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ABSTRACT

These three units are designed for use with standard science curricula. These publications, relating to animals of the sea, are: Protozoa, Sponges, and Coelenterates. Included are teacher guides, student activities, and demonstrations designed to impart ocean science understanding to high school students. Objectives to be attained from the unit on Protozoans include: (1) identification of radiolarians, foraminiferans and tintinnids; (2) descriptions of life processes in these protozoans; and (3) identification of oceanic sediment produced by radiolarians and foraminiferans. After studying the unit on Sponges, students should be ab[illegible]: (1) list the classes of sponges; (2) describe the life fun[illegible] habits; and (3) describe sponge reproduction and its [illegible]ce to sponge industry. At the end of the unit on Coelentera[illegible]dents should be able to: (1) list the classes; (2) describe l[illegible]on and feeding habits; and (3) describe relationship between the reproductive stages representing alternation of generation phenomena. This work was prepared under an ESEA Title III contract. (Author/EB)

ANIMALS OF THE SEA:
COELENTERATES

FOREWORD

Prior to 1970, Charleston County possessed no formal program to develop an organized study of ocean science. A few teachers would cover selected topics on occasion, but there was no formal, district-wide effort to make ocean science curricula available to all students in the secondary schools of the district.

The increasing emphasis on the study of the oceans by federal, state, and local governments and the resultant increase in the importance of the ocean to all citizens has created a need for coherent ocean science programs for all students. Nowhere is the need for coherent study of the sea more immediately relevant than in Charleston County. The county is permeated with food and sport-filled waterways and heavily dependent on naval and commercial shipping. Present and future problems in harbor maintenance and problems of estuarine multiple use indicate a need for a local citizenry literate in ocean science. The most effective means of developing large-scale literacy is the public school.

This publication is one of a series made possible through a Title III, ESEA grant entitled Oceanographic Science Conceptual Schemes Project. These publications are designed for use in standard science curricula to develop oceanologic manifestations of certain science topics. The publications include teacher guides, student activities, and demonstrations designed to impart ocean science understanding to Charleston County high school students.

The members of the ocean science staff include Dr. Gary Awkerman, Director of Natural Sciences, Mr. Michael Graves, Assistant Director of Natural Sciences, and Mr. Paul F. Teller, curriculum specialist in ocean science. They were assisted by the following writing staff: Sister Bernadette Kostbar, Ms. Beverly Lauderdale, Ms. Dorothy Bonnett, Ms. Caroline Pearson, Ms. Pat Hayes, Mr. Tommy Yon, Mr. Nat Bell, Mr. Steve Proctor, and Mr. Leonard Higgins. Principal typists were Ms. Anita Skinner, Ms. Roberta Brown, and Ms. Lynda Wallace. Without their cheerful, dedicated efforts and excellent typing, this project could not have been completed.

Special thanks are due to consultants Dr. Norman A. Chamberlain and Dr. F. J. Vernberg, who contributed much valuable information on tides and estuaries, respectively. Ms. Virginia Bolton prepared the cover drawings. Mr. Paul F. Teller completed the internal figures.

Gary L. Awkerman
Director of Natural Sciences

What kinds of animals live in the sea? Coelenterates

Objectives:

At the end of this exercise, the student should be able to:

1. SKETCH the basic body form of coelenterate polyps and medusae.
2. LIST the three classes of coelenterates.
3. DESCRIBE the relationship of medusoid and polyp stages in each of the three coelenterate classes.
4. DESCRIBE nematocysts and the two factors required to cause discharge.
5. DESCRIBE locomotion in the coelenterates.
6. DESCRIBE feeding in hydrozoan and anthozoan polyps.
7. DESCRIBE feeding in hydrozoan medusae and in *Aurelia*.

Materials and Supplies	No.	Source
1. Compound microscope	30	Classroom
2. Stereomicroscope	30	Classroom
3. Prepared microscope slides of:		
a. Obelia medusa	10	Biological Supply Houses
b. Obelia hydriod	10	" "
c. Gonicnemus medusa	10	" "
d. Craspedacusta medusa	10	" "
e. Aurelia schyphistoma	10	" "
f. Arelia ephyra	10	" "
4. Preserved specimens or plastic mounts of:		
a. Sea anemone (various sections of Metridium)	6	Biological Supply Houses (Ward's #55W0400)
b. Coral types	6	(Ward's #55W0435)
c. Portugese Man-of-War (Siphonophore)	6	(Ward's #55W0300)
d. Astrangis danae, preserved	6	Carolina POM 880
e. Sea Pansy	6	Biological Supply Houses
f. Aurelia medusa	6	Carolina POM 825
5. Living examples of:		
a. Obelia hydroid (or other hydroids)	15	Woods Hole, Pacific Bio-Mar.
b. Hydromedusae (any)	15	" "
c. Sea anemone (Metridium)	15	" "
d. Jellyfish	15	" "
e. Sea Pansy	15	" "
f. Coral (Astrangia danae), chunks	15	" "
6. Shrimp, clam, oyster (fresh)	15	Seafood house
7. Petri dishes, syracuse dishes, or small bowls	15	Biological Supply Houses
8. Individual slide boxes (for prepared slides)	10	" "
9. Depression slides and coverslips	15	" "
10. Artemia (brine shrimp) eggs (vials)	1	" "
11. Beaker (for brine shrimp culture)	1	Classroom
12. Air pump (or extension hose from main aquarium pump)	1	Biological Supply Houses
13. Salt-water aquarium assemblies (10 gallon)	2	Classroom
14. Rubber gloves (pairs)	15	Housewares of any store

15. Microslides (flat) and coverslips	15	Biological Supply Houses
16. Beakers (500 ml.)	15	" "
17. Dissecting Kits	15	" "
18. Beakers (50-100 ml.)	15	" "
19. Glass rods 1/8" - 1/4"	15	Class stock
20. Bunsen burner (for drawing roads)	15	Class stock
21. Hypodermic syringe or needle	5	Biological Supply Houses
22. India ink or carmine suspension (bottles)	1	Class stock
23. Filter paper, any grade (disks)	15	Class stock
24. Litmus powder (vials)	1	Biological Supply Houses

Teacher introduction

General

The coelenterates include jellyfish, sea anemones, corals, and the familiar Hydra. The corals include not only the animals who build the great reefs of warm oceans, but also the yellow weed-like growths and the sea pansies that are often encountered on the beach.

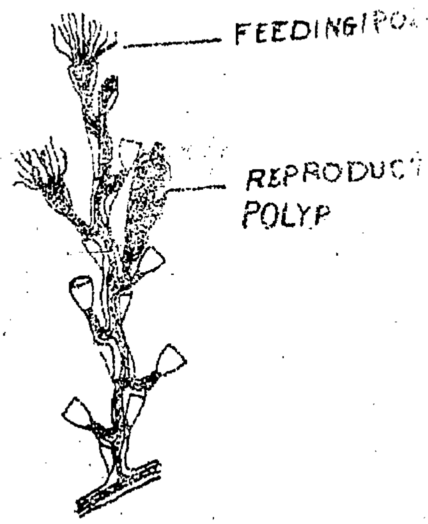
HYDRA - A POLYP

The coelenterates exist in two basic forms, the polyp and the medusa. Polyps are sessile, tentacled forms that remain in one place and trap animals on their tentacles. Hydra is an example of a coelenterate polyp. The medusae are umbrella-shaped animals that live up in the water column, moving through pulsations of their bell-shaped bodies. Their dangling tentacles serve to ensnare other animals on which they feed. The medusa is typified by the common jellyfishes.

HYDROZOAN JELLYFISH- A MEDUSA
AFTER MKOLITECH, 1967

In many cases, the medusa and polyp forms are parts of the life cycle of a single species. The polyps are generally asexually reproducing sessile forms that bud off sexally

reproducing, planktonic medusae. This existence of two vastly different forms fulfilling sexual and asexual roles in the life cycle of a single species is called <u>metagenesis</u>. The medusoid and polypoid forms show varying degrees of dominance in the life cycles of different species.



OBELIA GENICULATA
A COLONIAL POLYP
AFTER BARRETT & YONGE, 1958

The class Hydrozoa possesses a wide range of comparative dominance of the two forms from absence of polyp through equal dominance to absence of the medusae. The genus <u>Obelia</u> is a coelenterate frequently encountered in biology classes. The polyp phase is a branched colony composed of many diverse individuals. It buds off well-organized, conspicuous medusae which carry out the sexual reproductive functions. Other hydrozoans retain the medusae on the parent colony. Others have dispensed with medusae altogether and can reproduce sexually as well as asexually. <u>Hydra</u> fits the last category.

The class Scyphozoa includes the large jellyfishes, which range from a few inches to seven feet in diameter

with tentacles over a hundred feet long. In this class, the medusoid phase is clearly dominant. The polyp form is almost microscopic. It exists only as a body which buds off medusae. It is not a highly organized entity as in the case of *Hydra* and *Obelia*.

The class Anthozoa includes the sea anemones and corals. The medusoid phase is absent in the class and polyps are capable of both sexual and asexual reproduction.

Body Plan

The polyps and medusae are both built on the same basic plan. The body consists of inner and outer walls separated by a jellylike mesoglea. The basic shape is that of a barrel, the inside of the barrel being called the gastrovascular cavity. One end of the barrel is closed off. The outside surface of this end forms the pedal disk of *Hydra* and the sea anemones. The medusa is like an inverted polyp. The closed end of the barrel forms the upper surface of the umbrella.

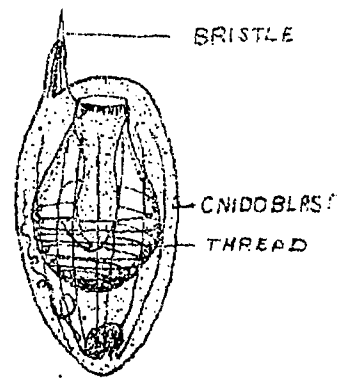
The other end of the barrel is open, forming the mouth. The mouth is

surrounded by one or more whorls of tentacles, each containing an extension of the gastrovascular cavity. The basic body plans of medusae and polyps are shown in figure 1.

Nematocysts

The tentacles of coelenterates possess entities found almost nowhere else in the animal kingdom. These are the nematocysts. Stinging nematocysts are the bodies responsible for the painful brushes with jellyfishes by summer swimmers. Other nematocysts include adhesive cells and snares which entangle the prey.

An undischarged nematocyst consists of a bulb with a thread coiled inside it. It is contained within a cell called a cnidoblast. The cnidoblast possesses a bristle which acts as a trigger for discharge of the nematocyst. When a prey animal or a swimmer brushes the bristle, the permeability of the nematocyst wall changes. The nematocyst swells with water and the resulting pressure causes the thread to explode from the capsule and hit the target organism. The nematocyst thread had been



NEMATOCYST OF A HYDRA
(UNDISCHARGED)
AFTER BROWN, 1950

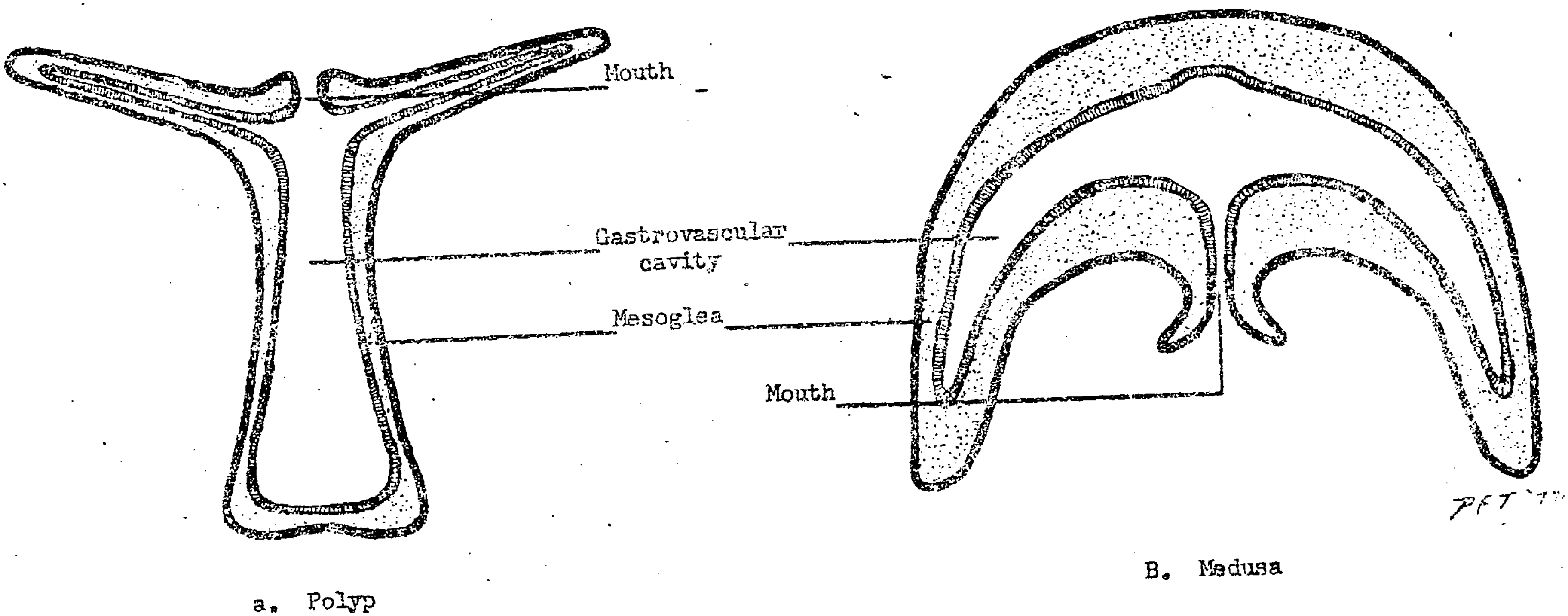
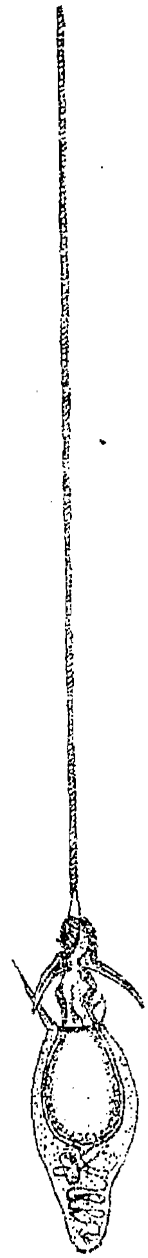


Figure 1. Coelenterate Body forms

coiled in the inside of the tube like the finger of a rubber glove that has been pushed down inside the palm of the glove. When the nematocyst ruptures, the thread everts just as if one had puffed the finger of the glove back out by blowing up the glove like a balloon.

The eversion of the nematocyst thread exposes the various end structures of the nematocyst. These can consist of adhesive ends, snares, or pointed barbed tips which penetrate the prey and inject powerful toxins. The toxins of some species, such as the Portugese Man-of-War, can cause severe pain in human beings. The pain can be so intense that the victim can be crippled and may drown.



HYDRA NEMATOCYST (DISCHARGED) AFTER BROWN, 1950

The Classes of Coelenterates

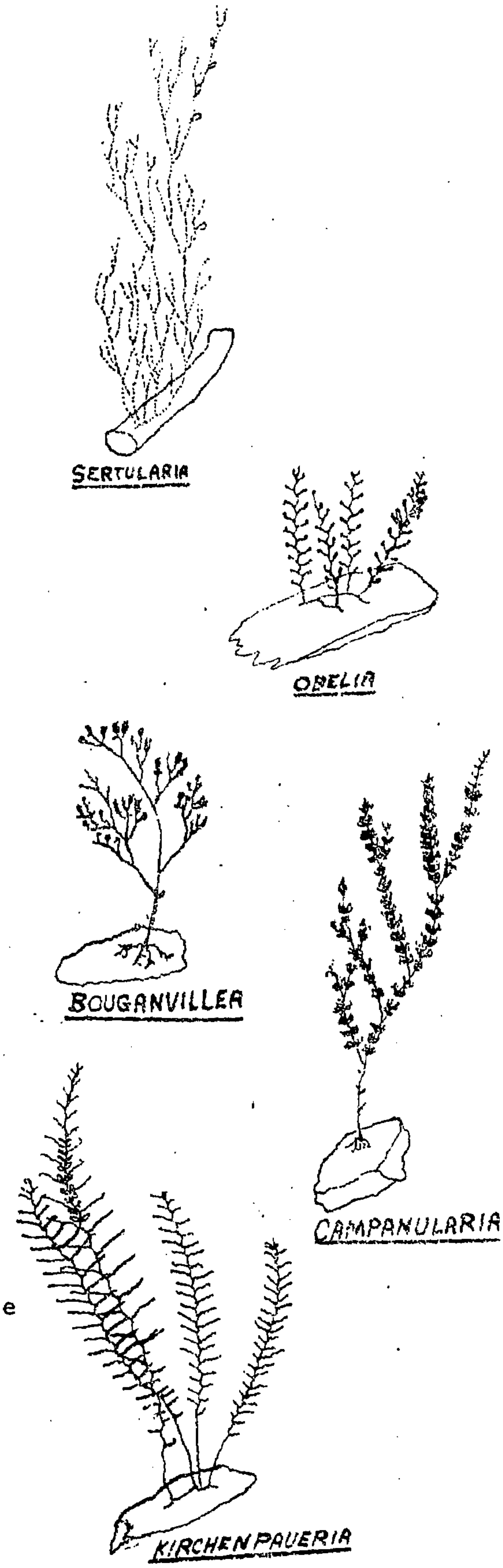
Class Hydrozoa

The hydrozoa include many common coelenterates usually overlooked by the layman. These include the hydroids, branched polyp colonies of various sizes which are usually mistaken for seaweed. Under even low magnification, the mistake is apparent. They appear

as variously branched colonies of one or more types of individuals that are definitely animal. The most animal-like members of the colony are the feeding polyps. These resemble multitudinous hydras, with one or more whorls of tentacles surrounding a mouth. There are also reproductive polyps, which contain medusae which will be budded off to swim away as independent animals. There may also be club-shaped defensive polyps with their ends loaded with various types of stinging nematocysts.

All of the individuals of the colony are connected by a common gas-grovascular cavity. The feeding polyps capture the food and partially digest it. They pass the resulting broth into the common gastrovascular cavity, whence it circulates throughout the entire colony. Various other members of the colony will pick out their share of the broth and digest it in intracellular vacuoles similar to those of protozoans.

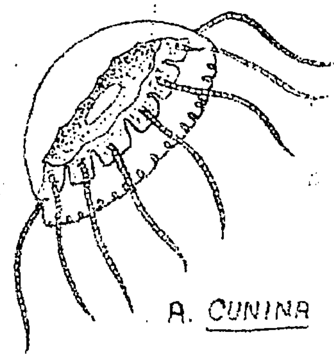
The entire colony may be covered by a thin transparent exoskeleton which



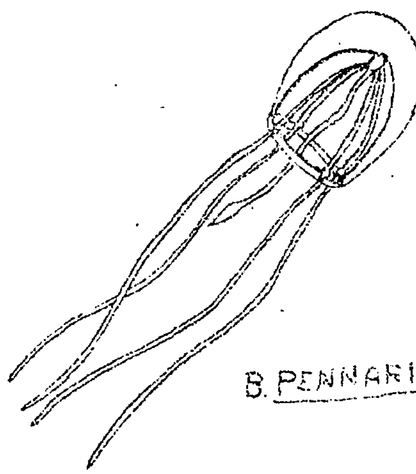
SOME COMMON HYDROIDS (x1)
AFTER BARRETT & YONGE, 1958

sheathes the branches. In some cases the exoskeleton may stop at the base of the feeding polyps, leaving the tentacles and mouths exposed. In others it may sheath the whole polyp, enabling the polyp to expand out of the exoskeleton and retract quickly back into it. There may even be an exoskeletal lid which will shut over the polyp, completely protecting it. The exoskeleton also sheathes the reproductive individuals, forming a vase-shaped covering with a terminal pore through which the young medusae may escape to the open sea.

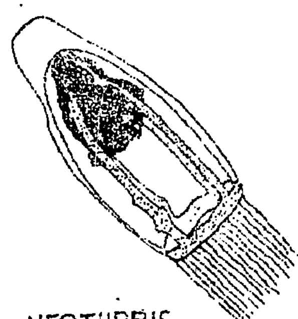
The medusae of the Hydrozoa are small compared to the commonly noticed Scyphozoan jellyfish. They range from an eighth of an inch to several inches in diameter. The lower margin of the umbrella usually projects inward to form a shelf called the velum. The gastrovascular cavity not only possesses the barrel-like shape of the polyp, but branches off in a series of radial canals which resemble the spokes of a wheel. These branch from the main cavity high up



A. CUNINA



B. PENNARIA



C. NEOTURRIS

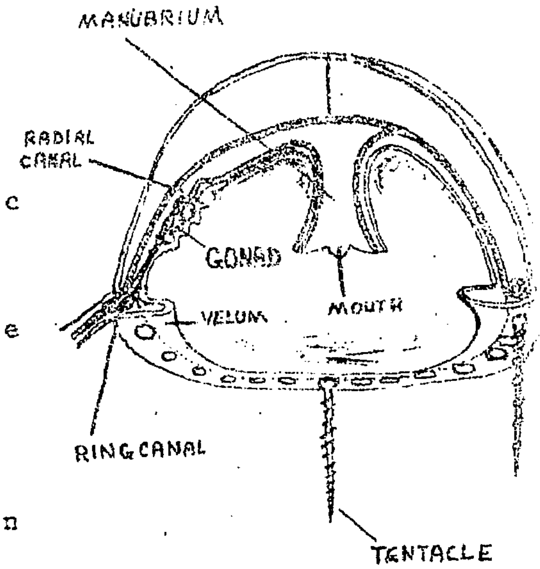
HYDROZOAN MEDUSAE
(A) AND (B) FROM MEGLITSC
(C) FROM RAYMONT, 1963

in the umbrella and run down the sides to the margin. In the margin of the umbrella, or bell, they enter a ring canal which runs all the way around the lip of the bell.

The mesoglea of the bell of the medusa is very thick and is responsible for the bulk of the animal. It is the thickening of this layer which gives the bell of both the hydrozoan and scyphosoan medusae their characteristic shapes.

The mouth of the hydrozoan medusae opens at the end of a long tube called the manubrium.

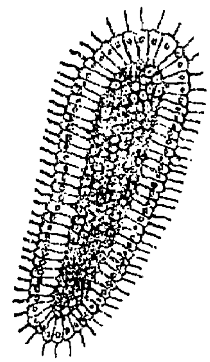
The medusa moves by jet propulsion which is especially effective in species with a well-developed velum. Muscles of epidermal origin are best developed around the margin of the bell. Contractions of these muscles squeeze water out of the subumbrellar cavity, pushing the medusa in the opposite direction. A well-developed velum constricts the subumbrellar opening and contributes to the buildup of a more powerful effective thrust of the ejected water. At the end of a stroke, water re-enters the



ANATOMY OF A HYDROZ[illegible]
MEDUSA
(FROM MEGLITSCH, 1967)

the subumbrellar space and the animal is ready for the next stroke. Contractions are rhythmic. The frequency of contraction is determined by various factors including light, temperature, and the presence of food.

The gonads of the medusae are often seen running beneath the radial canals. These shed eggs and sperm into the water. The resulting zygote usually becomes a flat, bilaterally symmetrical larva which attaches to some solid object and grows into a hydroid colony.

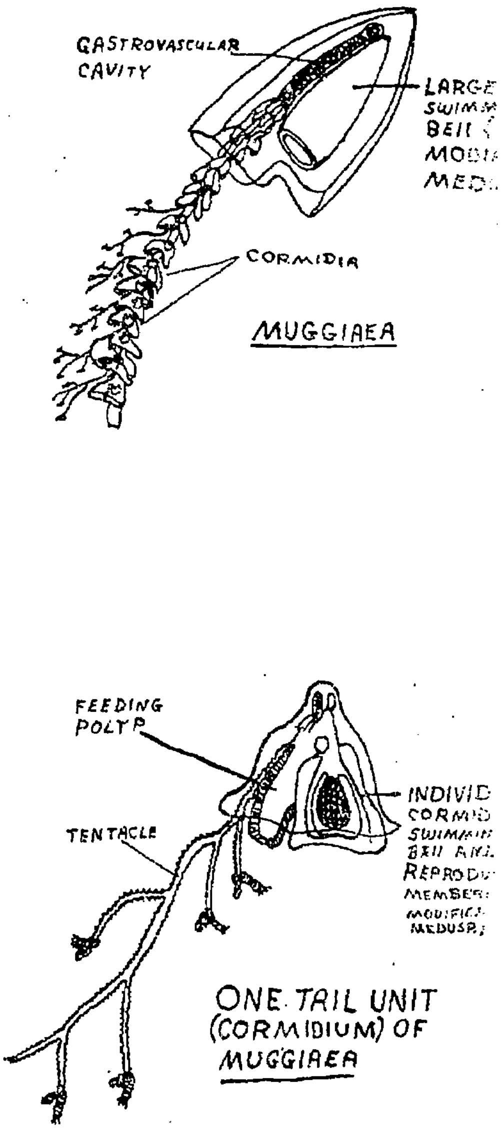


HYDROZOAN LARVA
(AFTER MEGLITSCH, 1967)

Many hydroids retain the medusa as part of the parent hydroid. Still other polyp stages have taken over the medusoid function of sexual reproduction. Some hydrozoans have gone to the opposite extreme. The medusa is dominant, and the polyp stage is insignificant or absent. The zygote of some produces a larva which transforms directly into a medusa. Very small polyps exist in *Gonionemus*, a common Atlantic medusa, and in *Craspedacusta*, the only freshwater medusa in the United States.

One order of hydrozoans merits

particular attention. These are the siphonophores, planktonic colonies of polyps and attached medusae. The famous Portugese Man-of-War (Physalia in figure 2) is one of these. Locomotion is produced by pulsating, modified, attached medusae whose collective thrust is utilized to push the colony along. Other medusae may be reproductive. Feeding is conducted by the polypoid members. Other members of the colony are modified to secrete gases into a bag-like float. Most siphonophores can control gas secretion to sink beneath the surface in inclement weather. The Portugese Man-of-War lacks this ability and is always seen drifting on the surface. Siphonophores may be quite large and may be of great beauty in form and in luminescence. They are mostly tropical and subtropical in distribution, but the stranded blue to purple floats of the Portugese Man-of-War are frequent visitors to the Atlantic shores of the United States.



A SIPHONOPHORE

(AFTER HYMAN, 1940)

Class Scyphozoa

The scyphozoan medusae are the large jellyfishes observed in ocean waters

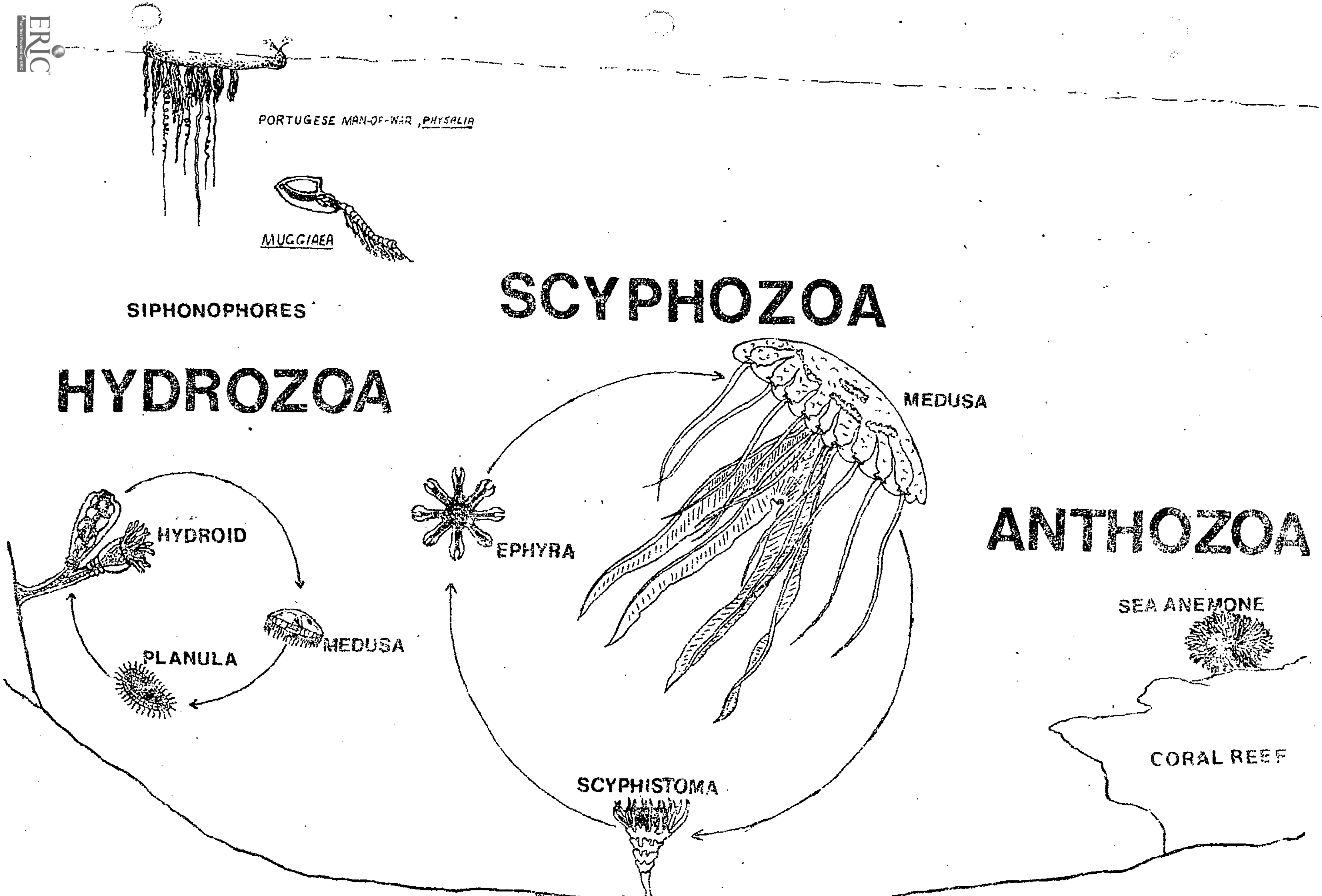
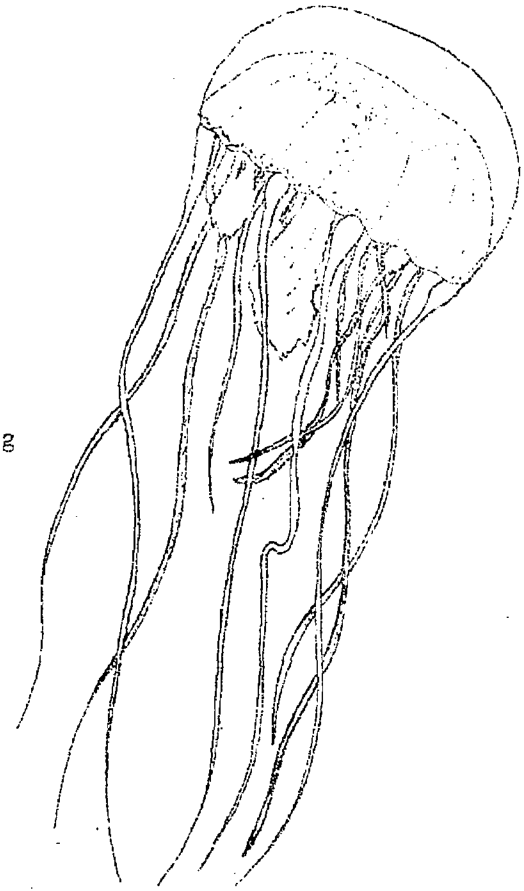


Figure 2. Coelenterate Types

and tossed up on beaches. The polyp stage is restricted to a tiny larval form which is relatively insignificant ("Scyphistoma" in figure 2). The colors of these jellyfish may be orange, pink, white, or almost any other hue. They are frequently met in painful encounters in swimming areas in saltwater, where they are known as stinging nettles or simply jellyfish. They are typically free-swimming animals, but one order (Stauromedusae) which inhabits the waters about both poles is sessile. The bell has been inverted and they are attached by the upper part of the umbrella to various stationary objects. The connection may be direct or they may be attached by a stalk.

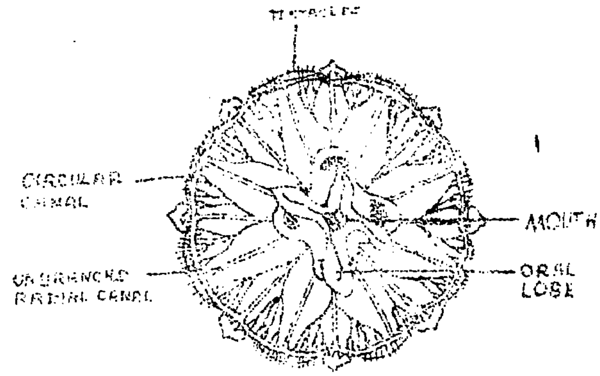


A SCYPHOZOAN JELLYFISH
FROM A PHOTOGRAPH

The bell of scyphomedusae may be shallow or deep. The margin is usually scalloped. They never have a velum, which marks them off, in company with their large size, from the small velum-possessing hydromedusae. The mesoglea contains wandering ameboid cells which are not present in the solely jelly-like hydromedusal mesoglea.

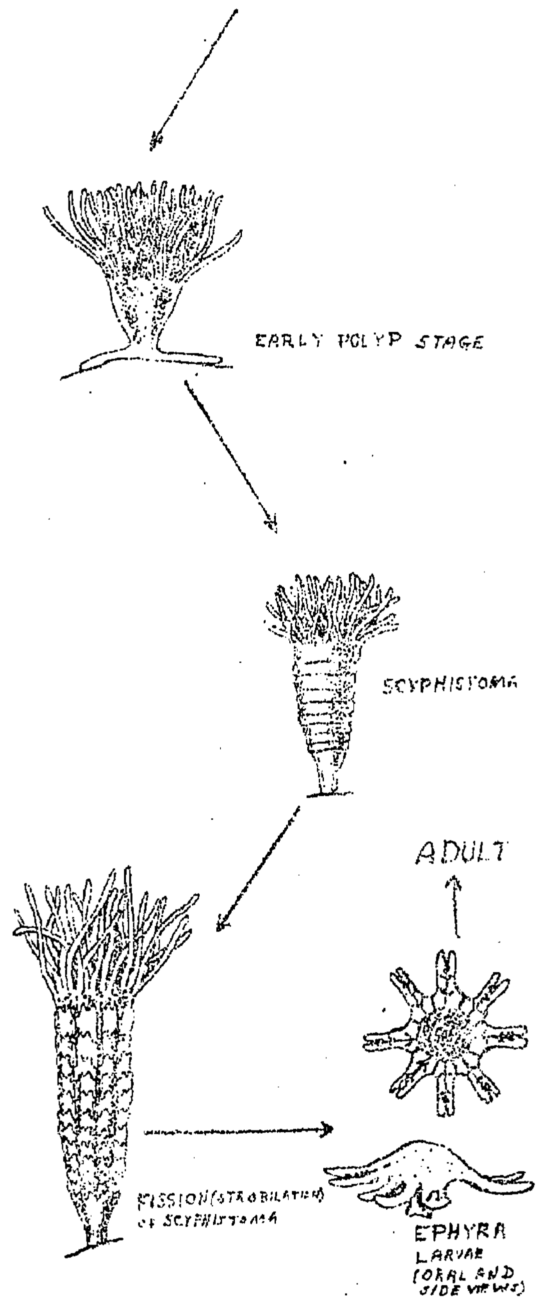
Jellyfish feed on various small animals, from protozoans to fish or whatever other manageable creature is paralyzed by their nematocysts. Some have abandoned the tentacular method of capture and have become strictly plankton feeders eating plankton trapped under the bell as the animal sinks. Mucus on the bell traps planktonic forms. The trapped plankton is licked off the bell by extensions of the mouth called <u>oral lobes</u>. The food is carried to the mouth along ciliated groves on the underside of the oral lobes. This is the case in <u>Aurelia</u>, a commonly studied jellyfish.

Reproduction is through production of eggs and sperm, usually by different individuals. The zygote forms a flat, bilateral larva as in the hydrozoa. The larva settles to the bottom to become a tiny polyp (Scyphistoma) strongly resembling <u>Hydra.</u> Medusae are produced by transverse fission of this polyp into a pile of larvae which lie stacked on top of each other like a pile of saucers. As each larva, called an ephyra, completes development, it breaks away and develops into an adult medusa. A



<u>AURELIA AURITA</u> - ORAL VIEW

AFTER BORRADAILE, ET AL, 1961
(ADULT)



<u>AURELIA AURITA</u> - DEVELOPMENT

AFTER BORRADAILE, ET AL., 1961

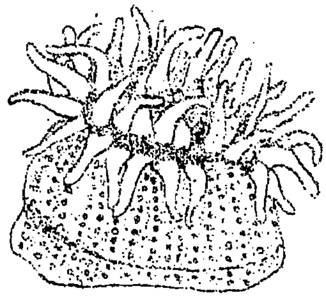
scyphistoma may bud off ephyrae for several years.

Class Anthozoa

The anthozoans have no medusoid stage anywhere in the class. They are strictly polypoid forms capable of both sexual and asexual reproduction.

The anthozoans may be considered the most important coelenterate group, if for no other reason than they include the reef-building corals. Coral reefs are dominant features of ocean geography throughout the tropical areas of the world. The anthozoans also include sea anemones and sea pansies, common denizens of the Atlantic coast.

The anthozoan polyp is much more complex than the polypoid stages of the other two classes. The mouth opens into a well-organized pharynx occupying much of the gastrovascular cavity. The cavity itself is divided into a series of longitudinal sections by partitions running its length. The partitions, called septa, have nematocysts along their edges. The mesoglea is cellular.



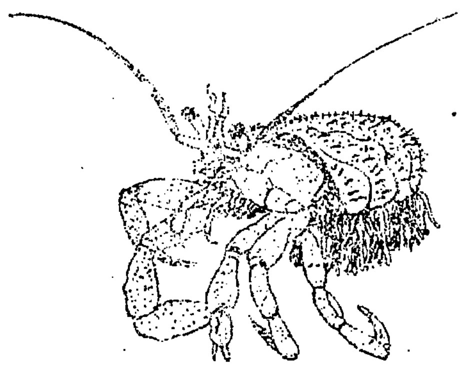
SEA ANEMONE
FROM SARRETT&YO 1958

BRAIN CORAL
A REEF BUILDER
FROM CARSON

The important Anthozoan groups

Sea Anemones

Sea anemones are solitary anthozoan polyps ranging from a centimeter to a meter or more in diameter. They appear as a heavy stalk crowned by a ring of tentacles. They live in coastal waters throughout the world, but are most abundant, varied, and colorful in the tropics.



HERMIT CRAB WITH SEA ANEMONE AFTER NICOL, 1967

Several species of sea anemones are selected as companions by hermit crabs which place anemones on their shells and travel about with them attached. The anemone camouflages the crab as well as being a formidable foe to potential hermit crab gourmets. In return, the anemone gets carried into new areas where it may find more prey to get trapped in its tentacles. It also may share the hermit crab's meal. Other crabs carry a pair of small anemones held in their claws like boxing gloves. They present the unpleasant rings of anemone tentacles to potential predators.

CRAB CARRYING SEA ANEMONES, AFTER NICOL, 1967

The sea anemones eat various invertebrates which stumble onto the tentacles. Larger species can catch fish. The

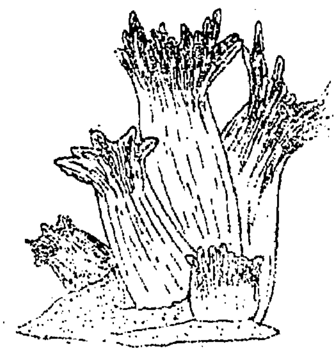
large anemones are sometimes aided in fishing by the existence of various small fishes which are immune to the nematocysts of the tentacles. These small fish live in and around the tentacles of the sea anemone and probably act as bait for larger fish. When an animal is trapped by a group of tentacles, other tentacles join the initial ones and all fold toward the mouth. The prey enters the anemone whole and is digested in the bag of the body. Some anemones are ciliary feeders. Beating cilia set up feeding currents which entrap small organisms on mucus on the anemone's surface and propel it toward the mouth.

Sea anemones may move about by gliding on the pedal disc, walking about upside down on their tentacles, or by floating.

A common method of reproduction is called "pedal laceration". As the anemone moves along, parts of the pedal disc are left behind to grow into new anemones. The anemones may also reproduce sexually. Gonads may change sex with age in hermaphroditic species.

The Corals

The stony or madreporian corals form the great reefs and coral islands of the world. Coral reefs form local centers of high productivity in the midst of the deep sea, which is generally almost a desert compared to coastal regions.



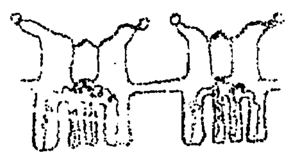
STAR CORAL WITH POLYPS EXPANDED, FROM A PHOTO

The polyps of the corals strongly resemble sea anemones. However, the stony corals lay down a calcium carbonate skeleton. The polyp sits in a cup in this skeleton. On the east coast of the United States the star coral, Astrangia danae, is very common as small coral clumps attached to shells and other flotsam. You have no doubt picked up pieces of shell with stony lumps on them containing holes almost entirely filled with thin radiating septa. These are the skeletons of star corals. The fine walls of calcium carbonate fit into the walls forming the longitudinal partitions of the anthozoan gastrovascular cavity. In large colonial corals, the cups are often confluent. This is the case in the brain corals of the great reefs. In the brain corals, rows of cups are separated but individual cups in a row are confluent.

A CUP CORAL, FROM BARRETT & YONGE, 1958

The bodies of the polyps are also

connected in the colonial corals. This is a similar connection to the one in hydroids, but it is lateral instead of coming from the bottom of the polyps. The gastrovascular cavities are confluent, so one feeding polyp still passes nourishment throughout the colony. The method of feeding is both catching and eating large organisms and ciliary feeding similar to that of some anemones.



THE GASTROVASCULAR CAVITIES OF COLONIAL CORAL POLYPS ARE CONNECTED.

The coral animals usually contain symbiotic algae which are important to the animals' existence. For this reason, most reef-building corals live in water no more than 300 feet deep. This is the greatest depth at which the symbiotic algae can carry on photosynthesis at a sufficient rate to supply the needs of the coral.

A SEA PEN, ONE OF THE ALCYONARIAN CORALS. AFTER MACGINITIE AND MACGINITE, 1968

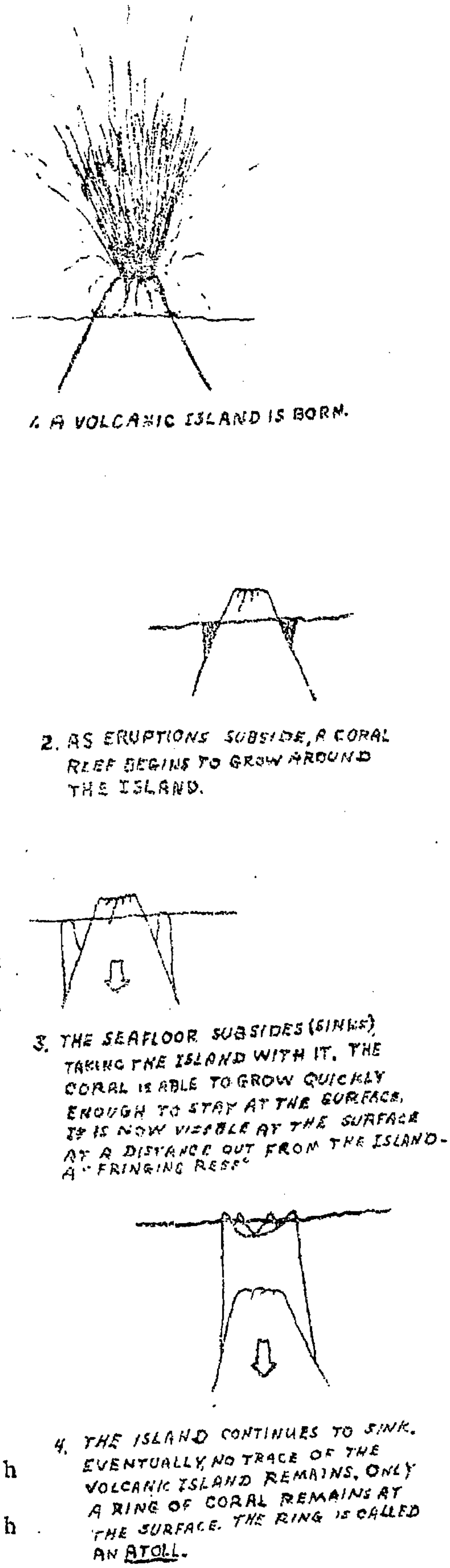
Other corals include he sea whips, sea pens, sea pansies, and organ corals. These corals are branched and always possess eight tentacles. The skeleton is internal instead of external, and is either calcium carbonate or a horny substance. These corals possess differing growth forms and may be hard or soft, but they are all classed as alcyonarion corals.

Coelenterates and Man

The corals are by far the most important of the coelenterates to mankind. However, the predations of both hydroids and medusae on the planktonic stages of commercially valuable marine animals should not go unmentioned. Medusae often feed in prodigious numbers in inland waters at a time when larval fish, crabs, shrimp, and other commercially important animals are trying to struggle to adulthood.

The reef-building corals have built islands and ring-shaped atolls throughout the Pacific on top of volcanoes which have subsided into the depths. Islands of coral or coral and volcanic origin have been the sites of development of whole civilizations in the Pacific. In the Atlantic, the Bahamas and other tropical paradises are largely built of coral.

The beauty and productivity of the coral reefs have paid huge dividends for man. The beauty of the reefs, coupled with the magnificent scenery and the often lush vegetation of the South Pacific volcanic and coral islands have made these islands an idea of paradise for people the world



CHARLES DARWIN'S THEORY OF THE ORIGIN OF CORAL ATOLLS

over. The reefs, like oases in the vast desert of the tropical mid-ocean, have supplied food of great variety for the inhabitants of these islands. In situations where a volcanic island was surrounded by fringing reefs, the rich volcanic soil was responsible for a lush and varied plant growth which included the famous coconut. The diet of the early inhabitants of the islands was richly varied with plants supplying the necessities of fresh green vegetables and the reefs supplying fresh animal protein of myriad kinds. Hawaii was once such a civilization.

Coelenterate activities - Morphological studies.

Preparation

1. Keep the prepared slides of coelenterates in plastic boxes. Each of 10 boxes should have a set of 6 slides of the coelenterates.

2. Give a short lecture from the teacher introduction, illustrating the lecture with the transparencies of coelenterate types.

3. Pass out the prepared microscope slides of coelenterate types.

4. Pass out the preserved and plastic-mounted specimens.

Activity 1. Hydrozoa. (Biology)

1. The class should first study the hydroid phase of Obelia. They should note the tentacles and mouths on the feeding polyps and emerging medusae on the reproductive polyps. The reproductive polyps will appear as vase-shaped bodies without tentacles. The reproductive polyps will show bumpy protuberances from their main stem. The bumps will be developing medusae. The general appearance of feeding and reproductive polyps is shown in the left-hand side of figure 2 in the illustration of the hydrozoan life cycles.

2. The class should now study the medusae of Obelia. They should note the tentacles, mouth, and gonads. The illustration of the anatomy of a hydromedusa will be of help here. The mouth of the medusa is located at the end of a long tube. The gonads appear as opaque objects on the under surface of the umbrella. They should realize that these gonads are the sexual organs of the medusa, which is the sexual phase of the hydroid. The medusae produce ciliated larvae which grow into new hydroid colonies.

3. The class should also look at Gonionemus, another marine medusa, and at Craspedacusta, the only freshwater medusa. In these medusae, the polyp stage is much reduced and solitary. Hydra is an example of medusa suppression, and should have been studied previously in the coelenterate section of standard texts.

4. The class should now turn to the study of Physalia, the Portugese Man-of-War. This is one of the siphonophores mentioned in the teacher introduction. They should note the gas-filled float which keeps Physalia on the surface and the nutritive polyps, from each of which hangs one long tentacle. They may also discover reproductive polyps hanging beneath the float. The similarity of Physalia to a floating hydroid should be stressed.

Activity 2 - Scyphozoa

1. The class should now study the life cycle of Aurelia, beginning with the medusa.
   They should take note of the generally larger, more complex appearance of the Aurelia medusa. The mouth is surrounded by four long frilly lobes extending out from the center. Aurelia traps microscopic food particles on the umbrella. The oral lobes lick them off and carry them to the mouth. The gonads occur as more or less circular organs clustered around the mouth. They should realize that the product of the sexual reproduction of Aurelia medusae are asexually reproducing scyphistomae. Eight prominent light-sensitive and balance organs called rhopallia are present around the edge of the bell.

2. The class should now look at the slides of the Aurelia scyphistoma. They should note the feeding tentacles and the ephyrae larvae being budded off by the scyphistomae. The developing ephyrae live nested within each other like stacked saucers. The class should follow the stack from the bottom to the top. If they examine the stack carefully, they will see that the edges of the protruding ephyrae become more complex near the top, developing fringes and finally a series of obvious arms with notches in their ends.

3. The class should now examine the slides of ephyrae. These are the larval stages of Aurelia which have budded off from the scyphistomae. They should look closely at the eight arms of the ephyrae and compare their notched ends with the notched edges of the budding ephyrae on the scyphistoma. This will help them to see clearly how the ephyrae arose from the scyphistoma.
   The class should identify the mouth and arms of the ephyra and examine the larval rhopallia. The ephyral rhopallia appear as small pegs at the ends of the inner, comparatively opaque portions of the arms, just below the notch in the ends of the arms. A quick glance at the

adult medusa will show a fleshy projection on either side of each rhopallium called a <u>rhopallial lappet.</u> The split ends of the ephyral arms are the larval lappets. Completion of the adult umbrella comes about through growth in the angle of each pair of arms. The growth begins in the angle and spreads outward to fill the space between adjacent arms. This growth, in company with maturation of the gonads and development of tentacles and other structures, results in a well-formed adult *Aurelia*.

Activity 3. Anthozoa (Biology)

1. The first anthozoan ("Flower Animal") in the present series is the sea anemone, Metridium. The first obvious difference between sea anemones and hydroids is that the anemone is solitary, like Hydra. However, it is a much more complex animal.
   The class should first examine the longtitudinal section of the sea anemone on its uncut side. The characteristic appearnace of the anemone is that of a short, heavy stalk crowned by tentacles. In the midst of the tentacles is a comparatively flat area called the oral disc. In the center of the disc is a slit-shaped mouth.
   The class should turn the longitudinal section over and examine the cut side. They should first examine the wall of the stalk. It is much thicker near the bottom and thinner near the top. The thick basal portion contains small pores through which water escapes when the animal contracts. The top of the stalk shows a definite fold inward. This fold is known as a collar. It covers the sea anemone when the animal contracts.
   One of the most obvious internal features is a definite tube extending well into the gastrovascular cavity from the mouth. The possession of this pharynx is a major difference between hydrozoan and anthozoan polyps.
   The body wall is highly folded, as revealed in the longitudinal and tranverse sections. The folds are called septa. These increase the surface area of the gastrovascular cavity. The inner edges of some septa are divided into three lobes. The upper lobe is flagellated and aids in water circulation. The middle lobe contains nematocysts and digestive-gland cells. In Metridium, a filament runs down the inner edge of the lobes and extends into the gastrovascular cavity as a thread. These threads are evident in the bottom of the longitudinal section.

2. The other important anthozoans are the corals. The class should now study Astrangia danae, the Northern Star coral.

The most obvious difference between *Medtridium* and *Astrangia* is that the coral is colonial. The students should take particular note of the tissue sheet connecting the polyps. Within this sheet is a hollow space which is a continuation of the gastrovascular cavity of each polyp. It is confluent with the gastrovascular cavity of neighboring polyps. In this manner, the cavities of all polyps are connected with each other and food ingested by one is shared by all.

One or more of the cups in which the corals rest will probably be vacant. If not, pull a polyp from its cup. The interior of the cup shows thin, radiating partitions of limestone. Each partition fits into the interior of one of the characteristic anthozoan gastrovascular septa. There will be several series of these partitions, each one representing a gastrovascular septum. This partitioning increases the surface area in the gastrovascular cavity of the coral polyp.

The cup, or *theca*, in which the coral rests is imbedded in the general limestone matrix of the animal. It supports the polyp and serves as a home into which the animal can contract in times of danger.

3. The tiny corals can build enormous reefs, as already mentioned. The colonies exist in many different forms. The plastomount of coral types shows only six of the many forms these colonies can take. The shapes are so distinctive as to merit common names such as brain coral, staghorn, or organ-pipe coral (*Tubipora* in the Plastomount).

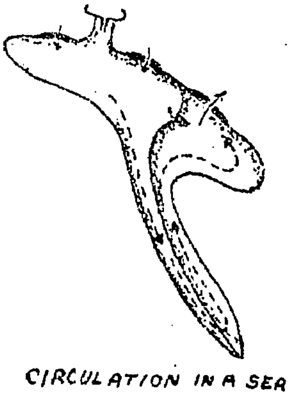
4. The sea pansy, *Renilla*, is a common denizen of our shores. The purplish, heart-shaped colonies may be found in great numbers on some beaches after heavy storms. The specimen on hand has expanded polyps to show its membership in the corals. The class should also be informed that living specimens can be beautifully luminescent. In these soft corals the skeleton is internal and is not as prominent as the external skeleton of the stony reef-building corals.

5. Each team of 2 students should take a small piece of living A. danae back to their desks in a bowl of seawater. The dish should be placed under the low power of the stereomicroscope.

6. When the polyps expand after alarm caused by transfer from the class aquarium, a quantity of Artemia should be introduced to the dish. Each team should look for incidences of capture of the Artemia by the coral polyps.

7. If the Artemia products are not observed moving between polyps, coat a little bit of ground seafood with litmus powder and offer this to the coral. Careful observation should reveal the color of the litmus moving through the fleshy layer between polyps. Coating the food with carmine particles may work as well.

8. The sea pansy Renilla is a soft coral. The colony appears thick and solid, but there are water currents passing through it which keep it turgid. Certain members of the colony are adapted as pumpers which suck in water and flush it through the whole colony.



CIRCULATION IN A SEA PANSY
AFTER BROWN, 1950

9. Each student team should take a sea pansy from the class aquarium and put it in a bowl of seawater to take it back to his desk. The colony should be examined under the low power of the stereomicroscope.

10. When the polyps re-emerge after contraction during transfer, a little india ink or carmine particles should be squirted into the water near the upper side of the pansy at the apex. The teams should look for:

   a. The drawing in of the ink or carmine by some individuals on the apex.

   b. The ejection of the ink from other pores near the stem of the animal.

Coelenterate activities - Behavior of living animals (Life Science)

Preparation

1. All animals should be ordered at least four weeks before the date when they are needed. Request delivery a few days before you plan to hold the exercise.

2. Set up two 10-gallon salt-water aquaria as outlined in the appendix on salt-water aquaria. The aquaria should be set up a few days before the specimens arrive. Adjust the temperature to 50°-65° F. for northern shipments and about 70° F. for southern shipments.

3. When the animals arrive, they will probably be in plastic bags. Put the bags in the aquarium for an hour or so to let the temperatures of the bag and aquarium water gradually equalize. If you open the bags carefully, they will float against the side of the aquarium and not turn over. This will allow fresh air to reach the specimens while the temperatures are equalizing.
After an hour or so, the bags should have reached the prevailing aquarium temperature. An additional precaution may be used. Over a period of 15 minutes or more, slowly replace small portions of bag water with that from the aquarium. After this final precaution, slow submergence and tilting of the bag will allow the animals to slide gently from the bag to their assigned place in the acquarium.

4. If the animals have arrived early, it would be advisable to feed them. Offer them small bits of minced oyster, clam, fish, shrimp, or other seafood. Make sure you remove scraps of food before they have a chance to decay and foul the water.

5. Before conducting activities on feeding methods the animals should not be fed for a few days. This will help in trying to elicit feeding responses from them.

6. The larvae of the brine shrimp, Artemia, will be used for feeding experiments with

hydroids and medusae. These shrimp should be started in culture at least 36 hours before the experiments are conducted.

The culture of *Artemia* is a simple process. Spread the floating eggs on the surface of a pan of salt water. The vial or package of brine shrimp eggs will usually give explicit directions.

In the OSCSP laboratory, *Artemia* are raised successfully by filling a large beaker (500-1000 ml) with water from the aquarium and putting an aquarium air stone on the bottom. The brine shrimp eggs are sprinkled on top of the rapidly moving water. They usually start hatching by the following morning. These early shrimp are the smallest stage of *Artemia*. They serve as usable food for hydroids and medusae.

Activity 1

1. To each group of 2 students, distribute the following:

   a. 1 petri dish, syracuse dish, small bowl, or other container suitable for use with the stereomicroscope.

   b. 1 beaker (500-600 ml) full of artificial seawater from the aquarium.

   c. 1 depression slide and a coverslip.

   d. 1 flat microscope slide and a coverslip.

   e. Each group should already have a scalpel, scissors, forceps, droppers, and needles from their dissecting kits.

   f. 1 stereomicroscope

   g. 1 compound microscope

   h. A small beaker (50-100 ml) of brine shrimp larvae.

2. Each team should secure a piece of hydroid and a medusa or two from the class marine aquarium. These should be placed in their containers, which have been filled with seawater from their beakers.

3. Each group should study their hydroids and medusae under high and low power under the stereomicroscope. They should look for:

   1. Movements of the hydroid tentacles.

   2. Any visible movement through the stems of the colony.

   3. The pulsating movement of the medusae.

   4. Entrapped food organisms in the medusae.

4. A few drops of <u>Artemia</u> culture should be added to the dishes containing the hydroids and medusae. Under low power of the stereomicroscope, each group should look for incidences of capture of <u>Artemia</u> larvae by the hydroids and medusae. When a capture is identified, they should turn to high power

and study the process of ingestion. They should look for tentacle movements, what the mouth does, and what happens to the *Artemia* after they enter the predator bodies. Are they digested right away? Are they stored in some way?

5. After this initial study, each group should snip off a small portion of the hydroid colony and put it in a depression slide. If the polyps on the slide are empty, the groups should add a few *Artemia* and try to see a capture under the low power of the Compound microscope.

6. Under the low power of the compound microscope, the groups should observe:

   a. The knobbed appearance of the nematocyst-studded hydroid tentacles

   b. Any movements within or on the body.

   c. Reproductive polyps. They should especially look for any movements of developing medusae on the stalk of the reproductive polyps.

7. Under high power, the students should look for nematocysts in the tentacles and scan the body generally.

8. The groups should now study the hydromedusae. The medusae should be left in their bowl while their swimming movements are observed under the stereomicroscope. After watching the swimming movements and possible capture of stray *Artemia* still in the dish, each group should cut off the bottom of the bell at the level of the velum to see which contracts, the lower margin of the bell or the bell itself.

Activity 2 - Scyphozoa

1. The class should now study the life cycle of Aurelia, beginning with the medusa.
   They should take note of the generally larger, more complex appearance of the Aurelia medusa. The mouth is surrounded by four long frilly lobes extending out from the center. Aurelia traps microscopic food particles on the umbrella. The oral lobes lick them off and carry them to the mouth. The gonads occur as more or less circular organs clustered around the mouth. They should realize that the product of the sexual reproduction of Aurelia medusae are asexually reproducing scyphistomae. Eight prominent light-sensitive and balance organs called rhopallia are present around the edge of the bell.

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Activity 3

1. The first part of this exercise is best conducted by using the sea anemones in the class aquaria.

2. A few pieces of clam, shrimp, or fish should be squeezed by wringing in a piece of cheesecloth or other convenient method to extract the juices. The seafood juice and meat should be introduced to a sea anemone (Metridium) in the following ways and the responses of the anemones should be recorded. If one anemone accepts a morsel, move to another for the next step.

   (a) Tear off a small piece of filter paper and place it gently on the tentacles. A contact that is too severe may cause the anemone to contract in alarm.

   (b) Soak a piece of filter paper in the juice of the food organism.

   (c) Drop some of the pressed-out meat onto the tentacles.

   (d) Drop some untreated meat onto the tentacles.

3. Drop a few grains of aquarium sand onto the oral disk of an anemone. Watch it and time how long it takes the ciliary currents to sweep the grains off the disk. Metridium is a ciliary feeder as well as an eater of large food particles. The cleaning of the sand grains from the oral disk is accomplished by a reversal of the beat of the cilia around the mouth. They beat outward toward the edge of the disc to drive off the grains, instead of inward to bring food particles toward the mouth.

4. The star coral, Astrangia danae, may serve as a living example of the stony corals. Expanded polyps of this species will be 8-10 mm. high and 4-5 mm. in diameter. The transparent polyps serve nicely for studying feeding.

Activity 4

1. Remove a few sea anemones from the aquarium. The number will be determined by how many anemones will be needed to supply 15 small pieces containing several tentacles each. At this time, the class should be heating glass rods and pulling them out to fine hair-like tips.

2. Remove a total of 15 small pieces from the crowns of tentacles and put each one into a dish of seawater supplied by each student team.

3. Each team should return to their desks and remove a tentacle from their anemone sample. A pair of scissors or a scalpel may be used for this. They should put the tentacle on a depression slide and cover it with a drop or two of seawater. They should not be covered with a coverslip. The slide should be observed under the low power of the compound microscope.

4. Each team should try the following experiments and record whether or not the experimental procedures evoke nematocyst discharge. The discharge of nematocysts will be seen as an explosive eruption of the nematocyst thread across the slide.

   a. Brush the thread-like end of the drawn glass rod along the surface of the tentacle.

   b. Poke the tentacle a little more forcefully with the rod.

   c. Remove a hair from the head of a volunteer and brush it along the tentacle surface.

   d. Put a drop of seafood juice or saliva in the water with the tentacle and brush the tentacle with the clean glass rod.

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ANIMALS OF THE SEA:
PROTOZOA

CHARLESTON COUNTY OCEAN SCIENCE PROJECT
ESEA TITLE III, P.L. 89-10

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FOREWORD

Prior to 1970, Charleston County possessed no formal program to develop an organized study of ocean science. A few teachers would cover selected topics on occasion, but there was no formal, district-wide effort to make ocean science curricula available to all students in the secondary schools of the district.

The increasing emphasis on the study of the oceans by federal, state, and local governments and the resultant increase in the importance of the ocean to all citizens has created a need for coherent ocean science programs for all students. Nowhere is the need for coherent study of the sea more immediately relevant than in Charleston County. The county is permeated with food and sport-filled waterways and heavily dependent on naval and commercial shipping. Present and future problems in harbor maintenance and problems of estuarine multiple use indicate a need for a local citizenry literate in ocean science. The most effective means of developing large-scale literacy is the public school.

This publication is one of a series made possible through a Title III, ESEA grant entitled Oceanographic Science Conceptual Schemes Project. These publications are designed for use in standard science curricula to develop oceanologic manifestations of certain science topics. The publications include teacher guides, student activities, and demonstrations designed to impart ocean science understanding to Charleston County high school students.

The members of the ocean science staff include Dr. Gary Awkerman, Director of Natural Sciences, Mr. Michael Graves, Assistant Director of Natural Sciences, and Mr. Paul F. Teller, curriculum specialist in ocean science. They were assisted by the following writing staff: Sister Bernadette Kostbar, Ms. Beverly Lauderdale, Ms. Dorothy Bonnett, Ms. Caroline Pearson, Ms. Pat Hayes, Mr. Tommy Yon, Mr. Nat Bell, Mr. Steve Proctor, and Mr. Leonard Higgins. Principal typists were Ms. Anita Skinner, Ms. Roberta Brown, and Ms. Lynda Wallace. Without their cheerful, dedicated efforts and excellent typing, this project could not have been completed.

Special thanks are due to consultants Dr. Norman A. Chamberlain and Dr. F. J. Vernberg, who contributed much valuable information on tides and estuaries, respectively. Ms. Virginia Bolton prepared the cover drawings. Mr. Paul F. Teller completed the internal figures.

Gary L. Awkerman
Director of Natural Sciences

What kinds of animals live in the sea?

Protozoa

Objectives:

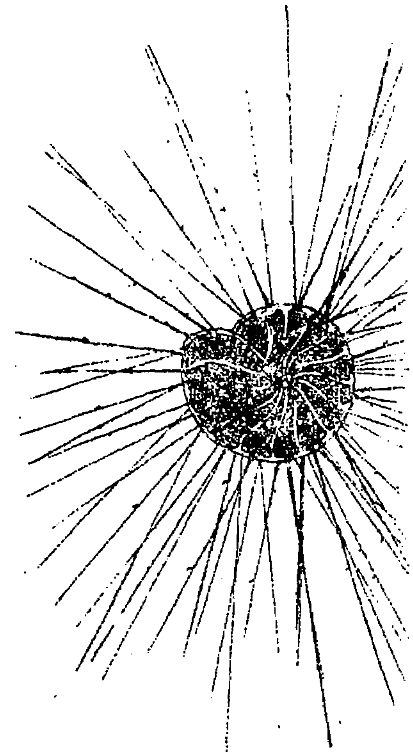
At the end of this unit, the student should be able to:

1. IDENTIFY a radiolarian, foraminiferan and a tintinnid in a chart of various protozoans.
2. MATCH a list of test materials to the correct group of protozoa in a second list.
3. DESCRIBE the methods of feeding and locomotion in the foraminiferans, radiolarians, and tintinnids.
4. IDENTIFY radiolarian and foraminiferous oozes on an unmarked chart of ocean bottom sediments.

Teacher Introduction

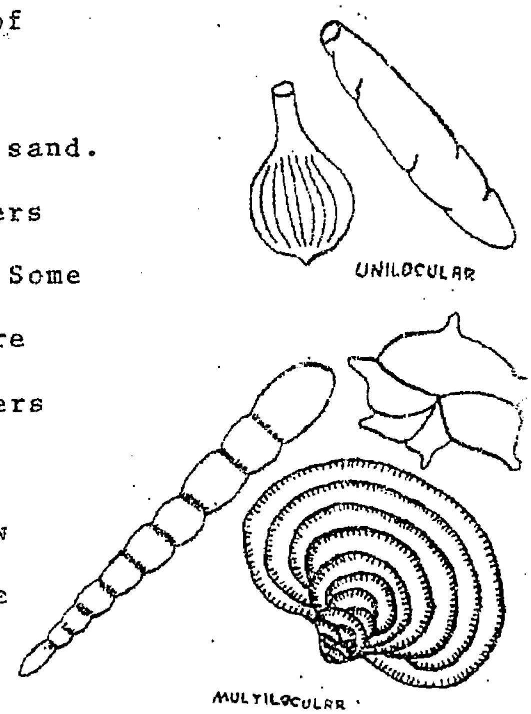
For years, you have probably taught your students the fundamentals of Ameba and Paramecium. This group of exercises will introduce your students to some beautiful relatives of the Ameba, the radiolarians and foraminiferans. They will also study the ciliate tintinnids, relatives of Paramecium.

The foraminifera and radiolarians are not as important now as they were at one time. The bottom of the oceans in some areas is filled with trillions of the fossilized shells of these relatives of the ameba.



A FEEDING FORAMINI

The foraminifera secrete shells of calcium carbonate (lime) or tectin, an organic matrix with imbedded grains of sand. The shells consist of perforated chambers housing the protoplasm of the animal. Some species secrete only one chamber and are called unilocular foraminiferans. Others secrete many chambers. The protoplasm overgrows old chambers and secretes new chambers at its surface. These are the multi-locular forams. The successive chambers may lie in a straight line like a



FORAMINIFERAL SHELLS (TESTS

set of beads, overlap to form layers like an onion, or they may be laid down in a spiral, resulting in a snail-like foram. Globigerina lays down spherical shells that lie in a spiral pattern. All these different configurations will be seen on the slides of the foraminifera.

The shells of the forams are perforated, with pseudopodia extending through the perforations. Unlike the pseudopodia of the Ameba, those of the forams are very finely branched and interconnected. The difference gives them a new name: reticulopodia. The heavy, blunt pseudopodia of the ameba are called lobopodia. The reticulopodia of the forams act as traps for the bacteria, algae, and protozoa eaten by these organisms. The reticulopodia are very sticky, and prey organisms adhere to their surfaces. A granular film of mucous-like substance on the surface of the reticulopods quickly coats the surface of the prey organisms. This coating helps to paralyze the prey and may also start digestion even as the new meal is being taken to the interior of the animal.

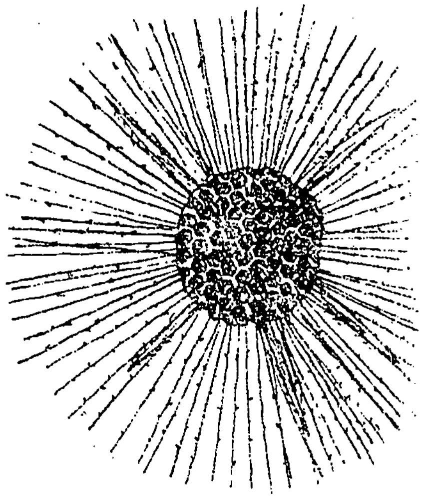
Movement in the forams differs from that of the Ameba. Whereas the Ameba moves

by flowing movements of its thick lobopodia, the benthic foraminiferans creep slowly along the bottom by pulling themselves with the reticulopodia. The pelagic forams probably show little locomotory powers. The remarks here will serve well for the group as a whole, because pelagic foraminiferans are quite rare. Globigerina is the most common pelagic foraminiferan genus, and it is so rare that its distribution cannot be worked out satisfactorily.

Pelagic forams were not always so rare. Thirty-five percent of the ocean is covered with thick deposits of foraminiferal ooze which is composed of the shells of dead foraminifera, usually in association with the calcium carbonate remains of a group of algae called coccolithophores. The relative abundance of certain species of foraminiferans in a core sample taken from the ocean bottom can be used to correlate the date of the cores from different areas. The abundance of various species indicates climatic changes resulting from various stages of glaciation on the continents. The use of forams for dating cores is very useful in the search for undersea oil.

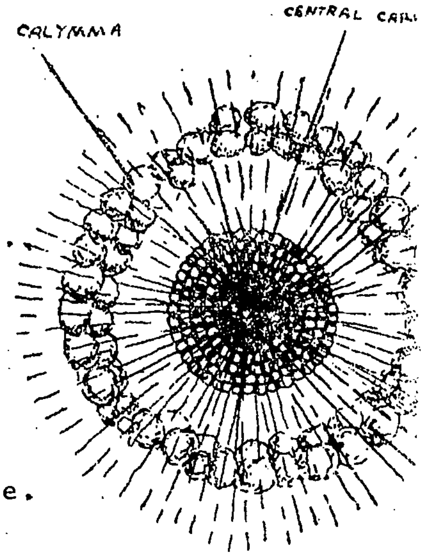
MUCH OF THE OCEAN FLOOR IS COVERED WITH THE REMAINS OF FORAMINIFERANS.

The shells of foraminifera have been found as nuclei of manganese nodules on the ocean floor. These nodules are the object of much speculative deep sea mining theory because they represent a potential source of great mineral wealth to the world.



A SIMPLE RADIOLARIAN

Radiolarians are relatively large marine protozoans, reaching diameters of several centimeters in some colonies. Individual radiolarians can reach several millimeters in diameter. The radiolarians are predominantly planktonic, in contrast to the predominantly bottom-dwelling foraminifera.

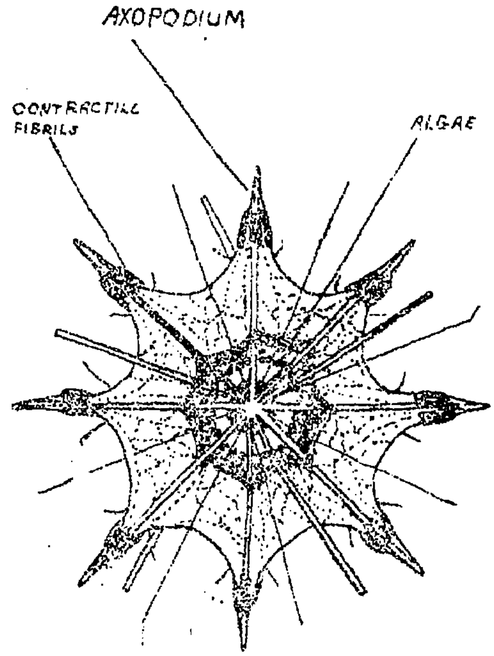


The radiolarian body is usually spherical and divided into a cyloptasmic outer portion, the calymma, and an inner nucleated portion called the central capsule. A distinct membrane surrounds the central capsule. The cytoplasm of the central capsule is continous with that of the calymma through perforations in the capsular membrane.

The calymma contains several forms of symbiotic algae called zooxanthellae. These organisms are capable of photosynthesis and probably act as a primary food source for the host, obviating feeding when

the radiolarian is in bright sunlight. The calymma also contains several vacuoles of variable size. These have been thought to contain low density fluids that help in bouying the animal as a whole.

The pseudopods are of two principal types. One type is fine and needleshaped with a central axial rod (axopodia). The other is composed only of cytoplasm and has pointed ends (filopodia). Both types originate in the central capsule or just outside it and pass through the calymma as dense cytoplasm.

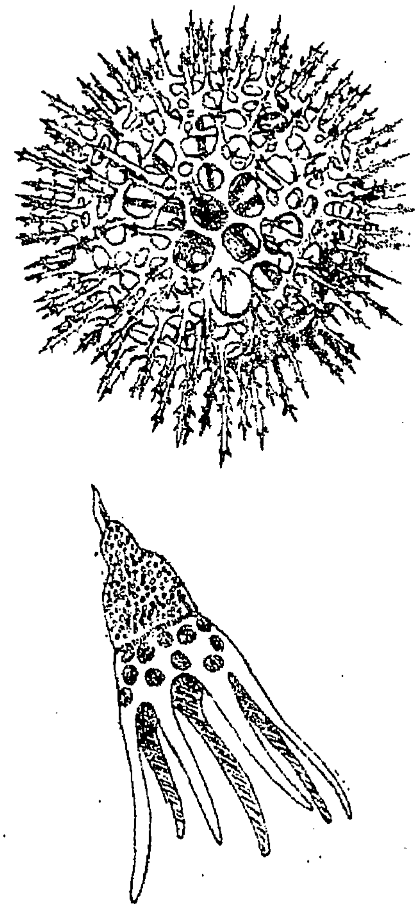


ACANTHOMETRA - A RADIOLARIAN WITH A RADIATING SKELETON, AXOPODIA, AND SYMBIOTIC ALGAE. (AFTER MEGLITSCH, 1967

The radiolarians' claim to fame is their skeletons. These are among the most beautiful structures in the living world. They are usually composed of compounds of silicon and are of two types, radiating and lattice. The radiating type of skeleton is composed of long needles originating from a common center in the central capsule and passing through capsule and calymma to the surface of the body. Their exit points from the body are surrounded by contractile fibrils which can move the spines and cause the entire calymma to expand or contract. The expansion and

contraction of the calymma in conjunction with the changing of the size of the calymmal vacuoles can help the radiolarian control its depth.

The second skeletal type is a delicate latticed sphere. These may exist singly or in concentric layers like carved Indian ivory balls. These delicate, lacelike structures can be further sculptured or armored in all imaginable ways, and one or more shells may possess long barbs which change the skeletal shape from a sphere to an elongated form like some delicately carved gazebo or pagoda. You and your class will soon see these forms on the prepared slides in the activities in this unit.

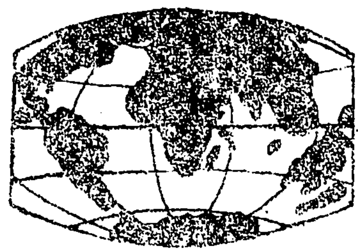


TWO TYPES OF LATTICE SKELETONS IN THE RADIOLARIANS. (FROM BARNES, 1964

Feeding in the radiolarians resembles that of the foraminiferans. Prey organisms become attached to the sticky axopodia or filopodia. They are covered with the granular slime film on those organelles and drawn into the body. Digestion occurs in the calymma of the radiolaria. In bright sunlight, feeding is probably not required because of the activities of the zooxanthellae on the calymma.

The pseudopodia of the largely

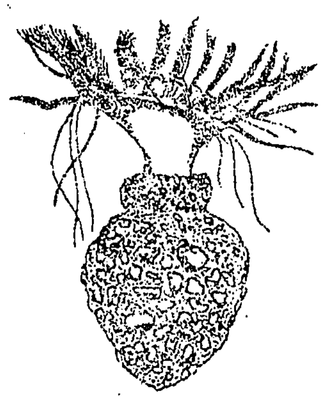
planktonic radiolarians are used for feeding, not locomotion. The expansions and contractions of the calymma and the varying calymmal vacuoles enable the organisms to move up or down through the water column.



SOME DEEP NEAR-EQUATORIAL REGIONS OF THE PACIFIC AND INDIAN OCEANS HAVE BOTTOMS COVERED BY THE REMAINS OF RADIOLARIANS.

The siliceous shell of a radiolarian is much less soluble at great depths than the calcium carbonate shell of a foram. They will remain intact at greater depths than will forams. They are not as predominant in the sediments as foraminiferans, however. They are often masked by other sediments. Areas of true radiolarian ooze exist in the deep near-equatorial regions of the Pacific and Indian oceans.

<u>The Tintinnids</u>

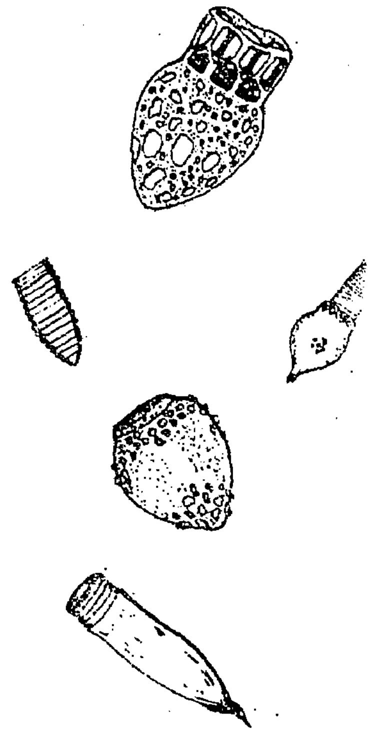


<u>TINTINNOPSIS</u> - A TINTINNID

<u>Paramecium</u> is a freshwater member of the large group of ciliate Protozoa. The best known ciliates in the sea are the tintinnids. These organisms are armored ciliates. They are easily identified in plankton collections by their armor, which is called a <u>lorica</u>. The lorica is like a vase with the animal attached to the bottom and protruding from the mouth. The lorica

is composed of a clear organic material which may have sand grains or other detritus cemented into it. It is filled with a low density fluid which aids flotation. . The animal is covered with body cilia over its surface. A series of cellular membranes projects from the mouth of the lorica. The membranes are used in feeding.

The tintinnids feed on microscopic plants and bacteria similarly to Paramecium. They may be recognized in a plankton collection as tiny crystalline or granular-looking vases.



SOME EXAMPLES OF TINTINNID LORICAE (FROM FRIEDRICH, 1961)

Materials and supplies	No.	Supplier
1. Microscope	15	Any
2. Foraminifera shells, microslide	5	Supply hous
3. Radiolarian shells, microslide	5	Supply hous
4. Tintinnids, microslide	5	Supply hou
5. Overhead transparency of marine protozoan types	1	OSCSP
6. Marine protozoan types desk outline	30	OSCSP
7. Overhead transparency of seafloor sediment types	1	
8. Overlay for (7), showing radiolaria and foraminifera in the sediments.	1	
9. Desk outline of sediment types	30	
10. Paste-on cutouts of radiolaria for (9)	30	
11. Paste-on cutouts of foraminifera for (10)	30	
12. Overhead projector	1	

Activity 1 (Life Science, Biology)

1. Set up the overhead projector.
   Distribute:
   a. Microslides of forams, radiolarians, tintinnids

   b. Desk outline of marine protozoan types

   c. Desk outline of sediment types

   d. Paste-on cutouts of radiolaria and foraminifera (b-d are in a packet marked "sediment distribution")

2. Display the transparency of marine protozoan types. Give a short lecture based on the teacher outline, including

   a. The general characteristics of each group

   b. General morphology

   c. Feeding habits

   d. Locomotion

3. Have the class observe their microslides of forams, radiolaria, and tintinnids. Each member of the class is to sketch the following organisms:

   a. a unilocular foraminiferan

   b. a multilocular foram

   c. a radiolarian with a radial skeleton

   d. a radiolarian with spherical skeleton

   e. a tintinnid

Activity 2 (Earth Science)

1. Set up the overhead projector.

2. Pass out the desk outlines of sea-floor sediment types.

3. Display the transparency of seafloor sediment types.

4. Introduce the class briefly to the concept of ocean sediments by telling them that each major sediment area covers millions of square miles and may be over 1000 meters deep.

5. Place the overlay of radiolaria and foraminifera on top of the sediment transparency. Orient it correctly to show the radiolarian and foram insets on top of the proper sediment areas.

6. Explain to the class that the sediments laid down in the areas shown by the insets of the overlay are largely composed of the shells of the forams and radiolarians they have been studying. The foraminiferans, especially, are so numerous that they cover the seafloor in a major part of the ocean. Explain that in order to do this, they have been dying and dropping to the bottom of the sea for millions of years, slowly building up the sediments.

   Tell the class that the record of fossil forams is so old that species can be found to become extinct as one searches from the lower to the higher portions of the sediments. Further point out that the extinction of species of forams at certain points in core samples throughout the world serve as correlation points in these core samples. The point of extinction of a species in one core will be of approximately similar age to the extinction point of that species on another core. In this way, forams help us to tell the age of the bottom of the ocean in various parts of the world.

The characteristics of the shells of fossil forams change with certain temperature changes. Study of changes in the shells of foram fossils have helped man to reconstruct the climate of the world in previous times.

ANIMALS OF THE SEA: SPONGES

CHARLESTON COUNTY OCEAN SCIENCE PROJECT
ESEA TITLE III, P.L. 89-10

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FOREWORD

Prior to 1970, Charleston County possessed no formal program to develop an organized study of ocean science. A few teachers would cover selected topics on occasion, but there was no formal, district-wide effort to make ocean science curricula available to all students in the secondary schools of the district.

The increasing emphasis on the study of the oceans by federal, state, and local governments and the resultant increase in the importance of the ocean to all citizens has created a need for coherent ocean science programs for all students. Nowhere is the need for coherent study of the sea more immediately relevant than in Charleston County. The county is permeated with food and sport-filled waterways and heavily dependent on naval and commercial shipping. Present and future problems in harbor maintenance and problems of estuarine multiple use indicate a need for a local citizenry literate in ocean science. The most effective means of developing large-scale literacy is the public school.

This publication is one of a series made possible through a Title III, ESEA grant entitled Oceanographic Science Conceptual Schemes Project. These publications are designed for use in standard science curricula to develop oceanologic manifestations of certain science topics. The publications include teacher guides, student activities, and demonstrations designed to impart ocean science understanding to Charleston County high school students.

The members of the ocean science staff include Dr. Gary Awkerman, Director of Natural Sciences, Mr. Michael Graves, Assistant Director of Natural Sciences, and Mr. Paul F. Teller, curriculum specialist in ocean science. They were assisted by the following writing staff: Sister Bernadette Kostbar, Ms. Beverly Lauderdale, Ms. Dorothy Bonnett, Ms. Caroline Pearson, Ms. Pat Hayes, Mr. Tommy Yon, Mr. Nat Bell, Mr. Steve Proctor, and Mr. Leonard Higgins. Principal typists were Ms. Anita Skinner, Ms. Roberta Brown, and Ms. Lynda Wallace. Without their cheerful, dedicated efforts and excellent typing, this project could not have been completed.

Special thanks are due to consultants Dr. Norman A. Chamberlain and Dr. F. J. Vernberg, who contributed much valuable information on tides and estuaries, respectively. Ms. Virginia Bolton prepared the cover drawings. Mr. Paul F. Teller completed the internal figures.

Gary L. Awkerman
Director of Natural Sciences

Objectives:

At the end of this exercise, the student should be able to:

1. LIST the three classes of sponges and their predominant skeletal materials.

2. DESCRIBE the feeding and respiratory method employed by sponges.

3. LIST four basic sponge cell types and their function.

4. EXPLAIN the function of spicules.

5. DESCRIBE three basic types of sponge organization.

6. DESCRIBE a method of sponge reproduction that is important to the sponge industry.

7. DESCRIBE the regeneration of sponges from dissociated cells.

Materials and Supplies

Activity 1	No.	Source
1. Aquarium, all-glass, 10 gal. or more	1	
2. Sponge, Leucoselenia, Living	15	Woods hole, Pacific Bio-Mari
3. Finger Bowls, 3-4", 1" deep	15	Biol. Supple Houses
4. Carmine particles, a pinch	1 gr. or more	" "
5. Dissecting needles	15	" "
6. Concavity slides	15	" "
7. Razor blades, single edge	15	Store
8. Microscopes, compound	15	School
9. Microscope, phase contrast (OPTIONAL)	1	School
10. Living sponges, Grantia	15	Biol. Supply House
11. Living sponges, Microciona	15	" "

Activity 2		
12. Modeling clay, 1/4 pound stick	15	Hobby shop, drugstore
13. Modeling clay, contrasting color, pat	15	Hobby shop, drugstore
14. Waxed paper, rolls	1	Grocery store

Activity 3		
15. Stereomicroscope	1-15	School
16. Cheesecloth or fine bolting cloth, 12" square	15	Dry goods store, Supply Hous
17. Large culture dish (8"), with seawater	15	Biol. Supply House
. Glass plate, 9 x 9", for culture cover	15	Hardware store

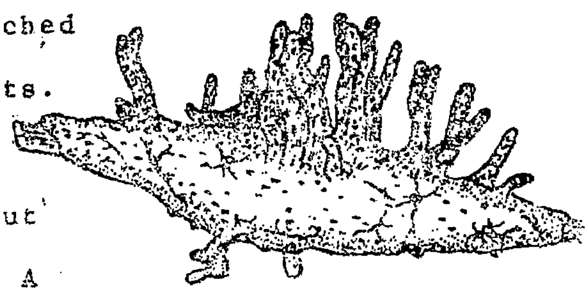
Activity 4

		No.	Source
19.	Scalpels	15	Student Kits
20.	Pebbles	30-40	Road, yard, etc.
21.	Thread, white silk, spool	1	Surgical Supply House
22.	Balance, triple beam, 0.1 gm sensitivity	Several	School

Teacher Introduction

General

Sponges are the most simply organized metazoa. They are essentially a bag pumping water in through myriad surface pores for feeding, gas exchange, and excretion and letting it flow out through a large excurrent opening. All sponges live as sessile masses attached to the bottom or to submerged objects. Their most frequent habitat is the bottom of shallow coastal waters, but they are also found in deep water. A few have become adapted to life in fresh-water.



SPONGILLA-A FRESHWATER SPONGE. (AFTER BROWN, 1950)

Classification

There are three classes of sponges; calcareous sponges, glass sponges, and the Demospongia, whose skeleton is composed of spicules of silicon compounds, a protein called <u>spongin</u>, or both. The Demospongia include the commercial sponges.

Body Plan

There are three basic types of sponge organization. The simplest type is the

asconoid organization. Asconoid sponges are simple, saclike sponges which draw water in through small pores in the bodywall called ostia. These empty into a large central cavity, the spongocoel. The water then flows out a large opening at one end of the sponge called an osculum. The ascon body plan is shown in figure 1a.

The next grade of sponge organization is called syconoid. In syconoid sponges, the body wall is folded as if one had squeezed an asconoid sponge from the ends and formed it into an accordion-shaped object. This permits a greater number of the water-moving cells to be placed in the same length of sponge body wall. The water now flows into the constructions of the accordion shape. The expanded portions are converted into chambers which drive the water into the spongocoel. Some sponges have further increased the efficiency of water movement by filling in the constricted portions with cortex cells. Small canals lead from the outside through the cortex and into the water-moving chambers. The syconoid plan is shown in figure 1b. The spongocoel is still very large. The large spongocoel

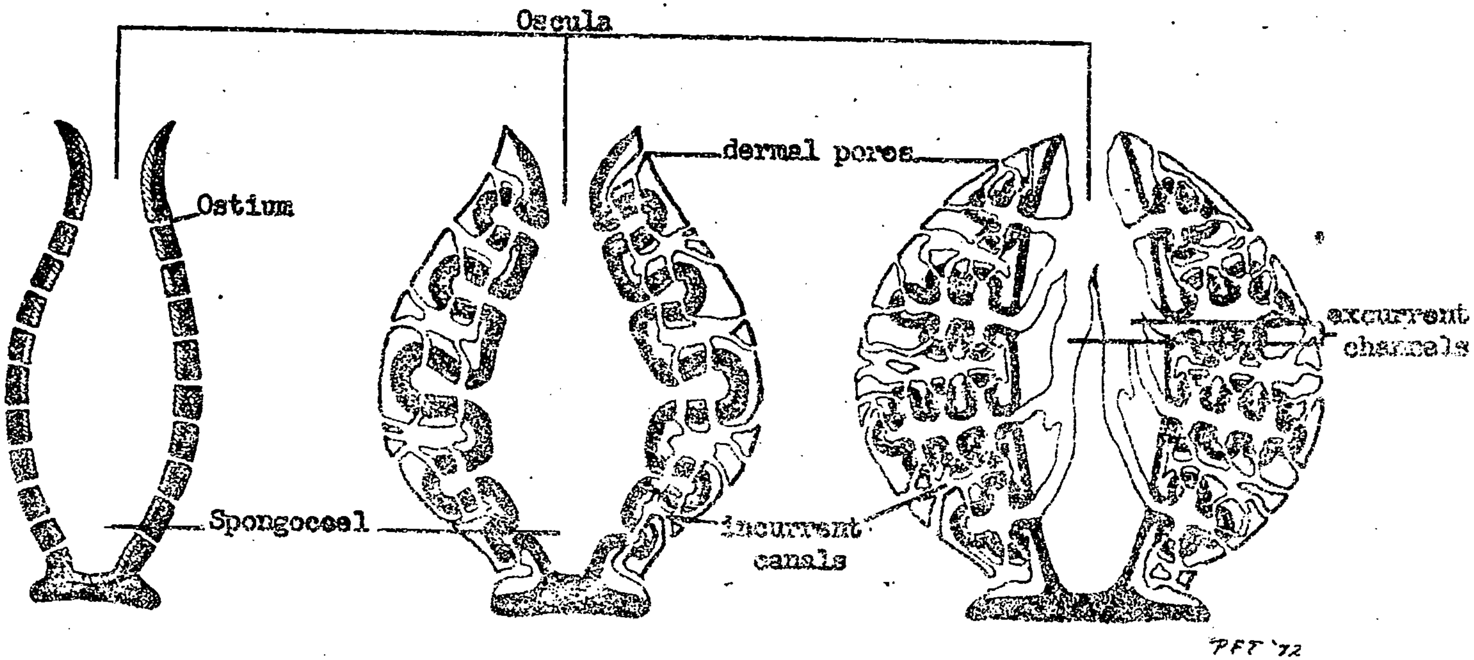


Figure 1. Schematic diagrams of sponge organization. (a) ascon grade (b) sycon grade (c) a simple leuconoid sponge. Bold lines indicate fundamental organization of the sponge. Areas enclosed by fine lines are filled with mesenchyme and cortex cells. Hatched portions indicate choanocyte layers. The spongocoel is open in (a) and (b), but is filled in with cortex cells in (c) to form channels leading directly from the choanocyte chambers to the osculum, increasing circulation efficiency. In (b) and (c), the bold organizational lines are only for illustration. The cortex cells actually occupy these areas as well as the light ones.

impedes circulation by acting as a large, relatively stagnant pool in the middle of the sponge. Once the trend toward more powerful circulation has begun, the next most useful step would be a reduction in the size of the spongocoel.

The leuconoid plan is the most complex type of sponge organization. In leuconoid sponges, as shown in figure 1c, the body wall has been folded again by folding the asconoid chambers, and the water-moving cells are confined to small chambers. The spongocoel has been largely filled in with tissue so that water movement does not take place toward a large, stagnant pool. Instead, the water passes from the chambers into a discrete, relatively narrow channel leading directly to the osculum in combination with channels from other chambers. The resulting constriction of the inflowing water into definite channels increases the efficiency and velocity of overall water movement through the sponges body.

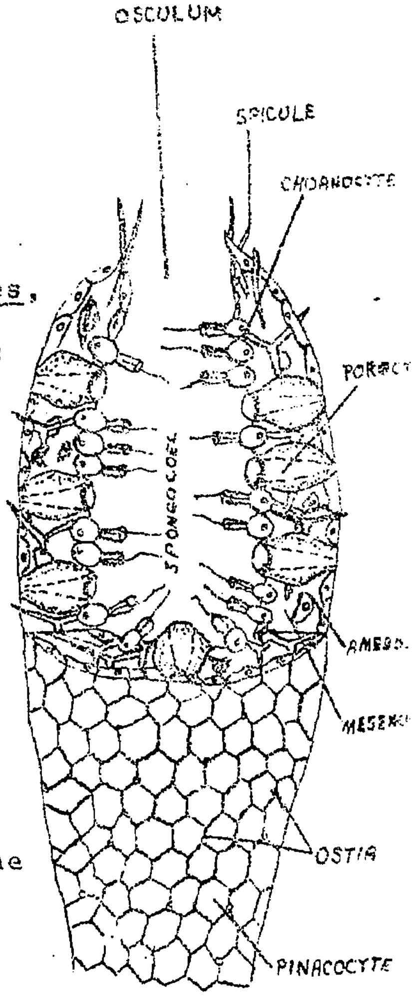
The movement of water through the sponge is important not only in the sense of bringing food to the organism. New water is essential to respiration and other vital

activities of the sponge. The constant renewal of the water allows the uptake of oxygen by sponge cells and the release of their CO_2 and other metabolic end products. Cells throughout the sponge's volume must have their surrounding water renewed at rates compatible with vital processes. Water is being drawn in only at the surface of the sponge. As the sponge increases in size, the volume will increase faster than the surface area. A certain point will eventually be reached at which the amount of water drawn in through the surface cannot meet the needs of the cells throughout the volume of the sponge.

The sycon and leucon organizational plans represent solutions to the volume-surface area problem. The folding (sycon) and refolding (leucon) of the body wall increase the surface area capable of bringing in water. The channelization of the water flow in leuconoid sponges increases the efficiency of the circulation resulting from the increased surface area.

The success of solving the surface area-volume problem is reflected in the maximum size of sponges built on the

three basic plans. The simple asconoid sponges never grow over about 10 cm. high, while syconoid sponges reach greater maximum sizes. The leuconoid sponges are the largest of all, reaching heights of several feet and diameters of similar dimensions.



ASCONOID STRUCTURE, SHOWING CELL TYPES (AFTER BARNES, 1964)

Histology

An asconoid sponge is made up of four basic cell types called pinacocytes, porocytes, choanocytes, and amebocytes. The pinacocytes cover the outside as an epidermis and choanocytes line the internal surfaces. Between these two cell layers is a jelly-like substance called mesoglea. The amebocytes crawl about in the mesoglea.

Porocytes are tubular cells unique to sponges. The incurrent pores, or ostia, pass through the center of the porocytes. The outer surfaces of the porocytes are found scattered among the cells of the epidermis. They extend through the mesoglea into the spongocoel, allowing water to pass into the spongocoel. The outer ends of the ostia can be closed to prevent the entrance of the water.

The choanocytes are the actual water-moving cells. They are more or less round cells with a

clear collar extending into the spongocoel. Rising out of the collar is a whiplike flagellum which is constantly beating, moving the water toward the osculum. The exit of water from the osculum allows more water to flow into the spongocoel through the ostia. In this manner, a constant current of water is drawn through the sponge. The choanocytes pick food particles out of the water and ingest them. No digestion occurs in the choanocytes. They pass the ingested food to amebocytes in the mesoglea.

The amebocytes are the workhorse cells of the sponge. They are undifferentiated cells which creep about the sponge like small amebas. It is unclear whether there is one adaptable kind or several kinds, but amebocytes have a variety of functions. Amebocytes can be seen to pick up food from the choanocytes, digest it, and travel throughout the sponge distributing the food.

Some amebocytes develop slender pseudopodia and may group together in a syncytial mass containing pigments or food. Others form sperm and ova. Porocytes and choanocytes have been seen to convert to amebocytes. Other amebocytes secrete limy or

glass spicules or spongin fibers which form the skeleton of the sponge.

Skeletal Structures

The skeleton of the sponge is made of spicules. The spicules are small, complex crystalline structures laid down by amebocytes. They may be rods, stars, anchor-like objects, gridworks, needle-shapes, or a host of other forms. They may be siliceous or calcareous. Some of the spicules form major skeletal structures, while others are randomly scattered in the soft parts of the sponge. The form and composition of spicules is very important in the identification of sponges.

SPONGE SPICULES

Reproduction

Budding and fragmentation are asexual methods of reproduction used by sponges. Budding is the most common form. In this process, a bud appears on the side of the sponge. The bud differentiates into a young sponge. The young sponges may detach from the parent to take up an independent life or remain attached as a member of a colony of parents and offspring.

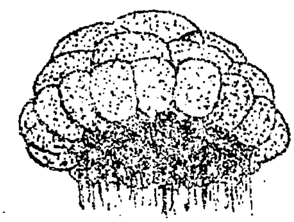
Fragmentation consists of the regeneration of a new sponge from bits and pieces of another. The fragment may come from breakup due to unfavorable environmental conditions or as a normal part of the life history of the sponge. Fragmentation is quite important to man. A large sponge may be cut into many smaller pieces, weighted with a rock or other heavy object, and planted in a favorable place on the bottom. Each fragment will grow into a complete sponge of harvestable size in two to three years.

Another asexual method involves the formation of <u>gemmules</u>. These are hard-shelled bodies which germinate into new sponges.

Reduction bodies can be formed by many sponges. In this case, the main body mass disintegrates, leaving a residual mass that develops into young sponges.

Sexual reproduction involves the formation of eggs and sperm from amebocytes. Fertilization is unusual in that sperm swept in with the water current are ingested by choanocytes. The choanocytes then fuse with the ovum and set the sperm free. Embryonic development is similar to that of higher metazoa, but with striking differences. The most

striking of these is that the cell layers of the blastula (called an "amphiblastula") are reversed in function. What would be the ectoderm of other groups becomes sponge endoderm. Development of the larvae proceeds through ascon, sycon, and leuconoid stages, stopping along the way if the adult sponge is asconoid or syconoid.



AMPHIBLASTULA OF SYCON (AFTER BORRADAILE, ET AL, 1961)

Regeneration

Sponges have the ability to regroup into completely organized sponges from a mass of scattered cells. A sponge may be squeezed through fine gauze to break it into individual cells. The separated cells will become ameboid, crawl together, and form a new sponge. The red sponge, Microciona, is best for this experiment. Complete regrouping into small sponges takes a week or 10 days.

Protective devices of the sponge and its role as a home for others.

At first glance, a sponge resting on the bottom resembles a defenseless blob waiting for anyone who is hungry. However, if you should pick up a sponge in your bare hands, you would quickly find it rather painful,

especially in the case of glass sponges. The spicules are quite effective in causing intense discomfort by penetrating the soft tissue of anything that tries to handle them. Sponges also have disagreeable tastes and smells and can produce irritants which cause severe discomfort or even death to potential predators.

The sprawling, porous mass of a large unpalatable sponge is full of small nooks, crannies, and holes of various sizes, including the ostia and oscula. Literally thousands of tiny sea creatures including crustacea, octopi, crabs, starfish, and others find refuge in the body of the sponge. The hauling aboard and careful tearing up of a large sponge reveals a treasure trove of small creatures delightful in form, activity, and color.

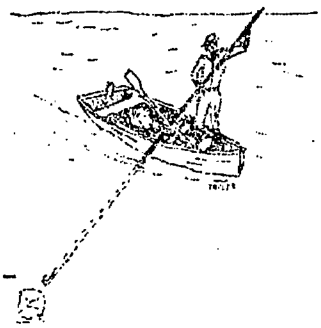
Sponges and Man

A. Commercial Sponges

The most obvious connection of sponges to man is the commercial sponge fishery. All commercial sponges are in the order of horny sponges. The skeletons of these sponges consist only of the protein spongin. There are

no limy or glass spicules. Commercial sponges can absorb 25-30 times their own weight of water. The main varieties of commercial sponges include Turkey cup, toilet, Zimocca, wool, velvet, yellow, grass, wire, and elephant's ear. Differences in quality depend on locality and bottom conditions. The best sponge grounds are in warm tropical and subtropical areas such as the Mediterranean, Gulf of Mexico, West Indies, the Sea of Japan, and the Phillipines. The depth of commercial sponge grounds varies from shallow water to 600 feet.

The sponges are gathered by hard hat divers, hooking from the surface, or dredging. The best sponges are gathered by hard hat divers at about 100 feet down. In the Mediterranean, sponges are taken from depths of 450-600 feet by dredges. This method destroys many valuable young sponges. In territorial waters of Florida, diving is prohibited. Sponge fishing there is by long-handled hooks worked from a boat at the surface. The sponge fishing is limited to depths of 30 feet by this method.


HOOKING SPONGES IN SHALLOW WATER

Sponge cultivation is carried out by cuttings, as discussed in the section on

asexual reproduction. The Japanese raised the best toilet sponges in World War II by suspending long strings of cuttings on a wire attached to a float in the Caroline Island lagoons of the Pacific.

The sponge catch is left on deck to decay or put in shallow ponds. After 2 days, the tough outer skin is peeled off and the sponges are washed and dried. The dried sponges are sorted by size in long strings and stored for sale at auctions. The usual market price in 1969 was seven or eight dollars a pound for prepared sponges.

A disastrous fungus disease hit the commercial sponge grounds in 1938 and 1939. It started in the Bahamas and spread to Florida and the Gulf of Mexico and Caribbean. It killed almost all the velvet sponges and 80% of the wool sponges in the Gulf and Caribbean. The wool sponge began recovery in 1950, but the velvet sponge has never recovered.

The scarcity of sponges in the wake of the disease stimulated the development of the artificial sponge. These have almost eliminated the demand for natural sponges.

B. Other important sponges

The boring sponge, Cliona, is a serious pest on oysters in many localities. In the state of South Carolina, it has been described as the most serious oyster pest. It has caused depletion of many formerly productive oyster beds in Chesapeake Bay.

The boring sponge attacks the shell of the oyster, honeycombing it with tunnels and causing the shell to become thin and weak. The boring sponge is easily identified. It is most usually found as small sulphur-yellow bumps all over an oyster. Shells that have been attacked by Cliona are completely riddled with small to medium sized holes. Severely infested shells may be easily broken between the fingers. The data on Cliona from South Carolina indicated 100% of the examined shells in some areas as being infested with the boring sponge. Four species of boring sponge were found in South Carolina waters.

Activity 1 (Life Science, Biology)

1. Remove 15 *Leucoselenia* sponges from the 10-gallon aquarium in which they have been held. Distribute these to 2-student groups in seawater-filled finger bowls.

2. Have each group add a pinch of carmine particles to their bowl. Placing the bowl over a white sheet of paper will help to show up the carmine particles.

3. Have the class sketch the path of carmine particles in the vicinity of the sponge.

4. Ask the class if they think oxygen also enters the sponge with the water (yes).

5. Have the students probe about the sponge with dissecting needles. They should probe gently in several areas of the sponge and then work toward the osculum. Can they probe close enough to the osculum to cause the sponge to close it?

6. The class should now dissect the living sponge. Have them make a cut down the length of the sponge, separating it into two pieces. Have them sketch what they see. CAUTION! If possible, all cutting of sponges should be done while handling them with gloves or holding them down with a needle. The spicules can cause a nasty irritation on bare fingers.

7. This part of the activity poses some difficulty, but some students should get good results. Each team should attempt to remove a thin section of tissue from the rim of one of their sponge halves and mount it in a drop of water on a microslide. A proper exercise of caution and good technique should yield a slide of a cross-section of sponge wall from epidermis through mesoglea to choanocytes. They should be able to see the beating choanoflagellates drawing water in through the porocytes, which will appear as gaps in the wall of the sponge. Amebocytes may also be seen as well as several types of spicules forming the cell wall. The class should look for cells containing carmine particles. They may also be

able to see how the sponge spicules form the skeleton of the sponge.

8. Repeat the procedures in this section with Living _Sycon (Grantia)_, a syconoid sponge, and with _Microciona_, a leuconoid sponge. In the case of _Grantia_, the class should carefully examine the rim of giant spicules forming a collar around the osculum.

9. As the class carries out the dissections of _Grantia_, have them look for foldings of the choanocyte layer and compare the size of the spongocoel.

Activity 2 (life Science)

1. Distribute modeling clay and a 15 inch length of waxed paper to each group of students.

2. Have the teams roll out a string of clay about 15 inches long and about 1/4 - 1/2 inch thick on the waxed paper. If the students desire, they can merely cut out flat strips 1/4 inch thick and pinch them together to make a string about 15 inches long. Rolling will usually be found much more satisfactory.

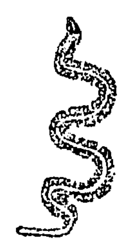
3. The strip should be curved in the shape of one half of an asconoid sponge, like this:

4. Little strings of contrasting clay should be laid on top of the basic sponge body at about 1/2 inch intervals to represent the porocytes, as shown.

5. Another thin layer of contrasting clay can be laid along the inside of the sponge to represent the choanocyte layer, like this:

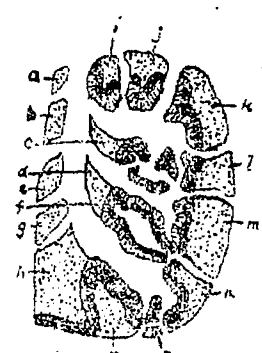
This step finishes the shematic diagram of an asconoid sponge.

6. Now, have the groups oppose their fingers and push on either side of the sponge to make an outpocketed configuration. This will become a schematic model of the next grade of sponge organization, the syconoid. This is done in the following manner:



7. The leuconoid sponge is produced by conducting the same procedure separately on each syconoid pocket.

8. The decrease in size of the spongocoel can be shown by filling in the sponge (a-h) with clay. Point out to the class that the stagnant space of the spongocoel is gone, and is replaced by channels which do not let the force of the water become dissipated.



9. (Optional) Sponges of sycon and leucon grade also become filled in on the outside

with cortex cells, channeling the outward flow as well as the inward. If the groups will fill in the shaded areas h-p with clay, leaving the channels open as indicated, they will have a clearer picture of the true organization of asconoid and leuconoid sponges. All they have to do is lay down a roughly elliptical outline to the sponge to give external shape to it, as shown. Then they lay down clay in all areas except the channels. If they ask you if the openings of the canals to the outside have a name, you can call them "dermal pores". The large bays between the pockets on the sponges are called incurrent canals.

Activity 3 (Biology)

1. Distribute the following items to each group of students:

   a. a small living *Microciona* sponge

   b. a large culture dish full of seawater

   c. a square of fine cheese cloth or bolting cloth (bolting cloth is better)

2. Each team of students should place their living sponge in the center of the cloth and bring the sides of the cloth up to form a bag.

3. The sponges in their bags should be held in the water in the culture dish. By holding the upper end of the bag, the class hould turn the lower portion so that the bag gets twisted tighter and tighter around the sponge.

4. The sponge will soon be squeezed through the cloth as individual cells or cell groups. As the sponge begins to squeeze through the cloth, the bag should be moved around the dish in a wide circle. This will spread the separated cells around the dish and avoid their collection into lumps at the bottom of the bowl.

5. When the sponge is thoroughly broken into individual cells, the dish should be covered to avoid evaporative changes in salinity. The 9 x 9" glass plate may be used for this purpose. The dish should be watched closely for the next few minutes.

6. The regeneration process starts quickly. In a few moments, many cells will have already become ameboid and crawled together in small lumps on the bottom of the dish. If a concavity slide and a compound microscope are still available from activity 1, you should try to take up a sample of water and debris from the bottom of the dish. With luck, you may

find ameboid cells actively crawling toward each other.

7. When a number of small balls have formed, you may replace the water in the dish with clean seawater and cover the dish. In a week to 10 days, each little ball of cells should develop into a small but complete sponge.

Activity 4

1. Distribute 2 pebbles, 2 three or four-inch lengths of surgical thread, and a small piece of Microciona sponge to each group of 2 students. Assign a number to each team.

2. Each group should cut their sponge in half with a scalpel, tie each piece securely to a pebble with the surgical thread, and put their team number in pencil on each pebble. Each team should make accurate notes and sketches of the appearance of their cuttings at this time.

3. Weigh the sponge and pebble when (2) is complete.

4. All the sponge cuttings should be placed in the salt-water aquarium in the classroom. The cuttings should be examined at least once every two weeks for the remainder of the school year. Notes and sketches should be made at each observation recording size, appearance, and any other changes the students may note.

5. At the end of the year, each sponge cutting and its pebble should be weighed again to determine how much weight it has gained since the original planting.