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ZOOLOGY 10

FEEDING HABITS AND GROWTH

OF

VENUS MERCENARIA

BY

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ZOOLOGY 10

FEEDING HABITS AND GROWTH

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Introduction

In a previous bulletin of the New York State Museum,[1] attention was directed to the fact that both the hard clam, or little-neck, and the common long-neck clam were rapidly diminishing in numbers, not only in the waters of New York State, but also along the entire Atlantic coast where these forms have previously been found. After a careful examination of a large part of the coast of New England and Long Island, it appeared that the apprehensions of many market men and clammers concerning the growing scarcity of these forms were well founded. It was not intended that the attitude of an alarmist should be assumed. Clams still may be had at almost any hotel or restaurant. Even if the natural beds alone are depended on, as heretofore, a certain supply may be had for some time. But it is certainly true that, unless something is done to check or modify the indiscriminate and unintelligent methods of taking these forms now in vogue, the supply is finally to fail more or less completely everywhere, as it has already failed in many localities. That time is not remote. It is difficult for one not personally familiar with the clam flats and beaches, and their histories, to realize the truth of such a statement. While at any time one may obtain fresh or canned lobsters in the market, it is difficult to interest him by the statement that he may not long be able to

[1] Clam and Scallop Industries of New York State. N. Y. State Mus. Bul. 43.

indulge his taste for them; yet even now lobsters are dangerously near extinction on our coast. But it is the consumer who should be interested, if possible, because from him, through his representatives in the Legislature, must come the action which shall make possible new and intelligent methods of propagation which may preserve the supply.

Unpleasant facts of this kind, in any case, should be considered seriously by the public-spirited citizen; but his interest would be enlisted, and his support obtained much more readily, if he could be shown some practical way out of the difficulty.

It has been proved, I think beyond question, that, not only are methods of cultivating the common clam, *Mya arenaria*, easy and inexpensive, but the results of the labor involved are astonishingly great. "Seed" clams may readily be obtained in many localities. They may, when necessary, be transported from one place to another without injury. The planting is a simple process. Small individuals may even be sown broadcast on a soft bottom like so much grain. Unlike the oyster, the salinity of the water makes little difference with their growth. Most important of all, their growth is extremely rapid.

This method of culture, the details of which have been carefully worked out and tested in artificial beds, was developed after a study of the life history, the habits, and the conditions of growth. Everything of scientific interest concerning the form has not been investigated. The early stages of development from the egg, for example, are not yet known; but enough was known to devise an entirely satisfactory and practical method of culture, and this method has been thoroughly tested.

The question may be asked, why, if the demand is increasing and prices are rising, if the supply has everywhere fallen off, and if a cheap and practical method of culture has been devised, do not those who are interested in supplying the market become clam "farmers," instead of remaining clam-diggers?

The answer is that ancient laws still leave beaches and flats to the people. They are public grounds where all have equal rights. On them any one may dig at any time. No man has a right to plant and protect his clams, and clam culture is impossible. To repeal a law of this character is extremely difficult, for it appeals to the many as a cession of their rights to the privileged few. But all would have equal rights to the property by lease or purchase. Good beaches are very numerous, and there is little danger that any would be excluded who might desire such property. The sale and lease of bottoms to oystermen along the shores of Long Island, have apparently worked injustice to no person who is desirous of entering that occupation. At a very few points on the coast, portions of flats have been leased to clammers. These experiments have failed because of a lack of adequate protection. Unless such a system, with proper protection, is introduced by the repeal of old, and the enactment of new laws, soft clam culture will be impossible, and such laws can be had only when they are desired by the people at large.

The little-neck clam, *Venus mercenaria*, grows most abundantly below the low tide line, where it is taken by means of tongs. Much of the shallow bottom about Long Island, in which clams were formerly taken, has been leased to oystermen. The profit from oyster culture is much greater, acre for acre, than that derived from the taking of hard clams, which are left to propagate by the natural method. The areas left to clammers are now limited, and the greater part of the supply used in the canning industry comes from the southern coast. At the same time, clams are rapidly diminishing in the available beds.

The little-neck is also found between tide lines. This fact suggested experiments to determine whether they grow well in such places. Beaches and flats are not now generally available by lease. If this were given, these areas could be more easily protected than those in deeper water, and the matter of planting and digging would be greatly simplified. It is of the utmost importance, however, that clams not continually submerged should increase in size with some degree of rapidity, to insure the success of culture methods under these conditions. An account will be given of this growth in Venus.

Very little is known of the growth of lower organisms. Among the Lamellibranchiata, the group of mollusks to which the clams belong, much is known concerning the growth of the oyster, which, for many years, has been artificially reared in Europe and

America. But, till very recently, no observations have been made on the growth of any clam. In work for the United States Fish Commission, the results of which have not yet been published, Mya was reared in many places, the experiments being carried out on a large scale. In many ways the results were astonishing, particularly in regard to the rapidity of growth. Not only was the actual amount of growth observed, but also the conditions under which it was least and most rapid, or altogether impossible. It was my desire to continue the same line of work with Venus, as nothing was known concerning its growth or the conditions governing it. Though from lack of time and facilities, these experiments were not extensive, they were most encouraging, and show that this form also increases in size rapidly, even when exposed at low tide.

Feeding habits of Venus. Growth a matter of food

Within wide limits, rapidity of growth in clams seems to depend directly on the amount of food. In order to make clear the conditions under which rapid growth is possible, the feeding habits of Venus should be described.

Before such a description is possible, some anatomical features must be noticed. In a clam bed, the animal lies but a short distance below the surface of the bottom. Though the shell is entirely hidden, the creature reaches up to the water above by means of a fleshy extension of the body, which has the form of a double tube. These tubes are known as the siphons, and may quickly be retracted within the valves of the shell. On a smooth bottom, the ends of the siphons may be seen, when the animal is undisturbed, extending out to the level of the surface. A close inspection will show that a steady stream of water is entering one tube [fig. 1, *in. s*] and leaving the other [*ex. s*]. The margin of the first tube is crowned by short, tactile tentacles. When touched by foreign bodies floating in the water, these sense organs cause a closing of the incurrent siphon, or perhaps a retraction of the entire structure. The microscopic diatoms, which form the food of clams, are so small and so evenly diffused in the currents, that they do not induce these movements.

When the animal is removed from the bed, the tight fitting valves of the shell are found to be firmly closed. It may be necessary to break the shell in order to insert a knife blade by means of which the two powerful muscles which connect the valves, and by their strong contraction close them, may be cut. Removing one half of the shell, it is seen that both shell valves are lined on their inner surfaces by thin, fleshy flaps which grow out from the sides of the body. These are known as the mantle folds [*fig.* 1, *m*], and they inclose a large space, the mantle or branchial chamber, in which is found the main part of the body. The body, however, does not entirely fill the mantle chamber, but a large space remains which is filled with water. The siphons are seen to be simply a modified portion of the mantle. It is into this space that the inflowing stream of water, bearing the microscopic food, must enter. The manner in which the food is collected and passed into the mouth will be described presently. While the mantle folds are free at their margins, their edges are closely applied to each other, and the mantle chamber is essentially a closed space, excepting for the siphonal openings.

If now one of these mantle folds be cut away, the body is exposed from the side and appears as represented in figure 1. The mantle fold on the farther side is shown at *m*, lining the entire inner surface of the shell valve, *s*.

Two large, conspicuous folds, *ig* and *og*, the gills, arising from the side of the body, hang free in the mantle chamber. In this position, they are continually bathed by the incoming stream of water, and they perform a very important function in addition to that of the aeration of the blood — that of food collection. Just anterior to the gills, and behind the large anterior adductor muscle, *aa*, are two small folds, *ap* and *pp*, the labial palps. The portion of the palp seen in the figure, *ap*, is simply the lateral extension of a fold which hangs in front of the mouth like a huge lip drawn out to a point on the sides. The posterior palp is similarly placed behind the mouth. The mouth opening is on the median line behind the anterior adductor muscle, and is hidden from view by the closely applied palps. It is a funnellike entrance to the digestive tract, and, because the food of the clam is microscopically small, it is supplied with no special organs such as teeth or rasping structures.

I would call particular attention to the relation in position between these palps and the anterior edges of the gills; for I wish presently to describe the manner in which food is transferred from gills to palps, and by these into the mouth.

When the gills are removed, there is exposed the main mass of the body [*vm*, fig. 2] which is made up chiefly of a large colored gland, the function of which is the secretion of the digestive fluid, and the greatly developed sexual glands. This body in anatomical descriptions, is called the visceral mass, to distinguish it from the muscular organ which is developed on its under or ventral surface — the so called foot, *f*. The last named organ is represented in the figure as being contracted within the mantle chamber. It is capable of great distension and, in a large clam, may be projected for a distance of two or three inches from the edges of the shell. Though a fleshy structure, it is, when protruded, quite tough and firm, being made rigid by a large quantity of blood which is pumped into it by the heart, in order to cause its distension. The foot is an organ of locomotion, and is also used in burrowing. It is possible for Venus to creep about by means of its thrusting and wormlike movements; but I believe that the animal uses it in this way much less than is generally supposed, and this is a point of much interest to the clam culturist.

In order to understand the mechanism by means of which food is collected, it is necessary to describe in more detail the structure of gills and palps. The gills are the most complicated organs in the bodies of lamellibranchs, and must be described here as briefly and as simply as possible, without mentioning their wonderful histological structure. Outer and inner gills are practically the same. Suppose that one of these is carefully removed from its line of attachment to the body, and studied by means of the microscope from the surface and in section: such an examination shows the gill to be not a solid flap or fold, but an exquisitely minute basketlike structure with an outer and inner wall inclosing a space between. These walls are made of extremely fine rods placed side by side, as represented in the most diagrammatic way possible in figure 3. In order that these rods, *r*, may retain their position, they are in many forms, irregularly fused with each other by secondary lateral growths of tissue, *ic*. The outer and inner walls of the gill are also held together by partitions which extend across the inner space between them, *p*. The gill is thus seen to be basketlike, the walls being made of rods between which are spaces, *s*, which put the interior chamber in communication with the mantle space in which the gills hang.

These rods, or filaments, of which the gill is made, contain an interior space in which the blood flows. They were probably primarily developed in order that the blood of the body might be brought in close contact with the water, that, by diffusion, the carbon dioxid of the blood might pass outward through the thin walls, while, by the same process, oxygen, carried by the water, might pass into the blood. But, in addition to performing the function of breathing, the gills have taken on that of collecting minute organisms used as food. This is accomplished by a complicated process.

We have seen that a constant stream of water entered the mantle or branchial chamber. What becomes of it? And what is it that causes the current? All of this water in the mantle chamber streams through the minute openings between the filaments of the gill and enters its interior space. It now rises to the base of the gill, and flows into a tube, the epibranchial chamber [*fig.* 1, *ec*], through which it passes backward, leaving the body by the upper or exhalent siphon, which is directly continuous with the epibranchial chambers of the four gills. The currents which we first noticed, then, enter the mantle chamber by the lower siphon, pass into the interiors of the four gills, flow to their upper or attached edges, and are directed backward and out through the upper siphon tubes of the mantle.

The cause of these rapid currents is revealed by a microscopic examination of the rods or filaments of the gills. These are found to be covered on their outer surfaces, which face the water on both sides of the gill, with innumerable short, hairlike structures which project perpendicularly from the surface. These cilia are protrusions of the living protoplasm of the cells which form the walls of the filaments. Each possesses the power of movement, lashing in a definite direction, and recovering the original perpendicular position more slowly. This movement is so rapid that it can not be seen till nearly stopped by inducing the gradual death of the protoplasm. It is very effective in causing strong currents in the surrounding water.

A microscopic examination, and direct experiment with minute, floating particles, will show that other cilia are present on the filaments than those which cause the water to enter the gills. The diagrammatic figure of the gill [fig. 3] does not show why the minute food particles may not be taken into the interior of the gill by the entering stream of water, and finally out of the body through the broad water channels. This is prevented by long cilia arranged in bands which project out laterally between contiguous filaments in such a way as to *strain* the water which enters the gill, thus preventing all floating matter from entering. These highly specialized cilia tracts of lamellibranch gills, I have called the "straining lines."[1] In some forms there is a single line, in others there are two. In some cases the lines are formed by a single row of cells; or a section across the line sometimes reveals several closely crowded cells bearing the greatly elongated straining cilia.

That foreign matter is really excluded as the current of water enters the gill, may be demonstrated by direct experiment on a living gill. Carmine may be ground into a fine powder, and suspended in water without becoming dissolved. If a small amount of this is allowed to fall on the surface of a living gill, it will be seen to lodge there. A wonderful thing now occurs. A myriad of separate minute grains, which may represent the food of the clam, are almost instantly cemented together by a sticky mucus which is secreted by many special gland cells in the filaments, and the whole mass, impelled by the oscillations of the cilia, begins to move with some velocity toward the lower or free edge of the gill. On this free margin is a groove into which the material collected on the faces of the gill is turned.

1 Kellogg, J. L. Contribution to Our Knowledge of Morphology of Lamellibranchiate Mollusks. U. S. Fish Com. Bul. 1892.

This groove is also lined by ciliated cells, and the whole mass is swept swiftly forward in it toward the palps. The natural food of the clam, of course, is carried forward in the same way. It is evident that a large proportion of the organisms floating in the water which enters the mantle chamber must come in contact with the sides of the gills, and be carried forward to the mouth folds, to which they may be transferred.

These points may be made more clear by referring to the diagram [fig. 4]. It represents a section made transversely across the filaments of a typical lamellibranch gill. In a single gill there are thousands of these rods. But five are shown here on each side, standing in row to form the perforated walls of the gill. Each rod is represented as being more or less oval, when its cut end is viewed in this way. In three places are shown the lateral union of filaments. The reference letters *ig* are supposed to be placed in the interior space of the gill, and *p* shows the nature of the partition, or septum, which, at more or less regular intervals, stretches across this space and holds the two walls of the gill together.

The details of cellular structure have been drawn in two filaments. The long, straining cilia, which stretch across the spaces between rods, are shown at *sc*, and the arrow indicates the course taken by the water current as it enters the interior of the gill. The cilia which cause this entering current are the frontal cilia, *fc*. Opening on the surface between them and the straining cilia are the gland cells, *gc*, the secretion from which cements together the food particles.

This figure is not intended to represent the details of structure found in the gill of Venus, which is much more complicated in many ways. The general plan of structure and of function in that form, however, is very much as represented, and this diagram is used because it may be so much more easily described.

If we now examine the palps with a hand lens, we may notice that their inner surfaces — those nearest to the mouth — are covered by a set of very fine parallel ridges. The lateral portions of the palps are shown in figure 2, *ap* and *pp*. They are capable of many movements. They may be bent and spirally twisted, lengthened or shortened, and, if their inner faces touch the edges of the gills, any material which is being brought to this region is transferred onto the ridges of the palp. This is accomplished by strong cilia which are developed on the ridges. These same cilia carry the foreign matter on across the ridges, and finally force it into the mouth [arrow on *pp*].

This, in brief, is the method by which clams and oysters and other lamellibranchs collect and ingest their food. The process, till very recently, has not been closely studied, but this automatic feeding process has been known in a general way for a long time. It has sometimes been said that, if a lamellibranch is to prevent suspended mud from being collected by the gills, it must close its shell, thus entirely preventing all ingress of water into the body. It has been found that these creatures have no more control over the activities of the cilia which have been described than a man has over the cilia in his trachea. As long as the animals live, the cilia continue to lash in the same definite directions, though their activities soon become lessened after the shell is removed.

But I have found that the animal can prevent food or particles of dirt from being taken to the mouth while the stream of water is yet flowing. It seems never to have been suspected that complicated mechanisms existed, by means of which collected particles could at once be discharged from the body. They are present, however, probably in all lamellibranchs, differing somewhat in different forms, and I shall describe the comparatively simple one which is found in Venus.

If the mantle and gills are removed from one side of the body, so as to expose the visceral mass and the foot, and the creature is put into a dish of sea water, grains of carmine, which are allowed to settle on the surface of the visceral mass, at once indicate the presence of a ciliation there, as well as on palps and gills. These experiments require care and patience, but they show with great certainty that the most definite cilia currents exist in this region. These are indicated by the arrows placed on the visceral mass in figure 2. It will be seen that all the currents converge at a definite point, *x*, just above the line of the base of the muscular foot on the posterior margin of the visceral mass. Any material, then, which touches this surface, instead of being taken toward the mouth, tends to be forced in the opposite direction. Immediately on touching the wall of the visceral mass, the fine particles are cemented together by an abundant mucus, as on the gills. When much carmine or mud is used, a large ball of it is collected at *x*. It will be noticed that this region lies directly in the path of the incoming stream of water from the branchial or lower siphon; and at first sight it would seem that from this position there could be no means by which it could escape from the mantle chamber. Clams undisturbed in the bottom, however, from time to time may be seen to discharge a strong jet of water from both siphons. This habit of many lamellibranchs is better shown in Mya. When these clams are kept in a bucket of water over night, the floor will be wet for many feet around it in the morning, and indeed one may at any time when they are so kept, see them violently close the shell by contracting the adductor muscles, thus emptying the mantle chamber by throwing a strong jet out of both siphons. This peculiar habit of all lamellibranchs which have been observed is, without doubt, for the purpose of removing masses of material which the animal can not use as food.

This is not the only means of discharging undesirable material from the mantle chamber. If the entire body be removed, leaving only the mantle lining the shell on one side, it also will be found to be ciliated. In this case, as illustrated in figure 5, everything is swept downward toward the free edge of the mantle, and falls into a line parallel with the edge, and is then directed backward. Particles which may fall on the extreme edge are also passed into this well marked stream. Everything is directed backward, but can not be carried out of the incurrent siphon against the stream which is entering through it. In a little bay beneath the base of the siphon, where it is out of the current, the material is collected. By the contraction of the adductor muscles, and the resulting emptying of the mantle chamber, as described above, this collected mass is expelled.

But, in spite of the activities of these two surfaces, which tend to rid the body of material not fit for food, it is evident that, if much mud is entering, large quantities of it must be collected on the gills and be sent forward toward the mouth. I have spoken of the fact that the palps are capable of extended movements. If they are withdrawn so as not to touch the gills, material will accumulate in the anterior parts of the gill grooves till masses are formed so large that they fall off into the space of the mantle chamber below — perhaps to be taken up by the currents on the mantle. At any rate, they would be discharged when the mantle space was emptied. I have no doubt, especially after what I have observed in forms like Yoldia, that the palps of Venus are from time to time withdrawn from contact with the gills, in order that they may receive no material from them.

It is when we come to examine the palps that we find the most complex arrangement for keeping material from entering the mouth when that is desirable. A close examination of the inner faces of the palp shows a narrow strip around its margin which is without the ridges previously described. Both of these margins are very densely ciliated. When suspended material falls on the upper margin, it is carried up onto the surface of the ridges [fig. 2, *um*] and across them to the mouth. Anything which touches the other margin, on the other hand, is swept with great rapidity in the other direction — out to the end of the palp, where it accumulates and is finally thrown off into the mantle chamber below. It is true that this margin is narrow, and not much material suspended in the water would strike it; but probably when a large quantity is collected on other parts of the palp, this edge is folded over so as to touch these heavily laden surfaces, and sweeps them clean.

It thus appears that there are extensive ciliary tracts for collecting and conveying food to the mouth; but that, in addition to these, there are other ciliated surfaces by means of which undesirable material may be excluded without the necessity of closing the shell. Because of the advantage of sustaining the aeration of the blood, this must be of very great service when the water is muddy.

In this description of the feeding habits of Venus many important details have been omitted, particularly in regard to the anatomy of the gill, which is much more complicated than is indicated in the figures.

The question of food is an important one when we are searching for means of rearing this clam by some culture method. In order to force the growth of oysters in French *claires*, water is held in reservoirs back of the beds till the contained diatoms may have multiplied greatly, and is then allowed to run over the beds. Such methods are expensive, and under proper natural conditions, Venus will grow very much faster than either the European or American oyster. Enough has been said of the food of Venus to make it clear that, if it were raised on beaches or flats, we should not expect to find so rapid a growth as if it were never exposed, for feeding is impossible without water currents. I hope to show, however, that growth seems to be very rapid even under these circumstances.

Growth experiments

Before speaking of these experiments, it will be well to make it clear that the planting was done on a small scale, and was pursued under the most adverse circumstances. I believe that the results as we have them are perfectly certain — and they are most satisfactory as they are; but I am also sure that under favorable conditions growth would have been very much greater.

A trip was made to Riverhead, and the shore examined carefully as far as Greenport. Many clams are found along this shore, and several sites were located, which, so far as currents and character of bottom were concerned, seemed to be ideal. In every case, however, I was assured that clams would not be allowed to remain unmolested for a week. So certain did this seem, that the very much less favorable harbor at Cold Spring, on the sound, was selected. Here also it appeared that no portion of any of the beaches would be free from molestation by clam-diggers. The only thing to be done was to ask the privilege of a small space on an oyster bed which extended close to the low water mark. This was granted by Captain Jones, who has my sincere thanks for this favor, and also for the kindly interest which he showed in the work.

The rights of the oystermen seem to be strictly respected. I ventured to run some of my beds up on the narrow beach nearly to the high tide line, marking them by labeled wires which were run down out of sight. These I easily found in the winter, but some of the beds had been raked clean. Others certainly escaped observation. Before planting, the ground was raked, that I might be assured that no little-neck clams were present in it. I am very positive that the beds and sealed wire cages on the oyster ground had not been touched when they were examined after an interval of six months.

But the unfavorable conditions were these. Everywhere above and below these beds, oysters covered the bottoms as close as they could lie. They take from the water the same floating organisms which Venus uses for its food. Everywhere, too, above and below low tide line, soft clams were burrowed almost as close as they could be placed. They also use the same food. Now, we have experimental evidence to show that the growth of all these forms is, up to a certain point, directly proportionate to the amount of food. They all grew here; for, on account of the conditions of the upper harbor, where at high tide the shallow water, fed by fresh-water streams, was warmed for hours by the sun, diatoms must have multiplied with great rapidity, and, when carried out, offered abundant food. But undoubtedly none of these lamellibranchs grew as they would if the life of the bottom had not been so abundant.

As an example of the number of these organisms on the bottom, this case may be cited. A flowerpot, 4 inches across the top, filled with clean sand, was sunk nearly to the level of the ground on June 19, 1901. In it was placed a little-neck clam. When examined Dec. 28 of the same year—six months afterward—the sand in this pot contained 11 soft-shelled clams ranging from half to three quarters of an inch in length, besides the hard clam, which had increased considerably in size. These soft clams had settled in the pot from the swimming larval condition, as they settled elsewhere on the bottom, and had begun to grow. It is most reasonable to suppose that, if this hard clam had been growing on almost any beach where less life was being supported, its growth would have been more rapid, for diatoms are more or less abundant all along the shore.

Another serious hindrance to the growth of clams is the presence of the seaweeds, Ulva (sea lettuce) and Enteromorpha which, during the greater part of the year, grow profusely after their attachment to large pebbles or other solid bodies on the bottom. Not only the larger stones on these beds, but, especially, the wire cages which were sunk into the bottom, were in December more or less completely covered by them. In extended experiments on the growth of the soft clam, Mya, the same difficulty was met with in many localities. The masses of weed, flattened out on the bottom by the tide currents, greatly hinder the clams underneath from obtaining from the water their needed food. My experiments with both forms show that this condition is detrimental to the best results. If one were free to select sandy ground which would afford no means of attachment, this difficulty would not appear.

These matters are spoken of in detail because the results which will be given should, without doubt, have been far greater. Any one with rights to certain parts of a beach, who could watch his beds at all times of the year, could, with very little labor, prevent these drawbacks.

Still another difficulty attending the work at Cold Spring was the fact that it was almost impossible to obtain clams small enough for planting. None were to be had in this locality. A number were sent from Jamesport, L. I., but most of them were of marketable size, and hence too large for the most important part of the experiment. The smaller ones came from New Bedford Mass., and these had perhaps previously been received from Edgartown. It must however be said that the hard clam, like the oyster and quite unlike the soft clam, Mya, will live for many days, and even for weeks, after being removed from the water during the hot summer time, without apparent injury. The soft clam may be preserved in this way for a long time during the winter, and very small individuals may safely stand much exposure in hot weather; but the larger forms of this species succumb after a short time. The tenacity of life in the small Venus may also be greater than in the adult, but nothing is known in regard to it.

Methods

Each clam was measured in sixteenths of an inch at the time of planting, and also when taken from the bottom six months afterward. Merely to state the increase in length, however, gives no adequate idea of the actual growth. It is much better to give the increase in volume. To state that a clam increases from $1\frac{2}{16}$ to $1\frac{12}{16}$ inches in a certain time gives little idea of its actual growth. If individuals of the two sizes are held in the hand and compared by the eye, the bulk of one is seen to be much greater than that of the other. It is really this increase in volume which we wish to determine, so each clam was measured also by determining its displacement in water. A table was made showing the displacement of clams of various sizes. For example, many individuals just 1 inch in length were measured in a graduated vessel. There is some slight variation, because some are thicker than others. The average of many measurements, however, show that a clam of this length displaces 2.5 c.cm. The average displacement of other sizes was determined in the same way.

To illustrate the difference in the two ways of stating the increase, we may compare clams 1 and 2 inches in length. One is 100% longer than the other. One has a volume of 2.5 c.cm, the other a volume of 22 c.cm; and, while a clam 1 inch long has increased in length 100%, it has increased in bulk or volume 780%. This increase in size or volume is what we wish to determine.

Suppose that in a certain bed are placed clams all of a size. When these are dug, after a lapse of several months, some individuals will have increased in size more than others, though the differences may not be great. In order to determine the increase in such a bed, the arithmetical mean length of the whole series has been calculated, and the volume of the mean has been compared with the volume of the clams when planted.

In one bed, for example, several clams $1\frac{3}{16}$ inches in length were planted. In six months they were removed, and the length of each individual carefully measured. There was some individual variation in the length; so the mean length of the series was calculated. It was found to be $1\frac{12}{16}$ inches. The average volume of clams $1\frac{3}{16}$ inches long is 4.5 c.cm; that of individuals $1\frac{12}{16}$ inches long is

14.5 c.cm, or 3.22 times as great. The increase in volume in the six months, therefore, was 222%.

Growth between tide lines

The most important point brought out in this experiment is the fact that growth is considerable on bottoms exposed for several hours at low tide. This is shown in the following cases.

A line of flowerpots was run from below ordinary low water mark up the steeply sloping beach to a point about two feet below the ordinary high water line, the fall of the tide being about six feet. The pots were sunk so that their tops were level with the ground, and were separated by a space of about two feet. June 19, 1901, there was placed in each of these pots a clam 1.25 inches, or — to give the measurements for convenience's sake in sixteenths of one inch — $1\frac{4}{16}$ inches in length. These were examined, after an interval of six months, on Dec. 28. Some of the pots were empty or contained dead shells. In the first or highest, the clam had grown to a length of $1\frac{11}{16}$ inches, an increase of 148% in volume in the half year. If we had no other example of growth, this would be very suggestive, for the increase is great, the creature having become in this short period almost two and a half times as large as when planted.

We should expect to find still greater growth with longer immersion.. In the second pot, the clam had increased 154%, and in the third, still lower down, 172%.

The fourth pot was empty. In the fifth, the increase, instead of being greater still, was only 87%. The explanation of this seems to be perfectly clear, and is exemplified in several other cases. Around the margin of this pot there had grown a large quantity of Ulva. There was much of it at this level of the beach, while higher up it was not abundant. Without doubt this seaweed was flattened out over the top of the pot by the current, in such a way as to prevent free access to the food-bearing stream, and for this reason growth was not so rapid.

The presence of these weeds, which grow on so many bottoms, should not seriously inconvenience the clam culturist. They may be removed without difficulty with a rake, and do not grow abundantly on a surface which is reasonably smooth. If it had been possible to visit these beds a few times during the summer, the results in the case of many lower beds would undoubtedly have been different.

In pots still lower down, all of which were covered with Ulva, the growth was much the same as in the fifth — from 80% to 100% increase.

In this line of pots, then, the fact is demonstrated that between tide lines, hard clams 1.25 inches long may increase 2.5 times or more in volume in half a year. Localities more favorable for their growth could easily be found. If experiments were made on a large scale, I should expect to get a more rapid average growth even where the forms were exposed at low tide, and a much greater increase on bottoms which are never exposed. As it is, this growth as compared with that of the oyster is marvelously rapid, just as it is in the soft clam.

It should be noticed that we are not attempting to make extended generalizations on the data given by four or five individual clams. Two clams side by side will not increase at the same rate. It is possible that one might grow twice as fast as another. But, if we had a single case in which we were certain of the amount of increase, it would assuredly indicate the possibilities of growth, and the chances are that it would not by any means be the limit of possibility.

On the other hand, when we compare the growth in pots 1, 2 and 3 and find a progressive increase from the higher to the lower pot — an increase of 145%, 154% and 172% — our induction is founded on insufficient data, and really means nothing. The result is as we should expect it, but it may be entirely accidental. But it is suggestive, and, if it were possible to observe many rows of clams similarly placed, we might reasonably expect to establish it. Unfortunately it has not been possible to do this.

The simple case of the line of flowerpots has been spoken of first because it was more or less typical of the results obtained in many small beds planted under similar conditions. Many hundreds of clams, after being carefully measured, were segregated into groups according to length and planted together. Their growth substantiates the results obtained in the flowerpots.

Very briefly the following results will be described. Several small beds, each with an area of 16 square feet, were laid out on the gravel between tide lines. A group of these was separated by an interval of 20 or 30 yards from another group. Most of these small plots were within the boundaries of the oyster bed already mentioned, but some were above the line of the bed, and a few of them were dug clean. Others were not discovered by clam diggers, and apparently entirely escaped molestation.

In each of these small beds, clams all of a size were planted. The number on a bed varied from 100 to 175. I would call particular attention to the fact that on the deeper beds, where the tide currents were swiftest, larger stones were exposed, and there was here an abundant growth of seaweed, which was not found farther up on the beach. This always interfered seriously with the growth of the clams.

For example, on these beds which were below the ordinary low tide line, where we should expect to find the most rapid growth, there was an increase in volume in clams $1\frac{12}{16}$ inches long, of 35%; in those $1\frac{4}{16}$ inches long, of 41%; and in those $1\frac{10}{16}$ inches long of 42%. I am all the more certain that this low rate of growth is to be explained by the presence of the seaweed, because I had previously had the same experience in a much larger experiment in the soft clam. Fortunately, as I have already stated, a little labor by one who is able to be on the spot during the entire year would prevent this result.

Some of the higher beds, however, which from the character of the bottom were free from the weed, gave different results, and show the possibilities of growth much better. On a bed only three or four feet from ordinary high water line, there was placed on July 6, 130 clams, $1\frac{4}{16}$ inches long. On Dec. 30, almost the entire number was removed. Some had increased more than others. The mean of the series was calculated, and showed an increase of 255% in volume in a little less than six months.

On another bed, somewhat lower, 150 clams $1\frac{6}{16}$ inches long had increased 157% in volume. One of the things to be expected is that clams of smaller size would show a relatively greater growth. It has not been possible to make comparisons to demonstrate this because of the influence of the seaweed on so many beds. The variation in the size of planted clams in this experiment was from $1\frac{2}{16}$ inches to $1\frac{12}{16}$ inches in length, and this is not a very great range.

On a third bed, also situated well up on the beach, clams $1\frac{8}{16}$ inches long when planted had increased 155% in volume in the six months. Whether the amount of food in the summer is greater than in the winter, I do not know. I have no doubt that the increase goes on during the winter months, though, it may be, with diminished rapidity. It would be extremely interesting to carry out these experiments on a large scale through the entire year. These facts certainly show that the possibilities of growth in Venus are very great, and indicate that its artificial culture between tide lines would be easy and inexpensive, and that it would yield large results. Considering the place which the little-neck has in the markets, it would seem that the artificial culture of the form should yield a larger income than does the culture of the oyster as carried on in Long Island sound. The latter is expensive and laborious, and growth is very much slower than in the case of either of the clams.

Wandering habits of Venus

The soft or long-neck clam, Mya, is capable of locomotion only when very small. As the body increases in size, the foot, or locomotor organ, becomes relatively smaller. An individual 2 inches long, while it can not move along the surface of the bottom, is still able to use the foot as a burrowing organ. When it has attained a length of 3 or more inches, however, it seems to be incapable even of covering itself in the bottom.

In the case of the hard clam, Venus, on the contrary, the foot remains throughout life a very well developed locomotor organ. Though no definite experiments have been made to demonstrate what it is able to do, one might assume, from the size of the organ and its power of extension as demonstrated in aquaria, that the animal is able at all times in its life, not only to burrow but also to move from one locality to another, as the fresh-water clams, with a similar foot, are known to do.

The beds in this experiment were planted with the fear that the clams would wander. The result, however, showed conclusively that they do not have this habit — or that they did not exhibit it in this particular case. The clams were found where they were placed within the limits of the original beds. Careful digging around the margins of the beds failed in every instance to show any wandering tendencies.

Growth under wire netting

In order to be perfectly certain that clams should have no means of escape, three cages of wire netting were constructed, bounding the margins of the area containing clams in each case to a depth of 5 inches and covering the top. These forms never burrow to a greater depth than this, and there was no possibility of escape. In each case the netting remained intact, and certainly was not disturbed. These beds were exposed only during the full moon tides. Here also the seaweed seemed to play an important part in the results. In one case the netting was sunk so deep as to be covered with sand, and consequently no seaweed attached, as it did on the other cages. Growth was much more rapid here, though the clams in this bed were smaller when planted, and, as a consequence, a more rapid growth should have been expected.

The results were as follows:

Cage 1 Clams planted July 6, $1\frac{8}{16}$ inches long. Some seaweed was attached to the wire of the cage. The clams were removed Dec. 30. The increase in volume was 145%.

Cage 2 Planted July 6, $1\frac{6}{16}$ inches in length. Removed Dec. 30. A very large quantity of weed over the cage. Increase in volume, 78%.

Cage 3 Planted July 6, 1 ^{4} inches long. This cage was sunk so deep that no weed was attached on the surface. The increase Dec. 30 was 222% in volume in the six months.

Growth above the bottom

In methods of oyster culture as developed in France, the forms are placed in racks above the bottom, and from the tide which sweeps over them, they are enabled to obtain nourishment enough for comparatively rapid growth. It would be an interesting thing to show that clams could be made to grow in this way. The clam culturist could then make himself independent of beach rights, and perhaps more easily obtain a lease of ground for such a purpose below low water mark.

But one or two very small experiments on the soft clam have indicated that the creatures do not do well under these conditions. At Cold Spring a wire rack was constructed, and anchored above the bottom in a swift current. Into it were put several hard clams ranging from $1\frac{4}{16}$ to $2\frac{12}{16}$ inches in length. Every one of these seemed to be in a healthy condition at the end of six months, but not one had increased a particle in size. Not being able to cover the body in sand, they seem to have remained most of the time with valves closed. They may possibly have moved about at times, for their shells were worn, but more likely this was due to the fact that they were rolled about in the cage by the currents. On their smooth, clean surfaces numbers of Anomias, or silver shells, had attached and grown, as shown in figure 6.

Though this small attempt to induce growth above the bottom ended in failure, it should, on account of its importance, be repeated on a large scale under as many different conditions as possible, in the hope that some combination of circumstances might prove to be the right one.

Enemies

Neither of the clams is molested by the starfish after it has become large enough to burrow, though the very small soft clam, and perhaps the hard clam also, is destroyed in great numbers by small starfish, before it is able to cover itself. So far as I have been able to discover, there is but one natural enemy of Venus which might possibly be destructive. It is the gastropod mollusk, Lunatia [fig. 7], which is abundant in some localities. It is found in numbers at Cold Spring. On several occasions I have observed it digging below the surface and attacking both hard and soft clams in their burrows. By long continued labor, it files a smooth, clean hole through the shell of its victim by means of a rasping organ in its mouth cavity, and then destroys the soft parts of the body within. Figure 8 illustrates the character of the borings on shells taken from the beds at Cold Spring. In every case the perforation is near the prominence of the shell called the umbo, directly over the pulpy visceral mass, which might most easily be sucked up through the opening. It is a curious fact that this region of the shell is selected by Lunatia for boring in any lamellibranch which it attacks. It may not invariably be so, but I have many shells of different species which have been drilled in this region, and have happened to notice no exceptions to it.

No matter how numerous it might be, this enemy would probably not be as troublesome to clam culture as the starfish is to the oyster industry. In several places I have seen it collected by fishermen for bait, simply by pegging a bit of fish, or even a dead starfish on the bottom. In a short time numbers of them will be found collected on the bait. By some such simple means, if it were desirable, a clam bed probably could easily be rid of the creatures.

Conclusion

This experiment on the growth of Venus from lack of means and time and favorable locality has been a limited one. In order fully to demonstrate the feasibility of the artificial culture of the form, it should be carried out on a very much larger scale, and should be extended through a longer period of time. There can be no doubt about the accuracy of the results in the case of the wire cages, the growth in which has been described; and, from their position, I have no reason to think that the clams were disturbed on the other beds which have been cited as examples of growth. Some of the higher beds seem to have been discovered by clammers, and these were raked clean.

The figures giving the percentages of growth, though not numerous, at least indicate the fact that the most essential feature of the culture of the little-neck clam — rapidity of growth — is all that could be desired. Neither has anything appeared which would suggest a natural difficulty in the way of artificial culture.

DESCRIPTION OF FIGURES

Figure 1

Side view of large *Venus mercenaria.* Mantle fold on right side of the body has been removed. The edge of the left fold of the mantle is shown at *m.* The exhalent, *ex. s,* and inhalent, *in. s,* siphons are modified parts of the mantle.

Water bearing food and other floating substances enters the space between the mantle folds — the mantle chamber — through the inhalent siphon. Hanging in this chamber are the foot, *f,* and gills, *og* and *ig.* Cilia on the gills cause water to enter them, forcing it to their bases, into the epibranchial chambers, *ec,* and then backward and out of the body through the excurrent siphon. This is indicated by fine, dotted arrows. The two large transverse muscles — the anterior and posterior adductors — which, by their contraction, close the valves of the shell, are shown at *aa* and *pa.*

Reference letters: *aa,* anterior adductor muscle; *pa,* posterior adductor muscle; *ec,* epibranchial chamber; *og* and *ig,* outer and inner gills; *ap* and *pp,* anterior and posterior palps; *ex. s* and *in. s,* exhalent and inhalent siphons; *f,* foot; *m,* edge of left mantle fold; *s,* ventral margin of shell.

Figure 2

Drawn to show that floating particles which touch the surface of the visceral mass are taken posteriorly and thrown off into the mantle chamber at x. From this region, they are removed from the body by the contraction of the adductor muscles, which discharges a large part of the water in the mantle chamber.

At *pp* is shown the striation of the inner side of the posterior palp, over which food is taken to the mouth. The unstriated margin is also shown.

Other reference letters as in figure 1.

Figure 3

Paper model of lamellibranch gill. A diagrammatic figure to show the basketlike structure of the gill.

Reference letters: *ic,* interfilamentar connections; *p,* partition or septum holding the two halves of the gill together; *r,* a rod or filament; *s,* space between filaments.

Figure 4

Diagrammatic section across the filaments of a typical gill. Arrows represent the course taken by water which enters the gill. Reference letters: *ig*, interior of gill; *p*, septum between sides; *gc*, gland cells, the secretion from which cements floating particles into a mass on the outer surfaces of the gill; *fc*, fine frontal cilia causing water to enter gill; *sc*, straining cilia preventing solid matter from entering the gill and moving it to the ventral margin.

Figure 5

View of inner surface of left mantle fold of Venus, showing course taken by particles which touch it. These are discharged from the body when the stream entering the mantle chamber through the lower siphon is reversed by contraction of adductor muscles.

Figure 6

Hard clams kept in wire cage above the bottom for six months. All shells were covered by attached Anomia, or silver shells.

Figure 7

Lunatia, a gastropod mollusk, which bores shells and destroys clams.

Figure 8

Venus shells bored by Lunatia.

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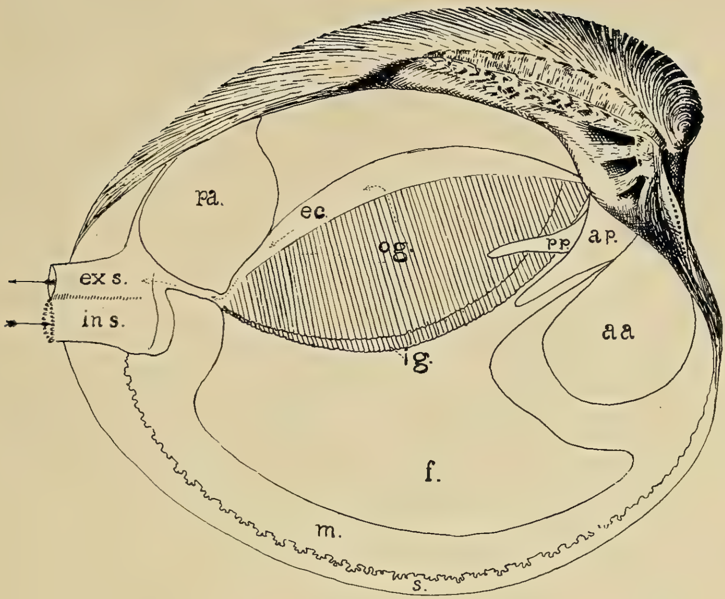
Figure 1



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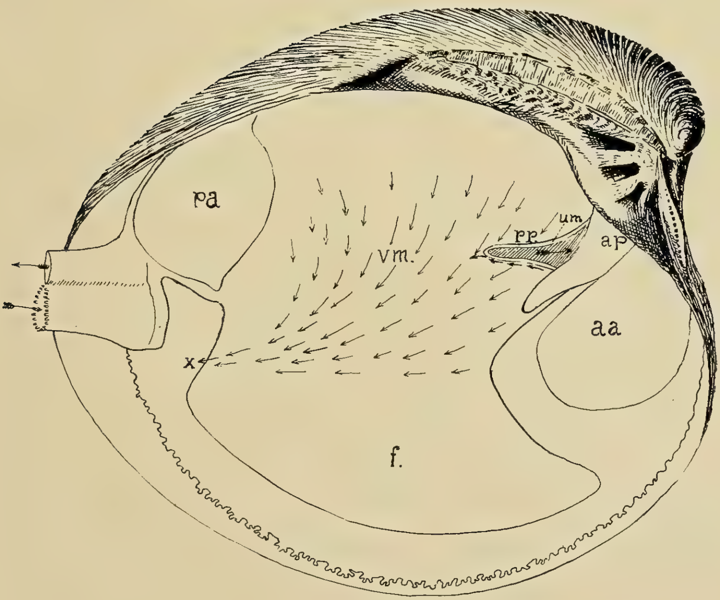

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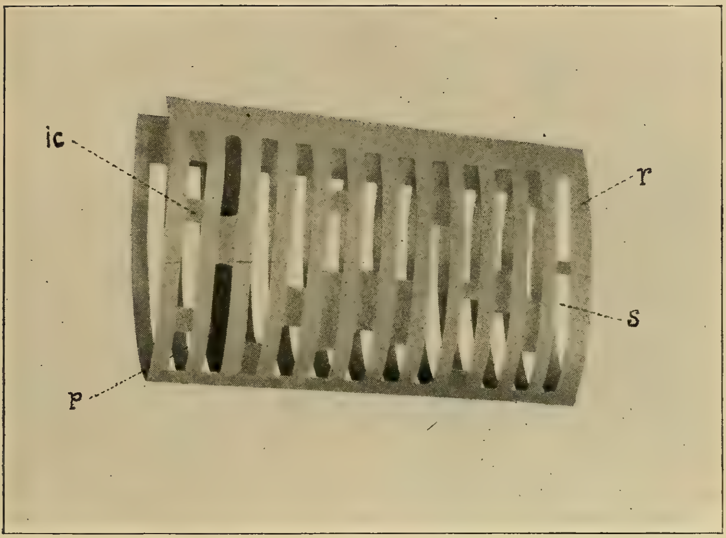

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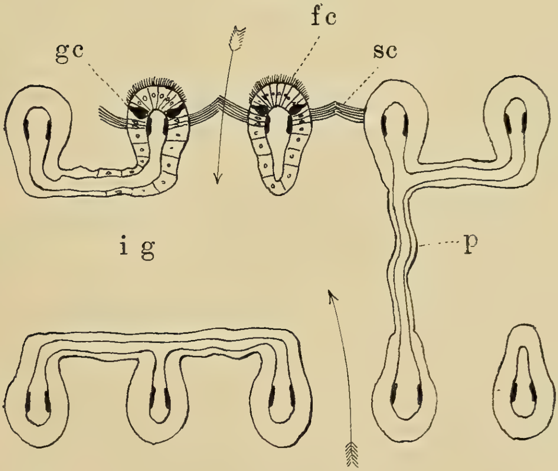

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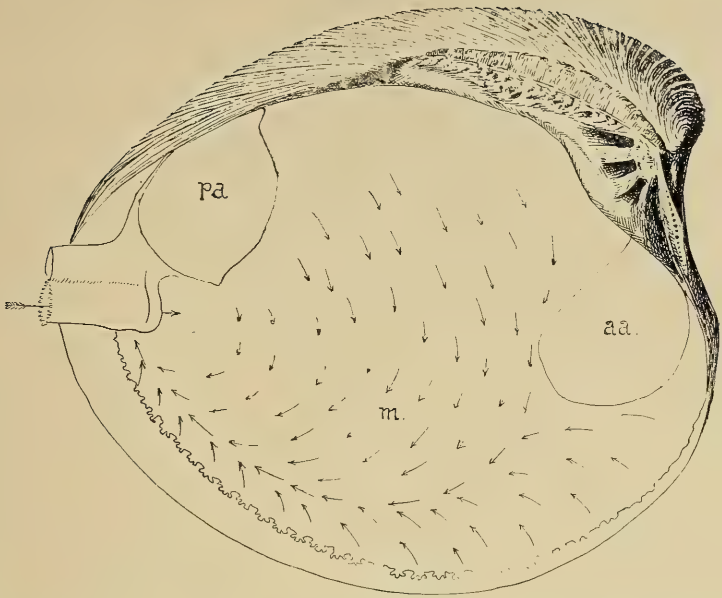


Figure 6

Figure 7

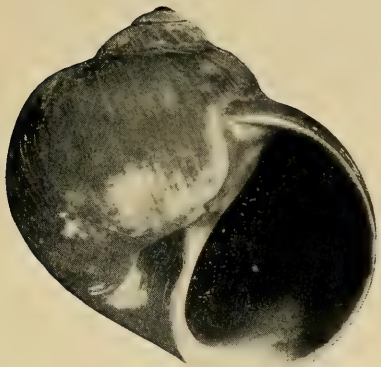
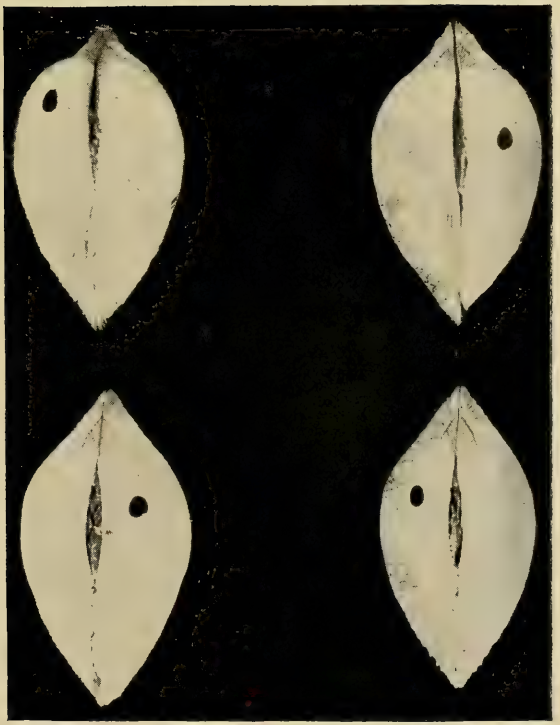


Figure 8



University of the State of New York

New York State Museum

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These reports are made up of the reports of the director, geologist, paleontologist, botanist and entomologist, and museum bulletins and memoirs, issued as advance sections of the reports.

Geologist's annual reports 1881–date. Rep'ts 1, 3–13, 17–date, O; 2, 14–16, Q.

The annual reports of the early natural history survey, 1837–41 are out of print.

Reports 1–4, 1881–84 were published only in separate form. Of the fifth report four pages were reprinted in the 39th museum report, and a supplement to the 6th report was included in the 40th museum report. The 7th and subsequent reports are included in the 41st and following museum reports, except that certain lithographic plates in the 11th report (1891) and 13th (1893) are omitted from the 45th and 47th museum reports.

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Report	*Price*	*Report*	*Price*	*Report*	*Price*
12 (1892)	$.50	16	$1	19	$.40
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15, 2v.	2	18	.75	21	.40

In 1898 the paleontologic work of the State was made distinct from the geologic and will hereafter be reported separately.

Paleontologist's annual reports 1899–date.

See fourth note under Geologist's annual reports.

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Reports 3–17 bound also with museum reports 40-46, 48-55 of which they form a part. Since 1898 these reports have been issued as bulletins. Reports 3-4 are out of print, other reports with prices are:

Report	*Price*	*Report*	*Price*	*Report*	*Price*
1	$.50	8	$.25	13	$.10
2	.30	9	.25	14 (Ent. bul. 5)	.20
5	.25	10	.35	15 (" 9)	.15
6	.15	11	.25	16 (" 10)	.25
7	.20	12	.25	17 (" 14)	.30
				18 (" 17)	.20

Reports 2, 8-12 may also be obtained bound separately in cloth at 25c in addition to the price given above.

Botanist's annual reports 1867–date.

Bound also with museum reports 21-date of which they form a part; the first botanist's report appeared in the 21st museum report and is numbered 21. Reports 21-24, 29, 31-41 were not published separately.

Separate reports 25-28, 30, 42-50 and 52 (Botany bulletin 3), are out of print. Report 51 may be had for 40c: 53 for 20c; 54 for 50c; 55 (Botany bulletin 5) for 40c; 56 (Botany bulletin 6) for 50c. Since 1901 these reports have been issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have been published in volumes 1 and 3 of the 48th museum report and in volume 1 of the 49th, 51st, 52d, 54th and 55th reports. The descriptions and illustrations of edible and unwholesome species contained in the 49th, 51st and 52d reports have been revised and rearranged, and, combined with others more recently prepared, constitute Museum memoir 4.

Museum bulletins 1887–date. O. *To advance subscribers, $2 a year or 50c a year for those of any one division:* (1) *geology, economic geology, mineralogy, general zoology, archeology and miscellaneous,* (2) *paleontology,* (3) *botany,* (4) *entomology.*

Bulletins are also found with the annual reports of the museum as follows:

Bulletin	*Report*	*Bulletin*	*Report*	*Bulletin*	*Report*
12–15	48, v. 1	20–25	52, v. 1	35–36	54, v. 2
16–17	50 "	26–31	53 "	37–44	" v. 3
18–19	51 "	32–34	54 "	45–48	" v. 4
				49–54	55, v. 1

The figures in parentheses indicate the bulletin's number as a New York State Museum bulletin.

Geology. **G1** (**14**) Kemp, J. F. Geology of Moriah and Westport Townships Essex Co. N. Y., with notes on the iron mines. 38p. 7pl. 2 maps, Sep. 1895. *10c.*

G2 (**19**) Merrill, F: J. H. Guide to the Study of the Geological Collections of the New York State Museum. 162p. 119pl. map. Nov. 1898. [*50c*] *New edition in preparation.*

G3 (**21**) Kemp, J. F. Geology of the Lake Placid Region. 24p. 1pl. map. Sep. 1898. *5c.*

G4 (**48**) Woodworth, J. B. Pleistocene Geology of Nassau County and Borough of Queens. 58p. il. 9pl. map. Dec. 1901. *25c.*

G5 (**56**) Merrill, F: J. H. Description of the State Geologic Map of 1901. 42p. 2 maps, tab. Oct. 1902. *10c.*

G6 Cushing, H. P. Geology of the Vicinity of Little Falls, Herkimer Co. *In preparation.*

—— Crystalline Rocks of the Northeastern Adirondacks. *In preparation.*

Kemp, J. F. Crystalline Rocks of Warren and Washington Counties. *In preparation.*

Woodworth, J. B. Glacial Geology of New York. *In preparation.*

Economic geology. **Eg1** (**3**) Smock, J: C. Building Stone in the State of New York. 152p. Mar. 1888. *Out of print.*

Eg2 (**7**) —— First Report on the Iron Mines and Iron Ore Districts in New York. 6+70p. map. June 1889. *Out of print.*

Eg3 (**10**) —— Building Stone in New York. 210p. map, tab. Sep. 1890. *40c.*

Eg4 (**11**) Merrill, F: J. H. Salt and Gypsum Industries in New York. 92p. 12pl. 2 maps, 11 tab. Ap. 1893. *40c.*

Eg5 (**12**) Ries, Heinrich. Clay Industries of New York. 174p. 2pl. map. Mar. 1895. *30c.*

Eg6 (**15**) Merrill, F: J. H. Mineral Resources of New York. 224p. 2 maps. Sep. 1895. *50c.*

Eg7 (**17**) —— Road Materials and Road Building in New York. 52p. 14pl. 2 maps 34x45, 68x92 cm. Oct. 1897. *15c.*

Maps separate 10c each, 2 for 15c.

Eg8 (**30**) Orton, Edward. Petroleum and Natural Gas in New York. 136p. il. 3 maps. Nov. 1899. *15c.*

Eg9 (**35**) Ries, Heinrich. Clays of New York; their Properties and Uses. 456p. 140pl. map. June 1900. *$1, cloth.*

Eg10 (**44**) —— Lime and Cement Industries of New York; Eckel, E. C. Chapters on the Cement Industry. 332p. 101pl. 2 maps. Dec. 1901. *85c, cloth.*

Eg11 (**61**) Dickinson, H. T. Quarries of Bluestone and other Sandstones in New York. 108p. 18pl. 2 maps. Mar. 1903. *35c.*

Mineralogy. **M1** (**4**) Nason, F. L. Some New York Minerals and their Localities. 20p. 1pl. Aug. 1888. [*10c*]

M2 (**58**) Whitlock, H. P. Guide to the Mineralogic Collections of the New York State Museum. 150p. il. 39pl. 11 models. Sep. 1902. *40c.*

M3 (**70**) —— New York Mineral Localities. *In press.*

Paleontology. **Pa1** (**34**) Cumings, E. R. Lower Silurian System of Eastern Montgomery County; Prosser, C: S. Notes on the Stratigraphy of Mohawk Valley and Saratoga County, N. Y. 74p. 10pl. map. May 1900. *15c.*

Pa2 (**39**) Clarke, J: M.; Simpson, G: B. & Loomis, F: B. Paleontologic Papers 1. 72p. il. 16pl. Oct. 1900. *15c.*

Contents: Clarke, J: M. A Remarkable Occurrence of Orthoceras in the Oneonta Beds of the Chenango Valley, N. Y.
—Paropsonema cryptophya; a Peculiar Echinoderm from the Intumescens-zone (Portage Beds) of Western New York.
—Dictyonine Hexactinellid Sponges from the Upper Devonic of New York.
—The Water Biscuit of Squaw Island, Canandaigua Lake, N. Y.
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