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MORPHOLOGICAL NOTES.

The Tenth Session of the Chesapeake Zoölogical Laboratory was held under the direction of Dr. W. K. Brooks, Associate Professor of Morphology, on the Island of New Providence, about three miles from the town of Nassau, from March 1 to July 1, and it was occupied for a month longer by several members of the party. This consisted in all of twelve persons, eight of whom were advanced investigators, while four were younger men who pursued more elementary studies.

A statement of the work of the session is made in the Report of Dr. Brooks, accompanying the Twelfth Annual Report of the President of the University.

Preliminary communications as to some of the scientific results of the season's work are published herewith.

Statements are also given of the results of some recent researches in the Biological and Pathological Laboratories.

On a New Method of Multiplication in Hydroids. By W. K. BROOKS.

(*Preliminary Abstract.*)

When animals which pass through a metamorphosis also multiply asexually at any stage in their life-history, the new organisms which are thus produced do not repeat, in their own life-history, the stages which the parent organism has already passed. If the life-history of the species from the egg to the adult consists of a series of larval stages *A*, *B*, *C*, *D*, *E*, and if after the larva has reached the stage *C* it multiplies asexually, the asexual progeny do not pass through the stages *A* and *B*. In most cases they begin their life with the stage *C*, and repeat in their own ontogeny only so much of the life-history as still lies before the parent, that is, the stages *C*, *D*, and *E*. In other cases they outstrip the parent, and pass at once to a more advanced stage, *D*, or *E*.

The hydroids which are produced by budding from the stems or roots or hydroids of an ordinary hydroid community, and the medusae which, in many cases, bud from the bodies of other medusae are familiar examples of the first method of development in which the new organism starts its existence at that stage in the life-history of the species which the parent, at the time, exhibits; while the medusae which are budded off and set free from the bodies of the ordinary hydranths, as in Bouganvilleia, or from the bodies of specialized hydranths or blastostyles, as in Eucope, are examples of the second method of asexual reproduction, in which the new organism passes at once to a more advanced stage of the life-history than that which characterizes the parent.

Hydroids which bud off other hydroids, hydroids which bud medusae, and medusae which bud medusae are familiar to all naturalists, but so far as I am aware no one has ever recorded the occurrence of buds which recapitulate in their own ontogenetic development, like egg embryos, larval stages which the parent has already passed.

In fact the rule that bud-embryos do not thus recapitulate the life-history of a species is so general that it has been regarded as a universal and necessary result of the process of specialization which the cells of the body undergo during their development, and in virtue of which they gradually lose the power to give rise by ordinary cell multiplication to less specialized cells. As the organism gradually develops from the egg to the adult condition, its constituent cells and tissues are believed to gradually lose their generalized or embryonic character, and to become incapable of producing embryonic cells. If, therefore, when specialization is somewhat advanced the tissues of the larva shape themselves into a bud, this bud, and the organism to which it gives rise, must share this specialization, and must from the first partake of the characteristics of the parent larva, or else of characteristics to which advancing specialization tends to lead the parent larva. If asexual reproduction takes place after the adult form has been assumed, the tissues of the new bud, being also adult, will not recapitulate passed larval stages, and the phylogenetic history of the species is recapitulated in full in the ontogeny of no embryo, except those which are sexually developed from germ cells which have undergone no specialization but have been set apart for reproduction while still embryonic.

While this is a general rule, which prevails very widely throughout the animal kingdom, the life-history of an undescribed species of Oceania which I found in the seasons of 1886 and 1887 at the Bahama Islands, shows that the rule is not absolute and necessary.

The hydroid larva of this medusa is a small campanularian which is common upon the floating algae in the harbors of Nassau and Green Turtle Key. The hydranths are carried in toothed cups, at the tips of slender erect, unbranched stems, which are annulated at the bottoms of the cups, by one or two rings. The blastostyles spring from the root, inclosed in annulated, nearly sessile, gonothecae, and produce a series of medusa-buds which mature and escape in succession from the distal end. Each blastostyle usually carries four buds; the proximal one a simple papilla, and the distal one nearly or quite ready to escape.

Soon after it is set free the medusa has a shallow bell, about $\frac{1}{25}$ inch in diameter, and somewhat less than half as high, of nearly uniform thickness; four radial and four inter-radial tentacles capable of extension to eight or ten times the diameter of the bell; an otocyst on each side of the base of each inter-radial tentacle, and four rudimentary reproductive organs, one food-yolk, and the digestive canal is thus completed (Fig. III). During the whole of this process the "yolk-membrane" remains passive, though engaged in the digestion and absorption of food-yolk. The digestive glands, "Liver," are seen as arising from diverticula, from the prolongation of the proctodeal cavity, as the salivary glands arise as diverticula at the beginning of the stomodeum. In other words, owing to the large amount of food-yolk to be digested, other morphological structures are completed before the absorption of food-yolk has taken place, and the share the "yolk-membrane" would otherwise contribute is diverted from its ordinary destination. The alimentary canal of the adult consists then of fore-gut and hind-gut only, and the "yolk-membrane," which is morphologically a mid-gut, is left out. Hypoblast in Cephalopods then, is to be looked upon as a temporary, embryonic structure, which has no chance to form any definite structure and leave the traces of its existence in the organization of the adult.

Thus, although the "yolk-membrane" does not contribute any share in the formation of the digestive tract, this fact does not seem to interfere with the view that it is the true hypoblast.

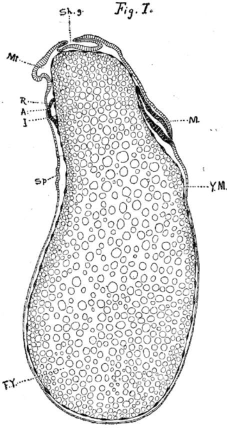
Explanation of the Figures.

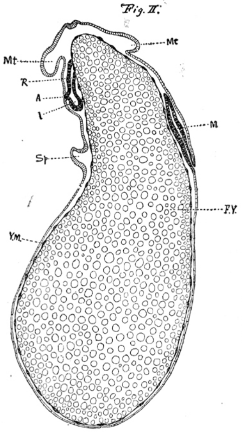
Fig. I. The median longitudinal section of the Squid embryo, in which the stomodial and proctodial invaginations have commenced to take place.

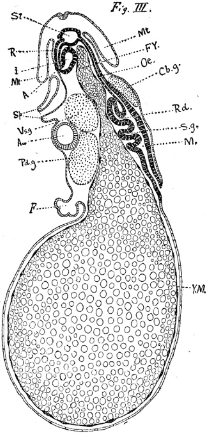
Fig. II. The same, in a more advanced stage.

Fig. III. The same, in a still further advanced stage. The fore- and hind-gut have met at the apex of the food-yolk mass, completing the whole digestive tract.

A.,	Anus.	Pd. g.,	Pedal ganglia.
Au.,	Auditory sac.	R.,	Rectum.
Cb. g.,	Cerebral ganglia.	Rd..	Radula sac.
F.,	Foot.	S. g.,	Salivary gland.
F. Y.,	Food-yolk.	Sp.,	Siphon.
I.,	Ink-bag.	St.,	Stomach.
M.,	Mouth.	Vs. g.,	Viscual ganglia.
Mt.,	Mantel.	Y. M.,	"Yolk-membrane" (Hypoblast).
Oe.,	Oesophagus.		







The Abbreviated Metamorphosis of Alpheus, and its Relation to the Conditions of Life. By F. H. Herrick.

The abbreviated development of certain species of Alpheus is the most interesting phenomenon which the study of their life-histories has brought to light. The majority of this genus (as *A. minus* and several undescribed forms which have been studied) hatch as ordinary macrouran zoëas, with three pairs of maxillipeds, which function as swimming organs, and with the thoracic feet, usually two pairs, represented by biramous and simple buds. In *A. heterochelis* however the metamorphosis, as first observed by Packard, but first accurately described by Brooks, is considerably abbreviated. Furthermore in a Bahaman species, which is parasitic in sponges, there is practically no metamorphosis, or at any rate no larval life of importance, inasmuch as the animal acquires all its adult characters in twenty-four hours after hatching. As this form has never been described, so far as can be learned, the specific name of *Praecox* is given to it in allusion to this interesting fact.

Alpheus heterochelis according to Brooks (*Univ. Circ.*, No. 17, 1882) hatches with the usual swimming organs, but with all five pairs of thoracic legs present as rudimentary biramous buds. The abdominal segments are formed, and the buds of the first five pairs of feet belonging to them. The eyes are not covered by the carapace. At the first moult the rudiments of the sixth pair of abdominal feet only are added, but with the second moult the larva becomes a true schizopod. All the appendages are now functional and the eyes are nearly hooded. Upon the third moult the fourth zoëa assumes adult form, but the marked difference of the great claws appears only after several months.

In *Alpheus praecox sp. nov.* (from either brown or green sponges) the embryo hatches as a schizopod loosely enfolded in a larval or zoëal skin. This is immediately shed, being evidently due to a moult begun within the egg, where I believe it is sometimes completed, so that the animal practically hatches in the form called the second zoëa in the following account. The first larva is about $\frac{1}{14}$ of an inch long. All but the last pair of walking legs have long exopodites, tipped with short hairs, only those of the maxillipeds being perfectly functional for swimming. The large claws belonging to the first pair of thoracic feet are already conspicuous, and were so even within the egg. The second pair are not chelate, or only imperfectly so.

The eyes are not as yet covered over by the carapace. Both pairs of antennae are biramous and jointed. The outer flagellum of the first pair has already developed sensory hairs, and equals or slightly exceeds the length of the jointed endopodite. The second antennae bear a well-developed scale, which is half as long as the stout multi-articulate flagellum. The maxillae and maxillipeds have more or less of their adult character. The latter are all biramous, and as stated above, their exopodites are the swimming organs. The abdomen is well-developed, with all its appendages present, which are biramous and tipped with rudimentary hairs. The larval telson is an inversely heart-shaped plate, carrying seven pairs of plumose hairs which belong to the zoëal tail, already degenerate and partially separated from the true telson at the time of hatching. The sixth pair of abdominal limbs, seen under the larval skin, are well advanced. There is a median pigment spot, possibly an ocellus, between the eyes and the bases of the first pair of antennae. Rudimentary gills are present, and the food-yolk is reduced to a small remnant in the stomach. The rostrum is three pointed, the two lateral spines being insignificant. The animal is transparent and colorless, excepting the large characteristic spots of vermilion and yellow pigment on the abdomen and appendages.

In a collection of adult Alpheus of either sex of the same or of several species, where there is a difference in size of the large claws, it is noteworthy that either the right or the left, indifferently, may be the greater. As we have seen, this differentiation of the chelae begins in one instance before the animal is hatched. Is this right and left-handedness to be explained by inheritance from the parents? In about forty zoëas of a small brood of *Alpheus praecox*, all invariably had the *left* claw enlarged, and in a smaller number (all that were preserved) from another female of the same species, the left chela was also in each case the larger. This would indicate that the young of the same mother have always the same claw, either right or left, the greater, and that this phenomenon is one of direct heredity from the parents. But to prove this it is only necessary to trace right and left-handed broods to parents, which are themselves right and left-handed respectively. This, unfortunately, I have not done, as my attention was not called to the subject while at the seashore.

After the first moult, which as already stated takes place very soon after hatching, the second zoëa has more decidedly schizopod characters. The exopodites of the first four pairs of thoracic feet have developed long swimming hairs like those of the maxillipeds, and the telson and the appendages of the sixth abdominal segment have their adult character. The flagella of the antennae are twice their former size, the second pair equalling the carapace in length. The fifth thoracic segment is partially uncovered, and the eyes are still naked.

About twenty-four hours after hatching the larva passes through a second moult, and appears with all the characteristics (excepting alone color) of the adult form, even to its pugnacious habits. Although this animal is now only about $\frac{1}{10}$ of an inch long, yet it snaps quite audibly the fingers of its large claws. The carapace at this stage covers all the thoracic segments, and has grown forward so as to form a hood over each eye. The ocular spines, traces of which appear even at the time of hatching, are well marked, so that when viewed from above the larva shows a three-spined front, which is later produced considerably beyond the eyes in a form characteristic of this species. The food-yolk is practically absorbed. The gills are functional, and possibly were so before this stage. The exopodites of the first four pairs of ambulatory feet lose their swimming hairs, become rudimentary, and shortly disappear. The animal swims like an adult, chiefly by the aid of its abdominal feet. Moults now occur at short intervals, but these alter only the size of the animal. If we compare the history of this species with that of *Alpheus heterochelis* quoted above, we find that the first zoëa of the former is potentially equal to the third zoëa of the latter.

In the genus Alpheus we thus have two stages in the abbreviation of metamorphosis between the typical macrouran zoëa and the adult form. What is the cause of this gradual suppression of the zoëa? The conclusion seems to be unavoidable that in the Bahaman species at least this shortened life of the larva is directly due to the conditions of life. As the adults of the species in question became more and more dependent upon a semi-parasitic mode of life, it would be clearly beneficial to reduce the larval period, in order that the young might be hatched fitted to live in an environment similar to that of the adults. If the zoëa brood were swept out to sea by the tides, and were to spend several weeks in the larval condition at the surface of the ocean, the chances for large numbers to find particular sponges along the shores, when the adult state was reached, would be greatly lessened. It is likely that the larvae of this Alpheus are never carried far from the shores, but while they undoubtedly leave the sponge in which they are born, they probably establish themselves very soon in a new one.

It is interesting to learn that *Alpheus heterochelis* is found in the exhalent orifices of sponges at Key West, Florida (*v.* Packard, *Am. Nat.*, Vol. 15, 1881), where *A. minus* also occurs with it. No fewer than three species of macroura, together with the Alpheus above described, occur in the large brown sponges of the Bahama Islands. But these three (one of which is also an Alpheus) live in the larger oscula, are less regular in their occurrence, and evidently have not adopted a stationary, parasitic life. In none of them is the metamorphosis of the larva abbreviated.

S. J. Smith (*Am. Jour. Sci.*, Ser. 3, Vol. 28) thinks that many deep sea crustacea, living at a depth of from 500 to 3,000 fathoms, undergo an abbreviated metamorphosis which their habits of life would seem to require. This is further indicated by the great size of the eggs of many of these forms. Moreover we are indebted to this writer for a very full account of the peculiar metamorphosis of the American lobster (*Homarus*). This animal hatches in a Mysis stage, but without abdominal feet and with somewhat rudimentary antennae. The first zoëa of the lobster is less advanced in other respects also than that of *Alpheus praecox*, which excepting perhaps the crayfish, hatches more nearly in the adult form, than any of the crabs or prawns at present known.

The eggs of Alpheus are quite small and very numerous. In the two species with shortened metamorphosis, the eggs are fewer and many times larger. Moreover, as might be expected, the degree of the abbreviation is correlated with the size and number of the eggs. This is shown by the following table:

Species.	Habitat.	Metamorphosis.	Number of Eggs.	Diameter.	Length of ♀.
Alpheus minus...	Shell heaps and exhalent oscula of sponges.	Complete.	500 to 600.	$\frac{1}{35}$ in.	½–1 in.
A. heterochelis...	Ditto.	Abbreviated.	200 to 300.	$\frac{1}{28}$ in.	1½ in.
A. praecox.........	Interior of sponges.	Nearly lost.	5 to 350.	$\frac{1}{24}$ in.	⅓–1⅔ in.

The mean of the short and long diameter of the eggs of *Alpheus praecox* is given in the above table, for the sake of readier comparison with those of the other two which are quite spherical. The number of eggs of this species is also usually small, those living in the brown sponge commonly having from fifteen to twenty.

It is now pretty well ascertained that the larval zoëa of the decapod crustacea is not a phyllogenetic or primitive form, but was gradually acquired as soon as the habits of the larva began to diverge from those of the adults, in order to bridge over this gap. Thus it has found a place in the ontogenetic history of many forms. If this is true, it follows that if the habits of the adult and larva tended to converge, this zoëal stage would need to be dropped, or rather shifted to the egg.

The genus Alpheus comprises numerous species spread over a large part of the globe, many of which are closely connected by intermediate forms. In view of these facts it is quite remarkable that only two of them are known to undergo an abbreviated development. This is, however, only another evidence of the extreme plasticity which the young of animals possess, and of their tendency to vary with varying conditions of life.

The Habits and Color Variations of Alpheus. By F. H. HERRICK.

Five species of prawns belonging to the genus Alpheus are now known to the eastern coast of the United States: three from Florida, and two others, *Alpheus minus* and *A. heterochelis*, which range from Panama to as far north as Virginia.

During our residence at Nassau, N. P., last spring and summer (1887), we found the Alpheus both one of the most abundant and characteristic representatives of the varied fauna of the coral reefs. Upwards of a dozen species or nearly as many as have been described for the whole continent of North America were found to inhabit a small reef of growing coral called Dix Point to the eastward of Nassau harbor, and the margin of the bay just in front of our laboratory.

Some of these animals lead a semi-parasitic life in sponges, or seclude themselves in the porous limestone which forms the solid floor of the beach, and others again live under loose shells and stones in the white coral sand. Some are highly and beautifully colored and with few exceptions the pigment is characteristic of the species. In all cases the claws of the first pair of walking legs are enormously enlarged, and serve as formidable weapons of defense so remarkable in this genus. One species, however, the habits of which are peculiar, carries the larger of these claws so folded under the body as to be completely concealed. It can, however, quickly withdraw this weapon and make a rapid thrust when an enemy comes near. By rapidly closing the scissor-like blades of these claws, a sharp metallic report is produced. This is true of all the species, and so abundant are many in these islands that a constant fusilade is kept up along some of the shores at low tide. This snapping propensity is shared by both sexes whether in or out of the water, and it is undoubtedly correlated with their pugnacious habits. If two males or females of the same or different species are placed in the same aquarium, they will dismember each other in a very short time, and one is usually literally torn to pieces.

A large brown sponge, which is not to be mistaken, grows on the shallow reefs and off the shores of all the Bahama Islands which I visited. It is found from just below low tide mark out to one-half a fathom or more of water, where its great size and sooty brown color distinguish it at once on the white bottom. If a sponge colony of this kind is pulled and torn apart, one is certain to find it swarming with a small species of Alpheus, which quarter themselves in the intricately winding pores of the sponge. Hundreds, or even thousands of individuals might be collected from a single large specimen. These animals vary from $\frac{1}{8}$ to $\frac{3}{4}$ of an inch in length. They are nearly colorless, excepting the large chelae, which are tipped with brown, reddish orange, or bright blue. The females are so swollen with their eggs or burdened with the weight of those attached to the abdomen that they can crawl only with great difficulty, if taken from the water. The eggs are few in number, and of unusually large size, their diameter varying from $\frac{1}{22}$ in. to $\frac{1}{25}$ in., and their number from six to twenty. These are most commonly yellow, but may be either bright green, olive, flesh color, brown, or dull white.

Another quite different sponge grows on all the reefs in from one to two fathoms or more of water. There are several varieties of this, which may be told by their olive green color, yellow flesh, and clumpy, irregular shape, as well as by the putrescent mucous which some of them pour out, when broken open. In nearly nine out of ten of these sponges one will find a single pair of Alpheus, which resemble those living in the brown sponge, but differ from them in several important points. They are distinguished by their large size, and by their peculiar and very uniform color. They vary in length from $\frac{2}{3}$ to $1\frac{2}{3}$ inches. The females exceed the males greatly in bulk owing to the great size and number of their eggs.

Both sexes are nearly transparent and colorless excepting the large claws, which are bright vermilion-orange. The female is practically inert during the breeding season (which lasted during our stay, March to July), and at such times is well protected in her sponge or against any green surface, by the bright green ovaries which fill the whole upper part of the body, and by the mass of similarly colored eggs attached to the abdomen below. Only two pairs or four individuals out of a hundred or more which were examined showed any variation from these colors. In these the eggs were yellow, and the pigment on the claws more orange than red. The table which follows shows the variations between two large females taken respectively from the brown and green sponges, and between the size, number, and color of the eggs.

Habitat of Alpheus.	Length of ♀.	Number of Eggs.	Diameter.	Color.	Color of Adult.
Brown sponge...	½ in.	19	$\frac{1}{22}$ in.	Yellow—(variable).	Large chelae, red, blue, or brown.
Green sponge....	$1\frac{5}{16}$ in.	347	$\frac{1}{25}$ in.	Usually green; in this case yellow.	Large chelae, always orange-red.

These two forms, although apparently distinct, are seen however, by closer examination, to belong to the same species, but they show very interesting variations. The Alpheus living in the brown sponges, tends to vary in several ways, chiefly in size and in the color of the body and eggs. The rostrum usually has three spines, but occasionally only two are present, the median one being lost. It is evident that these animals are perfectly protected from outside enemies, while within the tortuous mazes of the sponge, as their numbers would show. Parasites, such as Isopods however are not uncommon. There has thus been no chance or need for natural selection to act along the line of color. On the other hand, possibly, the Alpheus of the green sponge does require color protection, since the females are very sluggish during the breeding season, which extends over a good part of the year. This animal is certainly well protected against any green surface as already stated. But as will be shown, natural selection has probably nothing to do with it. The bright coloring of the tips of the claws which only are protruded from the place of concealment, recall the similarly colored heads of boring annelids which abound on the reef, and may have a protective significance. This evidence, however, is not very reliable.

The colors of certain crustacea, and also the colors of their eggs are known to vary greatly with the surroundings. In the Alpheus, parasitic in the brown sponges, these colors vary considerably where the surrounding conditions are the same. However, the color of the ovarian eggs is always the same as that of those already laid, and although these animals were kept for several days at a time in different colored dishes, I never observed any very marked change in the color of the eggs, but these experiments were not continued long enough or carefully enough to be conclusive. The eggs of *Alpheus heterochelis* are almost invariably of a dull olive color, while, as in the case of the parasite of the green sponge, about one in a hundred has bright yellow eggs. In the first case at least this is probably an instance of reversion to one of the original colors from which the green was selected. In most species of Alpheus the color of the eggs is fixed and uniform, and as already suggested may have a protective significance, but in a few other cases where this is not true, the color is not only variable in different individuals, but probably also in the same individual.

In order to explain the variations which we find in these two forms, we must assume either (1) that the parasites of the green sponge are a fixed variety with distinct habits, or (2) that they represent individuals which have migrated from the brown sponges and adapted themselves to their new surroundings, or further (3) that only those chance individuals with orange-red claws and bright green eggs, which occasionally occur in the brown sponge, find their way to the smaller green species, where they acquire great vigor and size. This last supposition is evidently untenable. If moreover the two forms, which I supposed at first were specifically distinct, represent fixed varieties, we ought to find the young or at least adults of all sizes in both sponges, whereas it is only in the large brown variety that any small or undersized individuals occur, while a single pair, of large and tolerably uniform size, is invariably found in the exhalent chambers of the green sponges.

These and other considerations render it probable that the second (2) proposition above stated is the correct one, viz., that the parasites of the green sponges were born in the brown variety, and after attaining considerable size migrated thither, where they adapted themselves at once to their slightly different surroundings, growing to three or four times their former size and the females acquiring bright green eggs, which become a source of protection in their new habitat. This view implies the greatest variability in color and in size of the individual, and in the color of the egg, which is the more remarkable from the fact that it is quite unusual in this genus.

The Development of Alpheus. By F. H. Herrick.

[The drawings for the detailed paper on the development of this form are nearly completed, and a monograph on the genus Alpheus is also in preparation].

Some observations were published last year (in No. 54 of this *Circular*) on the embryology of Crustacea, with special reference to Alpheus, and to the development of the eye of this prawn. With much better and ampler material obtained last summer at the Bahama Islands, I have been able to make a more thorough study of the early stages, and to trace the development of these animals from the first nucleus of the fertilized egg up to the larval and adult condition. Four distinct species have been studied, viz., *Alpheus heterochelis, Say; A. minus, Say; A. praecox sp. n.*, and another form which is probably new, to which no name is now given. Unless otherwise stated the following notes on the early stages refer to the last unknown species. The development in the egg is the same for all, excepting *A. minus*, which will be referred to separately.

This prawn has proved to be a good subject in which to study the origin and rôle of certain much disputed bodies, which are met with in several Crustacea and are known as "secondary mesoderm cells." My studies have convinced me that the germinal layers in the early stages of development have not the significance which is usually assigned to them, The mass of cells which results from gastrulation, some of which are poured into the yolk, is an unspecialized, indifferent layer, and cannot be regarded as mesoderm and endoderm in the sense in which these terms are used. It is potentially both epithelium, muscle and gland, since all these structures may be formed from it. The ectoderm on the other hand, by its position and function, is more clearly defined from the start. The development in general is characterized by great secondary modification.

Segmentation of the Nucleus and of the Yolk.

The egg when laid, is enveloped by a single membrane, the chorion or shell, which functions as an egg sac. If the nucleus is unfertilized, it is not able to initiate the process of segmentation. The fertile nucleus divides, and its products pass towards the surface, until a syncytium of eight nuclei is formed. Either just before or after the division of these, the yolk segments simultaneously over the whole surface into a similar number of partial pyramids. Each yolk cell or pyramid has a large nucleus at its base, while its apex fuses with the common yolk mass in the interior of the egg. The process is now a regular one until 128 to 256 small segments are formed. The rate of cell multiplication is then retarded over one-half of the egg, while it still continues and perhaps is accelerated over the remaining portion of it. The egg thus loses its radial symmetry and becomes two-sided. It is important to notice that no products of the segmentation nucleus are left in the interior of the yolk. The superficial pyramidal structure is lost; the primitive blastoderm is established, and there now takes place a general migration of nuclei from the surface to the yolk within, but principally as would be expected from that part of the egg where the blastoderm cells are most numerous, corresponding to the future embryo. This is followed by a partial secondary segmentation of the food-yolk into balls. The yolk-ball is apparently formed about the migrating nucleus, but as the latter is moving, this segmentation is irregular.

We have been able to follow very closely the entire process of segmentation in Stenopus, where it is substantially the same as that just described, except that there is no general migration of cells from the surface prior to gastrulation. This is also true of Pontonia domestica, and it is quite probable that the majority of macroua pass through the same phases in their early development.

Alpheus minus is anomalous from the fact that the products of the first nucleus instead of multiplying by regular binary division, appear to multiply by endogenous cell formation, and to give rise to numerous spores or nuclei, before the blastoderm is formed.

The Egg-Gastrula.

A slight invagination occurs where the superficial cells are thickest, and the egg becomes a modified gastrula. The depression is shallow, and does not form an enclosed chamber within the yolk. The included cells multiply rapidly, and form a mass of similar elements, some of which pass into the yolk. The protoplasm surrounding the nuclei of these cells is prolonged into a reticulum, which encloses myriads of small yolk fragments, and probably digests them by an intracellular process, after the manner of feeding amoebae. The thickening in front of and surrounding the blastopore, which is now obscured, is the rudiment of the abdomen. Anteriorly the "procephalic lobes" or more properly the optic discs make their appearance on either side of the long axis of the embryo, as circular patches of ectoderm. Meantime nuclei wander from the cell mass below the abdominal plate to all parts of the egg. Some pass to the opposite side, and take up a position beside the flattened epithelium cells, of what was the primitive blastoderm. The majority, however, pass forward and upward in two divergent lines from the sides of the abdominal plate, and eventually large numbers of these wandering cells settle down over the dorsal surface of the embryo.

Secondary Mesoderm Cells.

At the beginning of the egg-nauplius period, when numerous yolk cells have passed forward and joined the inner surface of the embryonic ectoderm, certain new bodies begin to appear in great numbers. They vary in size from small refringent particles to spores nearly as large as ordinary nuclei. The latter stain deeply and uniformly, and with high powers it is possible to demonstrate a clearer zone about them, which is evidently the first trace of a cell body proper. How do these bodies, the "secondary mesoderm cells," originate, and what is their function? As to their origin I believe there can be no doubt whatever. They arise by a process of endogenous growth from the embryonic cells or nuclei, chiefly from those wandering cells just described. Many of the latter may be seen to be swollen out, and their chromatin divided into coarse grains and balls of various sizes. The wall of the cell probably breaks down and thus sets the spores free.

The fate of these bodies is not so easily determined, but I have reason to believe that some of them become ordinary mesoderm cells, while there is some evidence that others are converted directly into blood corpuscles. These spores are most marked in the fully developed egg-nauplius, where there is a large accumulation of them around the oesophagus and at the bases of the rudimentary appendages. After this stage they generally disappear from these regions. Somewhat later, however, when there is a well-developed nervous system and six pairs of post-naupliar appendages, a patch of ectoderm cells on the surface of the egg opposite to the embryo becomes noticeable. It reminds one of a median unpaired dorsal organ. A slight invagination apparently takes place at this point, but at any rate a number of cells pass into the surrounding yolk, and these give rise in the way described to a swarm of minute spores.

By the time that pigment is deposited in the eyes, it is easy to demonstrate the presence of blood corpuscles in the stream of plasma which bathes the nervous system. They have the adult characteristics, that is they possess a deeply staining nucleus, and a clear irregular body. In the nauplius stage, moreover, some of the larger "secondary mesoderm cells" have a similar appearance, and are therefore possibly primitive blood cells. My study of these bodies has convinced me that Reichenbach's views on the origin of the secondary mesoderm cells of Astacus, although adversely criticized, are the true ones. According to this naturalist they arise from the nuclei of the endoderm cells, forming the ventral wall of the primitive stomach.

The Germinal Layers.

The plasticity of the embryonic cells and layers and the comparative tardiness by which they are clearly differentiated cannot fail to impress anyone who follows closely the early stages of development. The cell-mass developed around the blastopore, forming the abdominal process, cannot be artificially divided into layers. It certainly represents very largely the primitive mesoderm, but some of its elements pass to the opposite pole of the egg and become indistinguishable from the superficial ectoderm. A part of this mass remains as the mesoderm of the rudimentary abdomen, while many of the cells which migrate from it give rise to spores, which are undoubtedly mesodermic in function.

The endoderm does not appear as a definite layer until comparatively late. It arises from yolk cells which assume a peripheral position, and joining the cells of the hind-gut form the walls of the mesenteron.

The Eye.

The optic discs as already stated appear as patches of ectoderm, one cell thick, on either side of the long axis of the embryo in front of the rudimentary abdomen. Before the appendages are definitely formed, these have become thickened ectodermic discs. This thickening is due, (1) to delamination, or to a division of cells in a plane parallel with the surface; (2) to emigration of cells from the surface, due to crowding or to a division of superficial cells in a plane at right angles to the surface. A disc of cells is thus formed which gives rise chiefly to the eye and its ganglia. The cord of cells uniting the two optic discs represents mainly the future brain. The eye proper is due to the differentiation of the outer layer of the cells of this disc, while the ganglion is developed from the inner layer. The details of the process have been briefly stated in a previous paper.