

NATURAL HISTORY OF HAMINEA SOLITARIA SAY.

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THE shell-bearing species of the family Bullidæ have been found freely distributed in the rocks since the Tertiary period. A large number of species have been found as fossils. Ludwig in Leunis *Synopsis der Thierkunde* states that there are between two and three hundred recent species. They have a wide distribution in both European and American waters, being commonly found in the sandy and muddy bays of the temperate regions.

The Bullidæ belong to the general order of Opisthobranchia and to the suborder Tectibranchia.

Thomas Say read before the Academy of Natural Sciences at Philadelphia on July 24th, 1821, a paper in which he gives "An account of some of the marine shells of the United States." In this article we have the first reference to *Bulla solitaria*. His description is as follows: "*Bulla solitaria*. Shell remarkably thin and fragile, pellucid, oval, narrowed at base, with numerous impressed, revolving lines, and transverse very obtuse wrinkles; apertures surpassing the tip of the shell; spire none, substituted by an umbilicus; umbilicus of the base none, less than half an inch. Inhabits the southern coast of the United States.

July 4th, 1835, J. G. Totten described a species of *Bulla*, variety *insculpta* which he dredged in about fifteen feet of water from the muddy bottom of the harbor at Newport, R. I. He maintains that *insculpta* is distinct from *solitaria* because of some slight variations in the color and shape of the shell. He says, "Thus (*insculpta*) can hardly be Say's *Bulla solitaria*. It is not umbilicated at the top as that species is; having merely a shallow pit in which nothing of the interior whirls can be seen. The *solitaria* is described as being narrowed at the base; but though our shell is regularly rounded in the passage, below, of

the right into the left margin, it is widely rounded; and the widest part of the shell is below the middle."

A. A. Gould, in his *Invertebrata of Massachusetts* ('41), considers *Bulla insculpta* and *Bulla solitaria* identical: he concludes his description of *Bulla insculpta* with the following paragraph:—"The differences between *solitaria* and *insculpta*, if there be any, must be very slight. Nor do I see that the two descriptions (Totten and Say) are at all inconsistent with each other. Still it is true that the shells from Martha's Vineyard are precisely like those from Charleston, S. C., and accord with Mr. Say's *solitaria*; and those from Roxbury are precisely like those found by Col. Totten at Newport, R. I., and described by him. The observable differences are, that the first are of a more dead white, are more cylindrical, the summit has a more square appearance, the revolving lines are less distinct, and there is always a perceptible opening in the region of the spire. These differences may be ascribed to age or locality."

Verrill ('73) describes *solitaria* as occurring along the Atlantic coast from Massachusetts Bay to South Carolina and makes no mention of *insculpta* except to assume that it is the same species as *solitaria*. The shells of *insculpta* and *solitaria* as figured by Totten, Gould, and Verrill seem to be identical.

The size of the shells which I have found at Wood's Holl, Mass., varies to a considerable degree; one shell found was only one-fourth as large as the average, the shape of a large number of shells which were examined varies in regard to the width and length of the lip. All of the shells examined were dextral. The distinctness of the revolving lines seems to depend on



FIG. 1.—*Haminea solitaria* showing the proboscis and tentacular disks. The parapodial folds conceal the anterior part of the shell and the mantle extends posterior to it. Natural size.

the age, the larger ones being the more distinctly marked. The statement that the shells of *insculpta* seem to be more of a dead white color than that of *solitaria* is easily explained. The shell of the living animal is a golden gray; the golden tinge being given by the thin struc-

tureless membrane, the periostracum, which completely covers the shell (Fig. 1). When this membrane has suffered disinte-

gration the shell has the dead white color mentioned by Gould. In view of these variations I think that the shell as originally described by Say is identical with the *insculpta* of Totten and is the *solitaria* found in the vicinity of Woods Holl, Mass., and of Long Island, N. Y.

Pilsbry has decided to limit the family Bullidæ to the single genus Bulla. Formerly the members of the Akeridæ were included with the Bullidæ but the character of the radula, form of the shell, and relation of the animal to it enables one to sharply differentiate the two families.

The Bullidæ have in the radula a few longitudinal rows of teeth (formula I. 2. I. 2. I.). The animal is capable of complete retraction into the shell. There are no epipodal or parapodal lobes; the foot is long and tapering behind. The shell has a mottled color pattern.

The animal described by Say, Totten and others and referred to in this article is placed by Pilsbry¹ in the family Akeridæ and in the genus Haminea. "The Akeridæ are a much lower stock of Tectibranchs than Bullidæ, retaining the primitive multi-dentate radula, and the epipodal lobes, and having a thin, fragile unicolored shell.

The following is the specific description of *Haminea solitaria*: "Shell thin, subcylindrical, with gently convex sides, truncate vertex and rounded base; color horny or light brown. Surface shining, having irregular growth wrinkles and (under a lens) *fine, deeply impressed spiral grooves*, much narrower than their intervals, sometimes with smaller ones intercalated. Vertex white, somewhat impressed in the middle, subperforate. Lip arising to the right of the center, slightly thickened; outer lip gently arched forward. Columella thin, concave. Alt. 10, diam. $6\frac{1}{2}$ mill" (Fig. 2).

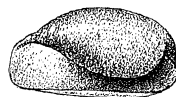


FIG. 2.—The shell of *H. solitaria*. $\times 2$.

Habitat.—Until the report of Verrill, ('71-'72) nothing was said of the animal or its natural history. All writers confined themselves to a conchological description of the species. Verrill says that *solitaria*

¹ *Manual of Conchology*.

"is restricted to muddy shores and bottoms, in sheltered situations and is found also in muddy ponds and estuaries." Smith and Prime state that the animal is rare, found in mud at a depth of one or two fathoms. Balch ('99) states that the animal, "*Haminea solitaria*, *Bulla solitaria*, is rather uncommon alive, sometimes occurs on marsh grass, top of sea walls." In regard to the general distribution of this species Verrill says, "From Mass. Bay to South Carolina it is common in muddy lagoons and salt ponds, in shallow water where not too brackish, along the shores of Vineyard Sound, Buzzard's Bay, and Long Island Sound. Abundant in a small pond near Holme's Hole, in New Haven Harbor, in ditches near Fort Hale."

Haminea solitaria is found rather commonly in the Eel Pond and Big Harbor at Wood's Holl, at Hadley Harbor, and at the bathing beach on Buzzard's Bay at Wood's Holl. During the laying season the animal migrates into shallow water and may occasionally be seen upon the eel grass and algæ, but usually not in water less than two feet deep at low tide. If the eel grass be disturbed they drop at once into the water and fall to the bottom, where it is very difficult to see them, owing to their form and color being so similar to the ordinary weeds and mud at the bottom; thus it is practically impossible to gather animals by looking for them on the weeds or bottom. They have been secured in two ways: first, by taking an ordinary fine-mesh dip net and skimming off the sea weeds and half an inch of mud from the bottom, then carefully washing out the mud; in this way a number have been secured in the shallow ponds and lagoons about Wood's Holl; secondly, by dredging; this method is necessary in deep water. *Bulla* may be found, even in the breeding season, in water thirty feet deep in the Big Harbor at Wood's Holl, — the greatest depth where they have been found. This peculiarity may be due to the fact that their former laying spot in shallow water is now occupied by a deep sea wall. Dr. Charles B. Wilson obtained a number of *solitaria* by skimming in clear water near Edgartown about the 18th of August. He was sure that the net did not pass over any eel grass or sink beneath the surface. I feel sure that this is the real explanation of the occurrence of *Bulla* in great abundance

just before the egg-laying time, and their equally sudden disappearance after the egg-laying time. They simply rise to the surface and swim away.

In the summers of 1897 and 1898 most of the specimens obtained by me were collected in the larger of the two so-called "oyster ponds" near the Marine Biological Laboratory. Although a large number of capsules were taken from this place, over one hundred capsules were gathered from another locality and put into this lagoon in order to assure an abundance of material in succeeding seasons. In the summer of 1899 no capsules could be found in this lagoon, in the summer of 1900 three capsules were found here, but all of the eggs had died before reaching the twenty-cell stage; the tide flows freely into the lagoon thus keeping the water comparatively fresh. The drainage from the Marine Biological Laboratory flows into an adjacent lagoon and it is possible that the water seeping through may have some poisonous effect which kills the eggs and has destroyed or driven out the animals themselves.

The Bulla found on the sandy bathing beach at Buzzard's Bay occurs about half an inch below the surface of the sand; usually near the capsule, which is the only indication of the presence of the animal.

*General Morphology.*¹—It is not my purpose in this section to go into the details of the various systems of organs except in so far as they are directly related to the development of the egg; I purpose, however, to give a brief sketch of the general form of the animal.

Probably the most striking feature of this species is its color, which is a golden gray thickly mottled with dark brown and occasional orange spots; one might almost say that the gray background looks as though sprinkled with fine sand. The shell is translucent and slightly striated spirally; it is not at all glossy or shiny. One would hardly expect to find much of a shell in a tectibranch, but in *solitaria* the reduction of the shell

¹ For a full discussion of the Morphology of the family Haminea (Bullacea) see M. Vayssiere, *Recherches Anatomique sur Les Mollusques de La Familles des Bullides Ann. Sci. Nat. Tome 9. 1879.* R. Bergh, Bullacea. *Reisen in Archipel d. Philippinen*, pp. 211-312, 1901.

has only just begun. The most noticeable feature in this process is the fact that the shell is thin and fragile, so much so that it must be handled very carefully. The second feature is that in the mature animal the shell is not large enough to shelter the whole body in its contracted state. The shell certainly cannot afford particular protection against enemies, but when we remember where the animal lives and its habit of crawling along the mud and sand, we can readily see that it could have no better protection than its color. It imitates the color of the roots of eel grass most closely; at first sight I have often mistaken the detached fragments of these roots for *Haminea*.

The size of the animal depends largely upon age; the smallest shell measured was three mm. in width, and five mm. in length; the average size of the mature shell is 7 mm. in width, and 10 mm. in length. The average length of the extended animal including the shell is 2 cm.; the smallest animal was 8 mm. in length. I can make no definite statement as to the age or size at which *H. solitaria* begins to lay, but can say that I have never known the smaller ones to lay. In the aquaria the animals die after laying, but I do not believe that this fact can be used as proof that they always do.

The foot of *Haminea* possesses, though not clearly distinguished, the three divisions characteristic of the typical molluscan foot. From the mesopodium arise the parapodia; these are lateral lobes, or folds, like extrusions of the edges of the foot. In some of the Opisthobranchia the parapodia (epipodia of Pilsbry) are highly developed and unite upon the back, completely covering the shell. In our species however the parapodia cover only the anterior part of the shell.

The young animal moves by stretching forward the head and foot, and then drawing the visceral mass forward, so that the progress results from an alternate stretching and contraction of the anterior flexible part of the body. The posterior part being drawn ahead at each contraction. In the mature animals there is no such noticeable division in the movement; with them locomotion is apparently a continuous gliding process.

The anterior part of the animal terminates in a broad thin proboscoidal snout. Running back from the end of the snout

there are two tentacular disks, which are divided only part way. There is very little movement in these disks, except as they shift about over the anterior portion of the shell. In this species there seem to be no special sense organs in the tentacular disks. So far, I have been unable to explain their function. The tactile sense is usually located in the tentacles, but in our animal the anterior portion of the snout performs this function, as is very evident from its movements. In many of the Opisthobranchia the mantle folds over part of the shell, but in *H. solitaria* the only external evidence of the mantle is a thick fold which occupies the lip of the shell and extends back of it for about four mm., it is here extended and affords a surface equal in width to the shell. At first sight one would think because of this arrangement that the foot extended from the snout to the posterior portion of the animal, but closer inspection shows a sharp demarcation which indicates the boundary between the posterior portion of the meso-podium and the mantle. All of the parts of the body that are exposed are covered with columnar, ciliated epithelium. A great quantity of mucus is secreted by the animal, so that in crawling about the dish they often leave a nearly perfect tube of mucus. This is secreted by numerous typical single-celled glands, which are especially abundant at the edges and tip of the snout, and the outer portion of the tentacular disks.

The especial characters aside from the shell which distinguish *H. solitaria* are the stomach plates and the form of the radula.

There are three stomach plates so arranged that the food is triturated by them (Fig. 3). The plates are composed of chitin, having their bases firmly imbedded in the strong muscles of the stomach. The form of a single plate is shown by the camera drawings (Figs. 4, 5). The portion of the plate that comes in contact with the food is differentiated into a number of ridges which are larger and more pronounced at the anterior end. The

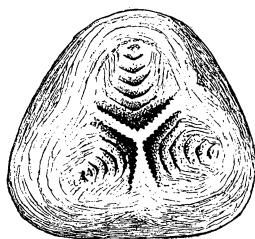


FIG. 3.—Showing the arrangement of the stomach plates, each of which is imbedded in a large amount of muscle. The free surfaces are so arranged as to triturate perfectly the food.

largest teeth are found on the anterior part of the plate, having

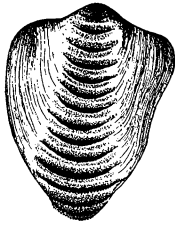


FIG. 4.—One of the chitinous stomach plates as seen from the free surface. $\times 24$.

a triangular form. The size and prominence of the teeth gradually decreases toward the posterior part of the plate. This gradual increase in size of the teeth and the ridges indicates how both are continually forming to take the place of the more anterior ones as they become worn



FIG. 5.—One of the chitinous stomach plates as it appears from a profile view. $\times 24$.

out. The youngest teeth are those found on the smallest ridges. In some instances it is difficult to be certain that teeth are even present.

The radula is an interesting structure but one that is difficult to represent in a drawing. When this organ is removed from the animal, it is somewhat triangular in shape (Fig. 6). In the center of the anterior part there is a single row of teeth, having

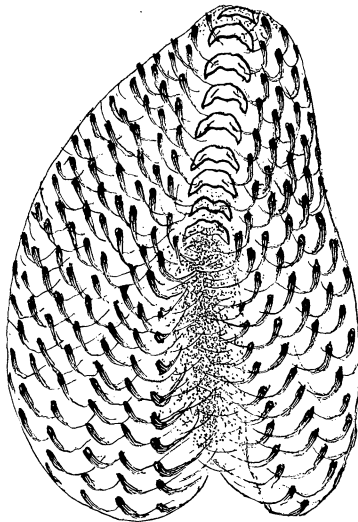


FIG. 6.—The radula seen as a transparent object. The anterior end is uppermost in the drawing. The formula is infinity. one. infinity. $\times 72$.

a broad free margin and terminating at each side in a rather broad blunt process (Fig. 7). There are an indefinite number of long, slender, sharp teeth arranged in rows which correspond to the teeth of the median ridge. The bases of these lateral teeth are imbedded in the muscles of the radula (Fig. 8). Each lateral tooth is bent at an angle of about 90 degrees. This arrangement of the teeth would give the following formula for *H. solitaria* ∞ . I ∞ .

The genital organs.—This system of organs is fully dis-

cussed by Lang; I have been able to demonstrate of all the

parts as given by him and will, therefore, quote freely from his description. The Opisthobranchia are all hermaphrodites. Haminea is no exception to the general rule and comes under the first type as described by Lang. The germinal gland consists of numerous "converging diverticula." The eggs and spermatozoa arise from the same part of the gland and are intermingled. During their development they become detached and lie free in the cavity of the gland. The ducts of *H. solitaria* are considerably complicated, because of the development of the accessory organs. The ovotestis lies between the lobes of the liver and the posterior part of the body; this gland has numerous branches, which finally collect into the common hermaphroditic duct; the duct empties into the common genital cloaca.

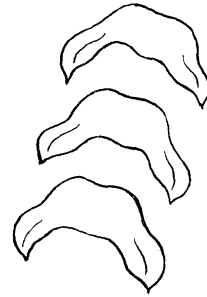


FIG. 7.—Three of the median plates from the radula. $\times 390$.

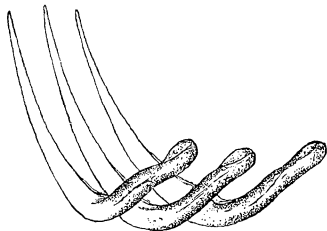


FIG. 8.—Three of the lateral teeth from the radula. $\times 390$.

into the extreme right anterior part of the mantle cavity, and from it there is, continued forward, an open ciliated furrow, which carries the spermatozoa to a gland called the "prostate"; this opens into the penis. "The penis itself lies in the right, on the boundary between the head and foot. When it is at rest its sheath lies in the cephalic cavity near the buccal mass." Two important glands open into the genital cloaca by a common duct; first, the albumen gland, which is comparatively small and lies upon the surface of a second, known as the nidamental gland; the latter is much larger than the former and yields the outer protective envelope of the egg. The albumen gland supplies the albumen for the egg capsule.

The "receptaculum seminis" is connected by a short duct with the genital cloaca and receives the spermatozoa at the time of copulation. Of course the size of this vesicle varies according to the season and according to whether or not it is full of spermatozoa.

Breeding habits.—In general the breeding season of our species extends from the last of June to the first of September. There seems to be considerable variation in the time when the egg laying begins, in 1897 the capsules were first found July 9th. In 1898 none were found until July 25th. Then three were found which had been laid within thirty-six hours. In 1900 collecting was begun July 10th and capsules were found which must have been laid as early as June 25th, judging from the fact that the embryos had already left some of the capsules and were leaving others. However, the animals lay most abundantly between July 15th and August 15th. The egg capsules may be found scattered through the eel grass and algæ on the edges of the pond, or lagoon, but each capsule is attached to grass or algæ from two to six feet below the surface of the water. Apparently the animals congregate in favorable spots to lay their eggs. In one place in the eel pond, where the water is about three feet deep at low tide, over five hundred capsules were collected in ten days within an area about ten feet square. During the same period repeated trips were made to various parts of the pond, but only a very few capsules were found.

On the sandy bathing beach previously mentioned the animals lay in the same place from year to year. Here there is a small patch of eel grass in about three feet of water; in and around this patch the eggs are laid in great numbers. In this locality the capsules are attached either to the eel grass or, as in most cases, simply to the sand. The sandy bottom slopes out gradually for about one-fourth of a mile, merging finally into a muddy bottom. I have never dredged here, either before or after the breeding season, so I do not know where *Haminea* stays during other seasons; but I have dug down into the sand, both before and after the laying season, and have never been able to find any of the animals. It is difficult to ascertain where *Haminea* lives at other times than the breeding season, but the fact that it cannot be found in shallow water except at this time seems to show that it migrates into deeper water. This idea is also supported by the occurrence of *Haminea* in thirty feet of water in the Big Harbor, and by the statement of Verrill ('72) to the effect that, "A specimen of winter flounder

(*Pseudopleuronectes americanus*) caught at Wood's Holl in August, contained a large number of the shells of *Bulla solitaria*." The winter flounder is dredged in the vicinity of Wood's Holl at a depth of about fifteen to thirty feet, and is mentioned by Verrill as devouring *Bulla* in large numbers. *Haminea* has been dredged in May in Hadley Harbor at a depth of twenty-five feet. These facts would tend to show that its natural habitat for the most of the year is the deeper water. A further proof that *H. solitaria* lives in deep water except during the breeding season is supplied by the following facts: August 28, 1900, Dr. C. V. Wilson while skimming the surface water with a fine mesh net near Edgartown, secured a large number of *H. solitaria*. They all died during the first night although they were placed in a small aquarium. The time that these individuals were collected was after the usual egg laying periods for the forms that live in the vicinity of Wood's Holl. When taken, they were evidently migrating into the deep water. The observations of Verrill and those of Wilson seem to show conclusively that *H. solitaria* is a deep sea dweller except for about six weeks, when it takes up temporary quarters in some favorable place in shallow water.

During the first two summers that *H. solitaria* was under my observation I was unable to discover any evidences of copulation, owing to the fact that early in the season I did not have in the laboratory any considerable number of animals; but in the summer of 1900 I had in the laboratory about forty animals at one time and was able to make observations on copulation. The habit which these molluscs have of crawling over one another and of collecting into a pile, concealed the fact and method of copulation for a long time. One day, however, I noticed two animals apparently copulating, the genital grooves were slightly extended and came together, from one the penis protruded into the genital groove of the other. The animal receiving the penis laid a mass of eggs eight hours after the copulation, the other one did not lay. In a second case of copulation the animal laid after the lapse of thirty-six hours, but this was an unusually long time and probably due to the unnatural conditions surrounding it. In the time that elapses between the period of copulation and deposition, *H. solitaria* is similar to many of the nudibranchs (Smallwood :03).

The question arose as to whether or not copulation took place after laying; in the three cases that I was able to observe copulation did take place after one of the animals had laid but I was unable to observe it between animals both of whom had already laid. Fresh *Haminea* were collected, put into separate dishes, and kept there for three days; during this period they did not lay; then specimens which had copulated and laid were put in with these, copulation followed in each case in about an hour and the animals laid in about twelve hours. Sections of the ovotestis before and after copulation prove the correctness of the above observations.

In copulation the animals do not uniformly assume any definite position in regard to each other. The genital groove opens on the right side just anterior to the lateral fold of the parapodium, thus obviating the necessity for an exact position. Copulation continues for about fifteen minutes.

This species lays a single gelatinous mass (Fig. 9) which is

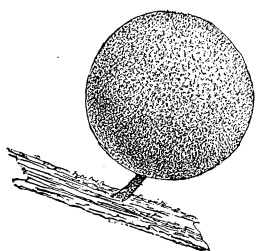


FIG. 9.—The eggs of *H. solitaria* are laid in a gelatinous mass, spherical in form, and attached to some foreign object. The drawing is natural size.

spherical, about three-quarters of an inch in diameter. Its contents are chiefly composed of albumen, which is secreted by the albumen gland. As soon as the albumen comes in contact with the water it swells by the rapid absorption of water, and thus affords a gelatinous protection for the egg. When the eggs first leave the genital groove they are in strings; in a few hours the strings lose their continuity and the eggs are scattered throughout the egg mass. It

would be very difficult to count the eggs in a single mass. The size of the capsule varies considerably; as a rule those found on the eel-grass are about a third less in diameter than those laid on the bottom. The egg masses laid in the laboratory were often irregular in shape and much smaller than those collected from the pond. The specimens in confinement that laid small and irregular masses, often laid a second time without a second copulation. It takes from 40 to 50 minutes for an animal to lay a complete normal egg mass.

The living egg of *H. solitaria* is so small and so richly supplied with deutoplasm that satisfactory observations on the segmentation are impossible except in the early stages. The egg is spherical, enclosed within a thin structureless membrane. The size of the egg varies, the average is about .08 mm., being smaller than the eggs of *Umbrella* (Heymons, '93), *Crepidula* (Conklin, '97), *Nucula* (Drew, :01) and that of most molluscs that have been studied.

Before segmentation the polar differentiation of the egg is but slightly indicated, the yolk being almost uniformly distributed except in the region of the polar bodies. It has already been

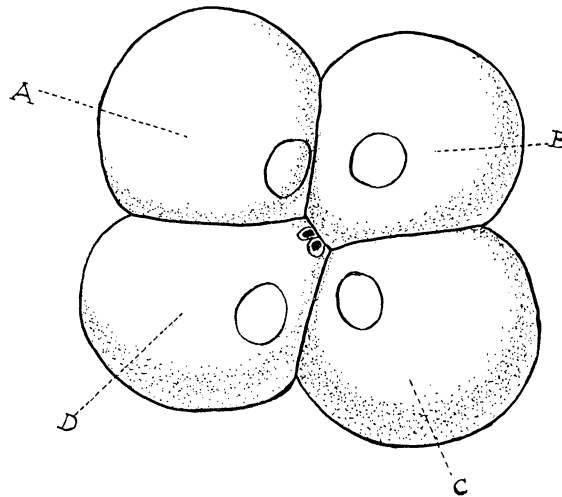


FIG. 10.—The four celled stage which shows the relation between the four blastomeres characteristic of Mollusca. $\times 275$.

stated that it takes forty minutes for the animal to lay a mass of eggs. Within ten or fifteen minutes after each egg is laid the first polar body appears at the animal pole and thirty minutes later the second polar body can be seen. It happens occasionally that the first polar body is very large and may even contain yolk spheres.

The egg segments into two cells a half hour after the second polar body has appeared. In about thirty per cent. of the eggs observed, the first division of the egg did not divide it into two equal blastomeres, one being noticeably larger, a variation which

is similar to Umbrella (Heymons '93). Within thirty or forty minutes after the formation of the two celled stage, the four

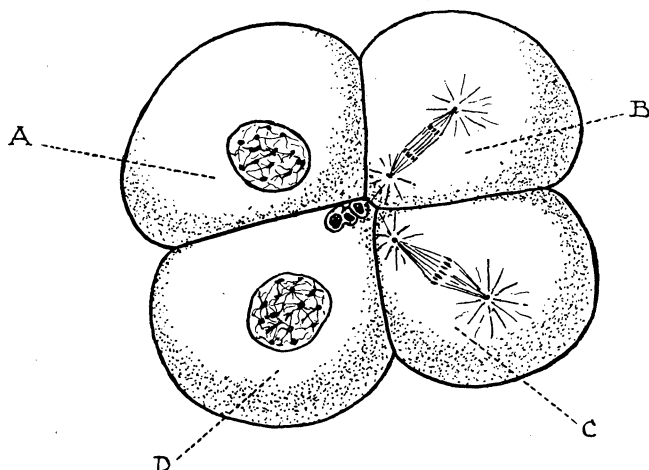


FIG. 11.—The four-celled stage preparatory to the formation of the first quartette of micromeres. $\times 275$.

celled stage is formed. Just prior to the formation of the four celled stage, the spindles do not lie parallel which is an agreement with other molluscs and indicates a spiral division¹ (Fig. 10).

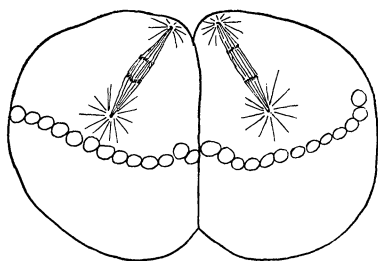


FIG. 12.—A section of the four celled stage passing into the eight celled stage to illustrate the position of the spindles when the micromeres are formed. $\times 140$.

After not more than thirty minutes, the third cleavage separates the egg into two conspicuous parts, the protoplasmic micromeres and the deutoplasmic macromeres. These micromeres are considerably larger in comparison

with the size of the macromeres than in many molluscs. The same is true for the two following quartettes of micromeres

¹ For a complete discussion of the method and significance of segmentation in Mollusca see Mark, E. L., Maturation, Fecundation, and Segmentation of *Limax campestris*. *Bull. Mus. Comp. Zool.* vol. 7, 1881. Conklin, E. G., The Embryology of *Crepidula*. *Jour. Morph.* vol. 13, 1897. Holmes, S. J., The early development of *Planorbis*, *Jour. Morph.* vol. 16, 1900.

which results in the complete envelopment of the macromeres at an early stage. The third cleavage is dextrotropic (Figs. 11, 12, 13, 14).

The time that intervenes between the formation of the second and third quartettes of micromeres is the same as that for the second and third cleavage. From this time on it was impracticable to follow the further cleavage stages on the living egg. Stained preparations confirmed the observations made on the living egg.

The second quartette of micromeres is formed by the fourth cleavage which takes place in an anti-clockwise direction, the

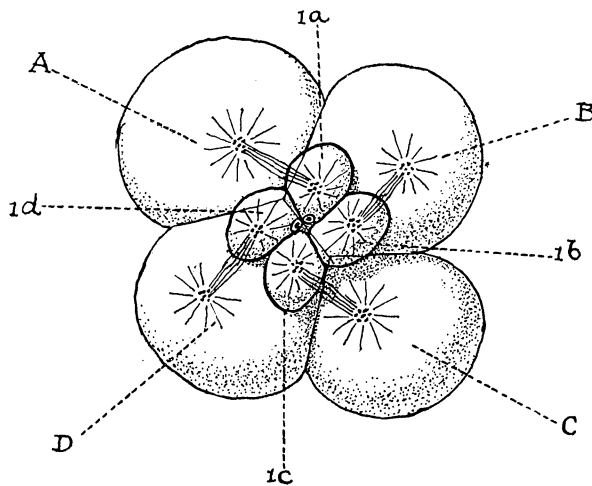


FIG. 13.—The telophase in the formation of the first quartette of micromeres. The movement is dextrotropic.

cells taking a position alternating with the cells of the first quartette (Fig. 15). The next cells to undergo segmentation are the first micromeres formed, segmentation takes place in a laetotropic direction giving rise to the turret (trochoblast) cells (Figs. 15, 16); immediately after, indications of division in the second quartette of micromeres and the macromeres are evident. The egg sketched shows eight complete spindles in the metaphase. The spindles occurring in the macromeres participate in the formation of the last quartette of micromeres, the movement being in a right handed spiral. Soon after the above described

changes have taken place the macromere which is designated by the letter D divides independently of the three other macromeres into two cells of unequal size but both containing yolk spheres. The smaller cell is concerned in giving rise to the mesoblastic bands and is entirely covered above by the micromeres.

It can be seen from the brief description of the early segmentation stages and the accompanying sketches that *Hamina solitaria* does not exhibit any segmentation phenomena other than those characteristic of mollusca. The subsequent cleavage

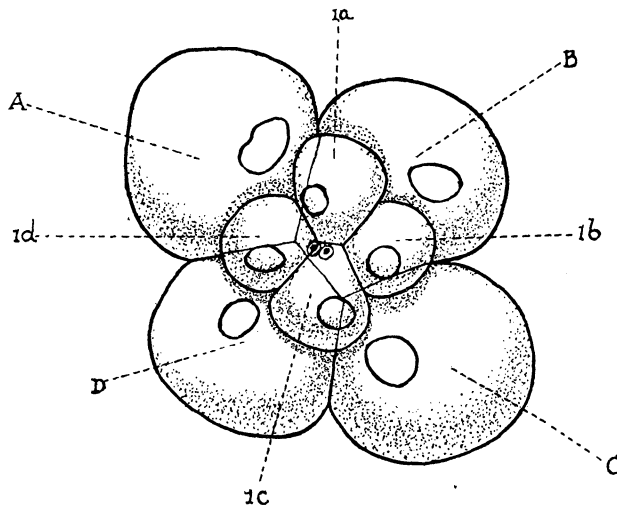


FIG. 14.—The eight celled stage fully formed showing the position of the micromeres above the furrows of the macromeres. $\times 275$.

stages have been followed sufficiently to indicate that they are in agreement with related forms that have been described heretofore.

The embryo usually begins to move in the egg capsule at the end of the seventh day; the cilia on the mantle border are well differentiated and can be seen in motion. It is difficult to ascertain the exact length of time the embryo remains in the egg capsule but I have known it to continue there for a week. In most of the egg masses that have been under observation the embryos have died before becoming free swimming individuals although some were immediately placed in aquaria or in the

eel pond in bottles closed with several thicknesses of cheese cloth. In placing the embryos in their natural environment, it was hoped that it would be possible to determine the changes taking place between the embryo and the adult. Although repeated experiments were made in various parts of the eel pond, no satisfactory results were obtained and I am unable to state how the transition from the embryo to the adult takes place.

During the summer of 1899 a number of pressure experiments were tried for the purpose of determining the effect on segmentation and the subsequent history of the embryo. The fact that the eggs are surrounded by a great mass of albuminous

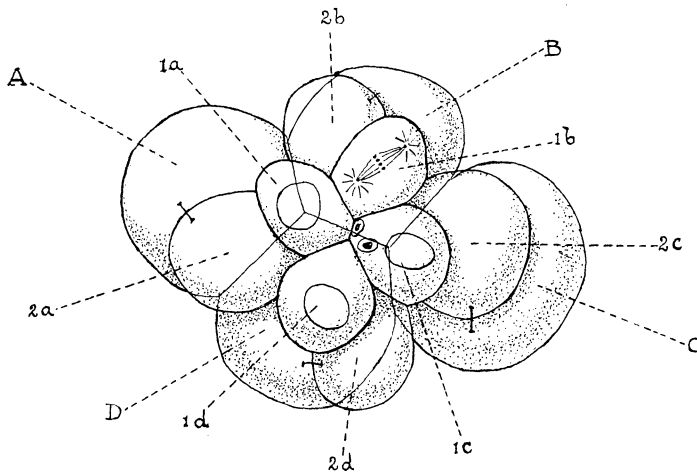


FIG. 15.—The twelve celled stage. The second quartette of micromeres was formed by a laeotropic movement. One cell, 1b, is undergoing segmentation which will result in the formation of a turret cell. $\times 275$.

material made it easy to apply light pressure. A small number of eggs were placed on a slide and covered by a second slide, the amount of pressure was regulated by passing a small rubber band around the slides. The eggs were taken in the one celled stage after the polar bodies had formed; they were left under pressure two hours and the changes which took place during the period were carefully noted. I took pains to see that all of the eggs were forced to segment in an irregular manner. After the pressure was removed the eggs were placed in the aquarium in a bottle which was stoppered with cheese cloth. Although a

number of experiments of this kind were tried with different degrees of pressure I was not able to get any normal embryos. A few abnormal embryos were reared but they lived but a few days. It hardly seems that it will be possible to get any fruitful results from pressure experiments on the eggs of *H. solitaria* for these further reasons: eggs in the egg masses broken during collection develop abnormally, probably because the sea water gains access to them; eggs laid in imperfect egg masses in the laboratory frequently develop abnormally; occasionally I have

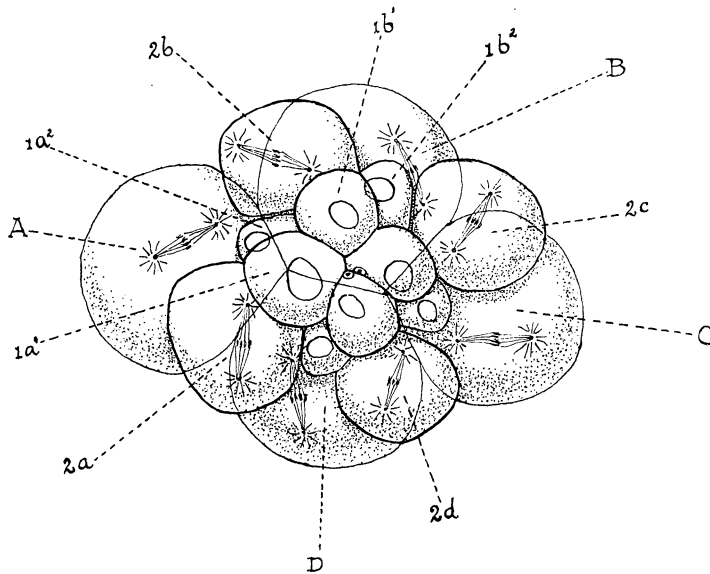


FIG. 16.—The sixteen celled stage. The first quartette of micromeres have given rise to four turreted cells, $1b^2$. The third quartette of micromeres is forming by a dextrotropic movement. The second quartette of micromeres is the process of division. $\times 275$.

collected what appeared to be perfect egg masses and found that the segmentation was very irregular, keeping these eggs under observation, I found that they invariably died in a short time; some apparently normal egg masses have been found to contain eggs in all stages of segmentation from the one celled to the thirty celled stage.

In brief then to summarize: The Tectibranch mollusc, first described by Say, and subsequently by Totten, Verrill, and others, should, according to Pilsbry, properly be regarded as *Haminea solitaria*. The dental formula is $\infty. 1 \infty$. The egg

laying period extends from the middle of June to the last of August during which time the adults migrate from the deep water into shallow ponds and lagoons. The eggs are laid in a gelatinous mass, spherical in form, attached to eel grass, algæ, stones, sticks, etc. The eggs pass from the one celled stage to the free swimming embryo in seven days. The method of segmentation of *Haminea solitaria* is in close agreement with the other mollusca. No positive results were obtained from attempts to produce abnormal segmentation.

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