varieties of endodermal and mesoglœal sphincters. So far as the endodermal are concerned, the terms "diffuse" and "circumscribed," already in general use, serve to divide them into two groups; but a further subdivision of the circumscribed forms would be useful. I would suggest as a first subdivision that those which arise by a number of main branches from the column mesoglœa, as in *Myonanthus ambiguus* and *Oulactis californica* for example, be grouped as "sessile," while those which have a distinct peduncle be termed "pedunculate." The latter group may again be divided, according as the lamellæ radiate from a central mass or are inserted into an axial lamella, into "palmate" and "pinnate" varieties. Such a classification may be represented in tabular form, thus:

Endodermal sphincter	diffuse.		
	circumscribed	sessile.	
		pedunculate	palmate.
			pinnate.

Such a classification is of course merely tentative and presumably imperfect, but it may serve to some extent to obviate the long description now necessary.

in the regions of the siphonoglyphes. That irregularities occur the arrangement of the latter structures has already been noted. In one of the three specimens which I sectioned I found three siphonoglyphes, while in the second individual though only two were present they were not opposite one another, thirty-seven pairs of mesenteries intervening between the two on one side while on the other side there were fifty-five pairs. In the third specimen but a single siphonoglyphe occurred.

In connection with the siphonoglyphe a peculiarity of structure exists. The endoderm over the general surface of the stomatodæum is comparatively low and inconspicuous, but in the region of the siphonoglyphes it suddenly becomes very high and retains this condition over the entire surface of the grooves (**Fig. 12**). I speak of the endoderm being thickened, but the appearance is rather as if the endodermal surface of the mesoglœa were drawn out into exceedingly fine fibrillæ which anastomose with one another to form a reticulum with elongated meshes, the endodermal cells being arranged on the terminal part of the fibrillæ. The appearance presented is very similar to that which I have described as occurring in the mesenteries of *Cerianthus americanus* ('90).

The individual with three siphonoglyphes had three pairs of directives, while the one with two siphonoglyphes had correspondingly two pairs unequally spaced, and the third specimen with one siphonoglyphe had but a single pair. As might be expected from the arrangement of the directives considerable irregularity occurred in the mesenteries. In the upper part of the column each alternate pair seemed to be perfect as a rule, but lower down seven imperfect pairs intervened in certain sectors between successive perfect ones. It may be supposed from this that there were typically four cycles of mesenteries, three of which were perfect and one imperfect. The typical arrangement occurred however only in a few sectors ; examples of a fifth incomplete cycle occurred here and there and in addition both imperfect and perfect pairs were not infrequently intercalated so that it was impossible to determine even whether the arrangement was hexamerous or not, although it may be supposed that in one specimen at least it was decamerous. To illustrate the irregularity which exists, **Fig. 1**, representing the arrangement of the mesenteries in the specimen with two siphonoglyphes a little below the middle of the stomatodæum, is appended.

Attention may be called to one interesting irregularity in this specimen, and that is the development of two pairs of mesenteries in the endocœl of one of the perfect pairs.

The longitudinal musculature of the perfect mesenteries is fairly well developed (**Fig. 14**) and there is a well-marked parieto-

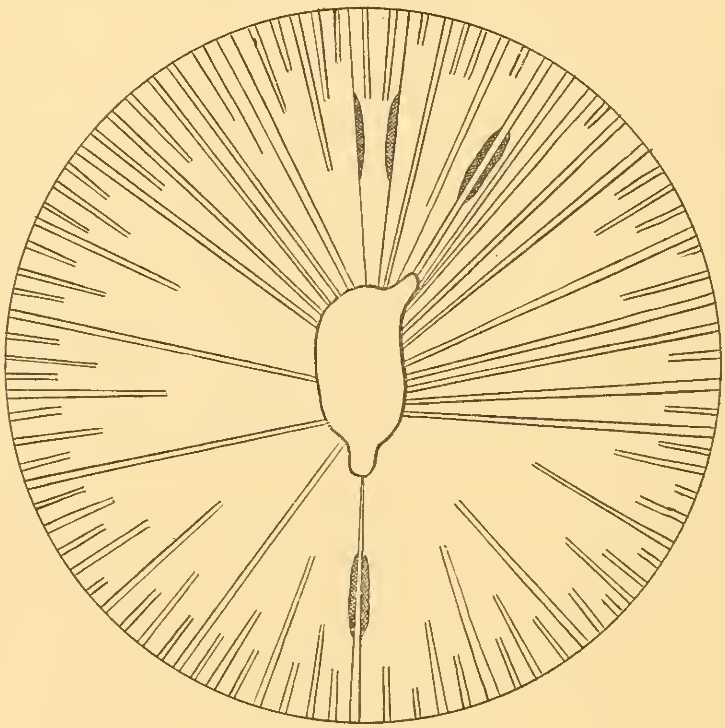

Fig. 1.

basilar forming a fold upon the peripheral portion of each mesentery. Both inner and outer mesenterial stomata are present. Reproductive organs may apparently be developed on any of the mesenteries, with the exception of the directives and of the incomplete cycle, but in the two specimens examined minutely with this point in view they are not distributed with perfect regularity, some mesenteries of every cycle lacking them.

There is no doubt but that in many respects of structure this form approaches closely to *Urticina crassicornis*, the differences in the arrangement of the ectodermal musculature of the disk and tentacles and in the form of the sphincter being possibly explicable on the assumption that the specimens examined by me were all young. I have not had the opportunity of comparing any of the large specimens of this species with fully grown urticinas, but it would seem that the irregularities in the siphonoglyphes which occurred in all of the three specimens examined indicate the distinctness of the species, since such irregularities have not been found to occur in Urticina.

3. *Cribrina artemisia* (Pickering)

Synonyms.—Actinia artemisia, Pickering in Dana.
Cereus artemisia, Milne-Edwards.
Evactis artemisia, Verrill.

Habitat.—The individuals of this species were found at Discovery Bay, the same locality from which they were originally described by Dana ('46). They live buried in the sand, the disk being flush with the surface in expansion, and are attached below to valves of shells or more rarely to stones.

External Forms.—The base is adherent and the column in contraction is club-shaped (**Fig. 25**). A short distance above the limbus the column suddenly contracts and then gradually enlarges again until above it may equal or exceed the base in diameter. In all three specimens which I had for examination the tentacles and disk were completely hidden and the upper extremity of the column presented an almost flat surface, slightly depressed towards the center. The appearance presented by these specimens little resembles accordingly the figure given by Dana, but it must be remembered that this figure is of an expanded individual. Dana describes the column as being enlarged at its middle and contracted more or less above and below. It is probable that in the preserved specimens the upper contracted portion is completely involuted, and the enlarged extremity corresponds to the middle enlargement of the expanded form.

The column in its lower part is horizontally rugose, evidently as the result of contraction, and is provided with a number of rather low tubercles arranged in about twelve longitudinal rows, the individual tubercles of each row being separated by considerable intervals. Higher up, where the column begins to enlarge, the rows are more numerous, and at the upper part, the tubercles become decidedly papilliform. They are arranged in about 96 rows and have particles of sand and shell adhering to them, their verrucal nature being thus demonstrated.

By dividing the column longitudinally, it became evident that there were no acrorhagi, the papillæ of the margin being the uppermost verrucæ of the longitudinal rows.

The number of the tentacles could not be determined with certainty. They were simple, rather short and acuminate, and, as Dana has stated, are ectacmæous. The disk and mouth were hidden in all the specimens.

Color.—The coloration as stated in Dr. Calkins' notes differs a little for that described by Dana. It was "greenish-yellow" at the upper portion of the column and "yellowish-white" lower down, while the tentacles are stated to have "scarlet or purplish tips." According to Dana, who quotes a description by Drayton "the general color of the exterior of the body is a yellowish-green. The tubercles have a dark sap-green color; they become obsolete below, yet the green line continues to the base of the animal. The colors of the tentacles are various and shaded like those of the prism; the disk is dull greenish, becoming darker towards the base of the tentacles, and the mouth is flesh-colored."

Size.—In the preserved specimens the base measured 2.5 cm. in diameter. The column a short distance above the limbus, at its narrowest point, measured 1 cm. in diameter, but above it equalled the diameter of the base or even reached a diameter of 2.8 cm. The height of the column was about 6.0 cm.

The inner tentacles were about 0.5 cm. in length, while the outer ones measured 0.65–0.7 cm. For the expanded animal, Dana gives the greatest diameters of the column as about 5.5 cm. (2¼ inches), while the outer tentacles he states to have been 2.5 cm. (1 inch) in length and the inner ones 1.25 cm. (½ inch).

Internal Structure.—The mesoglœa of the column wall is, relatively to the size of the individuals, rather thin and is provided with a well-developed circular musculature, whose general appearance resembles that of *C. elegantissima.* In the upper part of the column, however, it is comparatively poorly developed, and also on the inner walls of the evaginations which produce the verrucæ, being entirely wanting at the apex of these.

The sphincter (**Fig. 18**) is large and is of the pedunculate bipinnate type, the lateral lamellæ of one side being, however, stronger than those of the other so that it is properly described as unequally bipinnate. In one of the three specimens a deep incisure occurred on one side of the sphincter, reaching almost to the median axis and giving the section of the sphincter a reniform outline. This was wanting, however, in the other two in which the sphincters were oval in section.

The tentacles are not ridged and have a well-developed, though simple, ectodermal musculature. Their endoderm, as well as that of the disk and of the upper part of the column wall, is richly laden with granules of black pigment, insoluble in the reagents employed in hardening and sectioning. The ectodermal musculature of the disk (**Fig. 18**) resembles that of the tentacles, being supported on well-developed simple or but slightly branched processes of mesoglœa.

Two siphonoglyphes are present and the walls of the stomatodæum are longitudinally ridged and in addition considerably folded.

The mesenteries are arranged in four cycles and there are in all forty-eight pairs (6, 6, 12, 24). In sections through the upper part of the column all but those of the fourth cycle are seen to be perfect, but below the level of the stomatodæum the various cycles can be distinguished by the relative breadths of the various pairs, those of the first and second cycles being however nearly similar in this respect. The mesenteries of the fourth cycle do not bear mesenterial filaments and there are two pairs of directives, placed symmetrically.

The longitudinal musculature is well developed (**Fig. 19**), covering almost half of the non-gonophoric portion of the mesenteries and ending somewhat abruptly at either edge. At the outer edge a mesoglœal process, stronger than usual, is developed and from it a number of mesoglœal processes arise. The parieto-basilar muscles form a distinct fold on the lower portions of the mesenteries, and the basilar is fairly well developed, having the appearance shown in **Pl. III, Fig. 20.**

Both the inner and outer mesenterial stomata are present, and all the mesenteries, with the exception of those of the fourth cycle and the directives, bear reproductive organs.

From the examination of this species it has seemed to me impossible to separate it from the genus Cribrina. Verrill ('69) has established for its reception the genus Evactis characterized by possessing pores in the column wall as well as verrucæ and by the tentacles being ectacmæous. I have not been able in sections to discover any distinct pores in the column wall and am inclined to believe that the emission of jets of water "as from a watering pot" which has been observed, was through minute ruptures of the wall, the mesoglœa being comparatively thin especially in the upper part of the column. If this be correct, little importance can be attributed to their power of ejecting water. The tentacles of *C. artemisia* are, indeed, ectacmæous but in every other respect the form has the typical structural characteristies of a Cribrina, and it seems advisable to regard the ectacmæous arrangement of the tentacles as a specific rather than as a generic peculiarity.

Genus Urticina Ehrenberg.

Cribrinidæ without true acrorhagi; with numerous perfect mesenteries frequently arranged decamerously; sphincter strong; ectodermal musculature of the disk and tentacles imbedded in the mesoglœa; column wall destitute of an epidermal covering, and usually provided with verrucæ arranged more or less definitely in vertical series; tentacles simple.

The synonymy of this genus has been recorded by Andres ('83) and more recently by Carlgren ('93). As at present understood it includes but a single species, *A. crassicornis*, a fact which renders the establishment of a final definition exceedingly uncertain.

The name Urticina was originally applied by Ehrenberg ('34) to a subdivision of his subgenus Actinia Isacmæa, and included numerous forms now assigned to other genera. It was not until much later that the genus became at all definitely limited and then it was under the name Tealia, proposed by Gosse in 1858. The essential peculiarity of the genus according to the definition given by Gosse, was that the verrucæ were scattered irregularly over the column wall and were not arranged in vertical series, and this supposed characteristic was generally accepted by succeeding authors. Messrs. G. Y. and A. F. Dixon ('89) pointed out that this peculiarity does not really exist, the verrucæ being really in vertical series, though the regularity of the arrangement is not always readily perceivable, and Carlgren ('93) has called attention to the same fact. The original distinguishing peculiarity which separated the genus from Cribrina being thus disposed of, both the Dixons and Carlgren found a new distinction in the decamerous arrangement of the mesenteries, the former authors, indeed, going so far as to suggest that this peculiarity was worthy of being raised to the dignity of a family characteristic.

To establish a genus on its decamerism seems to me, in view of what we now know concerning departures from hexamerism in the Hexactiniæ, to place it on an exceedingly insecure foundation. And that this is true in the present case has been recently shown by Verrill ('99, p. 216, note) who states that he found "many specimens [of Urticina crassicornis] hexamerous both as to tentacles and mesenteries; many others decamerous; some octamerous; and a few irregular or unequally developed on opposite sides." A careful study of the mesenteries of the individuals contained in the present collection reveals in no case a perfect decamerism, but an irregular arrangement which appears, however, to be based on a decamerism. Consequently we may, I believe, hold the character of decamerism to be insufficient for the characterization of the genus, and if it is to be maintained distinct from Cribrina, we must seek for other peculiarities.

As the definition I have given above suggests, such a distinction may possibly be found in the enclosure of the longitudinal musculature of the tentacles and the radial musculature of the disk in the mesoglœa, an arrangement which seems to be absent in typical Cribrinas. It must be remembered, however, that as in the case of *C. elegantissimus* described above, transitional conditions between what is found in Urticina and in typical Cribrinas occur, and the absolute value of such a characteristic is accordingly open to question. Personally I am somewhat inclined to regard the distinctness of Urticina from Cribrina as not proven, but prefer to await the discovery either of additional species clearly belonging to the former genus or of transitional forms which will clearly bridge over such differences as may appear to exist between the two.

4. *Urticina crassicornis* (Müller) Ehr.

[For the synonymy of this species vide Andres (**'83**) and Carlgren (**'93**).]

Several specimens of this form, which has previously been described for the West Coast by Verrill (**'69**), occur in the collection and show considerable variation in their external characters.

Habitat.—The majority of the specimens were found attached to stones under wharves and accordingly in shallow water. Two, however, were found imbedded in sand to a depth of six inches or a foot, being attached below to stones. This habit does not seem to be a usual one for the species but Dicquemare (**'73**) has described it for individuals obtained by him at Havre, and Teale (**'37**) speaks of individuals being partly buried in sand on the coast of Yorkshire.

External Form.—It does not seem necessary to give a detailed description of this well-known form, but mention should be made of certain peculiarities presented by the various specimens. And first as regards the verrucæ. These in all the specimens were distinctly in vertical series, but their distribution varied somewhat. In some specimens they were large and somewhat irregular in shape and were distributed over the entire surface of the column, those towards both the margin and the limbus being, however, smaller than those situated in the intervening region. In others again they became obsolete above, occurring on only the lower two-thirds or three-quarters of the column and in one specimen they occurred only on the lower half of the body, those at the limbus in this case being relatively very small, while those above were larger, about 1 mm. in diameter, but were more scattered, that is to say were separated from one another by larger intervals than usual. In the arenicolous specimens again the verrucæ were limited to the upper third of the column, not extending upwards, however, quite as far as the margin, and the lower portion of the body presented no signs of them, except very faint indications immediately above the limbus. A further peculiarity of these forms was that numerous particles of sand and shell were adherent to the verrucose region of the column, a condition not presented by any other specimens in the collections.

I have not access at present to all the literature dealing with this species, but it seems evident that there is considerable variation in the distribution, size and number of the verrucæ in different individuals. As regards their distribution the verrucæ may present the various conditions described above, or may be apparently entirely absent. To a certain extent at least these variations as seen in preserved specimens may be due to the retractibility of the verrucæ, which, to quote the statement of Teale (**'37**) "admit of retractibility to such a degree as to render the corium perfectly smooth, so that the small opaque spot alone indicates their former situation ; they also can be protruded to nearly a line in length, when they bear a close resemblance to rudimentary tentacula. The eminences on one side are often seen in the utmost degree of protrusion, whilst, on the other, they are scarcely perceptible." In some of the present specimens, "the small opaque spots" mentioned by Teale and due to the peculiar structure of the epithelium of the summits of the verrucæ, could be perceived on those portions of the column which appeared to be destitute of verrucæ, but this was not the case in the arenicolous individuals. The extent of the protrusion of the verrucæ together with the amount of contraction of the column would bring about variations in the proximity of the verrucæ, which are frequently described as being separated from one another, though in the present specimens they are so closely approximated as to be in some cases more or less quadrangular in outline, owing to mutual contact. So too the amount of protrusion will produce variations in their size; in all the specimens of the present collection the verrucæ about the middle of the column are larger than those above and below, but in the different individuals the size of the largest ones vary, being as much as over 1 mm. in diameter in some specimens, while in others they are less than half that size.

I have discussed these varieties of the verrucæ somewhat at length because they serve to illustrate very pointedly the uncertainty of taking external peculiarities alone as a basis for specific distinctions. When I first examined the specimens of the present collection I regarded the arenicolous forms as quite distinct from the others and it was only after I had studied the internal structure of both that I became certain of their identity.

One other point in the external structure I may refer to briefly namely, the arrangement of the tentacles. The decamerism is fairly well pronounced, but never perfect: thus in one specimen is which an accurate count was made there were 133 tentacles only, instead of the 160 which might be expected. The variations of the tentacles however being associated with the arrangement of the mesenteries, need not be discussed in detail and I mention it merely on account of the importance which has been assigned to it by Cunningham ('89).

Color.—All the specimens collected were uniform in color throughout the column, and were either red or orange brown (the "color of an over ripe banana" Calkins). The arenicolous forms were of a bright vermilion color, with paler tentacles, and their appearance when dug from the sand has been so graphically described by Dr. Calkins that I quote his description. "They look very much like a tomato baked in bread crumbs. They have the same wrinkled appearance of the skin, while the appearance of the bread crumbs is given by the numerous small pieces of shell attached to the upper end." [1] The tentacles in some of the specimens at least were banded with color. Although none of the specimens showed any traces of green in their coloration, yet such varieties have been described from the West Coast. Verrill ('69) has described them, and one of the drawings of Mr. Agassiz is evidently of an individual of this species in which the color of the column is grass green irregularly blotched with deep red, the tentacles being pinkish, with a dark red band a short distance above the base. The drawing shows no indication of warts in the lower portion of the column; whether or not they were present on the upper part cannot be determined since it is hidden by the tentacles.

Size.—All the specimens were of a goodly size, the smallest measuring about 4.5 cm. in height and diameter while the largest was 7.5 cm. in height and 5.5 cm. in diameter. Dr. Calkins describes one of the specimens as having in life a height of 7.5 cm. and a diameter of 5.0 cm. while another he describes as reaching a height of 12.5 cm.

Internal Structure.—I have found some variation in the form of the sphincter in the Puget Sound specimens. Its general appearance in the majority of the individuals examined resembles closely the condition figured by the Hertwigs ('79), that is to say, the mesoglœal lamellæ radiate out for a central mass of mesoglœa, sometimes more or less homogeneous in appearance, sometimes showing more or less clearly its origin by fusion of the basal portions of the lamellæ. In all my preparations, however, the lamellæ are much more numerous and much more delicate than figured by the Hertwigs, a condition also noted by Carlgren ('93) in the specimens examined by him. It may be noticed that at one point in the periphery of the specimen figured by the

[1] Since writing the above lines I have received from Professor Verrill drawings of a specimen taken at Port Townsend in 30 fathoms which is evidently the same as the arenicolous variety of *Urticina crassicornis* described above. The drawing represents the column as being of a bright scarlet color, with very numerous and distinctly marked verrucæ of a yellowish color in its upper part and with long, rather stout tentacles of a yellowish or buff color without bands but with a certain amount of red at the base.

Hertwigs there is a deep incisure, extending almost to the central core of mesoglœa ; I found a similar incision, somewhat more extensive indeed, in one specimen I examined, but in others it was entirely wanting. Carlgren ('93) states that in the individuals he examined the arrangement of the lamellæ differed from what the Hertwigs describe in being attached at their bases to an axial lamella instead of a solid core ; that is, he finds the sphincter is bipinnate instead of palmate as the Hertwigs describe it. In a single specimen of those I examined I found a typically bipinnate sphincter a figure of which is given on **Pl. I. (Fig. 6)**. It seems accordingly that we may find in individuals of *Tealia crassicornis*, either palmate or pinnate sphincters, the latter probably representing what may be considered a persistence of an embryonic condition from which the palmate is derived by a fusion of the basal portions of the lateral lamellæ.

As to the arrangement of the musculature of the mesenteries and of the tentacles and disk I find nothing to add to the descriptions given by Carlgren.

It is well known that the mesenteries of *U. crassicornis* are arranged more or less perfectly on a decamerous plan. In none of the specimens I have examined, however, is the total number of mesenteries an exact multiple of ten ; thus in one specimen there were altogether 81 pairs of mesenteries, in another 91, and in another 104. The variation from the typical number depends on irregularities in the development of the younger series of mesenteries. Thus in the three specimens just referred to the first three cycles were regularly decamerous, their formula being 10, 10, 20, but considerable irregularity occurred in the succeeding cycles. Thus in the specimen with a total of 81 pairs the fourth cycle was completely developed except that in a primary interspace on one side of one of the directive pairs there were only two representatives of it instead of four, the two pairs which were lacking being those nearest the pair of directives. To compensate for this diminution in the total number, in another primary interspace there were two accessory pairs of mesenteries which may be regarded as representatives of a fifth cycle, and in still another interspace there was a single additional pair of this fifth cycle. In the individual with a total of 91 pairs irregularities occurred in only two of the primary interspaces. The fourth cycle was completely developed so that there were 10, 10, 20, 40 = 80 pairs of regular mesenteries; and in addition 11 pairs representing a fifth cycle. Eight of these were situated in a primary interspace next one of the directive pairs and alternated in a regular manner with

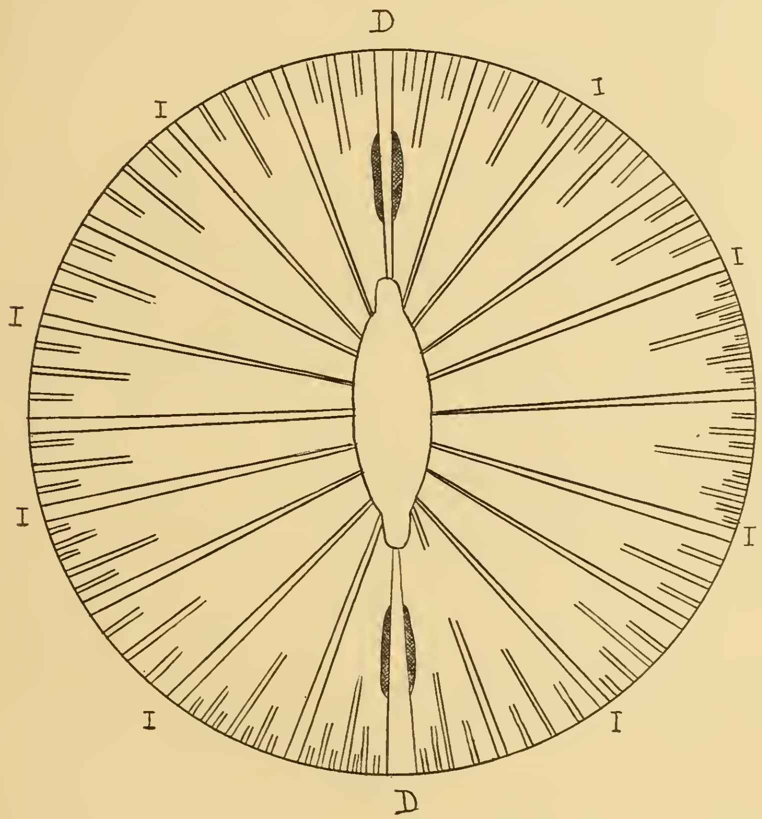

FIG. II.

the pairs of the older cycles; the other three occurred in the middle lateral interspace of the other side of the body, one of them intervening between the primary mesenteries on one side of the interspace and the succeeding member of the fourth cycle, while the other two alternated with the fourth cycle pair next the primary pair on the other side of the interspace. Finally in the individual with 104 pairs there are again four cycles regularly developed; in a primary interspace next one of the directive pairs there are 8 pairs of a fifth cycle regularly arranged and in the interspace lateral to this there are two pairs of the fifth cycle. In each the two interspaces on the other side of the same directives there is a single pair of the fifth cycle, and in the middle lateral interspace of this same side of the body there are 8 pairs of the fifth cycle and in addition 6 representatives of a sixth cycle. The arrangement in this specimen is shown in the annexed figure, from which it may be seen that Carlgren's law that the mesenteries of the last cycle develop earliest in the interspaces adjoining the oldest pairs already present, is complied with.

The mesenteries of the first cycle are complete throughout the entire length of the stomatodæum; those of the second cycle are also complete, but are not attached so far down the stomatodæum as the members of the first cycle, while those of the third cycle reach the stomatodæum only in its uppermost part. The fourth, fifth and sixth cycles are incomplete. All the members of the first two cycles are sterile, the reproductive organs being borne apparently by the members of the third and fourth cycles. Both oral and marginal mesenterial stomata are present, the latter usually quite small.

Finally a word as to the synonymy of the West Coast specimens of *U. crassicornis*. As already stated, Verrill ('69) was the first to correctly identify this species from the West Coast of America, and he records its occurrence in Puget Sound, and in the Arctic Ocean north of Behring Straits, while Murdoch ('85), found it at Point Barrow. Verrill in his list of synonyms includes, with some doubt however, the *A. Laurentii* and the *A. elegantissima* of Brandt ('35) obtained in Behring Sea and at Sitka; Andres regards these two forms as being *species delendæ* on account of the insufficiency of their descriptions. I believe, however, that there are sufficient grounds for identifying the *A. Laurentii* with *U. crassicornis*, though I think Verrill was probably in error in likewise identifying the *A. elegantissima* with that species, since I have found in the present collection forms, described in preceding pages, which seem to agree with Brandt's description. I may say that I made an endeavor to ascertain if any of the specimens collected by Mertens were still in existence, but the endeavor proved futile.

Genus Anthopleura, Duch. & Mich.

In 1860 Duchassaing & Michelotti established the genus Anthopleura for a Cribrinid characterized by possessing verrucæ arranged in longitudinal rows and with tentaculiform acrorhagi. In a later paper ('64) they added to the original single species, *A. Krebsi* upon which the genus was founded, other forms, one of which at least possessed lobed acrorhagi, altering at the same time the definition of the genus so that it became rather indefinite. In 1864 Verrill established a genus Aulactinia for a Cribrinid also possessing verrucæ arranged in longitudinal rows though becoming obsolete below and having prominent acrorhagi which were distinctly lobed. The later action of Duchassaing and Michelotti in including in their genus a form with lobed verrucæ led Verrill in 1869 to suggest the possibility of the identity of the two genera, but Andres ('83), going back to first principles, recognizes both, placing the forms with simple acrorhagi in the genus Anthopleura, while those in which they are distinctly lobed he refers to Aulactinia. Verrill in his most recent papers ('99) considers the two genera distinct and adds a third Bunodosoma to which he refers the *A. granulifera* of Lesueur and his *Bunodes cavernata*, and which he characterizes by possessing lobulated acrorhagi and verrucæ which are not adhesive.

It does not seem to me that the simplicity or lobulation of the acrorhagi is a feature worthy of generic importance when we find as much general similarity in such forms as *Aulactinia capitata, Anthopleura granulifera* and *Bunodosoma cavernata*, all of which forms I have had the opportunity of studying. As to whether the adhesiveness of the verrucæ may prove to be a feature of generic importance, I feel more uncertain, but at present am inclined to deny it that value.

The genus Ægeon described by Gosse ('65) seems to be undoubtedly identical with Aulactinia and need not be discussed.

I would then define the genus Anthopleura as follows :

Genus Anthopleura Duch. & Mich.

Synonyms.—Aulactinia, Verrill, 1864.
Ægeon, Gosse, 1865.
Bunodosoma, Verrill, 1899.

Cribrinidæ with true acrorhagi, usually with numerous perfect mesenteries, sphincter strong, column destitute of an epidermal covering and provided with verrucæ arranged more or less definitely in vertical series, tentacles simple.

5. *Anthopleura xanthogrammica* (Brandt)

Synonym.—Actinia (Taractostephanus) xanthogrammica, Brandt, 1835.

This species was found in only one locality, under the slaughter house at Port Townsend, but it occurred there in large numbers. An excellent figure of it is among the drawings kindly lent me by Mr. Agassiz, the individual figured having been obtained at San Francisco. Dr. Calkins states that evidences of multiplication by fission were not unfrequent among the Port Townsend specimens.

External Form.—The base is adherent. The column (**Pl. II, Fig. 17**) is provided with rows of tuberculiform verrucæ, to which particles of sand and small stones adhere and which are arranged in distinct vertical rows extending to the limbus as a rule, though in the upper part of the column shorter rows alternate with the longer ones. The margin is separated by a distinct though shallow fosse from the bases of the outermost tentacles, and from the margin of the outer wall of the fosse there project blunt processes, one of which corresponds to the summit of each row of verrucæ (**Fig. 19**, *a*, *c*). These are undoubtedly acrorhagi. They are much more distinct in some of the preserved individuals than in others and, indeed, may be more prominent at one portion of the margin than at another in the same individual, here appearing as mere hemispherical elevations and there as distinct blunt tentaculiform projections, or again having a distinctly lobed form.

The tentacles in the preserved specimens are very moderate in length, conical and rather obtusely pointed. In Mr. Agassiz's drawing they are represented however as rather long and slender, while in that by Dr. Calkins they agree more with the condition in the preserved specimens. They are quite smooth and are arranged in about four cycles and are fairly numerous, though I did not succeed in making an accurate enumeration of them. The disk is smooth and somewhat concave and the peristome slightly elevated. The lips are ridged and there are two rather feebly marked gonidial grooves in the specimens examined.

Color.—Dr. Calkins describes the individuals obtained by him as being "crystalline" in appearance with "pink-tipped tentacles." The drawing which accompanied his notes (**Fig. 17**) shows the column, disk and bases of the tentacles to be faintly greenish-yellow, the tips of the tentacles being the only brightly colored portions of the animal. Mr. Agassiz's drawing, which is undoubtedly of the same species, represents the column as being of a bright green color, the disk of a dark olive green ; this color extending upon the bases of the tentacles, being there succeeded by a yellow band, beyond which the tentacles are of a bright pink.

Size.—The preserved specimens sent me measured 1.0–1.5 cm. in height and about the same in diameter. Dr. Calkins states that the largest individuals "when expanded, measured fully three inches across the crown, but the average was much less."

Structure.—A longitudinal section of the column wall resembles closely what I have described and figured for *Cribrina elegantissima.* The tubercles differ from those of *Cribrina* only in the absence of a special development of endodermal muscles at their summits and in the presence of a distinct though fine band of nerve fibers in the basal portion of the modified ectoderm.

The sphincter is situated upon the floor of the fosse, just internal to the acrorhagi. It is oval in section and is of the pedunculate palmate variety (**Fig. 22**). The ectoderm of the acrorhagi is abundantly supplied with nematocysts, whereby they can readily be distinguished from tentacles in section. In these latter the longitudinal musculature is not imbedded in the mesoglœa and resembles in appearance that of *C. elegantissima*, as does also the radiating musculature of the disk, though here the reticular arrangement of the mesoglœal processes cannot be distinguished as clearly as in that form.

The stomatodæum is longitudinally ridged and in the specimens examined was provided with two siphonoglyphes, which have the same structure as those of *C. elegantissima.*

The arrangement of the mesenteries is somewhat irregular. Apparently an hexamerous arrangement is the basis, the primaries, secondaries and tertiary cycles being perfect, the last to a less extent than the others. A fourth cycle is also present and is complete, but there are in addition representatives of a fifth and even of a sixth cycle irregularly distributed, a disturbance of the symmetry being thus produced.

Both the outer and inner stomata are present. The longitudinal musculature is well developed and in sections of the perfect mesenteries about half way down the column terminates at its outer edge in a strong process from which lateral lamellæ arise (**Fig. 23**). Lower down this arrangement is not apparent, the muscle processes diminishing in size toward each edge of the muscle area. The parieto-basilar (**Fig. 24**) is well developed, forming a marked fold. The basilar muscle (**Fig. 25**) is fairly well developed, resembling somewhat that of *C. artemisia*, though smaller in accordance with the smaller size of the specimens. The tertiary mesenteries are all fertile, and, in addition, reproductive organs occur on some of the mesenteries of the fourth cycle.

The identification of this species with Brandt's *Actinia xanthogrammica* is suggested in the memoranda accompanying Mr. Agassiz' drawing, and though Brandt makes no mention of the conspicuously pink-tipped tentacles yet it is quite possible, indeed probable, that this is the proper identification, as it is evident that the coloration of the species may vary considerably.

I was for a time inclined to identify it with Verrill's *Anthopleura Dowii*, but hesitate to do so on account of the geographical distribution of that form and the absence of data as to its internal structure. It is evidently a highly variable species, so far as its coloration is concerned, and it may be noted that a specimen from Acajutla is described as having the tips of the tentacles "dark red." For the present, however, it seems advisable to regard it as distinct from the present form, but I may point out that the form described by Fewkes from Santa Barbara as *Bunodes californica* is in all probability assignable to Verrill's species.

Genus Epiactis, Verrill.

This genus was established by Verrill in 1869 for the reception of a form from Puget Sound which was characterized by having the young adherent to the outer surface of the column. In 1899 Verrill published a brief description of the structural peculiarities of the type, referring it to the family Cribrinidæ (Bunodactidæ) on account of its possession of a circumscribed endodermal sphincter.

It seems doubtful whether the fact that the young adhere to the column wall is sufficient for the establishment of a distinct genus, but in other respects *E. prolifera* seems to be sufficiently distinct from other Cribrinids to warrant the retention of the genus. It is one of the smooth-walled genera and differs from Leiotealia (Hertwig, '82) in the form of the sphincter and of the muscle pennon, while from Isotealia (Carlgren, '99) it is distinguished by the absence of pseudoacrorhagi.[1]

6. *Epiactis prolifera*, Verrill.

Synonyms.—Epiactis prolifera, Verrill, 1869[a].
Epiactis fertilis, Andres, 1883.

The specimens in the collection were found growing upon the weeds and water grasses at Hadlock Harbor, Puget Sound.

External Form (**Fig. 25**).—The base is adherent. The column is marked by longitudinal grooves and more distinctly with transverse grooves and wrinkles, probably due to contraction,

[1] I am inclined to agree with Carlgren ('99) that the form I described ('93) as *Leiotealia badia* is identical with his *Isotealia antarctica*. In looking over my preparations I notice that in some of the sections the sphincter is decidedly nearer the margin than it is in others, though in all it is the same distance above the floor of the fosse. This seems to indicate the existence of the pseudoacrorhagi which Carlgren describes. But, since my preparations were made from a small portion of a single highly contracted individual, it seems preferable to await a reëxamination of the type, now in the U. S. National Museum, before deciding the question.

but otherwise it is smooth and is unprovided with verrucæ or tubercles. In two of the specimens embryos were adherent to the surface, and appeared as small, oval, pale bodies, in one specimen arranged in a single incomplete and interrupted circle a short distance above the limbus, a few lying a short distance above this circle in one part of the circumference, while a single one was attached high up on the column wall not far from the margin (**Fig.** 28, *Em.*). In the second specimen but one embryo occurred, situated a short distance below the margin.

The margin is quite distinct, but smooth, except for wrinkles produced by contraction, and it is separated by a slight fosse from the bases of the outer tentacles. The tentacles are moderately long and acuminate and are distinctly entacmæous. I did not succeed in making a satisfactory enumeration of them, but they are fairly numerous and appear to be arranged in five or six cycles.

The disk in the only specimen in which it could be seen was of slight extent and concave. The peristome is prominent and the lips grooved. Two gonidial grooves were distinguishable.

Color.—According to Dr. Calkins' description the color is a "bright grass green or weed green" striped with darker green. Verrill apparently had no notes of the coloration of the specimens he studied, but among the drawings loaned me by Mr. Agassiz I find two which apparently represent this species. One is undoubtedly identical though it has no embryos adherent. The column is represented as bright grass green marked with longitudinal streaks of dark brown. The disk is very dark green with numerous radiating stripes of cream white and the tentacles are buff with a distinct dark greenish-brown spot at the base of each. This specimen was obtained at Crescent City. The other specimen is less certainly identical though having the same general external form. The column is dark brown streaked longitudinally with lighter brown and the tentacles are a dull grayish green. This specimen was obtained at San Rosario.

Size.—The living specimens measure from 1.2 to 2.5 cm. in diameter and the largest about 1.2 cm. in height. The preserved individuals measure 1 cm. on the average in height and about 1.2 cm. in diameter, the base being in all cases somewhat larger than the column. Verrill's measurements of preserved specimens are identical with those just given. The tentacles in the most expanded form I examined measured 1.3 cm. in length but in others they were only about half that length.

Structure.—The column mesoglœa is thin and of a fibrous structure and its inner surface bears a well-developed layer of simple muscle processes. The inner ends of the endoderm cells are heavily laden with dense, black pigment. At the margin the endodermal musculature becomes considerably lower and on the inner wall of the fosse there is situated the sphincter. In the first individual I examined this had the form shown in **Fig. 26** and was situated on the outer wall of the fosse, and from its general appearance I was led to regard it as being mesoglœal and so referred the species to the family Paractidæ. The publication of Verrill's description ('99) of the structure of the type and correspondence which I had with him on the subject induce me to examine the sphincter in other individuals and in these I found perfect agreement with what Verrill had described. The sphincter is of the circumscribed sessile form, situated upon the inner wall of the fosse, and has an almost circular form in cross-section; the mesoglœal lamellæ which compose it are rather fine and anastomose more or less in places. It was evident then that the first individual that I examined either had an abnormal sphincter or else belonged to a different species from the others. The latter possibility seems very improbable on account of the complete similarity in other respects and I conclude that the former one is correct. An extension of the area of attachment of the sphincter and a greater development of anastomoses of the lamellæ would readily convert the normal sphincter into the condition shown in **Fig. 26.**[1]

[1] This figure is, accordingly, of interest only as representing an abnormality. The plates were unfortunately in process of reproduction before I perceived the error into which I had fallen and it was not possible, therefore, to replace the figure by a represention of the normal sphincter.

I may add that Mr. H. B. Torrey has recently informed me that in all the specimens of *E. prolifera* which he has examined, the sphincter was of the circumscribed sessile type.

In **Fig. 27** is represented a section through a portion of the column wall bearing one of the embryos. It shows that the embryos are in an early stage of development, having just reached the stage at which the stomatodæum (*st*) is being invaginated. The ectoderm of the embryo (*e. ec*) forms a continuous sheet completely separated at every point from the ectoderm of the parent (*ec*) on which it rests, and it is evident that the embryos are not buds, but really egg-embryos which have become attached to the surface of the adult actinian and are held there by the mucus (*m*) secreted by the numerous ectodermal gland cells.

In the specimens which Verrill ('69) originally examined and which he has recently figured ('99) the attached embryos had reached a much more advanced stage of development than those just described, the smallest one having twelve tentacles and the largest twenty-four. Verrill seemed inclined, in his earlier paper, to regard the embryos as buds and states that they "probably derive nutriment from the parent." In his more recent account he evidently recedes somewhat from this position and I may point out that it seems clear from what I have stated above as to the distinct separation of the embryos from the parent that they are not nourished by the parent in the sense that there is any communication between the cavities of the parent and those of the embryos.

The tentacles are thin-walled and their ectodermal musculature is but feebly developed. The radial musculature of the disk is fairly strong in its peripheral portions, but more centrally it is very feeble ; it is throughout ectodermal.

In the region of the lips the mesoglœa becomes considerably thickened forming ridges corresponding to the ridges of the stomatodæum. Occasionally, though not always, the tip of one of the thickenings seems to be separated from its main portion by a slight interval, producing a minute tubercle immediately external to the lips. The stomatodæum is ridged and there are two siphonoglyphes, one of which is much deeper than the other.

The mesenteries are arranged in four cycles with occasional representatives of a fifth. Twelve pairs are perfect in the upper part of the body, but a little farther down, even above the middle of the body, only the six primary pairs reach the stomatodæum. There are two pairs of directives.

The longitudinal musculature of the mesenteries (**Fig. 28**) is fairly well developed, but possesses no special features of interest; it gradually tapers off towards both edges and occupies about half the muscular portion of the mesentery at the level of the middle of the stomatodæum. The parieto-basilar in its lower part does not form a special fold, but consists of a number of processes arising directly from the surface of the outer portions of the mesenteries, but above a slight fold is visible in some of the mesenteries as shown in **Fig. 28**. The basilar muscle has the appearance represented in **Fig. 29**. All the mesenteries, with the exception of those of the first and fifth cycles, are gonophoric.

UNIVERSITY OF MICHIGAN, February 22, 1901.

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PLATE I.

PLATE I.

Fig. 1. Transverse section of sphincter of a specimen of *Metridium dianthus* measuring 1.5 cm. in height (Leitz I, 3, camera).

2. Transverse section of sphincter of a specimen of *Metridium dianthus* measuring 8 cm. in height (Leitz I, 3, camera).

3. Transverse section of sphincter of a specimen of *Metridium dianthus* measuring 3 cm. in height (Leitz I, 3, camera).

4. Transverse section of a mesentery of the first cycle of *Metridium dianthus* (Zeiss a, Leitz I, camera).

5. Transverse section of a directive mesentery of *Metridium dianthus* (Leitz I, 3, camera).

6. Transverse section of sphincter of *Urticina crassicornis* Leitz I, Zeiss a, camera).

7. *Cribrina elegantissima*, from a preserved specimen. Natural size.

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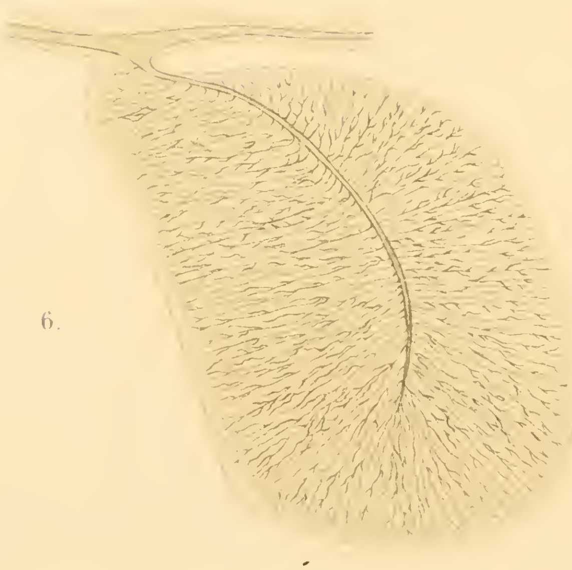

5.

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PLATE I.

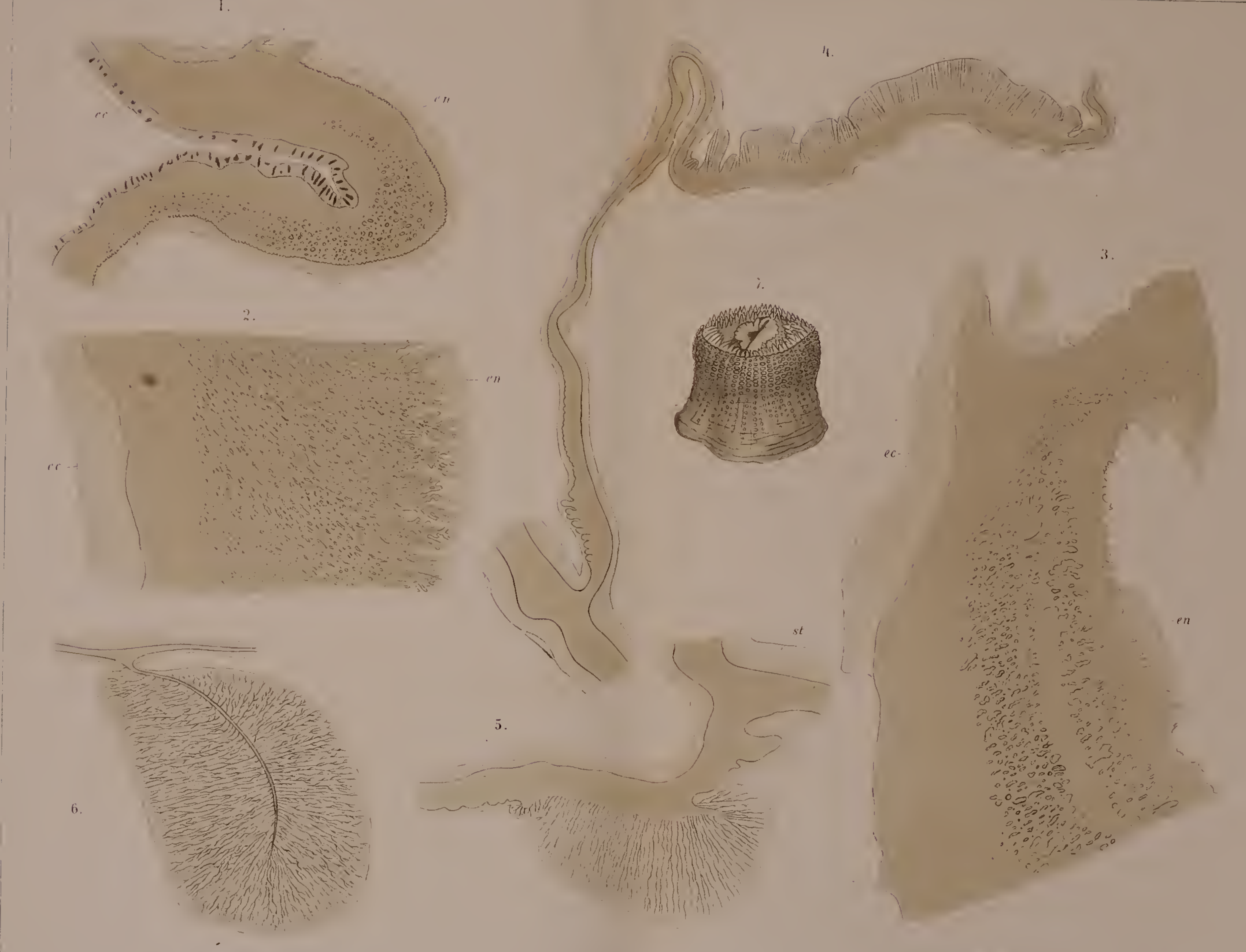

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PLATE II.

PLATE II.

Fig. 8. *Cribrina elegantissima* (drawn by Dr. G. N. Calkins).

9. Longitudinal section of upper part of the column wall of *Cribrina elegantissima*. *cm* = circular muscle at apex of verruca; *ec* = column ectoderm; *en* = column endoderm; *ve* = modified epithelium at the apex of the verruca (Leitz I, 3, camera).

10. Transverse section of sphincter of *Cribrina elegantissima* (Leitz I, 3, camera).

11. Tangential section of disk of *Cribrina elegantissima* (Leitz I, 3, camera).

12. Transverse section of tentacle of *Cribrina elegantissima* (Leitz I, 3, camera).

13. Transverse section of siphonoglyphe of *Cribrina elegantissima* (Zeiss a, Leitz I, camera).

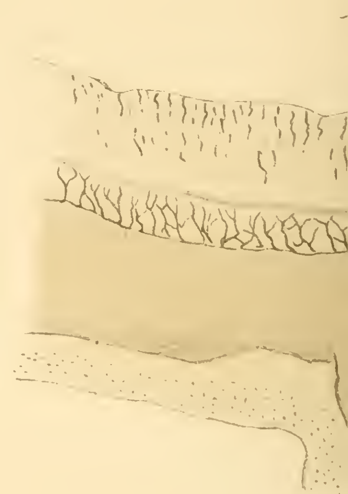
14. Transverse section of perfect mesentery of *Cribrina elegantissima* (Zeitz a, Leitz I, camera).

15. *Cribrina artemisia* from a preserved specimen. Natural size.

16. Transverse section of *Cribrina artemisia* (Zeiss a, Leitz I, camera).

17. *Anthopleura xanthogrammica* (drawn by Dr. G. N. Calkins.

8.



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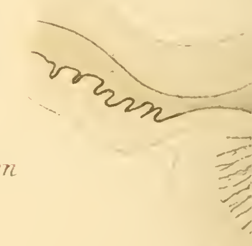

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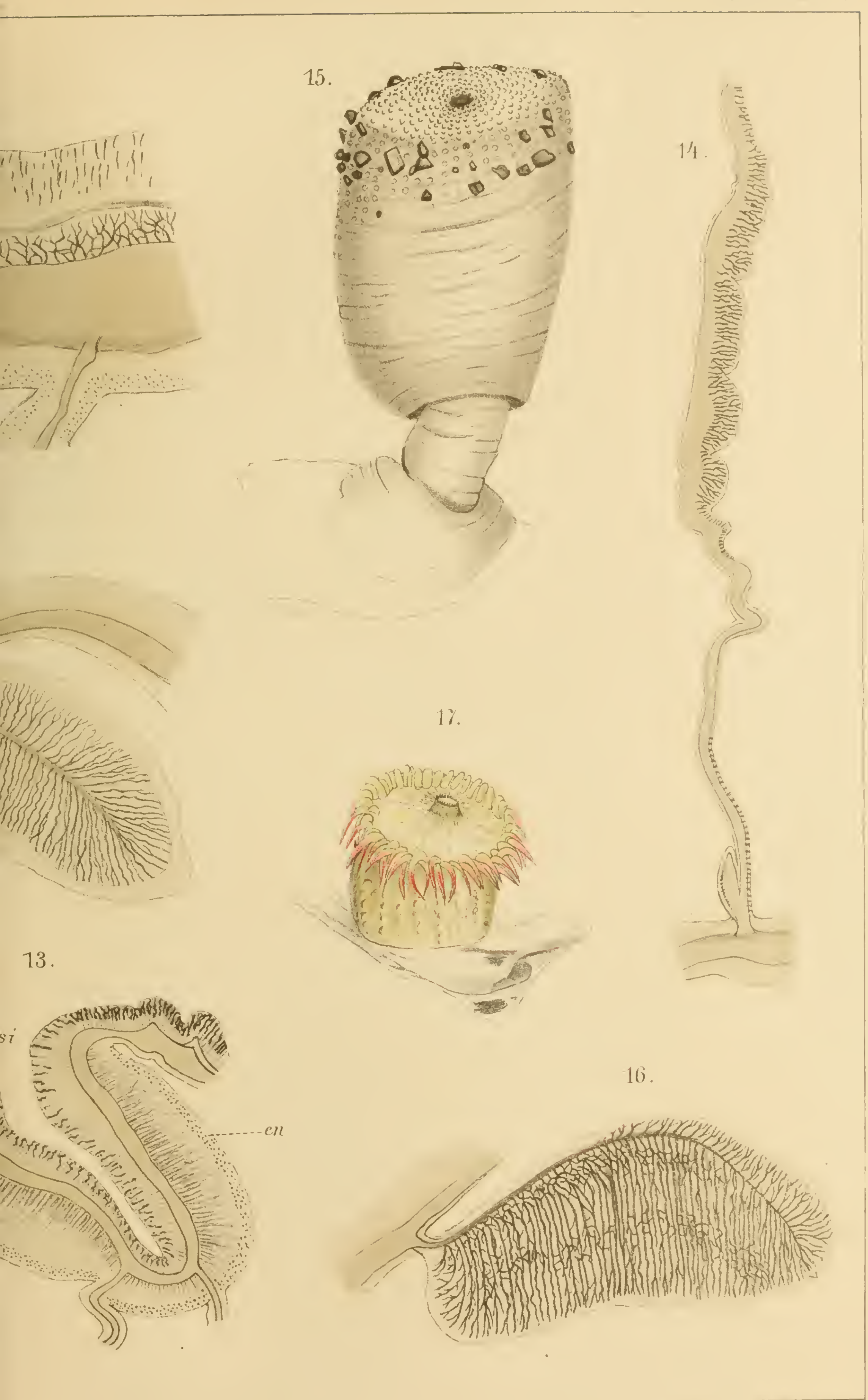
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PLATE III.

PLATE III.

18. Tangential section of disk of *Cribrina artemisia* (Leitz I, 3, camera).
19. Transverse section of perfect mesentery of *Cribrina artemisia* (Leitz I, 3, camera).
20. Transverse section of basilar muscle of *Cribrina artemisia* (Leitz I, 3, camera).
21. Portion of upper part of a perfect mesentery, with disk, margin, and upper part of column in section, of *Anthopleura xanthogrammica*; *ac* = acrorhagus; *sp* = sphincter; *t* = tentacle. (× 6.)
22. Transverse section of sphincter of *Anthopleura xanthogrammica* (Leitz I, 3, camera).
23. Transverse section of primary mesentery of *Anthopleura xanthogrammica* (Zeiss a, Leitz IV, camera).
24. Transverse section of basilar muscle of *Anthopleura xanthogrammica* (Leitz I, 3, camera).
25. *Epiactis prolifera* from a preserved specimen. *Em* = adherent embryo (nat. size).
26. Transverse section of sphincter of *Epiactis prolifera*. *L* = lower extremity of section; *U* = upper extremity. (Leitz I, 3, camera).
27. Transverse section of a portion of the column wall of *Epiactis prolifera*, with an adherent embryo. *Ec* = column ectoderm; *E.ec* = ectoderm of embryo; *E.en* = endoderm of embryo; *M* = mucus; *St* = stomatodæal invagination. (Leitz I, 3, camera).
28. Transverse section of perfect mesentery of *Epiactis prolifera*. (Zeiss a, Leitz II, camera).
29. Transverse section of basilar muscle of *Epiactis prolifera* (Leitz I, 3, camera).

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J. P. Mc M. DEL.


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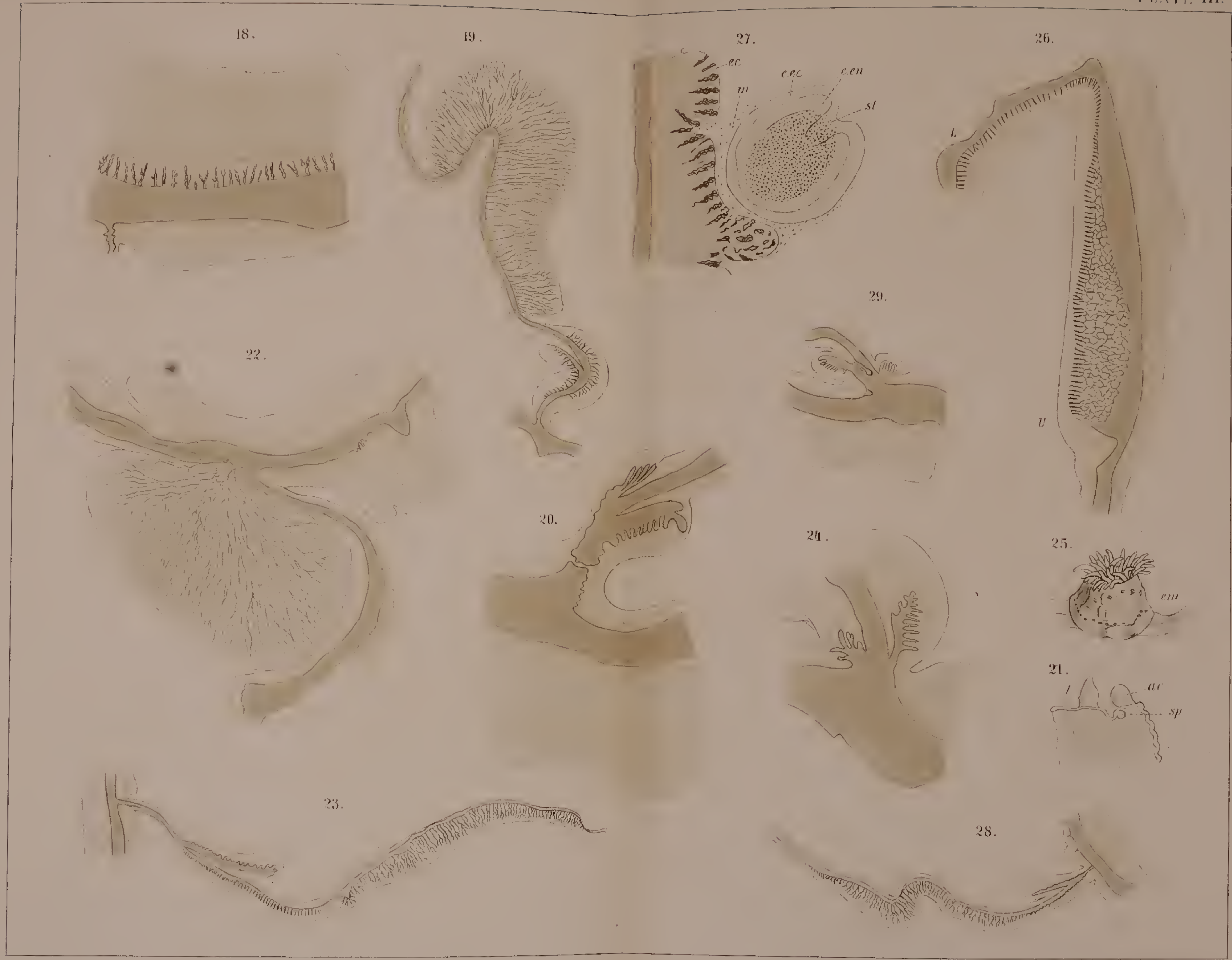


J. P. M^c M. DEL.

[ANNALS N. Y. ACAD. SCI., Vol. XIV, No. 2, pp. 53-66, June 5, 1901.]

THE MORPHOLOGICAL SIGNIFICANCE OF CERTAIN PERICLAVICULAR SUPERNUMERARY MUSCLES

WITH A REPORT OF A NEW M. SUPRACLAVICULARIS PROPRIUS POSTERIOR

GEO. S. HUNTINGTON

[Plates IV–V.]

(Read February 12, 1900)

Among the muscular variations of the human pectoral girdle the group of periclavicular supernumerary muscles possesses a peculiar morphological interest, by reason of the complex myological character of the region involved and the importance of correctly interpreting the significance of the variant conditions.

The abnormal muscle, of which this paper treats, is now described and figured for the first time as the *M. supraclavicularis proprius posterior.* It was found as a nearly symmetrical bilateral muscular slip in a male subject, of German birth, 43 years of age, arising by a slender tendon from the upper surface of the sternal extremity of the clavicle, under cover of the sterno-cleido-mastoid and extending laterad across the supraclavicular fossa to be inserted behind the clavicular attachment of the trapezius into the superior surface of the acromial end of the clavicle by a narrow tendon which on the left side can be followed nearly to the extremity of the bone.

SUPERNUMERARY CLAVICULAR MUSCLES

The nearest approach to the conditions presented by this variant muscle—*as regards the attachment by both extremities to the clavicle*—is afforded by a group of supernumerary clavicular muscles, of which five instances have been recorded, possessing the following common characters: Origin from the sternal extremity of the clavicle, *ventrad* to the clavicular attachment of the sterno-cleido-mastoid. The muscle, fleshy in the middle and tendinous at either end, passes laterad, above the clavicle, inserting at the acromial end of the bone, between the trapezius and the deltoid.

WENZEL GRUBER described the first of these instances under the name of *M. supra-clavicularis proprius, s. præclavicularis subcutaneus*, in 1865, in Reichert's Archiv, p. 703. The same author subsequently in 1877 observed a second instance of the variation which is recorded in Virchow's Archiv, Vol. LXXII, p. 496. BARDELEBEN has recorded an example of the muscle in the "Sitzungsberichte d. Jenaischen Gesellschaft für Med. und Naturwiss.," March, 1877.

KNOTT (Jour. Anat. and Phys., Vol. XV, p. 139) observed the fourth case, which he reports as *M. supraclavicularis proprius, vel. Tensor fasciæ colli* (Gruber). The muscle in this instance had a medial attachment in front of the clavicular head of the sterno-cleido-mastoid, about 1¾″ outside the sterno-clavicular articulation, while the lateral extremity, at a distance of about 2″ from the acromial end of the bone, had a somewhat broader attachment in front of the trapezius. The muscle was enclosed in a sheath formed by the deep cervical fascia, a condition also noted in Gruber's cases, whence this author defines the muscle as a "Tensor of the cervical fascia."

DUBAR (Soc. Anat. Paris, 1880) described a "muscle ansiform sus-claviculaire" which presented the same connection with the clavicle at both ends and was enclosed in a sheath derived from the cervical fascia.

While the clavicular attachments of these five muscles agree with those of the variation above described, their position *ventrad* of sterno-cleido-mastoid and trapezius differentiates them sharply from the muscle here under consideration whose course is dorsad to both. I consider this *superficial* position of the *supraclavicularis proprius* of Gruber and of the other authors quoted, as determining the definite relationship of the five variations recorded to the other members of the *præclavicular* group of supernumerary muscles. In spite of the similarity of attachment to both extremities of the clavicle the muscle described in this paper belongs to the *retro-clavicular group* and possesses hence an entirely different morphological significance. The following instances have been observed of supraclavicular muscles situated behind the sterno-cleido-mastoid and trapezius.

M. J. WEBER (Vollständiges Handbuch der Anatomie des Menschlichen Körpers (Zergliederungs-Kunde und Kunst), I Bd., Bonn, 1839, p. 560) says:

"I have observed once a variation, remarkable on account of the analogy of the clavicles and ribs, and of the subclavius with the intercostals, in which from the posterior surface of the manubrium sterni to the post. surfaces of the sternal ends of both clavicles a fairly strong semicircular flat muscle passed which could depress the clavicles down and in."

LAWSON TAIT (Journ. of Anat. and Phys., p. 237) described a muscle arising by two heads, one from the posterior surface of the manubrium sterni at its junction with the cartilage of the first rib, the other from the posterior edge of the first rib itself. It lay on the brachiocephalic trunk, on the lower thyroid veins and the scalenus anticus, and was inserted into the clavicle, along the posterior border of the bone, at the inner margin of the insertion of the trapezius.

KNOTT is quoted as having observed a muscle identical in all respects with that described by TAIT.

These two instances of WEBER and TAIT are quoted by most authors treating of the periclavicular supernumerary muscles under the name of *M. retroclavicularis* or *sternoclavicularis posterior*. MACALISTER ("Additional Observations on Muscular Anomalies in Human Anatomy (Third series), with a catalogue of the principal muscular variations hitherto published," Trans. Royal Irish Acad., Vol. XXV, Pt. I, Dublin, 1872, p. 51) quotes Weber's and Tait's cases as instances of the "M. retroclavicularis" and adds concerning the latter's case: "This is much rarer than the foregoing (M. supraclavicularis of Luschka and Haller, cf. infra), and is probably only a form of the M. supraclavicularis given above."

Both TESTUT ("Les anomalies musculaires chez l'homme," Paris, 1884, p. 55) and LE DOUBLE ("Traité des variations du système musculaire de l'homme," Tome I, Paris, 1897, p. 266) quote Weber's and Tait's cases—under the name of "*M. retro-clavicularis*" or "*Sterno-clavicularis posterior*"—without adding any new instances of the variation.

In the interests of a consistent terminology it would appear advisable to describe Weber's case as a "*M. sterno-clavicularis posterior*," Tait's instance as "*M. chondro-sterno-clavicularis posterior*," the five cases of superficial muscles above quoted as examples of the "*M. supra-clavicularis proprius anterior*" and the muscles here described as "*M. supra-clavicularis proprius posterior*."

MORPHOLOGICAL SIGNIFICANCE

To establish the morphological significance of the muscle in question, the following facts deserve consideration: GRUBER ("Die Supernumerären Brustmuskeln des Menschen," Mém. de l'Acad. Imp. des Sciences des St. Pétersbourg, VII Serie, Tome III, No. 2, 1860, pp. 3 and 6) describes a "*M. sterno-clavicularis superior, seu supraclavicularis*," as arising from the manubrium sterni above and behind the origin of the sternal head of the sterno-cleido-mastoid, from the margin of the clavicular incisure and in some cases also from the margin of the semilunar incisure. The muscle passes upward and outward, over the sterno-clavicular capsule, behind the clavicular head of the sterno-cleido-mastoid, to be inserted into the posterior surface of the clavicle between "the beginning of the second and third fifth of the bone." GRUBER found this muscle five times in 100 subjects, four adult males and one boy. Twice it was bilateral, twice present only on one side (right) and in one case only on the left side. He figures an instance of the variation (loc. cit., Taf. I, fig. 4).

A number of other anatomists have observed and described the muscle, beginning with HALLER, in 1766 ("Elem. physiol.," Tome III, p. 46, Lausanne, 1766). LUSCHKA ("Ein M. Supra-clavicularis beim Menschen," Müller's Archiv, 1856, p.

282) describes and figures a supra-clavicular muscle as arising from the middle of the posterior surface of the clavicle and passing over the sternal end of the bone to be inserted into the manubrium sterni just below the inter-clavicular ligament. Luschka suggests a relation between this muscle and the ossa suprasternalia.

He found the muscle three times in male subjects, once bilateral, twice only on one side. Later (quoted from Gruber, loc. cit., p. 4) Luschka encountered four additional instances of the muscle.

Hyrtl ("Zwei Varianten des M. Sterno-clavicularis," Sitzber. d. Math. naturw. cl. d. Kais. Akad. der Wiss., Bd. XXIX, Wien, 1858, p. 265) describes Luschka's supra-clavicularis as "M. sterno-clavicularis" in six subjects out of 83, 5 men and 1 woman. In four of these (3 bilateral, 1 on left side) the muscle corresponded to Luschka's description. The two remaining cases Hyrtl regards as variations of the same muscle. The first variation (subject æt. 30) consisted of a tendinous bundle, arising from the manubrium sterni at the level of its junction with the body, which ascended to the jugular notch and divided into two diverging transverse bundles, which, becoming muscular, passed over the sterno-clavicular joint, behind the clavicular head of the sterno-cleido-mastoid, to the clavicle. The second variation appeared as an *inter-clavicular* muscle, a flat transverse band uniting the sternal extremities of both clavicles lying upon the inter-clavicular ligament above the upper margin of the manubrium. The muscle was attached to the sterno-clavicular capsule between the inter-clavicular and sterno-clavicular ligaments and to the intra-articular cartilage of the joint. Hyrtl regards this variation as derived from the first by suppression of the median tendon of origin from the manubrium and by arched fusion of the two muscular bellies thus detached across the median line.

Other instances of the *M. supraclavicularis* or *sternoclavicularis superior* are recorded by Retzius ("Hygeia," 1856, Bd. 18, p. 649), Hellema (Geneeskundig Tijdschieft, 5 Jahrg., I Afd.) and Macalister (loc. cit., p. 50). I have observed 13 examples of the muscle.

If the muscle forming the subject of this communication is compared with the typical *supraclavicularis* or *sternoclavicularis superior* it will appear that the lateral attachment and the relation to the clavicular head of the sterno-cleido-mastoid of both agree. In our *M. supraclavicularis proprius posterior* the lateral extremity of the muscle is attached to the posterior surface of the clavicle, and it attains this position by passing dorsad of the clavicular head of the sterno-cleido-mastoid. The same arrangement obtains in those instances of the typical *sternoclavicularis* in which the muscle extends further laterad than is usually the case (Retzius' example, outer third of clavicle), although in the majority of recorded cases the typical *sternoclavicular* muscle is short, not extending beyond the inner third of the clavicle. That the lateral end of the muscle here under consideration extended beyond and behind the trapezius to the acromial end of the clavicle is therefore unusual when compared with the typical arrangement of the *sternoclavicularis*, but it brings the entire group, to which both muscles belong, into harmony with other muscular variations which serve to satisfactorily explain the significance of the aberrant condition.

The mesal extremity of the muscle herein described differs at first sight radically from the typical *sternoclavicularis.* The mesal tendon is attached behind the sterno-cleido-mastoid to the posterior and upper border of the sternal extremity of the clavicle, but entirely confined to that bone, not extending to the sterno-clavicular capsule or to the manubrium. In contrast to this arrangement the mesal tendon in the great majority of the typical *sternoclaviculares* occupies a more ventral position, being attached above and in front of the sterno-clavicular articulation to the manubrium.

If, however, this typical arrangement of the mesal tendon of the usual *sternoclavicularis* is compared with the variations reported by Hyrtl, and with the cases described by Weber and Tait, it will be seen that a series, depending upon regression of the sternal extremity of the common form of the variant muscle, can be established, leading from the usual type, through three stages, to the conditions found in our *M. supraclavicularis proprius posterior.* In Hyrtl's first recorded case the beginning loss of the sternal attachment is signalized by the single median tendon which connects the two muscles with the manubrium. In his second variation the muscles have largely given up the manubrial attachment and have fused into an inter-clavicular muscle. Separation of the inter-clavicular muscle in the median line into its original components, and further regression of each laterad would lead to the arrangement described in Weber's case, while Tait's case only differs in having an additional attachment to the posterior margin at the first rib, which is likely to be acquired in the course of migration. Lastly, in our instance, the mesal extremity of the muscle has lost all connection with the sternum, the episternal (inter-clavicular) structures and the sterno-clavicular articulation and has acquired a purely clavicular attachment. We may, therefore, be justified in regarding the typical sterno-clavicularis as the antecedent of the mesal extremity of the three supra- or retro-clavicular muscles heretofore recorded, the condition presented by our case being the final stage in a progressive migration of the mesal tendon of the muscle from the sternum successively to the inter-clavicular ligament, the capsule of the sterno-clavicular articulation and finally to the posterior surface of the clavicle.

Turning to the lateral termination of the muscle under consideration and examining cognate variations in order to determine its significance, we have to consider in the first place, a group of aberrant muscles extending between the upper border of the scapula and the clavicle.

The *M. scapulo-clavicularis*, or *coraco-clavicularis* has in several instances been observed to extend as a muscular slip between the superior border of the scapula, or the transverse ligament, or base of coracoid process, and the posterior border or inferior surface of the clavicle, passing behind the clavicular attachments of the trapezius and sterno-mastoid.

Moreover, a human muscular .variation, described by Wood, Gruber, Hellema, Curnow, Reid and Taylor, Shepherd, and

Brown, the *M. sterno-chondro-scapularis*, corresponding to a muscle normally encountered in many mammalia, is found not very uncommonly, extending between manubrium of the sternum, or the first rib or its cartilage and the upper border of the scapula, usually near the suprascapular notch or the base of the coracoid process. This aberrant muscle passes behind the normal subclavius, when that muscle is present, while in other cases the typical subclavius is absent and is replaced by the abnormal muscle.

Considering the relationship of the subclavius insertion to the coraco-clavicular ligaments and to the coracoid process of the scapula it is not a very farfetched view to regard the normal human subclavius muscle as a derivative from the mammalian sterno-chondro-scapular sheet, which has lost its scapular attachment, and receded to the inferior surface of the clavicle, while its original distal portion, metamorphosed into fibrous tissue, remains as the coraco-clavicular ligaments.

Again the whole group of retro-clavicular supernumerary muscles are properly to be referred to the same mammalian sterno-chondro-scapular muscular sheet of which they represent myotypical reversions in the sense defined by me on a previous occasion. I think that Testut (loc. cit., p. 55), in quoting the only two previously recorded cases of retro-clavicular supernumerary muscles (Weber's and Tait's), strikes the correct keynote of their morphological significance, when he says, regarding Tait's case: "If this muscle had had a few centimeters greater length it would have become attached to the upper border of the scapula, and we would have changed its name and place in the classification; it would have been a sterno-chondro-scapularis."

REPORTED INSTANCES OF UNION OF THE STERNO–CLEIDO–MASTOID AND TRAPEZIUS

In conclusion it may be well to consider that some reported instances of more or less complete union of the sterno-cleido-mastoid and trapezius may find their explanation in the persistence of portions of this same muscular plane and their secondary fusion with the muscles named near their clavicular attachment.

Thus QUAIN ("Anat. of the Arteries," p. 186) describes a muscular fasciculus which detaches itself from the anterior border of the trapezius and joins the sterno-cleido-mastoid, passing above the subclavian artery. Testut quotes this instance as representing a first stage in the fusion of the two muscles.

DAVIES-COLLEY encountered in several cases a distinct muscular fasciculus which left the anterior border of the trapezius, crossed the subclavian triangle diagonally and inserted into the clavicle underneath the sterno-cleido-mastoid. In some instances the descending branches of the superficial cervical plexus were placed behind this fasciculus.

In the case of the muscle here reported the supra-clavicular nerves descended to the thorax between the clavicle and the abnormal muscle. The connection of the two extremities of the muscle with the deep surface of the clavicular head of the sterno-cleido-mastoid and the trapezius was very intimate. A firm fibrous fusion of its sheath with the fascia of these muscles made a complete exposure from behind and careful dissection necessary in order to demonstrate the independence of the muscular fibres and their true insertion into the clavicle. When first encountered *in situ* from in front the case was reported as a muscular band joining the anterior edge of the trapezius to the deep surface of the clavicular head of the sterno-cleido-mastoid. It is conceivable that further reduction of the intermediate portion of the typical sterno-chondro-scapularis, with loss of the secondary clavicular attachment seen in our case of *supraclavicularis proprius posterior* might leave a muscular fasciculus apparently extending between the deep surfaces of trapezius and sterno-cleido-mastoid, and thus give rise to the reports of partial fusion of these muscles.

PLATE IV.

PLATE IV.

With the case here recorded it is possible to present the entire group of retro-clavicular supernumerary muscles in their mutual relationship and in their common reference to the potential parent muscular system of the mammalian sterno-chondro-scapularis. Schematically this can be done as indicated in the plate IV.

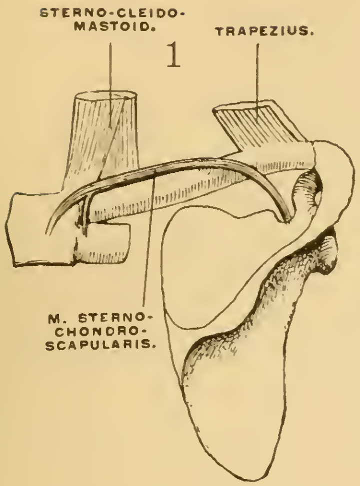
Fig. 1 represents the typical mammalian sterno-chondro-scapularis, encountered as already stated in the human subject, as an occasional variation.

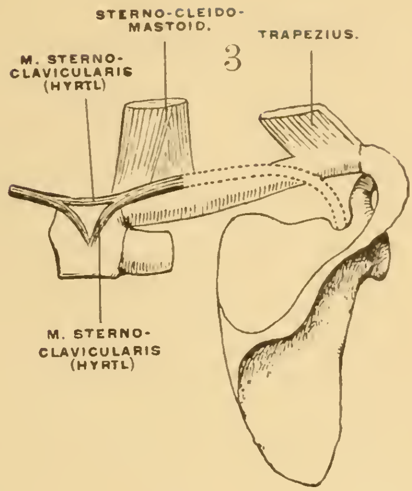
Fig. 2 corresponds to the retro clavicular muscle as described by Weber and Tait; the "*M. sterno-chondro-clavicularis posterior*" results from the sterno-chondro-scapularis by loss of the scapular attachment and transference of the distal insertion to the clavicle.

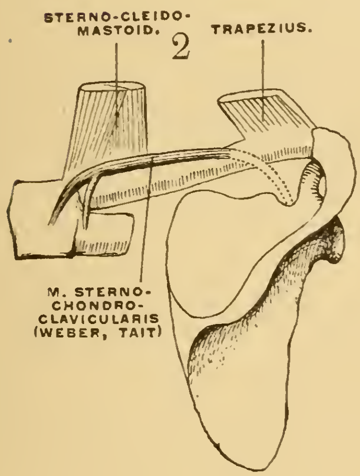
Fig. 3 may be taken as illustrating Hyrtl's variations of the usual M. sterno-clavicularis in which the sternal attachment of the slip is beginning to show a tendency to migration laterad towards the clavicle.

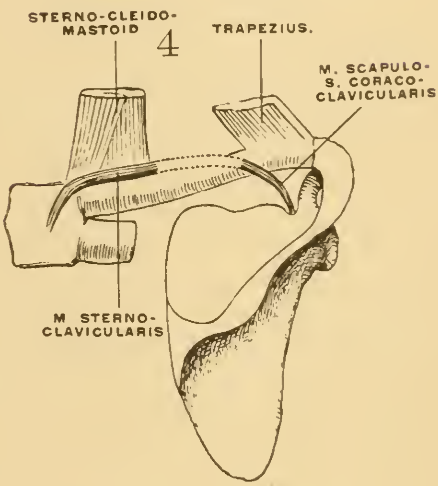
Fig. 4 shows a theoretical combination between the sterno-clavicularis posterior and the occasional scapulo-clavicularis or coraco-clavicularis. These two muscular slips would appear respectively as the proximal and distal segments of a typical sterno-chondro-scapularis whose intermediate portion had disappeared.

In Fig. 5 is shown the reverse condition, illustrated by the case reported in this paper. In place of the disappearance of the intermediate segment of the sterno-chondro-scapularis, which produced in Fig. 4 two muscles, a sterno-clavicularis and a scapulo-clavicularis, we have in our instance the converse of this. The central part of the typical sterno-chondro-scapularis persists, while the loss of the proximal sternal and distal scapular attachment leaves us with a retro-clavicular muscle, fixed at both extremities to the clavicle, and hence properly designated as the "supraclavicularis proprius posterior." This muscle, as well as the remaining members of the retro-clavicular groups are, therefore, to be regarded as myotypical reversions, in the sense that they represent the occasional development of portions of a common ancestral mammalian muscular plane, which in many living forms finds its expression in the sterno-chondro-scapularis.


STERNO-CLEIDO-
MASTOID.
TRAPEZIUS.
1
M. STERNO-
CHONDRO-
SCAPULARIS.


STERNO-CLEIDO-
MASTOID.
TRAPEZIUS.
3
M. STERNO-
CLAVICULARIS
(HYRTL)
M. STERNO-
CLAVICULARIS
(HYRTL)


STERNO-CLEIDO-
MASTOID.
TRAPEZIUS.
2
M. STERNO-
CHONDRO-
CLAVICULARIS
(WEBER, TAIT)


STERNO-CLEIDO-
MASTOID
TRAPEZIUS.
4
M. SCAPULO-
S. CORACO-
CLAVICULARIS
M STERNO-
CLAVICULARIS

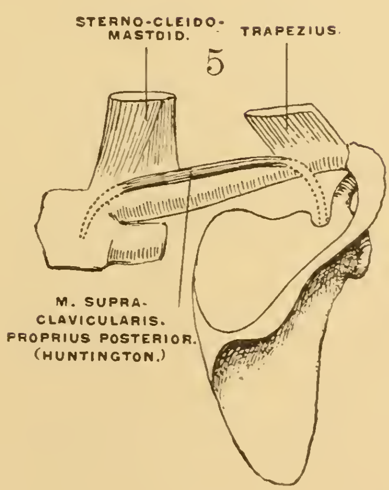
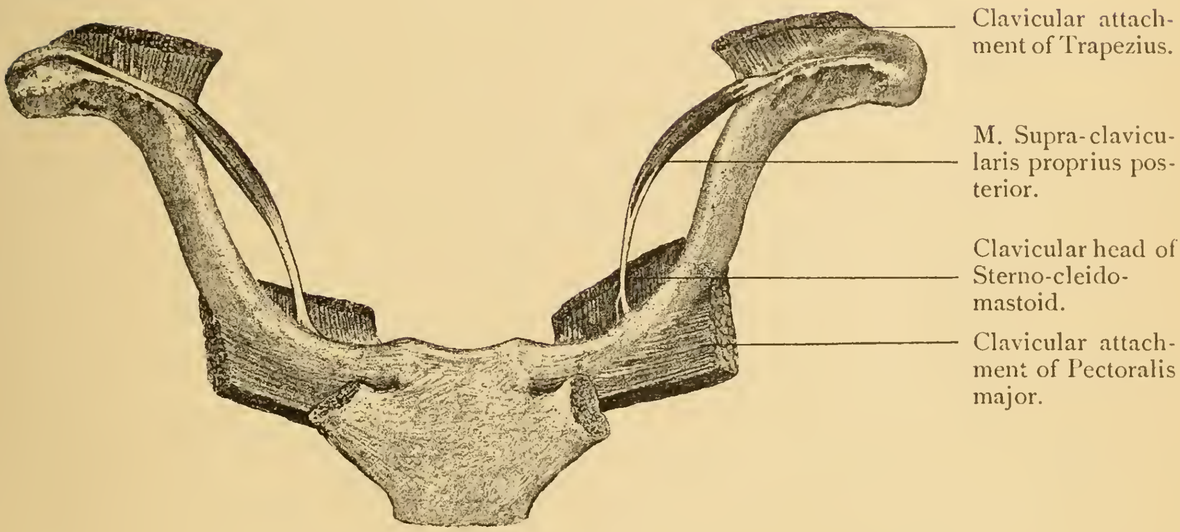

STERNO-CLEIDO-
MASTOID.
TRAPEZIUS.
5
M. SUPRA-
CLAVICULARIS.
PROPRIUS POSTERIOR.
(HUNTINGTON.)

PLATE V.

Annals N. Y. Acad. Sci., XIV, July 6, 1901—5


Clavicular attachment of Trapezius.
M. Supra-clavicularis proprius posterior.
Clavicular head of Sterno-cleido-mastoid.
Clavicular attachment of Pectoralis major.

[Annals N. Y. Acad. Sci., Vol. XIV, No. 3, pp. 67-68, July 6, 1901.]

DISCOVERY OF A MASTODON'S TOOTH AND THE REMAINS OF A BOREAL VEGETATION IN A SWAMP ON STATEN ISLAND, N. Y.

By Arthur Hollick

(Read Nov. 13, 1899)

In the Moravian Cemetery at New Dorp, Staten Island, was a swamp, which, until the past summer, was rather a conspicuous feature, by reason of its quaking margin of peat and sedges, with a pool of dark coffee-colored water towards the center. It occupied a depression in the moraine, at a distance of about 1,200 feet from the margin and at an elevation of about 120 feet above tidewater. The superficial area of the swamp was about 3,500 square feet and the pool of water would fill up and overflow in time of rains and become almost or completely dry in periods of drought.

In the recent development of the cemetery it was decided to drain off the water, dig out the mud, and allow the depression to fill up again as a pond. It was during the progress of this work that the discoveries here recorded were made.

The surface deposit was found to consist of a fine moss peat and a coarse peat composed of all kinds of swamp vegetation, extending out to the margin of the pool, while below this and forming the bottom of the pool was a black organic mud, such as may be seen in almost any swamp where decaying vegetation has accumulated. Below this the deposit was a fine sandy silt, distinctly stratified, the layers following the general contour of the depression, thicker towards the middle and thinning out at the edges. The general shape of the depression is roughly pyramidal, with steeper sides on the north and east than on the south and west. The deepest part is in the northeast angle, where the entire deposit was about 25 feet in thickness. All this deposit has been taken out and the sides and bottom of the depression are now exposed to view.

The first thing which attracted my attention was a number of logs and branches in the upper part of the silt, beginning at a depth of about 5 feet from the surface. There was nothing in connection with these to indicate that they were anything more than the remains of a comparatively recent forest growth. Below this, however, at a depth of about 8 feet, were a number of layers, aggregating about 2 feet in thickness, containing a large number of small cones and twigs. There are no coniferous trees now growing in the vicinity and no record of any in recent years so that these were manifestly the remains of a forest growth which antedated the one now growing there and a subsequent careful examination and comparison of the cones showed them to belong to the white spruce (*Picea Canadensis* (Mill) B.S.P.)—a tree of northern range, which does not now extend farther south than northern New England and the Adirondacks—and this fact naturally led to the conclusion that at least the lower portion of the deposit was of Quaternary age.

On inquiry of the superintendent of the cemetery, Mr. N. J. Ostrander, information was subsequently obtained to the effect that "some bones" had been dug out by one of the workmen, at a depth of about 23 feet, and these were very kindly turned over to me. They proved to be the broken pieces of a mastodon's molar and the Quaternary age of the deposit was established beyond question and inasmuch as it was in a morainal basin it must all have been post-morainal in age.

The indications are that a pond was formed in the depression immediately after the recession of the ice sheet and that this pond was a receptacle for silt, dust and decayed vegetation ever since; the accumulations finally filling it up and converting it into a swamp, with a little pool of casual water remaining in the middle.

Incidentally it may also be worth recording, that a considerable amount of charcoal and charred wood was found in connection with the cones, near the northeastern side, which fact might indicate the presence of man at the time this portion of the deposit was laid down.

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OBSERVATION AND EXPERIMENT[1]

BY R. S. WOODWARD

The near coincidence of this anniversary meeting of the Academy with the end of the nineteenth and with the beginning of the twentieth century imposes peculiar and quite unexpected restrictions in the way of freedom of choice of a fitting subject for an address. Naturally one would like to pass in review some of the brilliant achievements of science in the past century, and perhaps forecast the still more brilliant advances that may be expected to mature in the present century. Especially one might feel tempted to present a semi-popular inventory of the more striking or recondite scientific events with which he is particularly familiar. But all this and more, strange as it may seem, has been done, or is being done, by the public press. Specialists in almost every branch of science have been employed to expound and to summarize the discoveries, the theories, and the useful applications which have rendered science, by common consent, the most important factor in the civilization of the nineteenth century. Statesmen, philosophers and divines are likewise sounding the praises of science and the scientific method with a warmth of recognition and with a stamp of approval which tend to make one who is old enough to have lived in the pre-scientific, as well as in the present epoch, feel as if a millennium were close at hand. Indeed, such a wealth of good scientific literature is just now thrust before us and such a wealth of praise is just now bestowed on scientific achievement that the modest man of science must hesitate before adding a word to that literature or a qualification to that praise.

[1] Address of the President of the New York Academy of Sciences, read before the Academy on February 25, 1901.

The requirements of official position are remorseless, however, and one must speak his thought although silence with respect to science may appear to be the most urgent need of the hour. In view of these circumstances, it seems best to avoid topics of current interest and to invite your attention to a brief consideration of the elements which lie at the basis of scientific investigation and scientific progress. A recurrence to the slow and painful beginnings of knowledge and the first principles evolved therefrom is always instructive; and it is especially fitting at a time, like the present, when the ardor of research is somewhat in danger of the sedative influences which spring from the popular glorification of triumphant successes.

The fundamental data from which all scientific knowledge grows are furnished by observation and experiment. After these come the higher steps of comparison, hypothesis, and finally the correlation and unification of phenomena under theory. Even pure mathematics, though long held apart from the other sciences, must be founded, I think, in the last analysis, on observation and experiment.

Of the infinite variety of phenomena, which appeal to our senses, some, like those of sidereal astronomy, are subject, in the main, to observation only; while others, like those of terrestrial physics, chemistry, and biology, are subject to both observation and experiment. All phenomena are more or less entangled. They point backward and forward in time; any one of them appears and disappears only in connection with others; and the record any one of them leaves is known only by its interaction with others. Out of this plexus of relations and interrelations it is the business of science to discover the conditions of occurrence and the laws of the continuity. Happily for man, although the ultimate complexity of phenomena is everywhere very great, it is frequently possible to discern those conditions and occasionally possible to trace out those laws. But the results we reach are essentially first approximations, depending, in general, on the extent to which we may ignore other phenomena than those specially considered. In fact, a first step towards the solution of a problem in science consists in determining how much of the universe may be safely left out of account. Thus the method of approximating to a knowledge of the laws of nature is somewhat like the method of infinite series so much used by mathematicians in numerical calculations; and as it is a condition of success in the use of such series that they be convergent rather than divergent, so is it an essential of scientific sanity that the mind be restricted by observed facts rather than diverted by pleasing fancies.

The prime characteristic of the kind of knowledge that leads up to science is its dependence on facts which are permanent and hence verifiable. In the course of the progress of our race there have been certain luminous epochs during which observers and experimentalists have revealed more or less of such knowledge. These epochs have been followed, generally, by others of camparative dullness, or positive darkness, during which fact has been replaced by fancy and what is permanent and verifiable has been eclipsed by what is ephemeral and illusory. It is my purpose to-night to recall some of the principal events of these epochs, and to enforce, as well as I may, the great lesson they seem to teach us, namely, that science can be maintained only, and can be advanced only, by a constant appeal to observation and experiment.

As we look out on the universe about us the most striking phenomena visible are those which belong to what Galileo and his successors have fitly called "the system of the world." The rising and setting of the sun and moon; the majestic procession of the seasons; the splendid array of the stars in the heavens; the ebb and flow of the sea; and the never-ending variety from wind and weather, need only to be mentioned to enable us to understand why astronomy is at once the oldest and one of the most highly developed of the sciences. No classes of phenomena are so obvious, so omnipresent, and so enduring. They have furnished the symbols of continuity and permanence for all languages in all historic times. The "fixed stars," for example, are in fact, as well as in fiction, our standards of reference in the reckoning of time and space; for are not "Sirius and Orion and the Pleiades," as Carlyle has remarked, "still shining young and clear in their courses as when the shepherds first noted them on the plains of Shinar"?

But before astronomy there were mythology and astrology, and we may well marvel how it has been possible, even after the lapse of twenty odd centuries, to educe the orderly precision of science out of the complicated miscellany of fiction, fact, religion, and politics bequeathed to our era by the fertile imaginations of our distinguished ancestors. What, for example, could be more confusing than the paleontological jungle called the stellar constellations, with its gods and goddesses; with its dogs, lions, bears and fish, great and small, northern and southern; with its horse, whale, and goat; and with the slimy forms of serpents intertwining them all?

Although it is impossible to set any date for the emergence of astronomy out of mythology and astrology, the epoch of Hipparchus undoubtedly is the earliest one of conspicuous advances known to us. This epoch, which may be called also the epoch of the Alexandrian school of science, extends from about 300 B.C. to about 150 A.D. It is distinguished by the remarkably perfect work in pure geometry of Euclid and Apollonius, and by the still more noteworthy work of Archimedes in laying the foundations of statics and hydrostatics; it comprises the measurements according to correct principles of the obliquity of the ecliptic and the dimensions of the earth by Eratosthenes; it includes the observations of the sun, moon, stars and planets collected by Aristyllus and Timocharis and later turned to so good account by Hipparchus; it embraces the work of Aristarchus, who maintained the heliocentric theory of the solar system and who was the first to attempt a measure of the dimensions of that system by means of the fine fact of observation that the earth, sun and moon form a right triangle with the right angle at the moon when the latter is in dichotomy—or when its face is just half illuminated; and finally it includes the work of Ptolemy, a worthy disciple of Hipparchus, whose Almagest has come down to our own time.

From the observational point of view we must rank the principles with respect to fluids at rest discovered by Archimedes as amongst the capital contributions to the science of all times; for while his successors, of the last two centuries especially, have added to hydromechanics the large and vastly more difficult branch of hydrokinetics, they have found no change essential in his laws of hydrostatics.

Equally important, also, in its far-reaching connections was the work of Eratosthenes in determining the size of the earth. This work required an hypothesis as to the shape of the earth and appropriate observations. Supposing the earth to be spherical, an assumption which Eratosthenes knew well how to justify, he saw that to determine its size it is only necessary to apply the rule of three to the measured length of an arc of a meridian and to the measured difference of the latitudes of the ends of such arc. He observed that at the city of Syene, which is about 500 miles south of Alexandria, the sun shone vertically downwards into deep wells at noon on the day of the summer solstice, showing thus that at that place and time the sun was in the zenith. On the same day at Alexandria he observed, by means of the gnomon, that the sun at noon was south of the zenith by one-fiftieth of a circle, or 7°.2. The distance between the two points was found by the royal road masters of the country to be 5,000 stadia, thus giving for the complete circumference of the earth 250,000 stadia. Although the measurements thus made by Eratosthenes were very crude and undoubtedly subject to large errors, we see in them the beginnings of some of the most refined geodetic operations of the present day. Unfortunately for us, also, the measurement of the distance is expressed in a unit whose relation to modern units is only roughly known.[1]

But commendable as was the work of his predecessors and contemporaries, the work of Hipparchus rises to a still higher

[1] As illustrating the slow growth of ideas with respect to precision, it may be related that when the Arabians, in the ninth century undertook, for the same purpose, the measurement of a meriodinal arc on the plain Singiar, in Mesopotamia, they were not more successful in preserving for posterity the standard of length used by them. This standard is said to have been the "black cubit, which consists of 27 inches, each inch being the thickness of six grains of barley."

plane. He was an observer and a theorist of the highest type, being able at once to collect facts and to interpret their relations, and he deserves to be ranked among the great astronomers of all times. He was the first to clearly appreciate the value of a catalogue of the fixed stars and constructed one giving the relative positions of 1,080 stars. He observed with surprising precision the interval of the tropical year; he made the first tables of the sun and moon; he discovered the remarkable fact of the precession of the equinoxes; and he thus early led the way to the great advances of modern times.

The peculiar merit of the work of Hipparchus lies not alone in the fact that he saw how the apparent motions of the heavenly bodies may be determined by observations, but also in the fact that he saw how these motions may be determined by a very small number of appropriate observations. Thus, for example, the interval from the vernal equinox to the summer solstice and the interval from the latter to the autumnal equinox sufficed to give him a close approximation to the apparent motion of the sun; while the records of a few eclipses of the moon enabled him to deduce a closely correct value of the precession of the equinoxes, that shifting of the line of intersection of the equator and the ecliptic which goes on so slowly that an interval of nearly 26,000 years is required for a complete circuit.

Hipparchus may be called the founder of the geocentric theory, since he demonstrated the accordance of the phenomena known to him with that theory. The fact that this theory is false detracts little from his merits; for the sole requisites of a good theory are simplicity of statement and conformity with observation. We now know, indeed, that mechanical phenomena are, in general, susceptible of multiple interpretations, and that observation must decide which of them is to be preferred.

The method which Hipparchus used to measure the sun's apparent motion among the fixed stars is very noteworthy, especially when we consider the utter lack of effective instruments in his time. If the sun moves regularly about the earth, as first supposed by Hipparchus, it ought to return at any epoch, as that of an equinox, to the same position among the fixed stars. Imagine a line drawn at the time of the vernal equinox, say, from the center of the earth to the center of the sun. This line prolonged will pierce the celestial sphere in two points, and if either point can be located, the position of the sun with reference to the stars becomes known. Hipparchus fixed this position by noting the location among the stars of the center of the shadow cast by the earth at the times of eclipses of the moon. By a comparison of his own observations of such eclipses with those made by his predecessors he was able to determine the apparent motion of the sun with reference to the stars, or what we now know to be the motion of the equinoxes with reference to the stars. To establish this fact of precession from such meager observations was a great step; and it seems not a little singular that a phenomenon so striking should not have led to speedy investigations for its source. But about eighteen centuries elapsed before Newton clearly visualized the mechanical interpretation of this phenomenon, and it was only after an additional half century that the interpretation was fully worked out by d'Alembert.

How rapidly the spirit of science dies out when its devotees cease to observe and experiment is shown by the failure of the "Divine School of Alexandria" to maintain the high standard set by Hipparchus. His immediate successors became at best only commentators. They wrote much but observed little; and it does not appear that any of them attempted even to verify the remarkable discoveries of Hipparchus during the two hundred and fifty years which elapsed between the period of his activity and the advent of his worthy disciple and expounder Ptolemy.

It is to the work of Ptolemy chiefly that we owe our knowledge of the discoveries and theories of the Hipparchian epoch. His treatise on the "Great Construction," the Megiste Syntaxis, or the Al Magisti and hence Almagest of the Arabians, is the earliest of the great systematic treatises on astronomy. It is in this work that the theory of eccentrics and epicycles of Hipparchus is explained and elaborated, and it is this work which has given the name of Ptolemy rather than that of his acknowledged master to a system of the world which dominated scientific thought for nearly fifteen hundred years.

The period during which the observations and researches of Ptolemy were carried on is commonly referred to in history as extending from the reign of the emperor Hadrian to that of Marcus Aurelius. Thus, while Ptolemy was an Egyptian by birth, the fact that he was permitted to pursue his astronomical studies under the empire helps to some extent to relieve the Romans of the charge that they were, as regards science, the most ignorant people of antiquity. But the gravity of that charge is only palliated by the work of Ptolemy, for he left no successors. Roman astronomy did not rise above the level of astrology; the spirit of scientific enquiry gave way to speculation and declamation; and the long night which followed was not broken until the dawn of the epoch of Galileo — the modern epoch, whose advances have been founded on observation an experiment.

If astronomy is preëminent among the sciences for its dependence on observation, chemistry and physics are equally preëminent for their dependence on experiment. This difference in methods of investigation between the former and the two latter sciences is a difference imposed by the circumstances that astronomy deals chiefly with objects at long range while chemistry and physics are concerned with objects near at hand. It seems not a little singular, however, at first thought, that progress in the development of knowledge concerning the behavior of distant bodies should have been almost as rapid up to the present time as the development of knowledge concerning bodies much more familiar and accessible to us.

Chemistry and physics, like astronomy, had their forerunners in mythological follies and extravagances. Semi-civilized and civilized man required a long time after he had learned how to talk and to write well, after he had founded states and constructed systems of philosophy and religion, before he could reason rationally and successfully with respect to the commonest material things about him. Thus, chemistry was long obscured by merely verbal speculations on the "four elements, earth, air, fire and water" or on the "three elements, salt, sulphur and mercury"; while the beginnings of physics were perhaps even more clouded by the fantastic unrealities of fertile but unchecked imaginations.

But man early learned to measure the value of chemistry by the "gold standard." It is hinted, in fact, though without adequate evidence, that the Golden Fleece of the Argonautic expedition was a manuscript containing valuable secrets of the chemist's art; and Suidas, of the eleventh century, to whom the word chemistry is attributed, relates that Diocletian, fearing that the Egyptians, by reason of their knowledge, might become rich and restive, ordered, in true Roman fashion, that their books on chemistry should be burned. The thirst for gold assisted also in the development of alchemy, which flourished from the eleventh to the fifteenth century, especially, and has had not a few adherents, it would seem, during all the centuries down to and including the one just past. The philosopher's stone was almost universally believed to be a real agent in medieval times; and this strange fiction also has its survivals in the "mad stones," "moon stones," "lucky stones," and other "charms" whose use even at the present time is not uncommonly justified by the wise saying that "there may be something in them."

The difficulty in getting the human mind started with the elements of physical science is well illustrated, likewise, by the superstitious rubbish that encumbered the early progress of knowledge concerning magnets. They were endowed with imaginary qualities far more wonderful than subsequent observation and experiment have disclosed. It was believed, for example, that they would cause some diseases and cure others; that they were effective as love philters; that they would lose their properties when rubbed with garlic (which seems not so unlikely), but that a bath in goat's blood would readily counteract this destructive effect. And in this case, also, as with alchemy and the philosopher's stone, it is to be noted that such crude notions of the phenomena of matter find their survivals at the present day in a wide acceptance of the unverified efficacy of "magnetic healers" and "electric belts," and in the ease with which capitalists can be persuaded to invest in a "Keely motor" or in anything that promises the marvelous.

With the decline of alchemy the field for chemistry shifted somewhat. Not unnaturally, since most chemists were also physicians in those days, a knowledge of the chemical properties of substances came to occupy a prominent place in the physician's art. Thus Paracelsus in the sixteenth century, cutting loose from the teachings of Aristotle and Galen, boldly asserted that the true use of chemistry is not to make gold but to prepare medicine; and he and his follower Van Helmont, in addition to attaining fame for skill in compounding remedies, were amongst the first to appreciate the true import of the processes of analysis and synthesis which came to be called in their day the spagyric art. Then followed the doctrine of the mutually neutralizing substances, acid and alkali; the fruitful hypothesis of elective attractions or affinities; the ingenious, if erroneous, theory of phlogiston, and the more permanent theory of oxygen. All these led up through more and more searching experimentation to the first great epoch in the history of chemistry—the epoch of Lavoisier.

Among the early workers in the century preceding the epoch of Lavoisier the names of Becher and his disciple Stahl deserve especial mention, not only by reason of their introduction of the theory of phlogiston, but also by reason of their enthusiastic and steadfast devotion to science without hope of pecuniary reward. In his remarkable treatise entitled "Physica Subterraneæ," published in 1681, Becher defends the scientific pursuit of chemistry as not less worthy of attention than philosophical and theological studies. He insists especially on the need of careful observations and on the necessity of constantly verifying theory by experiment. With true scientific enthusiasm he describes the chemist as one willing to work amid the flames and fumes, and, if need be, the poisons and poverty of the laboratory. He has no patience with the charlatans, of which it appears there were still many in his day, who are looking chiefly for ways and means of extracting the precious from the baser metals. As for himself he says, "My kingdom is not of this world. I trust that I have got hold of my pitcher by the right handle—the true method of treating this study; for the pseudo-chemists seek gold, but the true philosophers, science, which is more precious than any gold."

It is a peculiarly noteworthy fact that while much attention was given to chemistry during ancient and medieval times, comparatively little attention was given to the other branches of physical science. Our knowledge of heat, light, electricity, and magnetism is almost wholly a development of modern times. The Greeks were acquainted with a few of the more elementary phenomena of electricity and light; and Ptolemy and Alhazen came near discovering the law of optical refraction; but there was no contribution made to either of those physical sciences comparable with the discoveries of Hipparchus in astronomy until the epoch of Galileo. What a marvelous increase in the rate of scientific progress began with this epoch is shown on nearly every page of the subsequent history of science. Galileo and his contemporaries may be said to have established the methods of observation and experiment. Their systematic application has borne fruit in every science. Almost every step forward has led to additional advances, until now each of the physical sciences has its wide array of determinate facts correlated under a great theory. In the domain of light, for example, the only solid contribution of the ancients is the obvious fact of radiation in straight lines. After nearly sixteen hundred years of our era had elapsed, there came Galileo's invention of the telescope, and about the same time Snell's discovery of the law of refraction. To the telescope were soon added the microscope and the camera obscura. Then followed Newton with explanations of the rainbow, dispersion, and kindred phenomena; Hooke with his discovery of the colors of thin plates; Dolland with the combination of two lenses to produce achromatism; and Huygens with his discoveries and explanations of double refraction and polarization; while in the meantime Roemer had measured the velocity of light. All these accessions crowded one another so closely that the emission theory of Newton and the undulatory theory of Huygens followed almost as a matter of necessity. The battle royal of these two rival theories, as you know, lasted for nearly a century until the emission theory, by the sheer force of critical observations and experiments, was displaced by the undulatory theory through the brilliant researches of Young and Fresnel.

When we turn from the physical to the geological and biological sciences, the same lessons of the necessity and the efficiency of observation and experiment are still more strikingly apparent. For although geology and biology are the youngest of the grand divisions of science, they have accomplished more than all others toward giving man a proper orientation with respect to the rest of the universe. Geology as we now understand the term is but little more than a hundred years old, and biology in the sense now attached to the word, is less than fifty years old. Nevertheless, these sciences have been the chief contributors to the doctrine of evolution, which, in view of the wide range of its applicability, must be regarded as the most important generalization of science.

It is a singular circumstance, however, considering the early advances made in the interpretation of the phenomena of astronomy, that the equally ubiquitous and far more accessible phenomena of geology and biology should have been so tardily investigated. The cause of this delay seems to lie in the fact, not without examples in the present day, that our remote ancestors had the habit of constructing their theories first and making their observations, if at all, afterwards ; and in the cases of geology and biology they were so well satisfied with their theories that the trouble of making observations was for a long time dispensed with.

We of the present day have no right, perhaps—and I for one would not be disposed to use such a right if conceded—to blame our predecessors for the narrow, and in some instances crooked views they held with regard to these subjects. But on the other hand, we shall fail, I think, to make proper use of our opportunities if we do not learn speedily to conduct scientific investigations in the future so as to avoid such colossal blunders as mar the history of geology and biology from its beginnings down almost to our own time.

As an illustration of the blunders referred to I may cite the profound reluctance even of eminent men of science to accept the plainest teachings of observation with respect to geological time up to the middle of the century just passed. Not until Lyell the great champion of uniformitarianism, as opposed to catastrophism, had published his "Principles" (1830) did scientific opinion show a tendency to accept the fact of the hoary age of the earth everywhere attested by the rocks in her crust.

And what a storm of opposition and condemnation, amounting almost in some cases to social ostracism, was visited by the very "salt of the earth" against those who ventured during the sixties and the seventies of the last century to consider favorably the arguments of the "Origin of Species"! All this has about it the freshness, and possibly the pain and the humor, of personal recollection for those of us who are old enough to have lived in two epochs. That a mistake of this sort could have been made thirty or forty years ago seems strange enough in these peaceful times of ours. But while we may properly let the recollection of the storm and stress of this earlier period fade away, the moral of the conflict should be held up as a permanent warning to scientific as well as unscientific men; for no episode in the previous experience of the race demonstrates so clearly the sources of knowledge and the methods of attaining it.

As a final illustration of the validity of my thesis I would invite your attention to one of the most instructive and beneficent of the many brilliant biological researches of recent times. No one who has suffered from repeated attacks of intermittent fever and has survived the ravages of the materia medica, can fail to take a lively interest in the wonderful progress made during the last twenty years towards a definite knowledge of the natural history of that disease. Nor can any one interested in the general aspect of science fail to see in the investigations leading up to this progress some of the finest examples of the scientific method.

It would appear that malarial fever has been one of the commonest disorders, in certain localities, with which man in his struggle for existence has had to cope; and before the discovery of the properties of Peruvian bark it must have been a very serious affliction by reason of its secondary if not by reason of its primary effects. The symptoms, course, and distinguishing characteristics of the disease, as well as the remedies therefor, were long known, however, before it was suspected that the mosquito had anything to do with its dissemination. Bad water, foul air, and sudden or extreme changes of temperature were supposed to be promoting causes. The dampness of marshes, swamps, and other areas holding stagnant water was held to be an especially common attendant, if not inducing, condition. There was, indeed, no lack of acute and painstaking observations and no lack of ingenious and well-supported hypotheses with regard to this widely prevalent but obscure disorder. The details of its diagnosis, prognosis, nature, and causation as laid down in the medical manuals of a few decades ago, are particularly interesting and instructive reading now in view of recent developments. For example, Hartshorne in his "Essentials of the Principles and Practice of Medicine," published in 1871, gives the following explanations:

"No disease has ordinarily so regular a succession of definite stages as intermittent fever, namely the cold, the hot, and the sweating stage." * * * "Upon the origin of malarial fevers," he adds, "the following facts seem to be established: 1. They are reasonably designated as autumnal fevers, because very much the largest number of cases occur in the fall of the year. Spring has the next greatest number of cases. 2. They are always strictly localized in prevalence. 3. They never prevail in the thickly built portions of cities. 4. An average summer heat of at least 60° F. for two months is necessary for their development. Their violence and mortality are greatest, however, in tropical and subtropical climates. 5. They prevail least where the surface of the earth is rocky; and most near marshes, shallow lakes and slow streams. The vicinity of the sea is free from them, unless marshes lie near it. 6. The draining of dams or ponds, and the first culture of new soil, often originates them.

7. Their local prevalence in the autumn is always checked by a decided frost."

Here we have the facts with regard to the symptoms and cause of the disease stated with a clearness and a conciseness that could hardly be surpassed. But the real cause of the malady eluded the insight of the discriminating observers who collected those facts. A quite different class of facts required consideration. It was essential to concentrate attention on the pathological aspects of the enquiry. As to the nature of the disease Hartshorne writes, with commendable caution, "It is only possible to speculate at present. It is most probable that ague is a toxemic neurosis. The importance of the blood change attending it is shown by the disintegration of the blood corpuscles, and deposit of pigment in various organs." This destruction of the blood corpuscles was the critical point on which the investigation turned. About 1880, Laveran, a French army surgeon, discovered the destructive agency in a minute parasite, one of the protozoa, which takes up its residence in, and then ungratefully enough, destroys our red blood corpuscles. What a splendid problem was presented by the facts thus brought to light! The exquisite refinement of the researches which followed may be inferred when we reflect on the minuteness of an organism which can work out a part of its life history within blood corpuscles so small that four to six millions of them find plenty of room in a cubic millimeter. But stranger still is the fact established within the past year or two that the mosquito plays the rôle of an intermediary host and transmits the parasites to us while feasting upon our blood. The details of this remarkable discovery need only be alluded to here, for they have been so recently explained by the experts participating in them that their essential features are a part of popular information. Suffice it to remark that they show how we may secure almost complete immunity from malarial fevers at no distant day.

Thus, in whatever direction we look for the sources of scientific progress, the same elementary methods of advancement are found to be effective. Whether we consider the dimensions of the solar system or the distances between the molecules of a gas; whether we seek the history of a star as revealed by its light or the history of the earth as recorded in its crust; whether we would learn the evolution of man or the development of a protozoön; whether we would study the physical or chemical properties of the sun or the corresponding properties of a grain of sand; in short, whether we turn to the macrocosm or to the microcosm for definite, verifiable knowledge, it is found to originate in and to advance with observation and experiment.

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Lancaster, Pa.

NEW YORK ACADEMY OF SCIENCES

SESSION, 1901–1902

The Academy will meet on Monday evenings at 8.15 o'clock, from October 7th to May 19th, in the rooms of the Chemist's Club, **108 West 55th Street.**

[Annals N. Y. Acad. Sci., Vol. XIV, No. 5, pp. 85–163, March 4, 1902.]

RECORD OF MEETINGS

OF THE

NEW YORK

ACADEMY OF SCIENCES

January, 1901, to December, 1901

RICHARD E. DODGE

Recording Secretary

[ANNALS N. Y. ACAD. SCI. NO. 5, pp. 85–163, March 4, 1902.]

RECORDS OF MEETINGS

OF THE

NEW YORK ACADEMY OF SCIENCES.

January, 1901, to December, 1901.

RICHARD E. DODGE, *Recording Secretary.*

BUSINESS MEETING.

JANUARY 7, 1901.

Academy met at 8:15 P. M., Professor William Hallock presiding.

The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows:

That Volume XIII of the Annals would be very shortly completed, the larger part of the manuscript being already in press. Also that the Council had voted, beginning with Volume XIV, of the ANNALS, to send the *Transactions* of the Academy only to all members, but to send the rest of the publications to such members as may signify their desire to receive them, and to take steps to find out the will of the members in reference to this point.

The name of one candidate for resident membership was read and referred to the Council.

RICHARD E. DODGE,
Recording Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

January 7, 1901.

Section met at 8:20 P. M., Professor William Hallock presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered :

Harold Jacoby, A New Telescope for Photographing the Pole of the Heavens. Illustrated.

Geo. B. Pegram, Reflection of Light from White Surfaces.

Professor **Jacoby** announced that this plan of photographing the close polar stars had made material progress. A special instrument has been constructed and mounted at the observatory at Helsingfors, Finland. Photographs of the actual instrument in position for use were exhibited. It is planned to make photographs with this instrument in which the close polar stars will trace out "trails" on the plate corresponding to their diurnal motion. The effects of refraction, etc., having been eliminated by computation, it is possible to obtain from such photographs the exact position of the celestial pole among the stars and on the date of observation. The intercomparison of results taken on dates six months apart should furnish a new determination of the constant of aberration, and photographs taken annually throughout a series of years should determine the constant of nutation and ultimately perhaps even that of precession.

The actual observing with the instrument will commence in the spring as soon as the Helsingfors astronomers have finished with the observations of Eros now in progress, and the plates will be sent to Columbia University, New York, for measurements and reductions. An outline of the method to be used, together with a preliminary trial of the same, has already been published by Professor Jacoby under the title "Photographic Researches near the Pole of the Heavens," *Bulletin of* *the Imperial Academy of Sciences of St. Petersburg*, 5th Series, Vol. 9, p. 41, 1898, June.

The second paper presented the results of an experimental study of some white surfaces with regard to the relation between the intensity of the reflected ray and the angles of incidence and reflection. It was carried out by means of a special photometer allowing the use of any desired angles of incidence and reflection. Among the surfaces tested were plaster of Paris, several kinds of unglazed paper, compressed powders of several kinds, powders not compressed, but gently smoothed with a metal plate, and finally a surface made by allowing fine plaster dust to settle from suspension in the air on a suitable plate. These surfaces in the order named showed decreasing polarization of the reflected light, and less approach to specular reflection. The fine dust surface showed no polarization and almost no tendency to regular reflection. The results with this surface as shown by sets of curves, follow pretty closely the old Lambert's or cosine law.

$$\text{Intensity} = A \cos i \cos r.$$

with some departure when both angles were very large. With all the other surfaces the departure was very great for angles greater than 70°. Contrary to the results of Mr. Wright (*Phil. Mag.*, Feb., 1900) these experiments were quite in accord with the demand of theory that the intensity of the reflected ray should be expressed as a symmetric function of the angles of incidence and reflection.

William S. Day.
Secretary.

SECTION OF BIOLOGY.

January 14, 1901.

Section met at 8:15 P. M., Professor C. L. Bristol presiding.

The minutes of the last meeting of Section were read and approved.

The name of one candidate for resident membership was read and referred to the Council according to the By-Laws.

The following program was then offered:

H. B. Torrey, A New Species of *Phoronis.*

J. H. McGregor, Characters and Relationships of the Belodont Reptiles.

F. E. Lloyd, (1) Notes on *Chrysoma paucifloscula.* (2) On the Occurrence of Nectaries in *Pteris aquilina.*

Prior to the reading of the minutes, Dr. H. E. Crampton was elected Secretary of the Section, in place of Professor Lloyd, resigned.

Summary of Papers.

Mr. **Torrey** described a new species of *Phoronis*, the first that has been collected on the western coast of America. It is intermediate in its characters between the European and eastern American species, and those found in Australia and the Philippines. In size it agrees with *P. Buskii.* The lophophore, though spirally coiled—thus differing from that of the European species—is less complex than that of *P. Buskii*, and the tentacles are fewer in number (200). The longitudinal muscles are stouter than those of *P. Buskii*, agreeing more nearly with the condition in *P. architecta* of the east coast. The new species agrees with the latter species in habit, in the possession of a longitudinal ciliated ridge in the digestive tract, and in the possible separation of the sexes.

Dr. **McGregor** presented the results of a recent study of the Belodonts, a group of fossil reptiles occurring in the Triassic of Germany and North America. The Belodonts have usually been regarded as ancestral Crocodiles, though many students of the group have admitted possible affinities with Rhynchocephalia and Dinosauria. The material used in the present study, chiefly from the genera *Mystriosuchus* and *Rhytinodon*, yielded some parts new to science, *e. g.*, the atlas and the clavicle. The presence of two cervical intercentra and a large clavicle tends to ally the group more closely to the Rhynchocephalia. The hyoid apparatus was found to be suspended from the skull as in *Hatteria;* and there is strong evidence that the carpals (and probably also the tarsals) remained cartilaginous throughout life. Some doubt was expressed regarding the Belodont ancestry of the Crocodiles, though it was admitted that the Belodonts stand near the Crocodilian stem. The suggestion was made that the Belodonts may belong on or very close to the line of descent of the Ichthyosauria, occupying a position midway between some Permian land-living Rhynchocephalian and the marine Ichthyosauria of the Jurassic. In support of this theory, many structures of the Belodonts were shown to be such as one would expect to find in an ancestor of the Ichthyosauria, *e. g.*, position of nares, elongated premaxillary, bicipital ribs, two or more cervical intercentra, abdominal ribs, form of shoulder-girdle, etc. Some other structures, apparently incompatible with this view, were shown to be in reality not inconsistent with it.

In discussion of Dr. McGregor's paper, Professor **Osborn** emphasized the importance of the Belodonts, and the conflicting nature of the opinions regarding them. Huxley placed them near the crocodiles as evidenced by his choice of the name Parasuchia for the group. The palæontologists of the Stuttgart school relate them to the Dinosaurs. Dr. McGregor is the first to bring out the idea of their relationship to the Ichthyosauria, and based as it is upon many new characters described for the first time, the theory is of great interest and importance.

Professor **Lloyd** stated that the chief point of interest in *Chrysoma pauciflosculosa*, a sub-tropical marine form, is in the structure of the leaves. The surface of these is sculptured in the form of a mosaic. This appearance is caused by deep and regularly-arranged involutions of the epidermis. At the bottom of each sulcus are to be found flagellated and glandular hairs, such as have been described by Vesque for the Compositæ. Transverse sections show that each element of the mosaic contains chlorenchyma, which, though packed densely around the edges, forms in the middle a large air-chamber, suggesting in appearance the air-chambers of certain Hepaticæ. The leaf, a bifacial one, is maintained in a vertical position.

In a second paper, Professor **Lloyd** drew attention to the occurrence, in *Pteris aquilina*, of nectaries near the bases of the pinnæ. The activity of these glands reaches a maximum during the development of the frond in spring and early summer, at which time large drops of syrupy nectar exude from the openings, which are modified stomata. The object of the speaker was to call the attention of teachers of general biology to the presence, in a much-used laboratory type, of organs which, though discovered by Francis Darwin in 1877, were very generally overlooked.

In discussion of Professor Lloyd's first paper, Professor **Britton** remarked that the author's results were of value as throwing light upon the vexed question of the relationship of *Chrysoma* to the golden-rods (*Solidago*). The two groups were probably distinct. It was also recalled that the late Dr. Gregory had worked extensively upon the problem, but her full results had never been published.

HENRY E. CRAMPTON,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

JANUARY 21, 1901.

Section met at 8:15 P. M., Dr. A. A. Julien presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

Richard E. Dodge, THE LANDSLIDES OF THE ECHO AND VERMILION CLIFFS.

William Hallock, SOME PECULIAR MINERALOGICAL EFFECTS OF LIGHTNING DISCHARGE.

Alexis A. Julien, A PETROGRAPHIC STUDY OF THE SPECIMENS DESCRIBED BY PROFESSOR HALLOCK.

THEODORE G. WHITE,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

JANUARY 28, 1901.

Section met at 8:15 P. M., Dr. Franz Boas presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

Dr. A. Hrdlicka, CERTAIN RACIAL CHARACTERISTICS OF THE BASE OF THE SKULL.

Dr. L. Farrand, THE ALSEA INDIANS OF OREGON.

SUMMARY OF PAPERS.

The first paper dealt with the middle lacerated foramen, the petrous portions of the temporal bones, and the styloid. The author demonstrated the different stages of development of these parts in primates and at different stages of life in the whites, and the differences of those parts, fully developed, in the negroes, Indians and whites. In the adult whites the middle lacerated foramen is large, the petrous portions appear considerably sunken (bulging of surrounding parts), the styloid is well developed. In the Indian the foramen is but a moderate size, in the negro small, in apes absent; the petrous portions are less sunken in the Indian than in the white, on, or almost on, the level with the surrounding parts in the negro, bulging more or less beyond these in the primates; the styloid is in the majority of cases small in the negro and small to rudimentary in most of the Indians. Where the styloid is rudimentary the vaginal process often plays a compensatory part. In whites all the mentioned stages of the parts described may be observed at different periods of life. Brain development accounts for the differences in the size of the middle lacerated foramen and the relative position of the petrous portions.

The second paper reported observations made by the author on the language, customs, and traditions of the Alsea Indians of Oregon.

CHARLES H. JUDD,
Secretary.

BUSINESS MEETING.

FEBRUARY 4, 1901.

Academy met at 8.15 P. M., President Woodward presiding.

The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows :

The nomination of the following four candidates for honorary membership : Charles Vernon Boys, F.R.S., 66 Victoria St., London, S. W., England ; Emil Fischer, Professor of Chemistry, University of Berlin ; William Ramsay, Ph.D., LL.D., S.D., F.R.S., University College, London, England ; James Geikie, LL.D., D.C.L., F.R.S. (L. & E.), University of Edinburgh, Scotland.

That the Council had voted not to nominate any corresponding members.

That the Council nominated the following resident members to be promoted to Fellows : Dr. Henry E. Crampton, Dr. C. A. Herter, Prof. Graham Lusk, Dr. Charles Lane Poor, Mr. C. A. Post, Dr. E. L. Thorndike, Dr. R. S. Woodworth.

The Secretary also reported the list of officers to be nominated according to the by-laws.

The following Candidate for resident membership, approved by the Council was duly elected :

Herman C. Bumpus, American Museum of Natural History.

Richard E. Dodge,
Recording Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

February 4, 1901.

Section met at 8:20 P. M., Prof. William Hallock presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered :

George E. Hale, Astronomical Photography with a Visual Telescope.

W. G. Levison, Note on a Cause of the Deterioration of Gelatine Photographic Dry Plates.

Summary of Papers.

Photography was discovered in 1837 and the first astronomical photograph was taken in 1840 by Dr. Draper of New York. It was a photograph of the moon made on a daguerreotype plate and gave great promise for the future. Bond in 1850 made the first photographs of the stars. Rutherford of New York in 1858 made some remarkable photographs of the moon, and later some star photographs.

Photography has now become so valuable in astronomy that it is applied in every department. It is not true, however, that it will displace the eye. There are certain fields where the eye will be superior to the photographic plate, but in many other fields photography has led to results that never could have been obtained by visual observation. I shall speak to-night of work done at the Yerkes observatory with a telescope designed for visual observation. It is fortunate that this telescope was not designed for photography alone, for by the use of methods recently devised it has been possible to use it for photography and the results are not at all inferior to what they might have been in a telescope designed for photography alone.

The forty-inch telescope of the Yerkes Observatory can be considered as a long camera with a focal length of about sixty-four feet. Its field of view embraces a circle in the sky of only about five minutes of arc in diameter. In photographing groups and clusters of stars this long focal length makes it possible to separate stars which would have been run together into one mass with an instrument of shorter focal length. A means of counteracting the uncorrected chromatic aberration has been devised by Mr. Ritchie of the Yerkes Observatory. He employs a yellow collodion film in front of the photographic plate at the eye end of the instrument, by which the blue rays are cut off. Suitable isochromatic plates such as can be found in the market are used. This is a very inexpensive means of using the telescope for photography. A special form of guiding apparatus to keep the star image at the same point of the plate has to be employed. On account of the unavoidable flexure of the large telescope tube, an auxiliary telescope placed parallel to the telescope tube cannot be used. The image of another star just outside of the photographic plate is made use of. By means of a little eye-piece with a fine pair of cross hairs, attached to the plate holder which is adjustable in two directions at right angles to each other, the image of the guide star is kept on the intersection of the cross-hairs during the entire time of exposure. The photographs taken at the Yerkes Observatory in this manner by Mr. Ritchie are much finer than those taken at Potsdam with a photographic telescope.

A most important application of photography with this telescope will be the determination of the parallax of stars, which has not yet deen done to any extent by photographic means.

Photographs of small planetary nebulæ taken with this telescope show more than can actually be seen with our eyes, in some cases for example, a radial structure.

The instrument can also be used to study stellar spectra and stellar evolution. We can pass by gradations from the types of hot and white stars like Sirius, to the more developed and colder ones like our sun, and then to the red stars. There are two types of red stars and by the aid of their spectra photographed with this telescope we have detected a relationship between the two types, through the presence of carbon bands. Even in the atmosphere of the sun there is a very thin layer of carbon vapor and above this the gases of the chromosphere. In the red stars we have this carbon vapor, which is very dense in one of the types.

Another important line of work is that of measuring the motion of stars in the line of sight. Professor Frost uses the titanium line for this purpose, and has just had a new spectrograph constructed for the work.

In photographing the spectrum of Saturn with its rings, we find a faint band in the red, indicating the presence of a comparatively dense absorbing atmosphere on the planet which is absent from the rings.

With the help of a spectroheliograph, we are able to photograph solar phenomena. These photographs show that the mottling of the sun's surface persists throughout the minimum period of sun spots as well as through the maximum. Prominences can be photographed nearly as well with it as at times of total solar eclipse.

Mr. **Levison** in his note, suggests that there is some emanation, probably Becquerel rays, from the pasteboard of the boxes in which the plates are packed for the market, which causes their deterioration. He found that if he cut a star from the pasteboard of a plate box and laid it on the sensitive side of a plate, the whole then being enclosed in a box for a week, when he developed the plate he found an image of the star. This would explain the deterioration at the edges of plates where they come nearly in contact with the box, or the deterioration due to the pasteboard separators at the edges of the plates. The author's experiments led him to the suggestion that metal boxes would be better for the plates than the pasteboard boxes. Wrapping with paraffine paper might also have the same effect.

WM. S. DAY,
Secretary.

SECTION OF BIOLOGY.

FEBRUARY 11, 1901.

Section met at 8:15 P. M., Professor C. L. Bristol presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

D. T. MacDougal, THE CRITICAL POINTS IN THE RELATION OF LIGHT TO PLANTS.

A. G. Mayer, THE VARIATIONS OF A NEWLY-ARISEN SPECIES OF MEDUSA.

SUMMARY OF PAPERS.

Dr. **MacDougal** stated that an examination of all the data at hand shows no correspondence among the maxima, minima, and optima of intensities of light with regard to the various influences exerted upon the plant by light, and that the current conception of *phototonus* is not based upon well-defined generalizations.

Etiolative phenomena of plants are irritable reactions, consisting chiefly in the elongation of organs which would carry the chlorophyl screens and reproductive bodies up into the light. Light is not necessary to the motility of protoplasm or to the activity of the motor mechanisms of such plants as *Mimosa;* the condition known as *darkness-rigor* does not exist. Appearances commonly supposed to be due to rigor of darkness are pathological phenomena occasioned by the disintegration of chlorophyl and other substances.

Light may exert a direct chemical (disintegrative) effect upon the constructive material of the cell, but it does not retard growth ; on the contrary, it accelerates growth among the algæ. Evidence that light exercises a paratonic influence upon plants is not at hand, and no observations could be found by the speaker supporting the conclusion that a similar retarding influence of light upon growth occurs among animals.

In discussion of Dr. MacDougal's paper, Mr. **M. A. Bigelow** called attention to some experiments made by him, under the direction of Professor C. B. Davenport, to determine the influence of light upon embryonic development and post-embryonic growth in Amphibia. Light does not retard, but rather accelerates developmental processes, the effective rays being red in embryonic and blue during post-embryonic stages.

Dr. **Mayer** stated that in 1898 he had discovered a pentamerous Hydromedusa at the Tortugas, Florida, and had named it *Pseudoclytia pentata.* In this form there are five radial canals, five lips, and five gonads 72° apart, instead of four of these various organs at intervals of 90°, as in other Hydromedusæ. In its anatomy it is related to the genus *Epenthesis*, being very close to *E. folleata*, which also occurs at the Tortugas. It is probably the descendant of some *Epenthesis*, and seems to be a newly-arisen species. No studies have as yet been made by zoologists upon the variations of such forms.

The medusa is highly variable. Out of 1,000 individuals 703 are normal radially symmetrical medusæ, with five radial canals and five lips at intervals of 72°, while 297 are abnormal in some respect, having 4, 3, 2, or 6, 7, 8 canals or lips. It is remarkable that fully 50% of the abnormal individuals are radially symmetrical. The greater the departure from the normal form the smaller is the ratio of radially symmetrical individuals. Thus only 11.2% of the medusæ having five canals are irregular, while 30–33% of those with four or six canals are irregular; in medusæ with seven or three canals 50% are irregular, while 100% of those with two or eight canals are so. The lips show a decided tendency to revert to the ancestral number of four, at intervals of 90°, but the canals, on the contrary, incline toward the higher numbers. We have here a medusa which is continually producing radially symmetrical sports, and is initiating, so to speak, what might become new species were conditions favorable.

On comparing the variations of *P. pentata* with those of *E. folleata* or *Eucope*, one is struck with many remarkable family likenesses. This is especially true in the former comparison. Similarity of the variations, the likeness of their abnormalities, in these closely-related forms, indicates apparently a race kinship. The abnormal young of *P. pentata* appear to survive fully as well as normal individuals, and abnormal medusæ mature their gonads quite as commonly as the normal forms. The former are not weeded out by natural selection, yet they have not succeeded in establishing new types of medusæ.

In discussion of Dr. Mayer's paper, Dr. **MacDougal** spoke of a sport of *Populus tremuloides*, discovered by Dr. Britton, in which the irritability to gravity of the leaves had been reversed so that they now pointed downwards. The reversal appeared in the buds. New plants propagated by grafting retained the positive geotropism of the leaves. It was also stated that the "weeping" varieties of certain trees were usually produced in this way.

HENRY E. CRAMPTON,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

FEBRUARY 15, 1901.

Section met 8:15 P. M., Professor J. McK. Cattell presiding. The following program was offered:

Dr. **D. R. Major,** Physical and Mental Tests of School Children.

A. E. Spitzka, The Brains of two Distinguished Physicians, Dr. Edouard Seguin and his son Dr. Edward Seguin.

Summary of Papers.

The first paper reported the results of physical and mental tests on school children of high and low class standing, the aim of these tests being to discover what relation, if any, exists between class standing and the ability shown in the particular tests used. The tests were as follows: visual and auditory memory for figures and words, striking out of A's, naming 100 words, copying columns of figures, weight discrimination, perception of size, sensation-area test as used in the Columbia laboratory, eyesight, age and talkativeness. The tests were made on 150 New York City school children, 68 having high class standing, 82 low. The results of the tests tend to show that the class standing bears a close relation to the ability to pronounce words, to carefulness or accuracy in striking out A's, to memory for words, to eyesight, to age (the average of the good pupils being less than the average age of the class) and to talkativeness (the good pupils being as a rule talkative). There is apparently little, if any, relation between class standing and the ability shown in the other tests mentioned. The study, however, is not completed and the opinions expressed here are subject to change. In addition to the use made of the standard psychological tests, an attempt is being made to devise tests to determine the presence, nature and quality or worth of apperception activities.

The second paper described with special reference to their similarities, the brains of two distinguished physicians, Dr. Edouard Seguin and his son Dr. Edward C. Seguin. The most striking similarity discoverable in these brains is the unusual development in the left insula. This similarity was attributed by the author to heredity, and was held to be the physical basis for the high type of ability shown by both the Seguins in the use of language.

Charles H. Judd,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

February 18, 1901.

Section met at 8:15 P. M., Dr. A. A. Julien presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

George I. Finlay, The Granite of Barre, Vermont.

A. A. Julien, Note on a Sand Fulgurite from Poland.

Summary of Papers.

Mr. **Finlay** described the occurrence of the Barre granite as a single intrusion through the country rock, which is a biotite-schist, in the southern portion of Barre township. Many inclusions of the schist are found in the granite, and this rock has almost surrounded other masses of the schist, which remain in place, with their original dip and strike unchanged. The speaker employed a series of original lantern views to illustrate the character of the jointing, the "onion structure," and the zones of shearing together with certain large systems of joints, standing at right angles to each other, resulting from pressure. Microscopic examination shows that the granite consists of microcline and orthoclase, plagioclase in very small amounts, quartz, biotite and muscovite, with occasional crystals of apatite and magnetite and rarely pyrite. Variations in the shade of the marketable granite, from very light to very dark gray, are due to the relative amount of biotite which it contains. The rock is of medium grain and its constituent minerals are but slightly weathered. Pegmatitic offshoots, traceable directly to the granite mass, were recorded by Mr. Finlay, and their dynamic effects on the enclosing schist were illustrated. The contact metamorphism of the schist is inconsiderable. It is chiefly shown in the greater abundance of biotite and quartz in the immediate vicinity of the granite. Two dikes of augite-camptonite were found; one in the granite, the other in the country-rock. They are noticeable for the manner in which they have weathered. At times sixteen successive shells may be counted which are ready to break away from the main mass of the dike. Mention was also made, in discussing the glacial geology of the region, of sand plains and of two well-developed eskers.

The paper was discussed by Professor **Kemp** and Doctors **Julien** and **White.**

Doctor **Julien** exhibited a specimen of fulgurite formed from sand in Poland, with a series of photo-micrographs which he had made from the same. Some new features in fulgurites were pointed out in this specimen; pustules of glass on the inner lumen, glass fibres on the exterior and adhering sand-grains, two-thirds of which consisted of orthoclase. In the thin cross section, examination of the minute gas cavities showed the absence of condensed water-vapor, and this indicated a dilatation of both lumen and cavities by air, more than by steam. The radial arrangement of layer cavities, the horn-like projections on the outside of the tube, and the pustules along the lumen, were all shown to be connected with relief of intense pressure outwardly during the electric discharge, or inwardly, during the reaction after its passage. This fulgurite is of further interest in presenting the first instance yet observed of devitrification, the glass being generally filled with delicate crystallites, apparently of feldspar. All the bubbles, however, are enclosed in pellicles of homogeneous glass, and some of the larger within a coating of suddenly chilled glass, which is free from crystallites. The relation of these facts was discussed in reference to Lagorio's view as to the difficult saturation of a magma by the constituents of feldspar.

Other occurrences of fulgurites were discussed by Doctors **Kemp, Levison** and **White.**

Theodore G. White,
Secretary.

ANNUAL MEETING.

February 25, 1901.

Academy met for the Annual Meeting at 8:15, President Woodward in the chair.

Reports of the officers for the past year were called for and presented in the following order :

The accompanying report of the Corresponding Secretary was read by the Recording Secretary.

The report of the Recording Secretary, herewith filed, was read.

The accompanying report of the Treasurer was read and referred to the Finance Committee for auditing.

The accompanying report of the Librarian was read.

The following nominations for Honorary Members, selected by the Council according to the By-Laws, were read, and the Secretary was instructed to cast one ballot in each instance, which was done.

Charles Vernon Boys, F.R.S., 66 Victoria St., S. W., London, England.

Emil Fischer, Professor of Chemistry, University of Berlin, Germany.

William Ramsay, Ph.D., LL.D., D.Sc., F.R.S., F.C.S., Professor of Chemistry, University College, London, England.

James Geikie, LL.D., D.C.L., F.R.S. (L. & E.), Murchison Professor of Geology in the University of Edinburgh, Scotland.

The following list of Fellows, nominated by the Council according to the By-Laws, was read, and the Secretary was empowered to cast the affirmative ballot of the Academy therefor, which was done.

Dr. Henry E. Crampton,

Dr. C. A. Herter,

Dr. Charles Lane Poor,

Dr. E. L. Thorndike,

Dr. J. G. Curtis,

Professor Graham Lusk,

Mr. C. A. Post,

Dr. R. S. Woodworth.

The President then appointed as tellers Dr. Wiechmann and Mr. Tufts. Ballots were distributed, votes received and counted, and the following list of officers elected :

President, Robert S. Woodward.

First Vice-President, Nathaniel L. Britton.

Second Vice-President, J. McKeen Cattell.

Corresponding Secretary, Harold Jacoby.

Recording Secretary, Richard E. Dodge.

Treasurer, Charles F. Cox.

Librarian, Livingston Farrand.

Councillors: Franz Boas, Charles H. Judd, Charles A. Doremus, M. I. Pupin, Frederic S. Lee, L. M. Underwood.

Curators: Harrison G. Dyar, George F. Kunz, Alexis A. Julien, Louis H. Laudy, E. G. Love.

Finance Committee: John H. Hinton, C. A. Post, Cornelius Van Brunt.

The President then delivered his Annual Address entitled, "Observation and Experiment."

At the close of the address a vote of thanks to the President was moved by ex-president Osborn, and carried.

Adjourned.

Richard E. Dodge,
Recording Secretary.

REPORT OF THE CORRESPONDING SECRETARY.

The number of honorary members now on the Academy lists is forty-one; corresponding members, two hundred and six.

There have been five losses by death in the last year, namely Professors Richard Ackerman, Silas Newcomb, Hugo Geinitz, P. S. Michie and Sir Joseph Hooker.

Respectfully submitted,

William Stratford,
Corresponding Secretary.

REPORT OF RECORDING SECRETARY.

During the last Academy year the business of the Academy has progressed in the customary paths. The several sections have held their usual meetings, with ordinarily the same attendance as in former years. The Councils have held the meetings prescribed by the By-Laws, and have accomplished several important objects. On the whole, however, the year cannot be called a year of progress.

During the last year there have been eight meetings of the

Council, eight business meetings, thirty sectional meetings, one public lecture, and one public reception. At the sectional meetings there have been seventy-four papers presented, which may be classified as follows:

- Anthropology 4.
- Astronomy 3.
- Botany 2.
- Chemistry 1.
- Geology 15.
- Mineralogy 4.
- Miscellaneous 3.
- Palæontology 2.
- Physics 15.
- Physiography 2.
- Physiology 2.
- Psychology 12.
- Zoology 9.

There are at present a total of 321 Resident Members, and 96 Fellows.

The Annual Reception and Exhibition was held in April at the American Museum of Natural History, and proved as usual eminently successful. Owing, however, to financial stringency on the part of the Academy it has been voted to recommend to the succeeding Council that no Reception be held in the year 1901.

The accomplishments of the year leading to increased efficiency in the Academy work are first, the establishment of a series of publication rules that will make the future work of the Editor, and the cost of publication, much less than formerly; secondly, the vote to establish a budget for the next fiscal year, within the limits of which each officer will be required to work; thirdly, the hiring of the rooms of the Chemists' Club for the meetings of the next year, at a greatly reduced rental, with accommodations equal to those which we now enjoy; and finally, a vote to send the ANNALS and MEMOIRS only to those members of the Academy signifying their desire to receive them.

The publications of the academy have been unfortunately delayed during the last year, owing to no fault of the Editor; but the current volume will be very shortly completed and issued. Owing to the expense of the current volume the amount of publication possible by the Academy during the present year will be seriously reduced, unless a publication fund can be established.

It should also be recorded that the Council, in June, 1900, presented to President Morris K. Jesup, of the American Museum of Natural History, a letter of congratulation and good wishes on the occasion of his seventieth birthday.

RICHARD E. DODGE,
Recording Secretary.

REPORT OF THE TREASURER.

RECEIPTS.

Balance as per last Annual Report			$2,239.11
Mortgage paid off, account Permanent Fund		$1,202.75	
" " account Audubon Fund		1,797.25	3,000.00
Income, Permanent Fund		426.38	
" Audubon Fund		99.04	
" Publication Fund		90.00	615.42
Life Membership Fees			200.00
Initiation Fees			75.00
Annual Dues, 1897		10.00	
" 1898		30.00	
" 1899		170.00	
" 1900		2,395.00	
" 1901		50.00	2,655.00
			$8,784.53

DISBURSEMENTS.

Cost of Publications	$2,499.72		
Less Sales	30.06	2,469.66	
Cost of Publications (paid by Audubon Fund)		309.72	
Rent of Rooms		510.00	
7th Annual Reception		329.68	
Dues to Scientific Alliance		32.58	
Lectures		20.00	
Expenses of Recording Secretary		291.44	
" Librarian		363.95	
" Treasurer		41.93	
General expenses		78.37	4,447.33
Balance on hand			$4,337.20

BALANCE SHEET.

FEBRUARY 25, 1901.

	Dr.	Cr.
Permanent Fund		$10,426.43
Publication Fund		1,823.69
Audubon Fund		1,897.25
Income, Audubon Fund (unexpended balance)		81.90
Investments, Bonds and Mortgages.		
a/c Permanent Fund	7,200.00	
a/c Publication Fund	1,800.00	
General Income Account	892.07	
Cash on hand	4,337.20	
	$14,229.27	14.229.27

Examined and found correct.

(Signed)

JOHN H. HINTON,
Chairman,
For Finance Committee.

REPORT OF THE LIBRARIAN.

The work of the Library during the past year has been mainly directed toward keeping the accessions catalogued and in order. This, it is believed, has been successfully carried out. The current numbers of the more prominent periodicals are placed upon accessible shelves and upon the completion of any volume are arranged permanently with their respective sets. In this connection it is desirable to call attention to the crying need of binding many of the accessions of late years. Hundreds of volumes are stored in their pamphlet form, and much injury and loss is the result. During the last year the Librarian was able to have some sixty volumes bound, but financial stringency has prevented any considerable work in this direction.

By arrangement with the authorities of the New York Botanical Garden, the bulk of the botanical portion of the library, which since the removal to Schermerhorn Hall at Columbia

University had been stored in boxes, has now been deposited in the library of the Garden at Bronx Park, and is thus more available than heretofore for general reference.

The Librarian takes pleasure in reporting a gift to the Academy from Professor D. S. Martin, of about a hundred volumes of miscellaneous scientific interest.

The statistics of the Library are at this date approximately as follows : Volumes (bound and unbound) at Columbia University, 9,000 ; Pamphlets at Columbia University, 2,000 ; Volumes and Pamphlets at Columbia University, 350.

Thanks to the activity of Messrs. Van Ingen and White, assisted by Mr. Graham, the files of the Academy's publications have been brought from a state of chaos to one of order, the exchange list has been revised, and the business of correspondence and exchanges is now carried on with promptness and regularity. The Librarian takes this opportunity to call the attention of the Academy to the absolute necessity of considering the disposition of the library in the immediate future. We have practically reached the limit of accommodations in the library room, and the department of exchanges is housed in the Gallery of the Museum of Fossil Plants and Vertebrates, in Schermerhorn Hall of Columbia University, solely by courtesy of the Department of Geology, and has already exceeded the space which that department can conveniently spare. Radical measures must be adopted in the near future or the library must close its doors.

Respectfully submitted,

Livingston Farrand,

Librarian.

BUSINESS MEETING.

March 4, 1901.

Academy met at 8:15 P. M., President Woodward presiding.

The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows :

That a budget had been adopted for the ensuing fiscal year ; that the Academy had voted to subscribe to the 5th International Congress of Zoölogists, and to appoint Professor E. B. Wilson delegate. That the meetings of the next year would be held at the rooms of the Chemists' Club, 108 West 55th Street. That the delegates to the Scientific Alliance would be President Woodward, *ex-officio*, Mr. Cox, and Professor H. F. Osborn.

RICHARD E. DODGE,
Recording Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

MARCH 4, 1901.

Section met at 8.25 P. M., Professor J. K. Rees presiding.

The minutes of the last meeting of Section were read and approved.

The following program was offered:

R. S. Woodward and **J. W. Miller, Jr.**, THE ELASTIC PROPERTIES OF HELICAL SPRINGS.

F. L. Tufts, A PHOTOGRAPHIC STUDY OF THE AIR MOVEMENTS NEAR THE MOUTH OF AN ORGAN PIPE.

Before the program of the evening, an election of officers of the Section was held, resulting in the election of Prof. William Hallock as Chairman and Dr. F. L. Tufts as Secretary of the Section for the ensuing year.

SUMMARY OF PAPERS.

In his paper, Dr. **Tufts** described preliminary experiments in which he applied the "method of striæ" similar to that used by Toepler, Boys, Wood, and others, to the study of the vibrations within an organ pipe. The pipe used had sides made of plane parallel glass plates. The tongue of air at the mouth of the pipe was made visible by using air mixed with alcohol vapor, which changed its optical density. The vibrations and air currents within the pipe were made visible by the introduction into the pipe of small jets of illuminating gas. The intermittent illumination used was the spark between magnesium ribbons from an induction coil. It was found quite easy to adjust the rate of interruption of the coil so as to produce a stroboscopic effect, and thus the movements of the tongue of air in the mouth of the pipe and the vibrations and air currents in the pipe could be readily followed.

The same method was also applied by the author to study the behavior of unignited jets of illuminating gas when acted on by sound waves.

The paper was illustrated by a number of photographs of the phenomena observed.

W. S. Day,
Secretary.

SECTION OF BIOLOGY.

March 11, 1901.

Section met at 8:15 P. M., Professor C. L. Bristol presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

H. F. Osborn, Systematic Revision of the American Eocene Primates and of the Rodent Family Myxodectidæ.

O. P. Hay, The Composition of the Shells of Turtles.

M. A. Bigelow, Some Comparisons of the Germ-Layers in Entomostraca Crustacea.

Prior to the reading of papers, a communication from the Secretary of the Academy was read, stating that a grant of $100 from the John Strong Newberry Fund had been authorized by the Scientific Alliance, and as the subjects in which an award might be made this year were Geology and Palæontology, he would be pleased to receive a nomination from the Section of Biology. On motion of Professor Osborn the matter was referred to a committee consisting of the Chairman and two additional members. The Chair nominated Professor Osborn and the Secretary of the Section.

Professor Charles L. Bristol and Dr. Henry E. Crampton were re-elected Chairman and Secretary respectively.

SUMMARY OF PAPERS.

Professor **Osborn** stated that the only fossil Primates at present known are those in the Eocene. The supposed Oligocene genera described by Marsh and Cope have proved to belong to the Artiodactyla. Associated throughout with the discovery and literature of the primates is the family Mixodectidæ, including *Mixodectes* of the basal Eocene or Torrejon beds; Mathew has suggested that this animal is a rodent. Careful comparison of this type with the supposed primates *Cynodontomys* of the Middle Eocene and *Microcyops* of the Upper Eocene proves that these animals also belong probably with the Rodentia; they represent a primitive stock with strong affinities to the Tillodontia which are thus brought nearer to the ancestral rodents. This conclusion removes all these animals from the primates where they have hitherto been placed. This leaves three families of monkeys as follows: Hypsodontidæ including *Hypsodus* and *Sarcolemur*, animals of medium size retaining the typical series of 44 teeth; a second family, the Notharctidæ, including *Pelycodus* and *Notharctus*, animals of larger size, with teeth reduced to 40 by the loss of 4 incisors, and like the foregoing, comprising long-jawed types; and the third family, the famous Anaptomorphidæ of Cope, short-jawed, very progressive types, with 36 to 32 teeth, the premolar series being reduced. The identification of these families with the Eocene *Adapidis* or with *Necrolemur* of Europe is not sustained. The Hypsodontidæ and Notharctidæ are well distinguished by sexituberculate superior molars.

Dr. **Hay** called attention to the fact that for a long time there has been much discussion regarding the origin of the elements entering into the shell of turtles. As to the bones known as costal plates, the great majority of anatomists have held that they have resulted from the union of dermal bones with the underlying ribs; the neural plates from the union of dermal bones with the neural arches. Recently Goette has studied the development of the costals and neurals of the young of *Chelone squamata*. He finds that the whole costal plate develops continuously from bone which appears beneath the perichondrium of the cartilaginous ribs. No part of either the costal plates or of the neurals arises in the skin. While accepting Goette's results as established, the speaker did not accept his conclusion. Neither did he accept the other view that the costals and neurals are composed of dermal bones united with those of the internal skeleton. The speaker held that there were originally three strata of bones on the dorsal surface of turtles. One of these was in the skin, and is represented by the mosaic found in the skin of *Dermochelys*. Another layer was sub-dermal, and this united with elements of the third stratum, namely the ribs and neural arches. The union has become so complete that the bones arise from the same centres. These three strata of bones on the dorsal surface correspond to those which are found in the ventral wall of the Caiman, viz., true ribs, "abdominal ribs," and bony dermal scutes.

Mr. **M. A. Bigelow** compared the germ-layers of various Crustacea with especial reference to the Cirriped *Lepas*. It was pointed out that in the cleavage leading to the segregation of the germ-layers there are very many resemblances between *Lepas* and other Entomostraca. *Lepas* resembles most other Crustacea with respect to the position of the blastopore, and the extension of the entoblast and mesoblast from that region as a starting point. In *Lepas*, as in most other Crustacea, the mesoblast and entoblast originate from cells which, speaking in general terms, at first lie in the blastoderm and later migrate into the cleavage cavity. But among these immigrating mesentoblastic cells one can distinguish the individual cells of entoblast and two varieties of mesoblast—entomesoblast and ectoblast. There are observations indicating that similar conditions exist in other Crustacea.

Henry E. Crampton,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

MARCH 18, 1901.

Section met at 8:15 P. M., Dr. A. A. Julien presiding.

The minutes of the last meeting of Section were read and approved.

Dr. A. A. Julien and Dr. Theodore G. White were re-elected Chairman and Secretary respectively.

The following program was then offered :

J. F. Kemp, THE CAMBRO-ORDOVICIAN OUTLIER AT WELLSTOWN, HAMILTON COUNTY, NEW YORK.

G. van Ingen, A METHOD OF FACILITATING PHOTOGRAPHY OF FOSSILS.

SUMMARY OF PAPERS.

In introducing the main subject of the paper, Professor **Kemp** gave a brief account of the physiographic problems presented in the Adirondacks and of the significance of the smaller outliers of Paleozoic strata which occur within the crystalline area. He then discussed the Wellstown exposure and described it in much the same way as he has already done in print in the 18th Annual Report of the State Geologist of New York, page 145. The general conclusion favored the existence of land areas of ancient crystalline rocks in the vicinity of Wellstown, and it seemed to the speaker that the peculiar sediments could not be explained in any other way. Pebbles as large as one's fist, of gneiss similar to that found in the ancient hills, are imbedded in the Trenton limestone, and much sand is found in the limestones of both the Calciferous and the Trenton. It was admitted that the present valley is due to faulting, as has been previously claimed by Doctor R. Ruedemann, but the shores of the late Cambrian and early Ordovician could not have been far from the present outcrops of the Palæozoics at Wellstown.

Mr. **van Ingen**, and Doctors **Levison**, **Dodge**, **White** and **Julien** took part in the discussion of the paper.

Doctor **Julien** remarked, in regard to the sand found in the limestones to which Professor Kemp referred, that although the smaller and angular portion of the sand, in which feldspar is common, and particles of garnet, epidote and menaccanite also occur, may possibly be residual, derived from decay of gneiss adjacent to the shores of the ancient basin, the predominant quartz grains, well-rounded and even perfectly spherical, could not possibly be of that origin. These Doctor Julien has already discussed before the Academy and elsewhere, pointing out that their sculpture indicates prolonged action during ages before they assumed spherical form and that although found in sediments, loose or consolidated, of all ages from the quartzites of the Laurentian down to the sea beaches of the present day, along river, lake and ocean, they represent in all cases ancient materials which have been worked up over and over again from period to period. In the Potsdam of the North American continent they have been accumulated in an extensive outer-beach deposit, the result of an enormous resorting of materials throughout the vast Cambrian time. These "paleospheres" were doubtless derived from the same Potsdam horizon which has yielded the oolitic quartz sand of the "singing beach" on the shores of Lake Champlain, near Plattsburg, not many miles from the Wellstown outcrop of the Ordovician limestones.

As to their method of transport, they had certainly not been swept into this limestone basin by currents, since the absence of sorting and the parallel disposition of their axes showed that they had been dropped down from the surface in a continuous gentle shower. The conditions which have favored this have been studied abroad as well as along our Atlantic coast and consist, first, of the coating of sand from the beaches along sheltered bays, such as Long Island Sound, on every quietly rising tide, then its seaward transport, often to hundreds of miles off the coast, commonly caught in the dredges of surveying steamers, as noted by Verrill and others, and its constant deposition over the bottom, as illustrated by soundings at great distances off Nantucket. Such a sand transport was plainly in progress over the quiet embayment occupied by this limestone, from surrounding beaches supplied from the decay and disintegration of an ancient shore of Potsdam and Calciferous sandstones. The various sands referred to in these remarks were illustrated by photomicrographs.

A Method of Facilitating Photography of Fossils was described by Mr. **Gilbert van Ingen.** The speaker noted the difficulties met by all investigators in the illustration of their specimens. All methods by which the published figure is derived from an original drawing produced by hand-work are dependent for their degree of correctness upon the accuracy of eye and skill of hand of the draughtsman. Such figures contain a variable percentage of the personal element which the artist unconsciously incorporates into his work. The majority of investigators find it difficult to. produce a drawing of satisfactory excellence and at the same time have not at their disposal the means wherewith to engage the services of a trained artist. Photography, often employed as affording a correct and cheap method of illustration, has, up to the present time, yielded results of varying and uncertain degrees of accuracy. The difficulty of obtaining a satisfactory negative from the object has caused direct photography to be looked upon by disfavor by many palæontologists. This difficulty is due to the effect upon the photo-plate of the colors and reflected light emanating from the surface of the specimen to be photographed. A method of illuminating these disturbing elements was sought and, at the suggestion of Professor Kemp, the use of ammonium chloride was tried.

A simple apparatus has been devised by which a fossil of any size can be coated with a thin, opaque, white film which effectually illuminates under the influence of both color and reflected light. The necessary articles for construction of the apparatus are : a foot-blower, large wide-mouthed bottle of gallon capacity, with three-holed rubber stopper, two bottles of quart capacity, each with two-holed rubber stopper, glass tubing of one-eighth-inch bore and rubber tubing to fit same (three feet of each), two U-shaped calcium chloride tubes filled with chloride, strong ammonia water, strong HCl. To use : Air from the foot-blower is forced into the large bottle, which equalizes the pressure, and thence through the ammonia water and HCl into the smaller bottles. The air, mixed with the gases taken up, is passed through the calcium chloride tubes, where the moisture is extracted, and escapes from the two glass tubes held in the hands at a short distance from the object to be coated. The union of the two gases escaping from the tubes forms ammonium chloride, which settles as an exceedingly fine powder upon the surface of the specimens. The coating thus obtained, when deposited slowly, is of a dead white, which effectually hides all coloration of the surface, and, instead of obliterating the finer modelling, renders the details of the topography with the utmost distinctness. Some surfaces take the coating more readily than others. Fine-grained black limestones and all other rocks that present a velvety surface, take the coating well. Porous rocks are difficult to cover. Specimens which have been handled must be washed with benzene. The coating of the salt is perfectly harmless, and may readily be removed by water, gentle heating, or the use of a soft brush. Photographs of such coated specimens fulfil more nearly the requirements of the work than do those taken by the ordinary methods. The coating is also of great assistance in the elucidation of the details of small species, as was found to advantage while studying the lobation of the heads of small trilobites. Since the above described method had been devised the speaker had learned of a similar method patented by Professor H. S. Williams. Claim 640,660 (Off. Gaz., 89, p. 2,602) is for "a photographic process consisting in the deposition by sublimation from vapor of a temporary film of extreme tenuity on surfaces of the object to be photographed, the film being of a character which removes itself by dissipation, or which may be manually removed without injury to the surface of the object." On the face of it this patent is different from the process described above, although the exact method employed has been guarded as a secret. The claim is for a method employing sublimation, which process, as known to chemists and assayers, does not enter in the least degree into the method described by the speaker.

The paper was discussed by Professors **Stevenson** and **Kemp** and Doctors **Levison, Julien** and **White.**

THEODORE G. WHITE,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

March 25, 1901.

Section met at 8:15 P. M., Professor Cattell presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

F. H. Giddings, The Use of the Term "Race."

Stansbury Hager, The Wards of Cuzco.

Summary of Papers.

Professor **F. H. Giddings** presented a paper on the use of the term "race." He spoke in part as follows: "The term "race" as used by many different groups of investigators—anthropologists, ethnologists, philologists and historians—long since ceased to have a definite meaning. Efforts to establish a technical and conventional use of the word have thus far been unsuccessful. As one more attempt I suggest a combination of the word 'race' with various descriptive adjectives, denoting successive degrees of kinship. The narrowest degree of relationship is consanguinity, or the relationship (physiological, psychological and sociological) of father and mother and children, brothers and sisters, grandparents and grandchildren, uncles, aunts and cousins. Let us designate this degree of kinship by K_1. The next degree of kinship, or K_2 is propinquity. The primary meaning of this word is 'nearness in place' and the secondary meaning is 'nearness in blood.' The word is thus perfectly descriptive of a state of facts which we find when a number of families live in the same neighborhood and, through intermarriage and association, become related (but less closely than the consanguini of K_1) in blood, in type of mind, and in institutions. K_3 is nationality, that wide degree of kinship (physical, mental and social) which includes those who speak the same language, and, for many generations, have dwelt together under the same political organization. K_4 is potential nationality, or the degree of relationship (physical, mental and social) of a heterogeneous people composed of many nationalities, undergoing assimilation, or blending, into a new nationality, as in the United States. Potential nationality includes the familiar census divisions, 'native born of native parents,' 'native born of foreign parents,' and 'foreign born.' K_5 is ethnic-race, a group of closely related nationalities, speaking closely related languages, and having well-marked psychological characteristics in common. Examples are, the Celtic ethnic-race, including the Welsh, the Irish, the Highland Scotch, some of the Cornish and the Bretons; the Teutonic ethnic-race, including Germans, Swedes, Norwegians, Danes and Dutch; and the Latin ethnic-race, including Italians, Spaniards and Greeks. K_6 is glottic race. This is that very broad relationship, to a slight extent physical, to a somewhat greater extent mental and social, of those related ethnic-races that speak languages derived from a common ancient tongue. Examples are, the Aryan glottic race, including the Celtic, Teutonic, Latin and other ethnic races; the Semitic glottic-race, and the Hamitic glottic-race. K_7 is chromatic race, that extremely wide and vague relationship, which includes related glottic-races marked by the same color. Examples are, the white chromatic-race, which includes the Aryan, Semitic and Hamitic glottic-races; the yellow chromatic-race, which includes the various glottic-races known as Mongolian or Turanian; the brown, the red and the black chromatic-races. K_8 is cephalic-race, or that widest relationship which includes chromatic-races of like cephalic index. The distinction about which I feel most doubt is this between chromatic- and cephalic-race. Remembering that, according to this scheme, variability and multiplicity of specific characteristics produced by differentiation, should increase as we proceed backward from K_8 to K_1, I think that probably cephalic index is rightly placed as K_8 and color as K_7 because, in the organic world in general, coloring seems to be a less stable characteristic than anatomical structure. The compound terms which I have here introduced are admittedly clumsy, but they have the advantage of conveying precise meanings. If a writer speaks of 'race' without a qualifying word, his reader must guess at his meaning. If he says 'cephalic-race,' 'chromatic-race,' 'glottic-race,' the meaning cannot be mistaken."

In reply to a question Professor Giddings said that the clan is developed between K^1 and K^2 and the tribe between K^2 and K^3.

The following paper was read by Mr. **Stansbury Hager,** on the "Wards of Cuzco." The speaker presented a portion of the evidence collected by him which tends to show that the twelve so-called wards of Cuzco, the ancient capital of the Inca Empire, were the terrestial representatives of the signs of the Peruvian zodiac. The evidence bearing on this hypothesis is divided into four main classes. In the first place, the system of 'mamas' under which the Peruvians regarded every material object as merely a product of the real spiritual essence, of which it was the expression, gave rise to an attempt to imitate on earth the features of the world above as observed in the heavens. This system, in turn, resulted in the production of an elaborate ritual, the features of which, each month, corresponded with the supposed attributes of the mama which governed the corresponding sign through which the sun was passing during that month. The ideas associated with the 'mamas' are shown to correspond with the names of the Cuzco wards. Again these names correspond very definitely with the names of the zodiacal signs upon the native star map of Salcamayhua. And finally the names of one or two of the wards can be identified directly with definitely known native constellations situated in the zodiac. The nature of the evidence thus adduced is such as to indicate that the native Peruvians had made remarkable advance in astronomical knowledge in times long anterior to the arrival of the earliest Europeans known to history.

The annual election of Section officers was held, resulting in the choice of Professor Livingston Farrand as Chairman, and Dr. R. S. Woodworth as Secretary.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

April 1, 1901.

Academy met at 8:15 P. M., Professor William Hallock presiding.

The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows:

That Mr. Edward D. Adams had qualified as a Life Member.

Letters of thanks were read from Professor James Geikie, and Mr. C. V. Boys, elected Honorary Members at the Annual Meeting.

Adjourned.

Richard E. Dodge,
Recording Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

April 1, 1901.

Section met at 8:15 P. M., Professor William Hallock presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

H. C. Parker, Experiments on Standards of High Electrical Resistances.

J. K. Rees, Remarks on Temporary Stars, with Especial Reference to the New Star in Perseus.

J. K. Rees, Photographs of Nebulae taken with the Crossley Reflector of the Lick Observatory.

Summary of Papers.

The paper by Mr. **H. C. Parker** gave an outline of Professor Rood's electrometer method of measuring high resistances. This method has been described by Professor Rood in the

American Journal of Science for October, 1900. Mr. Parker stated that by this method it seemed possible to measure resistances as great as 1,000,000,000 megohms while by the methods at present in common use the practical limit was stated to be about 100,000 megohms. The author gave the results of a series of measurements made on a new form of standard high resistance devised by Professor Rood. This form of standard consists of oxide of manganese on cobalt glass. It gives a convenient means for obtaining resistances of from one to ten thousand megohms. Most of the measurements were for the purpose of determining the best protective insulating material with which to coat the above resistances. The author stated that the work was still in progress.

The first paper by Professor **J. K. Rees** gave an outline of the present classification of variable stars and a history of the discovery of the new star in Perseus. A number of the theories to account for the phenomena was given and commented upon.

In the discussion of the paper, Mr. **C. A. Post** inquired concerning the evidently rapid transformations of energy taking place in the temporary star. Dr. **W. S. Day** suggested as a possible explanation the retransformation of much of the kinetic energy of the vibrating atoms into gravitational potential energy by the sudden expansion of the matter after collision.

The second paper by Professor **Rees** consisted of an exhibition of some very beautiful photographs of nebulæ which the Columbia Observatory had lately received from Mr. W. Campbell, the director of the Lick Observatory.

The photographs were taken by the late Dr. J. E. Keeler and an enthusiastic tribute was paid to him for his remarkably successful work in this field.

The photographs exhibited were:

1. Orion nebula, taken November 16, 1898; exposure 40 minutes.
2. Orion nebula, taken December 11, 1899; exposure 1 hour.
3. 51, M, Cannea Venaticarum, taken May 10, 1899.
4. Dumb-bell nebula in Velpecula taken July 31, 1899; exposure 3 hours.

5. Trifid nebula in Sagittarius ; exposure 3 hours.
6. The Pleiades, showing nebulosity.
7. Ring nebula in Lyra.
8. Crab nebula in Taurus.
9. Small nebula in Andromeda.
10. Spiral nebula M, 74, in Pisces.
11. " " in Pegasus.
12. " " in Triangulum.
13. " " in Ursa Major.
14. Net-work nebula in Cygnus.
15. M, 13, in Hercules—star cluster.

Reference was made to Keeler's determination of the radial velocities of nebulæ and to the distances of these masses.

After a brief discussion of the paper, the Section adjourned.

F. L. Tufts,
Secretary.

SECTION OF BIOLOGY.

April 8, 1901.

Section met at 8:15 P. M., Mr. M. A. Bigelow presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered :

E. B. Wilson, The History of the Centrosomes in Artificial Parthenogenesis, and its Relation to the Phenomena of Normal Fertilization.

F. S. Lee, Some Observations on Rigor Mortis.

Summary of Papers.

In continuation of his communication given at the December meeting, Professor **E. B. Wilson** presented the results of further studies on the development of the unfertilized eggs of *Toxopneustes* when treated by Loeb's magnesium chloride method. The principal points considered were the origin and history of the centrosomes and the general relation of the phenomena to those occurring in normal fertilization. Evidence was brought forward that the cleavage centrosomes of the primary division figure arise by the division of a single primary centrosome that is formed outside, but immediately upon, the nuclear membrane. As regards the chromatic transformation of the nucleus, two types of chromosome formation were described. In both cases a large nucleolus is formed, which attains a much greater size than in the fertilized eggs. In one type this nucleolus remains a plasmosome, or true nucleolus, which fades away at the time of division, the chromosomes arising nearly in the usual manner from the chromatin network. In the second type, the entire chromatic content of the nucleus is gradually accumulated in the nucleolus, which thus forms a chromatin-nucleolus from which the chromosomes are afterwards derived nearly in the same manner as in *Spirogyra.*

In regard to the accessory asters, or cytasters, it was shown that they contain central bodies often indistinguishable in sections from the centrosomes of the nuclear figure, though in many cases less well developed. Sections demonstrate that the division of the cytasters is preceded by division of the central body, which draws out to form a central spindle in a manner similar to that described by MacFarland in the eggs of gasteropods. This fact, taken in connection with the physiological activities of the cytasters seems to remove every doubt regarding the identification of the central bodies as true centrosomes.

In comparing the phenomena in the magnesium eggs with those of normal fertilization, it was pointed out that the formation of accessory asters at the time of fertilization or cell division, is a widespread phenomenon. In normal fertilization or division, the accessory asters are of a very transient character. In the magnesium eggs they attain a much greater development both structurally and functionally, but they are probably to be regarded as differing only in degree from those which appear during the normal process. In all cases their disappearance is probably due to a concentration of the protoplasmic activities about the more active centres, connected with the nucleus, which alone survive to perform the normal functions of division. Evidence was adduced that the nuclear transformation occurring in normal fertilization is not primarily due to the union of the sperm-nucleus, or sperm-centrosome, with the egg-nucleus, but to a general stimulus of the ovum effected by the entrance of the spermatozoon. Apart from the different character of the stimulus, this transformation of the egg-nucleus does not differ essentially from that taking place in the magnesium eggs. This is proved by the fact that in etherized eggs the egg-nucleus may undergo the karyokinetic transformation *without union with the sperm-nucleus or centrosome*—an observation which agrees with the much earlier results of O. and R. Hertwig on eggs treated with chloral hydrate. In normal fertilization this activity of the egg-nucleus is modified through its union with an active individualized sperm-centrosome, the presence of which inhibits the formation of an egg-centrosome such as occurs in the magnesium eggs.

The paper was discussed by Mr. **Bigelow**, Dr. **Calkins**, and Dr. **Linville**.

Professor **F. S. Lee** stated that rigor mortis is characterized by a shortening of the muscles of the body, accompanied by a coagulation of the contents of the muscle cells. The nature of the phenomenon is disputed. Hermann has long insisted that it is analogous to muscular contraction and is the final vital act of the dying muscle cell.

In connection with the studies of muscle fatigue, the author, with Mr. C. C. Harrold, has made some observations on cat's muscle, which seem to contradict Hermann's conclusion. Fasting, which is characterized especially by a diminution of the free carbohydrates in muscle, hastens the oncoming of rigor mortis. The administration of the peculiar drug, phlorhizin, which eliminates both the free and the combined carbohydrates, has a similar but much more pronounced effect. On the other hand, the ingestion of grape-sugar by a phlorhizinized animal, delays rigor. Hence the conclusion seems justified that the absence of carbohydrates is favorable, and their presence unfavorable to the development of rigor mortis. As regards the ability of the muscle to contract, carbohydrates have exactly the opposite effect, their absence being unfavorable and their presence favorable. Hence, in this respect, contraction and rigor mortis are not analogous processes.

Henry E. Crampton,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

April 15, 1901.

Section met at 8:15 P. M., Dr. A. A. Julien presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

Gilbert van Ingen, The Silurian Fauna of Batesville Arkansas.

Heinrich Ries, The Iron Mines of Bilbao, Spain. Illustrated.

Theodore G. White,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

April 22, 1901.

Section met at 8:15 P. M., Professor Livingston Farrand presiding.

The minutes of last meeting of Section were read and approved.

The following program was then offered:

A. L. Kroeber, Notes on the Arapahoe Indians.

C. H. Judd, Practice in Visual Perception.

E. L. Thorndike, Origin of Human Intellect.

R. S. Woodworth, Voluntary Control of the Force of Movement.

Professor Eberhardt Fraas, of Stuttgart, a corresponding member of the Academy, was introduced by Professor Osborn, and briefly addressed the meeting.

In Mr. **Kroeber's** paper the social and ceremonial organization of the Arapahoe Indians was compared with that of other Plains Indians. On superficial examination various tribes appear to be organized according to identical principles, but fuller knowledge generally reveals differences among the similarities. From this it was concluded that such terms as gens, band, age-fraternity, and dance-society have no stable or exact meaning, and hence little descriptive value, detailed information being the great desideratum.

Professor **C. H. Judd** reported an experimental study in PRACTICE IN VISUAL PERCEPTION. It is a generally recognized fact that an illusion grows weaker as the observer becomes more familiar with it. A quantitative determination of the disappearance of the illusion seen in the Muller-Lyer figure was the subject of the paper. Two series of results were reported, one from an observer who did not know that the illusion would disappear, and did not discover that it was disappearing. In both cases the illusion disappeared in about 1,000 observations. The curves of practice differ in form and show many details of effects of pauses. In the case of the first observer the effects of the practice gained in the first series was easily marked in all the additional series which were performed with other figures, and with other positions of the first figure. In the case of the second observer the effect of the practice was in some cases positive, but in one case it was so decidedly negative that it exaggerated the illusion and prevented any disappearance of it through a series of 1,500 observations.

Professor **E. L. Thorndike,** in a paper discussing the ORIGIN OF HUMAN INTELLECT, proposed as a working hypothesis that the development of ideation and rational thinking in the human species was but an extension of the typical animal form of intellect. He defended this hypothesis by showing that mere increase in the number, delicacy, and complexity of associations between sense-impressions and impulses might give concepts, feelings of relationship and association by similarity as secondary results, that in the human infant this seems to occur, and that down through the vertebrate phylum a clear evolution of the associative processes along these lines could be traced.

The last report of the evening was by Dr. **R. S. Woodworth,** on the VOLUNTARY CONTROL OF THE FORCE OF MOVEMENT. By recording simultaneously the force of a blow struck by the hand and the extent of the movement preliminary to the blow, it is possible to see how far the force is dependent on the extent. The results showed a certain degree of correlation between the two, but comparatively a slight degree. The inference was that the force of the movement was only partially and loosely dependent on the extent, and that the control and perception of the force of a movement were in some measure direct and independent functions.

R. S. WOODWORTH,
Secretary.

BUSINESS MEETING.

MAY 6, 1901.

Academy met at 8:15 P. M., President Woodward presiding.

The minutes of the last business meeting were read and approved.

In the absence of the Recording Secretary Dr. F. L. Tufts was appointed Recording Secretary *pro tem.*

The Recording Secretary was authorized to cast a favorable ballot for the Academy in reference to the following recommendation from the Council:

"Voted to recommend to the Academy the election of Franz von Leydig, of Würzburg, Germany, as an Honorary Member of the Academy."

Voted, on motion of Professor Wilson, that the Academy send the following message of congratulation to Professor Leydig:

"The New York Academy of Sciences extends to Professor Franz von Leydig many hearty congratulations on the occasion of his eightieth birthday. In offering to Professor Leydig an election to Honorary Membership, the members of this Academy desire to express their appreciation of his long-continued services to science and of the profound and lasting influence that his memorable researches have exerted on the progress of zoology. With all best wishes they send him a cordial greeting from America."

President Woodward presented the accompanying minute respecting the death of Professor Henry A. Rowland, which was adopted and ordered incorporated in the minutes of the Academy.

Adjourned. F. L. Tufts,
Recording Secretary, pro tem.

Professor Henry A. Rowland.

The committee appointed to prepare a minute respecting the death of Professor Henry A. Rowland, would respectfully submit the following report:

The last half of the nineteenth century is remarkable as a period of great discoveries and advances in the mathematico-physical sciences. It is especially noteworthy for extraordinary progress in the theories of light, electricity, magnetism and thermodynamics. Soon after 1850 the phenomena of these intimately related theories were seen to unify themselves under the recently established doctrine of energy; and almost every application of this doctrine in the fields of those theories yielded a rich harvest of results.

Many distinguished names fall in the list of those who contributed to the advances of this period. Naturally, most of the pioneers, like Helmholtz, Joule, Clausius, Henry and Kirchhoff, have passed over to the silent majority. But a singular fatality has attended the most eminent followers of the earlier workers. Thus, within less than a quarter of a century, science has not only lost the distinguished Maxwell and his brilliant disciple Hortz, but is now called upon to deplore the untimely deaths, within a few weeks of one another, of the equally eminent physicists Fitzgerald and Rowland.

Professor Henry Augustus Rowland, an Honorary Member of the New York Academy of Sciences since 1900, was born at Honesdale, Pa., November 27, 1848. His death occurred at

Baltimore, Md., April 16, 1901. His early academic studies were pursued at the Rensselaer Polytechnic Institute, from which he was graduated with the degree of Civil Engineer in 1870. After a brief career as a teacher at Wooster College and at Rensselaer Institute he became connected with the Johns Hopkins University. Appointed professor of physics in that institution in 1876, he devoted the remainder of his life to the work of instruction and investigation in mathematical physics. In both lines of work he set and maintained a high standard. His laboratory speedily came to be recognized as a source of fundamental knowledge; and a number of the researches carried out therein by him and his pupils are amongst the most noteworthy of the nineteenth century. Of these, especially important are his determination of the mechanical equivalent of heat, and his analysis of the solar spectrum by aid of his incomparable concave diffraction gratings. The skill and success with which he executed these investigations give him rank along with the ablest experimenters and theorists of his time.

Professor Rowland was devoted to science with rare fidelity and tenacity of purpose. No baffling obstacles discouraged him in the pursuit of truth. He was animated by a high ideal. "But for myself," he said in one of his addresses, "I value in a scientific mind most of all that love of truth, that care in its pursuit, and that humility of mind which makes the possibility of error always present, more than any other quality. This is the mind which has built up modern science to its present perfection. . . . It is the only mind which appreciates the imperfections of the human reason and is thus careful to guard against them. It is the only mind that values truth as it should be valued and ignores all personal feeling in its pursuit." These words explain at once his personal character and his course in life. With unflagging industry he consecrated his talents and his strength to the attainment of his ideal of the scientific mind.

R. S. WOODWARD,
Chairman.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

May 6, 1901.

Section met at 8:15 P. M., Professor William Hallock presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

C. B. Warring, What Theology Owes to Modern Science.

C. C. Trowbridge, A Differential Astatic Magnetometer Suggested by Professor Rood.

Summary of Papers.

The paper by Mr. **C. B. Warring** was a very interesting interpretation of the story of the creation, as found in Genesis, in the light of modern scientific theories. The author defended the thesis that the order of events given in the first chapter of Genesis did not necessarily contradict the order assumed by modern science.

The paper was followed by a very interesting discussion.

The essential part of the magnetometer described by Dr. **C. C. Trowbridge,** is the suspension system, which consists of two groups of small magnets set 23 cm. apart, and rigidly connected by a fine glass fibre. The system is suspended by a single raw silk fibre 10 cm. long. By making the polarity of the two groups of magnets opposite, a system that is approximately astatic is obtained.

The object of the arrangement employed is partly to annul the effects of distant magnetic disturbing influences, such as those that arise from trolley-car motors, etc., and partly to obtain a sensitive system, acting on the differential principle.

A magnet placed within a meter of the instrument and outside the neutral plane between the two groups of magnets acts strongly on the nearest group, producing a deflection of the system. The instrument was used in relative determinations of magnetic movements.

Mr. Trowbridge also gave a preliminary note on some experiments conducted by him on the influence of liquid air temperatures on the magnetization of steel and iron.

Adjourned.

F. L. Tufts,
Secretary.

SECTION OF BIOLOGY.

May 13, 1901.

Section met at 8:15 P. M., Professor C. L. Bristol presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

R. Weil, A Contribution to the Problem of the Ear-Bones.

A. G. Mayer, On the Variation of Snails of the Genus *Partula* in the Valleys of Tahiti.

O. S. Strong and **C. E. Doran,** A Case of Unilateral Atrophy of the Cerebellum.

Summary of Papers.

Dr. **Weil's** paper was a critical discussion of the theory of the ear-bones, as embodied in the recent articles of Gaupp and Kingsley. Two main contentions were considered: First, that the malleus and incus of mammalia were homologous with the quadrate and articular of lower forms, while the temporo-maxillary articulation is a new formation; second, that the ossicles of mammalia cannot possibly have descended from those of Sauropsida. The first contention is based upon the embryonic connection of malleus and incus with the Meckelian bar, upon the embryonic situation of the last anterior to the Eustachian tube, and upon the innervation of the muscle of the malleus by a branch of the trigeminus. Embryonically, however, the malleo-incudal complex, in addition to its continuity with the Meckelian bar, arises from the auditory capsule, which contributes to both malleus and incus, the stroma of the tympanic cavity, contributing to the manubrium mallei, and a membrane bone which forms the Fallopian process. Furthermore, as Gegenbaur points out, the continuity of malleus and incus, if they be the quadrate and articular, is itself in contradiction to the independent embryonic origin of these elements in the lower forms. The pretrematic origin of the ossicles in the pig, as described by Kingsley, is contrasted with their postrematic, or hyoidean, origin in lower forms. Dr. Weil stated that his studies of a full series of pig and opossum embryos did not enable him to decide whether the malleus, and still more, the incus, lay primarily in front or behind the tube. The bones cross the anlage of the tube in a transverse direction, lying above it; by the gradual absorption of the intervening stroma they come to occupy the cavity of the tympanum. Finally, the innervation of the tensor tympani muscle of the malleus by a branch from the otic ganglion of the trigeminus is taken to indicate the relation of the malleus to the mandibular arch. But lesions of the trigeminus at its root do not involve hearing, while the contrary is true of lesions of the facial. This fact would point to the origin of the above-mentioned nerve from the seventh nerve, and would make the malleus a part of the second arch. The second contention is supported, first, by the difference in the embryonic relations of the bones to the Eustachian canal, an argument already considered, and second, by the differences in the relations of the chorda tympani nerve, which in Sauropsida crosses *above* the chain, and in mammalia *below* it. The speaker showed that the pathologists, from a comparison of a large number of lesions of the trigeminus and of the facial at the base of the brain, had demonstrated the exit of the chorda tympani in man with the roots of the former. But since it leaves the brain in lower forms with the seventh, its relations to bony structures are evidently not sufficiently constant to constitute a criterion of homologies. From these facts, it would appear that the homology of malleus and incus with the quadrate and articular has not yet been demonstrated.

Dr. **Mayer** showed that the snails in question are subjected to conditions of isolation very similar to those affecting the Achatinellidæ of Oahu in the Hawaiian Islands, occurring in valleys which are separated by comparatively barren ridges. The farther apart the valleys, the less intimate is the relationship beneath their snails. Although geographical isolation is probably the chief factor in determining the establishment of definite varieties, yet the differing environmental conditions obtaining in each valley may exert considerable influence.

Dr. **Strong** presented a preliminary report, illustrated by lantern slides, upon a case of unilateral atrophy of the cerebellum in a child which lived to the age of three years and four months. The principal external anomalies noted were the following : the left hemisphere of the cerebellum was almost entirely absent ; the right olive was wanting and the transverse pontile fibres on the left side were deficient ; the left half of the pons protruded more than the right ; the right crus cerebri was much narrower than the left ; the left restiform body was smaller than the right, and the superior cerebellar peduncle of the left side was deficient ; the posterior corpora quadrigemina were asymmetrical, while the left anterior corpus quadrigeminum was apparently lacking ; the median line of the fourth ventricle was curved with its convexity toward the left, and such structures of the medulla as the clava, cuneus, ala cinerea, and eminentia teres were located or extended further cephalad on the left side than on the right. Preliminary transverse sections cut at various levels through the medulla, pons, isthmus, and posterior corpus quadrigeminum showed the following points : only small parts of the right olive and left corpus restiforme were present, and there was a corresponding deficiency of the cerebello-olivary fibres ; the transverse pontile fibres on the left side were reduced, but the nuclei pontis were larger on the left side ; the longitudinal pontile fibres were deficient on the right, as shown by the smaller orus cerebri of this side ; the left lemiscus was the smaller, and the left superior cerebellar peduncle was reduced. Other deficiencies were noted, which, however, require further study. Full discussion of the case was postponed, as the research is as yet uncompleted.

Henry E. Crampton,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

May 20, 1901.

Section met at 8:15 P. M., Dr. A. A. Julien presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

William D. Matthew, Conditions of Deposition of the Fossil Mammal Beds of the West.

Richard E. Dodge, The Toroweap Valley in Arizona.

Theodore G. White,
Secretary.

BUSINESS MEETING.

October 7, 1901.

Academy met at 8:25 P. M., President Woodward presiding.

The minutes of the last business meeting were read and approved.

The President, in welcoming the Academy to its new quarters, and its new year's work, emphasized particularly the necessity of increasing the number of our members, and suggested the possibility of holding joint meetings of the several sections occasionally, for the purposes of discussing subjects of mutual interest.

The Secretary reported from the Council that a letter of congratulation had been sent to Professor Rudolf Virchow, of Berlin, on the occasion of his eightieth birthday.

Adjourned.

Richard E. Dodge,
Recording Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

October 7, 1901.

Section met at 8:15 P. M., Professor William Hallock presiding.

The minutes of the last meeting of Section were read and approved.

The meeting was devoted to the presentation of reports of summer work by members.

Summary of Papers.

Professor **William Hallock** reported that he had tried and failed to secure permission of the Calumet and Hecla Company to make measurements of underground temperatures in their shaft at Keweenaw Point. He gave a brief review of the report upon underground temperatures rendered to the British Association at their Glasgow meeting (1901).

Professor Hallock also described a new and very simple form of wired musical instrument which he found on sale at the Buffalo Exposition. The instrument was operated by blowing through the nose, and the mouth cavity of the operator acted as the resonance chamber. The tone quality of the instrument was very similar to that of a flute. One of the instruments was exhibited before the Section.

Professor **J. K. Rees** reported that the Astronomical Department of Columbia University had recently received from the Lick Observatory a number of star photographs which were to be measured for the determination of parallax.

Professor **Harold Jacoby** reported upon some photographs of stars near the celestial poles, which had been received by the Astronomical Department of Columbia.

Professor **R. S. Woodward** reported the results of an investigation he had carried on upon the effects of secular cooling and meteoric dust on the length of the terrestrial day. His investigation showed that, due to secular cooling, the length of the day will not change or has not changed as the case may be, by so much as a half second in the first ten million years after the initial epoch, and that the total effect from secular cooling will accrue before the effect from meteoric dust will begin to be appreciable.

Professor **Doremus** gave a brief account of the research laboratory in chemistry which had been lately established at Schenectady, N. Y.

Adjourned.

F. L. Tufts,
Secretary.

SECTION OF BIOLOGY.

October 14, 1901.

Section met at 8:15 P. M., Professor C. L. Bristol presiding.

The minutes of the last meeting of Section was read and approved.

The evening was devoted to the presentation of reports on summer work by members.

Summary of Papers.

Professor **E. B. Wilson** described his work carried during the early part of the summer at Beaufort, N. C., where he had been successful in making further observations upon the fertilization phenomena in living sea-urchin eggs treated with various chemicals. Professor Wilson spoke also of the meeting of the International Congress of Zoologists at Berlin, which he had attended as a representative of the Academy, and where he had acted as Chairman of the Section on Experimental Biology. It was before this section that papers of the greatest interest were presented by Driesch, Bütschli, Roux, Ziegler, and many others.

Professor **Bashford Dean** told of some of the results he had obtained during his work in Japan of more than a year. Special endeavors were made to obtain embryological material of the important shark-types *Cestracion*, and *Chlamydoselachus*. In eggs of the former, there appeared to be a series of cleavage planes in the yolk, extending out from the blastoderm proper. Some *Chlamydoselachus* material was obtained. A new hagfish, intermediate in gill-characters between *Bdellostoma* and *Myxine*, together with a new *Chimæra*, was found in deep water.

Professor **F. S. Lee** reported briefly upon a research recently made in his laboratory by Dr. William Salant upon the action of alcohol on muscle. The details of this work will be communicated by the Academy later. Professor Lee then gave an account of the Fifth International Physiological Congress which was held at Turin in September.

Dr. **H. R. Linville** described the location and work during the summer of the Dominion of Canada laboratory at Cansa, Nova Scotia, which is under the direction of Professor Prince. Many investigators were in attendance, among them Professor Ramsay Wright, of Toronto. Dr. Linville's work, upon the natural history of annelids, was continued later at Woods Holl.

Dr. **G. N. Calkins** reported upon the work at the Woods Holl station of the United States Fish Commission, in charge of the Scientific Director, Dr. Hugh M. Smith. Dr. Calkins' work consisted of a survey of the protozoa of the waters of the station, and also included a continuation of his experiments upon senile degeneration in *Paramœcium*. A paper on this subject will be presented at an early date.

Professor **F. E. Lloyd** spoke of his cytological studies carried on during the spring in Strasburger's laboratory at Bonn. A series of botanizing trips in Germany and Switzerland was also described, as well as the meeting of the International Congress of Botanists at Geneva.

Mr. **J. C. Torrey,** who spent the summer at the Beaufort, N. C., station of the U. S. Fish Commission, reported a successful season. He obtained a further series of the eggs of *Thalassema*, enabling him to carry forward his work upon the cytogeny of this form.

Dr. **A. G. Mayer** described the results of dredgings in the waters of Massachusetts Bay, carried on by him, with Dr. Gerould of Dartmouth. Besides collecting considerable museum material for the Brooklyn Institute, he obtained extensive data bearing upon variation in star fishes.

Mr. **W. E. Kellicott** spoke of the summer's work at the Cold Spring Harbor laboratory, where he had been a John D. Jones scholar. A good attendance was reported.

Professor **C. L. Bristol,** who had again conducted the work of the N. Y. University Laboratory at Bermuda, described an interesting change in the distribution of many species as the result of a protracted winter's storm. Forms previously scarce or absent from the shores of the bay near the laboratory appeared this summer in profusion, while large areas of the exposed reefs, or "flats" were swept bare.

Professor **Crampton** reported a good season at the Marine Biological Laboratory at Woods Holl. The classes were well attended, and a goodly number of investigators were present. A brief statement was made regarding the survey of the invertebrate fauna of Long Island, carried on during the spring and summer by the Columbia Department of Zoology, with funds given by an anonymous donor for the purpose. A station was established at Bay Shore, favorably situated on Great South Bay opposite the Fire Island Inlet from the open ocean. Among the numerous forms obtained, a large *Balanoglossus* and a fine *Clymenellid* were of special note.

Mr. **C. W. Beebe** described his attempts to rear various birds at the Bronx Zoological Garden. Many interesting observations were made on the length of time which might elapse after egg-laying without rendering the eggs incapable of incubation, with a view to the possible importation of eggs of rare foreign birds.

Henry E. Crampton,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

October 21, 1901.

Section met at 8:15 P. M., Dr. A. A. Julien presiding.

The minutes of the last meeting of Section were read and approved. The names of two candidates for resident membership were read and referred to the Council according to the By-Laws.

In calling the meeting to order the Chairman spoke of the sudden death during the summer of Dr. T. G. White, Secretary of the Section, and of the death of Professor Joseph LeConte, Corresponding Member of the Academy.

Dr. E. O. Hovey was elected Secretary of the Section and Professor R. E. Dodge, Secretary *pro tem.*, owing to the absence of Dr. Hovey.

A committee consisting of Professor Stevenson and Professor Kemp was appointed to draw up suitable minutes in reference to the deaths of Dr. White and Professor LeConte.

PROGRAM.

A. W. Grabau, RECENT CONTRIBUTIONS TO THE PROBLEM OF NIAGARA. Illustrated.

J. F. Kemp, A NEW ASBESTOS REGION IN NORTHERN VERMONT. NOTES ON THE PHYSIOGRAPHY OF LAKE GEORGE.

SUMMARY OF PAPERS.

Mr. **Grabau** said that Davis has shown that the topography of the Niagara region conforms to the type generally found in ancient coastal plains, the original features of which have been more or less modified by subsequent warpings, and by glacial erosion and deposition.

The Niagara escarpment is the inface of the Niagara cuesta, traceable through the Indian peninsula and Grand Manitoulin Island. The Ontario lowland is continued in the Georgian Bay lowland. A second cuesta—the Onondaga—has its inface slightly developed north of Buffalo, but becomes prominent in the Lake Huron valley, where its inner lowland forms the deeper part of the lake. The third cuesta and lowland (the Erie) occurs north of the second.

The Tertiary drainage is supposed to have been to the southwest, instead of the northeast, as Spencer holds. The principal streams of that time are supposed to have been (1) the Saginaw —whose path is indicated in part by Saginaw Bay and the deep channel between the Indian peninsula and Grand Manitoulin Island ; (2) the Dundas, breaching the Niagara cuesta at Hamilton, Ont., and crossing the Erie lowland near Fort Stanley, and (3) for a time, at least, the Genesee, though this may later have had a northward course. The subsequent streams tributary to these consequents carved the various lowlands. St. David's Channel is regarded as an obsequent stream, which was accidentally discovered by the Niagara. The whirlpool gorge was probably, in part, the southward continuation of this stream, and not wholly postglacial.

Mr. Grabau's paper was discussed by Professor **Dodge** and Dr. **Julien**.

In speaking of the new asbestos region in northern Vermont,[1] Professor **Kemp** said that asbestos had recently opened up on a commercial scale in the towns of Eden, Lamoille county, and Lowell, Orleans county, Vt. The towns are adjacent, though in different counties. The asbestos lies from 15 to 25 miles north of Hyde Park, a station on the St. Johnsbury and Lake Champlain R. R. As is quite invariably the case, it occurs in serpentine, either in veins, or in matted aggregates along slickensided blocks. The serpentine where the best fibre is found lies on the south shoulder of Belvedere mountain, and forms an east and west belt. It is bounded on the north and west by hornblende schist, which forms the summit of the mountain. The contact on the west is a visibly faulted one, and that on the north is probably also of the same sort, because the hornblende-schist rises in a steep escarpment.

The serpentine seems to have been derived from enstatite, since unaltered nuclei of this mineral are found in it. The vein of asbestos ranges from a fibre of microscopic length up to ¾ of an inch as thus far exposed. It is fine and silky and of excellent grade. It would, however, be classed as second grade according to the Canadian practice, which makes a first grade of fibre above ¾ of an inch (about 2½ in. being the maximum), and a second grade of ⅜ in. to ¾ in. All below this and all fibre not vein-fibre goes to the mill and is mechanically separated, as the third grade. In the Vermont localities the slip fibre is exposed on the property of the New England Co., and of its neighbor the American Co. The vein fibre is limited, so far as yet opened up, to the property of Mr. M. E. Tucker and associates.

It is difficult with the data in hand, which were gathered under the direction of Dr. C. W. Hayes, of the U. S. Geological Survey, to trace the geological history of the serpentine, but it must have been originally either an igneous pyroxenite, or a richly magnesian siliceous limestone. There are such slight traces of calcium-bearing minerals, however, that the former supposition has the greater weight. The hornblende schist con-

[1] Communicated by permission of the Director of the U. S. Geological Survey.

sists of common green hornblende and of an unusual amount of titanite, there being little less than those two present.

Physiography of Lake George.—Observations extending over several years have suggested the following conclusions. Lake George occupies a submerged valley very similar to many others in the Adirondacks, which are not submerged. The valley has been largely produced by faulting, and the fault-scarps still remain in precipitous cliffs, whose sharpness has not been much affected by weathering and erosion. Before the Pleistocene, the valley was probably a low pass with both a north and a south discharge. The portion rich in islands near Pearl Point, and the Hundred Island House, was probably the divide, and the islands represent the old hillocks near the top of the divide. At the south the water is backed up by sands and morainal matter in the valleys on each side of French Mountain, viz., at the head of Kattskill Bay, and at Caldwell. On the north they are held in by Champlain clays and syenitic gneiss at the Ticonderoga outlet, and probably by morainal material at the low pass just south of Rogers Rock and leading out to the very depressed Trout brook valley, just west of Rogers Rock and Cook Mountains. Trout brook is now as much as a hundred feet lower than Lake George at points south of the Ticonderoga barrier. The northern barrier is rock because the Ticonderoga river passes through a narrow and shallow channel in the exposed ledges a mile south of its actual first waterfall. There is a broad flat valley buried in clays, however, beneath which an old channel may lie submerged. At the same time, the marked depth of the Trout brook valley to the west makes this the natural outlet and there is reason to believe from the general topography that the discharge passed north into the Champlain valley near the south boundary of Crown Point. It is also not to be overlooked that a valley with much drift leads eastward to Lake Champlain, from the head of Mason's Bay.

A curious feature that is common to both shores of the lake north of Sabbath Day point (and perhaps also south of it), is the presence of pot holes of great perfection and as high at times as 30 feet above the present level of the lake. These are best developed on Indian Kettles point, about two miles north of Hague. They were doubtless excavated by lateral or subglacial streams when the ice filled the lake valley, because in no other conceivable way could flowing water be forced into such unnatural situations.

There is great need of a good hydrographic survey of the lake, and of detailed pilot charts, with soundings. They would be of great service, not alone to navigators, but to science as well. So far as could be learned from local fishermen, whose deep trolling for lake trout gives them familiarity with the bottom, there appear to be channels whose general trend is parallel with the long dimension of the lake, and which have precipitous sides, precisely like the valleys and gulches now visible. The lake is relatively shallow as compared with Lake Champlain. In Lake George the greatest depth is believed to be near Anthony's Nose, and to reach 190 feet. Elsewhere the deep parts are placed at about 100 feet, more or less. All this, however, requires confirmation by soundings and with regard to the physiography one cannot say to what extent the bottom of the valley has been filled by drift, but the islands to which physiographic importance has been given by the speaker are rock.

Professor Kemp's first paper was discussed by Dr. **Julien** and Dr. **Martin**; the second by Dr. W. P. **Northrup**, Professor **Dodge** and Dr. **Julien**.

Adjourned. RICHARD E. DODGE,
Secretary, pro tem.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

OCTOBER 28, 1901.

Section met at 8:25 P. M., Professor Livingston Farrand presiding.

The minutes of the last meeting of Section were read and approved. The names of two candidates for resident membership were read and referred to the Council according to the By-Laws.

The following program was then offered:

J. McK. Cattell, Psychology at the Denver Meeting.

G. G. McCurdy (Yale), Anthropology at the Denver Meeting.

Franz Boas, Anthropology in Berlin.

H. H. St. Clair, 2nd, Report of Field Work in Wyoming and Oregon.

William Jones, Report of Field Work in Iowa and Oklahoma.

Summary of Papers.

Professor **J. McK. Cattell** made a brief report regarding psychology at the Denver meeting of the A. A. A. S.

Professor **G. G. MacCurdy**, of Yale University, reported on anthropology at that meeting, and in addition described the explorations that are being carried on in the Mesa Verde of southwestern Colorado by the Colorado Cliff Dwellings Association.

Professor **Franz Boas** described the facilities for anthropological study in Berlin, as observed by him in a recent visit. Within the last 20 or 30 years, the anthropological equipment of Berlin has progressed enormously. The museum now contains better East Indian collections than can be found in England; and it is strong in nearly all departments, notably so in American and especially South and Central American anthropology. Fifty scientific workers are engaged on these collections, and 16 of these are at work on American subjects. Besides the museum, there are several other institutions in Berlin, such as the Anatomical Institute of Waldeyer and the Pathological Institute of Virchow, in which anthropological work is done.

The leader of German anthropology is Virchow. He disbelieves in the study of the variation of the whole body, and insists that only the study of the variation in the individual cells of the body can lead to fruitful results.

H. H. St. Clair, 2d, reported observations made last summer among certain Indian tribes in Wyoming and Oregon.

William Jones also reported observations made during the past summer. The work of Mr. Jones was carried on among the Sauks and Foxes, a people of Algonquin stock. One band of this people is located in central Iowa, and another in Oklahoma. Both bands practice similar customs, live in much the same way, wear the same kind of dress, show similar physical types, and, with the exception of certain differences in idiom, and with the exception that the Iowa band have a slower, more deliberate pronunciation, they speak the same tongue. The Iowa band is the more conservative, and among them the law of the clans still holds. The education of the children is accomplished not by instruction but by imitation. The older boys imitate the men, and the younger boys imitate the older ones ; and similarly with the girls. The life of the children is but a smaller edition of the life of the older people.

Adjourned.

R. S. Woodworth,
Secretary.

BUSINESS MEETING.

November 4, 1901.

Academy met at 8:15 P. M., Professor William Hallock presiding.

The minutes of the last business meeting were read and approved.

Dr. F. L. Tufts was elected Secretary *pro tem.*

The Secretary reported from the Council as follows :

1. That in accordance with the Constitution, notice is given that at the December meeting there will be an election of a Councillor to fill the vacancy caused by the resignation of Professor Judd.

2. That the Council had voted to coöperate with the Ethnological Society in extending a cordial invitation to Professor A. C. Haddon, of Cambridge University, England, to deliver a lecture before the Academy and the Ethnological Society at some early date in December.

3. That Professor Franz Boas has been appointed representative of the Academy on the general committee for the 13th International Congress of Americanists.

The following candidates for resident membership, approved by the Council, were duly elected:

Amadeus W. Grabau, Ph.D., Columbia University.

Charles Holt, 255 West 45th Street.

Professor E. A. Lough, School of Pedagogy, N. Y. University.

Professor Robert MacDougal, School of Pedagogy, N. Y. University.

The name of one candidate for resident membership was referred to the Council according to the by-laws.

F. L. Tufts,
Recording Secretary,
pro tem.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

November 4, 1901.

Section mets at 8:15 P. M., Professor William Hallock presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

S. A. Mitchell, Report of the Recent Eclipse Expedition to Sumatra.

William Hallock, A Review of the Report of the British Association Committee on Underground Temperatures.

L. Boroschek and **F. L. Tufts,** A Study of the Absorption of Light by Dyes of the Fluorescein Group.

Summary of Papers.

The account of the Eclipse Expedition to Sumatra was illustrated by lantern slides showing the arrangement of apparatus at the several stations. The paper is published in full in a current number of *Science*.

Professor **Hallock** gave an account of some of the recent determinations of underground temperatures. This paper is also published in full in *Science*.

Dr. **L. Boroschek** gave an account of some work he had undertaken in connection with Dr. **Tufts** on the absorption of light by some dyes of the fluorescein group. The dyes studied were fluorescein and a number of its nitro-derivatives.

It was stated that Hewitt and Perkins (*Journal Chem. Soc.*, 1900, page 1324) claim that a double symmetrical tautomerism furnishes a satisfactory explanation for the fluoresence of Fluorescein, and that in the case of dinitro and tetranitro fluorescein this tautomerism is inhibited by a secondary tautomerism between the nitro and hydroxyl groups when in ortho position to each other. It was found that the mono-nitro-fluoresceins, obtained by us by condensing the 3-nitro and the 4-nitro-phthalic anhydrides with resorcin, in which the nitro group is on a different benzol nucleus from the hydroxyl groups show no fluorescence in alkaline solutions. According to the theory of Hewitt and Perkins alkaline solutions of such dyes should fluoresce.

Photographs of the absorption spectra of alkaline solutions of the dyes were taken and it was found that the substitution of nitro groups displaces the prominent absorption band of fluorescein toward the red end of the spectrum and increases the absorption in the ultra violet.

The absorption of light in the visible spectrum was studied by means of the flicker photometer. The amount of light transmitted by equal thicknesses of solutions of different concentrations was measured for the various dyes. A relation was thus obtained between the absorption of light and the concentration of the dye. The work is still in progress.

F. L. Tufts,
Secretary.

SECTION OF BIOLOGY.

November 11, 1901.

Section met at 8.15 P. M., Professor C. L. Bristol presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered :

H. F. Osborn, Dolichocephaly and Brachycephaly as Dominant Factors in the Skulls of Mammals.

F. E. Lloyd, Tetrad-formation in the Rubiaceae.

Summary of Papers.

Professor **Osborn** stated that the proportions of the skull in the lower mammals are no less distinctive than in the races of men. Although confined to the cranium in anthropology, the principles of dolichocephaly, mesaticephaly, and brachycephaly could be applied to the skull (*i. e.*, cranium plus face), and are found to illuminate the whole morphology of the skull and teeth, and in many cases the correlation with other parts of the skeleton. Dolichopodal and dolichocephalic, brachypodal and brachycephalic types are frequently but not invariably correlated, the numerous instances of non-correlation being due to exceptional adaptations in feeding. Apart from its relation to foot structure, skull proportion is, in evolution, progressively in one direction or the other, and is the underlying cause of hundreds of cranial and dental characters which have hitherto been described by comparative anatomists without appreciation of their true significance. The generalization was first made by the speaker among the rhinoceroses, was subsequently found to apply with equal force to the Titanotheres, and many other ungulates, unguiculates, and primates.

Professor **Lloyd** gave an account of the so-called tetrad divisions of the mother cells of the pollen and embryo-sac, in *Crucianella* (2 species), and *Asperula* (1 species). Briefly stated, these divisions are heterotypic and homotypic in the sense of Flemming and Strasburger. The pollen and embryo-sac divisions are homologous. In *Crucianella* all the megaspores undergo the first embryo-sac mitosis.

Henry E. Crampton,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

November 18, 1901.

Section met at 8:15 P. M., Dr. A. A. Julien presiding.

The following program was offered:

J. F. Kemp, Theodore G. White (Obituary).

J. J. Stevenson, Joseph Le Conte (Obituary).

E. O. Hovey, Notes on the Triassic and Jurassic Strata of the Black Hills of South Dakota and Wyoming.

A. A. Julien, Erosion by Flying Sand on the Beaches of Cape Cod.

On motion it was unanimously voted by the Section that the obituary notices of Messrs. White and LeConte be referred to the Council for printing in the *Records* of the Academy.

Summary of Papers.

Theodore Greeley White, Secretary of the Section of Geology and Mineralogy, in this Academy, passed away after a brief illness on the seventh of July, 1901. The announcement that one who was just entering upon the full exercise of his powers had fallen came to his friends with all the shock of a sudden bereavement. It is difficult to realize, even at this day, that one who had long been a faithful worker in this Academy is no more.

Mr. White was born in New York, August 6, 1872, and therefore lacked just a month of completing his twenty-ninth year. He was the only child of his parents, both of whom he had but recently lost. He fitted for college at the Columbia Grammar School, entered the School of Mines in the course in geology and palæontology in October, 1890, and received his degree of Ph.B. in June, 1894. He immediately registered for graduate work at Columbia, as a candidate for M.A., and received the degree in 1895. He continued his studies for Ph.D., and obtained it in 1898. He was appointed assistant in the Department of Physics in 1896, and held the position until 1900, being especially in charge of the experimental work in optics. The organization of this particular laboratory at the new site of Columbia largely fell to him, and in the work he displayed administrative abilities which won for him the warm commendation of his superiors.

As a boy Dr. White early manifested a special interest in natural science, and was an earnest worker in a chapter of the Agassiz society, which made its headquarters in the parish house of Dr. Mottet's church, and from which have been recruited several of our vigorous younger workers in science. While an undergraduate, he began investigations both geologial and botanical. His Ph.B. thesis was a description of the geology of Essex and Willsboro, towns on Lake Champlain, and was published in our *Transactions*, XIII., p. 214. His work led him to take up the study of the faunas of the Trenton in the Champlain valley for his doctorate. In the end he studied them not alone in this district, but all around the Adirondack crystalline area. He also carried on work for the State Museum under the direction of Dr. F. J. H. Merrill. In association with Professor Crosby, of the Massachusetts Institute of Technology, he described the petrographical characters of the Quincy granite. His complete work upon the Trenton remains to be issued as a posthumous paper.

Dr. White was a man of indefatigable industry and of great perseverance. Besides his efforts in geology, he had a number of additional undertakings in hand. He was especially interested in the parish work of the church with which he was connected (Church of the Holy Communion, Rev. Dr. Mottet, Rector, 6th Avenue and 20th St.), and the past spring he made up his mind to devote himself to a life-work among its young men. He was largely instrumental in founding Gordon House, a club house and centre of interest for them, and to it he has bequeathed his estate. Indeed, during an excursion to the neighboring seashore with his young men friends in the club, he became exhausted while bathing in the salt water, and took a cold, which developed into pneumonia, and caused his death after a brief illness. He has left a large circle of sincere and devoted friends, who can with difficulty reconcile themselves to his loss.

Joseph LeConte was born in Liberty County, Georgia, February 26, 1823, and died in Yosemite Valley, California, June 6, 1901. He was descended from Guilleaume LeConte, a Huguenot, who left Rouen, France, in 1685, and settled near New York City. Louis LeConte was a distinguished naturalist who was graduated from Columbia College, New York, in 1800, and soon afterward went to Georgia to take charge of a plantation inherited from his father. There he married. Of his seven children, John was the fourth and Joseph the youngest. The latter, after graduating at the University of Georgia, came to New York and studied medicine, receiving his degree in 1845. He practiced medicine for only three or four years, and then went to Harvard as a special student in zoology and geology, receiving in 1851 the degree of B.S.

His original purpose was to become a zoologist, but in 1850 he accompanied Professors Hall and Agassiz on a geological excursion through the Helderberg mountains of New York. In his own words, "It was my first lesson in field-geology. The intense interest developed in my mind by the rambles, the observations, and especially the discussions between these two men, definitely determined my chief scientific work in the field of geology rather than zoology."

After graduating at Harvard, Professor LeConte accompanied Professor Agassiz during the 1851 study of the Florida reefs, and upon his return was chosen Professor of Natural Science in Oglethorpe University, Georgia. From 1852 to 1856 he was Professor of Geology and Natural History in Franklin College, and from 1857 to 1869, of Geology and Chemistry in South Carolina College. During the Civil War he was chemist of the Confederate Medical Laboratory at Columbia, S. C., as well as of the Nitre and Mining Bureau. In 1869 he was called to the chair of Geology in the University of California, which he retained until his death. A singular proof of his reputation throughout the South at the close of the war, was the outburst of a Charleston journal in 1869, asserting that the election of the LeConte brothers to positions in the University of California was proof of the suspected conspiracy to cripple the South intellectually as it had been crippled materially.

Professor LeConte loved nature, he loved to wander where civilization had not destroyed its charms. In 1844, with his cousin, John L. LeConte, the entomologist, he journeyed in the northwest, travelling along the upper Mississippi more than one thousand miles in a birchbark canoe, and afterwards visited Lake Superior, piercing a region inhabited then almost wholly by Indians. In later years he spent his vacations in the Sierras, camping where he might make studies of structure. His life closed amid the scenes which had been so dear to him for more than thirty years.

Professor LeConte was a prolific writer. His early training, both as a student and as teacher, had given him a breadth of culture, which in this day of specialization is becoming too rare. He wrote upon physics, geology and psychology, making to each of these sciences contributions of capital importance. A vein of poetry runs through his papers, making his style almost unique in the scientific literature of our time. The excellence of his work was recognized at an early date, and he was elected to the American Philosophical Society before the Civil War. He was made member of the National Academy of Sciences shortly after the close of that war. He was president of the American Association for the Advancement of Science in 1892, and of the Geological Society of America in 1896.

Professor LeConte was a man of positive convictions, which were always expressed in clear-cut language, admitting of no misunderstanding. But there is reason to believe that he had not a personal enemy in the world. Of singular sweetness of disposition, unfailingly courteous in his manner, he was a welcome and honored guest wherever he went. His wholesome integrity, his conscientious devotion to accuracy, his keenness as an observer always gained for him a more than respectful hearing in discussion, even from those who remained unwilling to accept his conclusions. He is dead ; but his memory will be cherished affectionately by those who were his associates in science—still more by the students of fifty graduating classes, who were privileged to listen to his lectures, and to find in him one who cared for them as for his own children.

Dr. **E. O. Hovey** gave a brief summary of the chief facts known in regard to the formation of the Black Hills, describing first the most striking features of the great Red valley, which has been formed by the comparatively rapid erosion of the Triassic beds, which are softer than the Permian limestone on the one side, and the Jurassic sandstones on the other. The Triassic beds are very variable in texture, consisting of clay-, sand- and gravel-rock ; they show much strong cross-bedding, being evidently a shore deposit. They seem to have suffered much from local slipping, making a close estimate of their thickness hard to give. They are entirely destitute of animal remains. The Jurassic beds are separated from the Red beds by an unconformity due to erosion. They consist of argillaceous and calcareous shales, limestones and sandstones, but they are very variable in composition. Some of the layers contain abundant fossils, forty-six species having been reported from the formation. Apparently there are ten or twelve new species in the material collected by the author for the American Museum last summer (1901). The upper boundary of the Jurassic is still a mooted question, the beds running conformably up into undoubtedly Cretaceous, with no invertebrate fossils for hundreds of feet. The paper was discussed by Professors **Stevenson** and **Dodge** and Dr. **Grabau.**

Dr. **Julien**, in his paper on Erosion by Flying Sand on the Beaches of Cape Cod, described the physical characteristics of the beach sand of Cape Cod, and showed them to be in general derived from the Tertiary formation and from the glacial sands and gravels. The motion of the sands is from the west along the south shore, and from the north down the east and west sides of the "forearm" of the cape. The sand movement under the influence of the wind is extensive, and many results of erosion by moving sand are seen in the wearing of cliffs and in the pitted surfaces of the pebbles on the beaches.

The author showed also that the sand grains suspended in the air are subjected to rapid erosion from mutual impact, and thus that sand particles too small to be eroded in water are much comminuted when dry, and set in motion in the air. The fine resulting silt is carried and deposited as fine mud. This paper was discussed by Dr. **Grabau**.

Dr. **W. S. Yeates**, State Geologist of Georgia, being present as a visitor, the chair called upon him for remarks. In response he gave a brief outline of the State Geological Surveys of Georgia, and made a short statement of the work now in hand. Remarks appreciative of the difficulties under which state geological surveyors often labor were made by Professors **Stevenson** and **Kemp**, and Mr. **G. F. Kunz**.

The Section adjourned at 9:30 o'clock.

EDMUND O. HOVEY,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

NOVEMBER 25, 1901.

Section met at 8:20 P. M., Professor Livingston Farrand presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered :

Robert MacDougal, COMBINATION OF SIMPLE RHYTHM GROUPS IN HIGHER SYNTHESES, AND THEIR EQUIVALENCES.

E. L. Thorndike, THE CORRELATION OF MENTAL ABILITIES.

J. Franklin Messenger, AN EXPERIMENTAL STUDY OF NUMBER PERCEPTION.

SUMMARY OF PAPERS.

Professor **MacDougal** has found that the simplest rhythmic units are always combined into larger groups, provided only the units succeed each other with sufficient rapidity. And these larger groups may be combined into others still larger—a process to which no definite limits can be set. The simplest group of rhythmic units is the pair or dipody, which appears in every rhythmic series that admits of such grouping. The means by which this coupling of the units is accomplished in poetry are : Subordination of the accent of one unit to the accent of the other, differentiation in the intervals, introduction of mid-line and final pauses, catalexis and rhyme. In any sort of rhythm that is objectively expressed, the first unit of a dipody receives the major accent, and also occupies more time than the second unit. Even in a long rhythmic series there is properly no mere reduplication of units, but each unit fulfils a unique function in the series, in virtue of which it is differentiated from all the other units, in emphasis and duration and also in its internal configuration.

Professor **Edward L. Thorndike** spoke of some general aspects of the investigation which he is at present carrying on in the correlations amongst mental abilities. He found that regular correlation, where each degree of one function involves a similar degree of the other, is by no means the rule in the case of mental abilities. The relationships are often extremely irregular. For instance a high degree of one ability may go with a high degree of another but all other grades may involve no similarity in the other. A single coefficient of correlation in such cases is of course an absurdity. Correlations seem more marked between complex than between simple abilities. A variation of the Pearson method was outlined, which is well adapted to work with mental correlations and especially with studies involving few cases.

As samples of his results, Dr. Thorndike demonstrated the absence of correlation between certain motor and mental tests, the pronounced correlation between ability to spell and ability to notice the structure of words, the pronounced correlations between school marks in different subjects and the lesser degrees of correlation in the case of objective tests in the same subjects.

Mr. **J. Franklin Messenger** outlined an Experimental Study of Number Perception. His experiments had reference to the so-called space threshold in tactile sensations, to the fusion of touch sensations, and to the perception of number through touch. The validity of a threshold determined only by the distance apart of the two points applied to the skin was denied, because distance is only one of the elements on which the perception is based, and often not the most important element. The fusion of two tactile sensations was also denied because of such facts as the following, that two points, *one on each hand*, may be perceived as one point when the hands are close together.

The speaker offered a theory of the tactile perception of number. Number is not directly sensed by touch, but is inferred from various peculiarities of the tactile sensations, such as the geometrical arrangement of the stimulating objects, the distance apart of these objects, the contour of the surface stimulated—and also from the preceding sensation and the attitude of the subject.

R. S. WOODWORTH,
Secretary.

BUSINESS MEETING.

DECEMBER 2, 1901.

Academy met at 8:15 P. M., President Woodward presiding.

The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows:

The nomination of Dr. Henry E. Crampton as Councillor, to fill in the unexpired term of Professor Judd, resigned. It was voted that the Secretary be authorized to cast the ballot of the Academy for Dr. Crampton as Councillor, which was duly done.

The following candidate for resident membership, approved by the Council, was duly elected:

Mrs. Alfred Pell, Pellwood, Highland Falls, Orange Co., New York.

Adjourned,

RICHARD E. DODGE,
Recording Secretary.

SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

December 2, 1901.

Section met at 8:15 P. M., Prof. William Hallock presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

Prof. **M. I. Pupin**, Energy Dissipation in a Weak Magnetic Field.

Prof. **J. K. Rees** and **C. A. Post**, Observations of Leonids made at Bayport L. I., from Nov. 13th to 16th inclusive.

Summary of Papers.

Prof. **Pupin** described an experimental investigation of the dissipation of energy in a weak magnetic field. The substance experimented on was a toroid of square cross section made up of iron plates .010 of an inch thick. The magnetizing force was supplied by a helix uniformly distributed over the core. The force applied was a simple harmonic of 1800 periods per second and its amplitude could be varied from 0 to .1 C. G. S. units. The inductance and resistance of the helix was determined in a Wheatstone bridge. The results were compared with the theory worked out by the author.

It was found that up to about .05 C. G. S. units of the magnetizing force the permeability of the iron was constant and equal to about 80, in the samples of iron employed: there was no hysteresis and the theory agreed very well with experiment. Beyond the above limit both the inductance (L) and the Foucault resistance (R) increased. The increase of R was very rapid on account of hysteresis.

When the core was magnetized by a steady force, and after the removal of the force L and R were measured, it was found that both were changed on account of the change of permeability, but within the above limits their values still agreed with the theory. Hence weak magnetizations are not accompanied by hysteresis both when the iron is neutral and when it is already, even strongly, magnetized.

It was found that an increase in the permanent magnetization diminished the permeability and vice versa. The maximum change in permeability thus obtained was 22 per cent.

The observations of Leonids were made at Mr. Post's observatory. For the purpose of photographing meteor trails four cameras were fastened to the equatorial. Exposures for known times were made on identical parts of the sky. The results showed meteor trails on the plates taken between midnight and sunrise of November 15th. A photograph was obtained of quite a remarkable meteor which appeared at 3:58 A. M. near the radiant point and exhibited a fine head and trail which remained visible for a minute or more. A lantern slide of this meteor was thrown on the screen and attention called to the peculiar details of the head and trail.

During the night of November 14th and 15th an attempt was made to count the meteors. Miss Edith Post and Miss Grenough watched the northeastern and southeastern sky; 418 meteors, of which all but a very few were well-defined Leonids were counted. Of these the greatest number was seen between 4:30 and 5:30 A. M., on November 15th, when 273 were counted.

The notes on individual meteors show that many bright Leonids fell showing trails which lasted many seconds, and extended 10 to 20 degrees.

Section adjourned,

F. L. Tufts,
Secretary.

SECTION OF BIOLOGY.

December 9, 1901.

Section met at 8:15 P. M., Professor Bashford Dean presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

F. S. Lee and **W. Salant**, The Action of Alcohol on Muscle.

A. G. Mayer, Instincts of Lepidoptera.

H. R. Linville, The Natural History of Some Tube-Forming Annelids.

Summary of Papers.

The first paper was presented by Professor **Lee**, and consisted of an account of an investigation by the two authors jointly. The study had been carried on by very exact methods, pure ethyl alcohol being used, and isolated muscles of the frog in the normal and in the alcoholized condition being compared. It is found that the muscle which has absorbed a moderate quantity of pure alcohol will contract more quickly, relax more slowly, perform a greater number of contractions in a given time, and become fatigued more slowly than a muscle without alcohol. The effect is most pronounced in from one-half to three quarters of an hour after the liquid has begun to be absorbed, and later diminishes. Whether the alcohol exerts this beneficial action on the muscle substance itself, or on the nerves within the muscle is not yet certain. The results allow no conclusion regarding the question whether the alcohol acts as a food or in some other manner. In larger quantities its presence is detrimental, diminishing the whole number of contractions, inducing early fatigue, and diminishing the total amount of work that the muscle is capable of performing, even to the extent of abolishing the contractile power entirely. In such quantities the action is distinctly poisonous. The after-effects of either small or large doses have not yet been studied.

Dr. **Mayer** reported upon a number of experiments designed to determine the nature and duration of associative memory in lepidopterous larvæ. In one series the larvæ were placed in a wooden box divided into two compartments by means of a central partition which was pierced by a small opening. On one side of the partition was placed moist earth containing growing food plants, while on the other side of the partition there was a barren chamber. The larvæ were placed in the latter and found their way through the opening to the food-chamber. Apparently they never learned the path to the food, but always wandered aimlessly about and never shortened their paths to the food. When the food was removed, however, they rarely entered this side of the box, showing that it was the presence of food which attracted them. Individual temperament is very well shown by the larvæ, for some quickly find the food, while others are much slower. This quickness is not due to superior intelligence, however, but is owing to the fact that these larvæ remain quiet for shorter periods of time than the slower ones. A number of experiments was made upon larvæ which devour only certain special kinds of leaves. These larvæ can be induced to eat sparingly of previously uneatable food, however, if the sap of their proper food plant be rubbed into the previously distasteful leaves. Similarly they can be prevented from devouring their proper food plant if the juices of uneatable plants be rubbed into the substance of the leaves. However, they can always be induced to bite at or devour any foreign substance if one allows the larva to commence eating its proper food plant and then slides up in front of it a distasteful leaf, sheet of paper, tinfoil, etc. The larva will take a few bites of the foreign substance but will soon draw back its head, snapping its mandibles with apparent disgust or aversion. Very soon, however, it recommences to devour its proper food in a normal manner. If the foreign substance or distasteful leaf be presented to the larva at intervals of one and one-half minutes or more, about the same number of bites is taken at each presentation, thus showing that the larva does not remember its disagreeable experience for the interval. If, however, the interval be about thirty seconds the larvæ will take fewer and fewer bites of the disagreeable leaf, and will soon refuse it altogether. Individual temperament is very apparent in the reaction of larvæ in these respects. Also when spinning their cocoons the larvæ of *Samia cynthia* and *C. promethea* are geotropic, for if the cocoon be turned upside down soon after the completion of the outer envelope, the pupæ are sometimes found reversed also, and may thus be imprisoned in the cocoon; for the densely woven (normally lower) end of the cocoon is probably impenetrable to the issuing moth. A series of experiments are now being tried to determine whether the peculiar coloration of male moths in dimorphic species is due to sexual selection on the part of the female. In the case of *Callosamia promethea* there appears to be none, for males are accepted even when female wings are pasted upon them, or when their wings or scales are entirely removed. In the case of *O. dispar*, however, there is a decided selection against males whose wings have been cut off; 57 per cent. of the perfect males succeed in mating with the females, whereas only 19 per cent. of the wingless males are successful. The peculiar coloration of the males in these cases has probably not been brought about through the agency of sexual selection on the part of the female, but may be due to race tendency toward variation in a definite direction unchecked by natural selection.

This paper was discussed by Professors **Dean, Crampton,** and others.

Dr. **Linville**, in his paper, showed that the investigation of the habits of *Amphitrite ornata* and *Diopatra cuprea* brings to light many interesting adaptations. The first named lives in U-shaped tubes in sand and mud, access to water and food being possible at either end. Additions to the tube are made at the ends by the tentacles, which are continually drawing in small masses of sand. However, there is every indication that in this animal, where no occasion exists for a protecting tube, continued tube-building is merely incidental to food getting. Food is brought to the mouth, which is always concealed, in the masses of sand and in water currents created by the inward lashing cilia which thickly covers the tentacles.

Diopatra lives in a tough, mucus-covered lined tube, with its deeper end bare, and serving as an anchor, while its outer free end is studded with bits of shell and gravel. The animal may expose its anterior portion while searching for food and for suitable material to add to its tube. Observations made in the laboratory indicate that the animal chooses these materials by tactile sense organs in the cephalic cirri. The particle is grasped between the palps or by the mandibles, or by both, and is then conveyed with a fair degree of precision to a place at the edge of the tube. During the construction *Diopatra* periodically ceases to build in order to "glue" the gravel and shell together. The mucous-secreting organs are pads upon the ventral surface near the head. These organs are brought in contact with the inner surface of the tube by long and vigorous contractions and expansions of the trunk-segments. All or nearly all of the newly-constructed portions are gone over in this way before the animal renews its search for bits of gravel and shell.

Henry E. Crampton,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

December 16, 1901.

Section met at 8:15 P. M., Dr. A. A. Julien presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

D. W. Johnson, Notes on the Geology of the Saline Basins of Central New Mexico. Illustrated by diagrams.

D. S. Martin, Geological Notes on the Neighborhood of Buffalo.

A. J. Queneau, The Grain of Igneous Rocks.

On motion, Professor Richard E. Dodge was made Secretary *pro tem.*, owing to the necessary absence of Dr. Hovey.

Summary of Papers.

In the Antonio Sandoval Grant, near the centre of the Territory of New Mexico, are noted saline deposits which have served as important sources of a very pure salt in past years. The character of these basins was discussed in some detail, and points concerning their historical interest briefly touched upon.

The general geology of the central portion of the Territory was then briefly reviewed, while the local geology of the Antonio Sandoval Grant was presented more in detail. It was shown that the saline lakes occur in the Red Beds of Jura-triassic or Permian age. These Beds are separable, on lithological grounds, into three divisions, designated as the Red Series, the Chocolate Series, and the Vermilion Series. Lenticular deposits of salt and gypsum are frequently found at the top of the lower or Red Series, and evidence was produced to show that the Saline Basins under consideration occur at this horizon. The facts were noted that Triassic types have been described from some part of the Red Beds (presumably the upper), while a characteristic Permian fauna has been recently found near the base of the Red Series. In view of these facts, and since no horizon of marked transition other than the salt and gypsum deposits occurs, it was suggested that these deposits might possibly mark the boundary line between the Jura-triassic and Permian in central New Mexico. This paper was discussed by Professor **Kemp** and Dr. **Grabau**.

Dr. **Martin**, in his paper, presented some geological notes on the neighborhood of Buffalo, N. Y., in the summer of 1901. He did not claim any special novelty for the data presented, but judged that they might be of interest to any members not acquainted with that region. Dr. Martin first outlined roughly the distribution of the series from the Medina to the Corniferous Limestone, and then mentioned in detail certain special features. He particularly noted certain joint seams in the Niagara Limestone near Lockport, New York, which have been much eroded and decomposed, and which are now filled with a dark brown clay-like material containing numbers of half-decayed modern land shells, such as *Helix albolabris*. He then described the series of rocks exposed in the quarries found on N. Main Street, Buffalo, which are the source of the famous *Eurypterus* specimens. This series extends from the Corniferous Limestone to the Saline series, and is divisible into five members, known as the Corniferous Limestone, the Blue Limestone, the Bullhead Rock, the Water Limestone and the Salina. Dr. Martin particularly emphasized the contact between the Bullhead Rock and the overlying Blue Limestone, and noted the occurrence of a sandstone dike extending to the top of the Bullhead series. The paper was discussed by Dr. **Julien**.

Mr. **Queneau** in his paper said that a general observation might be made in regard to intrusive dikes. Near the margin the rock is dense, often glassy, without any appreciable grain, whereas the grain begins to grow coarse according to some definite law, progressively as the distance from the wall increases. The present paper is based on the study of the laws governing such increase. It appears that the loss of heat is of paramount importance.[1] The problem taken up is very analogous to the one presented by the cooling of a slab of finite thickness and of great length and depth with respect to the first dimension, viz., the thickness. The method followed rests on the *Théorie de la Chaleur*, of Fourrer, and on the general theory of cooling by Professor R. S. Woodward.[2] The following laws have been deducted : (1) The zone of varying grain will vary indirectly as the initial temperature. From this follows that : (*a*) Plutonic rocks very deeply seated will not present a zone of varying grain to any extent. (*b*) Rocks which come to rest at a temperature nearing their consolidation point will present a wide zone of varying grain. (2) The time of cooling, other conditions being the same, varies as the square of the thickness of the dike.[3]

From this last law it is assumed that the size of the crystals vary as the square of their distances from the nearest margin ; then the square root of their area which can be measured varies directly as the distances from the margin. Thus we have a simple law of easy application.

The paper was discussed by Professors **Kemp** and **Dodge**, and Dr. **Julien**.

Adjourned.

RICHARD E. DODGE,
Secretary pro tem.

[1] Alfred C. Lane, Geol. Surv. of Michigan, Vol. VI.

[2] Annals of Mathematics, Vol. III.

[3] Riemann, "Partielle Differentiel Gleichungen."

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Vol. XIV Part III

ANNALS

OF THE

NEW YORK

ACADEMY OF SCIENCES

Editor:

CHARLES LANE POOR

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Lancaster, Pa.

NEW YORK ACADEMY OF SCIENCES

OFFICERS, 1901–1902

SESSION, 1903–1904

The Academy will meet on Monday evenings at 8.15 o'clock, from October to May, in the American Museum of Natural History, **77th Street and Central Park, West.**

[Annals N. Y. Acad. Sci., Vol. XIV, No. 3, pp. 165–246, Oct. 31, 1903.]

THE EARLY EMBRYOLOGY OF THALASSEMA MELLITA (CONN).[1]

John Cutler Torrey.

Contents.

[1] Submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy, in the faculty of Pure Science, Columbia University.

Introduction.

It has been the primary object of this investigation to trace as fully as possible the history of the mesoblast, and especially of the ectomesoblast[1] (often called "mesenchyme") in *Thalassema*,[2] of which I have endeavored to determine not only the origin, but also the fate of every constituent cell. In some ways this form has proved extremely favorable for such a research, since the cleavage-cavity is from the first large, the ectomesoblast abundant, and the cœlomesoblast very late in developing.

As has been indicated recently by Ray Lankester,[3] the study of cell lineage has proved and will continue to prove an efficient aid in the solution of the mesoblast question. Not alone in this problem, but in general, I believe, one of the principal values of this method of study lies in the fact that it supplies the firmest possible foundation for the investigation of all later morphogenic processes, whether normal or experimentally modified. If so much had not been taken for granted regarding the cleavage stages, many embryological blunders might have been avoided. But it is equally true that if many of the earlier embryologists began their studies at too late a period in the development, a number of the later students of cell-lineage have stopped too soon and have failed to connect definitely the various cell regions that they have so carefully described, with

[1] Throughout the paper the term "ectomesoblast" (Wilson, '98) is used in preference to the term "larval mesenchyme" (which has been employed by the majority of the students of cell-lineage), or the term "pædomesoblast" (Eisig, '98). I think this preference is warranted, first, by its origin in Annelids and Molluscs from cells of the ectoblastic quartets, and second, by Meyer's discovery that a large part of this mesoblast persists in the adult in the form of circular muscles, gut-muscles, etc. This is also in all probability the case in *Thalassema*. The term "cœlomesoblast" (Eisig) is employed to designate the mesoblast which arises from the posterior member of the fourth quartet (4*d*) and produces the secondary body cavity ("entomesoblast" of Wilson).

[2] The only existing account of the development of this genus (with the exception of a brief communication by Kowalevsky, '72) is the one given by Conn in 1886. This account covers the entire history, but, as might be expected in so early a paper, the early stages are treated very superficially and many of his descriptions are radically wrong.

[3] Lankester, E. Ray, "Treatise on Zoölogy," Vol. 2, Introduction.

the organs of the adult or even of the larva. This is especially true of the so-called "larval mesenchyme" (ectomesoblast). The cytogeny of a number of annelids and molluscs has shown that the mesenchyme arises by the insinking or delamination of ectomeres from either the second or third quartet, but never from more than one. In *Thalassema*, however, not only does functional "mesenchyme" arise from the same cells in the third quartet as in *Podarke* (Treadwell, '01), but also from a number of cells in the first quartet. Under the category of ectomesoblast I think may also be placed certain cells from the second and first quartets, which appear to have completely lost their function. These rudimentary cells sink into the segmentation-cavity, and are finally ingested and completely absorbed by the entoblast cells. It is a significant fact that these cells, with but two exceptions, have a radial arrangement and these two exceptions are found where the bilaterality of the embryo is first foreshadowed, *i. e.*, in the posterior arms of the prætrochal group of cells forming the structure designated by cytogenists as the "cross." A very probable explanation of such cells seems to be that they are vestigial structures, ancestrally reminiscent of certain radial and probably mesenchymatous organs in the ancestor of the annelids. All these facts tend to sustain the view that *the mesoblast had primitively a radial origin* (Conklin, '97); and also that *primitively the mesenchyme arose from all three ectodermal quartets* (Wilson, '97).

One of the most interesting questions in regard to the mesoblast, on which these observations bear, is whether we may, or may not, regard it as a morphological unit. Possibly the investigation has not been carried far enough in *Thalassema* to decide the question definitely for this form, but it is evident that in origin, at least, and I think without doubt in fate also, we are dealing with two distinct forms of mesoblast; the one arising from the posterior member of the fourth quartet and producing the secondary body-cavity, and the other by the insinking of certain ectomeres and not only producing all the mesenchyme of the larva, but also contributing to the mesoblast *of the adult*.

Finally, I would direct especial attention to the complete reversions to spiral cleavage which occur with surprising frequency. About nine per cent. of the eggs continue to divide radially up to a very late period and, I believe, never develop into trochophores. This seems to me an extraordinary case of the persistence in ontogeny of a primitive phylogenetic stage.

In order to facilitate comparison I have made use of the system of nomenclature adopted by Treadwell ('01) (a slight modification of that earlier employed by Wilson, '92, Mead, '97, and Conklin, '97) in his paper on the "Cytogeny of Podarke," where a full explanation will be found. In brief, the "four macromeres" are designated by the capital letters, A, B, C, D. The micromeres are indicated by small letters. Each has a coefficient, which indicates the generation; and a subscript, which indicates its relation to the other cells of the same generation. The terms "dexiotropic" (clockwise) and "leiotropic" (anti-clockwise) indicate the direction of the spiral cleavage. The product of a spiral cleavage lying to the right, when viewed from the animal pole, is the dextral cell; that to the left, the sinistral cell. This permits the use of the terms "right" and "left" to designate the sides of the bilaterally symmetrical body.

It is with pleasure that I acknowledge my great indebtedness to Professor E. B. Wilson for advice and criticism during the progress of this research. I also wish to express my thanks to Professor H. V. Wilson, Director of the U. S. F. C. Laboratory at Beaufort for the facilities for collecting and preserving the material that he placed at my disposal.

Material, Methods. — The material for the following paper, was obtained at Beaufort during the summers of 1900 and 1901. The species was first described in 1886 by Conn, who gave it the specific name "mellita" from the fact that, almost without exception, it is found in empty sand-dollar tests. Unfortunately, with the facilities at hand, the animals could not be raised beyond the trochophore stage. This is, in fact, a natural chapter in the life history, for the metamorphosis into the adult takes place only after an almost stationary, free-swimming larval stage of long duration.

Artificial fertilization is easily effected, although some care must be exercised to prevent polyspermy. After a little experience one has no difficulty in distinguishing the sexes by the difference in color of the sexual products which show through the semi-transparent body-wall. The eggs were preserved at intervals of 15 minutes during the early cleavage stages and then every half hour until the trochophore stage was reached. The most satisfactory killing agent proved to be picro-acetic (with 1 to 2 per cent. acetic). Kleinenberg's picro-sulphuric (dilute) was also of value, but Flemming's fluid was quite useless, except for the preservation of cilia, even for sections. After considerable experimentation, the best stain for total mounts was found to be that first described by Conklin ('97), *i. e.*, a weak solution of Delafield's hæmatoxylin slightly acidulated by a few drops of Kleinenberg's picro-sulphuric solution. In general, the method given by Child ('00) was followed in staining and mounting the eggs. All the essential points determined in optical sections have been confirmed by actual sections. These latter were stained with iron hæmatoxylin with a Bordeaux or Congo red counter stain. The figures are all from camera drawings.

I. Cell Lineage to Gastrulation.

General Sketch. — The following is the first description of the cleavage in the Armata, considered from the cell-lineage standpoint, and, as is naturally to be expected, it conforms closely to the determinate[1] type that has been described by Wilson ('92), Mead ('97), Child ('00), Treadwell ('01) and others to be the case in a number of other annelids. The cleavage, however, is equal and so closely resembles that of *Podarke* (Treadwell, '01) that the latter may be taken as a basis of comparison. Of other representatives of this type the best known are *Lepidonotus* (Mead, '97), *Hydroides* (Wilson, '91), *Eupomatus* (Hatschek, '85), *Sabella* and *Pomatoceros* (von Drasche, '84).

In accordance with the general rule, the first quartet of micromeres is formed at the third cleavage by a right-hand spiral (dexiotropic) division of the four subequal "macromeres." Then follow a second quartet by a left-handed (leiotropic) spiral and a third quartet by a right-handed spiral cleavage. These three quartets give rise to all of the ectoblast and also to all the ectomesoblast. The fourth quartet arises leiotropically and the

[1] Spengel's ('79) figures indicate that the same is the case in Bonellia.

fifth quartet, in turn, dexiotropically. The posterior member of the fourth quartet ($4d$) produces the cœlomesoblast, but the other members of this quartet as well as the fifth quartet and the macromeres give rise only to entoblast.

1. *To 64 Cells.*

I will pass over the maturation and fertilization of the egg with little comment, as Conn has described these phenomena in the living egg and Griffin with great detail in sections. When the eggs are first discharged from the segmental organs they are pressed out of shape and, only after the entrance of the sperm, become spherical. The small size of the eggs (about 70–80 μ in diameter) adds considerable difficulty to their study. During and after fertilization what at first sight appear to be spinning activities take place at the surface of the egg. Soon after the entrance of the sperm the egg membrane (chorion) begins to draw away from the egg itself and soon is completely detached. If the space that thus results between the membrane and the egg is now examined with a high power, fine protoplasmic strands may be seen running from the one to the other. These threads may vary from time to time in thickness and constitution and often contain granules. They remind one forcibly of the pseudopodia of *Gromia*. I have found them persisting during the early cleavage stages. The polar bodies lie suspended in the space between the egg and the membrane and are held at one place by these protoplasmic threads as guy-ropes. I would explain the formation of these threads by the fact that, when the membrane separates from the egg, the protoplasm sticks to the corrugations on the inner side of the membrane and, because of its viscid nature, is drawn out into threads. Similar phenomena have been described in the egg of *Petromyzon* (Calberla, '78). Conn recognized certain striations in the space between the membrane and the egg, but did not suggest their protoplasmic nature.

As has been described in many other forms, the first cleavage begins at the upper pole and cuts in somewhat more rapidly here than at the lower,[1] resulting typically in the formation of two equal blastomeres (Text-Fig. 1, *A*). Their nuclei immediately move slightly toward the left in preparation for the sec-

[1] In *Lepidonotus*, however, where the yolk has a more uniform distribution, the cleavage plane cuts at the same rate all the way around the egg (Mead, '97).

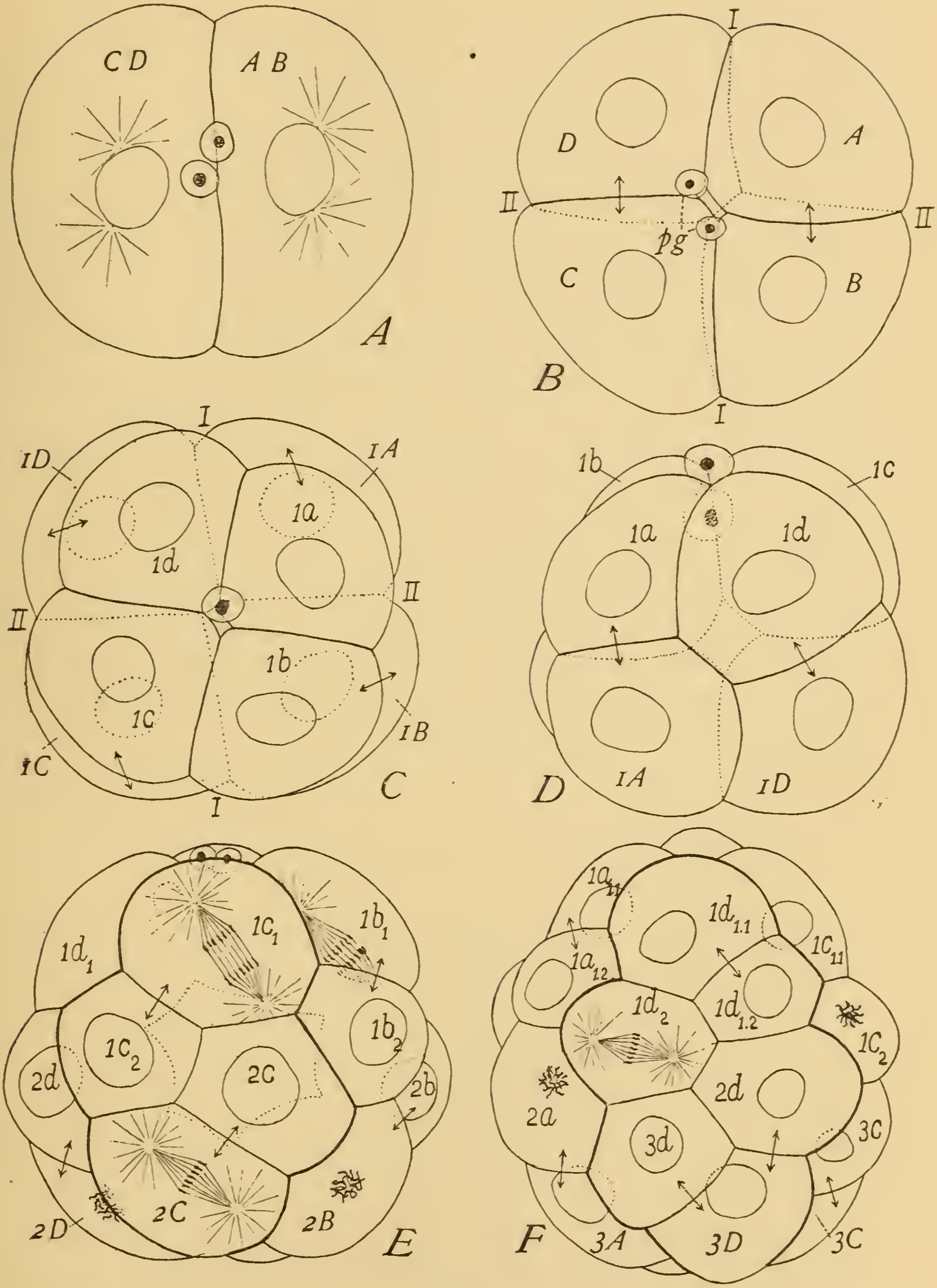
ond cleavage. At this time one of the polar bodies begins to sink in between the blastomeres and later passes into the cleavage space. At the second cleavage the spindles are not parallel, but are so placed that, when the cleavage is completed the *B* and *D* quadrants meet at the lower pole, and the *A* and *C* quadrants at the upper, forming two polar furrows which are at right angles to each other (Text-Fig. 1, *B*). They are, also, typically equal in length, as might be expected in an egg with scanty and evenly distributed yolk (Wilson, '92, Conklin, '97). In *Podarke* the shorter furrow is always at the upper pole, but in *Thalassema* we find every variation, even to its complete obliteration. As a rule the *A* and *C* blastomeres do not quite touch at the upper pole, and through this space one of the polar bodies has already slipped. All these four blastomeres are exactly the same size and, although it is possible by means of the polar furrow to distinguish the first cleavage plane from the second (Conklin, '97), there is no way of telling the anterior macromere, *B*, from the posterior, *D* (Treadwell, '01). As in *Podarke*, the polar furrow remains constant until other means of orientation appear. In *Thalassema* it is nearly at right angles to the future sagittal plane as in *Arenicola* (Child, '00). The various quartets and the first and second cleavage planes bear the same relation to the future axes of the adult as in *Amphitrite*, *Arenicola* and *Podarke*. An adequate discussion of this point is given by Treadwell ('01).

The first quartet of micromeres[1] arise simultaneously and are only slightly smaller than the "macromeres" (Text-Fig. 1, *C* and *D*). At this stage there seems to be no tendency for one quadrant to divide before the others. The small lenticular cleavage space, which appeared as early as the two-cell stage, increases rapidly in size as the development progresses. At the transition from 8 to 16 cells the second quartet of micromeres are formed by an equal leiotropic division of the macromeres and the primary trochoblasts by a somewhat unequal leiotropic

[1] The cleavages take place at intervals of about fifteen minutes, but, as in so many other cases, are greatly accelerated by heat and retarded by cold. In the living egg it is well-nigh impossible to follow the cleavages very far on account of the great flattening out of the blastomeres during the resting periods.

TEXT-FIGURE 1.

A, 2-cell stage from above; *B*, 4-cell stage from above, *pg.*, polar globules; *C*, 8-cell stage from above; *D*, 8-cell stage from the side; *E*, 16, forming 24 cells; *F*, 24, forming 32 cells, division of second quartet and primary trochoblasts. The boundaries of the four quadrants, *D*, posterior; *A* and *C*, lateral; and *B*, anterior; are indicated by heavy lines.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1c11
1a12
1d2
1d1.2
1c2
2a
2d
3d
3c
3A
3D
3C
F

Fig. 1.

division of the first quartet (Text-Fig. 1, *E*). These four cells divide twice, as in *Podarke*, and form the primary protroch. The first somatoblast is not indicated by any difference in size at this stage. The 24-cell stage (Text-Fig. 1, *F*) is brought about by the formation of the intergirdle cells and the third quartet of micromeres by dexiotropic cleavages after which the egg enters upon a resting period. The former divisions are slightly earlier than the latter and mark the beginning of an acceleration of divisions in the first quartet. Evidently here the presence of yolk has nothing to do with the rapidity of cleavages, as has been maintained by Kofoid ('95), but their rate is correlated with the large size and early differentiation of the prætrochal region (Lillie, '95; Conklin, '98). As in *Podarke*, the cells of the third quartet are slightly smaller than those of the second.

The 32-cell stage (Text-Fig. 2, *A*) is attained by the nearly simultaneous dexiotropic and equal division of the four cells of the second quartet and the four primary trochoblasts (Text-Fig. 2, *D*). The arrangement of the blastomeres conforms now exactly to what one would expect in the ideal ovum, as is also the case in *Podarke* and *Lepidonotus*, namely:

First quartet	16 cells.
Second quartet	8 "
Third quartet	4 "
Macromeres	4 "
	32 "

The cells of the fourth quartet next arise leiotropically and practically simultaneously (Text-Fig 2, *A* and *B*). There is nothing in size (Text-Fig. 2, *C*) or time of formation to distinguish the second somatoblast or *M* cell (4*d*) from the others.[1] During these cleavages there has been a steady shifting to the right of the upper part of the embryo on the lower (Text-Fig. 2, *B*), so that the polar furrows are now almost parallel instead of at right angles (Text-Fig. 2, *C*). Immediately after the

[1] In some forms the *M* cell arises still earlier (in *Crepidula* at the 25-cell stage), but its formation may also be greatly delayed as in *Ischnochiton* (Heath, '99), where it does not arise until the 72-cell stage, and then after the other three members of the quartet have been budded off.

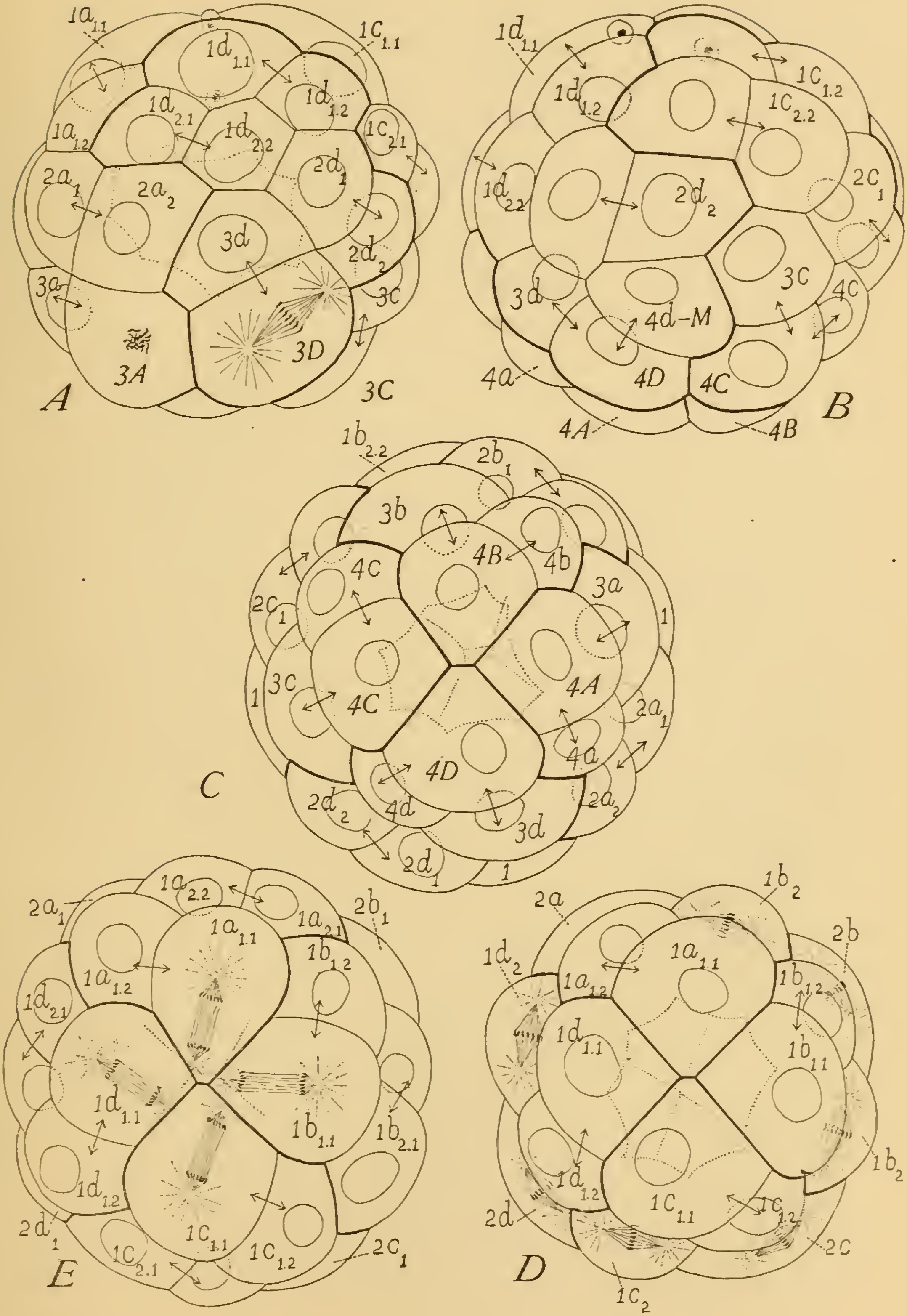
formation of the fourth quartet, mitotic figures appear in the four cells at the upper pole ($1a_{1.1}$, etc.) and the apical rosette is budded off leiotropically (Text-Fig. 2, *E*). These cells lie entirely on the surface at first and are much larger than in *Podarke*. Although in later stages they occupy a smaller space at the surface, they never sink in to the extent that they do in *Podarke* and *Lepidonotus*. At this stage two of the polar bodies are very commonly seen imbedded in the stem-cells of the cross (Pl. I, Fig. 2) or in the rosette, but they interfere in no way with the division of these cells. This sinking in of the polar bodies is of very general occurrence in annelids and molluscs (Treadwell, '01).

The next divisions take place in the third quartet. They are leiotropic and somewhat unequal (Pl. I, Fig. 8). From the lower cells in the *a*, *c* and *d* quadrants will later arise part of the mesenchyme. The prototrochal cells divide equally and leiotropically and at the same time the intergirdle cells divide in the same direction and unequally (Pl. I, Fig. 1). The smaller moieties lie in the spaces between the four groups of cells which constitute the primary prototroch and later form a part of the secondary prototroch as in *Podarke* (Pl. I, Fig. 6). The embryo now consists of fifty-six cells and is perfectly radially symmetrical (Pl. I, Fig. 2).

This stage marks the end of the purely radial cleavages, as in *Podarke*, and from now on bilateral or morphogenic cleavages take place in increasing numbers. The first of these initiates the formation of the cross. The posterior stem cells ($1d_{1.1.2}$ and $1c_{1.1.2}$) divide bilaterally, while the anterior divide spirally and leiotropically (Pl. I, Figs. 2 and 3). This cleavage, however, is subject to a number of variations as will be indicated later (see p. 187). From now on in the prætrochal region *the posterior quadrants* (*c* and *d*) *always divide before the anterior*, whereas in *Podarke* the reverse seems to be the case. As Child ('00) has indicated there are in annelids two types in regard to the formation of the cross. In *Nereis*, *Polymnia*, *Spio*, *Aricia*, *Amphitrite*, *Clymenella*, *Sternaspis* and *Arenicola* the spindles lie meridionally, whereas in *Podarke*, *Lepidonotus* and *Chætopterus* spirally

TEXT–FIGURE 2.

A, 32, forming 36 cells, formation of the fourth quartet; *B*, 36-cell stage from the side, 4*d* or *M*, cœlomesoblast cell; *C*, same stage from lower pole; *D*, 24, forming 32 cells from the upper pole; *E*, 36, forming 40 cells, formation of apical rosette.


$1a_{1.1}$
$1d_{1.1}$
$1c_{1.1}$
$1d_{1.2}$
$1d_{2.1}$
$1d_{2.2}$
$1a_{1.2}$
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A
$1d_{1.1}$
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$4C$
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$1b_{2.2}$
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$3b$
$4B$
$4b$
$4c$
$3a$
$2c_1$
1
$3c$
$4C$
$4A$
$2a_1$
1
$4a$
$4D$
$2d_2$
$4d$
$2a_2$
$3d$
$2d_1$
1
C
$1a_{2.2}$
$2a_1$
$1a_{1.1}$
$1a_{2.1}$
$2b_1$
$1b_{1.2}$
$1a_{1.2}$
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$1d_{1.1}$
$1b_{1.1}$
$1b_{2.1}$
$1d_{1.2}$
$2d_1$
$1c_{1.1}$
$1c_{1.2}$
$2c_1$
$1c_{2.1}$
E
$1b_2$
$2a$
$2b$
$1d_2$
$1a_{1.1}$
$1a_{1.2}$
$1b_{1.2}$
$1d_{1.1}$
$1b_{1.1}$
$1b_2$
$1d_{1.2}$
$2d$
$1c_{1.1}$
$1c_{1.2}$
$2c$
$1c_2$
D

FIG. 2.

and leiotropically, so much so in the last-named annelid that no cross is formed. *Thalassema* seems to be intermediate; the posterior arms conforming to the first type, and the anterior to the second. In this division, too, as Treadwell ('01) has pointed out, we have a clear foreshadowing of the bilaterality of the embryo: for the posterior cells divide typically equally, whereas the anterior cells bud off smaller cells toward the rosette. This difference is quite common in annelids, occurring as it does in *Nereis*, *Amphitrite*, *Clymenella*, *Arenicola* and *Podarke*. At the same time with the formation of the cross the lower sinistral cells ($2a_2$, etc.) in the second quartet divide unequally (Pl. I, Figs. 10 and 11). In the *a*, *b* and *c* quadrant the smaller cell is budded off upward toward the prototroch (Pl. I, Fig. 10), but in the *d* quadrant downward and lies over the *M* cell (Pl. I, Fig. 11). An exactly similar division occurs in *Podarke;* and, as there, this cell will be designated $x_{1.2}$. Treadwell ('99, '01) in his discussion of cell-homologies, calls attention to the fact that this cell has the same origin in all the forms of annelids and molluscs that have been studied. This, perhaps, cannot be said in regard to its fate, for in *Amphitrite* and *Podarke* it forms a part of the proctodæal wall, but in *Thalassema*, in all probability, that of the stomodæum. The posterior quadrant is now very effectively marked out by the cross and this cell. A cross-section of this stage (Text-Fig. 10, *A*) shows a peculiar arrangement of the blastomeres. The prototrochal cells are entirely superficial and lie over the second quartet cells, which in turn abut against the cross and intergirdle cells. The lower members of the third quartet, too, extend inwards and upwards for a considerable distance. It will be noticed in the following table that the 64-cell stage in *Thalassema* does not quite conform to the ideal, as it does in *Lepidonotus* and *Podarke*. This is due to the precocious formation of the cross and the failure of the upper dextral cells in the second quartet to divide.

Up to this stage in all annelids with equal cleavage the arrangement of the blastomeres is practically identical. As a matter of convenience the later divisions of each quartet will be described separately.

		Thalassema.	Podarke.
First quartet.	Rosette	4	4
	Cross	8	4
	Intergirdle	8	8
	Prototroch	16	16
		36	32
Second quartet		12	16
Third quartet		8	8
Fourth quartet		4	4
Macromeres		4	4
		28	32
		64	64

2. *Further Divisions of the Quartets.*

a. First Quartet. — From the first quartet subsequently arises a considerable part of the ectomesoblast, but, as it is not formed until after gastrulation, a description of the process is reserved for another section. The following section deals largely with the further divisions and fate of the cross and intergirdle cells, which are of interest from a comparative standpoint.

The Intergirdle Cells. — After the completion of the 64-cell stage, the first division in the first quartet is an extremely unequal and dexiotropic one of the intergirdle cells in the *a*, *b* and *c* quadrants ($1a_{1.2.1.}$, etc.). Three minute and entirely superficial cells ($1a_{1.2.1.2.}$, etc.) with dark staining nuclei are budded off toward the prototroch (Pl. I, Fig. 4). As will be shown later, *these cells are rudimentary and in the end completely disappear.* In the *d* quadrant, on the other hand, the corresponding division is nearly equal, with the spindle inclined very slightly dexiotropically (Pl. I, Fig. 4). The lower cell ($1d_{1.2.1.2.}$) soon divides bilaterally (Pl. I, Figs. 6 and 7) and gives rise to two cells, which lead the subsequent backward migration through the dorsal gap in the prototroch and into the post-trochal region. Although these cells are not "homoblastic" with, yet they appear to be "equivalent"[1] to the cells

[1] These terms have been recently suggested by E. B. Wilson (see *Science*, April 4, 1902.) "For practical purposes cells of like prospective value, giving rise to homologous structures, may, irrespective of their origin, be called *equivalent;* those of like ontogenetic origin and position, may, irrespective of their fate, be called *homoblastic;* but neither equivalent or homoblastic cells are necessarily homologous."

which lead the van in *Amphitrite*, *Arenicola* and *Podarke*. I have decided, accordingly, to follow Mead's ('97) nomenclature and designate them as l_1 and l_2. The upper cell ($1d_{1.2.1.1.}$) divides several times and its progeny also finally passes downward and through the dorsal gap. By a dexiotropic cleavage the intergirdle cell, $1d_{1.2.2.}$ (the "*l*" of Mead) gives rise to a rudimentary cell (Pl. II, Fig. 14). The subsequent fate of the former I have not definitely established, but it probably takes part in the post-trochal migration. The only further divisions of interest in the *a*, *b* and *c* intergirdle regions are those of the cells concerned in the formation of the prototroch ($1a_{1.2.2.}$, etc., see Pl. I, Fig. 6). The cells $1a_{1.2.2.}$ and $1c_{1.2.2.}$ divide dexiotropically and nearly equally. The lower products ($1a_{1.2.2.2.}$ and $1c_{1.2.2.2.}$) later form a part of the prototroch. The cell $1b_{1.2.2.}$ divides in the same direction, but buds off a rudimentary cell ($1b_{1.2.2.1.}$). The larger cell ($1b_{1.2.2.2.}$) finally enters the prototroch as in the other quadrants (Pl. I, Fig. 7).

The Cross. — The distal cell in each of the posterior arms of the cross buds off a very minute cell upward and toward the median dorsal line (Pl. I, Fig. 4). (Exactly similar cells are formed in *Podarke*.) They later degenerate completely. The subsequent divisions in the posterior arms of the cross are all directed toward the median dorsal line, so that, finally, the arms come in contact along this line and thereby shove the adjacent intergirdle cells through the dorsal gap in the prototroch (Pl. I, Figs. 5, 6 and 7). At the 64-cell stage each of the anterior arms of the cross consisted of two cells (Pl. I, Fig. 3). Equal, radial divisions of the distal or "stem" cells next take place (Pl. I, Fig. 4). By a series of bilateral divisions each arm becomes split throughout its entire extent (Pl. I, Figs. 6 and 7). A continuation of the lateral spreading of the arms, initiated by these cleavages, results in the formation from the descendants of the proximal cross cells of almost the entire upper part of the umbrella of the trochophore. The lower part of the præ-trochal region arises from an alternation of the intergirdle and distal cross cells, except in the dorsal region, which is almost wholly occupied by the cross cells. A detailed description of all these later cleavages has been omitted, as they are not of general interest. They may, however, be followed in the figures (Pl. I, Figs. 5, 6, 7). The rosette cells divide once certainly, leiotropically in the *a*, *b* and *c* quadrants and bilaterally in the *d* (Pl. I, Figs. 6 and 7). Some of them have been observed to divide again. *All of these divisions take place after the cells have developed cilia.* From the rosette cells, I think, is developed the entire apical plate.

b. Second Quartet. — The second quartet claims our interest from the fact that the posterior member (2*d*) has been found to produce in a number of annelids and molluscs, almost the entire post-trochal ectoderm and consequently that of the trunk of the adult. In the unequal types of cleavage this protoblast is often the largest cell in the egg (*Nereis*, *Amphitrite*, *Arenicola*, etc.). Its origin and subsequent history were first accurately determined by Wilson ('92) in *Nereis*, who designated it by the letter X. Treadwell ('01) has recently discovered that in an annelid with "equal" cleavage (*Podarke*), although 2*d* is no larger than the other three members of the quartet, yet it divides more rapidly and its progeny increase in number and size to such an extent as to give rise to a considerable part of the post-trochal ectoderm and to the "growing point." As will be seen later the same is still more markedly the case in *Thalassema*. The cell may accordingly be said to be homoblastic and, to a large extent, equivalent in both types of cleavage. I will first describe its divisions, following Treadwell's nomenclature.

X-Group. — As stated above, at the 64-cell stage, the sinistral cell in the *d* quadrant of the second quartet divides off a small cell downward and over the protoblast of the cœlomesoblast (4*d*) (Pl. I, Fig. 11). The dextral cell next divides somewhat unequally (Pl. I, Fig. 12). The upper smaller product of this division is X_3 and the lower X_2. There follows a leiotropic division of $X_{1.1}$ (Pl. II, Fig. 17). The upper and somewhat smaller cell corresponds to the entirely degenerate cells divided off earlier in the other quadrants ($2a_{2.1}$, etc.) $X_{1.1.2}$ very soon divides again and in the same direction (Pl. II, Figs. 17 and 18). $X_{1.1.1}$ has increased, in the meantime, considerably in size. X_2 and X_3 next divide at about the same time, unequally and dexiotropically (Pl. II, 18 and 19). The smaller product lies nearer the prototroch in each case. It is a significant fact that *the divisions in this quadrant have considerably outstripped those in the other quadrants, but are almost identical with the ones that will occur in them later.* This is the first indication that the subsequent posterior growth will be due to the multiplication and increase in size of the cells of this region. The radial symmetry of the earlier stages, on the other hand, persists very tenaciously in this form as in all annelids with equal cleavage. The cell $X_{3.2}$ enlarges somewhat (Pl. II, Fig. 20), but not nearly so much as in *Podarke.* The group now has assumed the shape of an open fan and retains it to a late period (Text-Fig. 3, *C* and *D*). The cells $X_{1.2}$ and $X_{2.2}$ divide at the same time dexiotropically (Pl. II, Figs. 20 and 21). In the division of $X_{1.1.2.2}$ the spindle lies toward $X_{3.2}$ (Pl. II, Fig. 20, shows result of division). The upper product of this division, $X_{1.1.2.2.1}$ later increases considerably in size and becomes by far the largest cell in the group (Pl. II, Fig. 24). $X_{1.1.2.1}$ buds off toward the prototroch a very small cell ($X_{1.1.2.1.1}$, Pl. II, Figs. 20 and 21) which very soon sinks into the cleavage-cavity. By this time gastrulation has begun, accordingly the subsequent fate of these cells will be described in a following section.

a, b and c quadrants. — The cleavages in the other three quadrants may be passed over very briefly. The small cells budded off toward the prototroch ($2a_{2.1}$, etc., Pl. II, Fig. 15), I have never seen divide again, and I am sure that they later degenerate and sink into the cleavage-cavity. Because of the peculiar shingle-like arrangement of the post-trochal blastomeres, the cells budded off upwards from the second quartet lie almost entirely under the primary prototroch (Pl. II, Fig. 13; Text-Fig. 10, *A*). In the later stages, however, in consequence of the thinning and stretching out of the body wall, this condition to a large extent disappears (Text-Fig. 10, *C*). The dextral cell in each of these quadrants ($2a_1$, etc.) now divides nearly equally and leiotropically (Pl. II, Figs. 16 and 17).

Soon after, the lower sinistral cell ($2a_{2.2}$, etc.) buds off, with the spindle lying in the same direction, a small cell ($2a_{2.2.2}$, etc.) toward the fourth quartet (Pl. II, Figs. 16 and 18). Accordingly, at this stage (about 80 cells) there are five cells in each quadrant with exactly the same arrangement, and this radial symmetry is retained, almost perfectly, until the beginning of gastrulation. The divisions of the sinistral cells may be followed in the figures (Pl. II, Figs. 18, 19, 20, 21). The upper dextral cell in each quadrant ($2a_{1.1}$, etc.) soon divides dexiotropically and is followed after a time by the lower dextral ($2a_{1.2}$, etc.) in the same direction (Pl. II, Figs. 18 and 21). The three upper cells in each quadrant ($2a_{1.1.1}$, $2a_{1.1.2}$, $2a_{1.2.2}$) later become ciliated and form a part of the secondary prototroch (Pl. II, Fig. 24). The lower cells in the *a* and *c* quadrants ($2a_{1.2.2}$, $2c_{1.2.2}$) give rise to a part of the lateral post-trochal ectoderm and in the *b* quadrant ($2b_{1.2.2}$) to a part of the stomodæum. The origin and fate of the "œsophagoblasts" (Eisig, '98) will be described in the next section.

c. Third Quartet. — Especial interest attaches to the third quartet in *Thalassema*, since from it arises the greater part of the functional ectomesoblast. At the 64-cell stage each member of the third quartet had divided once leiotropically and unequally (Pl. I, Figs. 10 and 11). The lower larger cell ($3a_2$, etc.) next divides dexiotropically and unequally in each quadrant (Pl. II, Figs. 13, 16 and 17). The smaller product of this division is dextral in the *a*, *b* and *d* quadrants, but in the *c* quadrant is sinistral. Accordingly, in the *c* and *d* quadrants the larger cells lie on each side of $4d$ and the smaller cells laterally (Pl. II, Fig. 13). These, as in *Podarke*, are the first bilateral divisions in the post-trochal region. The two larger cells, $3c_{2.1}$ and $3d_{2.1}$ show a marked tendency to sink in (Pl. II, Fig. 18), but come to the surface to bud off two more small cells (Pl. II, Figs. 19 and 20). When the embryo consists of about 130 cells they are seen lying in the cleavage-cavity entirely below the surface (Pl. II, Fig. 21). Their cell-lineage accordingly is $3c_{2.1.2.1}$ and $3d_{2.2.2.1}$. The remarkable similarity in the origin of this part of the ectomesoblast with that of *Podarke* is discussed beyond.

The rapidity with which the divisions have taken place in these cells illustrates Lillie's ('95) principle that the rate of the cleavages in the protoblast of an organ is directly correlated with the time that the organ becomes functional. The cell $3a_2$, after two divisions, also gives rise to mesenchyme. The first division has already been described. In the second the spindle first lies meridionally in both the *a* and *b* quadrants (Pl. II, Fig. 18), as in *Podarke* but later rotates to a dexiotropic position. The ectomesoblast cell, $3a_{2.2.2}$, divides equally as it sinks in (Pl. II, Figs. 22 and 23). For a description of the later history of all these cells the reader is referred to the section dealing with the mesoblast. The corresponding cell in the *b* quadrant plays a prominent *rôle* in the formation of the œsophagus. The upper sinistral cells ($3a_1$, etc.), have all been seen to divide dexiotropically (Pl. II, Fig. 18).

d. 4th and 5th Quartets.—The posterior member of the fourth quartet (4*d*) is first to divide (Pl. II, Figs. 14 and 19). This is the first true bilateral cleavage in the egg and does not take place until the embryo consists of over a hundred cells. The right product of this division is slightly larger than the left. Soon after their formation the nuclei of the two cells (*M*, *M*) become shoved up near the surface by the pressure of the invaginating entomeres (Pl. II, Fig. 20). From them are ultimately formed the right and left cœlomesoblast bands. They sink in immediately after the entoblast-plate and bud off two small cells toward the blastopore (Pl. II, Figs. 23 and 24; Text-Fig. 8, *E*). The other members of the quartet have almost invaginated (Pl. II, Fig. 18), but return to the surface to divide (Pl. II, Fig. 21). Child ('01) explains such a return by the turgor of the cells and their adhesion to the connecting cells of the surface layer. Just before sinking in, that part of the cell at the surface becomes swollen and is connected with a nucleated swollen part within the cleavage cavity by a narrow bridge (Pl. II, Fig. 22). The cells are thus dumb-bell-shaped. They later form a part of the entoblast.

The fifth quartet is formed when the embryo consists of about 86 cells (Pl. II, Figs. 17 and 18). The cells are somewhat smaller than the macromeres and, as usual, are all entomeres. The entoblast-plate, therefore, consists of 11 cells, namely, the four macromeres, the fifth quartet, and the anterior and lateral members of the fourth quartet (Text-Fig. 4, *A*). Gastrulation begins when the embryo contains about 150 cells.

3. Special Considerations.

a. The Prototroch. — The primary prototroch in *Thalassema* agrees in origin, cell by cell, with that of *Amphitrite*, *Arenicola*, *Podarke* and several other annelids ; each of the four primary trochoblasts divides twice, the remaining cells forming a more or less complete girdle of 16 cells about the embryo. The completed prototroch, however, differs from that of *Amphitrite* and *Arenicola* and agrees with that of *Podarke*, in that, in three quadrants an intergirdle cell is also incorporated in it. In *Thalassema*, again, the second quartet in each of the *a*, *b* and *c* quadrants contributes three prototrochal cells as in *Amphitrite* and *Arenicola*, whereas in *Podarke* only two are contributed.

The primary prototroch is completely formed at the 56-cell stage (Pl. I, Fig. 9). The 16 cells soon begin to swell and elongate to such an extent that at the 64-cell stage the four groups come in contact and form a complete and continuous band around the embryo (Pl. I, Fig. 11). There is, accordingly, no dorsal gap at this stage, but it subsequently arises by the actual shoving apart of the cells at the juncture of the *c* and *d* groups at the time of the migration of cells from the first quartet. This formation of an unbroken ring by the primary prototrochal cells is made possible by their superficial position (Text-Fig. 10, *A*). In the great majority of annelids, where the prototroch has been accurately determined, the four groups are wedged apart by the dextral cells of the second quartet. An apparent exception has been described for *Hydroides* and *Polygordius* (Wilson, '91), where the protrochal protoblasts divide only once and form a complete band of 8 cells around the embryo ; and also in *Nereis* (Wilson, '92), where the protoblasts divide twice, but four of the resulting cells are shoved out and the complete prototroch consists, accordingly, of a ring of

12 cells. Child ('00) ascribes the flattening and lengthening of the prototroch cells in *Arenicola* to their being pushed down posteriorly by the prætrochal divisions. This is, no doubt, in a measure true in *Thalassema*.

The prototroch of the trochophore is completed (Text-Fig. 3, *B*) by the addition of three more cells from the first quartet (Pl. I, Figs. 6 and 7) and nine from the second (Pl. II, Fig. 24). As has already been shown, the three cells from the first quartet arise from two divisions of the *a*, *b* and *c* intergirdle cells ($1a_{1.2.2.2}$, $1b_{1.2.2.2}$, $1c_{1.2.2.2}$). These same cells also enter the prototroch in *Podarke*. In *Ischnochiton* (Heath, 99) both products of the last division enter the prototroch. It is interesting to note that the dextral cell, which is the smaller in *Ichnochiton*, is entirely rudimentary in the *b* quadrant in *Thalassema*, and also in *Amphitrite*. Mead ('98) has called attention to the interest in the intergirdle cell that has subsequently been found to enter the prototroch in *Podarke*, and "recommends the investigation of its destiny . . . in Annelids as a fruitful problem in cell-lineage."

The cells which later enter the prototroch from the second quartet are the same as in *Amphitrite*, *Clymenella* and *Arenicola* ($2a_{1.1.1}$, $2a_{1.1.2}$, $2a_{1.2.1}$, etc.). In *Podarke* the upper cells of these three groups ($2a_{1.1.1}$, $2b_{1.1.1}$, $2c_{1.1.1}$) are small and are said to be pushed later entirely out of the prototrochal ring. Although in *Thalassema* this cell is smaller than the other two, there is no doubt that it here contributes to the prototroch. All of these cells are added to the prototroch and become ciliated very late in the development, as is also the case in *Podarke*.

To sum up: *The complete prototroch in Thalassema consists of 28 cells as against the usual number, 25; the primary prototroch is "completed" by four cells from each of the a b and c quadrants, of which one is contributed from the first quartet and three from the second.*[1]

[1] Conn ('86) manifestly influenced by Hatschek's earlier descriptions, has erroneously described the prototroch in *Thalassema* as consisting of a præ-oral and post-oral row of "high prismatic cells." The yellow color of the prototroch cells in

It may not be out of place to direct attention once more to the striking similarities in the formation of the prototroch in the larvæ of annelids and molluscs. So detailed and precise are these resemblances that the homology of this highly characteristic larval organ seems to be quite as complete as is that of any adult structure. Mead ('98) has stated this conclusion concisely in the following sentence, taken from a Wood's Holl lecture. ". . . The component cells of the prototroch are as homologous in the various types studied in the same sense as are the component bones in the skeleton of the vertebrate limb." With this conclusion the cytogeny of the prototroch in *Thalassema* falls in line. Judging by what we know of the variations that the vertebrate limb may undergo, Mead's comparison is strengthened rather than weakened, I think, by the fact that in some cases cells are added to, and in other cases what seem typical cells are entirely absent from the prototroch.

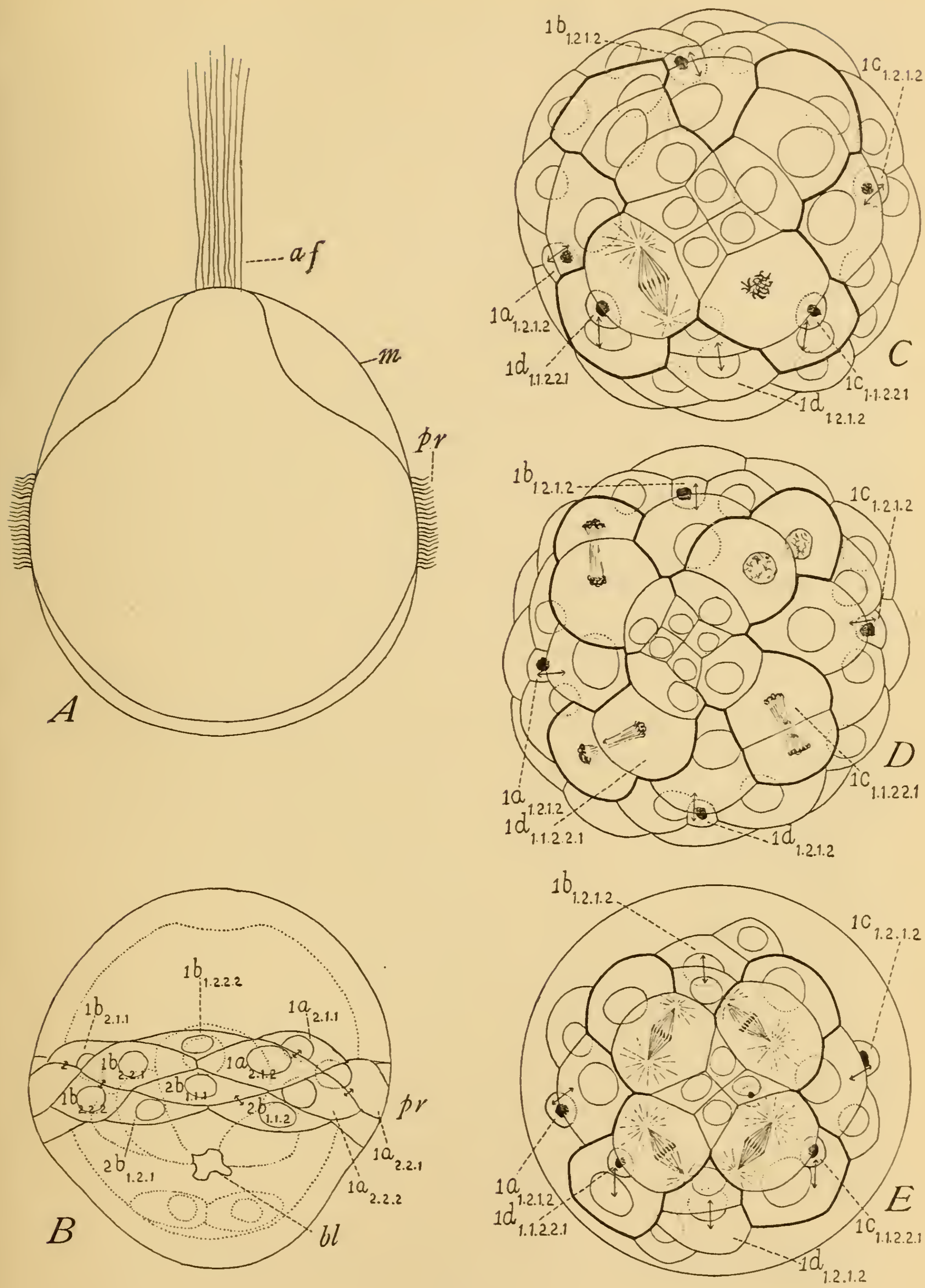
Cilia first appear with great regularity at four and one half hours after fertilization and simultaneously on the prototroch and rosette (Text-Fig. 3, *A*). Those on the former constitute a complete band and are first short and delicate but gradually increase in size and strength. On the rosette, however, they grow very rapidly and soon are more than half as long as the embryo itself. The cilia do not arise until about an hour after the formation of the primary prototroch and the rosette, but *immediately the after differentiation of the cross.* Up to this time the embryo is entirely separated from the egg membrane, just as in *Cerebratulus* (C. B. Wilson, '00), but by the practically bilateral divisions of protoblasts of the cross a very marked prominence arises at the center of the upper hemisphere, as in *Nereis.* The rosette and primary prototroch, accordingly, become pressed against the egg membrane and thus permit its being punctured by the

the older stages of *Arenicola* is ascribed by Child ('00) to the presence of yellow granules. In *Thalassema*, however, this color seems to be due to the fact that the protoplasm of these cells holds the picric stain with tenacity. The prototroch, wide at first, becomes narrower as the development proceeds and in the completely differentiated trochophore consists of three rows of greatly elongated cells. The first row consists of 11 cells, the second of 11 cells and the third (incomplete in the dorsal region) of 6 cells.

TEXT–FIGURE 3.

A, Somewhat diagrammatic sketch of a four and one-half-hour living embryo to show the ciliation; *af*, apical flagellæ; *m*, egg membrane; *pr*, prototrochal cilia. *B*, view showing the arrangement of the prototrochal cells; *pr*, prototroch; *bl*, blastopore.

Variations in cleavage. *C*, view from upper pole of an embryo of about 72 cells showing the normal type of cleavage; *D*, same stage in another embryo showing a reversion to a *purely radial type* of cleavage; *E*, an embryo in which the cleavage is almost purely *bilateral*. In each the cross is bounded by heavy lines.


af
m
pr
A
1b1.2.2.2
1b2.1.1
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pr
2b1.2.1
1a2.2.1
1a2.2.2
B
bl
1b1.2.1.2
1c1.2.1.2
1a1.2.1.2
1d1.1.2.2.1
C
1c1.1.2.2.1
1d1.2.1.2
1b1.2.1.2
1c1.2.1.2
D
1c1.1.2.2.1
1a1.2.1.2
1d1.1.2.2.1
1d1.2.1.2
1b1.2.1.2
1c1.2.1.2
1a1.2.1.2
1d1.1.2.2.1
E
1c1.1.2.2.1
1d1.2.1.2

FIG. 3.

cilia. The prominence that is formed at this time persists until the time of gastrulation, when the embryo becomes spherical again.

At first the cilia on the prototroch are uniform in size, but, during the differentiation of the trochophore, there appear two bands of longer cilia — one at the upper edge which beat actively, and a narrower one on the lower edge which hang down and move slowly and indefinitely (Text-Fig. 8, *A*). Between these two rows the shorter cilia[1] are retained. The long flagella, borne entirely by the rosette, are about 20 in number and when the embryo is actively swimming are carried stretched out in front, and bunched closely together, quite as in a pilidium larva. When the animal is at rest the flagella wave about slowly. In the trochophore of about twenty-two hours they are replaced by very short inactive cilia (Text-Fig. 8, *A*). These long apical flagella occur frequently in annelids and lamellibranchs and perhaps may be regarded as a primitive feature. They have been described in *Nucula*, *Yoldia* (Drew, '99) and *Dreissensia* (Meisenheimer, '01) and in *Eupomatus*, *Nereis* and *Amphitrite*.

b. Variations in Cleavage. — Of great interest in the cytogeny of *Thalassema* are certain variations in cleavage which occur with surprising frequency. As has already been indicated, the bilaterality of the trochophore is normally first foreshadowed by the formation of the cross, the posterior protoblasts dividing equally and bilaterally, while the anterior divide unequally and spirally — the smaller product lying next to the rosette (Pl. I, Fig. 3). The normal bilateral cleavage in the posterior cells is caused by a slight reversal in the direction of the spindle in the *d* quadrant which lies leiotropically (Pl. I, Fig. 2) instead of dexiotropically, as in the other quadrants. However, in a certain number of embryos this bilateral division does not take place and we find a complete reversal to a radial type (Text-Fig. 3, *D*). Furthermore, the posterior cells divide unequally exactly like the anterior. The intergirdle cells, too, bud off rudimentary

[1] Conn ('86) thought that the broad band entirely disappeared and was replaced by a single row of præ-oral and post-oral cilia. A careful examination of living and preserved material, however, has failed to show any evidence that this is the case.

cells in *every quadrant* (Text-Fig. 3, *D*) instead of only in the anterior and lateral, as in the normal type (Text-Fig. 3, *C*). In the next division of the cross the stem cells normally divide equally in the anterior, but extremely unequally in the posterior arms. Yet, here again, in the radial type we have an equal and strongly marked leiotropic division in *every arm* (Text-Fig. 3, *D*). In this type, too, we have a retention of radial division of the post-trochal region. No $X_{1.2}$ cell is formed and the second division of the third quartet is exactly alike in every quadrant. Accordingly, at 72 cells we find a complete reversal to radial cleavage. I have been able to follow this radial type to over 130 cells and, although certain bilateral features, in varying degree, creep in, the great majority of the divisions are purely radial. There is, also, strong reason for believing that this type never develops into an adult; for I found a few gastrula stages in which no X group, no M cells, no larval mesenchyme cells from the third quartet and no large anterior œsophagoblast ($2b_{2.2+}$) could be distinguished. It is significant to note, however, that certain cells (mesenchymatous) were sinking in from the first quartet.

These two types, the purely radial (Text-Fig. 3, *D*) and the normal bilateral (Text-Fig. 3, *C*), are connected by numerous transitions. The $X_{1.2}$ cell may be formed in embryos where the prætrochal region continues radial and the second division of the third quartet is also radial, or bilaterality may be alone expressed by the division of the posterior intergirdle cell.

There is another distinct, but very rare, type which seems to be a step toward a purely bilateral cleavage (Text-Fig. 3, *E*). In this case the cross is formed by equal and bilateral divisions in every quadrant, the rudimentary cells are formed as usual at the second cleavage in the posterior arms of the cross and the cells next to the rosette all divide toward the median line. The second division of the anterior and posterior intergirdle cells is nearly equal, but the rudimentary cells are budded off as usual in the lateral.

Treadwell has studied a few (only three cases) similar variations in *Podarke*. He calls attention to the fact that here "the reversion is always to the radial from the bilateral (from the type of the posterior to that of the anterior arms of the cross) and not in the opposite direction."

In *Thalassema*, however, as we have seen, the step (hardly here a reversion) may be from the type of the anterior to that of the posterior. It seems reasonable to suppose that the radial types are cases in which the primitive radial cleavage has been retained and which have not been affected by the "reflection" of the bilateral character of the trochophore. That such a reflection has really taken place (Wilson, '92; Conklin, '97; Treadwell, '01) and that the radial and bilateral types of cleavage are distinct in origin seems to be clearly indicated by the retention in some cases of the purely radial (for a fuller discussion see beyond). An examination of a hundred embryos shows that 89 conform to the normal type, 9 to the radial, and 2 to the bilateral.

c. Equal and Unequal Cleavage.—As a result of his investigation of the development of *Unio*, Lillie ('95) came to the conclusion that "the relative size of the cells in early cleavages is adapted to the size and time of development of the larval organs. Using this idea as a working basis, Treadwell ('99, '01) has given, recently, an interesting discussion of the relations of equal to unequal cleavage. The conclusions to which a study of the cytogeny of *Podarke* led him, are fully sustained by that of *Thalassema*. We find indications of differentiation appearing just as early and in exactly the same way in both. Indeed, this almost identical cleavage in these two forms and also in all other representatives of the so-called "equal" type calls for more than a passing notice. On the one hand it seems evident that such widely separated forms as *Hydroides*, *Lepidonotus*, *Podarke* and *Thalassema* have a practically identical equal cleavage because of their similarities in the trochophore stage. Again, the trochophore stages are similar because all are adapted to a free-swimming life of considerable duration. Such a condition involves a retardation of the trunk-forming region and hence the *D* blastomere is the same size as the others. Yet it does call for an equatorial prototroch and a highly developed prætrochal region in every case, and hence the blastomeres at the 8-cell stage are subequal in size. The above agrees essentially with the explanations that have been given by Lillie ('95), Conklin ('97), Treadwell ('01) and others and without doubt the principles of precocious segregation of formative matter, is an important factor in determining inequality or equality in cleavage.

Nevertheless, the cleavage of *Thalassema* seems to show that another and possibly more fundamental factor must be taken into consideration, and that is the tenacity with which the primitive radial cleavage and symmetry of the ancestral prototype of the annelids has persisted. In *Thalassema* and in *Podarke* the bilaterality of the adult is not expressed early in the ontogeny by bilateral cleavages, as in many annelids with unequal cleavage, but is first indicated by modifications in the size relations of the radial cleavages, either directly as a result of a cleavage or by a subsequent increase in size of certain cells or regions. A good example of the first is the fact that in the second division of the third quartet the larger products of both the *c* and *d* quadrants lie on each side of the mid-dorsal line (Pl. II, Fig. 13). Of the second, that the anterior œsophagoblast ($2b_{2.2.1.2}$), shortly after gastrulation is completed, is the largest cell in the embryo (Pl. II, Figs. 23 and 24; Text-Fig. 4, *C*); yet, up to the beginning of gastrulation this cell remained of equal size with the corresponding cells in the *a* and *c* quadrants. The last point, *i. e.*, the foreshadowing of the bilaterality of the adult by a rapid increase in size of certain regions, is clearly illustrated in the development of the *X* group (Pl. II, Figs. 15, 17 to 24; Text-Fig. 4, *C* and *D*). The protoblast of this group, when first formed, is not larger than the other members of the second quartet, nor does it divide much more rapidly than they, until the beginning of gastrulation. At this point in the ontogeny, the whole group increases rapidly in size, not only by cell divisions, but by the growth of the cells themselves, and in the end forms almost as much of the post-trochal ectoderm (Text-Fig. 5, *F*) as does the great "somatoblast" of *Nereis*. The important point to bear in mind is, I think, that even in determinate cleavage there is more than one method of procedure by which a practically identical result may be attained.

Finally, I would call attention again to the frequency of the cases in which radial cleavage and symmetry is retained after bilateral symmetry should have expressed itself. Bearing this in mind it would seem that Heath ('99) is correct in his criticism of Conklin's ('97) conclusion that "radial structures in the developing egg are a foreshadowing of larval characters, just as bilateral cleavages are usually attributed to a precocious development of adult characters." In reference to this statement Heath says: "The reflection of larval stages on early cleavage stages does not produce radial symmetry but tends to destroy it." These early radial characteristics may be better explained, as Heath further points out, by considering them as having been inherited from the radially symmetrical ancestors of the *Turbellaria*, annelids and molluscs. The transition from the equal to the unequal type of cleavage has been, without doubt, very gradual. With the shortening of the larval existence the posterior macromere has gained in importance until finally we reach the direct teloblastic development of oligochætes and leeches.

II. Gastrulation to Trochophore.

1. *Gastrulation.*

The process of gastrulation begins as a rule about seven hours after fertilization (Pl. II, Fig. 21). It is a modified embolic type and consists merely of the insinking of the entoblastic plate (Text-Fig. 4, *A* and *B*). I could not discover any infolding of cells such as Conn ('86) describes. The entoblastic plate consists, as has already been indicated, of eleven cells, just as is the case in *Aricia*, *Amphitrite*, *Clymenella*, *Arenicola* and *Podarke*. Although, in *Thalassema*, the order in which the cells leave the surface is subject to variations, the macromeres generally sink in first, next the fifth quartet and finally the fourth quartet (Pl. II, Figs. 21 to 24). As gastrulation proceeds there is a flattening at the lower pole and a rounding out of the wall of the prætrochal region (Text-Fig. 10, *D*). All of the entoblast cells become greatly elongated and the nuclei lie in their swollen inner ends. These cells sink in so far that some of them come in contact with the rosette region and the lateral ectoblastic wall. A little later the endoblastic mass rounds out and withdraws from the body wall, but the points of contact are still preserved by protoplasmic strands (Text-Fig. 8, *F*) which, owing to the viscid nature of the protoplasm, are drawn out. These threads are, accordingly, of the same nature as those occurring at the surface of the egg immediately after fertilization and are not due to spinning phenomena. It seems probable that a similar explanation may be given for the strands described by Treadwell ('01).

2. *Closure of the Blastopore.*

The blastopore, when first marked out, lies exactly at the lower pole of the egg, but it soon shifts slightly toward the future ventral side (Text-Fig. 4, *C*). It is bounded at the posterior end by the apex of the *X* group, at the sides posteriorly by small cells of the third quartet, *c* and *d* quadrants, and anteriorly by cells from the second quartet *c*, *a* and *b* quadrants (Pl. II, Fig. 23). Later the sides of the blastopore become lined

TEXT–FIGURE 4.

A, the invaginating plate. *B*, actual section of a gastrulation stage. *C*, an early gastrulation stage; the *X* group, ventral plate, is bounded by heavy lines; *bl*, blastopore; *e*, cells migrating from the prætrochal region; *œs.m.*, œsophagoblast median. *D*, a later stage showing the shifting of the blastopore toward the prototroch on the ventral side and the further migration of cells, *l*, from the prætrochal region.

entirely by the cells of the third quartet (Pl. II, Fig. 24), which have shoved aside or inwards those of the second. This phenomenon is due to the more rapid cell divisions and growth

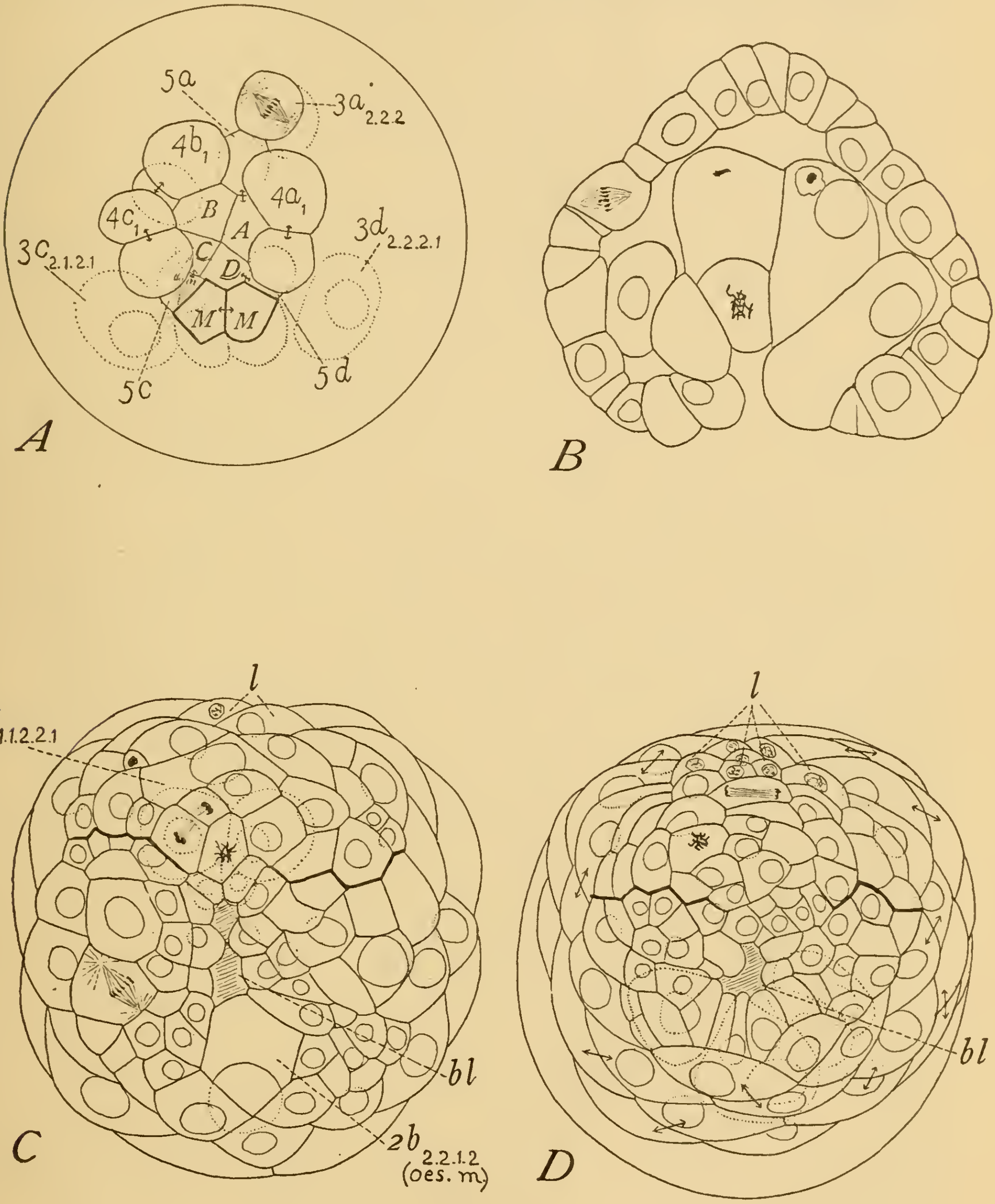

FIG. 4.

at the posterior end of the embryo, especially of the *X* group, which, thereby, push all the cells anterior to it toward the future ventral side (Text-Fig. 4, *D*). As will be pointed out directly, this movement lies in the closest association with the formation of the œsophagus. The cells, accordingly, which finally line the blastopore are the following: at the posterior end $x_{1.2+}$ on the right side the progeny of $3c_{2.2}$, $3c_{2.1.1}$, $3c_{2.1.2.2}$; on the left side that of $3d_{2.1}$, $3d_{2.2.2.2}$, $3d_{2.2.1}$; and at the rounded anterior end that of $2c_{2.2.2}$, $3b_{2.2.2}$, $2b_{2.2.2}$ and the large œsophagoblast $2b_{2.2.1.2}$. In *Arenicola* the cells of the second quartet are shoved away in a similar manner from the sides of the blastopore by cells from the *c* and *d* quadrants of the third quartet.

The blastopore, when fully formed in *Thalassema*, is an elongated slit with an enlargement at the anterior end (Text-Fig. 4, *C*). *This latter part never closes, but after the formation of the œsophagus becomes the mouth.* The subsequent movement of the blastopore toward the future ventral side is brought about, on the one hand, by the forward movement of the ventral plate (*X* group), which in turn is caused by the migration of cells from the præ-trochal region through the dorsal gap. On the other hand an equally important factor in the shifting of the blastopore is the simultaneous insinking under the prototroch of the large anterior œsophagoblast ($2b_{2.2.1.2}$, Pl. II, Fig. 24). The posterior part of the blastopore finally becomes closed by the approximation of the sides. The closure seems to be brought about, not so much by active cell divisions as by the fact that the post-trochal region becomes greatly flattened as a consequence of the insinking of the entoblasts, the *M* cells, and the ectomesoblasts from the third quartet. This flattening would naturally tend to bring the edges of the elongated blastopore together. The open anterior end at length comes to lie just under the prototroch (Text-Fig. 4, *D*)—the position of the future mouth. The closure of the blastopore from the sides reminds one in some degree of the process in *Lumbricus* (Wilson, '89). In cases where the macromeres are very large and fill the cleavage cavity, as in *Nereis* and *Amphitrite*, the closure takes place at the lower pole by the convergence of the cells from all sides. In *Capitella* (Eisig, '98) the blastopore is said to close completely, and this is probably the case in the majority of annelids.

3. *History of the Dorsal Gap in the Prototroch and of the Shifting of Embryonic Areas.*

Dorsal Gap. — A number of the early observers of the early development of annelids and molluscs have noted the dorsal interruption or gap in the prototroch. Among the first of these was Hatschek ('78). Until recent years, however, the cause of this phenomenon has not been known. There are two factors, I think, which we must now taken into consideration. In *Amphitrite* and *Clymenella*, as Mead ('97) has shown, the dorsal gap is due to the fact that the cells in the *d* quadrant of the second quartet, which corresponds to the secondary protochal cells of the other three quadrants, fail to develop cilia. This explanation seems to suffice, also, for a good many other forms, but in *Thalassema*, as will be shown below, the dorsal interruption in the prototroch is caused entirely by the migration of cells from the præ-trochal into the post-trochal region.

In all other types of annelids, whose cell-lineage has been determined, the dorsal gap is present from the beginning. In *Thalassema*, on the other hand, it does not arise until about the eighth hour (Pl. II, Fig. 22). It is caused, in this case, by the divisions and spreading out of the posterior arms of the cross (Pl. I, Fig. 7), which, thereby, push the posterior intergirdle cells down along the mid-dorsal line. At the appropriate time (during gastrulation) the prototrochal cells at the juncture of the *c* and *d* quadrants are shoved apart (Pl. II, Fig. 24). Before they come together again, two large cells and at least eight smaller ones, with dark staining nuclei, are pushed through the gap and finally lie between the *X* group and the prototroch (Text-Fig. 4, *C* and *D*). The large cells, $1d_{1.2.1.2.1}$ and $1d_{1.2.1.2.2}$ (Pl. II, Figs. 14 and 24) are designated by the letter "*l*," although as has already been indicated, they have not quite the same cell lineage as the "*l*" cells in *Amphitrite*, *Arenicola* and *Podarke*. The smaller cells probably represent all of the intergirdle cell $1d_{1.2.1.1}$ and it is also possible that some products of the posterior arms of the cross pass through the break. In *Arenicola* four descendants of the posterior intergirdle cell ($1d_{1.2}$) migrate into the post-trochal region, but in this form and

TEXT-FIGURE 5.

Diagrams to indicate the direction of the shifting of the embryonic areas. Line *acb*, egg axis ; line *acp*, anterior posterior axis of the trochophore ; *bl*, blastopore ; *l*, area migrating from the præ-trochal region through the dorsal gap in the prototroch ; *M*, cœlomesoblast ; *pr*, prototroch ; *x*, ventral plate ; *vl*, ventro-lateralregion.

in *Amphitrite* the migration is not so extensive as it is in *Thalassema* and *Podarke.* The gap does not close in *Thalassema* until about the thirteenth hour.

The cells, that have thus migrated, increase rapidly in number and in the trochopore constitute a considerable area in the

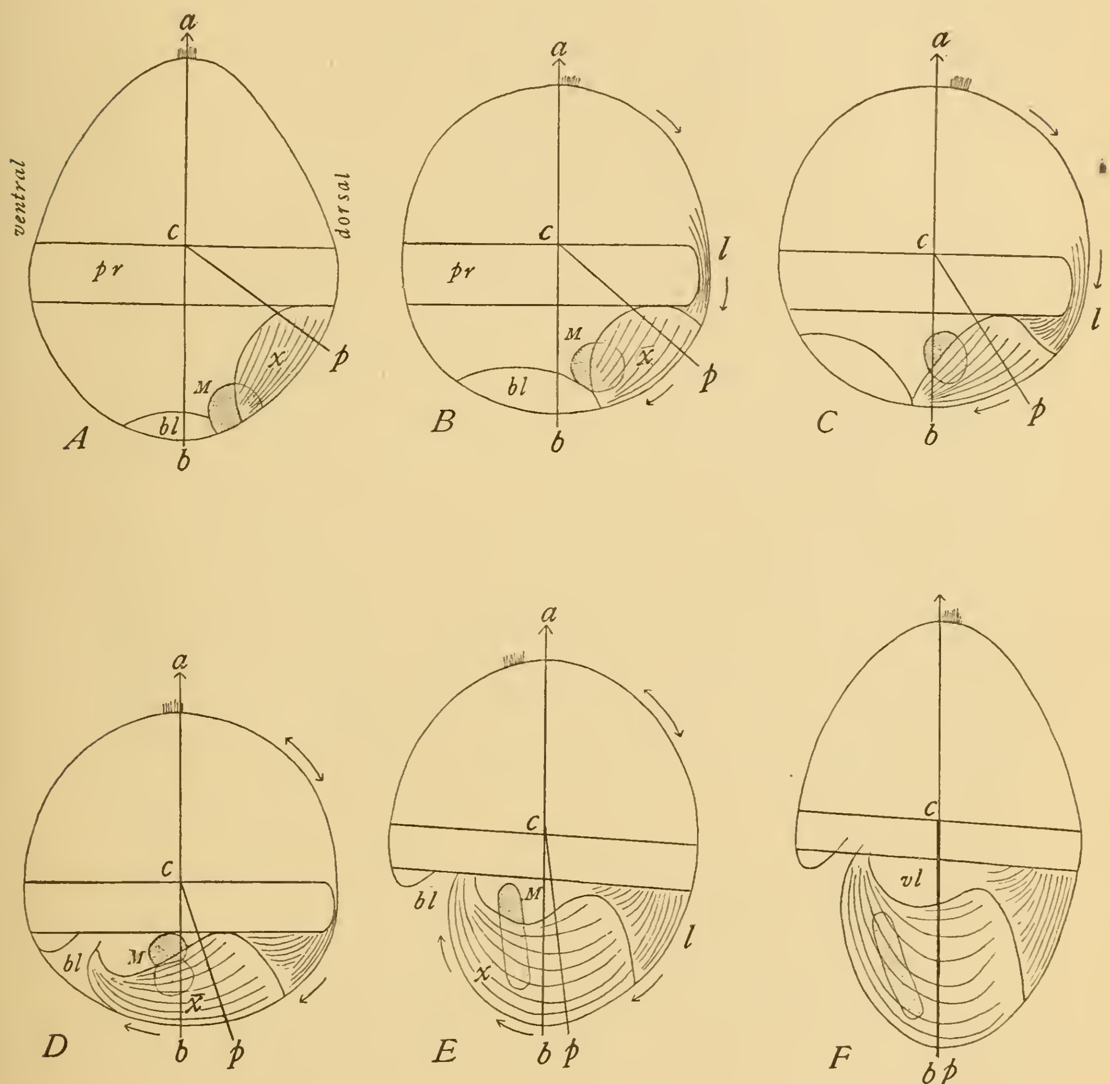

Fig. 5.

mid-dorsal region immediately below the prototroch (Text-Fig. 5). As most of the cells are small and thin and have dark staining nuclei (Text-Fig. 6), their fate may be followed to a late stage. In *Podarke* the migration of cells from the prætrochal region seems to be much greater than it is in *Thalassema* and the "*l*" cells become very much larger in the former than in the latter. In *Thalassema* any extensive lateral spreading of these cells is prevented by the fact that the *X* group reaches the prototroch on each side (Pl. II, Fig. 24).

Shifting of Areas (Text-Fig. 5). — The divisions of the *X* group to the beginning of gastrulation have already been described. The spreading of the group now continues rapidly, not only by cell division, but also by a swelling of the cells near the prototroch. These processes are all clearly morphogenic. Soon after the closure of the posterior end of the blastopore, the cells anterior to it become shoved around the open anterior end by the movement of the ventral plate toward the future ventral side (Pl. II, Fig. 24; Text-Fig. 4, *D*). At length some of the larger cells on the mid-ventral line sink into the opening and later take part in the formation of the posterior wall of the œsophagus (Text-Fig. 6, *B*, *C* and *D*). Owing to this forward migration, and in consequence of the great flattening and diminution in area of the post-trochal region, the ventral plate now extends to the stomodæal opening (Text-Fig. 5, *D*). A still further shifting of this plate is brought about both by the growth of the cell group which has migrated from the præ-trochal region, and by the elongation of the body along the future antero-posterior axis (Text-Fig. 5, *E* and *F*).

The *X* group gives rise to by far the greater part of the post-trochal ectoderm of the trochopore. A small ventrolateral region (Text-Fig. 5, *F*) is formed by the cells which do not enter into the differentiation of the œsophagus. They are certainly $2a_{1.2.2}$ and $2c_{1.2.2}$ and possibly also $3d_{1.1}$ and $3c_{1.1}$.

The behavior of the ventral plate in *Thalassema* is different from anything that has hitherto been described in annelids. There is no concrescence of the lateral edges on the ventral side, as is the case in *Nereis*, *Amphitrite*, *Arenicola* and *Podarke*. In the first three cases two factors may be said to cause this phenomenon. The first is the rapid development of the somatic plate *before* the closure of the blastopore, which necessitates its spreading laterally only. The second is the formation of a terminal proctodæal area at the same time with the closure of the blastopore, which causes a continuance of the lateral movement and ends finally in the meeting of the edges on the ventral side. In *Podarke*, on the other hand, the initiative of the lateral spreading is the fact that the posterior end of the blastopore does not close at all, but is directly transformed into the proctodæum. None of these factors are present in *Thalassema* and, as has already been shown, there is nothing to prevent and everything to cause the somatic plate to reach its definite position very early and by a *direct forward shifting*.

The final disposition of the plate is similar to that of *Nereis*. The side which was at first next to the prototroch in the end reaches a position corresponding to that at which the teloblasts could be last distinguished in *Nereis*. Wilson ('92) thought it possible that there is a still further shifting until the teloblasts lie at the extreme posterior end of the embryo and form the growing point. It is impossible to determine whether this is the case in *Thalassema*, since there are no large teloblasts. This fact, of course, is correlated with the long free-swimming trochophore stage. It is very evident, nevertheless, that before gastrulation the future anal region lies near the prototroch and shifts down during the metamorphosis until it comes in line with the former egg axis, and this involves an evident shifting of the antero-posterior axis (see Text-Fig. 5). This is a similar process to that at work in *Nereis*, but is much simpler and possibly more primitive.

Conn ('86) likewise studied and figured this shifting in *Thalassema*, but did not seem clearly to recognize the fact that the final antero-posterior axis coincides with the former egg axis, as has recently been found to be the case in a number of annelids, and that the shifting of areas is due to the very rapid growth of the dorsal (posterior) side. The distance of the apical plate from the prototroch, on the ventral (anterior) side, on the other hand, undergoes little change.

It is a difficult matter even to attempt to bring into line the divergent accounts of the axial relations in the development of the trochophore in polychætes that have been given in late years by Wilson ('92), Mead ('97), Treadwell ('01) and others. I think it possible, however, that in the last analysis it will be found that, in all cases where there is a trochophore stage, the cells which will later form the growing point have shifted downward from a position immediately below the prototroch on the dorsal side toward the anal region and that the mechanical cause of this shifting is the migration of cells from the præ-trochal region through the dorsal gap and into the post-trochal region. In the majority of forms this is not as clearly the case as it is in *Thalassema*, since the process may become modified by the early formation of the anus or anal region. Although Wilson did not describe any migration of cells from the præ-trochal region, it seems quite probable that the dorsal triangular space, covered with small transparent cells, originated in this way and that the growth of this area forces the teloblasts toward the lower pole. In *Amphitrite* it is possible that Mead has not given the migrating cells credit for forming as much of the dorsal region as they deserve. In this case, too, the shifting of areas is not readily recognized, because of the absence of teloblasts. This possibility also applies to *Arenicola*. In *Podarke*, with the exception of the concrescence of the ventral plate the shifting is exactly similar to that in *Thalassema* and the growing point arises from the same cell region.

These processes in *Thalassema* are very closely paralleled by those commonly occurring in molluscs. In *Chiton* (Metcalf, '93) and *Ischnochiton* (Heath, '99) there is the same shifting of the blastopore to the ventral side to form the stomodæum, and the anus also arises very late. In *Teredo* (Hatschek, '81) the blastopore closes on the ventral side in the region of the future mouth. In *Ostrea* (Brooks, '80), *Dentalium* (Kowalevsky, '83) and *Patella* (Patten, '86) the blastopore shifts toward the ventral side and stands in the closest relation to the stomodæum, but not to the proctodæum.

4. *Formation of the Enteron.*

After sinking in, the entomeres become rounded and divide rapidly in such a way that a very thick epithelium is formed surrounding a small lenticular shaped cavity (Text-Fig. 6, *A*).

By further divisions the cavity is increased in size and its wall becomes composed of columnar cells filled with yolk granules (Text-Fig. 6, *B*). According to Conn ('86), "the central cavity arises by an absorption of the digestive mass." This is certainly not the case, for sections show plainly that it is entirely due to the nature of the cell divisions. The macromeres give rise to the dorsal and dorso-lateral part of the stomach and intestine wall, while the progeny of the fifth and the *a*, *b* and *c* quadrants of the fourth quartet produce the ventral and ventro-lateral regions. The enteric cavity is secondarily divided into stomach and intestine by a shelf which grows out from the dorsal wall (Text-Fig. 6, *B*, *C* and *D*). Its origin is first indicated by the projection of a single row of cells, but this is immediately followed by a double row. In cross-section it is accordingly, wedge-shaped. This shelf, finally, completely divides the stomach from the intestine except on the ventral side where a circular opening is left. A similar description is given by Conn for this form and also by Treadwell for *Podarke*. The partition becomes attached much nearer the œsophagus on the right side than on the left, so that in the completely differentiated trochophore the greater part of the stomach lies on the left side of the body and the intestine on the right (Text-Fig. 7, *B*). There is no proctodæum, such as we find in *Amphitrite* and *Podarke*. The anus,[1] itself breaks through very late, even after the trochophore has begun to feed. This seems to be the case also in *Eupomatus* (Hatschek, '85).

5. *Formation of the Œsophagus.*

The œsophagus is formed after gastrulation by the invagination of the greater part of the progeny of the second and third

[1] Conn has made several statements in this connection which seem to be founded on errors in observations. He implies that the anus is formed at a point which corresponds to one end of an elongated blastopore. This is true only in the most general sense. Again, he says that the alimentary tract is complete in 12 hours. In all the embryos that I have examined this is never the case until at least the eighteenth hour. But the most radical error lies in the assertion that the cavity in the entoderm opens directly to the exterior by the blastopore. The enteron during its formation is, in reality, a closed sac and does not open to the exterior until it comes secondarily into connection with the ectodermal œsophagus. This is also the case in *Cyclas* (Ziegler, '85), *Pisidium* (Lankester, '75) and the Unionidæ (Lillie, '95).

TEXT-FIGURE 6.

Optical sections of the successive stages in the formation of the alimentary tract. *oes.m*, *oes.r*, *oes.l*, median, right, left œsophagoblasts; *gl*, ectodermal gland; *in*, intestine; *st*, stomach. Other letters as before. The ectomesoblast cells are stippled lightly; the ectodermal glands, heavily.

quartets of the anterior and lateral quadrants. Before the posterior portion of the blastopore has closed three cells ($2a_{2.2.1.2.1+}$, $2b_{2.2.1.2}$, $3b_{2.1.1}$) become prominent because of their greater size (Pl. II, Fig. 24). These cells have already been

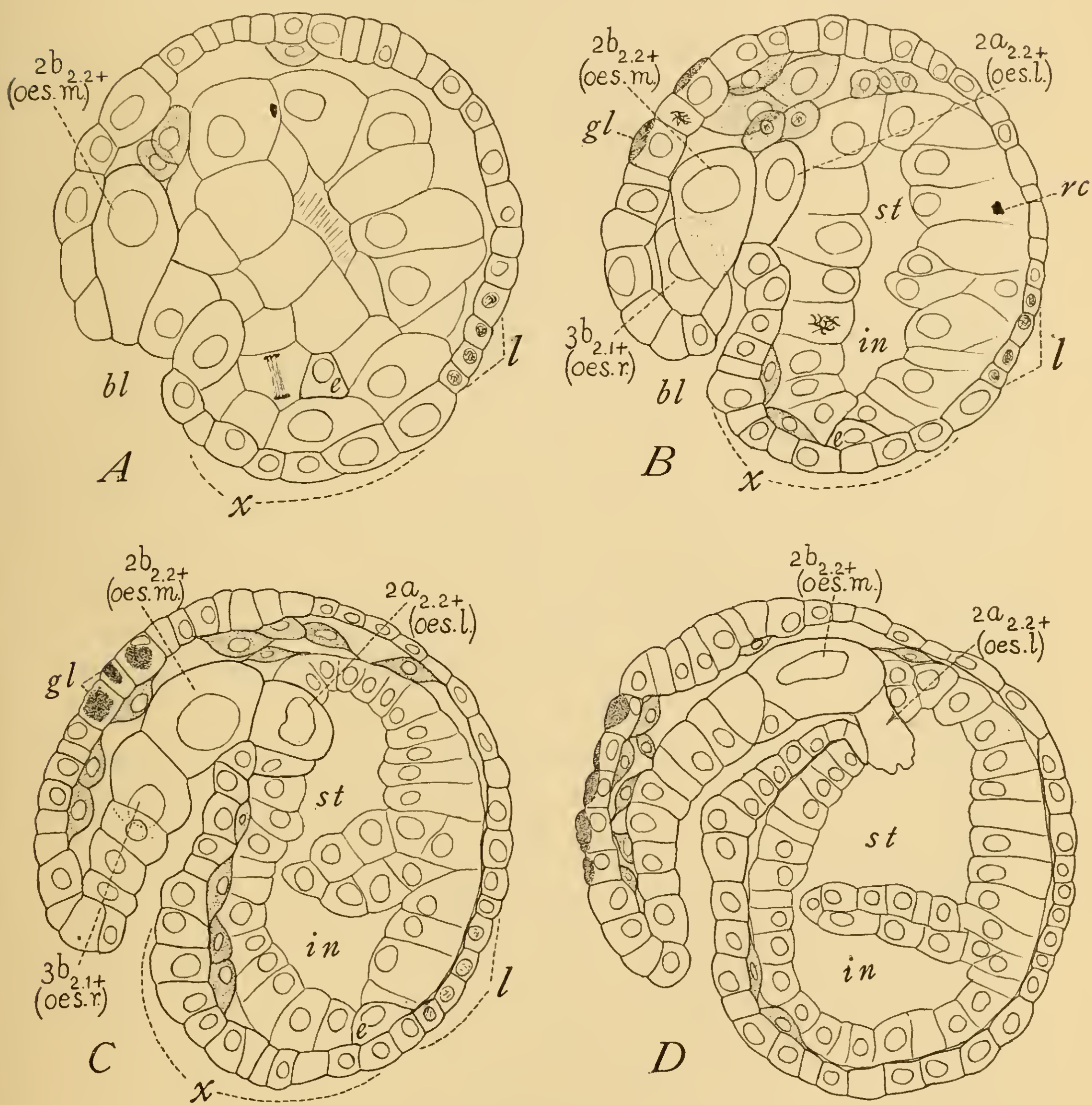

FIG. 6.

designated as œsophagoblasts. The anterior one attains a very great size (Text-Fig. 6, *A*) and at the end of gastrulation is the only cell that separates the anterior end of the blastopore from the prototroch (Pl. II, Fig. 24). By the continued insinking of this cell toward the apical plate the open anterior end of the blastopore approaches the prototroch and, finally, the position of the adult mouth. The three œsophagoblasts become grouped about this opening and sink in nearly simultaneously. The one on the right ($3b_{2.1.1}$) divides once and nearly equally just before sinking in, but the others do not divide again. The first, which possibly represents the larval mesoblast from the *b* quadrant, takes the place of the stomatoblast that as a rule arises from the second quartet on that side ($2c_{2.2+}$). The œsophagoblast on the left ($2a_{2.2.1.2.1+}$) meeting with less obstruction, sinks in faster than the anterior and that in turn more rapidly than the one on the right. Accordingly, they finally become arranged in a row extending dorso-ventrally (Text-Fig. 6, *B* and *C*). When the œsophagus has become differentiated, the one at the inner end of this row ($2a_{2.2.1.2.1+}$) surrounds in large part the opening into the stomach, the median ($2b_{2.2.1.2}$) forms the antero-dorsal wall, and the one at the outer end ($3b_{2.2.1}$) a part of the wall on the right side (Text-Fig. 6, *C* and *D*). The posterior wall is formed entirely by the infolding of the columnar cells which lie along the mid-ventral line. There is no doubt that a considerable number of cells of the ventral plate take part in this process.

Conn failed to note this invagination of ectoderm cells and so has described the œsophagus as endodermal and as resulting from a division of the digestive tract. Hatschek ('85), however, in *Eupomatus*, has recognized the fact that the entire œsophagus arises from the ectoderm. In this form the œsophagus and archenteron are described as being continuous from the first and as not coming secondarily into connection with one another as in *Thalassema*. The intestine, too, arises in this case as a later proliferation of cells from the posterior dorsal wall of the enteron. The same is the case in *Pomatoceros* (Von Drache, '84).

In annelids the stomatoblasts seem to arise, as a rule, from the second quartet, anterior and lateral quadrants (*Nereis*, *Capitella*, *Podarke*), but in *Arenicola*, according to Child ('01), they take their origin from the same quadrants of the third quartet. In these forms, also, practically all of the rest of the progeny of the second and third quartets of these quadrants enter into the formation of the stomodæum.

6. *Differentiations of the Ectoderm.*

About twelve hours after fertilization, glands and green pigment (Text-Fig. 8, *B*) begin to appear in the ectoderm. The pigment is first noticeable just above the prototroch, arising in the cytoplasm of the cells in close proximity to the nucleus. The glands, on the other hand, first appear in the larger cells between the apical plate and the mouth (Text-Fig. 6, *B*). A homogeneous liquid substance is deposited in the outer part of the cell which rapidly increases in amount until it almost entirely fills the cell and shoves the nucleus to one side (Text-Fig. 6, *C*). This substance does not stain in preserved material in hæmatoxylin as do mucous glands in general (*Amphitrite*), but it does stain brilliantly with Bordeaux red. It would seem, accordingly, that these glands may be of the same nature as the problematic bodies in *Amphitrite*. In the living trochophore a chemical stimulus causes a discharge of a gelatinous substance, as has been noted by Conn. Hatschek ('81) describes similar glands in *Echiurus* and says that they arise from vacuoles in single cells. Eisig ('98) thinks that they may be excretory and take the place of primary nephridia. This is probably not the case in *Thalassema*.

The cells which constitute the ventral neural ciliated region are differentiated early (about fourteen hours) and separately. Later they elongate somewhat and dovetail with one another (Text-Fig. 7, *A*), so that in the fully formed trochophore there are two rows of these cells. They are from the first easily distinguishable by their clear refractive protoplasm and larger size. Just below the mouth region these two rows separate and extend on each side of the oral opening to the prototroch. Their method of origin explains the fact that the neural cilia arise in separated bunches and also the manner by which these cilia become connected with those of the prototroch. The apical plate is, in all probability, formed entirely by the rosette cells which, in the trochophore, become elongated and columnar.

TEXT–FIGURE 7.

A, a stage which shows the development of the ventral neural ciliated region. *vc*, ventral ciliated cells ; *mo*, mouth. *B*, an optical longitudinal section from the ventral side of a young trochophore, twenty-four hours.

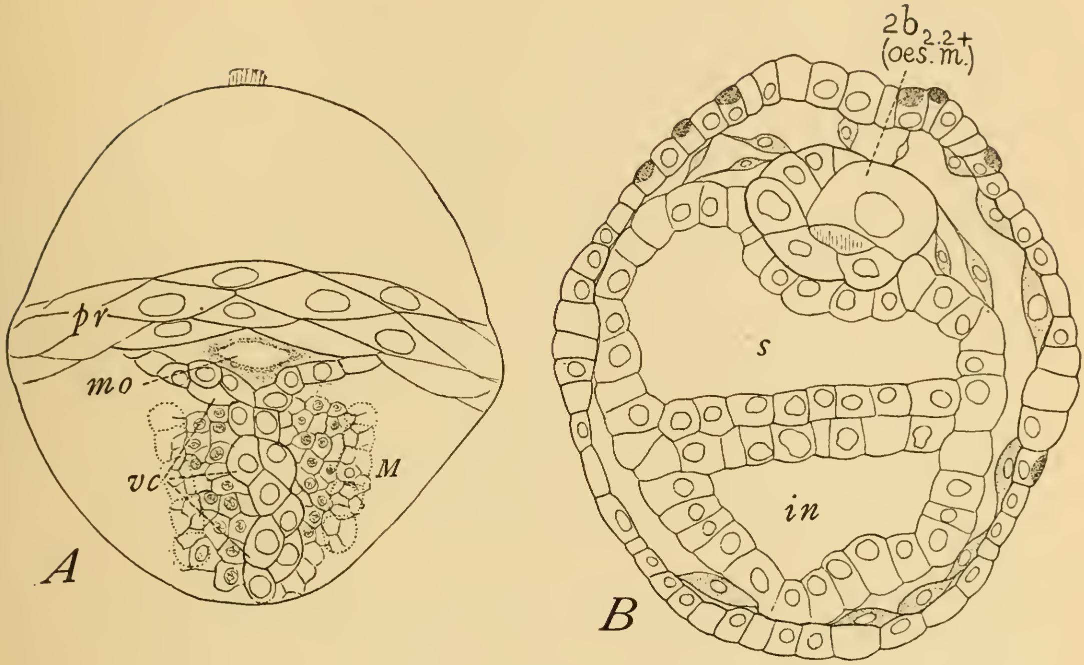

FIG. 7.

III. Fully Developed Trochophore.

Between the twenty-fifth and thirtieth hours there is a rapid increase in size of the trochophore, brought about by the stretching and consequent thinning out of all the tissues. Conn has described a similar swelling at the transition of the larva into the adult, as has also Spengel ('79) in *Bonellia*. Conn ('86) thinks that this is due to the absorption of water through the anal vesicles as it takes place immediately after their formation.

a. Ectoderm.—Since the differentiations of the ectoderm have been described in detail by Conn, they may be passed over without extended comment. When the trochophores are stained *intra vitam* with methyl blue or neutral red, certain loosely arranged groups of granules (Text-Fig. 8, *B*) stain with great intensity. These granules are present not only in the body wall, but also in that of the gut and in some mesenchyme muscles. It is questionable whether, as Conn ('86) maintains, the absence of green granules is correlated with a lack of nutriment. Hatschek ('81) concludes that the opposite is true, since, in *Echiurus* a lack of food and poor environment seem to increase the amount of pigment and decrease the number of S-shaped glands. In *Thalassema*, I believe, the differences are due merely to individual variations and are quite independent of the presence or absence of food, for the variations appear before the animals have begun to take in nutriment. Spengel ('97) figures an abundance of green pigment in the larva of *Bonellia*. A very careful search was made for ectodermal muscles, which, according to both Hatschek and Conn, lie in the body wall. I think that it may be stated, with absolute certainty, that no such muscles are present in the trochophore of *Thalassema*. The wrinkles in the outer cuticle simulate quite closely muscle fibers and might easily have been mistaken for them.

b. Ciliation. — The fact that the præ-trochal region is provided with scattered patches of cilia (Text-Fig. 8, *A*) seems to be in accordance with the widely accepted theory that at an earlier stage of its evolution the trochophore was entirely covered with cilia, as is the case to-day in the young *Pilidium* larva and the young trochophores of *Teredo*, *Dentalium*, *Nucula*, *Yoldia* and *Chætopterus*. In most forms, however, the cilia have become restricted to certain definite regions. The paratroch in *Thalassema* appears very late, after 36 hours, and is formed without doubt from cells of the somatic plate which were originally in close proximity to the prototroch. These cells, it will be observed, are different from those which enter into the formation of the paratroch in *Amphitrite* and *Arenicola*.

The œsophagus develops strong cilia even before its complete differentiation. At the opening of the œsophagus into the stomach a circle of long cilia hang down into the latter (see Text-Fig. 8, *A*). The stomach wall, itself, is covered uniformly with fine cilia, but these seem later to be restricted to certain swollen regions presently to be described. The wall of the intestine is also ciliated. A very curious ciliated groove or ridge (it was impossible to determine with certainty which) runs from the stomach into the intestine, a little to the right of the ventral side. At its stomach end it is bent in a half spiral and throughout its course bears a row of powerful, active cilia. Conn considered it to be the Anlage of the ciliated groove or the collateral intestine of the adult. Hatschek described the same organ in the form of *Echiurus* that he studied; as has also Salensky ('76) in the Naples larva. The latter ascribed to it a respiratory function. Without doubt in the larva of *Thalassema* it functions merely as a conductor of food from the stomach to the intestine.

c. Alimentary Tract.—The wall of the œsophagus, which is very thick, secretes a cuticle. In *Eupomatus* both the œsophagus and anal end of the intestine are lined in the same way. Conn has described a glandular region in the stomach wall immediately under the œsophagus, and there seems to be some evidence, especially in sections of the younger trochophores, that the cells here have such a function. It is equally probable, however, that the swellings occurring at regular intervals in the stomach-wall of older trochophores (Text-Fig. 8, *A*) may be concerned in digestion. Each of these contains a clear refractive drop and also a few pigment granules (Text-Fig. 8, *C* and *D*).

d. Mesoblast.—A detailed description of the development of the mesoblast is reserved for a separate section and only its differentiation in the trochophore will be indicated here. The cœlomesoblast is present in the form of two bands, each consisting of only five subequal cells. These are closely applied to the body-wall and lie in the usual position on each side of the neural row of cilia, but are more widely separated than in many annelids. The mesenchyme, on the contrary, is present in great abundance and has attained a considerable degree of differentiation (Text-Fig. 9, *A*), many of the cells having now been converted into muscles. The latter vary somewhat in number and position in different individuals, but there are certain typical ones which are always present. Two or three extend from the apical plate to the œsophagus. These, with similar muscles along the median line, running from the apical plate to the mouth, widen the cavity of the œsophagus and permit the passage of the larger particles of food. A group of

TEXT-FIGURE 8.

A, optical section of a living three-day trochophore. *ap*, apical plate ; *ct*, ciliated tract between the stomach and the intestine ; *ex*, excretory cells ; *pa*, paratroch ; *pr*, prototroch ; *vc*, ventral ciliated region. *B*, view of the body wall of a living trochophore. *gp*, green pigment ; *gl*, glands ; *gr*, granules. *C*, surface view of the stomach wall (living), greatly magnified. *D*, section of the same. *E*, optical transverse section of a stage of over 140 cells. The cœlomesoblast cells, *M*, are about to bud off two small entoblast cells. In this and the following figure the ectomesoblast cells are stippled and the cœlomesoblast cells are outlined with heavy lines. *emr*, ectomesoblast right, arising from the *c* quadrant ; *eml*, ectomesoblast left, arising from the *d* quadrant ; *emm*, ectomesoblast median, arising from the *a* quadrant. *E*, optical section from dorsal side and at right angles to the prototroch of a slightly older stage. *e*, entoblast cells budded off from the cœlomesoblasts, *M* ; *le*, lateral ectomesoblast cell ; *p.st*, protoplasmic strand running from the entoblast to the ectoblast. The prototrochal cells are indicated by diagonal lines.

elongated muscles runs from the apical plate and the anterior part of the umbrella region to the body-wall beside the mouth, and is continued by muscles which extend along the mid-ven-

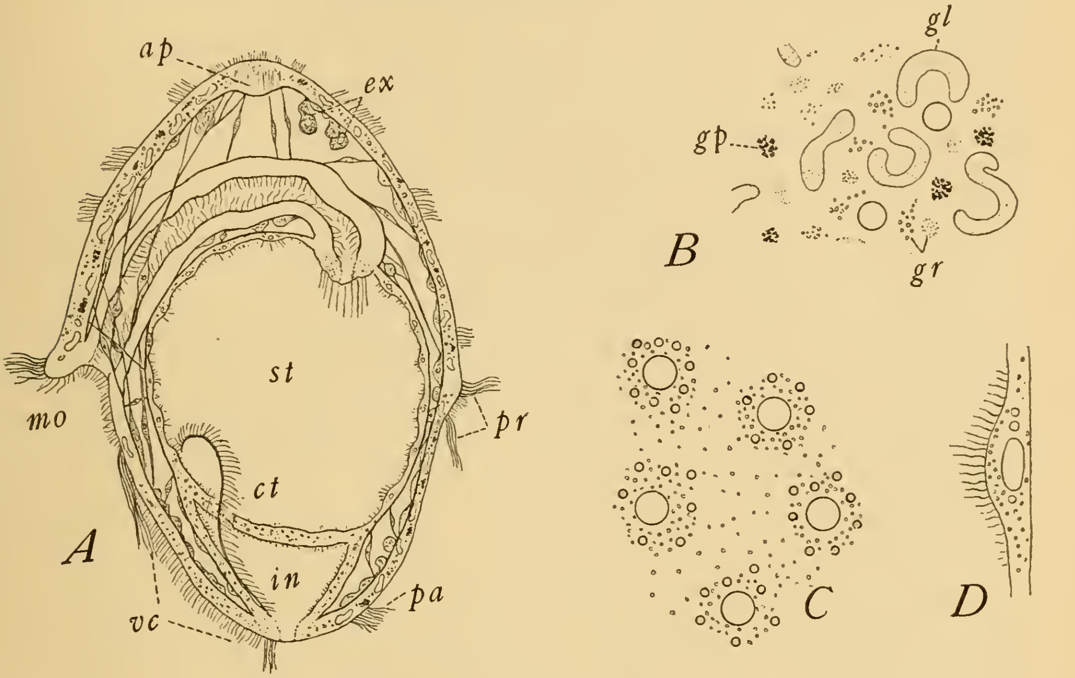

FIG. 8.

tral line. In *Echiurus* and *Eupomatus* the ventral longitudinal muscle is, in like manner, divided into a præoral and postoral part. A very constant muscle-cell is one that runs from the œsophagus to the stomach on the dorsal side. Muscles also run from the body-wall to the alimentary tract along its entire course. These muscles are, for the most part, mere threads with a central swollen nucleated part, but the latter seems sometimes to be entirely absent. As a rule the contractile thread-like part branches extensively and at both ends. I could not find "the broad loose bands of muscles connecting the apical plate with the *lateral* ciliated band" figured and described by Conn. It is probable that these were confused with the ventro-œsophageal bands. Besides these muscles there are a great many of what are apparently undifferentiated mesenchyme-cells, which, as Conn has noted, form an almost continuous layer on the inner side of the body-wall. This is also the case in *Echiurus*, the trochophore of which is in many respects closely similar to that of *Thalassema*.

e. Excretory Cells. — A careful search in living and preserved material has confirmed Conn's assertion that there are no primary nephridia in *Thalassema*. The excretory function seems to be relegated to a number of globular mesenchymatous cells, which are either loosely attached to the body-wall and muscles or float freely in the primary body-cavity (see Text-Fig. 8, *A*). These are especially prominent in the three- or four-day trochophore. They soon become stained a yellowish-brown color and in the oldest trochophores contain refractive granules. In several gastropod larvæ excretory cells have been described, and they are in every case of *ectodermal* origin. They are often found closely associated with the velum, *e. g.*, *Bythinia* (Sarasin, '82), *Ochidium* (Joyaux-Laffine, '82), *Neritinia* (Blochmann, '82), *Crepidula* (Conklin, '97). Of greater interest in this connection, however, is the fact that in certain adult tunicates, *e. g.*, *Botryllus*, *Polycyclus*, *Ciona* and *Salpa*, the excretory organ, according to Dahlgrün ('01), is represented by a small number of unmodified mesenchyme-cells in the protoplasm of which the excretory products form dark granules.

f. Habits. — The trochophore swims in the usual way with the apical plate directed forward and revolving spirally on its long axis. When it first acquires cilia (four and one half hours) it seems indifferent to light, but at about nine hours it shows a slight positive heliotropism. During gastrulation the great majority of the larvæ sink to the bottom and do not begin to swim actively until the transition into the trochophore is completed (about eighteen hours). During this time all the energy of the embryo seems to be directed toward the completion of the morphogenic processes. From this time to the seventh or eighth day the trochophores are very decidedly negatively phototactic, but after this they again become indifferent. Strange as it may seem, Mead finds that the embryos of *Lepidonotus* are affected by light in just the opposite way. When they first begin to swim they are positive, at fourteen hours negative, from twenty to twenty-four hours indifferent and from two to three days strongly positive. Eisig describes the seven-day embryos of *Capitella* as positively heliotropic, but older larvæ as indifferent.

As has already been indicated, the larvæ of *Thalassema* begin to feed as soon as the digestive tract is differentiated and even before the anus has formed. By a gradual loss of cilia, the trochophore sinks to the bottom and undergoes there the metamorphosis into the adult.

Considered as a whole this trochophore is a very simple and possibly a primitive one. There are no ring-muscles, no nerve-rings and no primary nephridia. Among its positive primitive characters may be reckoned the meager development of the cœlomesoblast, the formation of ectomesoblast from the first quartet, the presence of excretory cells, and the late formation of the anus.

IV. The Mesoblast.

1. *Cœlomesoblast.*

The two cœlomesoblast cells (*M, M*) are the last to sink in (Pl. II, Fig. 23) at gastrulation instead of the first, as is the case where the development is more direct (*Nereis, Amphitrite*). The right cell is at this time somewhat larger than the left. Immediately after invagination each buds off a small but functional cell toward the blastopore (Text-Fig. 8, *E*; Pl. II, Fig. 24). The right one being perceptibly larger than the left, the two pole-cells of the cœlomesoblast bands are thus rendered equal in size. Disregarding the latter for the moment, let us follow the fate of the small cells (*e, e*). Soon after their formation they migrate upwards and away from the blastopore (Text-Figs. 8, *F*, and 9, *A, B, C*), become *entirely surrounded by the entoblast* (Text-Fig. 6, *A*) *and are thus separated from the two cœlomesoblast cells.* The close association of these small cells with the entoblast (Text-Fig. 6, *B* and *C*) continues during the transformation of the latter into the enteron and when last distinguishable from their neighbors (about 18 hours), because of their small size, lighter stain and comparative freedom from yolk granules, they are incorporated in the wall of the intestine very close to the anal region (Text-Fig. 9, *D*). It seems therefore, beyond all doubt, that they are entoblastic in this case and take part in the formation of the same region of the intestine as do the corresponding cells in *Crepidula.*

Similar cells have been described as being budded off from the *M*'s in at least 16 species of annelids and molluscs and most diverse accounts of their fate have been given by different observers. In four forms they seem to be certainly entoblastic (*Crepidula, Nereis, Podarke* and *Thalassema*) and probably also in *Dreissensia, Patella, Serpulorbis, Cyclas* and *Aricia.* On the other hand, in at least four forms corresponding (homoblastic) small cells are said to contribute entirely to the mesoblast (*Amphitrite, Arenicola, Umbrella* and *Planorbis*) and possibly also in *Unio* and *Physa.* Between these two groups, the condition of affairs in *Aplysia*, as recently described by Carazzi ('00), seems to stand as a connecting link. Here each of the *M*'s buds off four small cells, three of which are mesoblastic and one entoblastic. Yet in *Umbrella*, according to Heymons ('93), although the divisions are the same in number and quite similar in character, all of the cells are stated to be mesoblastic. Finally, in the aberrant cleavage of *Capitella*, corresponding cells are believed by Eisig to give rise to the pædomesoblast.

The following interesting possibility has recently been suggested by Wilson ('98) in regard to these cells. If we interpret them as having the same morphological significance in every case, *e. g.*, entoblastic, we may arrange a series of annelids and molluscs in which at one extreme the entoblast budded off from the posterior member of the fourth quartet is greater in amount than the resulting pole-cells of the mesoblast bands, as is actually the case in *Crepidula* (Conklin), and at the other the entoblastic element is contained in a mere rudimentary cell as in *Aricia*. This graded series, according to Wilson, may represent a gradual elimination of the entoblastic element from the posterior member of the fourth quartet and the final complete conversion of the latter into mesoblast. It also clearly indicates the possibility that the mesoblast pole-cells are to be regarded phylogenetically as derivatives of the archenteron, as was long since suggested by Kowalevsky ('71). With this idea the fate of the small cells in *Podarke* and *Thalassema* also falls in line.

In the light of subsequent research, however, it would seem that we must recognize the probability that the small cells budded off from the cœlomesoblast pole-cells before formation of the cœlomesoblast bands may be either entoblastic, mesoblastic, or both. Of especial interest in this connection is a comparison of the results of Carazzi and Heymons (see above). In *Aplysia* (Carazzi) only one of the four divisions eliminates entoblast, while in *Umbrella* (Heymons) even this is lost and all of the small cells are mesoblastic. This suggests the possibility that the form of division has persisted while the resulting cells have changed their prospective value, or, to adopt Wilson's terminology, that the small cells still remain homoblastic but are

TEXT–FIGURE 9.

Optical sections of various stages to illustrate the history of the ectomesoblast cells. *A*, section at the same plane as Fig. 10, *A*, but of a slightly older stage, showing the teloblast-like budding of the right (*emr*) and left (*eml*) ectomesoblast, and also the migration of the median (*emm*) ectomesoblast. The *M*'s have each budded off a small entoblast cell (*e*, *e*). *B*, section at the same plane as Fig. 10, *B*, but of an older embryo. *le*, lateral ectomesoblast cells from the right and left intergirdle regions of the first quartet; *rc*, rudimentary cells sunk into the entoblast cells and degenerating. *C*, section from the left side. The blastopore (*bl*) has migrated toward the prototroch. The *M*'s have migrated laterally leaving behind the small entoblast cells (*e*, *e*). An ectomesoblast cell, *a*, in-sinking from the first quartet, probably from the *b* arm of the cross. *D*, longitudinal section of a considerably older stage. The small entoblast cells, derived from the *M*'s, are seen in the posterior end of the enteron. The ectomesoblast is, in part, becoming transformed into muscles.

no longer equivalent. This idea has been clearly expressed by Wilson in a discussion of a similar state of affairs. He says:[1] "The old building pattern was still retained but adapted to a

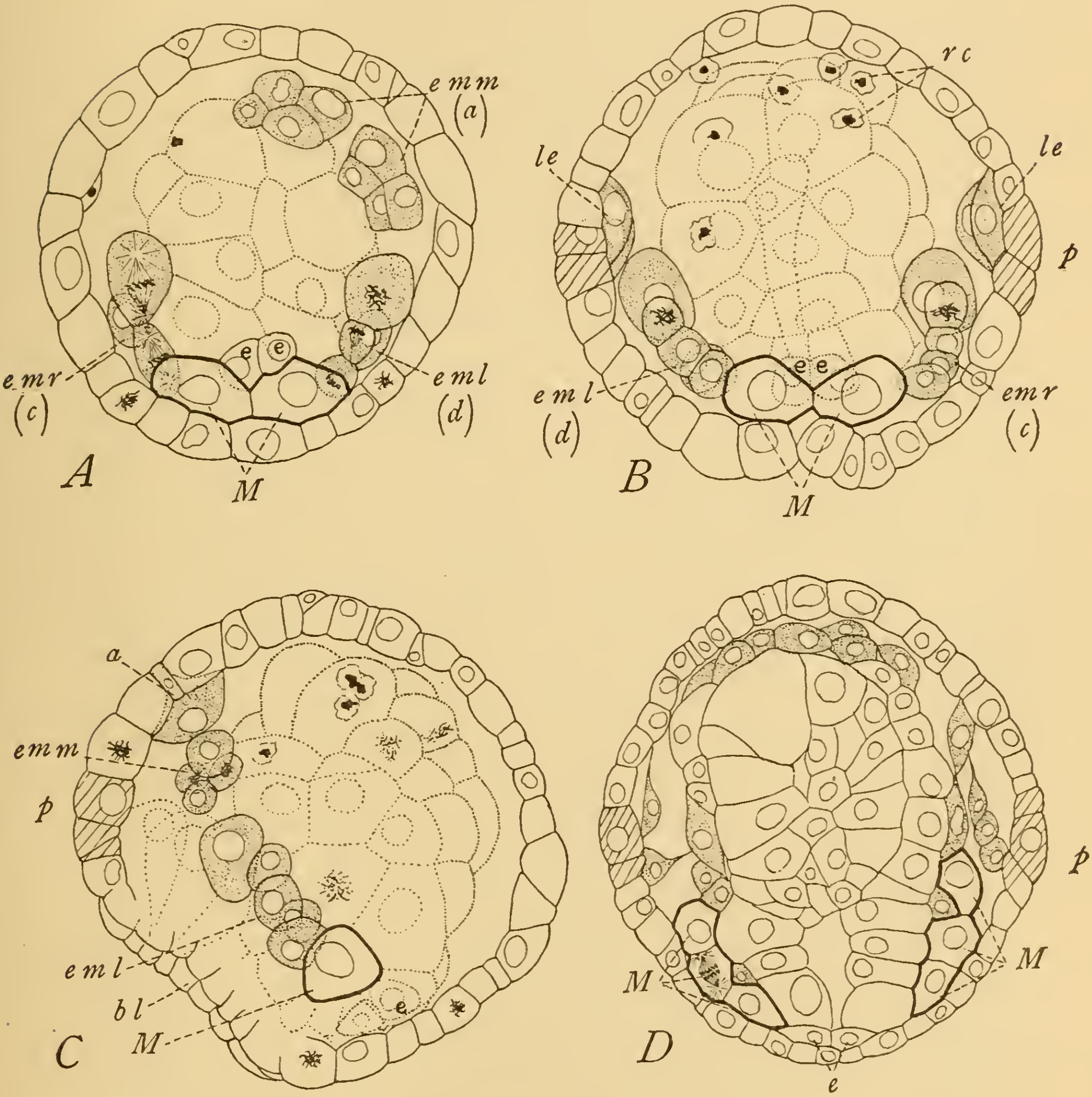

FIG. 9.

new use, precisely as has been the case with the evolution of larval or adult organs, such as the branchial or aortic arches and the limbs." Nevertheless, until we know more about the

[1] Wilson, E. B., "Cell-Lineage and Ancestral Reminiscence," Wood's Holl Biol. Lectures, 1898, p. 39.

factors which underlie differentiation in development, I think we should suspend our judgment in regard to the significance of these cells. It should also be borne in mind that these small cells have never, so far as I know, been proved to be the fundament of a typical mesoblast organ, but have been considered mesoblast merely because of their position.

The cœlomesoblast cells, which at first lie closely pressed together, under the posterior lip of the blastopore (Pl. II, Fig. 24), exactly as in *Eupomatus* and *Podarke*, soon separate and move apart toward the sides (Text-Fig. 9, *A*, *B*, *C*). The pressure of the entoblasts causes them to lie well up toward the prototroch. They may be distinguished without difficulty from the fact that their protoplasm is much more finely reticulated than that of the entomeres, and is also comparatively free from yolk-granules, as has been noted by Conklin in *Crepidula*. The lateral migration of the right cell is a little more rapid than that of left, owing to the fact that it is less obstructed by the entoblast mass. When these two cells are about half way to the future ventral side, each divides *equally*, with the plane of the division parallel to the prototroch. At length, after three more divisions in the same plane, the two cœlomesoblast bands of five cells each come to lie in the position already described. These rows of cells (Text-Fig. 9, *D*) are thus shown to have the same origin and early history as the mesoblast-bands in other annelids. To this we may add the statement of Conn that, during the post-larval development, these bands in *Thalassema* increase in size, become segmented, and finally give rise to the secondary body cavity in a typical annelid way. The meager development of the cœlomesoblast in the trochophore is clearly correlated with the long duration of its free-swimming and (as far as development is concerned) almost stationary larval existence.

It is a fact, as far as I know without exception, that in all forms where there is a trochophore stage of long duration (as is the case in all annelids with equal cleavage), the two cœlomesoblast cells do not, in the earlier stages at least, bud like teloblasts. This is certainly true in *Hydroides* and the Newport species of *Polygordius* (Wilson, '91) and also in *Podarke* and *Thalassema*. Although Hatschek's figures indicate that *Eupomatus* forms an exception to this generalization, I believe that this is due to his confusion of the cœlomesoblast and mesenchyme, as will be explained immediately, and that in this form, too, there are, in the earlier stages at least, no actively budding pole-cells. It is reasonable to suppose, in fact, that the presence of teloblasts in many types is a secondary adaptation to a more direct development; a conclusion supported by the conspicuously teloblastic character of the divisions in leeches and oligochætes.

2. *The Ectomesoblast.*

Heretofore the study of the cell-lineage of a number of annelids and molluscs has shown that the so-called "larval mesenchyme" arises from certain ectodermal cleavage cells of the second or third quartet, and entirely independently of the cœlomesoblast. This is also notably the case in *Thalassema* where ten large ectomesoblast cells sink in and give rise to all the mesenchyme. Three of these cells are from the *a*, *c* and *d* quadrants of the third quartet and seven from the first quartet of ectomeres. The most important source of functional mesenchyme in *Thalassema* are the three cells from the third quartet, namely, $3d_{2.2.2.1}$, $3c_{2.1.2.1}$, and $3a_{2.2.2}$. The first two sink into the cleavage-cavity, just before gastrulation (Pl. II, Fig. 21), and lie at first close to the two cœlomesoblast cells. They soon migrate laterally and bud[1] off simultaneously small cells toward the *M* cells (Pl. II, Fig. 24; Text-Fig. 8, *E, F*), dividing like teloblasts, but in the reverse of the ordinary direction. So close is the connection of these cells with the cœlomesoblast (Text-Fig. 9, *A*, *B* and *C*) that one would certainly be led to think that they formed a part of these bands unless their cytogeny had been carefully followed. The condition here observed is similar to that described by Treadwell in *Podarke*. The progeny of these two cells forms almost the entire mesenchyme of the

[1] Conn's error in describing the mesenchyme as arising from the entoderm near the blastopore is accounted for by the fact that these ectomesoblast cells lie in close association with the entomeres, and that he worked almost entirely on living material.

post-trochal region, and becomes differentiated for the most part into gut muscles (Text-Figs. 6, *C*, and 9, *D*). The teloblast-like cells, themselves, finally lie on each side of the œsophagus and give rise to a part of the ventro-œsophageal musculature. I would call attention to the fact that Hatschek has described cells similar in position, and probably also in fate, in *Eupomatus*.

The other ectomesoblast cell, $3a_{2.2.2}$, divides equally as it sinks in (Pl. 11, Figs. 22 to 24), and after two or more unequal divisions, the cells migrate toward the mid-ventral line (Text-Fig. 9, *A*). The progeny of the cell, which after the first equal division lay nearest the *b* quadrant, makes good the failure of this region to produce an ectomesoblast cell (as stated on p. 201 the corresponding cell in this quadrant produces a large œsophagoblast). (See Text-Fig. 9, *C*, *emm*). The migration of this cell in *Podarke* to a position symmetrical with the bilaterality of the embryo is even more remarkable because it does not divide until it lies in the future mid-ventral line and there equally and bilaterally. In *Unio*, according to Lillie, the entire mesenchyme arises asymmetrically from $2a_{2.1+}$, but "apparently by active migration becomes symmetrical in later stages." What causes this migration it is impossible to say, but it certainly well illustrates the idea expressed by Lillie ('01) in the following sentence: "That the entire organism at every stage of its development exercises a formative influence on all its parts appears to me an absolutely necessary hypothesis." By the shifting of the blastopore and the formation of the œsophagus the progeny of these cells becomes carried up into the prætrochal region and there gives rise in large part to the muscles running from the body wall to the œsophagus (Text-Figs. 6, *D*, and 7, *B*).

The ectomesoblast cells from the first quartet sink into the primary body-cavity somewhat later than those from the third. The late period at which these cells are differentiated makes it impossible to give their exact cell-lineage, but the general regions, from which they arise, are as follows: Two cells sink in on each side from the *a* and *c* intergirdle regions and just above the prototroch (Text-Figs. 8, *E*, and 9, *B*, *le*). They soon elongate just inside the body wall, and in all probability form later a part of the gut musculature. Another large ectomesoblast cell originates in the *b* cross region, near the median line (Text-Fig. 9, *C, a*). This cell arises by delamination, and another from the *c* cross region, also near the median line, arises by a like process. A small cell sinks in at the same time just in front of the apical plate (Text-Fig. 6, *A*). These cells also contribute in part to the gut musculature. Conn has found that the various gut muscles of the trochophore *persist in the adult.* He also thinks that some of the mesenchyme-cells become converted into blood-corpuscles. It seems altogether probable, too, that the undifferentiated ectomesoblast cells which line the inside body wall of the trochophore (Text-Fig. 8, *A*) later give rise to the ring musculature. As was indicated on p. 208 the floating ectomesoblast cells, without doubt, function as excretory organs. The term "larval," accordingly, applies to very little of the mesenchyme in *Thalassema*, for the greater part persists in the adult; as Meyer ('01) has also found to be case in his studies on the post-larval development of *Polygordius*, *Psygmobranchus* and *Lopadorhynchus*.

It is, indeed, remarkable that the ectomesoblast in *Thalassema* from the third quartet agrees so exactly in origin with that of *Podarke*. The anterior cell in both has exactly the same lineage, and the only difference between the posterior cells in the two forms is that in *Thalassema* they bud off an extra small ectoblast cell before sinking in; but in *Podarke*, according to Treadwell, this same division takes place as the cells sink in and the resulting small cells are mesoblast.

Although this is the first time that a study of the cell lineage of an annelid or mollusc has actually shown a part of the ectomesoblast to arise from the first quartet, this possibility was clearly indicated by Kleinenberg's ('86) and Meyer's discovery of neuro-muscular foundations in the prætrochal region of *Lopadorhynchus*. In *Dinophilus*, too, the mesenchyme, according to Schimkewitsch ('95), originates by an immigration of ectoderm cells in the *forward part* of the embryo.

Investigations of the cell-lineage of a number of representative annelids and molluscs have demonstrated, in recent years, that a part of the mesoblast in these groups arises from the ectoblast. This mesoblast, however, has commonly, and as I believe erroneously, been considered to be purely larval and transitory. In certain instances it has been possible to determine the blastomeres which give rise to the ectomesoblast, but in many others merely the general regions. Nevertheless in all the source has been either the second or the third quartet of ectomeres. In the first class belong *Unio* ($2a_{2.1+}$; Lillie, '95); *Crepidula* (*2a, 2b, 2c*; Conklin, '97); *Physa* (*3b, 3c*; Wierzezski, '97); *Planorbis* ($3b_2$, $3c_2$; Holmes, '00); and *Podarke* ($3a_{2.2.2}$, $3c_{2.1.2}$, $3d_{2.2.2}$; Treadwell, '01). In the second class we may place *Aricia* (Wilson, '89), *Dreissensia* (Meisenheimer, '00), *Cyclas* (Ziegler, '85), *Pisidium* (Lankester, '75), *Pholas* (Sigerfoos, '95), *Patella* (Patten, '86), *Paludina* (Erlanger, '91). The figures given by Hatschek ('81) for *Teredo*, Goette ('91) and Schierholz ('78) for *Anodonta*, and Horst ('82) for *Ostrea* also indicate, as Holmes ('00) points out, that the mesenchyme in these forms must have originated from the ectomeres. A study of Hatschek's ('85) figures of *Eupomatus* has led me to the conclusion that his description of the origin of the mesenchyme is founded on errors in observation, due to his working entirely on living material, and that in reality a part, at least, of the mesenchyme has exactly the same origin as in *Thalassema*, *e. g.*, from *3c* and *3d*. Hatschek described the cœlomesoblast pole-cells as budding off mesenchyme before giving rise to the cœlomesoblast bands, and, in fact, if the cell lineage had not been followed carefully in *Thalassema* and *Podarke*, the close proximity of the two forms of mesoblast would have led one into a similar error. The striking similarity in the origin of the ectomesoblast in these two forms justifies us, I believe, in supposing that we may have the same condition of affairs in *Eupomatus* where the cleavage is also "equal." Meyer ('01) has also expressed himself as sceptical in regard to the accuracy of the observations of Hatschek in this case and calls attention to the fact that he neither figures nor appears to have seen a single division of the protoblasts of the mesoblast.

In *Hydroides* (Wilson, '91) there is a like close association of the mesoblasts and, indeed, it is quite possible that in all annelids with equal cleavage we have an identical origin of the ectomesoblast, at least as far as the third quartet is concerned.

Embryologists during the last twenty-five years have been far from unanimous in their conception either of the origin or of the phylogenetic significance of the mesoblast. Hatschek ('78) was among the first to lay emphasis on the differences between mesenchyme and mesothelium, but his interpretation of the embryology of *Polygordius* ('78), *Echiurus* ('81) and *Eupomatus* ('85) led him to the conclusion that these two morphologically different mesoblasts arise from a common foundation. This view was adopted and developed by the Hertwig brothers ('81) in their well-known "Cœlomtheorie," which, as Meyer observes, has formed the foundation of all later work on the mesoderm. Among other investigators who have described the mesoblast as having a single origin are: Roule ('89, '94), Fraipont ('88), Wilson ('89, '92), Hacker ('95), Burger ('91, '94) and Rabl ('89, '97). On the other hand, the great majority of those who have studied the embryology of annelids and molluscs are agreed that the mesenchyme must be regarded as having an origin distinct from that of the cœlothel. Although a few have ascribed an endoblastic source to the former, the concensus of opinion seems to be at present that it originates from the ectoblast. This was first described to be the case by Kleinenberg ('78, '86). Among those who have subsequently confirmed his conclusions are: Whitman ('87), Berge ('90), Vejdovsky ('90, '92), Schimkewitsch ('94), Meyer ('01), and the extensive list of cytogenists that has already been given.

Treadwell in a discussion of the phylogenetic significance of the mesoblast takes the stand that "no hard and fast distinction can be made between the two forms of mesoblast." He bases his conclusion on the close association of the cœlomesoblast and mesenchyme in *Nereis*, *Lumbricus* and *Hydroides* as described by Wilson and also in *Capitella* (Eisig). This view is diametrically opposed to that expressed by Meyer ('90, '01), as a result of his extensive investigations of the post-larval development of annelids, and by Wilson ('98) from a comparison of the cell lineage of the mesoblast in platodes and annelids. Although working from an entirely different point of view, both of these authors have reached the conclusion that the ectomesoblast (primary mesoblast, Meyer) and the cœlomesoblast (secondary mesoblast, Meyer) are phylogenetically entirely distinct. The former has been found to resemble closely in origin (Lang, Wilson) and in fate (Meyer) the parenchyma of platodes, while the latter is not represented as such in the flat-worms, but is a later formation.

The great body of embryological facts, it seems to me, is in harmony with this view and the apparent exceptions emphasized by Treadwell are not as serious as they may appear at first sight. Although Wilson ('89) has described the outwandering of cells from the anterior part of the mesoblast bands in *Lumbricus* and their probable contribution to the primary musculature, yet it is also very important to bear in mind that the outer pair of teloblasts (ectoblastic) in the embryos of certain oligochætes and leeches have been found to give rise to the ring musculature. Bergh ('90) and Vedovsky ('92) have found this to be the case in *Lumbricus*, as has also Vedovsky ('90) in *Rhynchelmis* and possibly Whitman ('87) in *Clepsine*. It is very possible that in *Nereis* the true origin of the ectomesoblast has been overlooked and the mesenchyme-cells, which Wilson thought were differentiated from the cœlomesoblast bands, may have come secondarily into close association with them; or, again, the ectomesoblast may arise very late in the ontogeny, as Meyer has found to be the case in a number of annelids. As regards *Hydroides*, Treadwell calls attention to the fact that, according to Wilson ('91), "the mesenchyme cells graduate both in form and position into those of the germ bands"; but such is also the case in *Thalassema*, where their origin, nevertheless, is entirely distinct. Finally, I think it is generally agreed that Eisig's unique description of the origin of the mesoblasts in *Capitella* should not form the basis of wide generalizations until it has been confirmed in that and other forms. It is possible that he has overlooked the true origin of the cœlomesoblast and that what he describes as such is, in fact, the mesenchyme, especially as its origin is very similar to that of *Thalassema*. Over against this case we may place thirty or more forms of annelids, where the cœlomesoblast has been shown to arise from the posterior member of the fourth quartet. I believe that Treadwell has not sufficiently considered the problem in concluding that because the trochophore may "represent an ancestral stage in the phylogeny of annelids, the mesodermal structures found in it undoubtedly represent the mesoderm of the ancestral forms."

Meyer, in his last paper ('01), has given a most exhaustive review of the whole mesoderm question and has shown how strongly the great mass of the evidence, both embryological and anatomical, points to the conclusion that, in annelids, at least, there are two entirely distinct forms of mesoblast — the primary (ectomesoblast) and the secondary (cœlomesoblast). Of these he considers the primary mesoblast to be phylogenetically the older and, although as a rule derived from the ectoderm (Phillodocidæ, Aphroditidæ, Eunicidæ, Chætopteridæ), "cannot be considered a morphological unit, but is rather an embryological *synthetic* tissue, in which temporarily the undifferentiated foundations of very diverse organs and tissues are apparently united to a whole." The cœlomesoblast, on the other hand, is regarded as a later formation which has originated from gonad cells. If we add to Meyer's observations the results of the study of cell-lineage, his conclusions, I think, are greatly strengthened. New light will certainly be thrown on this question by a study of the cytogeny of some of the lower forms. In this connection the observations of Schimkewitsch on the development of *Dinophilus* are, to say the least, very suggestive. He found in this type two forms of mesoblasts, distinct in origin, one originating at the posterior end of the embryo and forming two bands, which later give rise to the gonads and possibly to certain ventral longitudinal muscles, the other consisting of scattered cells which have migrated into the cleavage cavity from the anterior end of the embryo and produce all the mesenchyme. Finally, in the adult, the secondary body-cavity is represented only by the gonad cavity.

Although far from proven, the gonococle theory, toward the development of which Meyer has done so much, seems to have more points in its favor than any of the other theories dealing with the origin of the mesoblast, and by it many apparent inconsistencies in the origin and development of mesoblastic organs may be explained. This is especially true, I think, if we agree with Kleinenberg ('81), Meyer ('90) and Eisig ('98) that the sex cells — the foundation of the later cœlomesoblast — arose primitively (in a phylogenetic sense) before the somatic cells had become resolved into the two primary germ layers, as is the case at present in *Volvox*.

V. Rudimentary Cells.

Perhaps the most interesting feature in the cleavage of *Thalassema* is the seeming prodigality in the formation of cells that degenerate and are ultimately completely absorbed by the entoblast. It is difficult to explain their existence save under the assumption that they have lost their original functional significance and only persist as a survival of an ancestral type of cleavage. It is interesting to note that some of these cells, when first formed, differ from their neighbors only in their much smaller size and not in any special cytoplasmic or nuclear feature.

The following eleven cells are budded off early enough in the cleavage to admit of an exact determination of their cell-lineage and fate. From each of the posterior arms of the cross arises one cell ($1d_{1.1.2.2.1}$, $1c_{1.1.2.2.1}$). (See Pl. I, Fig. 7 and Text-Fig. 10, *A*). They are the same in origin with the cells which in *Nereis* ("nephroblasts"), *Amphitrite* and *Capitella* form glands. In *Podarke*, however, they are rudimentary and have been tentatively described by Treadwell ('01) as suffering a like fate to those in *Thalassema*. The first dexiotropic divisions of the intergirdle cells of the *a*, *b* and *c* quadrants (Pl. I, Fig. 4), as has already been indicated, give rise to three more rudimentary cells ($1a_{1.2.1.2}$, $1b_{1.2.1.2}$, $1c_{1.2.1.2}$). In *Amphitrite*, too, the cell, $1a_{1.2.1.2}$, is entirely rudimentary and the cells, $1b_{1.2.1.2}$ and $1c_{1.2.1.2}$, very small. In *Arenicola* these same cells are also very small, with dark staining nuclei. Child ('00) was not able to determine their fate, but thinks it possible that they become mucous glands. Another rudimentary cell in *Thalassema* arises in the *d* intergirdle region ($1d_{1.2.2.1}$, Pl. II, Fig. 14). An exactly similar cell in origin and appearance is figured by Meade ('97) in *Amphitrite*. The corresponding cell in the *b* intergirdle region ($1b_{1.2.2.1}$) is also rudimentary in *Thalassema* (Pl. I, Fig. 6). The second quartet contributes the following rudimentary cells, $2a_{2.1}$, $2b_{2.1}$, $2c_{2.1}$ and $X_{1.1.2.1.1}$ (Pl. II, Figs. 15, 18, 20 and 21). In addition to these there are several found during the later development, making a conservative estimate of the total number at least sixteen. Treadwell has figured a number of similar cells in *Podarke* and thinks it very probable that they also occur in *Lepidonotus*.

The fate of all these cells is most remarkable. Soon after

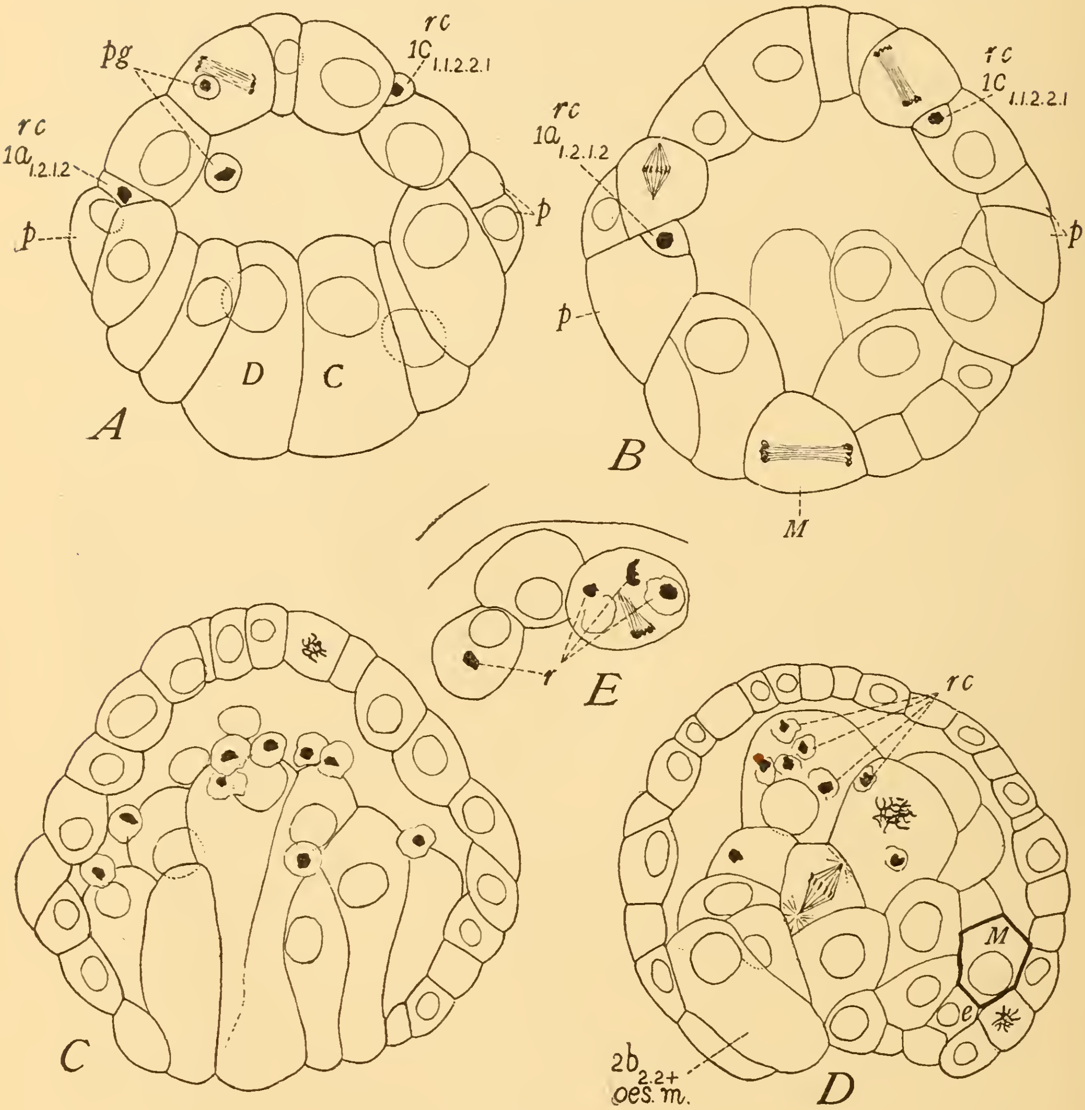

FIG. 10.

their formation they begin to decrease in size and the nuclei become still more closely reticulated (Text-Fig. 10, *A*). After a time they begin to sink in between the blastomeres (Text-Fig. 10, *B*) and finally lie inside the cleavage-cavity (Text-Fig. 10,

TEXT–FIGURE 10.

Optical sections of early stages illustrating the origin and fate of the rudimentary cells. *A*, two rudimentary cells as first budded off at the surface ; *pg*, polar globules, one inside a cross cell and another within the cleavage cavity. *B*, the same two rudimentary cells sinking toward the cleavage cavity. *C*, a much later stage, in which a large number of rudimentary cells are found within the cleavage cavity and lying on the endodermal cells. *D*, a still later stage showing the rudimentary cells inside the endodermal cells and undergoing dissolution. *E*, various stages in the degeneration of the rudimentary cells.

C). By this time their nuclei are mere dots of chromatin and it is impossible to distinguish them from polar globules (Text-Fig. 10, *A*), which, in fact, have an *exactly similar fate*. For a short time they rest on the entoblast cells (Text-Fig. 10, *C*) and then *sink into them* (Text-Fig. 10, *D*), gaining entrance by rupturing the cell wall. I have seen as many as five inside one entoblast cell, but they interfere in no way with its later divisions. Once inside they are quickly absorbed and, in the fourteen hour embryo, *they have completely disappeared*. This process of absorption consists first of the breaking down of their walls and then the complete digestion of what is left of their cytoplasm and nuclei (Text-Fig. 10, *E*).

As far as I know, this is the first instance in which, beyond all doubt, both the origin and the fate of rudimentary cells have been determined, although similar cells have been described in several other cases. E. B. Wilson ('92, '98) first called attention to them in his description of the very minute cells budded off from the cœlomesoblast pole-cells of *Spio* and *Aricia*. Again, in *Crepidula*, according to Conklin ('97), the tip cells of the anterior ends of the cross are very small and insignificant. He believes that "in *C. plana* they are crowded entirely out of the layer of the ectoblast cells and that they are thrown wholly away." Miss Langenbeck ('98) describes two cells in the blastocœl of the amphipod, *Microdeutopus*, which without doubt have sunk in from the surface layer. They soon begin to degenerate and finally disappear. The observations of Treadwell ('01), Mead ('97) and Child ('00) have already been touched on. In *Asplanchna*, according to Jennings ('96) two very small cells or "vesicles" are budded off from the entoblast entirely below the surface at the time of gastrulation. He was not able to determine their fate, but thinks that the whole process is comparable to the successive formation of polar bodies. Häcker ('99) has grouped all such cells under the category of preparatory or supernumerary divisions. "Their origin and fate," he adds, "is a problem of the highest interest."

The behavior of these cells in *Thalassema* bears a remarkable resemblance to that of the pædomesoblast (mesenchyme) cells in *Capitella*, which have been described by Eisig ('98) as wandering through the entodermal mass and finally emerging as functional mesenchyme-cells. Not alone in behavior, but also in appearance these cells are strikingly similar in both. Every step in their degeneration in *Thalassema*, however, has been followed and there is no doubt of their complete absorption. Another point of great interest, which should be taken into consideration in an attempt at their interpretation, is the fact that the cells, $1d_{1.1.2.2.1}$ and $1c_{1.1.2.2.1}$, which are typically rudimentary, in the *radial variety* (about 9 per cent. of the embryos) *are very large and apparently entirely capable of function.* Again the cell $1d_{1.1.2.1.2}$, which is as a rule small but functional, may sometimes be present as a rudiment (cf. Pl. I, Figs. 5, 6 and 7). In the first case, evidently, cells which were once functional have become functionless and in the second a cell manifests a tendency to lose its function. From every point of view, accordingly, the most reasonable explanation of the occurrence and the fate of these rudimentary cells seems to be that they are vestigial.

Child ('00) has expressed himself as rather sceptical of the existence of true rudimentary cells. This is natural, as it would be very difficult to account for their presence according to his theory of the significance of spiral cleavage. "If they are formed," he says, "it seems to me that the reason for their formation must be other than the absence of cytoplasmic material." This is doubtless true, but may we not go further and say, that possibly they are formed because of the presence of superfluous cytoplasmic (or nuclear) material. This possibility was indicated by Wilson ('98) several years ago in a paper in which he has called attention to the fact that we may not only have "persistence in cleavage of vestigial processes in the formation of the germ layers" (larval mesoblast of annelids and molluscs), but also "the persistence in cleavage of vestigial cells" (the rudimentary enteroblasts of *Aricia*). He further says: "It would be difficult to explain ancestral reminiscence in cell lineage by any theory which does not recognize in cell outlines the definite boundaries of differentiation areas in the developing embryo." Lillie in a recent paper agrees with Wilson that these rudimentary cells have as true a vestigial significance as the development of a tooth germ in a whale embryo." With this conclusion, too, the facts, as we find them in *Thalassema*, fall in line.

It seems possible that not only the complete reversions to radial symmetry are ancestrally reminiscent of a former condition, but also that the radially arranged rudimentary cells may be reminiscent of the foundations of certain radial organs.

That these cells may have once functioned as mesenchyme is indicated by their behavior, by the fact that the mesoblast has a radial origin in the polyclades, as has also, in a measure, the ectomesoblast of certain annelids and molluscs (*Crepidula*, *Podarke*, *Thalassema*), and lastly, by the fact that the cell which produces all the ectomesoblast in *Unio* ($2a_{2.1+}$) is very minute in *Amphitrite* and entirely rudimentary in *Thalassema*. As bilaterality has been acquired, the function of producing all the ectomesoblast has devolved on other cells. This whole process is but one chapter in the history of the development of determinate cleavage which finds its highest expression in the teloblastic development of oligochætes and leeches. Finally, the retention of these rudimentary cells in cleavage and the fact that they occur in exactly the same places in several forms, indicates that the cell itself is of greater importance in the process of differentiation than some recent writers have been willing to give it credit.

Columbia University,
June, 1902.

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PLATE I.

(243)

EXPLANATION OF PLATES.

All of the following drawings were made from camera outlines and from preserved material. The mitotic figures are somewhat schematized ; especially as regards the astral rays, which are actually very indistinct.

PLATE I.

FIG. 1. 48 cells forming 56. Second division of the trochoblasts and first division of the intermediate girdle cells.

FIG. 2. 56 cells from the upper pole. The first divison of the cross cells. *pg*, polar globule.

FIG. 3. 60–64 cells. The cross formed.

FIG. 4. 74–80 cells. Rudimentary cells budded off in the posterior arms of the cross and in the anterior and lateral intergirdle regions.

FIG. 5. About 80 cells. Further divisions in the cross cells.

FIG. 6. Three cells have been added to the prototroch from the anterior and lateral intergirdle regions — ap'' to cp''. *ar* to *dr*, rosette cells. *cr* has divided.

FIG. 7. Latest stage to which the divisions of the cross cells have been followed. The posterior arms have become conjoined. All of the rosette cells have divided.

FIG. 8. Posterior view of embryo containing 48–52 cells. Divisions of trochoblasts and intermediate girdle cells. The fourth quartet has been formed.

FIG. 9. 56 cells from the left side. The third quartet has divided.

FIG. 10. 64 cells from the left side. The primary prototroch now forms a complete ring. The second quartet has divided off three rudimentary cells — $2a_{2.1}$ to $2c_{2.1}$.

FIG. 11. Posterior view of 64-cell stage showing the divisions in the *c* and *d* quadrants. Formation of the small $x_{1.2}$ cell.

FIG. 12. Postero-ventral view of an embryo containing 76–80 cells. Further divisions in the *X* group and also in the third quartet.

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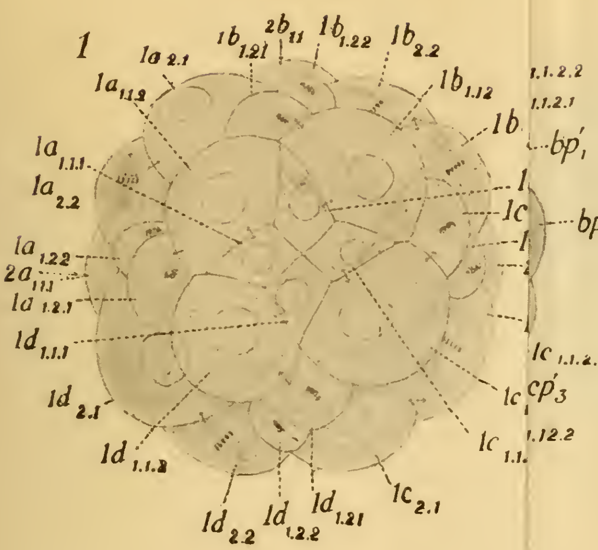

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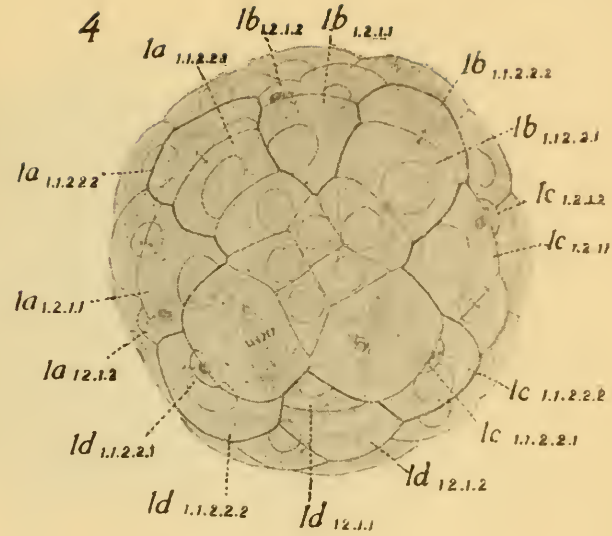
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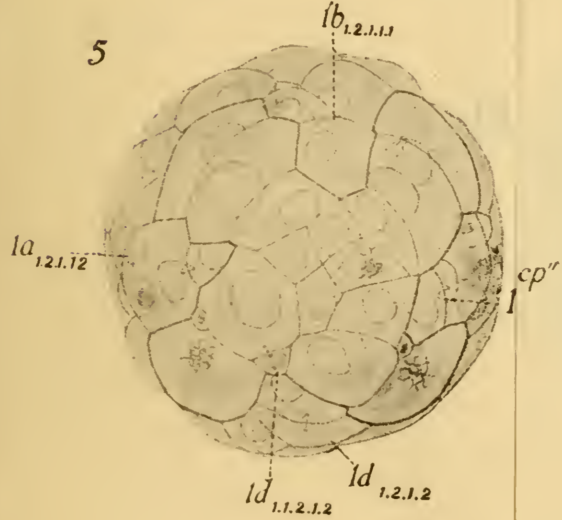

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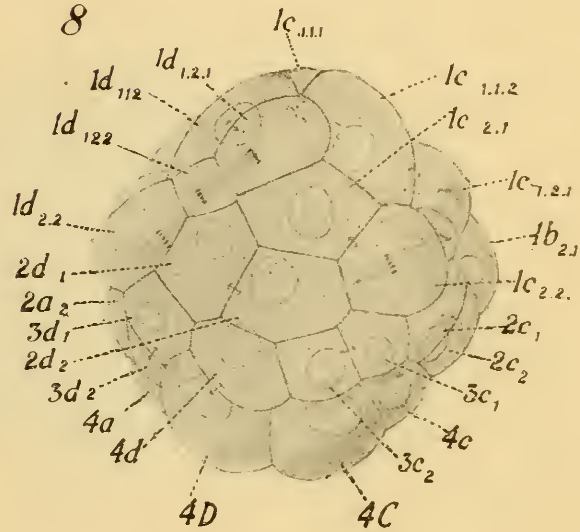
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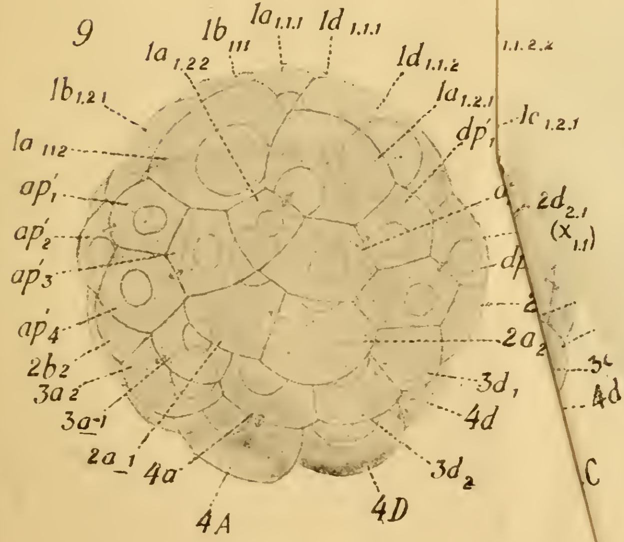

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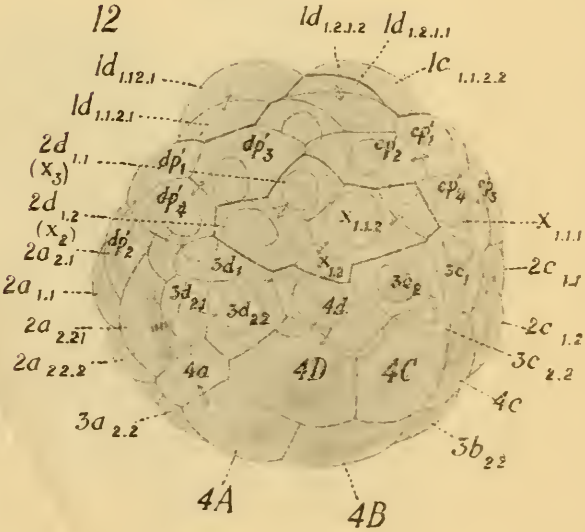

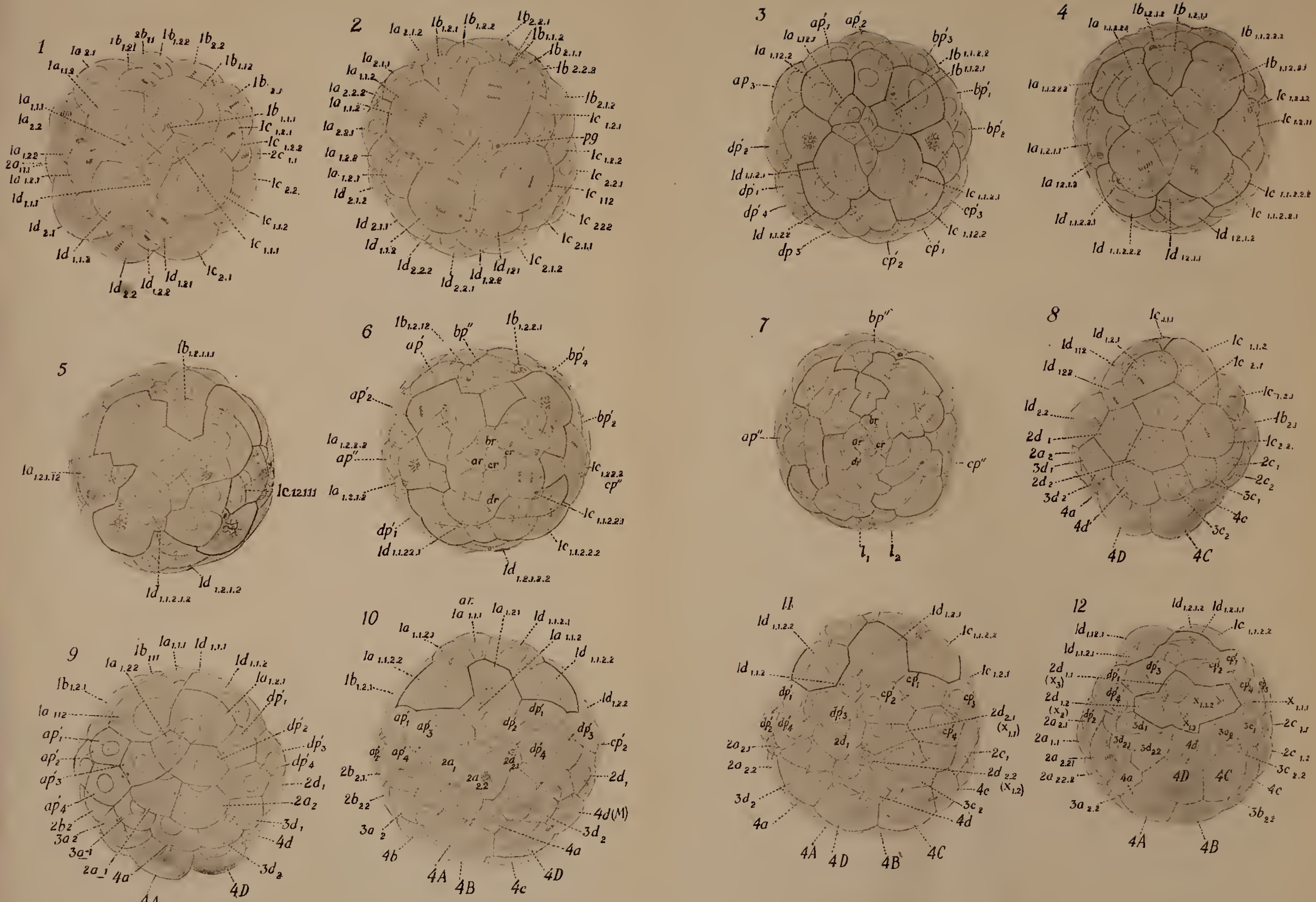
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PLATE II.

PLATE II.

FIG. 13. Posterior view of embryo containing 74–80 cells.

FIG. 14. Posterior view of a later stage. Bilateral division of 4*d*. Rudimentary cell budded off in the *d* intermediate girdle region.

FIG. 15. Ventral view of 64-cell stage.

FIG. 16. Ventral lateral view of 86-cell stage. Fifth quartet forming.

FIG. 17. Ventro-posterior view of 86-cell stage. Further divisions in the *X* group.

FIG. 18. Ventral view of a later stage. Fifth quartet formed. Bilateral cleavage of 4*d*.

FIG. 19. Postero-ventral view of the same stage.

FIG. 20. Postero-ventral view of a slightly later stage. Rudimentary cell budded off in the *X* group. 4*d* has divided.

FIG. 21. Beginning of gastrulation. $3d_{2.2.2.1}$, *eml*, ectomesoblast left and $3c_{2.1.2.1}$, *emr*, ectomesoblast right have invaginated. $3a_{2.2.2}$, *emm*, ectomesoblast median is sinking in.

FIG. 22. Fourth quartet has divided. *emm*, ectomesoblast median, about to divide. $l_1 - l_2$ cells beginning to migrate through the dorsal gap. *oes.r*, œsophagoblast right.

FIG. 23. Entoblast plate has almost entirely invaginated. $2b_{2.21.2.}$ (*oes m*), œsophagoblast median, has increased in size. Nine-hour embryo.

FIG. 24. Gastrulation completed. Small entoblasts budded off from the cœlomesoblast ($M - M$) cells. Ectomesoblast cells have all divided. Migration of $l_1 - l_2$ cells. *oes.l*, œsophagoblast left. Ten-hour embryo.

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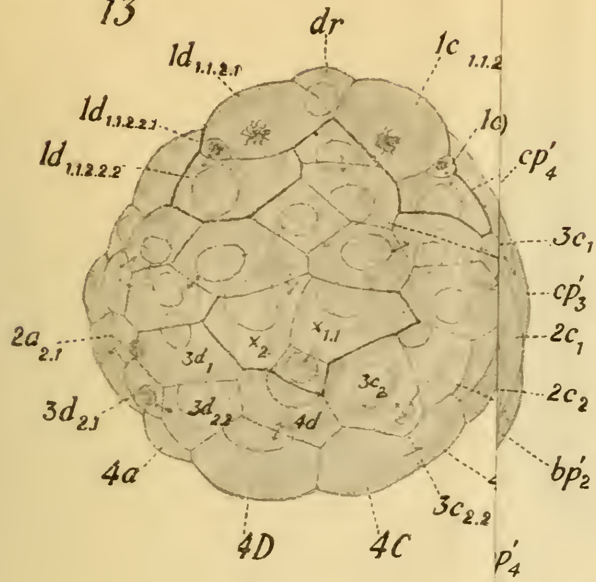

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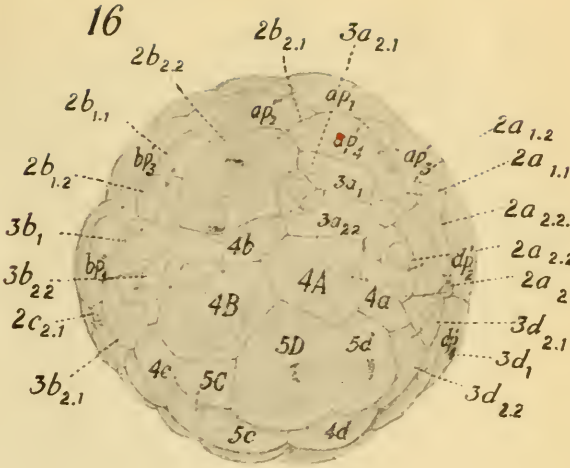

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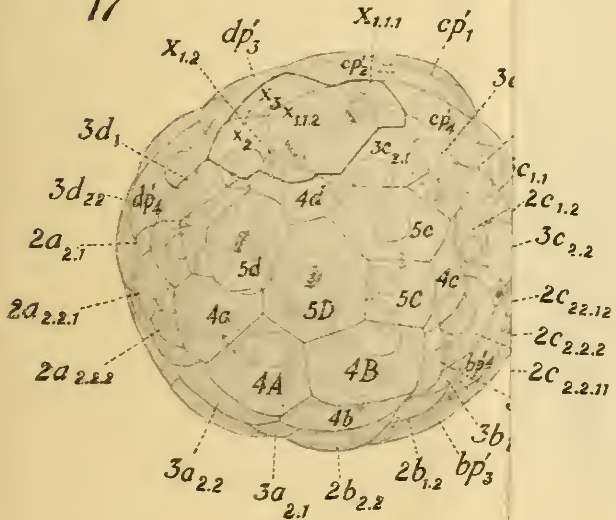

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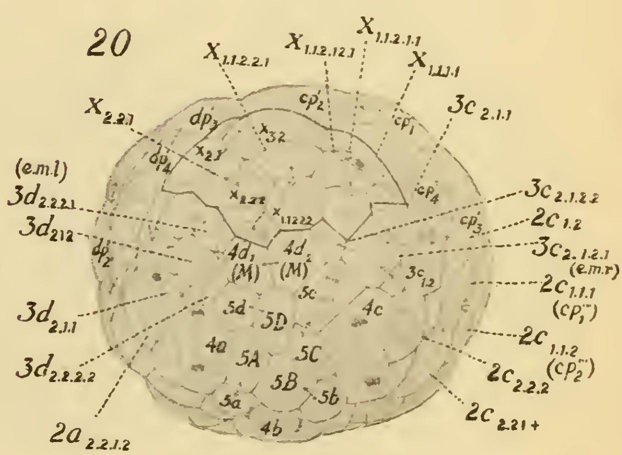

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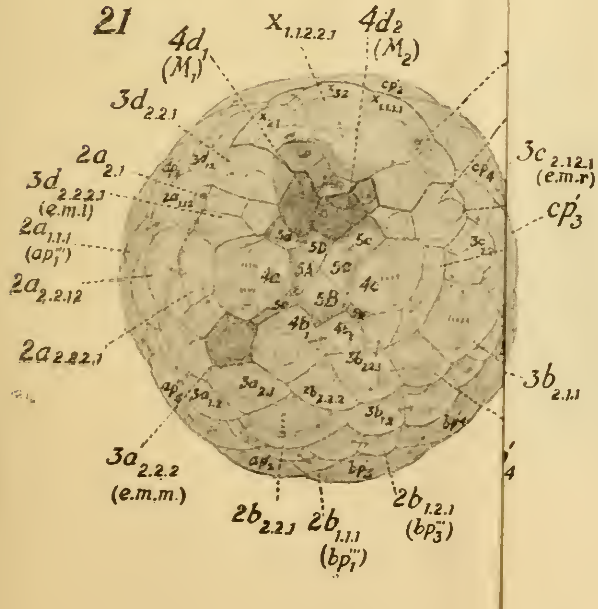

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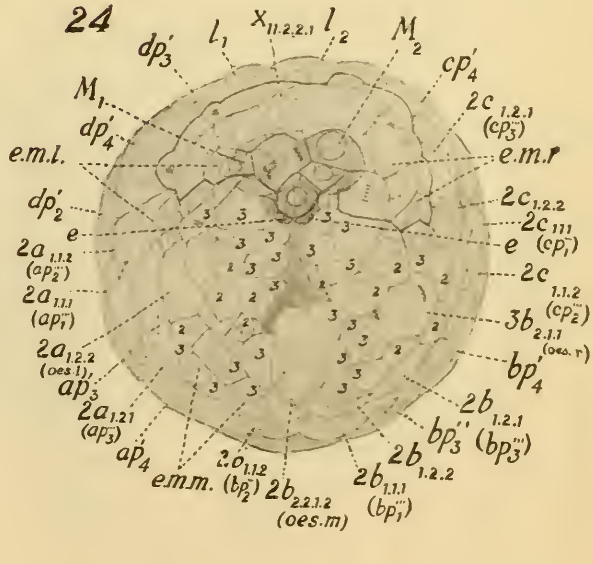

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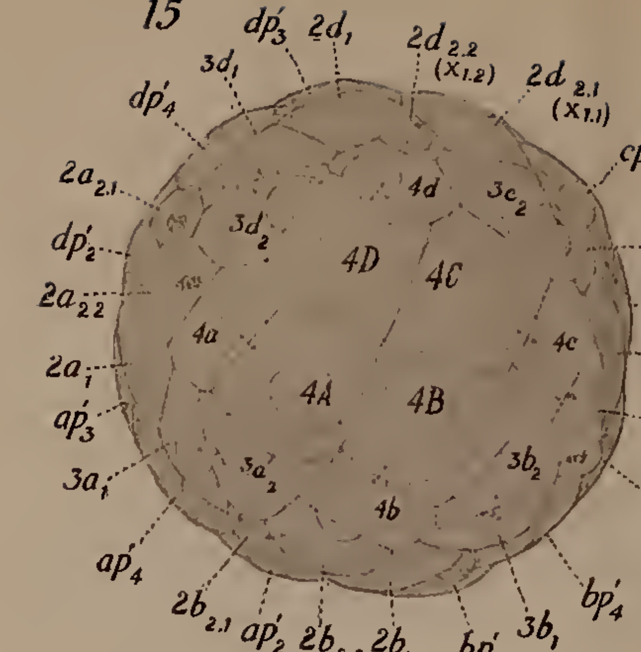

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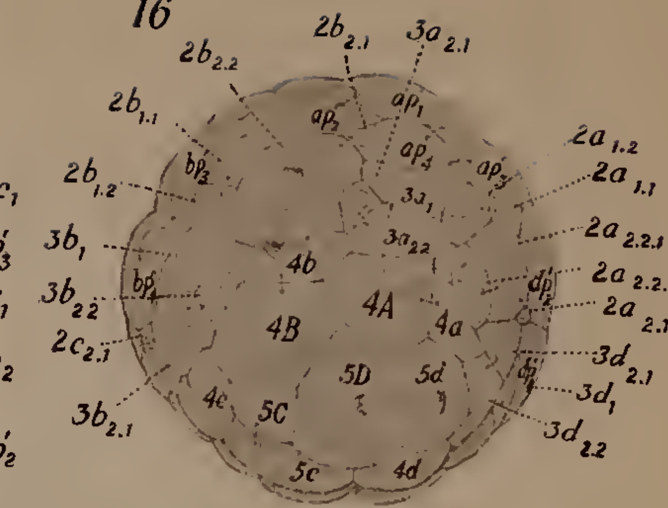

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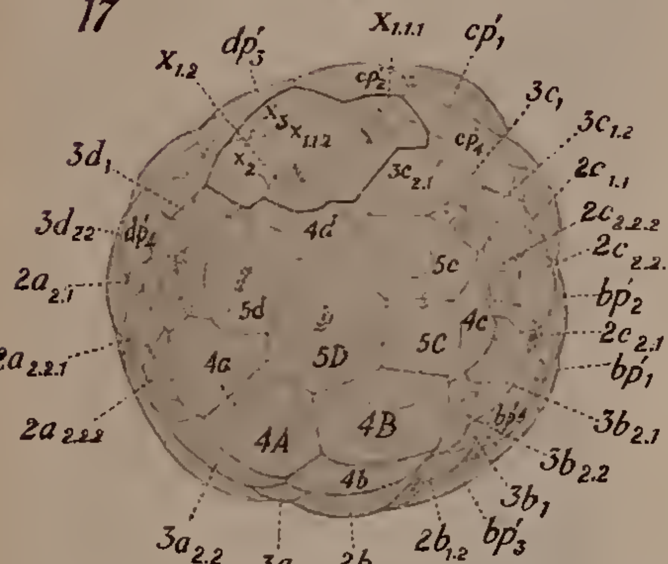

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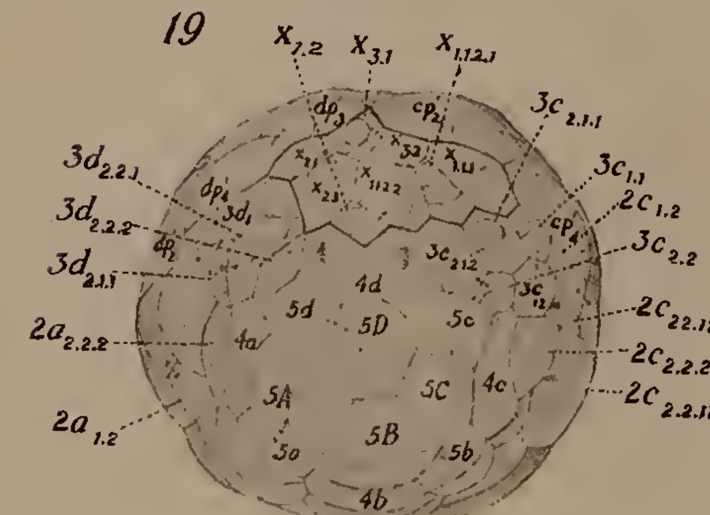

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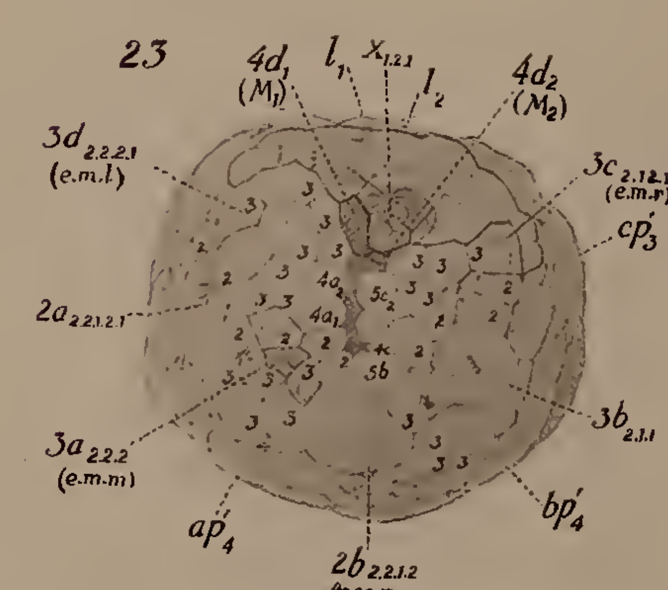

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VOL. XIV PART IV

ANNALS

OF THE

NEW YORK

ACADEMY OF SCIENCES

Editor:

CHARLES LANE POOR

The New Era Printing Company

Lancaster, Pa.

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[ANNALS N. Y. ACAD. SCI., Vol. XIV, No. 4, pp. 247–318, March 22, 1904.]

THE GEOLOGY OF THE SAN JOSÉ DISTRICT, TAMAULIPAS, MEXICO

GEORGE I. FINLAY

(Read April 20, 1903)

[PLATES VIII–XVIII]

CONTENTS

I. INTRODUCTION. ACKNOWLEDGMENTS

In 1899, Mr. E. D. Self, a graduate of the School of Mines of Columbia University sent a small suite of peculiar eruptive rocks, which occur near the mines at San José, Tamaulipas, Mexico, to Professor Kemp. They were at once recognized as tinguaite and nephelite syenite, of great scientific interest. A second shipment from Mr. Self of a larger series showed the presence of camptonite and andesite. In December, 1901, the writer accompanied Professor Kemp to San José with the object of studying the copper ores and the neighboring eruptive rocks. It was arranged that the writer should take up the petrographic investigation of the latter, and the results are here submitted. He cannot sufficiently acknowledge his indebtedness to Professor Kemp, not only for the opportunity so generously given him of studying the rocks petrographically, but also for encouragement of every kind during his work. Every facility was afforded him by Mr. Self, to whom his grateful acknowledgments are due, as also to Mr. W. H. Nichols, Jr., president of the San Carlos Copper Company. Dr. H. S. Washington very kindly analyzed specimens of the nephelite syenite, and of the tinguaite. The writer is anxious to express his obligations to him for this, and for invaluable assistance in the analytical work and calculations. The work was carried on in the geological laboratory of Columbia University.

II. TOPOGRAPHY

The town of San José, on the property owned by the San Carlos Copper Company, lies in an elliptical depression narrowly bounded by mountains on every side. The valley occupies about nine square miles. Its lowest point is 2,250 feet above the sea. The interior rounded hills near its center are five and six hundred feet higher. Anacuas and Ladinas, which shut in the view to the north are limestone mountains reaching altitudes of 3,000 and 3,200 feet respectively. The sag between them is inconsiderable, but there is a deep cut in the ridge immediately to the east of Anacuas. The road from San José to the town of Linares on the line of the Mexican Gulf Railway follows the main stream channel through this valley. Immediately to the east of San José is a line of mountains stretching for four miles from Mt. Anacuas to the south. Mt. Armadillos, which obtains an elevation above sea-level of 3,500 feet, is the highest and most striking point to the east. (See Pl. XV.) On the northwestern and western sides of the hollow in which San José lies, Mt. Tinaja, altitude 3,400 feet, and Mt. Parreño, altitude 3,500 feet, stand forth prominently as the highest points in the ridge which extends for seven miles southwardly from Mt. Ladinas. From Mt. Parreño it continues in that direction for a mile and a half until it meets the line of the Baril Mountains almost at a right angle. The Baril range terminates in two bold crags on the east where it is separated from Mt. Armadillos by a deep river valley. It extends westwardly from this point for a distance of two and a half miles with an average elevation of 4,800 feet to Mt. Baril, shutting in the San José valley on the south. From Mt. Baril the ridge turns to the southwest, becomes extremely sharp, and after extending for two miles in this direction bends in a great half circle and joins the northeastern spur of the Pic de Diablo. This mountain is 6,000 feet high. Its summit is formed by the union of several extremely sharp almost inaccessible craggy ridges. Its northern face which is bold and picturesque, looks down on the deep rounded valley that has been carved out of the mountain mass by the two forks of the Arroyo Grande. The north fork of this stream heads up under Mt. Baril and the Baril Range forms the divide on the north between it and the San José valley. The south fork of the Arroyo Grande has its source under the divide formed by the continuation southwestwardly of the Baril Range. The bottom of the valley of the Arroyo Grande is nearly three thousand feet lower than the Pic de Diablo. By the profound erosion which has taken place in this mountain valley the divide between the streams flowing eastwardly from the San Carlos Range and those which flow westwardly has been pushed far to the west. At the head of the Bocca de Alemos Arroyo, which is the stream in the next great valley to the south, the main divide has been driven well over toward the eastern side of the range. (See Pl. XVIII.) The valley of the Bocca de Alemos Arroyo opens from a rock-walled canyon, as one proceeds up stream into a broad elliptical amphitheater covering about six square miles. This great depression lies well in toward the center of the mountain mass. From the Pic de Diablo the San Carlos Range gradually declines toward the southeast. It extends in this direction for nine or ten miles from the Bocca de Alemos, and throughout its course exhibits the characteristic mountain forms which are found in the long lines of precipitous crags and sharp trailing ridges of the Pic de Diablo. The San Carlos Mountains, with their foot-hills, are a unit on the great plains of northeastern Mexico. (See Pl. XVI.) The lesser mountains which border on the central chain commonly show forms of high relief. When they have been carved out of sedimentary rocks their sides are invariably steep. They are at times precipitous along lines of faulting. Their tops are continued by three or four shoulders as pyramidal forms. When composed of igneous rock they are often nearly perfect cones. The lowest outlying spurs of the range run down to the plains in rounded contours, their line of slope being that of a parabola. The San Carlos mountain mass is separated from the Sierra Madre Mountains by a great plain, extending far to the northeast and to the southwest. The distance across it between the two ranges is fifty miles. When one travels across this plain it is seen not to be a unit, for erosion has proceeded far enough to level away a considerable space on either side of the main rivers and lesser streams. These level stretches are all situated at the same altitude. The ridges and rounded buttes which stand above them rise to a uniform height so that their tops are parts of a second common plane.

The mountain slopes of the interior valley in which San José is situated are nearly as steep as loose material can stand. The arroyos have commonly made V-shaped cuts with vertical walled trenches at the point of the V. The climatic conditions which affect erosion are peculiar, and deserve to be mentioned. The surrounding country is very dry, almost arid, but the San Carlos Mountains are high enough to be often surrounded by clouds. The dews are commonly heavy, and slight showers may fall once or twice in a fortnight, but the main portion of the annual rain supply comes down in one or two weeks of hard rain. At such times the torrents are immediately concentrated in the mountain gullies, and twenty minutes after the first drops fall the streams in the center of the valley begin to rise. Many which are dry throughout the greater part of the year then carry three or four feet of water, and their currents are so rapid that they are able to urge along bowlders which are over two feet across. With continued rain the streams may rise five and six feet, and be able to transport a great amount of detrital materials. Fifty thousand tons were removed in this way from a mine dump in twenty-four hours.

The streams in that portion of the valley which is near the town of San José and immediately to the northwest of it, have lowered their beds for 15 or 20 feet through a rudely stratified deposit of angular and subangular rock fragments. This represents the accumulation at low levels of the loosened material which is everywhere in process of transit down the steep slopes in the central portions of the valley. The andesite, which is the country rock here, is capped by a very scanty cover of soil in most places, while over wide stretches the bed rock comes to the surface. This is covered uniformly by fragments which have weathered away from its superficial portions. These have a maximum size of six inches. Under the action of gravity, and the occasional urging of torrential rains they are slowly traveling down to the low ground in the valley bottoms. The conditions by which weathering goes on in the San José region are those in which a prominent part is played by the daily temperature changes. Even in winter the extreme of cold is seldom much below the freezing point, but the air is dry and the nights are invariably cool. The maximum diurnal temperature change in the exposed rock masses is not less than 90° F. There can be no doubt that in the San José district that form of weathering which is accomplished by the alternate expansion and contraction of rock masses by heat and cold is of unusual importance. The riving action of frost is here reduced to a minimum. In the Baril Mountain range many great scales of the nephelite syenite have been stripped away from the exposed masses.

The drainage of the San José valley is toward the north by a stream which runs along the eastern flank of Mt. Anacuas, and to the east by a trunk stream which leaves the valley under Mt. Ladinas. The divide between the two systems coincides very nearly with a line drawn from Mt. Armadillos to Mt. Baril. About a quarter of the whole valley is drained by the second stream. Many of the lesser divides are mere knife edges and the Baril Range which lies between the drainage of the San José valley and those streams which flow into the north fork of the Arroyo Grande is so narrow that any further cutting must lower its crest line. At no point, however, except near Mt. Ladinas and Mt. Anacuas, have the arroyos which are everywhere gnawing headward against the ridge surrounding the valley of San José succeeded in tapping its drainage.

The Arroyo Grande rises against the Pic de Diablo six miles to the south of San José and takes an easterly course. (See Pl. XVII.) The amphitheater which it drains, with the open valley before it, bears a curious superficial resemblance to the cirques and tributary valleys in a country which has been the home of vigorous local glaciers.

The Bocca de Alemos Arroyo rises beyond the Pic de Diablo to the south. It receives the drainage from a much larger area than the Arroyo Grande does, and makes its way to the plains to the west through an extended canyon cut in limestone. The interior valley at its head is similar to that about San José.

III. STRATIGRAPHY. STRUCTURE

It will be seen by an inspection of the map that the sedimentary rocks surround the central mass of andesite, adjacent to the town of San José, almost entirely. The Baril Range appearing on the south is nephelite syenite. The sedimentary series about San José is composed of limestone and shale. The blue limestone is the important member of the series. It is a heavy bedded rock, in regular, gently dipping layers, capping the andesite on mounts Parreño, Tinaja, Ladinas, Anacuas and Armadillos. The limestone is siliceous, and has a dense even grain. It scarcely ever shows traces of organic life. Two poorly preserved fossils were found in it, a belemnite and an exogyra. It is a part of the great mass of Cretaceous sediments in eastern Mexico. Rarely shaly layers, an inch or less in thickness, are met in the limestone. They were carefully examined for fossils but none were found. The limestone once extended over the entire San José region. It has been stripped away on all sides from the andesite beneath it. The dips, as indicated on the map, are radially outward from San José at every point. They average nearly 35°. The mass of andesite is a laccolith. These relations are expressed in the sections [**Plate II**]. A few small outliers of the limestone have been left standing over the andesite near San José. A much larger remnant is found a mile to the south above Bretaña Creek. Three or four small outliers, besides these, are found to the south near the Baril Range. These are all identical with the main body of limestone. Like it they are but slightly affected, near the contacts, where they stand against the igneous rock. Rarely, the limestone is changed to marble for a foot and a half from the contact. Smaller limestone inclusions in the andesite have been thoroughly metamorphosed and made over into garnet (grossularite) and vesuvianite. These are found by the score over the whole region. They offer most interesting problems in contact metamorphism. The main mass of the limestone gives evidence of the dynamic effects of laccolithic intrusion. The siliceous bands, which appear as dense flinty included masses half an inch thick and a foot or more in length may often be seen to have been broken and faulted repeatedly. These effects were not observed at a distance from the andesite. It is impossible to say how thick the cover over the laccolith was. It is believed that the igneous rock was viscous rather than liquid. The amount of silica present, sufficient to allow for the formation of free quartz, is evidence in favor of this view. The laccolithic intrusion is of comparatively small extent with moderately high doming. No evidence could be gathered which would help decide the question as to whether or not the incoming of the molten rock was aided by the relief from pressure consequent to the initial stages of anticlinal folding. The limestone at a short distance from San José lies nearly horizontal, but the shaly member of the series constantly shows pressure effects. Exposures of this rock are found to the east of the Pic de Diablo, replacing the limestone in the foothills of the San Carlos Mountains. It is here a drab or gray coarse shale, thinly bedded, and everywhere broken by countless joint planes. These give it a platy parting horizontally. The vertical joints are frequently so numerous as to cut the shale up into small pieces. These fragments two inches or more in diameter are quickly broken out and rounded by the agencies of weathering.

In the slopes of Mt. Ladinas, and on Mt. Armadillos, as well as various points to the southwest and southeast of it the andesite has broken through the limestone cover in the form of dikes.

IV. STREAM ADJUSTMENT

The phenomena of drainage peculiar to eroded laccoliths have recently been treated in a paper by Dr. T. A. Jaggar, Jr., in the Twenty-first Annual Report of the U. S. Geological Survey, on "The Laccoliths of the Black Hills." The laws governing drainage changes on eroded laccoliths are there developed in a most interesting manner. The drainage of the San José region is similar to that of the Citadel Rock type, but at San José two originally radial streams have taken possession of the dome and cut into the exposed mass of andesite. The stream which flows past Mt. Anacuas is working at a lower level than that one which lies beside Mt. Laureles. The divide between the two drainage systems is slightly to the northeast of a line joining Mt. Armadillos and Mt. Baril. It is a low divide, and with a few feet of forward cutting capture of the Laureles drainage would result.

V. FIELD RELATIONS OF THE IGNEOUS ROCKS

The igneous rocks of the San José region are granitoid nephelite syenite and diorite, andesite, effusive basalt, and dikes of tinguaite, diabase, camptonite and vogesite.

The nephelite syenite appearing over the southern portions of the map is continued southward in the San Carlos Mountains beyond the limits of the sheet for fifteen miles. The andesite touches it in a fairly even east-and-west line along the northern slopes of the Baril Range. At the contact the effects of quick chill in the andesite are seen. The rock at this point is aphanitic, although elsewhere uniformly coarse-grained, as is common in laccolithic masses. The nephelite syenite is older than the andesite. It is probable that the main mass of the San Carlos mountains was faulted up through the sedimentary series. The limestones and shales, in every part of the region which was visited, are stripped back from the nephelite syenite, and the actual contact between this rock and the sedimentary beds was not found.

There are many slight faults in the San José region. It is probable that some of the lesser stream courses have been directed by them. There is no break between the nephelite syenite and the andesite by faulting. The latter rock would seem to have come in on the edge of the nephelite syenite under the limestone cover. It is also later than the exposures of diorite indicated on the map along the road leading to the Vegonia Mine, and in the stream-way a mile to the northeast of San José. The andesite has sent numerous small dikes into the diorite. This rock is met in three rounded bosses, enclosed by the andesite, and much weathered. It is often friable, and readily breaks up into a rusty brown soil like that which is furnished by the weathering of diabase.

On the eastern slope of the San Carlos range, and five miles from San José to the south, there is met a lava flow of basalt. The upper surface of the lava field, which is six miles long and a mile in width, is rough and vesicular. Much has been carried away from its surface by erosion. The body of the rock in the field is dense and aphanitic, rarely glassy. The basalt is black, at times with a slightly vitreous luster. It is of course much more recent than the massive nephelite syenite down whose flanks it flowed, and it is presumably younger than the diorite and the dike rocks. None of these were found cutting it. No cinder cone could be located in connection with it, if one ever existed.

The dikes, which are very numerous throughout the district, are of tinguaite, camptonite, diabase and vogesite. They vary in width from half an inch to ten or twelve feet. They are usually found but slightly inclined away from the vertical.

The tinguaites are distinct in field habit from all the others. They are uniformly colored green. Two types are found among them — those which carry conspicuous phenocrysts of sanidine, and those which are aphanitic, and are characterized by showing no porphyritic developments in the hand specimen. No tinguaite dikes were found cutting the nephelite syenite. Where they lie in the limestone they are seen to have had almost no effect upon it. The blue sedimentary rock continues up to the contact without being changed in any way. Two very large tinguaite dikes are indicated on the map in the midst of the andesite. The longer of them runs for two and a half miles. It carries phenocrysts of sanidine, by which its even clear green color is mottled with white. Its outcrop appears across the country in a line of huge rounded bowlders which lie four or five feet above the andesite. A second dike, two miles long, cuts the first almost at a right angle. Numerous other dikes similar to these in field habit but smaller are given on the map. It is not known whether they are older than the basic series of dikes or not, since the members of the one are not found intersecting those of the other.

The basic dikes present considerable variety. They lie in the nephelite syenite and in the andesite and diorite. They are not found cutting across each other. None were met crossing the flow of basalt. The camptonite dikes are as common as those of diabase. The vogesite dikes are rare. The most interesting of these is found along Bretaña Creek half a mile southeast of Mt. Parreño. Its appearance in the field is like that of coarse diabase, but the feldspar proves to be orthoclase and the dark silicate appears under the microscope as green fibrous hornblende.

The order of succession among the igneous rocks of the San José region is, therefore, so far as known, beginning with the oldest, as follows:

1. Nephelite syenite and diorite.
2. Andesite.
3. Basalt, tinguaite, camptonite, diabase and vogesite.

VI. PETROGRAPHY

A. The Granitoid Types

The granitoid rocks of the San José district are nephelite syenite, exposed throughout the San Carlos Mountain range, and diorite. The former may at times be free from nephelite and then appears locally developed as true syenite. The diorite is a medium-grained rock which is only found as isolated patches underlying the andesite where the laccolithic mass has been deeply eroded. Dikes and offshoots of the andesite cut through the diorite, which antedates the formation of the laccolith. The diorite has diabasic affinities.

Nephelite syenite, the product of long-continued, deep-seated cooling in magmas which are of medium percentages in silica, and contain large amounts of alumina and the alkalies, with low iron, lime and magnesia, has thus far been reported from but few localities in North America. It is found at Montreal, and in the county of Dungannon, Ontario, Canada; near the town of Litchfield, in Maine; on Salem Neck, and at Marblehead, in Massachusetts. It is met with at Red Hill, New Hampshire. A great dike-like mass occurs near Beemerville, New Jersey. Nephelite syenite has a large development near Magnet Cove, Arkansas, and the rock has likewise been described from Cripple Creek, Colorado, and from the trans-Pecos region of western Texas. Lawson's nephelite-pyroxene-malignite from the Rainy River district, Ontario, Canada, is a nearly related type. Similar occurrences of nephelite syenite and related rocks have been reported from the provinces of São Paulo, Rio de Janeiro, and Minas Geraes in Brazil by Derby.

The San José nephelite syenite is remarkable for its uniform character over large stretches. In the region studied it has not been split up into widely separated types such as are usually found where similar magmas have consolidated. Over nine tenths of the San José district it is a medium-grained, light or dark gray rock resembling granite. It is leucocratic and dull-looking by reason of the oily luster of the nephelite contained in it. The prisms and aggregates of the ferro-magnesian minerals are jet black, sharply outlined and in strong contrast with the lighter feldspars. Honey yellow, lozenge-shaped crystals of titanite are always found. It is only rarely that portions of the mass where the single crystals are locally developed in large size are observed, but individuals of orthoclase are sometimes an inch and a half in length; in other localities the basal sections of hornblende are three quarters of an inch in diameter, and rectangular masses of nephelite may be half as long again.

Black fine-grained basic segregations, like the knots in granite, are characteristic of certain limited tracts where they are so numerous as to give the nephelite syenite a mottled appearance. They are at times elliptical and again angular, and are found in all sizes up to five or six inches. They may be arranged in bands with great regularity, so as to cause the rock to resemble gneiss.

The San José nephelite syenite carries a comprehensive series of the commoner rock-making minerals at nearly every locality which was visited. Feldspar, nephelite, amphibole and pyroxene are the usual essential components of the rock. Mica is rare as an accessory constituent, while titanite, magnetite and apatite are common. No sodalite, cancrinite, garnet, calcite, olivine, lavenite or wollastonite was found. The essential mineralogy lies between widely varied amounts of orthoclase and nephelite with soda augite and brown barkevikitic hornblende. Plagioclase is rarely present. Mica is never an important constituent.

Varieties occur where by the disappearance of nephelite the rock is a typical syenite. Again by the coming in of plagioclase it approaches litchfieldite. One variant from the normal type very low in orthoclase consisting principally of nephelite, hornblende and augite marks the passage over to the ijolites.

The San José nephelite syenite bears some resemblance to the Red Hill, New Hampshire, rock, but it does not carry sodalite. It differs from the Litchfield and Dungannon occurrences in its field habit, for it is never so coarse as these rocks are. Nor is it except in rare cases so poor in the dark silicates. It is unlike the Dungannon rock by reason of its large content of orthoclase, and as being so poor in mica. It closely parallels some of the more acid varieties from Magnet Cove, but its dark silicates, though sharply automorphic, are not developed in such perfection. Again the basic portions of the Mexican rock might almost pass for certain facies of the Beemerville nephelite syenite. The latter is commonly darker by reason of the dusty iron inclusions which crowd its feldspars. This character is never seen in the San José specimens. The rock was nowhere observed to grade into porphyritic varieties as would seem to be the case at Beemerville.

The nephelite syenite in the San José district has not suffered metamorphism. It never displays a schistose structure. The effects of mechanical strains are not shown in thin sections.

Inclusions of another rock were not observed. The Mexican nephelite syenite is a dense compact rock and its specific gravity is high. Descriptions of the four chief types in the San José district follow below.

1. *Nephelite Syenite.*

(*a*) *Baril Type.*

This variety of the nephelite syenite is exposed in the Baril range just east of the mountain of that name. In the hand specimen it is dark gray, with the colorless constituents in excess. It is fine-grained, and exhibits the usual non-porphyritic granitoid texture. Nephelite is present in small amounts only, and this variety of the rock lacks the characteristic greasy look which that mineral commonly imparts to it. White feldspar is a prime constituent, and with it are flashing black crystals of amphibole and pyroxene, and honey yellow grains of titanite.

Examination with the microscope shows that this variety of the nephelite syenite contains orthoclase, nephelite, hornblende, augite, titanite, magnetite, apatite and pyrite. Of these the first two make up perhaps 65 per cent. of the rock. The orthoclase, which is far more abundant than the nephelite, has, as a rule, a glassy habit. It is often much clouded over with inclusions, which are seen with high powers to be stubby prisms, brown and yellowish-green. They lie in the direction of the basal cleavage. A second cleavage at right angles to this is well developed. There is evidence that all the orthoclase crystals were not contemporaneous. Now and then partly automorphic individuals may be observed standing against others quite different from them in habit, owing to incipient kaolinization. Intergrowths between the feldspar and the nephelite are frequently seen, with irregular boundary lines between the two minerals.

The nephelite cannot readily be distinguished from the orthoclase except by its interference figure. It lacks the two systems of cleavage cracks, however, which show in the feldspar, and such cracks as do occur are very irregular. The mineral is clear and glassy. It is often filled with inclusions essentially like those in the orthoclase. (See Pl. IX, fig. 1.)

The hornblende crystals tend to be automorphic. Cross-sections are octagonal by the equal development of prism and pinacoidal faces, rather than six-sided, as is usual where (100) is suppressed. Terminal planes were not observed. The pleochroism in certain instances is $\mathfrak{a}$ = seal brown, $\mathfrak{b}$ = yellowish-green, $\mathfrak{c}$ = light brown. Changing conditions in the composition of the magma are indicated by the dark green borders which usually surround the brown hornblendes. They are younger than the augite.

This mineral, which is much more abundant than the amphibole, is pleochroic, between olive green and dull green. Its surface is mottled by color changes in tones of green indicative of differences in chemical composition. The central portions of crystals are often tinged with violet. The short stubby prisms show poorly developed forms.

Apatite in six-sided prisms with perfect basal cleavage is common. The crystals are .4 mm. or less in length. They favor association with the dark silicates, as does also the magnetite. This mineral is in round grains .3 mm. across. Titanite is important in the rock. Its crystals are often 1.2 mm. in length. They are gray or nearly colorless. The Baril nephelite syenite contains numerous small grains of pyrite disseminated through it.

(*b*) *Arroyo Grande Type.*

The variety of nephelite syenite here described occurs midway between the Mesa Verde and Mt. Baril on the ridge overlooking the valley of the Arroyo Grande to the south. Its field habit is that of a very light gray rock in which the dark silicates make up only a very small portion of the whole. In the hand specimen the nephelite is very prominent, contrasting strongly by reason of its oily appearance with the kaolinized feldspar. With the aid of a pocket lens twinning may be observed on the orthoclase. Some titanite may also be seen occurring close beside the stray flecks of darker minerals. The texture is granitic with no porphyritic developments, and the rock is medium-grained.

Microscopic Characters. — Under the microscope the essential minerals are seen to be orthoclase plagioclase and nephelite. Augite is rare and no hornblende was observed. Magnetite, titanite, apatite and epidote are the accessories. Measurements were made by using the micrometer eye-piece to determine the relative proportions in which these minerals are present. Somewhat over one hundred times the grain was recorded and the assignments to orthoclase and nephelite were constantly checked by interference figures. The result is given below.

Orthoclase	60
Plagioclase	5
Nephelite	25
Augite	1
Magnetite	8
Titanite	.7
Average grain	.36 mm.

The large amount of feldspar and nephelite in this rock with not more than 10 per cent. of ferromagnesian minerals is very striking. The large amount of magnetite present is also noteworthy. Hornblende was not observed.

The orthoclase occurs as a rule in simple crystals, less often in carlsbad twins, kaolinized and earthy looking. It presents at times rectangular boundaries. Cleavage cracks, most numerous parallel to the base, are unusually well developed, with a second set of cleavage cracks parallel to (010). The angle between the two cleavages when they appear on sections approximately parallel to (010) is 65°, or nearly that of the angle β for orthoclase.

The plagioclase, which marks by its presence the passage to the variety of nephelite syenite known as litchfieldite, is albite, in automorphic crystals, twinned in excessively fine lamellæ. Like the orthoclase it is often much altered.

The nephelite is older than the orthoclase as being, frequently, entirely surrounded by it. The crystals are 1 mm. in length and show a strong tendency toward an automorphic habit. Their substance is fresh, so that they may usually be separated from the feldspars by this character. The cleavage cracks, extinctions and figure on the basal section are the usual ones.

The soda augite which occurs so sparingly in this variety of the nephelite syenite is clear green in color. Its crystals are small and irregularly bounded. They are conspicuously pleochroic, apple green to brown. Titanite is found as a rule close beside the magnetite. Reaction rims between the latter mineral and feldspar are occasionally seen. Apatite is rare. Epidote is present in minute amounts.

(*c*) *Mesa Verde Type.*

This variety of the nephelite syenite occurs immediately to the east of the Mesa Verde. Seen in the hand specimen it is of a dark gray color from the large amounts of ferro-magnesian minerals contained in it. Clear, greasy nephelite may be recognized, and slightly weathered feldspar, apparently not so abundant, its cleavage surfaces having a vitreous luster. Clear yellow grains and crystals of titanite are present. The dark silicates occur as black masses which, except for an occasional six-sided crystal of hornblende, cannot be identified. The rock is fine-grained with a granitic texture.

Microscopic Description. — Under the microscope it is found that nephelite, orthoclase, hornblende and augite are the essential minerals. Magnetite, apatite and titanite are the accessories. By measurements with the micrometer eye-piece the mineralogical composition or mode of the rock was found to be as follows:

Nephelite	18
Orthoclase	12
Hornblende	40
Augite	23
Magnetite	2.7
Titanite	2
Apatite	1.2

The average grain is .2 mm. The structure is granitic with all the minerals more or less completely xenomorphic. From the above table the great prevalence of the dark silicates over the feldspar and nephelite together may at once be noted, as well as the excess of nephelite over orthoclase.

The orthoclase is in crystals inclining to a prismatic habit which average .4 mm. in diameter. They may at times be slightly clouded over by the products of alteration. Occasional carlsbad twins are noted. This feldspar frequently surrounds large portions of the nephelite.

The substance of the nephelite is quite fresh. Its outlines tend to be rectangular. The cleavages parallel to the base and the prism are at times developed and the extinctions are parallel to these directions. Transparent microscopic crystals are present as inclusions in the nephelite, and surrounding it a secondary mineral, which is usually referred to cancrinite on account of its low index of refraction and high interference colors, is commonly developed.

Hornblende, the most abundant constituent of the rock, is the only mineral which has an automorphic habit, excepting the apatite. The unit prism and the pinacoidal planes, in the zone parallel to the *c* axis are well developed. The crystals are pleochroic from yellow to seal brown. The absorption is strong. Twins are not rare.

The augite in rude prisms and aggregates of grains is pale violet or greenish, with borders of deeper green from the coming in of the ægirite molecule. Intergrowths with amphibole are common. The augite encloses grains of titanite, and apatite needles.

Titanite occurs sporadically, in patches which are sometimes 1.5 mm. long. (See Pl. X, fig. 1.) The magnetite is in the usual grains with purple black luster. Apatite is very abundant in short stout crystals with its basal sections perfect hexagons charged with irregular dust inclusions. Some minute needles of epidote were observed.

The order of crystallization appears to have been as follows: First apatite, magnetite and titanite. Then hornblende and augite often enclosing the amphibole. The above minerals are frequently grouped together in such a manner, however, as to make it plain that their growth must have been in large measure simultaneous. After the dark silicates nephelite followed, and the feldspar came last.

(*d*) *Mesa Verde Type. Basic Facies.*

This variety of the nephelite syenite occurs closely associated with the Mesa Verde type in the same locality on the Baril

Range. It is a very dark gray, from the very large amounts of black ferro-magnesian minerals present. These are in prisms and grains surrounding masses of nephelite. No feldspar is apparent to the naked eye.

Microscopic Characters. — The microscope reveals, as the component minerals of this rock, apatite, titanite, magnetite, biotite, hornblende, augite, orthoclase and nephelite, in the order of their formation. The calculation of the mode by optical methods makes plain that only the last four play an important part in the rock. Hornblende is greatly in excess of all the other constituents put together. Orthoclase is very subordinate. Biotite is present in very small amounts. Its occurrence is significant. It is not found anywhere in the district except in the most basic forms of the nephelite syenite. The percentage composition is as follows :

Nephelite	13.2
Orthoclase	5.6
Hornblende	60.5
Augite	13.9
Biotite	2.2
Magnetite	0.4
Titanite	2.8
Apatite	1.4

The average grain is .16 mm. The texture is granitoid.

The mineral nephelite is younger than the orthoclase, with which it is in part intergrown. It appears in large areas, extinguishing at the same moment in which the feldspar and dark silicates are enclosed. It is very clear, except for inclusions of glass and fluid cavities. Its polarization tint is deeper than that of the feldspar. It is shown to be uniaxial and negative.

Orthoclose is largely interstitial between the crystals of amphibole. No plagioclase was observed.

The anhedrons of amphibole are gathered together to form large patches in the slide. Intergrowths with pyroxene are not found. The mineral is brown with pronounced pleochroism. $\mathfrak{a}$ = light brown, $\mathfrak{b}$ = seal brown, $\mathfrak{c}$ = deep brown. The optic angle is large. The clinopinacoid is the plane of the optic axes. Extinction 21°. These properties are those which we should expect from barkevikitic hornblende.

The augite is light green. It differs from the usual varieties of this mineral in never showing borders indicative of an increase in the soda molecule. It is never tinged with violet. Rarely it may be seen as if grown out from the ends of the amphibole.

Brown biotite in thin lath-shaped plates .5 mm. in length is present as an accessory. It is notable for its inclusions, acicular transparent prisms of an undetermined mineral resembling rutile. They are usually inclined to the base at a sharp angle. Magnetite is rare, apatite and titanite common.

The specimen of the nephelite syenite (Baril type) analyzed by Dr. H. S. Washington, represents the average grain and mineralogy of the rock along the north end of the Baril range. Nephelite makes up about 18 per cent. of the whole. Augite, hornblende and biotite are all present. Apatite is conspicuous, and titanite may be easily seen in the hand specimen.

The results of analysis are given below, column I. Numbers II, III and IV are placed beside it for reference.

	I.	II.	III.	IV.
SiO_2	58.40	59.01	60.39	51.90
Al_2O_3	20.25	18.18	22.51	22.54
Fe_2O_3	1.78	1.63	.42	4.03
FeO	2.41	3.65	2.26	3.15
MgO	.49	1.05	.13	1.97
CaO	3.11	2.40	.32	3.11
Na_2O	7.01	7.03	8.44	8.18
K_2O	5.39	5.34	4.77	4.72
H_2O^{110}	.27	.15		
H_2O^{ign}	.57	.50	.57	.22
CO_2	none		trace	
TiO_2	.25	.81		
ZrO_2	none	trace		
P_2O_5	.20	trace		
SO_3	.06			
Cl_2	.02	.12		
S	none			
MnO	trace	.03	.08	
BaO	trace	.08		
CaO				
	100.21	99.98	99.89	99.82
	Less O for Cl_2	.03		
		99.95		

I. Nephelite syenite, Baril type, Tamaulipas, Mexico. H. S. Washington, anal.

II. Nephelite syenite, Red Hill, N. H. W. F. Hillebrand, anal. W. S. Bayley, Bull. Geol. Soc. Amer., III, 250, 1892.

III. Eleolite syenite, Litchfield, Me. L. G. Eakins, anal., Bull. Geol. Soc. Amer., III, 241, 1892.

IV. Eleolite syenite, Brögger. Syenitpegmatitgänge, p. 33.

When the norm of this rock I is calculated in the standard salic and femic minerals the percentage composition is as follows :[1]

Orthoclase	31.69	Magnetite	2.55
Albite	37.73	Diopside	6.62
Nephelite	11.64	Olivine	.55
Anorthite	7.78	Fem	9.72
Sal	88.84	H_2O	.84

The rock is therefore persalane, it belongs to order 6, russare, it is domalkalic viezzenase and dosodic, viezzenose.

2. *Diorite*

The two principal areas in which diorite is exposed lie along the road leading to the Vegonia Mine, at a distance of about a mile from San José. The rock is also found in the gulch a mile due northwest of the town. It is usually deeply weathered and shows a rusty brown color in the field. The andesite is younger than the diorite and surrounds it completely, sending many small dikes into it. As before stated, the diorite probably lies below the andesite over much of the country where erosion has not revealed it.

When seen in the hand specimen this rock has the appearance of typical diorite. It has the granitoid texture. It is medium-grained, and dark gray in color. Plates of biotite are easily discernible through the rock. They are jet black, or brownish-black, and large enough to allow cleavage pieces to be scaled away. With the biotite small amounts of another dark silicate having no good cleavage may be identified. The microscope shows this to be a pyroxene. Taken together the darker constituents which are so prominent are not quite so

[1] "Quantitative Classification of Igneous Rocks," Cross, Iddings, Pirsson, Washington. The University of Chicago Press, Chicago, 1903.

abundant as the white or colorless feldspars. Carlsbad twins may occasionally be seen on these with the unaided eye. They are dull and show something of the oily luster which is characteristic of nephelite. Grains of titanite are scattered through the rock, and minute pieces of pyrite appear from time to time.

When examined with the microscope the rock is found to consist of plagioclase, augite, biotite, titanite, magnetite, apatite, pyrite and zircon, in the order of their relative abundance. There are no porphyritic developments. The outlines of the minerals (with the exception of apatite) are quite irregular, although the feldspars are commonly rectangular.

The plagioclase, as determined by the Michel-Levy methods is in two kinds, labradorite with the composition Ab_1, An_1 and a more acid andesine Ab_5An_3. Its substance is fresh and glassy, though broken by many irregular cleavage cracks. The feldspars are twinned polysynthetically on the albite and pericline laws, with very fine twinning lamellæ. A zonal structure is occasionally observed.

The augite is in large irregular patches intergrown with biotite. This variety of pyroxene has a high extinction angle. It is light clear green and non-pleochroic. Twins may often be noted. The enclosures are apatite and magnetite. (See Pl. XII, fig. 2.)

The mica is a rich chestnut brown biotite, with strong absorption for rays perpendicular to the cleavage. Irregular masses of nearly colorless titanite are from time to time noted in the slide. Magnetite is abundant in large grains, now and then surrounded by rings of titanite. Rarely it shows a tendency to form rods growing out from the borders of the mica. The apatite prisms are well developed. The results of two analyses of this rock are given below, columns I and II. Numbers III and IV are placed beside it for reference.

	I.	II.	III.	IV.
SiO_2	45.75	48.49	49.30	56.28
Al_2O_3	18.51	18.99	22.46	14.23
Fe_2O_3	6.55	9.59	12.04	4.69
FeO	6.02	1.00		4.05
MnO				.16
MgO	5.06	5.05	2.14	6.37

	I.	II.	III.	IV.
CaO	11.85	10.78	9.30	7.94
Na_2O	3.41	3.47	3.01	2.98
K_2O	2.35	1.42	1.27	1.23
P_2O_5	trace			.40
H_2O^{110}	.06	.10		
H_2O^{ign}	.20	.55	.78	.93
	99.76	99.44	100.30	.17 Cl
				trace SO_3
				.01 Li_2O
				100.28
			less O for Cl	.04
				100.24

I. Diorite, San José, Tamaulipas, Mexico. G. I. Finlay, anal.

II. Diorite, diabasic facies, San José, Tamaulipas, Mexico. G. I. Finlay, anal.

III. Diorite, Rosetown, near Tompkin's Cove, N. Y. J. F. Kemp, Amer. Jour. Sci., Oct., '95, 298.

IV. Diorite, Electric Peak, Yellowstone Nat. Park. J. E. Whitfield, anal. Monograph XXXII, Part II, U. S. Geol. Surv., p. 116.

The percentage compositions in standard minerals which give the norm for I and II are as follows:

I.		II.	
Orthoclase	8.34	Orthoclase	13.34
Albite	25.68	Albite	7.34
Anorthite	31.97	Anorthite	28.36
Nephelite	1.99	Nephelite	11.64
Diopside	16.85	Diopside	24.40
Olivine	3.36	Olivine	4.71
Magnetite	3.25	Magnetite	9.28
Hematite	7.30		99.07
	98.74		
H_2O	.65		
	99.39		

No. I is therefore salemose-limburgose, and No. II is salemose.

B. Porphyritic Types

As may be seen in the geologic map, Plate VIII, the town of San José lies in the depression formed by the erosion of the central portions of a laccolithic mass of andesite. The rock is exposed continuously over twelve square miles of territory. Throughout the laccolith it varies but little from the eventextured porphyritic habit which characterizes such intrusive masses. Denser textures show but rarely along the borders of the laccolith. The prevailing colors are light yellow and blue gray. Portions of the rock are locally richer in silica than the main mass, and show free quartz. All possible gradations exist between the normal andesite and the more siliceous dacite. Four types of these rocks will be described, as follows:

Andesite, San Narciso type; Vegonia type.

Dacite, Florencia type; Imogenia type.

1. *Andesite*

(*a*) *San Narciso Type.*—This variety of the andesite is largely developed to the north and west of San José.

In the field this rock presents an even gray ground-mass. It is leucocratic, with the darker crystals as scattered grains but sparingly developed, although basic segregations are more than usually common.

The feldspar, which is by far the most abundant mineral present, is recognized in the holocrystalline ground-mass by its bright cleavage faces. These show occasional twinning striations.

Under the microscope the structure is seen to be holocrystalline porphyritic, and plagioclase, orthoclase, augite, quartz, biotite, magnetite, titanite and zircon are determined as the constituent minerals.

The sections of plagioclase are lath-shaped pieces of labradorite, 1.2 mm. long by .5 mm. in breadth, appearing as porphyritic crystals in a very coarsely crystalline ground-mass which consists of orthoclase and quartz. (See Pl. XII, fig. 1.) The labradorite Ab_1An_1 appears in fresh crystals, largely free from the effects of weathering. These are twinned in fine lamellæ on the albite law, with many pericline lamellæ. When viewed between crossed nicols in the 45° position, one half of the crystal usually appears blue gray, the other yellow, indicating twinning on the carlsbad law. Zonal structure is very common. The outermost rims of the plagioclase crystals are often deeply changed by weathering. This material has the appearance of kaolinized orthoclase.

The crystals of orthoclase are shorter and stouter. They occur as carlsbad twins and are much altered and kaolinized. The largest crystals of orthoclase do not attain a diameter greater than 1 mm. They are xenomorphic rude prisms which show marked pleochroism from light green to brownish-yellow. The quartz is in xenomorphic rectangular and square pieces which give the characteristic uniaxial cross with one or two rings. They may be distinguished from the orthoclase squares by their glassy unweathered appearance. The quartz is seen to make up but a very small part of the whole rock.

Biotite, in small patches not above .2 mm. in length, is still rarer. Magnetite is found abundantly and small lozenge-shaped individuals of titanite are met in the slide. Some zircon is also present.

An analysis of the San Narciso type of the andesite is given below, as follows:

SiO_2	62.31
Al_2O_3	18.63
Fe_2O_3	2.38
FeO	1 33
MgO	.60
CaO	5.91
Na_2O	4.97
K_2O	3.52
P_2O_5	.07
H_2O^{110}	.16
H_2O^{ign}	.07
	99.98

The calculation of the standard mineral composition or norm gives the following percentages:

Quartz	8.9	Diopside	4.1
Orthoclase	20.6	Wollastonite	2.5
Albite	41.9	Magnetite	3.5
Anorthite	18.1		10.1
Sal	89.24		

The rock is persalane and belongs to order V canadare. It is domalkalic and dosodic, laurvikose.

(*b*) *Vegonia Type*

This rock is exposed along the brook course 100 yards south of the Vegonia Mine. It is found as narrow dike-like stringers and larger masses irregularly intruded into the San Narciso type of andesite described above.

Megascopic Description.—When seen in the hand specimen it appears as an even-grained bluish-gray porphyritic rock with inconspicuous phenocrysts of feldspar and smaller grains of the dark silicates. The feldspars are at times a quarter of an inch long, but this is unusual. They average not more than one sixteenth of an inch in length. They often show the characteristic twinning of the plagioclases to the unaided eye. The darker silicates are by no means so abundant as the feldspars. Except for an occasional yellow crystal of titanite they are black. Taken altogether the phenocrysts make up half the rock.

Microscopic Description.—In thin sections the principal constituents of this andesite are found to be plagioclase, augite and hornblende, in conspicuous phenocrysts, with titanite, magnetite and apatite as accessories, in a fine-grained holocrystalline ground-mass consisting principally of feldspar, with lesser amounts of augite and magnetite in a second generation.

The plagioclase phenocrysts are in tabular crystals which are equidimensional. *M*(010), *T*(110) and *l*($1\bar{1}0$) are conspicuously developed faces. Polysynthetic twinning occurs on the albite law and carlsbad twins are not uncommon. More rarely lamellæ which result from twinning on the pericline law have been noted. The lamellæ are generally broad, with intercalated fine bands. The extinction angles indicate labradorite. When a crystal cut at right angles to *M*(010) which shows twinning on the albite law and carlsbad law at the same time can be found the concurrent extinction angles correspond to a labradorite with the composition Ab_1An_1. The double refraction is high, often yellow of the first order. The labradorite crystals almost always show zonal structure. In habit they are usually microtinic and quite free from alteration products, but the core of a crystal has at times been shattered and afterwards surrounded by a glassy zone of later growth. Inclusions of apatite, in very slender needles are common, and the whole substance of a labradorite crystal is often clouded with microscopic irregularly disseminated inclusions, probably pyroxene. Again iron-bearing solutions have stained the feldspar along cleavage cracks.

Augite, which is the most important of the dark silicates, is rather more abundant than hornblende. It is found in simple light green crystals bounded in the prism zone by the faces *m*(110), *a*(100) and *b*(010), which favor association with the hornblende and magnetite. The crystals show an unusually good cleavage parallel to *a*(100). Zonal structures are rarely observed. The extinction angle is 42°.

The hornblende is in very long slender prisms which are either rounded at the ends or terminated by two flattish faces. Occasionally they are twinned. They are of a dull brownish-green color and absorb the light strongly. Pleochroism is confined to shades of green.

Titanite, which appears sporadically in large irregular crystals, is the most notable of the accessory minerals present. The customary cleavage parallel to *l*(110) is not well developed. Acutely rhombic sections are not common.

Magnetite, which but rarely shows crystal boundaries, is abundant in this andesite. Apatite is common among the older inclusions.

The ground-mass is a fine-grained aggregate of minute lath-shaped and irregular feldspars, microscopic magnetite grains and minute augite prisms of a second generation. The extinction angles on the feldspar microlites are low and point to oligoclase. Rude flow lines may at times be noted.

2. *Dacite*

(*a*) *Florencia Type.* — The rock here described exhibits every gradation towards the less siliceous andesite in the laccolithic mass. It is found in the hills immediately south of San José.

Macroscopic Description. — This type is very fine-grained. In the hand specimen the rock is of a pale brown color. It is plainly porphyritic by reason of the larger crystals of feldspar, with flashing cleavage faces, which are just large enough to be recognized. A hand lens shows that their centers are somewhat weathered, while the outer rims are fresh. The dark minerals are not determinable in the hand specimen. They appear as minute black patches sparsely distributed through the ground-mass.

Microscopic Characters. — The study of thin sections reveals the presence of plagioclase, augite and quartz phenocrysts in a ground-mass, which is an intimate mixture of quartz and feldspar. Apatite, epidote, titanite and magnetite are the accessory minerals.

The plagioclase crystals are 1.2 mm. long, often in highly complex forms with only (010) and (110) distinguishable. The center is often deeply corroded, and secondary muscovite produced inside a clear outer rim. Many of the medium-sized individuals of the mineral are, however, quite glassy. Twinning according to the albite law with extremely fine lamellæ is very common, but many other lamellæ are often intercalated on the pericline law. The two halves of the crystals twinned at once on the albite and carlsbad laws show different interference colors in the 45° position. One is usually yellowish, the other blue gray. Symmetrical extinctions on the lamellæ of the two halves gives readings for an acid labradorite Ab_1An_1.

The quartz phenocrysts are seldom above .1 mm. in diameter, but they are very common. Their substance is clear and glassy. It encloses needles of apatite, and only rarely shows, gas or liquid inclusions. The mineral is never automorphic. It has generally grown side by side with deeply kaolinized feldspar which comes in crystals much smaller than the labradorite phenocrysts. No twinning was observed on this second feldspar, which is identical with the feldspar of the ground-mass.

The pyroxene makes up a very small part of the rock. It is in irregular deep green twinned grains that are pleochroic yielding light and dark shades of green. Apatite in minute needles is a rare accessory, as is also epidote in short stubby grains. Titanite is present in irregular pieces not above .1 mm.

in diameter, and the grains of magnetite which are fairly abundant in the rock are still smaller. The ground-mass is a dense aggregate of pieces of quartz and kaolinized feldspars. These are on the average .05 mm. across and appear to be in nearly equal proportions.

(*b*) *Imogenia Type.* — The type here described occurs along Vegonia and Bretaña Creeks in the foothills of the Baril range.

Macroscopic Description. — In the field this rock when unweathered is grayish in color and shows a rough fracture. It is medium-grained and porphyritic in texture with a predominance of feldspar phenocrysts having bright cleavage faces as against the smaller proportions of the aphanitic ground-mass. Dark specks, shown by the microscope to be pyroxene, are scattered through the hand specimen.

Microscopic Characters.—The examination of this rock in thin sections shows that it is made up of plagioclase, orthoclase, quartz, augite, hornblende, biotite, magnetite, apatite and chlorite. Owing to the intimate mixture of quartz and feldspar in the ground-mass considerable difficulty is found in estimating the relative proportions between them optically. It is probable that there is an error of 5 per cent. in the subjoined table, which could not be guarded against. The mineral percentages by weight, as given in it, are however approximately accurate.

Plagioclase	32
Orthoclase	25
Quartz	17
Augite	16
Biotite	2.4
Magnetite	6.7
Hornblende, Apatite, Titanite, Chlorite	.9
	100.0

The phenocrysts are of feldspar and quartz, augite, some biotite and the older generation of the magnetite. The accessory minerals make up perhaps 1 per cent. of the quartz-feldspar ground-mass.

The plagioclase of the older generation occurs in equidimensional crystals which often are 2 mm. in length. The albite, carlsbad and pericline laws are all represented in the twinning. The lamellæ on the albite law are excessively fine. The symmetrical extinctions given by them in the two halves of a carlsbad twin make possible the determination of the plagioclase as labradorite Ab_1An_1. Zonal structure is very common. The substance of the plagioclase is often quite clear and glassy at the center, while the outer border of the crystal is commonly crowded with inclusions. Again the outer zone may be observed to extinguish at the same instant as the center of the crystal, while one or two intermediate shells have angles of extinction at variance with them. The outlines of the plagioclase individuals, as of all the other phenocrysts, are ragged and irregular.

Porphyritic crystals of orthoclase show twinning after the carlsbad law. Quartz is frequently intergrown with the orthoclase after the fashion of microgranite, where all the enclosed pieces of quartz extinguish at the same time. Perthitic intergrowths with plagioclase on a microscopic scale also occur. The orthoclase is always partly kaolinized.

The pyroxene does not usually show even an approach to good crystal outlines. Irregular grains of this mineral are common. It is light green, non-pleochroic, extinction 40°. Embayments produced in the crystals by the caustic action of the magma are frequently observed and the secondary minerals thus produced are magnetite and some little hornblende. By alteration the augite yields a dull green pleochroic fibrous chlorite.

Patches of a dull green slightly pleochroic hornblende, with an extinction of 15°, are rare, but may be as large as 2 mm. They are always ragged on all sides. Occasional poikilitic intergrowths between the hornblende and the pyroxene should be noted.

Patches of biotite as large as the hornblendes may be found at times. Secondary augite and magnetite grains occur around them as products of magmatic resorption.

The magnetite is usually surrounded by narrow rims of titanite, which may be secondary. The larger pieces of magnetite .4 mm. in diameter are to be taken as phenocrysts. Those of the second generation average .05 mm. They are in definite square sections of octahedra. Apatite needles are rare but titanite in dull grayish-yellow grains is often seen near the dark minerals. No pyrite was observed.

3. *Basalt*

Occurrence. —A lava flow of basalt may be traced on the eastern side of the San Carlos Mountains, extending back toward the range, along the course of the Arroyo Grande for four or five miles. The sheet is scoriaceous and vesicular on its upper surface, and appears to have issued from a fissure below the crags, at this point on the east of the Baril Range. The flow is perhaps half a mile in width. No volcanic cone was found on tracing it to its source.

Macroscopic Appearance. — In the hand specimen the rock is aphanitic and fine-grained. In color it is bluish-black. It breaks with a smooth splintery fracture. Blow holes show over its surface. The vesicular cavities are filled with calcite.

Microscopic Characters.—The rock is porphyritic with phenocrysts of feldspar and pyroxene. The augite was not observed in a second generation in the ground-mass, where lath-shaped feldspars, biotite and magnitite are the principal constituents.

The plagioclase phenocrysts are small, not above .4 mm. in diameter. The mineral occurs in poorly bounded thick tablets which are heavily charged with magnetite. The only inclusions are minute prisms of pyroxene. Wavy extinctions from center to margin are characteristic, but definite clearly marked zones of varying chemical composition are not observed. Twins on the albite law are common, but no other forms of twinning occur. Symmetrical extinction angles point toward labradorite. There is frequently a dense crowding together of magnetite grains for half a millimeter around a core of feldspar. Often the crystals of plagioclase have been acted upon by the magma until a mosaic of feldspar grains has resulted. Large, very irregular and ragged pieces of augite are found associated with such evidences of disturbance. The mineral is of a bright green color with faint pleochroism to yellowish-green. The extinction is 40 degrees.

Biotite, plagioclase and magnetite form the ground-mass, the two first minerals being equally abundant. The feldspar is in small lath-shaped crystals often arranged in rude flow lines. They invariably show several minute twinning bands which give extinctions indicating a more acid feldspar than labradorite. They are believed to be andesine. They are automorphic and have invariably crystallized before the dark minerals.

The biotite never occurs in phenocrysts. It is always xenomorphic and interstitial between the feldspars. Small brown rectangular pieces sometimes attain a length of .1 mm. and from that sink to microscopic dimensions.

Magnetite, in grains and skeleton crystals, is scattered all through the rock and titanite occurs in notable amounts. An unresolvable glassy base makes up a small portion of the ground-mass.

The analysis and calculated standard mineral percentages of this rock are as follows :

SiO_2	48.03	Orthoclase	11.68
Al_2O_3	20.98	Albite	24.10
Fe_2O_3	7.06	Anorthite	36.70
FeO	4.51	Nephelite	1.99
MgO	4.43	Diopside	8.37
CaO	9.54	Olivine	6.25
Na_2O	3.28	Magnetite	10.21
K_2O	1.99	H_2O	.61
H_2O^{110}	.21		99.91
H_2O^{ign}	.40		
	100.49		

G. I. Finlay, anal. The rock therefore belongs with order 5 of class II, in rang 4 and grad 3, hessose.

C. Dike Rocks

Over fifty separate dikes were observed in the region immediately about San José. They fall into two groups, the more acid, tinguaites and offshoots from the andesite mass, and the basic series. They tend to assume two general directions in their distribution. Most of them strike nearly north and south. The great tinguaite dike which extends from Mt. Anacuas to the south of Mt. Parreño is an exception to this rule. A second set of dikes follows the east-and-west direction at right angles to the first series. The great tinguaite dike which belongs with these, running from the foot of Mt. Armadillos to the slopes of Mt. Parreño, has been faulted aside for 150 yards near the town of San José.

The tinguaite dikes fall into two divisions:

1. The more acid types which in the field are easily recognized by their abundant porphyritic crystals of orthoclase.

2. Those which are aphanitic and are characterized microscopically by the presence of analcite.

The tinguaites cut the limestones and the andesites, but they were not found in the nephelite syenite. The other dikes are all of them presumably later, and they are believed to represent several periods of eruption. They do not cut across the tinguaites in the region examined. In only one instance was a dike found intersecting another. The basic dikes are seen cutting through the nephelite syenite as well as the other rocks of the district. Good exposures occur along the roads leading from San José to the Santa Helena, San Narciso and Vegonia mines. These dike rocks are all of them aphanitic and black-looking, somtimes slightly inclined to bluish, brownish or grayish. The following basic types are included in the descriptions:

Camptonite.

Vogesite.

Limburgite.

The tinguaites show a uniform field habit, with the characteristic green color due to microscopic prisms of ægirite. They are more numerous than any other of the San José dikes. They may be without phenocrysts, and again are notably porphyritic by reason of the orthoclase crystals which they contain. They are found not only in the andesite, and cutting the limestone, but far to the northwest of the San Carlos Mountains as well, and for many miles along the eastern and western flanks of the range. In some cases single dikes may be traced for one and a half or two miles with a width of ten feet.

1. *Tinguaite*

(*a*) *Santa Rita Type.* — The variety of the tinguaite here described is met in a dike between the Mesa Verde and Mt. Parreño near the pass which the Santa Rita trail takes on leaving the San José valley.

In the hand specimen the rock is noticeably darker than the other tinguaites of the district. It is a dense compact rock having a deep green aphanitic ground-mass in which tablets of sanidine often 2 cm. in length occur prominently as phenocrysts. Without a hand lens it is difficult to distinguish the larger crystals of ægirite in the dense aggregate made up of the minute individuals of that mineral. Amygdaloidal cavities occur which contain tiny shreds and patches of biotite, magnetite grains and the earthy aggregates that have resulted from the weathering of the zeolites.

Microscopic Description. — Besides the sanidine and ægirite the microscope shows that nephelite, plagioclase, hornblende and analcite are present.

The larger phenocrysts of feldspar are in sharply automorphic carlsbad twins bounded by (110) and (100). They attain a maximum length of 3.5 mm. and are one quarter as broad. (See Pl. X, fig. 2.) They contain many inclusions, minute prisms of ægirite zonally arranged with their long axes parallel to the walls of their host, and bundles of microscopic brightly polarizing needles having a high index of refraction. The feldspar crystals show peculiar effects of weathering and secondary replacement. Good cleavage cracks appear rarely. Now and then kaolinized cores remain, but nine tenths of their substance is usually of secondary origin, largely orthoclase feldspar, plagioclase and analcite. The cores of the original crystals have been eaten out and in the central portions analcite is now found. (See Pl. XI, fig. 2.) This mineral is isotropic, and it gives no interference figure. It has two sets of cleavage cracks at right angles to each other. It may extend out from the center as far as the original boundaries of the feldspar or it may be surrounded by a zone of feldspar crystallites packed in together like the skeleton crystal needles in spherulitic bodies. These bundles of needles are intergrown with definite initial forms of ægirite. The microscopic growths of this mineral resemble the occurrence of pyroxene in the Arran pitchstone. Now and then lines of grains of ægirite run out toward the center. Again a corroded space in the original orthoclase has been filled by bundles of plagioclase needles or by analcite and clear secondary feldspar, the latter untwinned and surrounded by the zeolite. These circumstances are favorable for deciding as to the relative indices of refraction by the Becke method. The lines of light migrate outwardly from the analcite into the feldspar on either side. When observed with high powers the zeolitic substance is clear and glassy while the secondary feldspar associated with it is distinctly granular.

Two other generations of feldspars besides the large phenocrysts are well marked. Those belonging to the second period are comparatively fresh. They appear as six-sided individuals .3 mm. in length. Finally, feldspar appears as an aggregate of orthoclase grains and minute lath-shaped crystals with soda pyroxene in the ground-mass. Here the emerald green prisms, arranged in felty aggregates, are noticeably shorter and stouter than is usual in the ground-mass of other San José tinguaites.

They are not frayed at the ends and their edges are firm and sharp. They have not been noticeably crowded together by the growth of the large feldspar phenocrysts, but have been forced to grow with their long axes parallel to the latter, when they lie near them. The ægirites at times cluster thickly about a large grain of magnetite.

Individuals of the pyroxene three times as large as those in the ground-mass represent an older generation. Very rarely phenocrysts of chestnut brown hornblende, pleochroic in shades of brown .1 mm. in diameter, twinned parallel to (100) are observed as nuclei for clusters of ægirite. The biotite of the rock, in minute patches, is rare and of secondary origin. Magnetite grains do occur but not commonly.

(*b*) *Iman Type.*—The variety of the tinguaite to be described under this name is found in a dike four feet wide which is exposed for fifty feet, extending in a north-and-south direction, immediately to the west of the Piedra Iman.

Macroscopic Characters.— In the field the rock has a light brown color. Its texture is porphyritic with many very small white tabular crystals of feldspar appearing as the only discernible phenocrysts in a dense aphanitic ground-mass.

Microscopic Characteristics.—Under the microscope it is found to contain, besides prevailing orthoclase and some little nephelite, smaller amounts of ægirite, magnetite and limonite. The ground-mass shows a marked fluidal arrangement.

The orthoclase appears in two distinct forms as the result of as many periods of crystallization. The phenocrysts are nearly always very long and narrow tablets twinned on the carlsbad law, but rectangular more isometric crystals are now and then found. The feldspar is always much kaolinized. The basal and clinopinacoidal cleavages show distinctly. The orthoclase laths in the ground-mass are very narrow, and hardly .2 mm. long.

The nephelite presents clear surfaces of low relief not broken by cleavage cracks. It is found in rudely hexagonal phenocrysts which give a uniaxial figure. (See Pl. XI, fig. 1.)

The ground-mass contains, besides the feldspar, rods of ægirite, small amounts of nephelite, ragged pieces of magnetite, and secondary limonite. The ægirites are broader and less regular than the feldspars. By weathering they take on a fibrous appearance and tend to lose their bright green colors. The nephelite is fresh and clear. It gives rise to the deep blue-gray colors with crossed nicols where it is seen in the interstices of the ground-mass.

2. *Analcite Tinguaite*

(*a*) *Mt. Armadillos Type.* — The variety of the tinguaite here described is found in the important dike which runs as a great wall across the country from the western slope of Mt. Armadillos to the foot of Mt. Parreño. It is so much more resistant than the andesite which surrounds it that it is always left in relief by the differential effects of weathering. It is of a light green color in the field. Its texture is porphyritic, with glassy sanidine crystals in a dense homogeneous ground-mass, as the chief phenocrysts. Small specks of biotite may be seen in the hand specimen. The rock has a peculiar greasy luster.

Microscopic Characters. — Under the microscope this tinguaite is found to have the pilitic texture where minute ægirite needles, amounting to 50 per cent. of the whole, make up a dense felty aggregate, in which sanidine, analcite, and, rarely, porphyritic crystals of pyroxene and biotite patches are found.

The analcite crystals are in small squares less than .1 mm. in diameter, and in polygonal and rectangular sections. They are colorless and appear so abundantly as to cause darkness by crossed nicols over most of the field.

The sanidine phenocrysts are clear and colorless. They give blue-gray interference colors. Carlsbad twins may often be noted. The sanidines have no good cleavage cracks, but they exhibit the usual crude parting parallel to (100).

A few ægirite needles of an older generation occur. This mineral in the ground-mass is faint green or almost colorless. The individuals are very small, usually only .1 mm. in length. They are sharply bounded, and appear packed in together with tiny feldspars to form a very dense aggregate. The small crystals of sanidine associated with them are all automorphic, and many of them show twinning. Traces of magnetite, rare patches of biotite and areas of secondary limonite are to be noted.

(*b*) *Corona Type.* — The type here described could not be found in place. The dike from which the bowlder, collected in the bed of Bretaña Creek, came, was doubtless up near the waters of that stream against the Baril Range.

Megascopic Description. — The hand specimen shows a slate-colored rock, having a felsitic texture. Phenocrysts of greasy-looking nephelite and crystals of sanidine are visible to the unaided eye, and with a pocket lens the carlsbad twinning may be noted on the feldspar. A dark silicate sparingly disseminated through the rock proves to be ægirine-augite.

Microscopic Characteristics.—Under the microscope two textures are observed. Besides the usually strictly porphyritic phase of the rock, a fine-grained variety occurs in which all the crystalline masses are of approximately equal size. Squares and hexagonal sections of nephelite, grains of ægirite and titanite and carlsbad twins of glassy sanidine are the constituents, with accessory minute needles of apatite. These are the commoner minerals which make up the rock. Analcite and rare augite should be mentioned to complete the list.

The orthoclase is in extremely long narrow carlsbad twins (1.2 mm. by .15 mm.), resembling the smaller ones common in the normal trachyte ground-mass, or again in thick tablets, colorless and glassy, but dusted over with extremely minute rod-like inclusions which tend to lie parallel to the prism directions.

Nephelite, in six-sided and rectangular sections .6 mm. by .8 mm., is very common. This mineral gives at times a satisfactory uniaxial interference figure. It is often white, inclining to buff color. Ægirite inclusions are observed in it with zonal arrangement. Minute inclusions of the same pyroxene, in sharp lines, produce an effect of ruling which is much like the appearance of definite cleavage cracks. The nephelite is altered but little. Analcite, chiefly, results by weathering.

Augite is the usual pyroxene. Three generations in all of the mineral are observed. It occurs in short stout prisms 1.2 mm. by .5 mm. as phenocrysts. The extinction angle is nearly 45°. Poikilitic intergrowths of the augite, tinged with a violet color, and included emerald green patches of ægirite are very common. Zonal structures are seen at times in such crystals, the several shells having unlike orientation optically. Much apatite and some magnetite are associated with the larger individuals.

Titanite, showing no unusual characteristics, is found in bladed crystals 1.2 mm. long. Patches of biotite were noted, but the mineral is present only in extremely small amounts. Grains of magnetite are scattered through the rock and pyrite is sometimes present.

The ground-mass is very rich in laths of orthoclase feldspar. These and ægirite rods make up almost the whole of it.

Two analyses of the analcite tinguaite are given below.

	I.	II.
SiO_2	52.83	49.42
TiO_2	.16	
Al_2O_3	20.70	22.99
Fe_2O_3	2.84	2.70
FeO	1.19	1.89
MgO	.41	.45
CaO	1.00	2.59
Na_2O	9.94	9.63
K_2O	4.87	4.21
H_2O^{110}	.37	
H_2O^{ign}	5.28	5.73
P_2O_5	.03	
Cl	.06	
	99.62	99.99

I. Analcite tinguaite, San José, Tamaulipas, Mexico. H. S. Washington, anal.
II. Analcite tinguaite, San José, Tamaulipas, Mexico. G. I. Finlay, anal.

The calculation of I results as follows in percentage composition by standard minerals :

Orthoclase	28.9	Acmite	4.2
Albite	25.7	Diopside	4.2
Nephelite	29.0	Magnetite	2.1
Sal	83.6	Fem	10.5

The rock, therefore, belongs to order 6 russare of the persalanes. It is peralkalic miaskase and dosodic miaskose.

Number II gives the following mineral percentages for its norm :

Orthoclase	25.02	Magnetite	3.94
Albite	19.91	Diopside	4.86
Anothite	7.23	Fem	8.80
	52.16		
Nephelite	33.23		
Sal	85.39		

It is tasmanare order 7 of the persalanes. It is peralkalic laugenase and dosodic laugenose.

3. *Camptonite*

(*a*) *San Carlos Type.* — Numerous small dikes of this rock are found in the more basic portions of the nephelite syenite mass. They are often less than an inch in width. To the unaided eye they present the appearance of dense basalt except as being porphyritic by reason of the shining black crystals of hornblende which they contain. The contacts with the enclosing nephelite syenite are very sharp. Even in the smallest dikes near the walls little included pieces of the nephelite rock may at times be found. These dikes are almost always quite fresh, but cavities filled with secondary minerals are met.

Microscopic Description. — Under the microscope this variety of the camptonite appears as a holocrystalline porphyritic rock with marked fluidal arrangement. Hornblende in two generations makes up over four fifths of the whole. Augite is present in phenocrysts, perhaps five per cent. of the total rock. Feldspar in minute areas is packed away in the interstices of the ground-mass. Apatite and magnetite are prominent. The ground-mass shows pronounced flow structure. The grain is much finer near the contact with the enclosing nephelite syenite.

The phenocrysts are chiefly brown basaltic hornblende, with no noticeable effects of alteration. The basal sections of this mineral are sometimes .5 mm. in diameter. They are of the usual six-sided forms and generally give indications of zonal structure. Long prismatic individuals are often dull green at the center with an outer rim of the brown hornblende. In other crystals this order is reversed. The angle of extinction is low, not over 9°. Pleochroism is confined to shades of brown. Twins are common. Apatite and magnetite are the usual included minerals and rims of the latter due to magmatic resorption are sometimes seen. (See Pl. XII, fig. 2.)

Phenocrysts of augite are much rarer. This mineral is violet gray in color and scarcely pleochroic. Its crystal outlines are never perfect for a surrounding rim of serpentinic alteration products is invariably present. The smaller augites of the ground-mass are entirely altered to serpentine. Almost the whole of the ground-mass however is made up of hornblende and interstitial feldspar. Magnetite grains at times .15 mm. across and large perfect crystals of apatite occur sporadically.

The hornblende prisms of the younger generation average .07 mm. in length by .01 mm. in breadth. They show the same colors and pleochroism as do the larger hornblendes. The pieces of feldspar packed in between the hornblendes are very minute, seldom above .02 mm. in length. No twinning could be observed. The feldspar in thin sections is very clear and fresh. Irregular pieces of magnetite, often nearly as large as the augites, are surrounded as the pyroxene is by serpentinic rims. The perfect crystals of apatite .07 mm. across on the basal section are notable for the inclusions which they contain of microscopic hornblendes, zonally arranged.

(*b*) *Casa Grande Type.* — The variety of camptonite here described is met in a three-foot dike on the road leading to San Carlos just as one leaves San José.

Microscopic Characters. — Seen in the hand specimen the rock is black and very fine-grained. Only a few shining prisms may be made out in the dense aphanitic ground-mass.

Microscopic Appearance. — Under the microscope the rock shows a holocrystalline porphyritic texture. The phenocrysts are of hornblende and augite, embedded in a ground-mass made up of little feldspars, hornblende, augite, magnetite and apatite. Calcite and analcite are secondary products.

The augites of the older generation are by far the most abundant phenocrysts. Eight-sided sections are developed, with very perfect crystal boundaries, which are defined by the usual faces *m*(110), *a*(100) and *b*(010). The pyroxene prisms are usually half as broad as they are long. They take all possible orientations. The color varies considerably. Violet gray prevails but light shades of green are often observed. Some crystals are nearly colorless. The mineral is pleochroic between gray and shades of green. A zonal structure is usually developed with green or violet cores, and a colorless outer shell. Inclusions of apatite and magnetite are in linear arrangement parallel with the crystallographic faces. An exterior shell of magnetite grains has often been added by magmatic resorption, or where no secondary magnetite has formed the crystal edges are usually frayed out. The extinction angle is nearly 45°.

Intergrowths with hornblende have been observed but they are rare. Sections approximately parallel with (001) show the emergence of an optic axis at one side of the field.

Phenocrysts of hornblende are associated with the porphyritic crystals of augite. This mineral is in eight-sided sections, .9 mm. by .6 mm., which have *m*(110), *b*(010) and *a*(100), in the prism zone, very sharply developed. The pleochroism is strong, $\mathfrak{a}$ = pale yellowish-brown, $\mathfrak{b}$ = deep earthy brown, $\mathfrak{c}$ = light brown. The crystals are often composed of two or more shells of varying chemical composition, the inner core being the darker. The whole individual may be surrounded by a thin rim of grains of magnetite, although embayments resulting from magmatic resorption are rare. The extinction angle is low, 4°. Alteration at the center of the larger crystals leads to the formation of calcite.

Both the above minerals occur in a second generation in the ground-mass. The hornblende is in long and very narrow clear brown blades which fray out at the ends. They are noticeably fibrous. Their extinction angle is low. They attain a maximum size of .7 mm. by .03 mm. but usually they are but half as large. They make up about 10 per cent. of the rock. Augite occurs in the ground-mass in rough grains and stubby prisms .2 mm. by .05 mm., gray or nearly colorless. It is perhaps twice as abundant in the ground-mass as is the hornblende. Much magnetite is associated with it and square sections of this mineral are very common. Needles of apatite which are large and perfect are found near the augite.

The feldspar of the ground-mass is commonly xenomorphic. It seems to have been the last mineral to crystallize out of the magma. Occasionally well-defined minute plagioclase individuals are found which are evidently secondary. Their extinction angle is uniformly one or two degrees, indicating oligoclase.

Alteration products are very common in this rock. Calcite is everywhere disseminated through it in granular masses. The zeolitic minerals have frequently formed in small cavities, and at the center analcite is generally found. In this rock the mineral is colorless, with very few cleavage cracks. It is completely isotropic. It clouds over when the section is heated to redness, and gelatinizes with acid.

An analysis of the above rock gave the following percentages :

SiO_2	42.49
Al_2O_3	17.68
Fe_2O_3	5.12
FeO	5.90
MgO	5.28
CaO	15.81
Na_2O	4.29
K_2O	2.97
H_2O	.38
	99.92

The calculated norm of the rock is given below.

Anorthite	20.02
Leucite	13.95
Nephelite	19.60
Diopside	14.84
Olivine	9.14
Ackermanite	14.55
Magnetite	7.42
	99.52

It belongs with order 8 of class III and falls in rang 3 and in grad 4, covose.

(*c*) *Rincon Type.* — The variety of the camptonite here described occurs in narrow dikes at various points to the east and southeast of San José.

Macroscopic Appearance. — In texture this rock is holocrystalline porphyritic with phenocrysts of plagioclase in a groundmass consisting of feldspar, augite, hornblende and magnetite. Chlorite, muscovite, calcite and epidote are the common alteration products. The plagioclase is in large complex individuals twinned polysynthetically with many fine lamellæ, the crystals being often 1 mm. on either dimension. They afford favorable cases for the estimation of the basicity when a section cut at a right angle to the albite lamellæ may be shown to represent the two halves of a carlsbad twin as well. Such readings indicate anorthite, and the extinction angles on many albite lamellæ are high enough to give confirmation to this determination. The phenocrysts of plagioclase often show an inner core surrounded by a rim which has a different orientation optically, or, more rarely, zonal structure, consisting of many shells, is observed. Colorless mica, in patches 1 mm. long has resulted where the feldspar is weathered, and with it more or less chlorite is associated as having come from the same source.

The small lath-shaped plagioclases in the ground-mass, which are fresh and glassy, have low extinction angles, near 10°. They are therefore much more acid than the feldspars of the first generation. They are often twinned in three or four fine lamellæ. They are automorphic and by their distribution they cause the rock, at times, to approximate the diabasic texture. Altogether plagioclase makes up about 50 per cent. of the whole.

The augite, which was once the most abundant dark silicate throughout the ground-mass, is now nearly all changed over to chlorite. This mineral is faintly pleochroic from yellowish-green to green, and shows but slight effects of double refraction.

The hornblende of the ground-mass has a rich brown color. It occurs as xenomorphic grains and patches which have a low extinction angle. The interference colors are high. The pleochroism is inconsiderable, various shades of brown prevailing. Square pieces and irregular grains of magnetite make up about 5 per cent. of the rock. Calcite is very generally present as an alteration product. Minute needles which give high interference colors are epidote.

4. *Vogesite*

The rock to be described under this name occurs as a four and a half foot dike in the andesite along Bretaña Creek. It is aphanitic and almost black. It carries no phenocrysts discernible to the unaided eye.

Microscopic Characters. — Under the microscope it is found to be holocrystalline and to contain hornblende, augite and orthoclase, with magnetite, some plagioclase and titanite and minute foils of biotite. There are no well-marked porphyritic developments. The orthoclase, which was the last mineral to take crystalline form, encloses all the other constituents. It is without good crystallographic boundaries. Carlsbad twins may occasionally be noted.

The augite crystals are light buff-colored, xenomorphic, .25 mm. in length by .1 mm. in width, and not pleochroic.

The extinction angle is large, nearly 45°. Zonal structures are developed. The pyroxenes are often surrounded by prisms of monoclinic amphibole.

The hornblende makes up by far the largest portion of the rock. The individuals of the mineral are in fibrous blades poorly defined by crystal faces in the prism zone. They attain a maximum extension of .4 mm. and are eight or nine times as long as they are broad. Their color is dull green. By pleochroism changes to dull brown are produced. The cores of the hornblende crystals are at times different in composition from the outer rims. Twins are rare. Extinction 20°.

Some plagioclase, evidently of secondary origin, occurs as minute patches in the orthoclase ground. Biotite foils .1 mm. or less in diameter are now and again associated with the clusters of hornblende crystals. Titanite is disseminated through the rock in microscopic lozenge-shaped individuals. The larger magnetite grains may be surrounded by rims of this mineral.

5. *Limburgite*

The rock to be described under this name is found in a dike on the western flanks of the San Carlos Mountains five miles south from San José. The hand specimen shows it to be a lusterless black aphanitic rock.

Microscopic Characters. — Under the microscope a well-developed porphyritic texture with a fine-grained holocrystalline ground-mass is at once apparent. The phenocrysts are augite and olivine. Hornblende, augite and plagioclase make up the ground-mass.

The augite phenocrysts as a rule are sharply bounded individuals which attain a length of .6 mm. or less. Their color is violet gray and they are slightly pleochroic. A zonal structure with many concentric shells may usually be noted, and with this the hour-glass structure is developed. Inclusions of magnetite grains are arranged zonally. At times there is evidence of magmatic resorption, and around the main crystal a rim of secondary augite is developed. Again the center is corroded while the outer zone is clear. Twins may often be noted with (100) as the composition face. The twinning is occasionally repeated in the same individual.

Olivine is the only other phenocryst. (See Pl. XIII, fig. 1.) Several crystals of this mineral often grow together. They almost always show corroded outlines. The inclusions are augite and magnetite.

The chief mineral of the ground-mass is a pale brown hornblende in short stubby prisms of microscopic proportions .05 mm. by .02 mm. These are slightly pleochroic. The basal sections are eight-sided by the development of the prism and pinacoid.

The many small augites of a younger generation are by no means so numerous. They may be easily distinguished from the hornblendes by their buff color. Interstitial feldspar is found all through the ground-mass in pieces which are too small to give a clue as to their characteristics. Grains of magnetite are everywhere present and secondary analcite should be noted.

Table I

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	58.40	42.49	62.31	45.75	48.03	48.49	52.83	49.42
TiO_2	.25						.16	
Al_2O_3	20.25	17.68	18.63	18.51	20.98	18.99	20.70	22.99
Fe_2O_3	1.78	5.12	2.38	6.55	7.06	9.59	2.84	2.70
FeO	2.41	5.90	1.33	6.02	4.51	1.00	1.89	1.89
MgO	.49	5.28	.60	5.06	4.43	5.05	.41	.45
CaO	3.11	15.81	5.91?	11.85	9.54	10.78	1.00	2.59
Na_2O	7.01	4.29	4.97	3.41	3.28	3.47	9.94	9.63
K_2O	5.39	2.97	3.52	2.35	1.99	1.42	4 87	4.21
P_2O_5	.20		.07	tr.			.03	
H_2O^{110}	.27	.38	.16	.06	.21	.10	.37	.38
H_2O^{ign}	.57		.07	.20	.40	.55	5.28	5.73
	100.13	99.92	99.95	99.76	100.49	99.44	99.62	99.99

I. Nepheline syenite. H. S. Washington, analyst.
II. Camptonite. G. I. Finlay, analyst.
III. Andesite. G. I. Finlay, analyst.
IV. Diorite. G. I. Finlay, analyst.
V. Basalt. G. I. Finlay, analyst.
VI. Diorite. Diobasic facies. G. I. Finlay, analyst.
VII. Analcite tinguaite. H. S. Washington, analyst.
VIII. Analcite tinguaite. G. I. Finlay, analyst.

TABLE II

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	.973	.708	1.038	.762	.800	.808	.880	.823
Al_2O_3	.198	.173	.182	.181	.206	.186	.203	.226
Fe_2O_3	.011	.032	.015	.040	.044	.060	.018	.017
Fe_2O	.033	.082	.018	.083	.062	.014	.017	.027
MgO	.012	.132	.015	.126	.110	.126	.010	.011
CaO	.056	.282	.105	.211	.170	.193	.018	.047
Na_2O	.113	.069	.080	.055	.053	.056	.160	.155
K_2O	.057	.032	.037	.024	.021	.015	.052	.045

TABLE III

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
$\frac{Na_2O}{K_2O}$	1.98	2.15	2.16	2.29	2.52	3.73	.307	3.44
$\frac{FeO}{Fe_2O_3}$	3.00	2.56	*1.20*	2.07	1.40	.233	.944	1.58
$\frac{Na_2O+K_2O}{SiO_2}$	.174	.142	.112	.103	.092	.087	.240	.243
$\frac{Na_2O}{SiO_2}$	.116	.097	.077	.072	.066	.069	.181	.183

VII. CHEMICAL RELATIONS OF THE SAN JOSÉ ROCKS

In Table I, page 292, are given the results of the eight analyses which have been made of the San José rocks. The percentage composition by weight is indicated here for each oxide. In Table II the molecular amounts of the oxides have been obtained by dividing the percentage composition for each constituent by the corresponding molecular weights. In Table III the ratios for certain of the oxides when compared with other constituents in terms of their molecular amounts in every case, are stated.

It will be noted, when the analyses which embrace nearly all the rock-types of the district are examined, that the range in silica between the most acid member, andesite, and the most basic, camptonite, is not large. The nephelite syenite is more acid than is usual with such rocks, and the tinguaites are more basic. The type andesite is also poorer in silica than the average of many andesites. Alumina is high in every analysis.

Fe_2O_3 and FeO vary between wide ranges. The rocks are all comparatively high in lime, some of them, as the diorite and camptonite, abnormally so. They are high in the alkalies, and in every one soda is two or three times as great as potash.

High soda and alumina, with low silica, makes necessary the formation of orthoclase and nephelite, with ægirite in the tinguaites, and light green soda augite in the nephelite syenites. Here also the dark brown hornblende, rich in iron, which appears in the more basic varieties, is edged with green by relative increase in the amount of soda present in the later stages of crystallization from the rock magma. Magnesia is very low in the nephelite syenites and tinguaites. Biotite is almost entirely lacking in these rocks. It only enters into the most basic of the nephelite syenites. The mineral is, however, present in the diorites where MgO is relatively high.

The character of the augite in all the rocks of the district is very uniform. It is a light green variety, poor in iron and magnesia and rich in soda. Its appearance and optical properties are much the same in the normal nephelite syenite, in the andesite, in the diorite, and even in the camptonites.

As stated above, the rocks of the San José district, so far as the proofs are at hand, fall into three divisions, from the earliest to the most recent.

1. Nephelite syenite and diorite.
2. Andesite and dacite.
3. Basalt, tinguaite, camptonite, vogesite and limburgite.

There are represented effusive and deep-seated rocks which vary widely in chemical composition. The analyses, however, when placed side by side in the order in which they have been printed are seen to follow in a definite sequence. They are not in a "series," according to Brögger's use of the term. They are related after the manner of his "faciessuite." The tinguaites when examined with the others are found to present striking differences toward them. It is possible that they are part of a tinguaite "series." The ratios between the sum of the alkalies and silica, and between soda and silica are nearly the same in the two tinguaites, but the alkalies function together in both, as do also the ferrous and ferric molecules, and in the same sense.

The ratios for all the other rocks of the region, so far as analyses are available, are found to vary in a definite manner. They tend to fix themselves as multiplies of $\frac{1}{4}$ for $\frac{Na_2O}{K_2O}$ and $\frac{FeO}{Fe_2O_3}$, and the variation is never more than .10, nor usually so large. $\frac{Na_2O}{K_2O}$ is constantly on the increase from left to right, between 1.98 and 3.73. $\frac{FeO}{Fe_2O_3}$ varies in the opposite sense, constantly decreasing, excepting in III, where 1.20 is a great deal too low. $\frac{Na_2O + K_2O}{SiO_2}$ is at the same time decreasing from left to right as is also $\frac{Na_2O}{SiO_2}$.

For the San José district, soda increases at the expense of potash, as silica decreases with reference to the combined alkalies and to soda alone. At the same time ferric iron is gaining over ferrous iron.

PLATE VIII.

PLATE VIII.

Scale: 2 inches = 1 mile.
3 cm. = 1 kilometer.

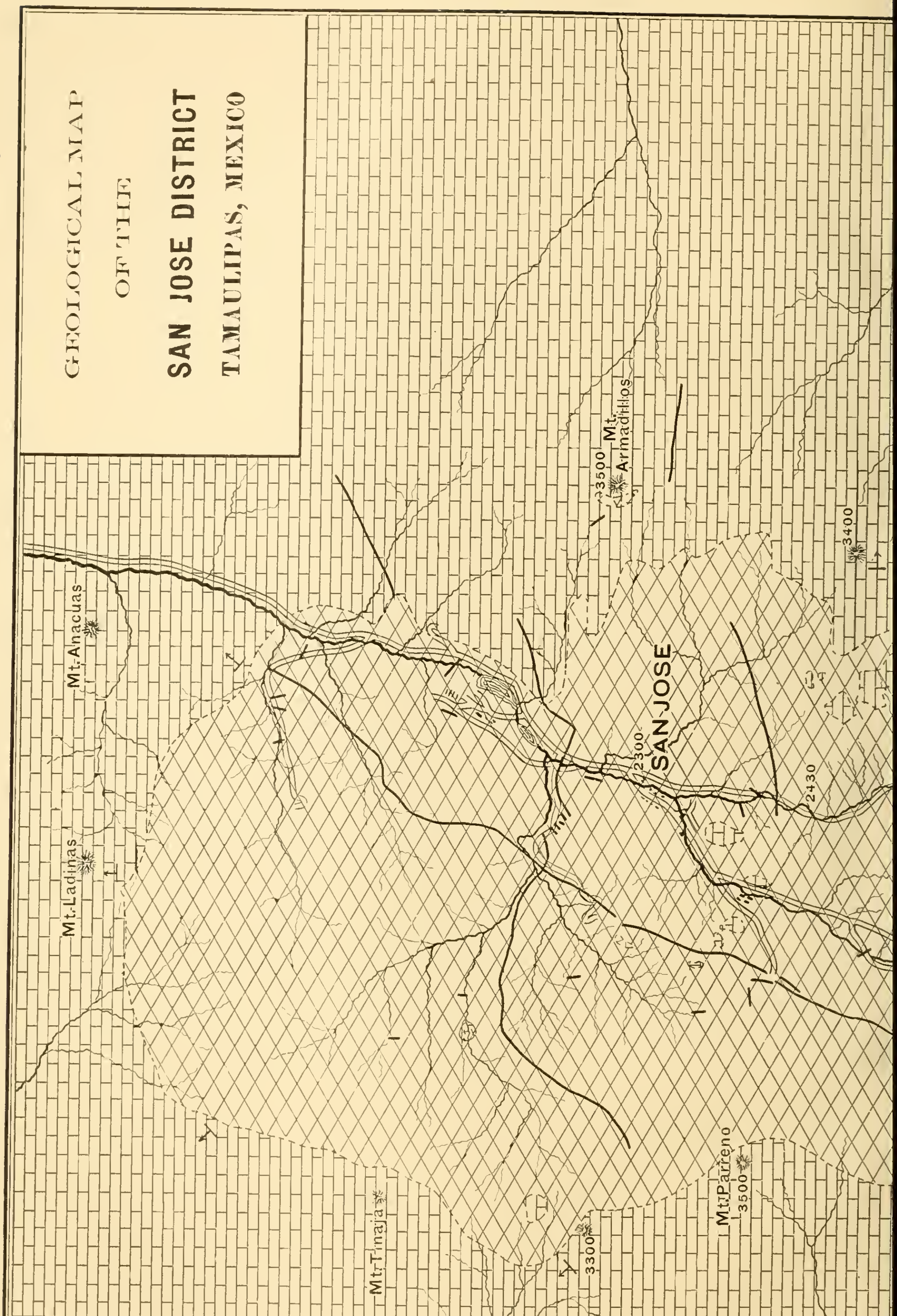
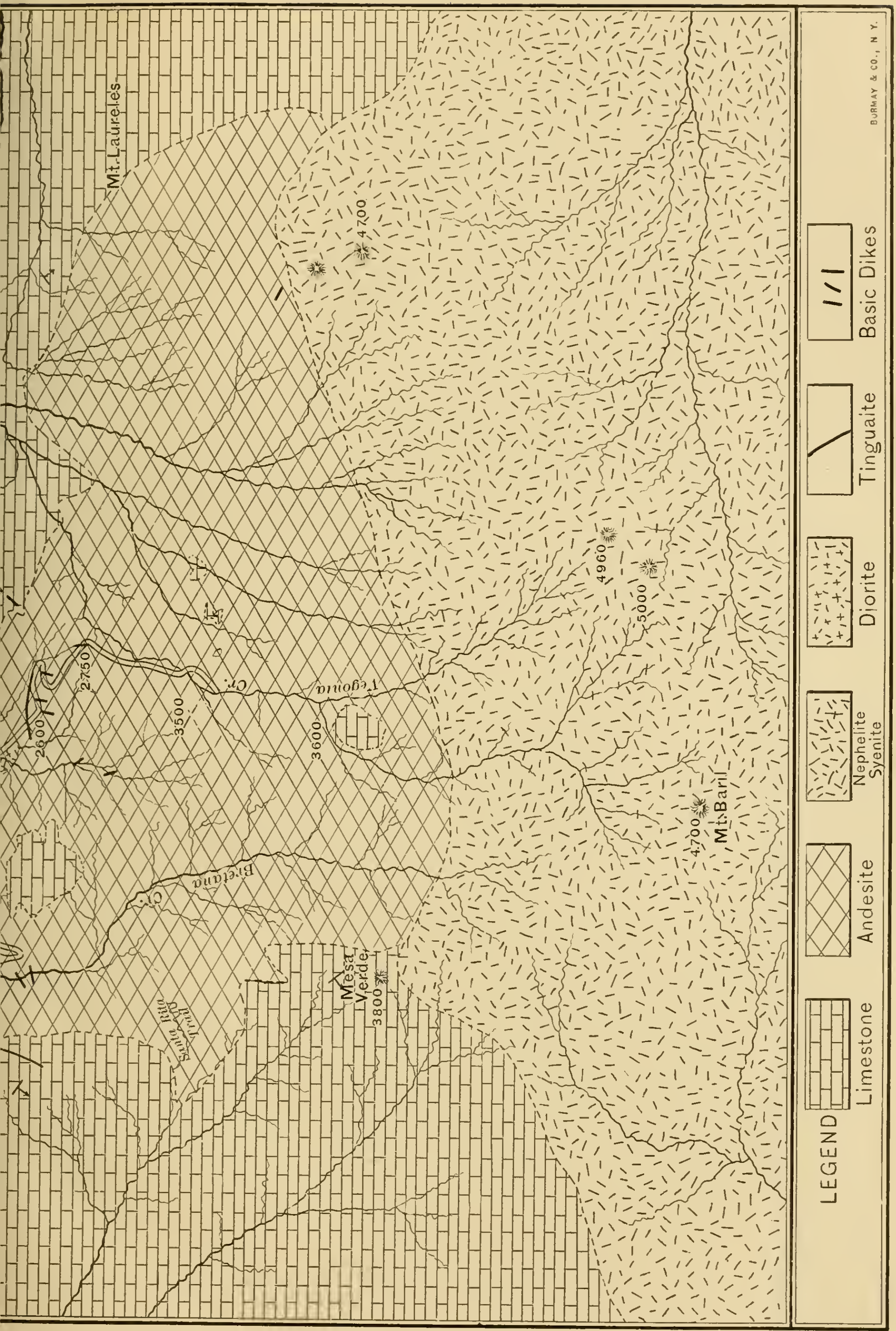

GEOLOGICAL MAP
OF THE
SAN JOSE DISTRICT
TAMAULIPAS, MEXICO
Mt. Armadillos
3500
3400
Mt. Anacuas
SAN JOSE
2300
2430
Mt. Ladinas
Mt. Parreno
3500
Mt. Tinaja
3300

Plate VIII.


Mt. Laureles
4700
4960
5000
Mt. Baril
4700
Tegonia Cr.
Bretana Cr.
2750
3500
3600
2600
Mesa Verde
3800
LEGEND
Limestone
Andesite
Nephelite Syenite
Diorite
Tinguaite
Basic Dikes
BURMAY & CO., N. Y.

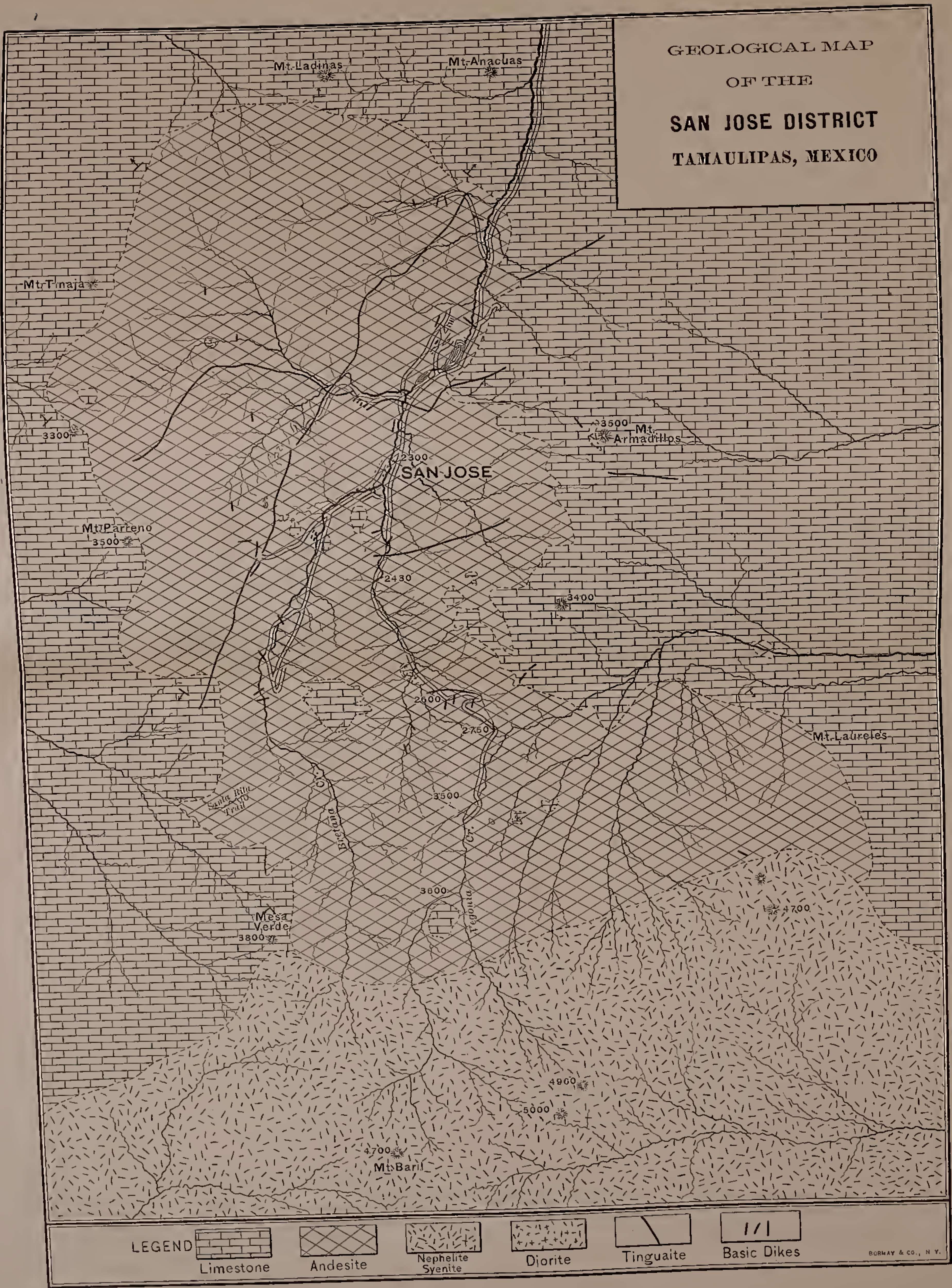

GEOLOGICAL MAP
OF THE
SAN JOSE DISTRICT
TAMAULIPAS, MEXICO
Mt. Ladinas
Mt. Anacuas
Mt. Tinaja
3300
3500 Mt. Armadillos
2300
SAN JOSE
Mt. Parteno
3500
2430
3400
2600
2750
Mt. Laureles
3500
Santa Rita Trail
Cr.
Borrego
Cr.
Tegoma
3600
4700
Mesa Verde
3800
4900
5000
4700
Mt. Baril
LEGEND
Limestone
Andesite
Nephelite Syenite
Diorite
Tinguaite
Basic Dikes
BURMAY & CO., N. Y.

PLATE VIII.

PLATE IX.

PLATE IX.

Fig. 1. Nephelite Syenite. Ordinary Light. × 33. The larger grain of magnetite is surrounded by clear, crystalline nephelite, and by augite. Kaolinized orthoclase appears in the upper part of the figure.

Fig. 2. Syenitic Dike Rock. Ordinary Light. × 33. The dark mineral is green fibrous hornblende. The colorless portions in the figure are orthoclase.

FIG. 1.

FIG. 2.

PLATE X.

PLATE X.

Fig. 1. Nephelite Syenite. Crossed Nicols. $\times 33$. The lozenge-shaped crystal is titanite. The grayish mineral below it is nephelite. Orthoclase appears in the dark and light areas above.

Fig. 2. Tinguaite. Crossed Nicols. $\times 33$. The ground-mass consists of ægirite needles and irregular pieces of feldspar. The porphyritic crystal is orthoclase.

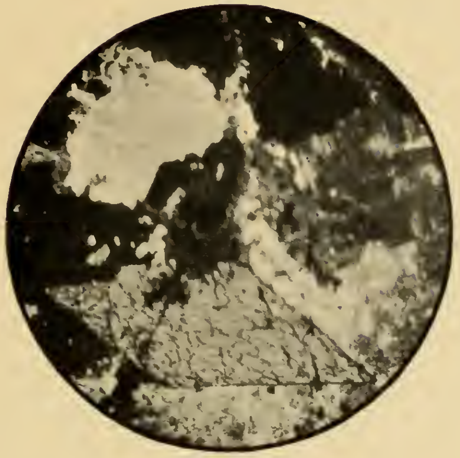


FIG. 1.

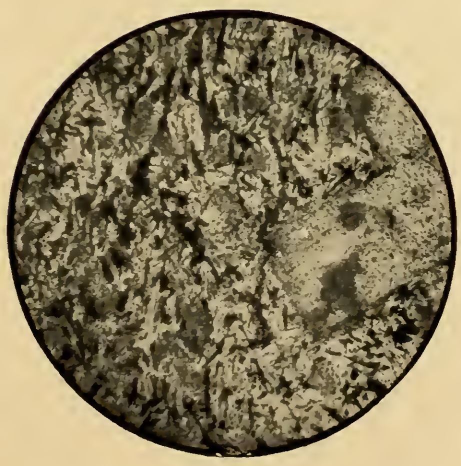


FIG. 2.

PLATE XI.

PLATE XI.

Fig. 1. Tinguaite. Crossed Nicols. × 33. Crystal of nephelite in ground-mass of ægirite and feldspar.

Fig. 2. Tinguaite. Crossed Nicols. × 33. The phenocryst is of weathered and corroded feldspar. The replacement by secondary minerals, beginning at the periphery of the crystal, is first by a zone of feldspar rods, and intergrown pyroxene needles. The dark zone is of analcite. The colorless central portion is orthoclase.

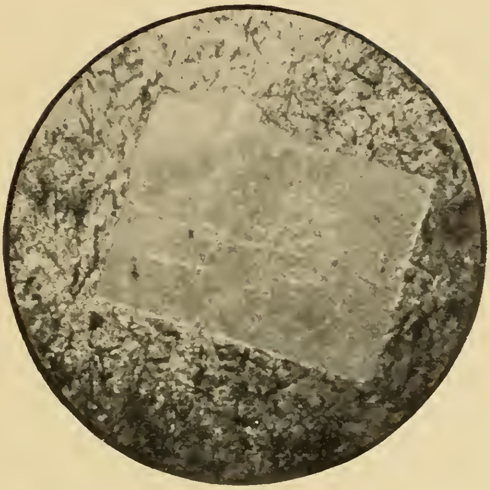


Fig. 1.

Fig. 2.

PLATE XII.

PLATE XII.

Fig. 1. Andesite. Crossed Nicols. × 33. Crystals of plagioclase feldspar in a crystalline ground-mass of feldspar and magnetic grains.

Fig. 2. Diorite in ordinary light. × 33. The colorless mineral is plagioclase. Augite appears above in contact with a large mass of magnetite, below bordering on a crystal of biotite.

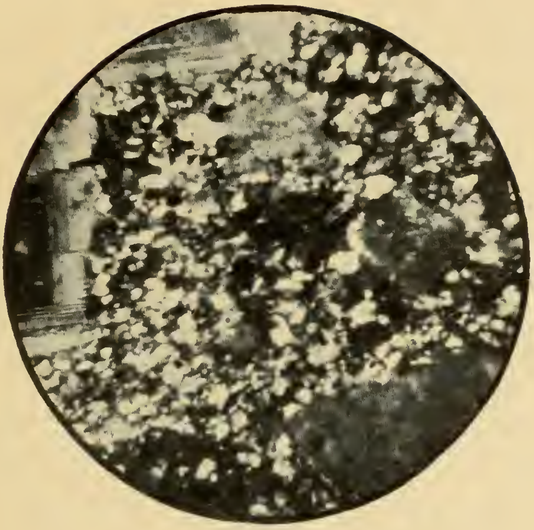


FIG. 1.

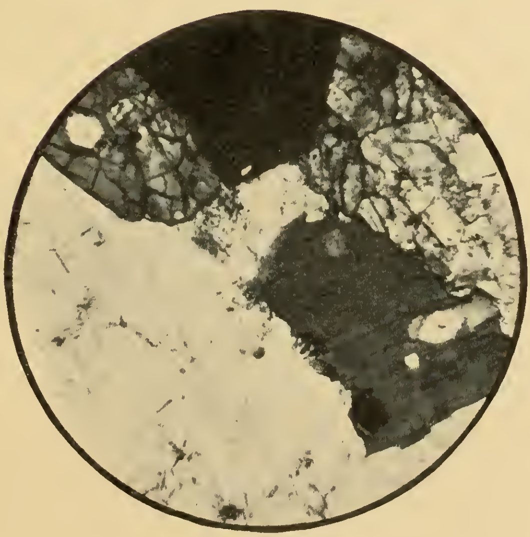


FIG. 2.

PLATE XIII.

PLATE XIII.

Fig. 1. Limburgite Dike. Ordinary Light. × 33. Crystals of colorless olivine in a ground-mass of augite, magnetite grains and brown glass.

Fig. 2. Camptonite. Ordinary Light. × 33. A phenocryst of augite appears in the lower left hand corner. The ground-mass is made up of hornblende prisms, irregular feldspar crystals (plagioclase) and grains of magnetite.

FIG. 1.

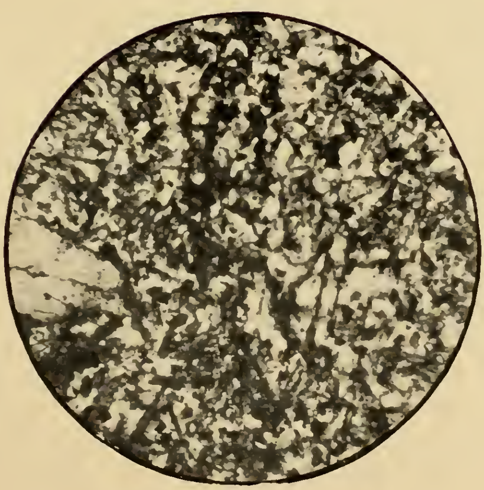


FIG. 2.

PLATE XIV.

PLATE XIV.

Piedra Iman, south of San José, at the Santa Helena mine. The mass in the center is of limestone included in the andesite. Mt. Armadillos on the left.

PLATE XV.

PLATE XV.

View from the west, looking across the San José valley toward Mt. Anacuas (left) and Mt. Armadillos (right). Limestone nearly horizontal capping andesite.

PLATE XVI.

PLATE XVI.

The San Carlos Mountains, (nephelite syenite), as seen from the Baril range, looking south across the Arroyo Grande.

PLATE XVII.

PLATE XVII.

View looking southeast across the valley of the Arroyo Grande toward the town of San Carlos. The mountain slopes on both sides of the valley are of nephelite syenite.

PLATE XVIII.

PLATE XVIII.

The Pic de Diablo from the head of Bocca de Alemos canyon. Nephelite syenite.

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