expressed diluted juice of horse-dung, it conclusively proves to me that the resting spores hibernate naturally in the same manner. The seat of danger from both parasites is clearly in dungheaps, ditch sides, and decaying Potato plants.

Any method of destroying the resting spores of these pests, or of warding off or mitigating their attacks, obviously depends in a great measure upon a full knowledge of their life history. That life history I have endeavoured to the best of my ability to watch and describe, and I am content to let the observations stand on their own merits. Sensibly conducted and extensive field experiments might probably teach some valuable lessons; but it is difficult, if not impossible, for any single individual, whether farmer or botanist, to institute and carry out such experiments.—*Gardeners' Chronicle*, pp. 39-42, 1876.

IV.—*The Affinity of the Mollusca and Molluscoida.*

By W. K. Brooks, Ph.D.

During last August and September (1875) I enjoyed, through the kindness of M. Agassiz, an opportunity of studying the development of several of our more common marine Gasteropoda; and the results reached seem to point to the conclusion, which I believe has never been pointed out, that although the Gasteropoda are much more specialized and highly evolved than the Lamellibranchs, nearly all their organs, excepting those of locomotion and relation, conform much more closely to the embryonic type than do the same organs in an adult Lamellibranch. The latter group must therefore be regarded as a side branch from the main stem, of which the Gasteropoda are a much more direct continuation.

I have already shown * that the embryonic shell of Anodonta is, at first, a cup covering what is to become the dorsal surface of the embryo, and is therefore homologous with the shell of a Gasteropod. This cup or hood soon folds down on to the sides of the embryo, precisely as described in Dentalium by Lacaze-Duthiers, and at a very early period splits along the dorsal median line and becomes separated into the two halves of a bivalve shell, which are thus shown to be together the homologue of the shell of a Gasteropod exclusive of the operculum, which, as Selenka has shown in his 'Entwickelung von Tergipes claviger,' is formed by a split which extends across the long axis of the body, and therefore at right angles to that which, in Anodonta, gives rise to the two valves. The valves of an adult lamellibranchiate shell are a specialization

* 'Proc. Amer. Association,' 1875.

of the embryonic shell; are bilateral in origin, and together represent the dorsal or hæmal cup or shell of a Gasteropod, a Polyzoon, or a Brachiopod; while the ventral or neural operculum of a Gasteropod corresponds to the neural valve of a Brachiopod or the lid of a cheilostomatous Polyzoon, and is wanting in the Lamellibranchs.

The digestive organs of an adult Lamellibranch, although they are very much less specialized than those of a Gasteropod, seem to be much more widely removed from the embryonic type. The stomach of the Veliger of Astyris, like that of a Polyzoon, is divided by a constriction into two chambers. (Compare also the figure of the embryo of the Pteropod, *Carolinia tridentata* by H. Fol, and that of Limnæa by Rabl.) In the embryo of Mytilus we have, according to Lacaze-Duthiers, a similar stomach, and in the adult of Yoldia we have the same a little modified; here the anterior portion of the stomach receives the bile-tubes; and the posterior portion is prolonged so as to form a conical, somewhat twisted, intestine-like pouch, from the bottom of which the small intestine originates. In Venus this peculiarity is much more marked; the posterior chamber is now tubular, and sharply separated from the true stomach, which represents the anterior half of the embryonic stomach. The tube is somewhat convoluted, and is imperfectly divided by a longitudinal fold of the inner wall into two parallel chambers, of which the anterior is the true intestinal cavity, while the posterior contains the crystalline style. In Cardium we find the process of differentiation carried a step farther. The partition, which in Venus is imperfect, here extends entirely across the tube, so that the cavity of the sheath of the style is completely shut off from that of the large intestine, although the two are still in contact, and are contained within the same outer wall. Solen will answer as an illustration of the next step in the process of differentiation. Here the large intestine is not united to the sheath of the style, although the former is nearly straight, and parallel to as well as near the latter. In such forms as Mya the large intestine is entirely independent of the sheath of the style, and its large semicircular convolutions begin at the point where it joins the stomach. This series seems to show that the stomach of a Lamellibranch is homologous with only the anterior half of that of the embryo, or of a Gasteropod, while the large intestine and sheath of the style are together a very peculiar modification of the posterior portion.

In the prosobranchiate Gasteropoda, as in the Lamellibranchs, the gill is formed as a series of tentacular prolongations into the mantle chamber; these increase in number, and at last form a broad sheet, which is well shown beneath the transparent shell of Crepidula during the later "Veliger" and the early "Gasteropod" stages. In the Gasteropoda these tentacles remain free from each other during the whole life, and the water circulates over and around them; while in the Lamellibranchs they become so bent upon themselves and united to each other, that the gill-tubes are formed, and the water is driven into and through these, to be discharged into the cloaca, which is a special chamber, peculiar to the Lamellibranchs. In such a form as Mytilus, where the union between the tentacles is somewhat imperfect, we have what appears to be an intermediate stage between the perfect lamella of Mya or Unio and the separate tentacles of a Gasteropod. The gills of a Lamellibranch are therefore, like the shell and the digestive organs, a specialized form of the embryonic type, which is pretty closely adhered to in the adult Gasteropod.

These facts must not be regarded as showing that the Lamellibranchs are higher than or derived directly from the Gasteropods, for any such conclusion is rendered impossible by the lack in the latter group of such peculiarities as the lingual ribbon; a centralized and highly evolved nervous system; and accessory organs of reproduction. Although it is true that these features might have been lost through adaptation to a sedentary life, their entire absence at all stages of growth, throughout the whole class, would seem to indicate that they never existed; so we cannot derive these animals directly from the Gasteropoda, but must regard them as an offshoot from a form of which the Gasteropods are the highly developed linear or nearly linear descendants. If this conclusion is accepted, it is plain that all attempts to trace the phylogeny of the higher Mollusca through the Lamellibranchs to the Molluscoida, must be erroneous and useless.

The history of the discussion of the affinities of the Mollusca is an almost unbroken record of generalizations based upon imperfect knowledge and erroneous conceptions, and so many arrangements of the group have been proposed, accepted for a time, and then shown to be unnatural, that it is not at all strange that many naturalists should now call in question the existence of any real affinity between the higher and the lower classes. As long as the attention of the investigator was confined to the study of shells, there seemed to be no difficulty in connecting the Lamellibranchs with the Brachiopods through such forms as Anomia; and although the slightest anatomical knowledge is sufficient to show that the resemblance between these forms is entirely superficial and without scientific value, this conception had been so generally accepted and so firmly established, that the confirmation by embryology of the results reached through anatomical research, has scarcely been able to thoroughly exterminate it.

This view has been replaced by another which is not open to the charge of superficiality, since it is based upon a thorough knowledge of adult structure, and its weakness is shown only when it is tested by embryology. The clearest and most forcible statement of this view is that given by Allman in his 'Fresh-water Polyzoa.' According to Allman, the Tunicata are intermediate between the Polyzoa below and the Lamellibranchs above. The branchial sac of a Tunicate represents the permanently retracted tentacular crown of a hippocrepian Polyzoon; the tentacles form the horizontal bars of the sac, and uniting to each other at intervals enclose the branchial slits. Although Allman's figures are necessarily diagrams, no organ is exaggerated or suppressed for the purpose of making the likeness more forcible; they are very accurate and faithful representations of the animals, and show the closest similarity between these two forms; the position, structure, and connections of almost every organ of the one being duplicated in the other. An almost equally perfect comparison may be made between a Tunicate and a Lamellibranch, but the recent great additions to our knowledge of the embryology of the Tunicate seem to show, with absolute conclusiveness, that we here have nothing but a very perfect and striking adult resemblance, reached in each of the groups in a different way, and therefore without homological signification. Whatever view of the Vertebrate affinity of the Tunicate we may incline to, we must recognize the fact that the branchial sac is morphologically part of the digestive tract, and in no sense whatever a lophophore or a tentacular gill. Moreover, we should expect, according to all analogy, to find the affinity to other groups most clearly shown in the low or embryonic forms, but Appendicularia presents none of the peculiarities upon which the comparison is based. As Ray Lankester has lately referred to Allman's homology in a way which seems to imply that he still accepts it, I will repeat more briefly my reasons for rejecting it. These are, first, that the development of the Tunicate shows that the resemblance is not due to community of origin, but is reached in different ways; and secondly, that the adult Lamellibranchs are a specialization of the embryonic type, and therefore cannot lie in the direct line connecting the Molluscoida with the Mollusca. Allman himself seems to have seen the force of the first objection, for in a much later paper (1869) he advances the view that the Polyzoa are connected, through Rhabdopleura, with the Lamellibranchs. His studies of this genus were made upon alcoholic specimens; and Sars, who enjoyed the superior advantages afforded by an abundance of living specimens, has shown that Allman was mistaken in regard to almost every one of the points upon which he attempted to establish the supposed relationship.

These are only a few of the arrangements of the Mollusca which have been proposed, and the fact that, of the three selected, two are by Allman must not be regarded as the result of a wish to unfavourably criticise the work of this author. On the contrary, the anatomical resemblances which he points out so clearly are worthy of the most thoughtful attention, and although they are not homological and do not indicate descent, they are excellent illustrations of the independent origin of similar structures; a class of relations which has not yet been sufficiently allowed for in the speculations of the modern school of zoology, but which seems destined to form, at some future time, an important element in the theory of the evolution of life. The superiority of the conceptions of Allman becomes evident as soon as we contrast them with many which have been advanced; for example, the comparison advocated by a very distinguished naturalist and embryologist between the foot of a Lamellibranch, the tail of Appendicularia, and the placenta of Salpa.

We come now to the question, If our present knowledge of the embryology of the Mollusca and Molluscoida disproves all the old ideas of their affinity, does it present anything to replace them?

Most of the Gasteropoda are known to pass through a free, locomotive "Veliger" stage. The veligers of different Gasteropods differ considerably in form; and in some the embryo, at this stage, is much less specialized than in others; but, omitting the complications introduced as adaptations to a spiral shell, the veliger of such a marine Gasteropod as Astyris may be regarded as presenting the typical form. A veliger may be described as a free-swimming, bilaterally symmetrical embryo, without a true heart or vascular system, or branchiæ, with the mouth and anus near each other on the median line. The digestive organs are suspended in the body cavity, and attached to the body-wall at the two external apertures, and by the various muscles. The foot is situated between these two openings; and the pedal ganglia, which are in most veligers the first ganglia to appear, are developed in the region of the foot; that is, between the mouth and the anus. The foot is generally supplied with a bunch of setæ, which are apparently sensory in function. The animal is enclosed in a shell composed of two portions; a large ventral cup, and a neural or pedal operculum, which is united to the anal margin of the cup at the earliest stages, and subsequently becomes separated from it. This shell and lid are found in the embryos of those forms where the adult is without an operculum, as Crepidula, as well as in those where the adult is destitute of a shell, as the Nudibranchs.

The most characteristic peculiarity of the veliger is the *velum*. This is a large bilaterally symmetrical circlet of cilia, developed from the cephalic region of the embryo, and supported, at some distance from the body, by a transparent double-walled veil, the cavity of which is irregularly divided into large sinuses, in free communication with the body cavity. The animal swims, usually near the surface of the ocean, by means of the long cilia of the velum, which would seem to perform the function of a respiratory organ as well, for the fluid which fills the body cavity is driven into and out of the sinuses of the velum by the retraction and expansion of this structure; in most veligers this circulation seems to be aided by the rhythmical contraction of the muscular fibres which bind the foot to the œsophagus. The mouth is not within the circlet of large locomotive cilia, but immediately behind it, and a ring or band of smaller cilia passes from the anterior margin of the mouth entirely around the velum, on its lower surface, and therefore outside the circlet of locomotive cilia. This second circlet seems adapted to convey food to the mouth, but there are no direct observations upon this point. The velum and the foot are retracted into the shell by the action of a pair of long muscles which pass from the sides of the œsophagus and region of the foot to the bottom of the ventral shell, and subsequently become the columellar muscle of the adult.

The veliger stage seems to be represented very perfectly in most of the marine Gasteropods, except some of those whose eggs are protected by strong cases, within which the early stages of development are passed. In some of these, as Purpura, there is a well-marked but somewhat rudimentary veliger stage, and it is probably represented more or less faintly in all, although the embryo does not pass this period in free locomotive life, and accordingly has no need of swimming organs.

Although the marine Opisthobranchs pass through a perfect veliger stage, and are locomotive at this period, the fresh-water Pulmonates undergo their embryonic development within the egg, and with them the velum is only faintly indicated, and it appears to be entirely wanting in the land Pulmonates whose young are not aquatic.

As regards the remaining classes of the Mollusca, the Scaphopods pass through an embryonic form which is easily recognized as a veliger, although it is not very highly developed. It would seem as if the Lamellibranchs, from their fixed or nearly fixed mode of life, had an especial need for a locomotive larval stage, but the veliger stage can hardly be detected in this group. Embryos of several of the marine Lamellibranchs have been described and figured as furnished with a circlet of cilia, and thus fitted for locomotion, but these embryos are so rudimentary in other respects, and so different from the highly specialized veligers of the Gasteropoda, that we cannot, with any safety, say that they represent this stage of development at all, although the fact that Anodonta has an unmistakable velum would seem to indicate that the Lamellibranchs, like the Gasteropods, are the descendants of a free-swimming veliger, and that the circlet of cilia described in the embryos of such forms as Cardium is also to be regarded as a rudiment of the same stage. It may be that the development of the young within the branchiæ or the mantle chamber in this class does away with the necessity for a locomotive embryo, but at present we know so little of the life history of the marine forms that we have very little ground for generalization. The imperfection of our present knowledge cannot, however, be fairly urged to restrain us from making as much use as possible of what knowledge we do possess, although we must constantly bear in mind that it introduces an element of uncertainty into all of our conclusions. This of course is true of all biological speculation at present, but no one would advocate the abandonment of all speculation and comparison until all of the facts of our science have been recorded and verified.

The embryo of Anodonta, at a very early stage, has, at the anterior end of the worm-like body, a simple band of cilia; as development progresses this is carried, by the formation of the mantle lobes, into the mantle cavity, and there increases in length, and the free ends bend towards each other and finally unite, thus forming a closed, bilaterally lobed circlet like that of the Gasteropods, except that it is not raised from the surface of the body, and its cilia are very short and are not used for locomotion. It is interesting to notice also that it is attached to the dorsal surface of the shell by two muscles like those of the veliger of a Gasteropod. In Anodonta these subsequently become the retractor muscles of the foot.

The thecosomatous Pteropoda present the veliger stage of development in a form as highly specialized as that of the marine Gasteropoda, and the embryos of the two do not differ at this time in any essential particular. The development of the gymnosomatous Pteropods, on the contrary, is entirely anomalous, and at present appears to be inexplicable on any theory of descent.

In the Cephalopoda, as so often happens in the higher representatives of a group, the indirect course of development has given place to the direct; the larval stages are usually entirely wanting, and the embryo shapes itself, from the beginning, into the form of the adult. In most Cephalopods there is no trace of a veliger stage, but its absence is what we should expect from the analogy of the higher forms of other groups.

The conclusion to be drawn from our present knowledge of the Mollusca will appear, from this review, to be that all of them are to be traced back to a free-swimming ancestral form, of which the veliger embryo is the representative; this seems to be the only way in which we can account for its appearance in at least certain representatives of so many widely separated groups; and the presence of rudiments of it in such forms as Anodonta and the Pulmonates seems to indicate the same conclusion. We have seen that in many of the cases where it is wanting, its absence can be reconciled with this theory, even with our present knowledge, and we may therefore hope that a more complete acquaintance with the embryology of the naked Pteropods will show that they are not an exception.

We come now to the interesting question, What are the affinities of this "Veliger" from which the true Mollusca are descended?

It is only necessary to glance at the side view of any fully developed veliger, such as Selenka's figure of Tergipes, in order to notice the resemblance to a Polyzoon, and more careful examination shows that the resemblance holds not only in the general plan, but in detail. The velum corresponds to the lophophore in position and structure, and subserves, like this, the function of respiration, and probably that of ingestion as well. The heart is absent in both, and the fluid which fills the body cavity and bathes the digestive organs is kept in motion by the contraction of the various muscles of the body. The digestive organs are similar in form and also in their connections. The epistome with its ganglion answers to the foot and pedal ganglia, and in Rhabdopleura the epistome is functionally as well as morphologically a creeping disk. The shell and operculum answer to the cell and lid of a cheilostomatous Polyzoon, and the retractor muscles are clearly homologous. The most important differences seem to be that, among the Polyzoa, the animals are fixed and multiply by budding; and that in all, the mouth, as well as the epistome, is within the circlet of the lophophore. (Rhabdopleura was described by Allman as an exception in this respect; Sars, however, has shown that although the tentacle-bearing portion comes to an end upon the sides of the foot, the line of cilia is continued entirely around it.) The lack of agreement between the positions occupied by the mouth and foot in the two forms seems to be the most serious objection which can be urged against the view here advocated. In answer to it we can only point out that in Dentalium the mouth is formed within the circlet, although the foot is outside it. It is not to be supposed, however, that the Veliger can be traced back to any existing form of Polyzoon, or even to any order of this class. In some respects its affinities are with the Hippocrepia, in others they are with the Cheilostomata, and in still others they are with Rhabdopleura, and they therefore indicate that the common ancestral type of the Mollusca was, not a true Polyzoon, but simply a Polyzoon-like form. A lack of agreement in points of detail is therefore no more than we should anticipate. In answer to the second objection, that the Polyzoa multiply by budding, we may refer to the well-known law, that agamic vegetative multiplication is antagonistic to high evolution, and is accordingly replaced by true sexual reproduction in the higher forms of all classes of animals; as its presence, if it occurred in any of the true Mollusca, could not be regarded as proof of an affinity to the Polyzoa, its absence does not disprove such affinity. No one will attach much importance to the remaining objection, that the Polyzoa are fixed; in fact, those which are developed from statoblasts are at first free, and swim by means of the cilia of the lophophore.

The similarity between the Polyzoa and true Mollusca, in general plan of structure, has long been recognized, but the attempts to connect the two groups through the Lamellibranchs are so evidently incorrect, that, led by the unquestionable affinity of the Polyzoa and Brachiopods to the Vermes, many geologists are now inclined to separate these lower forms from the Mollusca proper. As soon as we recognize that the Lamellibranchs are not to be regarded as typical Mollusca, and that all of the latter are to be traced back to a "Veliger," all difficulty seems to disappear, and it becomes plain, not only that the Mollusca and Molluscoida are related, but that they are connected so closely, that the advisability of such a division is very doubtful. We also obtain, at the same time, an explanation of the worm-like early stages of the embryo, exhibited by so many of the true Mollusca. The belief so firmly supported by nearly all zoologists a few years since, that the various branches of the animal kingdom are absolutely independent of each other, has been almost entirely overthrown by the accumulation of new facts, and the constantly increasing tendency to examine them in their bearing upon the theory of the evolution of life; and the union or junction of the Vermes and the Mollusca, in some manner, has already found a number of advocates.

Professor Morse, by his investigations upon the anatomy and embryology of the Brachiopods, has shown that, if we consider this group by itself, it must be placed with the Annelids. His investigations also show, with equal clearness, that the Brachiopoda are closely related to the Polyzoa, and we must therefore regard them as united by the "Veliger" to the true Mollusca. If we accept the view that the molluscan and vermian stems are thus united, the question, "Are the Brachiopods Worms or Mollusks?" will be regarded as nothing but a verbal discussion; for this class forms the connecting link between the two groups, and any sharp line of demarcation does not exist.

We are now prepared to form a provisional phylogeny of the Mollusca, which may be stated as follows:

The Brachiopods are derived from the Vermes; and from the Brachiopod stem, but from something very different from any known Brachiopod, the Polyzoa originated. From the Polyzoon stem, but not from any known Polyzoon, we have the Veliger. The true mollusks have originated as several offshoots from this Veliger stem. Of these the Scaphopods seem to be the least specialized, and in most respects nearest to the original proto-mollusk. The Pteropods are the representatives of another offshoot, to which the Cephalopods also seem to belong. The Gasteropods seem to represent several distinct branches. The Prosobranchiata and perhaps the Heteropods being the descendants of one; the Opisthobranchs and Pulmonates of another; and the Chitons of a third. From one of these, or perhaps from the branch now represented by Dentalium, the Lamellibranchs seem to have been derived at a very early period, and to have diverged considerably from the ancestral form, becoming degraded in certain respects and at the same time specialized in others.

In this scheme all reference to the Tunicata is omitted, since it will be conceded by all embryologists that, whatever the affinities of this group may be, they are certainly not mollusks.

I have already referred to one serious objection to the view here advocated; that is, that it fails to account for the remarkable embryonic forms of certain Pteropods. Huxley has advocated the view that the Pteropoda and Dentalium have an annelidian ancestry distinct from that of the remaining Mollusca. This view would help us to understand the remarkable larval form of such genera as Pneumodermon, and at first sight would seem to present a way of escape from our difficulty. It fails to account for the perfect agreement between the veligers of the thecosomatous Pteropods and the Gasteropods, however, and thus introduces a difficulty at least as great as that which it removes. At present the safest plan seems to be that of waiting for more knowledge, bearing in mind the existence of this at present insoluble difficulty.—*From the Proceedings of the Boston Natural History Society*, Feb. 1876.

V.—*The Application of Photography to Micrometry, with special reference to the Micrometry of Blood in Criminal Cases.*

By J. J. Woodward, M.D. (U.S.A.).

Recent experiments in photographing the blood-corpuscles of man and other animals lead me to propose photography as affording the means of making comparative measurements more accurately, and with less expenditure of time, than can be done by any other method.

The plan I propose is simply as follows. The blood is placed on a glass stage micrometer and photographed with any convenient power, both blood and micrometer appearing sharply defined in the picture. The measurements are then made on the negative.

The stage-micrometer must be ruled on the upper surface of a piece of glass, and must have no thin cover. For mere comparative measurements any ordinary stage-micrometer in which the lines are equidistant can be made to answer by simply removing