

# Invertebrate Food Selection

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## Abstract

This laboratory exercise was developed for a one-semester course geared for the nonscience student. The course, MARS 1020, is one option for students to choose when fulfilling a life science requirement in their core curriculum. Students work in groups of two to four, depending upon class size, to observe various feeding strategies employed by marine invertebrates. The feeding experiments are designed to assist the students in making conclusions about how organisms find food in different marine environments. A concerted effort is made to relate the feeding strategy to the physical environment in which the organism is found.

**Instructional Objectives:**

*Upon completion of this exercise, you should be able to:*

1. Distinguish between **visual receptors**, **mechanoreceptors**, and **chemoreceptors** and give an example of each.
2. Distinguish among the following feeding behaviors: **deposit feeder**, **filter feeder**, **scavenger**, and **carnivore**. Give an example of a marine invertebrate which exhibits each type of feeding behavior.
3. Describe the feeding behavior of a sea anemone.
4. Describe the feeding behavior of a barnacle.
5. Describe the feeding response of the serpent star.
6. Interpret the results of serpent star feeding experiments relating water temperature and dissolved oxygen to the time it takes for the sea star to contact the food item.
7. Describe ciliary mucus feeding as demonstrated by the sand dollar.
8. Conduct feeding preference experiments using mud snails.
9. Graphically summarize the results of snail feeding experiments.

**Additional Required Materials:** Ask the students to bring a colored pencils with them to class. Also provide photographic atlases and/or video of various invertebrate groups and the feeding structures.

**Related Web Sites of Interest:**

1. Plume-Following Behavior in the Crab: <http://tbone.biol.sc.edu/~dean/model/model.cgi>
2. Sea Anemone Feeding Behavior Video:  
<http://dept.kent.edu/projects/cell/video/video2rm.html>
3. Marine Life Profile: Sea Anemone:  
<http://waquarium.mic.hawaii.edu/MLP/root/html/MarineLife/Invertebrates/Cnidarians/SeaAnemones.html>
4. Life on Australian Seashores- Feeding Relationships:  
<http://www.mesa.edu.au/friends/seashores/feeding.html>
5. Life on Australian Seashores- Barnacles:  
<http://www.mesa.edu.au/friends/seashores/barnacles.html>
6. Sensory Systems:  
<http://faculty.clintoncc.suny.edu/faculty/Michael.Gregory/files/Bio%20201/201%20lectures/Sensory%20Systems/sensory.htm>

**Introduction**

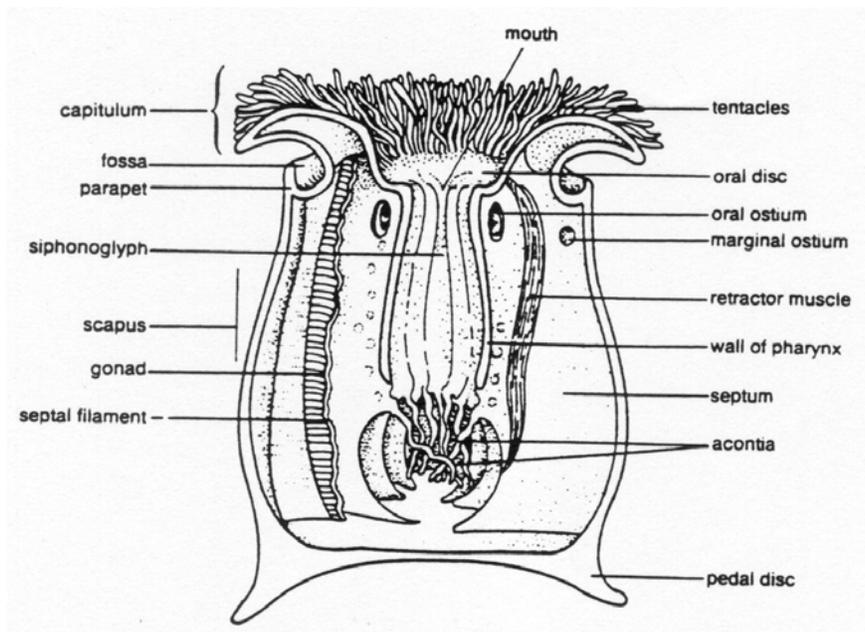
The behavioral mechanisms by which marine **heterotrophs** find food vary widely. Some organisms use **visual receptors** to detect the color, size, and shape of food items. Other organisms locate food by **mechanoreceptors** that sense hydrodynamic disturbances caused by moving prey. Certain sharks can detect electromagnetic fields. Still other organisms have **chemoreceptors**--they use chemical cues such as taste and smell to track their prey. Of course the goal is to obtain food, and some animals can and do use more than one type of strategy to locate food. The purpose of this

exercise is to observe some of the strategies marine consumers use to find and select food of appropriate quality. You will examine feeding behavior in several marine organisms during the laboratory class.

## A Survey of Invertebrate Feeding Behaviors

### Sea Anemone

Sea anemones are solitary polyps belonging to the Phylum Cnidaria. Sea anemones are widely distributed throughout the world; the majority of sea anemones are found in tropical waters. They typically grow completely submerged attached to rocks, shells, or pieces of wood below the surface of the water. Sea anemones are **carnivorous**, feeding on a variety of invertebrates. Larger species can capture fish using their tentacles! Smaller species with delicate bodies and tentacles are usually wedged in a protective crevice. Some large subtidal species will feed on crabs and bivalves dislodged from the upper intertidal zone by wave action. All sea anemones have specialized stinging cells called **cnidoblasts**. Inside the cnidoblast is the stinging apparatus, the **nematocyst**. When prey touch the sea anemone tentacles, the nematocysts are released, harpooning the prey.



**Figure 10.1** Oral-aboral section of the sea anemone, *Metridium*, showing internal structures. *Invertebrate Zoology: A Laboratory Manual* (5<sup>th</sup> edition), 1997, Wallace, R. L., and W.K. Taylor, p 68, Prentice-Hall.

The prey is paralyzed by the sea anemone venom, and it is moved toward the anemone mouth by the tentacles (see Figure 10.1). The mouth is opened by radial muscles in the body wall, and the prey is swallowed. The sea anemone feeding response is activated by amino acids (the by-products of proteins) that are produced by the prey.

### Feeding A Sea Anemone

To observe feeding behavior in sea anemones, two types of “prey” are available for feeding.

Using forceps, gently brush a piece of small shrimp across the tentacles. Describe the events in the space below.

The sea anemone's response to live prey is somewhat different. Using a disposable pipette, add several drops of a solution containing live brine shrimp. Detail your observations in the space below.

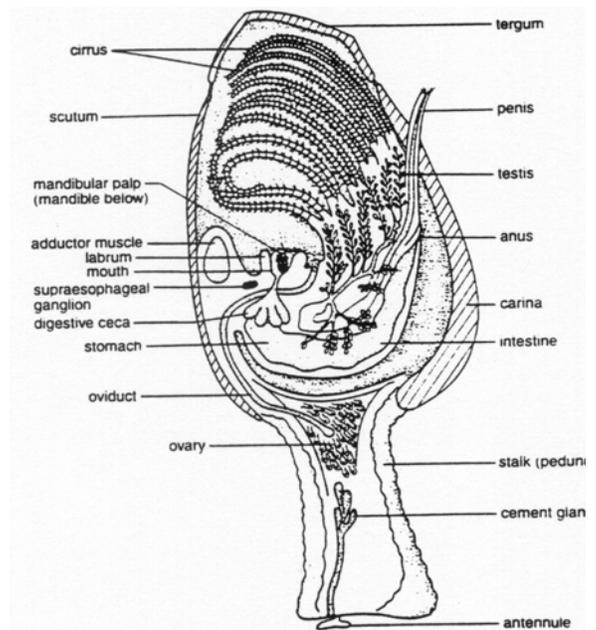
Is there a difference in anemone feeding response as a function of prey type (live versus dead)?

Does the anemone feed again immediately after placing the prey into its mouth?

## Barnacles

Barnacles are classified in the Phylum Arthropoda, Subphylum Crustacea, Class Cirripedia. The class is named for the feather-like feeding appendages, **cirri**, which are common to all barnacles. Barnacles are exclusively marine organisms, and they are the only entirely **sessile** group of crustaceans. Almost two-thirds of the nearly 900 described species of barnacles are free-living. They live attached to rocks, shells, timbers (such as docks and boats), rocks, and other substrates. Some barnacles live in commensal relationships with whales, sea turtles, fish, and other large, motile organisms. A few barnacles are parasitic.

Barnacles are **filter feeders**. In response to the presence of food particles in the water column, the cirri are extended beyond the shell plates (refer to Figure 10.2). To observe feeding behavior of barnacles, two types of food will be presented: commercial aquarium flakes and live brine shrimp.



**Figure 10.2** Lateral view of the stalked barnacle, *Lepas*. *Invertebrate Zoology: A Laboratory Manual* (5<sup>th</sup> edition), 1997, Wallace, R. L., and W. K. Taylor., p 210, Prentice-Hall.

## Feeding Barnacles

To make observations regarding barnacle feeding behavior, crumble a few commercial fish flakes into the water surrounding the barnacles. Describe what you see in the space below.

Using a disposable pipette, add a few drops containing live brine shrimp. Do you observe any difference in the barnacle's response to live prey in the water column?

### Serpent Star

*Ophioderma brevispinum*, the serpent star, is an extremely abundant echinoderm on sandy bottoms in the subtidal zone. The serpent star is distributed from just below the low tide mark to depths of 200 meters. It is frequently found with the sand dollar, *Melita quinquesperforata*. On the Atlantic coast of North America and South America, *O. brevispinum* naturally occurs from Cape Cod in Massachusetts south to Brazil. The serpent star avoids bright light and may be found underneath rocks or inside empty shells. The serpent star is a large and hardy echinoderm which locates food using chemoreceptors. It is a vigorous scavenger, and it is an excellent choice for observing **chemotactic responses** in captivity.

#### Feeding A Serpent Star

1. Place four serpent stars in a large dish containing sand and seawater.
2. Add one small piece of shrimp at some distance from the sea stars.
3. Observe time for any behavioral response and time for stars to contact the food.
4. Measure the water temperature and dissolved oxygen.
5. Repeat at various temperatures and plot temperature versus response time and/or dissolved oxygen.

**Table 10.1** Data for serpent star feeding experiment.

Observation	Water Temperature	Dissolved O <sub>2</sub>	Time to Food
<i>Initial</i>			
<i>Second</i>			
<i>Third</i>			

Did the serpent stars have to touch the food before responding to it?

How rapid was the feeding response observed in *O. brevispinum*?

Do the serpent stars seem to share, compete, or ignore the other sea stars when food is present?

What implications do you think that this type of feeding behavior has for sea stars in the subtidal zone with respect to the availability of food?

## Sand Dollar

*Melita quinquesperforata*, the sand dollar, is an irregular echinoderm. You can think of it as a flattened and burrowing sea urchin. This species is unique to North and South America, ranging from Nantucket, Massachusetts to Brazil. It is most common from Cape Hatteras, North Carolina to Florida and in the Gulf of Mexico. The sand dollar is found on sandy subtidal bottoms to depths of 15 meters. It frequently congregates in small depressions where it lies buried beneath the sand. In the late summer, the number of sand dollars per square meter may exceed one thousand! *Melita* lies buried crawling forward creating a U-shaped trail in the sand.

The sand dollar is a ciliary mucous feeder, picking up particles smaller than 20  $\mu\text{m}$  as it moves forward in the sand. A constant shower of sand and other particles cover the **aboral surface**. Larger particles are carried across the shell surface until they reach one of the five **lunules** where they pass through the holes and are deposited on the substrate. Smaller particles fall between the spines and are carried by ciliary action to and through the lunules to the **oral surface**. Once on the oral surface, food particles are carried along food tracts and in the ambulacral grooves in mucous filaments to the mouth. Cilia are located on the outer covering of the spines. In young animals, the lunules appear as notches in the shell. As the shell grows, the lunules are enclosed by the shell, forming the distinctive slits associated with sand dollars. The spines that surround the lunules provide protection, preventing large particles from blocking the openings.

Pipetting a suspension of carmine red particles or yeast stained with Congo Red over the sand dollar will allow you to observe the feeding process. The long and thick ambulatory spines on the oral surface of *M. quinquesperforata* are used to move the animal through the sand. When on the surface of the sand, *Melita* buries itself by advancing at a downward angle. It needs sufficient room to move forward and downward. If the container is too small, the sand dollar will not be able to bury itself. It will change direction by rotating the shell (in either direction) away from the obstacle until it can move forward again. Placing toothpicks in the container in front of the sand dollar will allow you to observe this avoidance behavior. If the sand dollar is inverted by a wave or current, it will turn itself so that the aboral surface faces upward. It accomplishes this task by using the posterior spines to pile sand on the shell until the animal is tilted upward in the water column. When the sand dollar is oriented at about a 45-degree angle, the water currents will topple the shell, restoring the proper orientation.

Sand dollars demonstrate a strong substrate preference. When placed in an aquarium with sandy and silty substrates, the sand dollars will migrate toward the coarser substrate. Substrate preference is a consequence of the mode of nutrition; the small silt particles would clog up the feeding apparatus.

### Feeding A Sand Dollar

1. Place a sand dollar in a large dish containing a very thin layer of sand barely covered with seawater.
2. Slowly pipette a small amount of stained yeast suspension over the aboral surface of the sand dollar.
3. Observe particle movement using the dissecting microscope or a hand-held lens.
4. Place the dish on several blocks or books with a mirror below the dish. Observe the transport of stained particles through the lunules to the oral surface.

How do you know that the animal is alive?

How fast do the colored particles move?

Describe the purpose of the five grooves that radiate from the mouth outward on the oral surface of the sand dollar.

How does the sand dollar right itself, move forward, or move around obstacles?

Which substrate does the sand dollar prefer? How is substrate preference related to the feeding habits of *Melita*?

### Mud Snails

Mud snails are **scavengers**. Their feeding habits range from **deposit feeding**, feeding on organic material deposited in the intertidal zone, to **facultative carnivore**. They belong to a group of Mollusks, the **prosobranchs**, which have a highly extensive proboscis that enables them to reach and penetrate vulnerable areas of the prey. Specific proteins from oysters or crabs have been demonstrated to elicit a search response, the protruded proboscis.

#### *Feeding Mud Snails*

##### **Trial 1 (dry)**

***Treatment 1***  
shrimp meat

***Treatment 2***  
filter paper soaked with de-ionized water

1. Obtain a large finger bowl with lines drawn on the bottom.
2. Place treatment 1 in one of the circles drawn on either side of the bowl, and place treatment 2 in the other.
3. Obtain four snails of different colors and place each of them on the line in the middle of the bowl and begin timing.
4. Observe the snails for the next ten minutes (or until they have reached the food). At every 1-minute interval, record the position (and the direction) of the snails by drawing their location on the data sheets provided. Once they have reached the food take the snails out of the experiment bowl and into their holding container.
5. At the end of ten minutes, remove all the snails and food from the bowl.
6. Answer the questions in Table 10.2 for trial 1.

**Trial 2 (wet)*****Treatment 1***

Shrimp meat

***Treatment 2***

filter paper soaked with de-ionized water

1. Add enough seawater to the bottom of the bowl to cover it.
2. Place treatment 1 in one of the circles drawn on either side of the bowl, and place treatment 2 in the other.
3. Obtain four snails of different colors and place each of them on the line in the middle of the bowl and begin timing.
4. Observe the snails for the next ten minutes (or until they have reached the food). At every 1-minute interval, record the position (and the direction) of the snails by drawing their location on the data sheets provided. Once they have reached the food take the snails out of the experiment bowl and into their holding container.
5. At the end of ten minutes, remove all the snails and food from the bowl, **and rinse the bowl out with de-ionized water.**
6. Answer the questions in Table 10.2 for trial 2.

Repeat the experiment for trial 3 and 4, using the same as the procedures listed above, but changing the treatments to:

**Trial 3*****Treatment 1***

filter paper with shrimp extract

***Treatment 2***

filter paper with de-ionized. water

**Trial 4*****Treatment 1***

shrimp meat

***Treatment 2***

tofu

Do you think these animals use visual cues, chemical cues, or both for feeding? Explain your results.

Based on your observations, what role does water play in helping the snails locate their food?

Did the same snail find the food first each time?

How are the snails in competition with each other? What kind of competition is it?

Do you think these animals use visual cues, chemical cues, or both for feeding? Explain your results.

**Table 10.2** Observations for mud snail food preference experiment.

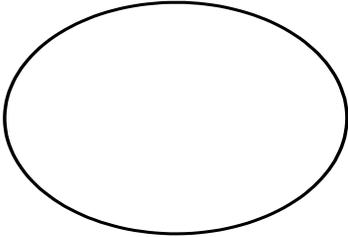
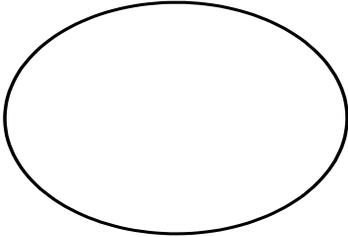
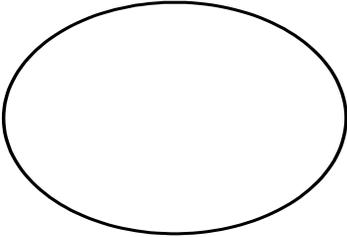
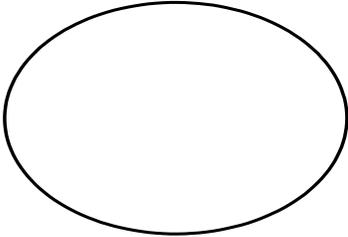
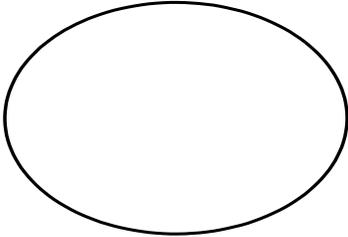
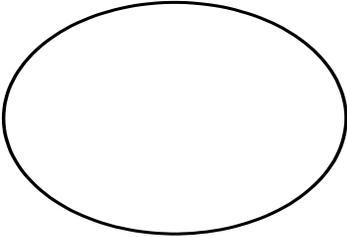
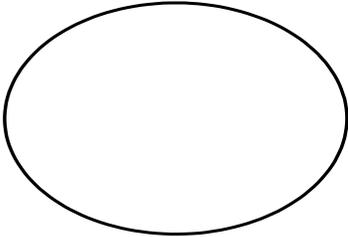
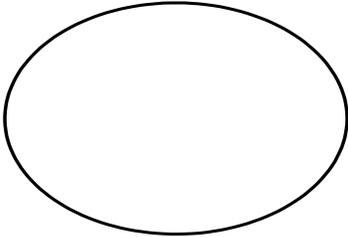
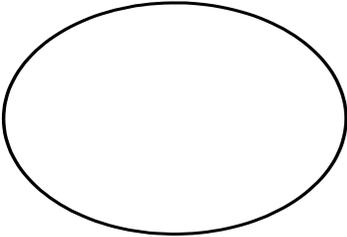
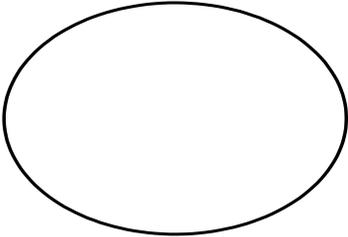
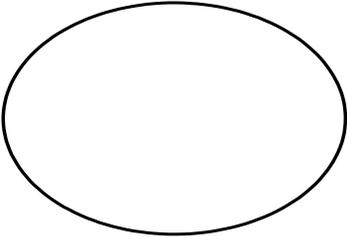
<b>Results</b>	<i>Trial 1</i> (Dry)	<i>Trial 2</i> (Wet)	<i>Trial 3</i> (Paper only)	<i>Trial 4</i> (Tofu)
How long does it take for the first snail to find the food?				
Can you see the snail's proboscis?				
Describe what happens to the proboscis during the feeding experiment.				
Do the snails follow one another's mucus trails?				
Describe any interactions which you observed among the snails in the feeding experiment.				

**Results**

In the spaces provided below, make a bar graph of each trial. Label the horizontal x-axis as time, and label the vertical y-axis as individual snails (1 through 4).

Mark the place on each graph at each time (to the nearest minute) that each snail found treatment 1 (the food).

**Figure 10.4** Results of mud snail feeding experiments. Sample Results recording page for mud snail feeding experiments. We would have similar figures for each of the 4 different feeding trials.

<b>Time: 0 minutes</b>	<b>Time : 1 minute</b>	<b>Time: 2 minutes</b>
		
<b>Time: 3 minutes</b>	<b>Time : 4 minute s</b>	<b>Time: 5 minutes</b>
		
<b>Time: 6 minutes</b>	<b>Time : 7 minute s</b>	<b>Time: 8 minutes</b>
		
<b>Time: 9 minutes</b>	<b>Time : 10 minute s</b>	
		

## Glossary of Terms

**aboral surface:** The surface of an echinoderm which is opposite the mouth.

**carnivore** (*carn-*, flesh; *vorare*, to devour): A heterotrophic organism which captures and eats other living heterotrophic organisms.

**chemoreceptor:** A sensory receptor which transmits information about the total solute concentration in a solution or about individual kinds of molecules.

**chemotactic response:** A response or change in animal orientation with the presentation of chemical agents.

**cirri** (singular, **cirrus**; to curl): A flexible appendage used for feeding in barnacles.

**cnidoblast** (*cnido-*, containing a nematocyst; *blastos*, bud or shoot): A specialized Cnidarian cell concentrated in the tentacles which contains a stinging apparatus, the nematocyst.

**deposit feeder:** A heterotrophic organism which eats its way through detritus (decaying organic matter) salvaging small pieces of decaying organic matter.

**facultative carnivore:** A heterotrophic organism which can alternate modes of nutrition, changing from grazing on primary producers to consuming other heterotrophs.

**filter feeder:** An animal which obtains its food by filtering water for small particles of organic matter or minute organisms which pass through the water current in some portion of its body.

**heterotroph** (*hetero*, different; *troph*, nutrition): Organisms which can not manufacture their own food and must ingest organic carbon and nitrogen produced by other organisms.

**lunule:** The slits in the shell of a sand dollar.

**mechanoreceptor:** A sensory receptor which detects changes in shape or physical deformations in the body's environment due to pressure, touch, motion, stretch, and sound.

**nematocyst:** Specialized cnidarian stinging structures consisting of a trigger, a harpoon-like structure, and a poison sac housed within the cnidocyte.

**oral surface:** The surface of an echinoderm which contains the mouth.

**prosobranch** (*proso*, in front; *branchion*, gill): A group of gastropod Mollusks which is characterized by a highly extensible proboscis, cleft or perforated shells, and a primitive gill and anal arrangement within the shell.

**scavenger:** A heterotrophic organism which feeds on dead, decaying organic matter.

**sessile** (*sessilis*, of or fit sitting low, dwarf): An organism which is attached to the substrate.

**visual receptor:** A sensory receptor which detects light and/or movement; examples include eyespots, ocelli, and "camera eyes" (like those in a squid).

## Acknowledgments

Some of the information in this exercise was modified from Tested Studies in Laboratory Teaching: Proceedings of the 20<sup>th</sup> Workshop/Conference of the Association for Biology Laboratory Education (ABLE), The Roles of Living Marine Organisms and Field Work in Teaching Invertebrate Biology, Anne Rudloe, 1999, pp 243-245.

## APPENDIX A: Sources for Marine Specimens and Aquarium Supplies

Gulf Specimens Marine Laboratories, Inc.  
 PO BOX 237  
 222 Clark Drive  
 Panacea, Florida 32346  
 (850) 984-5297

www.thatfishplace.com  
 237 Centerville Road  
 Lancaster, Pennsylvania 17603  
 (888)-842-8738

## APPENDIX B: List of Marine Specimens to Order

*Aiptasia pallida* (brown rock anemone) – These anemones reproduce by budding, so if you may soon have more than you started with. These can be used in place of the large *Condylactus* if aquarium space is limited.

*Balanus galeatus* (ivory barnacle) – Any species of *Balanus* will work provided that you put them in an aquarium or large tank with high water velocity.

*Condylactus gigantea* (tropical plumed anemone) – This large and showy sea anemone is easy to keep in a display aquarium, and it is commonly sold in pet stores which sell marine specimens.

*Littorina irrorata* (common periwinkle) – This organism feeds on algae attached to the cord grass stems and on algal mats on the mud flats. Warning: escapes from your aquarium, place a screen on the top.

*Melia quinquesperforata* (keyhole sand dollar) – This echinoderm is common in sandy bottom subtidal areas of the eastern United States and the Gulf of Mexico.

*Nassarius vibex* (pigmy dog whelk) – This organism can be used as a substitute for the common periwinkle; it has a very strong feeding response when presented with fish protein; not strictly a scavenger. Pigmy dog whelks do not tend to escape as readily as the common periwinkles.

*Ophioderma brevispinum* (serpent star) – This sea star exhibits a strong feeding response and is very easy to keep alive.

## APPENDIX C: Miscellaneous

### Brine Shrimp

Purchase brine shrimp eggs and follow the directions to hatch the eggs. Partial water changes and high aeration rates are essential to success. You need to initiate the hatching process 5-7 days before you plan to use them in the lab. Another alternative is to purchase live adult brine shrimp from a pet store. Be certain that you adequately aerate the adult brine shrimp, and that you do partial water changes (about 30% of volume) at least once a week. We use one liter flasks for hatching and rearing brine shrimp. If you are using a small aquarium, do not filter the water through pump as you will filter out your brine shrimp – rather aerate with air stones and a pump.

### Congo Red

Weight out 0.3 grams Congo Red powder and dissolve it in 100 ml of distilled water. Boil the mixture for 10 minutes. Place in glass dropper bottles and seal.

### Yeast

Purchase baker's yeast (activated works best) from the grocery store. Prime the yeast using sugar and allow it to bud. Start the yeast suspension 24 hours before you plan to feed it to the sand dollars.

### Other Items to Purchase

filter paper circles (sized to fit your specimen dishes/watch bowls)  
 tofu (extra firm works best)  
 frozen shrimp (grocery store) or frozen squid (bait store)

## APPENDIX D: Rearing Directions for Marine Specimens

Marine Invertebrates produce a large amount of protein that needs to be removed from the aquarium. You need to plan on using a filter that filters at a rate of about ten times the aquarium volume per hour. If you do not live in a coastal area, use one of the commercially available sea salts such as Instant Ocean®, Reef Crystals®, or CoraLife Salt®. You will need a hydrometer or refractometer to ensure the correct salt concentration. You should also use distilled or deionized water when making your salt water OR let the tap water stand in wide-mouth containers which are open to the air for four to seven days. Do not add a chemical dechlorinator to your water as most invertebrates are very sensitive to chemical additives. The sea salt should be mixed with water to obtain a final concentration of 32-35 parts per thousand of 3.2-3.5%. Remember that evaporation from your tanks will happen quickly, especially in a small volume aquarium. Check the salt concentrations daily or at a minimum twice weekly, and add water to adjust the salt concentration. Do not overfeed your animals. Feed them two to three times a week. Excess food in the water will foul the tanks. Unless otherwise specified, use aquarium sand (quartz or coral sand is preferable and wash the same with DI or distilled water before using it). Specific directions for feeding and care follows for some of the organisms used in this exercise.

### **Anemone**

Provide a shell or some other substrate (dead coral) for attachment. Do not use rocks from your area as many rocks contain minerals that will dissolve in seawater and harm the invertebrates. If using a filter that draws water from the bottom of the aquarium, place some cheesecloth or some type of fine netting over the intake siphon to prevent smaller anemones from being sucked into the filter.

### **Barnacles**

Barnacles need a high flow situation to be happy in an aquarium; in an aquarium of 20 gallons or more, install a power head to ensure adequate water flow. Feed with a brine shrimp/yeast suspension or a commercially available zooplankton/phytoplankton mixture.

### **Sand Dollars**

Sand dollars live in areas with strong bottom currents that bring food through the lunules. In the absence of bottom currents (as in an aquarium), provide a sandy substrate and place oral surface (upside down) up on the bottom. Feed with a yeast suspension by pipetting the yeast directly onto the oral surface of the live animals. If you use food coloring to dye the yeast particles, you will be able to visually inspect the sand dollars for active feeding behavior. The color will concentrate in the oral grooves on the oral surface.

### **Serpent Stars**

These animals prefer an aquarium with sand and/or coral/shell rubble that gives them a place to hide. Feed two to three times weekly, using small pieces of frozen shrimp or bait squid. Do not over feed.

### **Snails**

Periwinkles will feed on any algae growing in your aquarium although they prefer diatoms. We have had success feeding them *Ulva* left over from previous labs or rehydrating commercial seaweed sheets that are available at health food and oriental grocery stores (used for sushi). Be certain to read the labels, as most invertebrates do not really do well with food preservatives. Pigmy dog whelks prefer very small pieces of shrimp, fish (such as frozen smelt), or squid. Be certain to chop the food into very fine pieces (a food processor or blender can be used and then the food can be frozen in ice cube trays – remove the frozen fish cubes and store in Ziplock freezer bags).