DOCUMENT RESUME

ED 141 152 SE 022 674

TITLE	Observing Starfish--The Water Vascular System. A Learning Experience for Coastal and Oceanic Awareness Studies, No. 224. [Project COAST].
INSTITUTION	Delaware Univ., Newark. Coll. of Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	74
NOTE	32p.; For related documents, see SE 022 662-687
EDRS PRICE	MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS	Biology; *Instructional Materials; *Marine Biology; *Oceanology; Secondary Education; *Secondary School Science; *Teaching Guides; Units of Study
IDENTIFIERS	Project COAST; *Starfish

ABSTRACT

This unit is designed for students in secondary school science classes. Emphasized are various aspects of the anatomy and behavior of the starfish. Included are teacher background materials, lists of needed materials, suggested activities, evaluation materials, transparency masters, and selected references. (RH)

OBSERVING STARFISH--THE WATER VASCULAR SYSTEM

A Learning Experience for
Coastal and Oceanic
Awareness Studies

Produced by

MARINE ENVIRONMENT CURRICULUM STUDY
MARINE ADVISORY SERVICE
UNIVERSITY OF DELAWARE

and

POPULATION-ENVIRONMENT CURRICULUM STUDY
COLLEGE OF EDUCATION
UNIVERSITY OF DELAWARE

as part of a

PLAN FOR ENVIRONMENTAL EDUCATION

Fall 1974

Please send evaluations

of learning experiences

to

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COAST Project

310 Willard Hall Education Building

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Newark, Delaware 19711

Supported in part by

OFFICE OF COASTAL ZONE MANAGEMENT(NOAA)

DELAWARE SEA GRANT COLLEGE PROGRAM(NOAA)

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TITLE: OBSERVING STARFISH: THE WATER VASCULAR SYSTEM

* Concept: I.B.3.

I. The earth is a finite natural system.

B. All living things have arisen from and are dependent upon the natural system of the earth.

3. MOST ORGANISMS INTERACT IN BALANCE WITH THEIR PHYSICAL AND BIOTIC ENVIRONMENT.

** Marine Concept: 3.21

3. Marine organisms interact in complex ecosystems.

3.2 Marine organisms are adapted to their environments in different ways.

3.21 MARINE ORGANISMS ARE ADAPTED DEVELOPMENTALLY, STRUCTURALLY, FUNCTIONALLY, AND BEHAVIORALLY TO THEIR WAYS OF LIFE.

Grade Level: 7-10

Subject: Life Sciences

Periods: Various

Author: Fleming, O'Toole

* From A Conceptual Scheme for Population-Environment Studies, 1973. Cost $2.50.

** From Marine Environment Proposed Conceptual Scheme, 1973. No charge.

Both conceptual schemes are available from Robert W. Stegner, Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711.

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Observing Starfish:

The Water Vascular System - Locomotion and Feeding

I. Instructional Objectives

A. The student's scientific vocabulary will be expanded by addition of the words in the New Terms list. The student will identify these terms in a post-test.

B. The student will gain a basic understanding of the principle involved in the starfish water vascular system as it relates to the processes of locomotion and feeding and will demonstrate this knowledge on the post-test.

C. Starfish locomotion will be observed and the rate measured. All data will be recorded.

D. The students will feed small starfish in the classroom and record all observations.

E. The student will learn the basic principles of marine aquarium maintenance and will demonstrate this knowledge on the post-test.

II. Teacher Background

Asterias spp., common Atlantic coast sea stars, better known as starfish, are easily collected and maintained, at least for a few days, in a classroom for observation. Thus they are ideal subjects for study of the water vascular system, unique in the Phylum Echinodermata (from the Greek words echinos-meaning hedgehog, and derma-meaning skin.) A study of starfish locomotion (easily observed) and feeding mechanisms (probably observable to only a limited extent in a classroom situation) will illustrate the function and value of this system in the starfish's way of life.

Other echinoderm characteristics which may be observed include:
1. Pentamerous radial symmetry - the body can be divided into five parts arranged around a central axis.
2. An internal skeleton composed of calcified plates in the skin which gives the surface a warty or spiny appearance (like the hedgehog).

Characteristics of the Class Asteriodea (from the Greek words aster, meaning star, and eidos, meaning appearance), to which sea stars belong are:
1. Flattened, star-shaped with arms radiating from a central disc.
2. Ambulacral grooves (symmetrically spaced radiating grooves) with tube feet on the oral (under) surface.

The fluid-filled water vascular system of the starfish operates as a hydraulic system during locomotion. Sea water is drawn into the system by beating flagella which occur on the furrowed outer surface of the madreporite, also called the sieve plate or water sieve, located on the aboral (upper) surface, toward one side of the disc and between two of the arms. At the base of the furrows are tiny pores which lead through minute pore canals to collecting canals and into the stone canal, so named because of the calcified rings in its walls. The stone canal leads to the circular canal, or ring canal on the oral side of the disc. A flagellated radial canal extends from the ring canal into each arm and ends in a small external tentacle at the tip of the arm. Lateral canals extend from each side of the radial canal along its length. The flagella beat inward continually maintaining a strong current of sea water and keeping the entire system turgid with fluid.

The water enters sac-like structures called ampullae. The tube feet are an extension of these sacs. There are four rows of tube feet arranged in a double row on either side of the ambulacral groove. Contraction of the muscle bands within the thin walls of the ampulla forces fluid into the adjoining tube foot. The water is prevented by a valve from flowing back into the lateral canal. Hydrostatic pressure extends each elastic tube foot forward and it attaches to the substrate by a suction disc located at the tip of the foot. An adhesive secretion also aids in adherence. The longitudinal muscles of the tube foot then contract and the tube foot is slowly drawn forward while the fluid flows back into the ampulla. The action of hundreds of tube feet moving in the same direction will move the starfish slowly over the ocean floor. Starfish have been observed to walk as much as six inches a minute. On soft sand and mud, the suckers are of little use and the tube feet act as little legs. The terminal suction discs, suckers, attach the animal firmly to hard surfaces and enable it to move vertically over rocks or up the side of an aquarium. Some of the tube feet are broken when the animal is slowly lifted from a glass surface. As the starfish moves, any one or two of its arms may take the lead thus serving as a temporary "head."

The functioning of the water vascular system gives the starfish a striking and unique facility in opening shells of bivalve mollusks. Anyone who has ever tried barehanded to open a live clam or oyster will wonder how it can be done by a starfish which is not much larger than the bivalve it attacks. The starfish has been known to exert a pull of 1350 grams/square centimeter over a period of time. The bivalve can resist a much greater pressure for a short time, but the starfish uses its numerous tube feet in relays and is able to outlast the bivalve. The starfish maintains its pull until the large muscles which hold the valves together become fatigued and begin to relax. Only a slight gap is adequate for many starfish. Muscles in the starfish body wall contract and fluid pressure causes the globular cardiac stomach to evert through the mouth opening. The stomach engulfs the prey and digestion begins. The soft bivalve body is reduced to broth and absorbed. When digestion is complete, two muscles attached to the cardiac stomach contract, retracting it into the body and leaving an empty bivalve shell. The starfish is a serious predator of the clam and oyster bed.

Aboral to (above) the cardiac stomach is the smaller flattened pyloric region. It appears star-shaped because a large duct passes to each arm. This divides to enter two extensive pouches (pyloric ceca) in each arm. Digestive enzymes are produced by the pyloric ceca. Flagella in the ducts create incoming and outgoing currents. From the pyloric region a short intestine, with three small pouches (intestinal ceca) leads to a tiny anal opening in the center of the aboral surface.

OBTAINING LIVE SPECIMENS

a. Asterias may be purchased from biological supply houses but the difficulties of making and guaranteeing live shipments have resulted in the setting of minimum order amounts so high as to be unappealing for a single study unit. This would seem to be a source of last resort.
b. Asterias lives on rocky or shell-covered bottoms. It can be found among plants low on the rocky shore or along a stone jetty. Smaller sea stars will hide under rocks on the bottom while larger ones seek cover from receding tides by hiding in shaded and protected crevices. Collect at low tide, wading or snorkeling. IMPORTANT! For best results in school maintainance, collect small stars, one inch or less in diameter.

TRANSPORTING SPECIMENS OVER A DISTANCE

Arrange the collection in wide-mouthed gallon jars of sea water with about an inch of sea sand on the bottom. When ready to travel, place a plastic bag of crushed ice in the center of four of the gallon jars which have been placed about an inch apart in a cardboard box. The bag of ice should be in contact with each jar. This will keep the water at about 70° F or less (approximate the temperature at the collecting site) while traveling. To aerate the aquaria while traveling use a hand pump attached to plastic tubes which are pushed through small holes in the metal jar covers. The holes in the jar covers must hold the tubes firmly so that the level of the tubes can be adjusted to equalize the bubbling of air in the jars. A second small hole must be made in each jar cover, allowing air to circulate without allowing water to slosh out of the jars. Add ice to the icebag when necessary and operate the hand pump at least a few minutes in every hour. At night the aquaria can be maintained in an air-conditioned motel room with the aid of an electric air pump, or the animals could probably survive for eight hours without extra aeration, if they are not crowded.

SETTING UP OBSERVATION AQUARIA

The sea stars may be observed easily in small rectangular tanks or in culture dishes (finger bowls) on each laboratory table. Sea water collected with the specimens is far preferable to mixed synthetic sea water. Mark the original water level of the container and replace evaporated water regularly with distilled water. Do not use sea water as the salt concentration would become greater and greater. The crusts of salt that accumulate on the rims and covers of the aquaria should be returned to the water. Aerate and maintain temperature at about 65-70° F. Feed the starfish bits of oyster or other bivalve meat (frozen if most convenient) but be sure to remove all uneaten food promptly to avoid fouling the tank.

USE OF PREPARED MATERIALS

To facilitate understanding of the water vascualr system of the sea star, a large preserved specimen with the water vascular system injected with colored latex would be wonderfully helpful. It could be dissected by the instructor as a demonstration unless the students had had considerable practice in dissection methods. These specimens are available from one supply house for $1.50 apiece. A prepared microscope slide showing a cross-section of the starfish arm could be useful with a class accustomed to microscope use but an alternative is the use of the drawing of a cross-section included with this lesson.

WHAT TO DO WITH STARFISH AFTER SCHEDULED OBSERVATIONS ARE COMPLETED

a. Keep them for informal observation.
b. Release them at collecting site.
c. Preserve them in formaldehyde or by drying.

To preserve by drying simply relax and kill the starfish by immersing for an hour in a container of water to which epsom salts have been added. Then soak in a solution of 70% alcohol or 10% buffered formalin for 4-5 hours. Remove and allow to dry. The drying process can be hastened by placing in the sun. It may then be embedded on plastic, if desired.

III. INSTRUCTIONAL PROCEDURES

A. Teacher preparation

1. Order well in advance of the unit presentation any commercially prepared materials to be used.

2. Obtain live starfish.

A class field trip for collection would certainly be an exciting introduction to the unit; this would probably be impractical in many situations, however.

3. Duplicate materials for students and prepare transparencies.

4. Obtain all equipment and supplies needed (see list below).

5. Measure the volume of sea water in all starfish containers and mark the initial water line.

6. If funds permit obtaining an "extra" injected starfish, it is always wise for the instructor to practice a dissection before demonstrating.

B. Introduction of unit.

The presence of live starfish in the classroom will probably be sufficient to arouse great interest in observation. Mention where they were collected and the method used.

Give pre-test.

C. Classroom (or laboratory) procedures.

1. Equipment needed
   a. Distilled water
   b. Graduated volumetric container for measuring water
   c. Rectangular all-glass or stainless steel framed tanks and/or culture dishes (finger bowls)
   d. An aerating device and aquarium thermometers.
   e. Ice (for cooling) and an immersion heater
   f. Hand lenses or some type of magnifying glasses
   g. Binocular dissecting microscopes, if available.
   h. Watch with second hand or stopwatch and ruler
   i. Camera, movie or still (optional)
   j. Dart with suction cup
   k. Balloons (two)
   l. Epsom salts, alcohol or formalin and plastic resin, if specimens are to be dried and embedded
   m. Wooden sticks (like popsicle sticks) for scraping salt crusts from glass.

2. Introduction to observation and experiments.
   a. Starfish external characteristics.

Demonstrate features students will be observing using a dried preserved specimen (preferably large) or transparency (no. 1)

b. Water vascular system

This is probably best explained after observation of locomotion but before observation of feeding.

1. Locomotion

a. Use transparency showing schematic representation of water preserved specimen.

c. Do demonstration dissection on water vascular system injected, preserved starfish specimen.

c. Use transparency showing cross-section of starfish arm (no. 3) to show position and relationship of internal anatomy, or set up microscope demonstration for advanced class.

d. Explain how system provides locomotion. Emphasize that it is the water pressure maintained in the system that makes the functions of locomotion and bivalve possible.

Some suggested mechanical devices to aid explanation:

1. Small dart with rubber suction cup. Press cup onto surface of desk or laboratory table. Remove. Moisten undersurface with water, saliva, oil or other. Press down again. Remove. Let students perform the same operation. The difference should be evident. Compare to secretion of the starfish suction disc.

2. Two balloons and a short rigid cylinder of waterproof material to connect them. Fill one balloon with water (without stretching) and attach to connector. Add enough water to the other balloon to allow squeezing of water back and forth to demonstrate contraction of muscles in ampulla, with extension of tube foot, then contraction of muscles in tube foot to return fluid to ampulla. Attach the second balloon to the other end of the connector. Point out that hydrostatic pressure extends the elastic tube foot in much the same way that the balloon extends when water is squeezed into it. A suction cup could be tied to the tip of the "tube foot" to further develop the simulation. A plastic bag partially filled with water and then sealed or tied would also be easily used instead of the balloon device.

3. Feeding mechanisms

a. Give a brief explanation of digestive system anatomy using transparency (no. 4) and transparency (no. 3). Students should not be held responsible for details of digestive system anatomy unless dissection or further study is to be done.

b. Use transparency (no. 5) to explain the process of starfish opening bivalve shell and/or show a film loop illustrating the process. A pair of excellent photographs appear on pages 110 and 111 of The Life of the Seashore by William H. Amos, 1966, McGraw Hill Book Company, New York.

Small starfish are known to feed much more successfully than large ones in an artificial situation. Observation of the opening of a bivalve in captivity would be a rare occurence and should not be expected. If small oysters are available, a few could be placed in a tank with starfish in hopes that some action might take place.

4. Care of the marine aquaria.

Instruct students and assign responsibilities for care of the starfish

In any case, feed small pieces of clam, mussel, oyster or other bivalve. These will probably be taken in directly through the mouth; it is not likely that students will be able to observe the everting of the starfish cardiac stomach and the ensuing extra-body digesting.

STUDENT LABORATORY ACTIVITIES

Students should work in teams of two, three or four.

A. Starfish external characteristics.

1. Observe the upper surface (aboral surface) of a starfish with a hand lens or binocular dissecting microscope. What color is the skin? Locate the following:

   a. a central disc and five arms
   b. madreporite (or water sieve) - button-like structure located off-center between two arms. What color is it?
   c. rough texture due to presence of calcified plates in the skin projecting as spines.

   The next two structures may not be easily seen in small starfish.

   d. anal opening in center - tiny opening for digestive wastes.
   e. papula - finger-like projections which, together with the tube feet are the principal respiratory surfaces (exchange of gases between sea water and body fluid takes place here).

2. Observe the undersurface (oral surface) and locate the following:

   a. mouth -in center.
   b. ambulacral grooves - one runs from the mouth lengthwise along the center of each arm.
   c. tube feet - arranged in four rows along each ambulacral groove. Are the tube feet retracted or extended? They will probably retract when the starfish is handled. Can you see the suction discs, or suckers, at the tips of the feet? On small starfish these will be difficult to see.
   d. eye spot - near the tip of each arm, a pigmented, light sensitive area. What color is it?
   e. sensory tentacle - at the tip of each arm - this may be quite difficult to see in small starfish; it is the end of the radial canal.

   Label the sketch on your work sheet. Answer the questions.

B. Water vascular system - locomotion

1. Observe starfish locomotion
   Starfish show a marked tendency to move up the vertical sides of a glass aquarium. If starfish seem inactive in a brightlylit classroom, placing them in a darkened situation may stimulate movement. How does the starfish manage to stick to a smooth glass surface?
   Measure the rate of locomotion using a ruler and a timing device.
   Record three timed measurements.

__________ minutes for each measurement.

1. __________ inches
2. __________ inches
3. __________ inches

Average inches moved in __________ minutes = ________________.

2. Mark one or two arms with a ballpoint pen dot. Observe which arms take the lead (function as a temporary "head"). Does any one arm seem to act more often than the others as "head"? Over a long period of time it is unlikely that any predominace would be observed.
3. Optional: Photograph movement if cameras (especially movie) are available.
4. Gently invert a starfish. Observe the righting reaction. The starfish may right itself in one of two ways.
   a. Folding - the tips of one or 2 arms twist so that the tube feet can grip the surface. These arms then move back beneath the starfish so that the rest of the body is folded over.
   b. Arching the body and rising on the tips of the arms. The starfish then rolls over onto its oral surface.

   Which did you observe? Invert another starfish and observe its reaction. Record all observations.

C. Feeding mechanisms

1. Observe starfish feeding.
   Feed small pieces of oyster, clam, mussel or other bivalve. If meat is frozen, thaw partially in warm water for a few minutes. Record results for each feeding. Meat fed was ________________.
   Approximate size of pieces ____________.
   Number of pieces eaten ________________.
   Remove uneaten pieces of meat promptly. Why?
   Place a few small oysters or other bivalves, if available, in a container or starfish. Note whether any feeding action by starfish takes place over a period of several days.
2. Optional: if possible, photograph starfish feeding.
3. Optional: if the starfish seem to be feeding quite successfully in captivity, some experimenting with diet may be done. Asterias, this genus of Atlantic coast starfish, are strongly partial to bivalve mollusks but may also eat snails, crustaceans, polychaete worms, other echinoderms and even fish. Try feeding with small peices of these animals. Record the results.

4. Optional: a team of students, with assistance from the instructor, may construct a mechanical model, to a limited extent, a working model, of the starfish water vascular system. Some materials to use might be: a small funnel with screening at the mouth for the madreporite, a piece of heavy, stiff plastic tubing for the stone canal, thinner-walled plastic tubing for the ring canal fitted with T-connectors to connect with the radial canals and with the lateral canals, represented by plastic tubing of smaller diameter. The ampullae and tube feet could be of

rubber balloons or other material. It would be to see whether the system could be made water-tight.

D. Care of marine aquaria
1. Replace evaporated water with a measured amount of distilled water. Use a graduated container and record each amount added.
2. Scrape any salt crusts accumulated into the water in the container.
3. Feed regularly but remove any uneaten food promptly to limit its decomposition.
4. Check the temperature regularly. Take whatever steps are necessary to keep the temperature within the 65-70° F. range (insert a bag of ice cubes or a shielded immersion heater as needed).

THERMOMETER TROUBLES

If only a centigrade thermometer were available to measure the temperature in your starfish container and it read 29° C. would you need to take steps to adjust the water temperature? If so, what? Hint: 180° F. is equivalent to 100° C. 1°F. is 100/180 or 5/9 as large as 1°C. and 1°C is 180/100 or 9/5 as large as 1°F. Also, the Fahrenheit scale has a 32° "head start" over the centigrade scale in terms of freezing point. So to convert from centigrade to Fahrenheit, find 9/5 of the C. reading and add 32 to the result.

$$F = \frac{9}{5} C. + 32$$

SALT WATER PROBLEMS

Sea water contains about 30 parts of salt to a thousand parts of water. This means that it is approximately 97 per cent water and 3 percent salts. Assume that the concentration is the same for the sea water in your container of starfish. The amount of sea water in the container originally was ____________. The amount of distilled water which has been added to the container while in the classroom is ____________.

If the water evaporated off had not been replaced but the salt crusts accumulated on the sides of the container had been scraped into the water, the concentration of salts in the remaining water would have become ____________ parts per thousand or ____________ % water and ________ % salts.

If the salt crusts accumulated on the sides had all been removed from the container completely and then distilled water added to bring the volume up to the original level, the concentration of salts would have become ____________ parts per thousand. If sea water had been used to replace water evaporated, the concentration of salts would have become ____________ parts per thousand.

Why is water evaporated from a starfish container replaced with distilled water rather than with sea water?

Starfish cannot survive in water with a salt content of much less than 15 parts per thousand. Oysters will thrive in bays and estuaries where the salt content may be considerably lower. What does this suggest for the oyster industry?

<u>JUST FOR FUN</u>

The poem below, author unknown, needs two final lines.

Can you supply them?

Stars of the Sea

Have you ever seen a starfish
   lying on the sand,
And as you held him by his leg
   He left it in your hand?

He will hardly miss it,
   For you know what he will do,
He'll grow a new one in the place
   Like the one he left with you.

But how he loves the oysters!!
   To him they are the best,
He wraps himself about them
   And smothers them to death.

There he sits and has a feast
   On food fit for a king

STARFISH PRE-TEST

1. Have you ever seen a live starfish? If your answer is "yes", do you remember where?

2. Have you ever held a starfish? If your answer is "yes", was it a fresh or dried animal?

3. In one or two words describe the appearance of the starfish skin.

4. Where is the starfish mouth located?

5. Name one food of the starfish.

6. How does the starfish obtain food?

7. How does the starfish move?

8. What do you think the term water vascular system means?

ANSWERS TO PRE-TEST

1. ____________

2. ____________

3. spiny, warty, bumpy, prickly, or similar adjectives would all be correct

4. on the under surface, oral surface

5. oyster, clam, mussel (any bivalve) snails, marine crustaceans, polychaete worms, other echinoderms or some fishes would all be correct.

6. It is able to open and digest mollusks right inside their shells. The arms with their tube feet assist in capturing other foods as well.

7. It moves by means of its tube feet working in unison.

8. Literally it would be a system of vessels (tubes) filled with water.

Class Discussion

a. Share between teams the results of experimental observations. Be sure to discuss all questions and problems included in the laboratory activities.

b. Assuming that the class has been previously exposed to the scheme of taxonomic order, the instructor may state the starfish is a member of the Phylim Echinodermata and ask students to suggest the characteristics of the phylum based on observations. The instructor will need to guide the discussion. Write the correct responses on the chalkboard. Write those which apply specifically to Class Asteriodea in a separate column to be given a heading at the completion of definition of echinoderm characteristics. Help the class to analyze the origin of the words Echinodermata and Asteriodea.

Review Exercise

a. Distribute the New Terms lists.

b. Suggest that students review all terms by jotting in a brief identification or definition next to the word.

Give the Post-test

Part I.

Set up a laboratory quiz with separate stations for each question. Use dried, preserved, or live starfish or use transparency or handouts without labels to quiz students on the observation of starfish.

Sample questions:

1. Point to or place a label on the madreporite. Ask:
   a. What is the name of this structure?
   b. What is its use (function)?
2. Label the mouth.
   a. This structure is the ______________.
   b. It is located on the ______________ surface.
3. Name 2 starfish foods.
   a. Label tube feet.
4. These structures which by working together move the starfish along a surface are called ______________ ______________. a.
   b. They are located in the ______________ groove.
   c. At the tips of these structures are ______________.
5. The starfish has 2 types of respiratory structures. Name one.
6. Water pressure is the key to 2 important starfish activities. Name them.
7. Why was uneaten food removed from the starfish containers?
8. The starfish anal opening is located on the ______________ surface.
9. In 2 or 3 sentences describe how a large starfish would obtain and digest a meal.
10. Explain why only distilled water was added to the starfish containers.

PART II Make the best match. Write the correct letter in the blank space.

_____1.	sac that contracts and squeezes water into the tube foot	a.	spiny skin and radial symmetry
_____2.	star-shaped with arms radiating from a central disc.	b.	a colored, light-sensitive spot at the tip of each arm
_____3.	Echinodermata	c.	whip-like structures that create water currents
_____4.	a system of water-filled canals in the starfish	d.	ampulla
_____5.	the starfish water intake	e.	Asteroidea
_____6.	flagella	f.	radial canal
_____7.	canal that runs into each arm from a circular canal	g.	steady suction pressure
_____8.	eye spot	h.	locomotion and respiration
_____9.	opens a mussel	i.	madreporite
_____10.	tube feet	j.	water vascular system

PART III

In two or three sentences, name the starfish observation activity you enjoyed most and tell why.

Answers to Post test, Part II

1. d.

2. e.

3. a.

4. j.

5. i.

6. c.

7. f.

8. b.

9. g.

10. h.

Additional evaluation.

The quality of work done by the individual students during laboratory observation activities can be evaluated to some extent by examining the data and answers to activity questions in the laboratory notebook.

NEW TERMS

1. water vascular system
2. Echinodermata
3. Asteriodea
4. madreporite
5. central disc
6. arm
7. spines
8. anal opening
9. eye spot
10. tube feet
11. sensory tentacle
12. papula
13. ambulacral groove
14. oral surface
15. aboral surface
16. cardiac stomach
17. ring canal
18. radial canal
19. lateral canal
20. ampulla
21. stone canal
22. radial symmetry
23. flagella

Bibliography

Amos, William H. 1966. The Life of the Seashore. McGraw-Hill Book Company, New York.

Barnes, Robert D. 1963. Invertebrate Zoology. W.B. Saunders Co., Philadelphia.

Hegner, Robert W. ____ Invertebrate Zoology. The Macmillan Company, New York.

Miner, Roy Waldo. 1950. Field Book of Seashore Life. VanRees Press, New York.

Stegner, Robert W. 1963. Marine aquaria. The American Biology Teacher. February: 25(2), 128-129.

Visual Aids

Films, 16 mm:

Echinoderms - Sea Stars and Their Relations
17 minutes; color or B/W
Encyclopedia Britannica Films Inc.
1150 Wilmette Ave.
Wilmette, Ill.

Film Loops:

External Features of the Starfish
Internal Features of the Starfish
Water Vascular System of the Starfish

Potter's Photographic Applications Company
160 Herricks Road
Mineola, New York 11501

Echinoderms and Sea Squirts

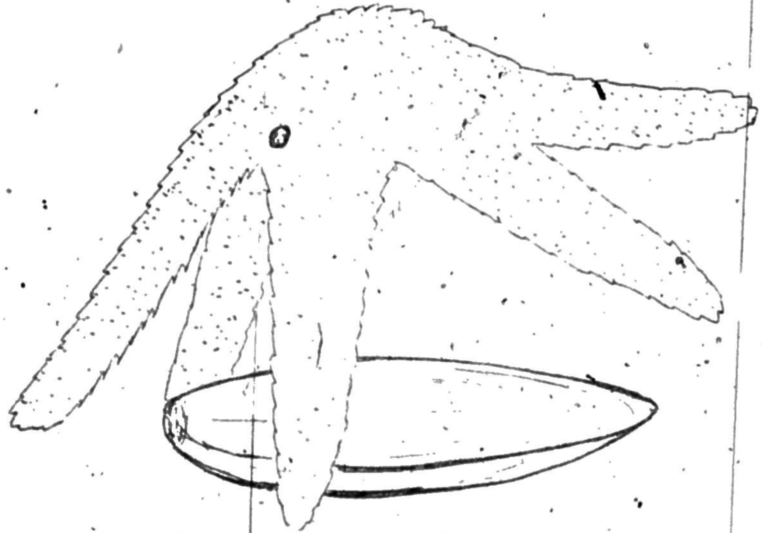
Gateway Educational Films Ltd.
470/472 Green Lanes
Palmers Green, London N. 13, England

Echinoderms and Sea Squirts

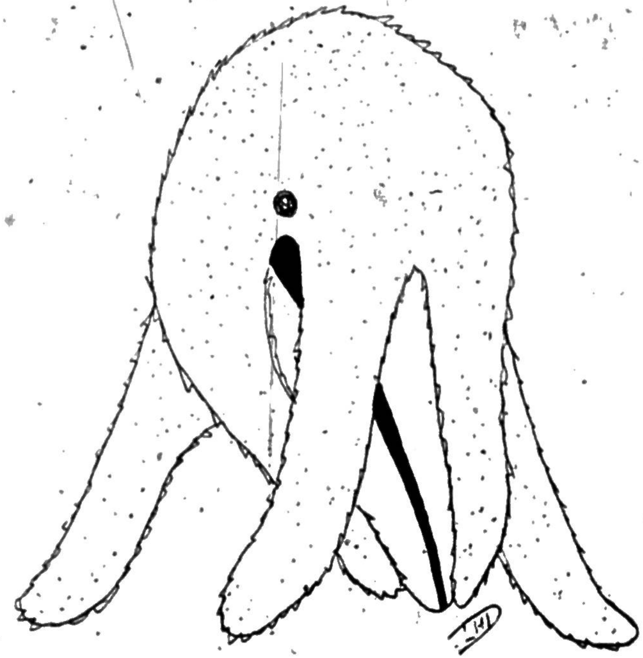
International Communication Films
1371 Reynolds Avenue, Santa Ana, California 92705

Starfishes (Predators)

Thorne Films
1229 University Avenue, Boulder, Colorado 80302



STARFISH OPENING CLAM



I.B.3
(Mar. 3.21)
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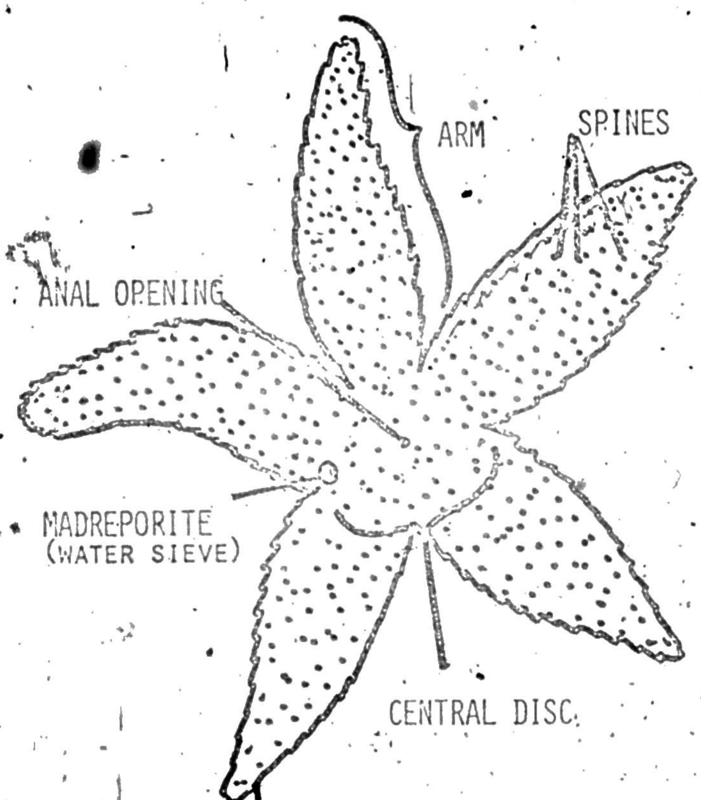
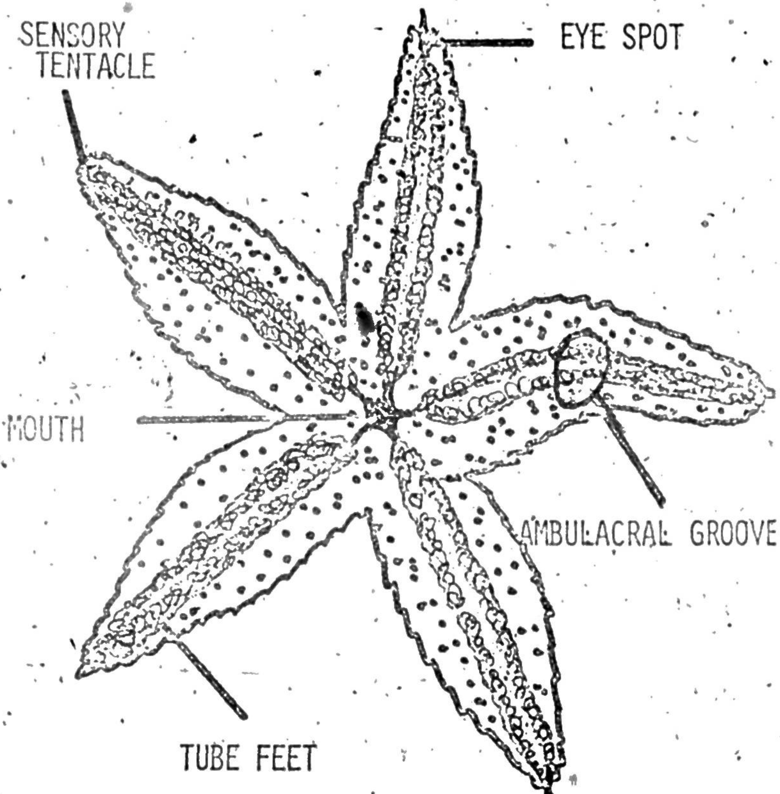
2 SURFACES OF THE STARFISH



ABORAL SURFACE



ORAL SURFACE

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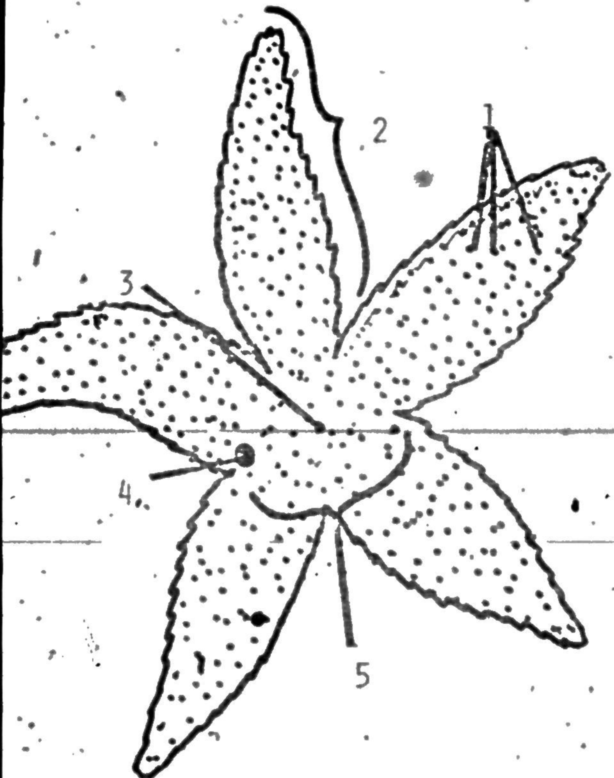
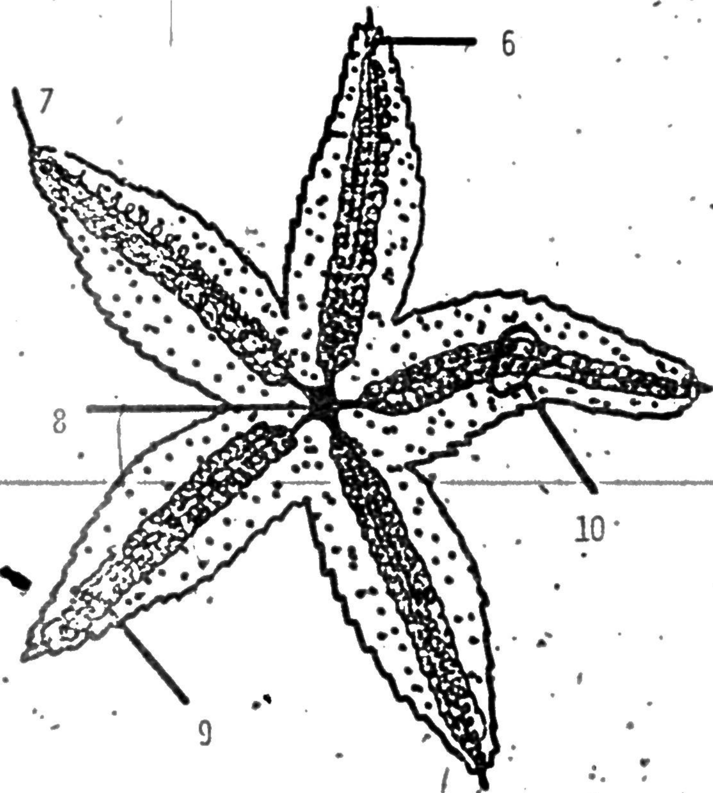
2 SURFACES OF THE STARFISH



________ SURFACE



________ SURFACE

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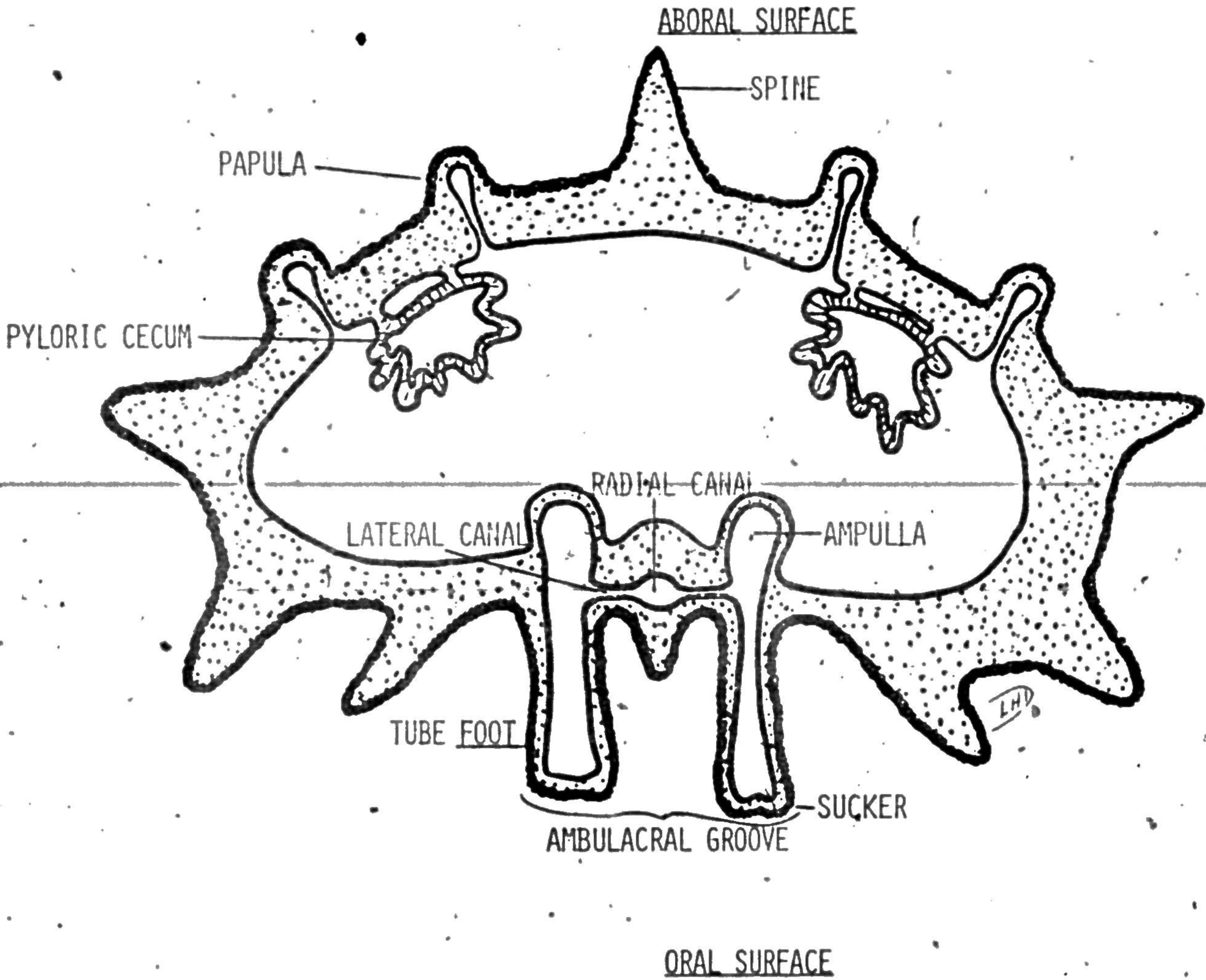
CROSS SECTION OF STARFISH ARM



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DIGESTIVE SYSTEM OF THE STARFISH

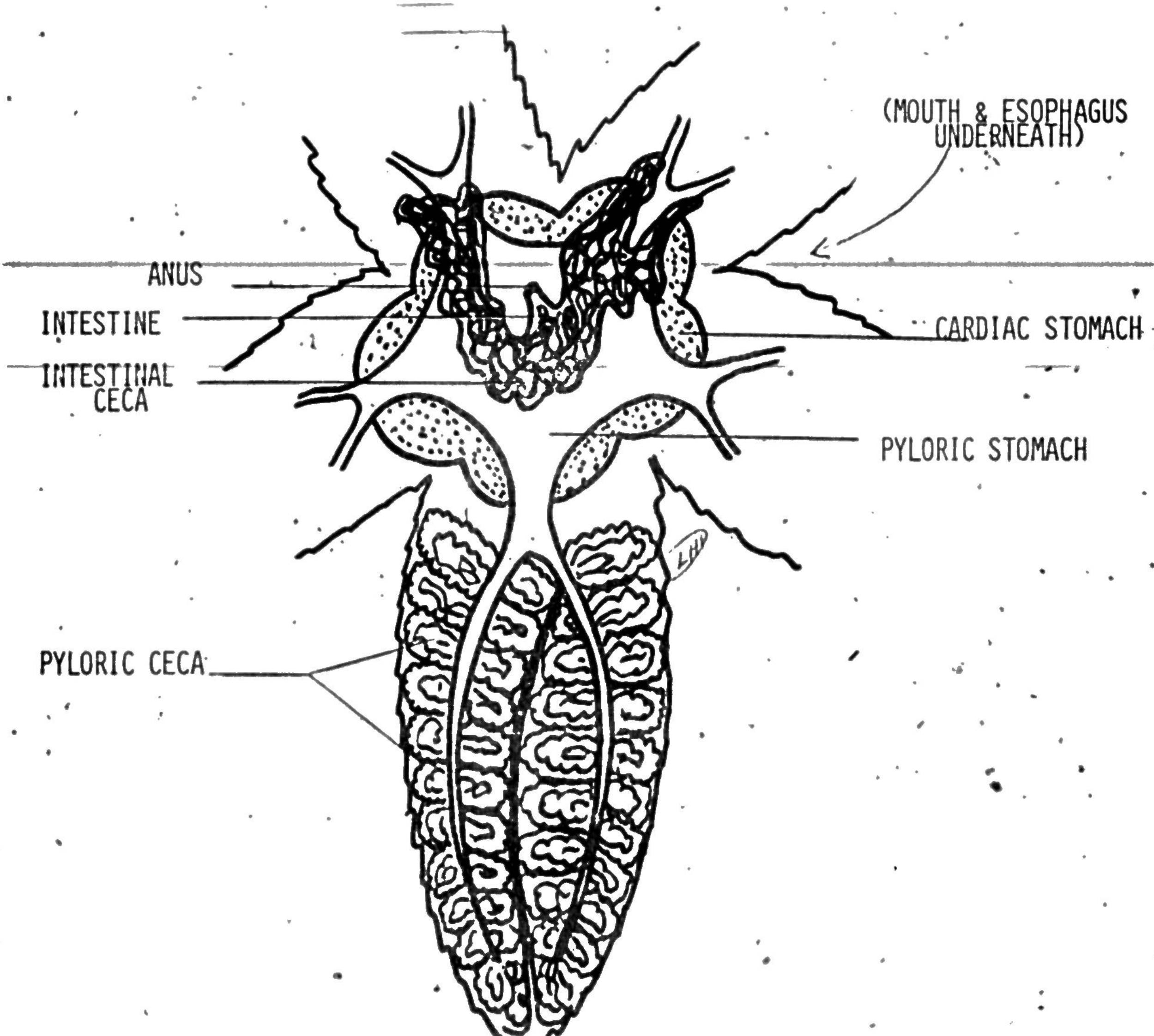
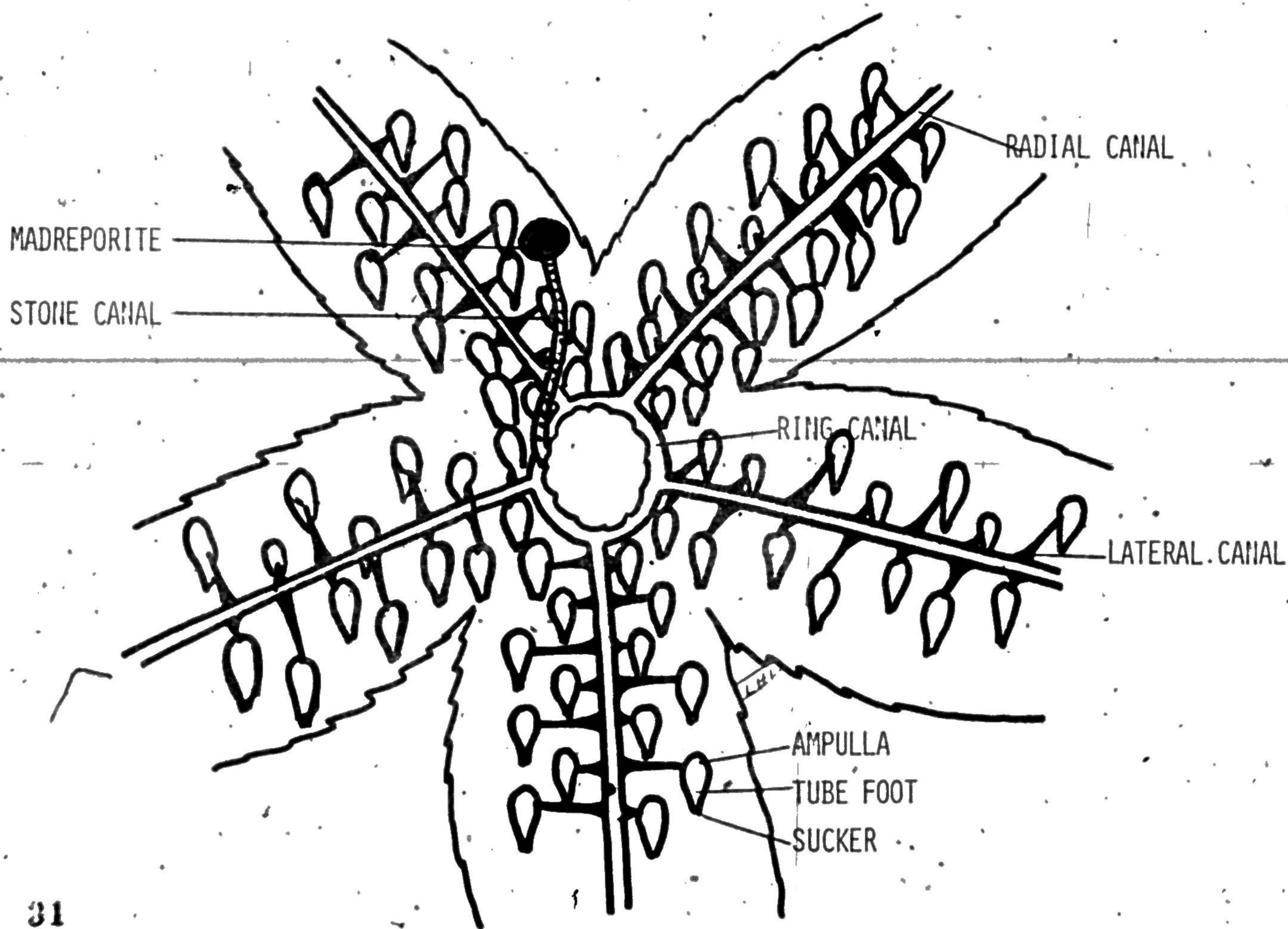


DIAGRAM OF WATER-VASCULAR SYSTEM



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(Maf. 3.21)
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