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ABSTRACT

Two dozen activities on the ecology of coastal areas, with special emphasis on North Carolina's coastline, comprise this manual for junior high school science teachers. Provided are a table correlating these lessons with state curriculum guidelines, and a summary of the unit's goals and behavioral objectives. Among the topics included are coastal habitats, fish, plankton, intertidal organisms, and food chains. Each section contains background information, vocabulary, 2 to 12 activities, and a list of films, books, and other related resources. This manual is one of a collection produced by North Carolina teachers and university faculty under the "Man and the Seacoast" project funded by Sea Grant. (WB)

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105 1911 Building
North Carolina State University
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NORTH CAROLINA MARINE EDUCATION MANUAL

UNIT THREE

COASTAL ECOLOGY

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The North Carolina Marine Education Manual is a collection of teaching materials generated by North Carolina public school teachers and university professors under a University of North Carolina Sea Grant College project entitled "Man and the Seacoast." Dr. Dirk Frankenberg is the principle investigator; the Resource Unit Development Committee project directed by Dr. William Rickards of North Carolina State University assisted with material production. The manual is designed to help middle school teachers put marine perspectives into their lessons. The activities can be modified for higher or lower grades.

This manual consists of separate units which cover environmental aspects of the coast such as geology, ecology, and seawater interactions and motions. Additional units cover facets of coastal communities and economics, history, anthropology, art, folklore, and literature. An appendix provides information on keeping aquaria, state and federal agencies, field trip guides, and film company addresses.

We wish to acknowledge the cooperation we have received from other marine education projects, North Carolina Marine Resource Centers, North Carolina Department of Public Instruction, National Marine Education Association, and many people who have contributed suggestions and opinions. Especially we wish to thank those people whose enthusiasm and contributions made this project possible -- the following North Carolina teachers:

1977 "Man and the Seacoast" teachers

Charlie Baker, Wells Baker, Edna Bell, John Britt, Fay Edwards, Marie Farris, George Glasson, Gwendolyn Guerrant, Clayton A. Harpold, Linda L. Helms, Katherine Helsing, Jan Jones, Connie Long, Lillie R. McInnis, Martha S. Mallard, Mary Olson, Laurie Oppenheimer, Donna Parrish, Barbara Ratliff, Julia Tingle, and Susan Warren.

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The North Carolina Marine Education Manual developed through the interaction and involvement of people interested in marine education. UNC Sea Grant would like to continue the involvement by inviting your opinions and suggestions for topics and activities. In this way, we can remain responsive to your needs with new additions to the manual.

Please address your comments to:

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INTRODUCTION

Coastal Ecology is an introduction to the marine organisms of North Carolina, where they live, some of the special adaptations which enable them to successfully inhabitat these places, and the interrelationships between the marine organisms and their habitats. The marine habitats have been divided into two groups: the water column inhabitated by feebly swimming plankton and actively swimming nekton, and the sea floor inhabited by burrowing, crawling or attached benthic organisms. North Carolina's habitats are simplied by lack of natural rocky shoreline. Most sea floor environments are loose sand or mud with only piers and man-made rock groins providing substrate for attached organisms. Coastal habitats and organisms are linked together in complex systems involving water circulation, exchange of water-born particles and dissolved materials, and animal migrations.

Table 1 provides a summary of the activities presented in Unit III in relation to the recommended program features of the North Carolina State Curriculum guide (Course of Study of Elementary and Secondary Schools, K-12, 1977). These activities and the background information could be included in many places in the middle school curriculum: life science, biology, earth science, and several elementary science programs. Table 2 provides a list of educational goals and behavioral objectives for Unit III.

Table 1. Correlation of Activities with some of the recommended features in North Carolina's school curriculum guide.

ACTIVITIES	Process Skills	Manipulative Skills	Organizational Skills	Creative Skills	Communicative Skills	Measurement Systems
Shoe Box Habitats	X	X	X			
Where Do I Live?	X		X		X	
Is This Picture Right	X			X	X	
Arts and Crafts in the Sea	X	X	X	X	X	
"Up the Creek"	X	X	X		X	
Fish-Biological Indicators of Temp.	X	X	X	X	X	X
Dancing Moth Balls	X	X		X	X	
Gills-Use and Design	X	X		X	X	
Detecting Age and Growth in Fish	X	X	X	X	X	X
Deep Sea Show	X	X	X	X	X	
Dichotomous Key for Fish	X					
Schooling Behavior in Fish	X	X	X	X	X	
Potato Fish	X	X		X	X	
Dangerous Animals' Message	X			X		
Sea Which I		X		X		
Sea Which II		X		X		
What Shell is This?	X			X	X	
Clams and Scallops		X		X	X	
Spineless Rummy	X	X	X	X	X	
Sea Which III		X		X		
Plankton Bodies	X	X		X		X
Make A Plankton Net		X		X		
Eat and Be Eaten	X	X		X	X	
Sea Weeds		X				
Food Chain Connections	X	X	X	X	X	

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Table 2

Goals: 1. To relate habitats of marine organisms to their adaptations.

Concept 1. Coastal habitats are defined by physical characteristics of water depth, salinity, and wave energy and include organisms living as benthos, nekton, and plankton.

Behavioral Objectives:

Upon completion of this unit, the student should be able:

a. To locate on a coastal map, areas of high energy (beaches) and low energy (marshes).
b. To label a shore profile with supra tidal, intertidal, and subtidal.
c. To label on a water column diagram where you would expect to find plankton, nekton, and benthos.

Concept 2. Nekton are free swimming animals -- bony fish, marine mammals, turtles, some mollusks, sharks, and rays.

Behavioral Objectives:

Upon completion of this unit, the student should be able:

a. To name 4 animals which are nektonic.
b. To demonstrate with hand motions, the swimming motions of fish, reef or grass flatfish, marine mammals, and octopus.

Concept 3. North Carolina's intertidal organisms are adapted to the environment in which they occur.

Behavioral Objectives:

Upon completion of this unit, the student should be able:

a. To name 4 animals which burrow and four animals which attach to solid objects.
b. To name one adaptation which enables a marine animal to live in the intertidal region at low tide.

Concept 4. Planktonic organisms are tiny but their activities are important to coastal zone ecology.

Behavioral Objectives:

Upon completion of this unit, the student should be able:

a. To name 2 types of plankton.
b. To describe how plankton manage to float.

Concept 5. Coastal organisms and habitats function together to form an ecological system.

Behavioral Objectives:

Upon completion of this unit, the student should be able:

a. To diagram a 3 unit food chain from a salt marsh, a 3 unit food chain from the open beach.
b. To diagram a 10 unit food web of coastal organisms.

Table of Contents

Concept 1. Coastal habitats are defined by physical characteristics of water depth, salinity, and wave energy and include organisms living as benthos, nekton, and plankton.

a. Background Reading

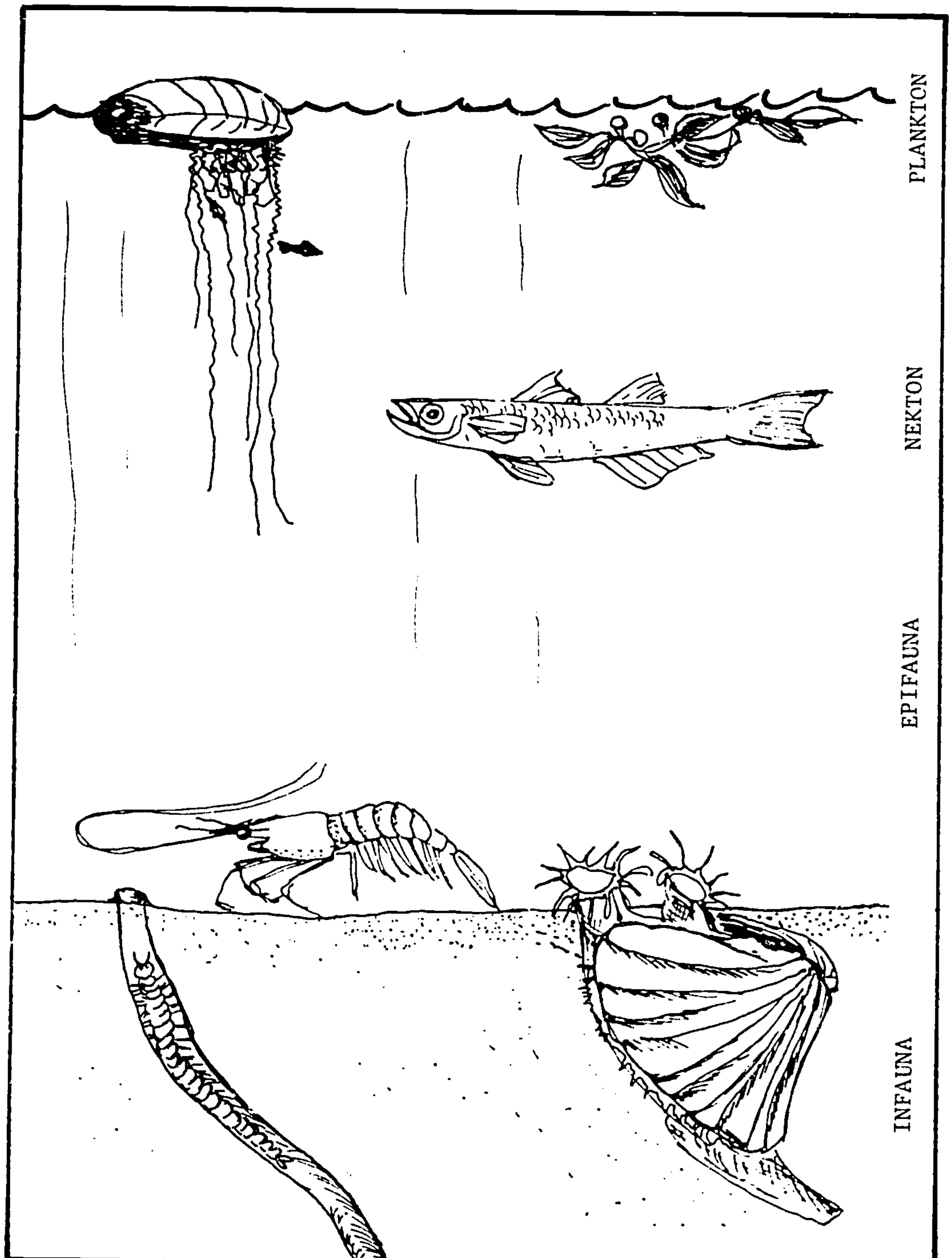
The living organisms of the coastal zone offer illustrations of biological and ecological principles. Not only are the biota intrinsically interesting to children, but the adaptations caused by the environmental stresses and the ecological relationships of the coastal zone are easy to perceive. Therefore, marine organisms can provide both classroom and fieldtrip examples of textbook principles.

Coastal habitats occur at the land/sea interface. Differences in the physical, chemical, and geological conditions create the suite of characteristic habitats. In North Carolina, the coastal environment is simplified by the absence of natural rock, so that the coast line consists of sedimentary features shaped by the influence of the ocean and land runoff. A transect from rivers seaward to barrier islands crosses a wide diversity of habitats; freshwater rivers and swamps, sounds and estuaries, salt marshes, oyster reefs, mud, sand, and grass flats, and dunes and beaches. The defining factors are concentration of salinity, amount of energy derived from waves and currents, degree of exposure to air, and type of bottom substrate. Within the coastal zone, these environmental conditions vary to such a degree as to produce a diversity of habitats and organism inhabitants.

North Carolina's coastal habitats can be divided into two major types: the aquatic or water column and the sea floor or benthic habitats. Water column environments are classified mainly with salinity--ranging from the open ocean (with salt concentration of 35 $^{0}/00$) through brackish water (area where fresh water runoff dilutes sea water to about 10-20 $^{o}/00$) to fresh water rivers and streams with no salt content. Benthic environments vary according to substrate - hard bottom (rocks, reefs, and pilings, etc.) and soft bottom (spectrum of sedimentary materials ranging from fine silts and clay to coarse sands). The organisms that inhabit water column environments are classified as plankton (plants and animals moving passively with the water) or nekton (animals swimming actively through the water). The organisms of benthic environments are divided into eipfauna (living on or attached to sea floor) and infauna (living burrowed into and through the sea floor). (Figure 1)

To survive all living things need to obtain food, excrete wastes, reproduce, and be protected from predators. Marine organisms of the coastal zone have evolved interesting adaptations. For example, menhaden, a type of schooling fish, have elaborate gills to strain food from the water while copepods (small planktonic crustaceans) have feathery antennae adapted for the same purpose. Many aquatic animals are generally similar in that they excrete ammonia in their urine, and distribute large numbers of eggs and sperm with little

FIGURE 1. MARINE BENTHIC AND AQUATIC HABITATS



parental care for the young. The body shape of plankton animals show adaptations for buoyancy in the water column, such as spines and body wall extensions to increase their surface area. Nektonic animals typically have torpedo shapes well suited for propulsion through the water. Benthic organisms have bodies specialized for attachment to and burrowing through the sea floor. (Think of barnacles and clams).

Organisms of different life styles like the nekton, plankton and benthos have obviously differing adaptations. Organisms with similar lifestyles have generally similar adaptations but differ in details. If two organisms were identical, they would be competitors and, in theory, the superior competitor would eliminate the inferior one. This ecological principle of competitive exclusion is phrased as "No two species can occupy the same ecological niche at the same time." Consequently, filter-feeding menhaden are very similar to filter-feeding anchovies, but menhaden live primarily in coastal water while anchovies primarily inhabit shallow portions of estuaries. These two species are similar, but live in different places. Three species of fiddler crabs inhabit North Carolina's salt marshes and each eats detritus. Yet, each species has a distinctive number of spines on its feeding appendages and each feeds on a different size of food particle thereby decreasing competition between them for food.

Another method for avoiding competition is zonation. Intertidal space provides a gradation of exposure to air and surf. On hard substrate (reef or pilings), examination reveals that different animals live at different heights above the low tide line. In North Carolina, oysters usually occupy an area near, and slightly above, the low tide line; barnacles occupy an area in the middle to upper intertidal; and blue green algae, snails, and some crabs occupy a zone near the high tide level. Similarly, on soft bottom sand beaches, sand dollars, olive shells, and heart clams occupy the low tide position; lugworms, bristle worms, and ghost shrimp occupy the mid-tide level; and sand fleas, ghost crabs, and insects occupy the high intertidal and supratidal levels. Sand beaches also have migrating organisms like mole crabs and coquina clams that move up and down with the tide staying in the swash zone produced by breaking waves. Zoned distributions reflect physiological tolerance limits and biotic interactions of the species involved. For example, oysters cannot tolerate as much exposure to air as barnacles and thus cannot live as high in the intertidal area. Biotic interaction is shown when two species of barnacles settle in the same area. One species grows under the edge of the other species and "pops" it off the substrate, thus producing zonation of barnacle species through competition.

The following sections provide examples of the biology and ecology of North Carolina's coastal zone which demonstrate general evolutionary adaptation and ecological principles.

a. Vocabulary

adaptations - changes in the organism that enable it to survive in a particular environment.

benthic - having to do with the ocean bottom.

benthos - organisms living on the bottom, e.g. crabs and worms.

biota - plants and animals.

brackish - less salty than the ocean; estuaries are brackish because fresh river water mixes with salty ocean water.

ecological relationships - physical, chemical, and biological connections between organisms and their environment.

energy level of coastal habitats - high energy areas are characterized by heavy waves, currents, tides or winds, substrate usually has coarse sand, examples: open beach or inlet; low energy areas are characterized by little water movement, waves, or currents, usually areas of sediment deposition, example: mudflats.

epifauna - animals living on the bottom, either attached to it or moving freely over it, such as crabs.

habitat - place where an organism lives (its address); salt marshes are one kind of habitat, beaches another.

infauna - animals which burrow into sand or mud, such as clams.

land/sea interface - the area where the land and sea come together; the coastline.

nekton - actively swimming animals such as fish.

niche - the position of an organism in its community defined by what it does (its profession - herbivore, carnivore, scavenger, etc.)

plankton - small organisms which float in the upper layers of the water column, drifting with the current.

substrate - the base on which a plant or animal lives. For example, barnacles attach to hard substrates like pilings while lugworms prefer soft substrates like sand flats.

zonation - distribution of organisms along a gradient.

b. Activities

Shoe-Box Habitats

Objective: To make shoe box sets of different coastal habitats which will intail a knowledge of the areas.

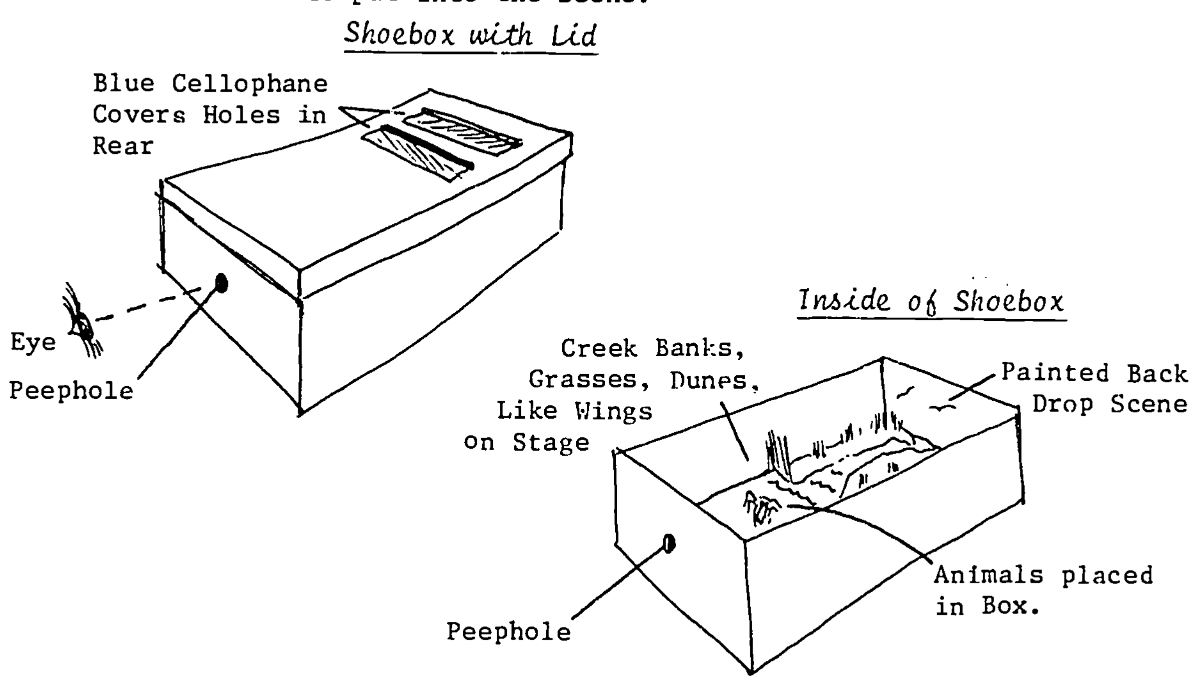
Teacher Preparation: Most of the materials, students can bring from home, e.g., shoe box, small figures, construction paper, rocks, dried plants, sand, and perhaps marine shells. Glue, blue cellophane, scissors, and scotch tape should be available for students to use in constructing their habitat.

Procedure:

1. Discuss typical North Carolina habitats such as marsh, barrier island, estuary, mud flat, rocky shore, sand shores, wharf pilings, and maritime forests. (See Unit One - Coastal Geology for descriptions) Films, slides, field trips, and books help convey the visual image to students.

2. Have groups of students choose habitats, research the chosen habitat, and discuss how to present it.

3. Design a peep-hole shoe box still-life which will depict the coastal scene. (See illustration for basic design). After arranging the dunes, forests, grasses, tidal creeks, and such, make small animals to put into the scene.



c. Activities

"Where Do I Live?" or "Habitats and Adaptations"

Objective: To learn to make decisions on where an organism lives based on its visual features. To review the organisms considered to be plankton, nekton, and benthos.

Teacher Preparation: This activity can be modified according to the level of your class. Simply, the pages of organisms and diagram are duplicated and students match habitat with organsim based on their knowledge of the organism. It is more interesting to stress the reason why that animal is able to live in that habitat. Review definitions of planton (organisms passively moving with water currents, usually in upper layers), nekton (animals which can move actively through the water column), and benthos (plants and animals which live on the bottom).

Although this is a simple worksheet activity, good discussion and follow-up research on other organisms can be included.

Adaptation: survival trait which enables an organism to "fit" into the environment.
Some adaptations increase survival chances by improving means of feeding, locomotion, defense and reproduction.

Habitat: where an organism lives; its address.
Some marine habitats includes benthic epifauna and infauna; water column plankton or nekton.

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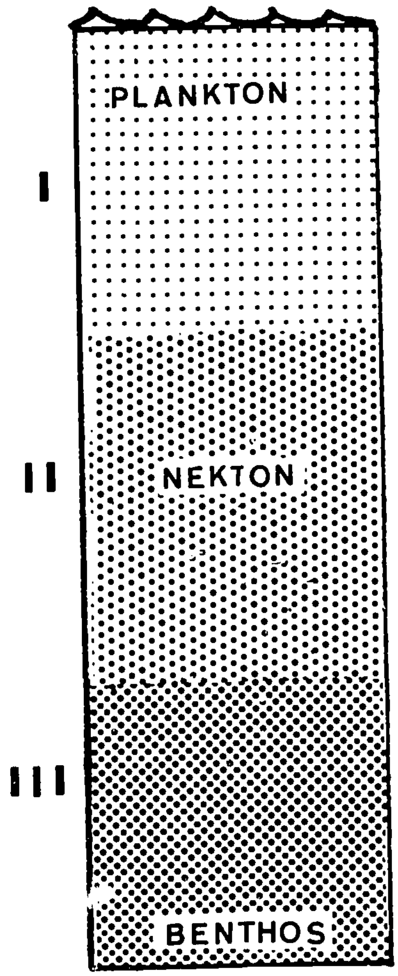
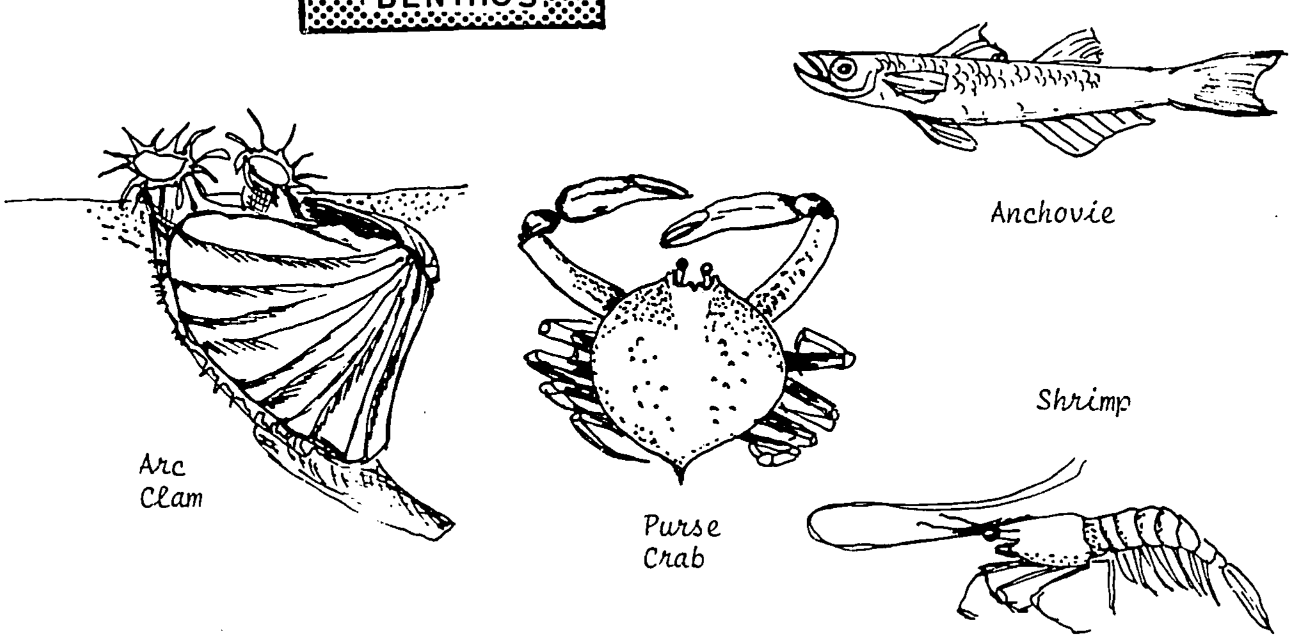
"Where Do I Live?"

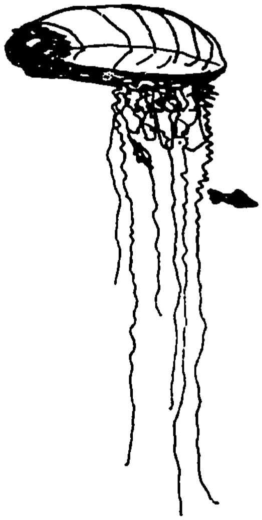
Diagram of a Column of Water Showing Three Habitat Locations		Write in Organism Name Living in each Habitat.	Key Adaptation
		B.	C.
I	1.	____________	____________
	2.	____________	____________
	3.	____________	____________
	4.	____________	____________
II	1.	____________	____________
	2.	____________	____________
	3.	____________	____________
	4.	____________	____________
III	1.	____________	____________
	2.	____________	____________
	3.	____________	____________
	4.	____________	____________

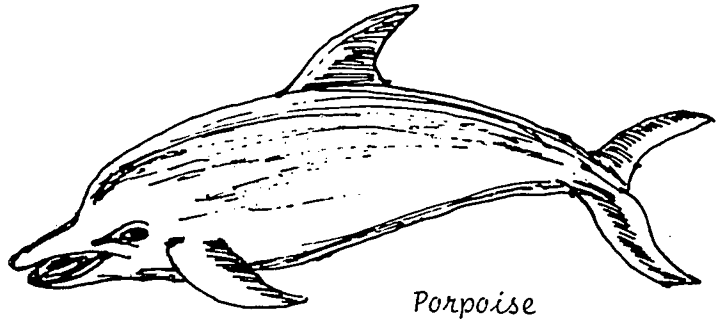




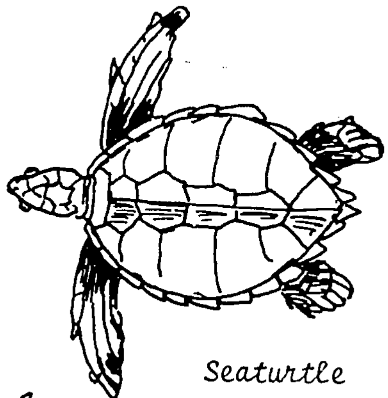
"Where Do I Live?"

Portuguese Man of War Jellyfish

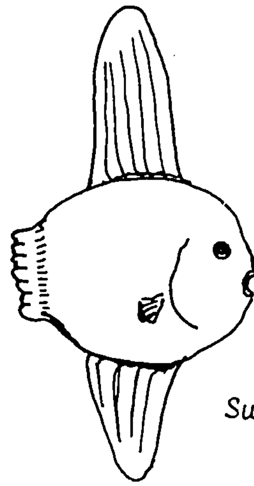




Porpoise

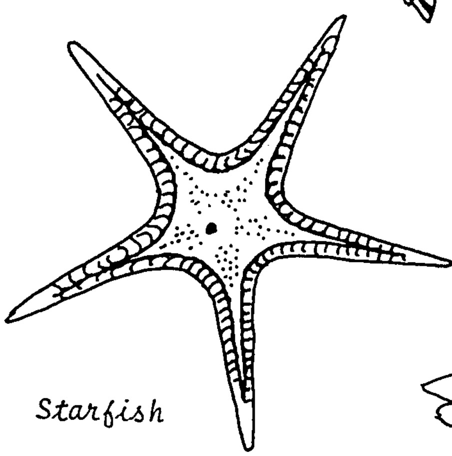


Seaturtle

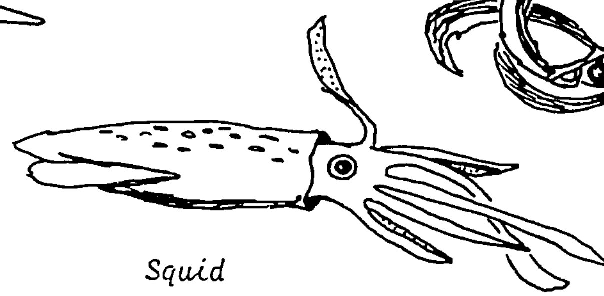


Sunfish

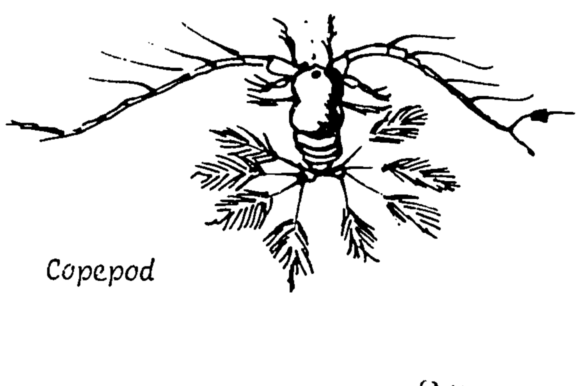
Sargassum Seaweed



Starfish



Squid



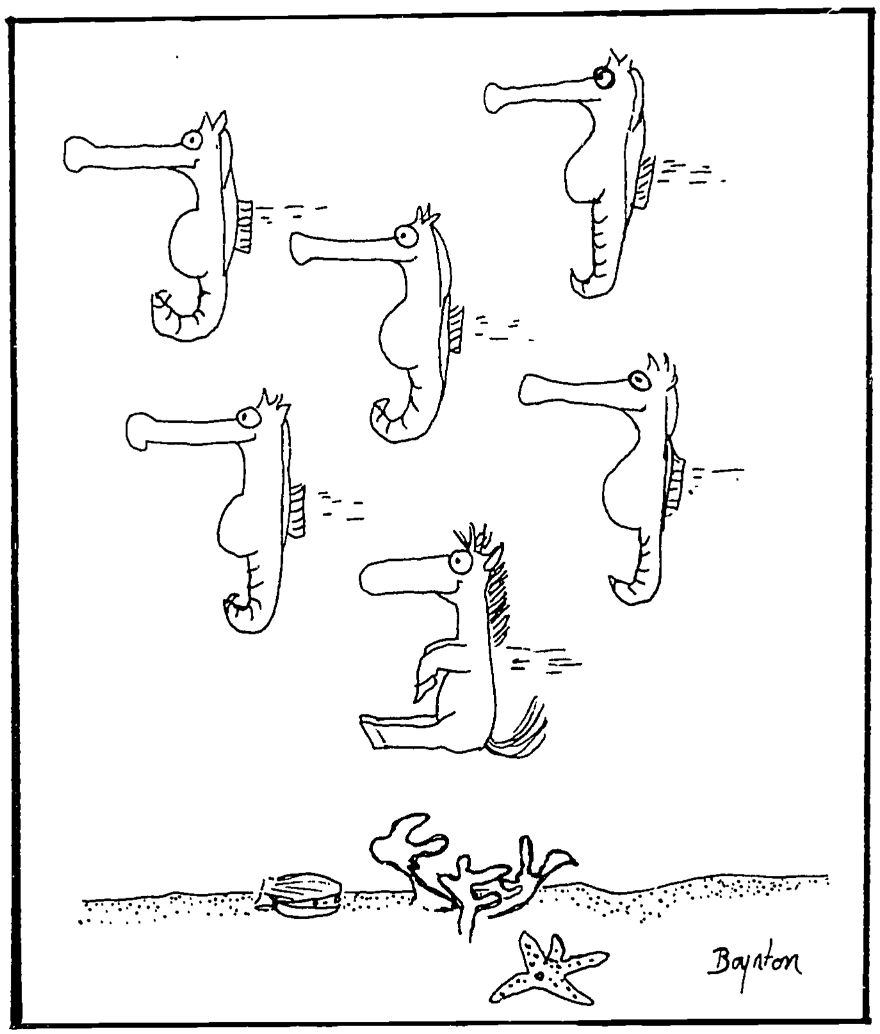
Copepod

b. Activities

"Is This Picture Right?"

Objective: To learn more about marine animals by comparing marine animal names with land animals.

Teacher Preparation: Duplicate this picture or make a transparency to project on a screen. Have picture books on marine life available or show marine films.



Procedures: Explain what's odd about this cartoon. Try to make a list and then draw similar cartoons about marine animals and plants. Examples: sea horses and horses, sea cows and cows, sea hares and hares (rabbits), sea snakes and snakes, sea robins (fish) and robins, starfish and stars, sea weeds and weeds, sea urchins and street urchins, sea cucumbers and cucumbers, sand dollars and dollars, brittle stars and peanut brittle, sea squirts and squirt guns, fiddler crabs and fiddles, ghost crabs and ghosts, sea pansies and pansies, sea pens (a shell) and fountain pens, jellyfish and grape jelly, elkhorn coral and elk's horns, parrot fish and parrots, catfish and cats, skates and roller skates, sea fans (coral) and fans, sea lions, lionfish, and lions, sea lettuce and lettuce, etcetera.

There are many names which can be added to these, see how many your students can think of.

Once you have a list, try to decide how these marine animals and plants got their names? Does a stonefish look like a stone? Do sand dollars look like our present dollar bills (a little history in coins and money)? Could you put a sea cucumber in a salad?

Good references for this activity are any of the "Our Living World of Nature" books published by McGraw Hill Book Company, New York in cooperation with The World Book Encyclopedia. William H. Amos, The Life of the Seashore, 1966. N.J. Berrill, The Life of the Ocean, 1966. William A. Neering, The Life of the Marsh, 1966. Each about $6.00.

b. Things to Do

Arts - The Sea is Full of Beauty

1. Objective: To use marine examples for making pictures and doing crafts.

A. Fish Printing (Japanese Art called Gyotaku)

2. Teacher Preparation: Obtain a fresh, washed fish (flatter fish are good starters, you can eat it later), some thick ink (finger paint, Chinese printer's ink), soft paper (rice paper, wahi, paper towels, news print).

3. Procedure:

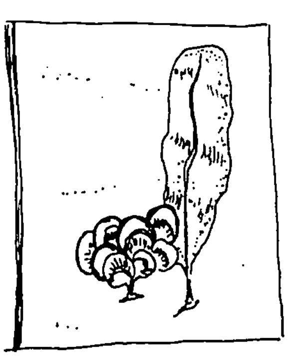
1. Rinse the fish to remove mucous (soap and water may help).
2. Brush ink onto the specimen from front to back including all fins (to stabilize fins upright, stick pins through them into a piece of clay on the opposite side). Paint around the eye, not over it.
3. Cover the fish with the paper on which a print is to be made, press evenly with fingers over the entire surface, emphasizing the outline.
4. Peel the print off carefully from head to tail. Add a dot for the eye and apply any additional colors or markings.

(This technique from the article by Rosanne W. Fortner, in "Sea World Journal", Fall, 1977)

B. Sea Weed Print

2. Teacher Preparation: When at the beach, collect seaweeds like sea lettuce, sargassum, mermaid's hair, etc. and keep it moist. To dry the seaweed for a mount, you will need a large tray to hold water and some good grade paper or light cardboard.

3. Procedure:

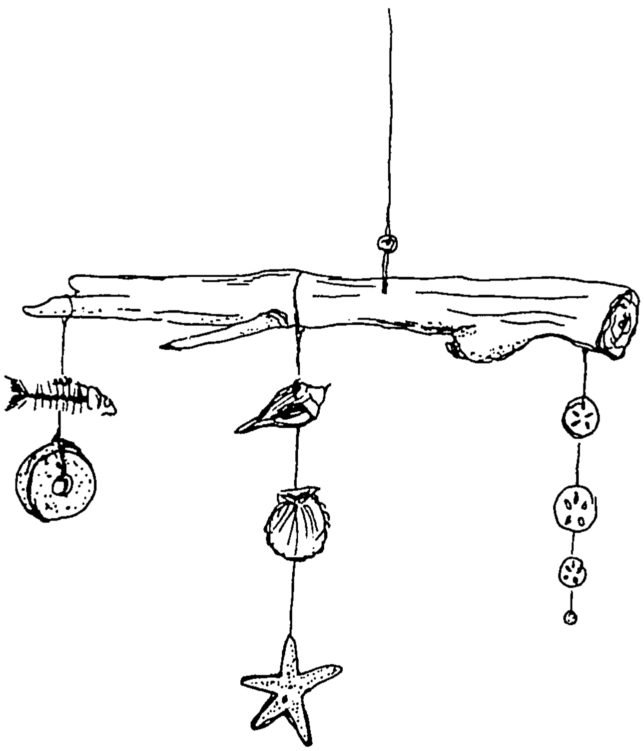


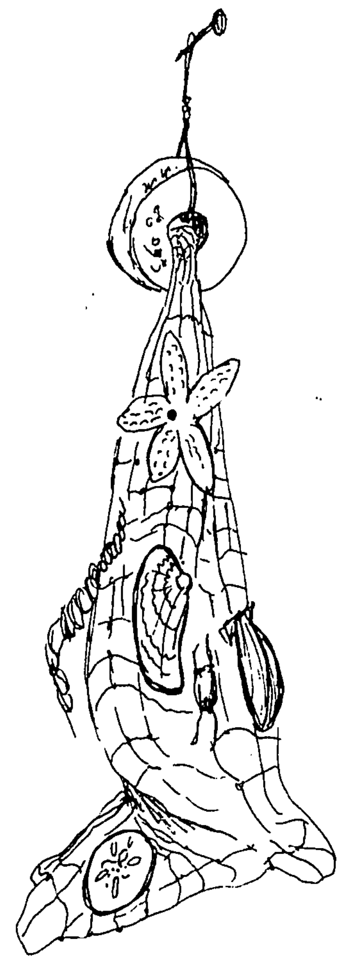
1. Float the seaweed in the tray of water and arrange it in a manner you like. Slide a piece of paper under it and slowly raise both out of the water.
2. Let the seaweed and paper dry.
3. Once the seaweed is dry, you have several things you can do.
   a. Leave it as is or mount it like a print.
   b. Transfer the seaweed to another sheet of paper and spray it with spray paint. After the paint dries, remove the seaweed, leaving the silouette of the plant.
   c. If the seaweed is sturdy enough, you may wish to use the fish print technique.

C. Marine Mobiles

2. Teacher
Preparation: Collect driftwood, nets, anything from the sea for the students (some of the driftwood from lakes and rivers is beautiful too!)

3. Procedure: Using the driftwood as the balance rod, arrange shells, sand dollars, star fish, corks, etc. on strings or yarn and on the wood.





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c. Resources to Use
(See appendices for addresses)

Project Coast Materials

#112 Useful Plants of the Sea $2.10.

Sumich, J.L. 1976. Biology of Marine Life. Wm. C. Brown Co., Publishers. Dubuque, Iowa. $9.95 (good general reference)

Our Living Oceans - Secrets of the Sea (free)
NOAA, 439 W. York Street
Norfolk, VA 23510

Spitsbergen, Judith. (in press). Sea Coast Life: An Ecological Guide to Seashore Communities in North Carolina. State Museum of Natural History, 101 Halifax Street, P.O. Box 27647, Releigh, NC 27611.

Close-Up Photography for the Marine Science Classroom. By Richard S. Lee. Marine Advisory Program, Cooperative Extension Service, University of Alaska, Anchorage, Alaska 99504. Free.

To Love the Sea. 6 Books - Fish of Coral Reef; Fish of Open Ocean; The Coral Reef; Plants of the Ocean; Mammals of the Ocean; Seabirds. Cypress Publishing Co.

Seashore Life Coloring Book. Anthony D'Attilio. Dover Publications, Inc. 180 Varece Street, New York, NY 10014.

1001 Questions Answered About the Seashore. N.J. Berrill and J. Berrill. Dover Publications, Inc., 180 Vanece Street, New York, NY 10014. $4.00.

NC Marine Resource Coloring Books. Division of Marine Affairs, Raleigh, NC. 25¢ (Lots of pictures of marine animals)

Concept 2. Nekton are free swimming animals - bony fish, marine mammals, turtles, some mollusks, sharks and rays.

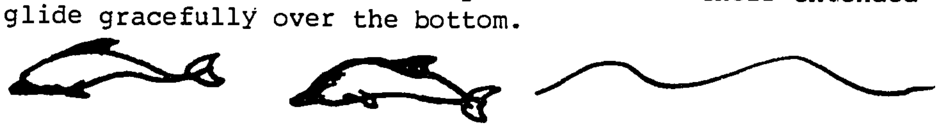
a. Background Reading

Nekton are free swimmers that maneuver actively in the water column. Therefore nekton comprise only animals which can disperse independently of water movement and bottom substrate. If an animal cannot swim actively enough to canteract water movement and drifts with the current, it is considered plankton. For example the huge ocean sunfish swims so weakly that it moves with ocean currents in tropical waters and is considered plankton, not nekton. A majority of nekton are fish. Other marine vertebrates include marine mammals, whales and seals, and marine birds, penguins. Very few invertebrates are considered nekton with the exception of squids, some pelagic octopuses and shrimp (Table 1). No plants are considered to be nekton. Nekton may have swimming powers to migrate long distances and traverse the water column from surface to ocean floor (Table 2).

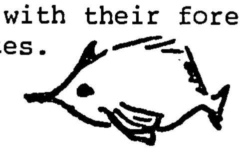
Although nektonic animals include many diverse creatures, patterns of locomotion, feeding, respiration and protection, are often quite similar. For example, methods of motion can be grouped into four categories based on body shape and appendage modification.

(1) Lateral undulation is the side to side swing of the animal's tail, usually including the sway of the whole body. Lateral undulation locomotion, combined with a torpedo body shape, enables the barracuda to have 45 mph bursts of speed and tuna to migrate thousands of miles.

(2) Dorso-ventral undulation is the up-down vertical movement characteristic of marine mammals like whales and porpoises and also, bottom-living fish such as skates and rays which use their extended "wings" to glide gracefully over the bottom.



(3) Pectoral scullers use the side (pectoral) fins for delicate maneuvering. File fish, sea horses, pipefish, and puffers need maneuverability, not speed, for survival. In fact, the sea horse's tail is modified so that it is used only for grasping stems of seaweeds. Sea turtles scull with their foreflippers as they dive for fish or migrate to nesting sites.



(4) Jet propulsion enables certain mollusks to have quick bursts of locomotion in the water column. Squids, octopuses, and scallops have openings through which they can squirt water, thereby pushing themselves in the direction opposite to that of the squirt.

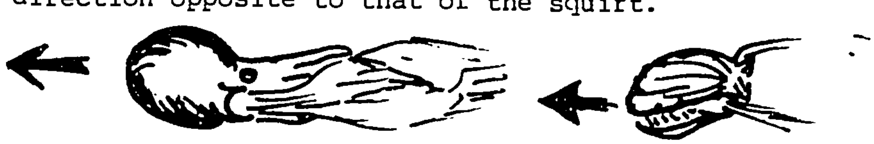
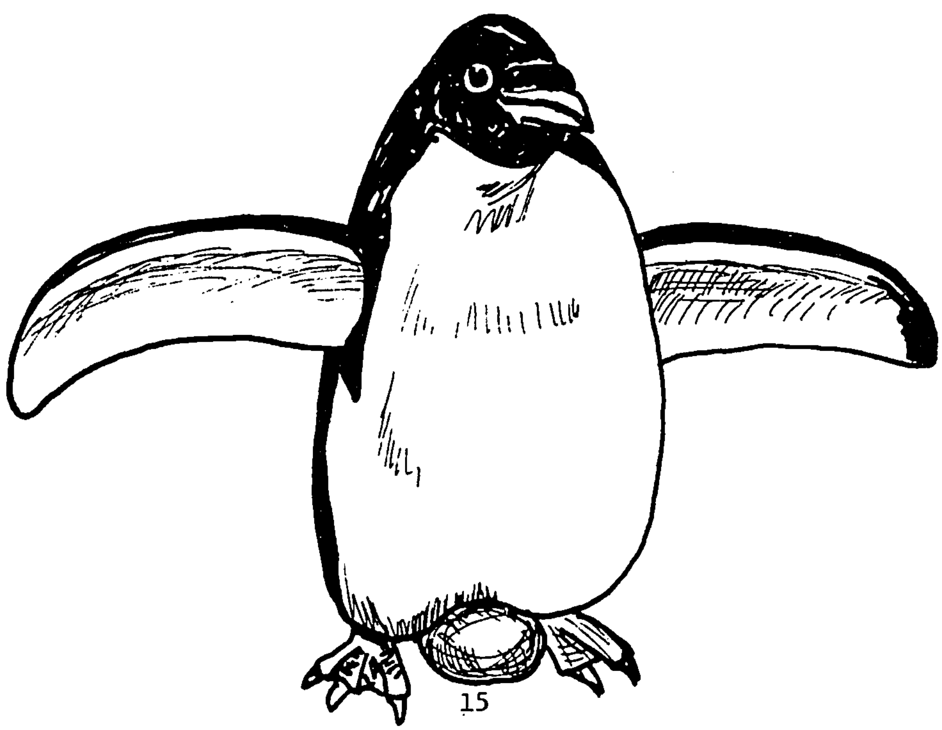


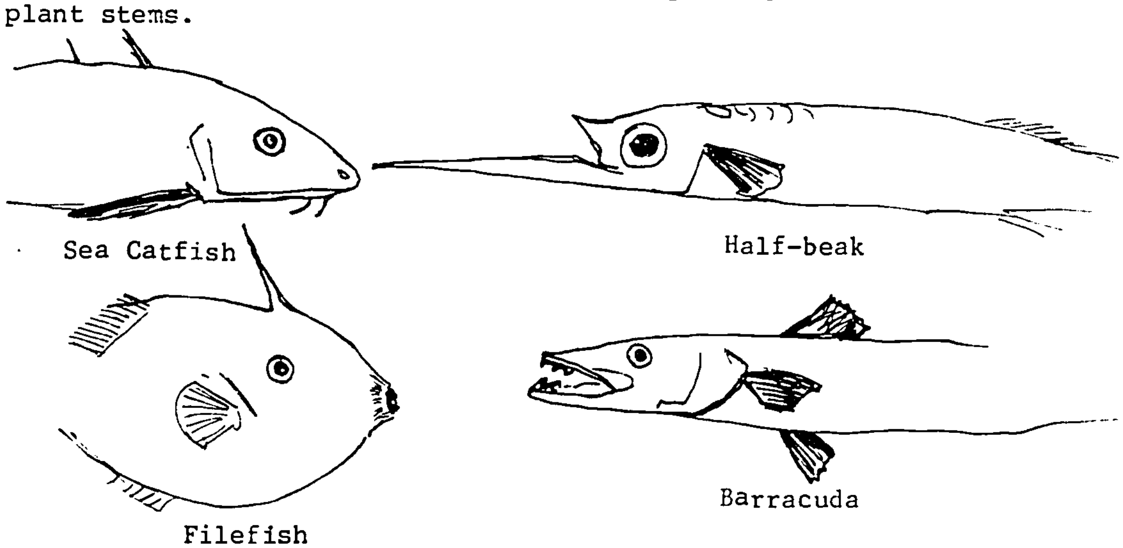
Table 1. Common Groups of Nekton

Characteristics	Examples
Vertebrates (with backbone), breathing by means of gills	
Body fish-like, skeleton of cartilage only	Sharks and rays
Body fish-like, skeleton includes bone elements	Bony fish, e.g., mullet, marlin, etc.
Vertebrates (with backbone), breathing by means of lungs.	
Marine reptiles	Turtles, crocodiles, and sea snakes.
Marine birds	Penguins, diving shore birds
Marine mammals	Whales, porpoises, seals
Invertebrates (no backbone)	
Mollusks	Squid, Octopus
Arthropods (jointed legs)	some pelagic shrimp



Feeding patterns usually break down into two groups: (1) Filter-feeding involves specialized mouthparts for straining large volumes of water to extract plankton. Herring-type fish have gills with long comb-like gill filaments which collect plankton as the fish swim open-mouthed through the water. Baleen whales, e.g., blue whale, have brush-like baleens which collect plankton in the roof of their mouths which is then pushed down the throat by the tongue. (2) Predation includes many forms of hunting and attacking prey. Sharks are the classic "killers of the seas" as some have extensive means of detecting movement and scent and conveyor belt teeth. Dainty butterfly fish of the coral reef hunt their prey swimming in and out of reef crevices searching for small crustaceans which they pick from holes with a specialized mouth.

Fish mouth parts are modified to indicate feeding behavior. Bottom-feeding fish have mouths pointed down while surface feeders have mouths pointing up. Half-beaks (quick, darting cigar-shaped fish) skim the surface with a highly adapted mouth in shich the lower jaw is long and narrow while the upper jaw is short and pushes water and food into the mouth. Predators like the barracuda, bluefish, and flounder often have a protruding toothy lower jaw. Sea horses and pipefish have a modified tube mouth designed to slurp up food particles with suction created by opening the gill covers. Several fish inhabiting grass flats have a small narrow mouth for picking small animals from plant stems.



Adaptations of nekton for obtaining oxygen also provide good examples for classroom discussions of evolutionary processes and their results. Marine cetaceans (whales and porpoises) have evolved modified nostrils on the top of the head. As a result, whales continue swimming while breathing through the "blowhole". Cetaceans also empty and fill their lungs more completely and quickly than land mammals. High concentration of respiratory pigments in the blood and muscles absorb large amounts of oxygen that allow the animals to maximize submergence time. Together these adaptations allow cetaceans to spend long periods underwater, then surface briefly, exhale warm breath as a spout, inhale quickly, and begin another dive. Sperm whales have been found tangled in telephone cables at depths of two miles. Evolution of air-breathing fish in stagnant water is also an interesting subject for discussion.

Fish extract oxygen from the surrounding water. Dissolved oxygen is far less abundant in water than in air (the atmosphere contains 21% oxygen while water usually has about 8 parts per million oxygen - about 26 thousand times less. Therefore, gills must have tremendous surface area to facilitate oxygen diffusion from water into the blood stream. When fish swim, water passes through the mouth, then over the gill filiments. During passage over the gills, oxygen diffuses into the blood while carbon dioxide diffuses into the water. Most fish can pump water through the gill by moving their gill covers. Under stress, exertion, or oxygen depletion, the rate of pumping increases - the fish "pants". Dr. John Cairns at the Virginia Polytechnic Institute measures this response as a pollution indicator. Test fish are put in individual tanks through which industrial effluents are passed. Sensitive equipment picks up and monitors the fish's breathing patterns. If a toxic substance causes abnormal breathing, the monitor sounds a warning.

Survival in the marine environment is similar to survival anywhere. Animals which are best adapted survive, others don't. In the nekton, those which swim the fastest, have the best offense/ defense, or are able to hide; avoid predation and continue reproducing. Many of the animals living in the sounds and coastal waters exhibit behavioral and visual adaptations which can be used as classroom examples. Quickness (squid, pinfish), schooling (menhaden, silver-sides, herring), and burrowing (flounder, toadfish, stargazers, and skate) enable fish to avoid predation. Countershading, a common coloration in which the top side is dark and the underside is white, matches the bottom or surface depending on the perspective of the viewer (examples are surface dwelling fish such as mullet, trout, drum, and croakers). Other fish are masters of camouflage. Pipefish resemble the grasses in which they live. Octopuses and flounders can rapidly vary their body color and knobby appearance; toadfish look like the substrate of the oyster beds where they live. Essentially any nektonic animals brought to the classroom can be used to demonstrate survival adaptations.

Fish are the most abundant members of nekton. North Carolina fish assemblages are among the most diverse along the eastern coast as both tropical and temperate organisms occur. Cape Hatteras is a major zoogeographic barrier separating northern and southern temperate species. South of Cape Hatteras, offshore fish have strong tropical affinities due to Gulf Stream influence. Fish migrate with seasonal and temperature change. Tropical offshore fish occur inshore only during summer months whereas many temperate species occur inshore all year long. However, during winter months all habitats show a reduction of species. Many fish migrate to deeper water, others migrate south, others die from exposure to low temperature. For example, flounders leave the sounds in autumn to spawn offshore, returning in late spring. Other summer residents as butterfly fish and damsel fish are nonmigratory and die when temperatures fall below their tolerance. As temperature rises in the spring, areas repopulate with new juveniles.

Table 2. Vertical Zonation for Nekton

Zone	Depth (m)	Environmental Characteristics	Example	Animal Characteristics
Epi-pelagic	0- 200	Lighted, variable temperatures	tuna, coastal fishes	well-developed eyes and swimming muscles most species and numbers.
Mesopelagic	200-2,000	Dim light, increased water pressure, colder	lantern fish, hatchet fish, squid	enlarged eyes, lumenescent
Bathypelagic	2,000-6,000	No light, increased water pressure, colder	gulper eel, angler fish, squid	small eyes, poor swimming muscles, flabby, few species and numbers.
Hadopelagic (trenches)		No light, most pressure coldest 4°C	pelagic fish (Benthic tripod fish)	

In addition to temperature distribution, salinity is also a major factor influencing the distribution of fish. Most fish are strickly marine and need salinity similar to that of the ocean ($35^{0}/00$). However, some fish can adapt to the lower salinities of sounds and estuaries. Marsh killifish which are of freshwater origin are able to live over a wide salinity range (fresh water to full ocean water). Mullet, spot, croakers, and juvenile sea trout are examples of marine fish which can tolerate salinity lower than that of the ocean.

Other members of nekton found in North Carolina include sea turtles. Logger heads are the only marine turtles that lay eggs on the beaches in North Carolina (Brown Island, Bear Island, Camp LaJune Beach and Cape Lookout). By tagging egg laying females and noting their return the following summer, scientists are learning about turtle populations and migrations. Sea turtle populations are decreasing; only 77 nests were counted in the 1977 summer. Egg collectors (both men and racoons) rob the nests, and shrimpers inadvertently catch and drown some turtles in their nets. Human intervention in beach developments with bright lights also appears to upset the female turtles so that they return to the sea without having laid their eggs.

Porpoises are marine mammals found commonly in sounds and coastal waters of North Carolina. They travel in social groups of up to 100 individuals. They hunt bottom fish and squids by echolocation. Whales, especially the humpback, migrate from Greenland to the West Indies passing off the Outer Banks. Fewer than a hundred a year are now sighted. Pilot and pigmy whales are sometimes stranded on North Carolina's beaches.

Nekton are exciting to study. Their adaptations are fascinating natural history and lend themselves easily to classroom activities and discussion. In addition, most of the fish sold in seafood markets come from North Carolina's waters, and can be caught by students when on the coast.

a. Vocabulary

cetaceans - whales and porpoises; a class of marine mammals

counter shading - a color pattern where the top side is dark and the underneath light; when seen from below the animal blends with the surface; when seen from above it blends with the bottom.

echo-location - a process for locating objects under water; the animal gives off high pitched sounds which bounce back to the animal from whatever they hit

nekton - actively swimming animals, such as fish

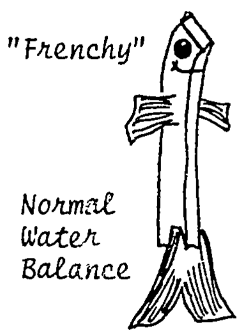
temperate species - organisms living between the arctic regions 66°33'N and S, and the tropics 23°30' N and S; they are adapted to changing seasons.

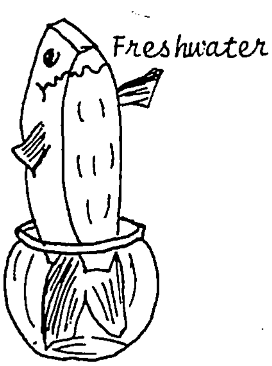
tropical species - organisms living approximately between latitudes 23° 30' north and south of the equator; they are adapted to warm temperatures with little seasonal differences

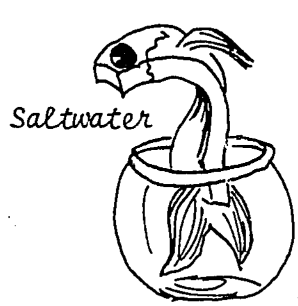
b. Things To Do

What Happens When a Salt Water Fish Goes "Up the Creek" or Investigating Osmoregulation

1. Background: Osmosis is the flow of water through a semi-permeable membrane (semi-permeable membranes allow only water molecules to pass through) from high to low concentrations of water. Thus, marine fish with body fluids containing higher concentrations of water than the seawater surrounding them constantly lose water through cell membranes. Freshwater fish with body fluid water concentrations lower than lakes or streams will gain water. Both tendencies must be countered to preserve body fluid water balance. A few fish or invertebrates survive where salinities range both above and below body fluid water concentrations. Most are adapted to only one end of the spectrum and thus are confined to marine or fresh water, and cannot tolerate the variable environment of estuaries.







Marine bony fish (as opposed to cartilaginous fish like sharks) lose water through gills and mouth and would become dehydrated except for adaptations designed to restrict water loss. These adaptations include (2) drinking seawater and excreting salt through the gills to offset the loss; (2) conserving water usually lost as urine by an elaborate kidney system. Freshwater fish on the other hand, do not drink large quantities of water and do excrete copious amounts of dilute urine. When fish enter estuaries, they must be able to adjust their water balance (osmoregulate). Marine fish have this ability to a greater degree than do freshwater fish. The adaptability of marine fish is largely dependent on low permeability of their body surfaces to water (thick scales and mucous membrane) and extraordinary salt regulating activities of gills and kidneys. Most estuarine fish return to the sea for spawning.

2. Objectives: To investigate how changes in the concentration of water affect the water balance in living cells.

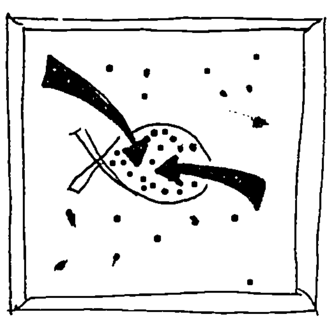
3. Teacher Preparation: There are several experiments to demonstrate this phenomenon. This one is the easiest. Cut a fresh potato into slices. Place half the slices in a bowl with tap water and the other half in a bowl with salty water. Have the students feel the potatos at the start and then feel them after 30 minutes or more. The potato slices cannot

regulate their water balance and therefore are altered by their environment. This represents what would happen if a fresh water fish were dropped into the sea or a marine fish dropped into a lake - both would die eventually. Estuarine organisms have mechanisms for maintaining water balance as explained above.

4. Procedure: Feel the potato slices in both tap and salt water at the start of the period. Repeat this at the end of the period and record the changes which have occurred.

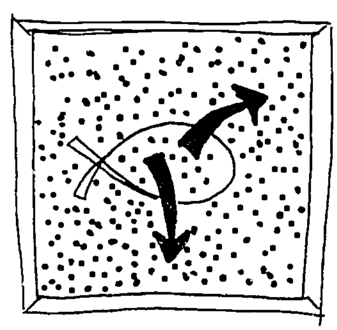
5. Discussion:
   1. What happened to the potato slices left in fresh water? Relate this result to a marine fish being dropped into fresh water, what would happen to it? (Potato slice becomes very stiff, cells have absorbed maximum amount of water. A marine fish would also swell and probably his cells would burst.)

   2. What happens to potato slice left in salty water? Relate this result to a fresh water fish dropped into the ocean. (Potato slice becomes limp; cells have lost water and become dehydrated. A fresh water fish would become dehydrated.)



FRESHWATER

High Concentration of Water Outside Cell. Water Flows In. Result: Bloat



SEAWATER

Higher Concentration of Water in Cell. Water Flows Out. Result: Desication

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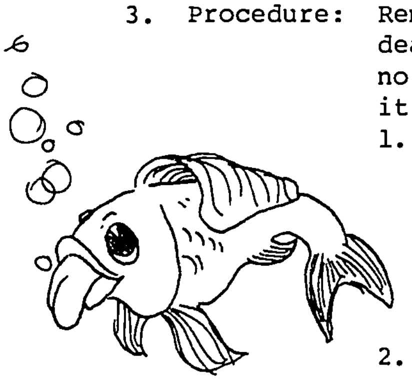
b. Things to Do

Using Fish as Biological Indicators of Temperature

1. Objective: To investigate the effect of temperature on the respiration rate of fish.

2. Teacher Preparation: This experiment requires the use of several small goldfish. It is a good idea to have two tanks available - one for fish used in experiments and one for fish "recovery". Each team of students will need one baby food jar with lid, two larger containers (coffee cans or large beakers), some method of heating (hot plate or alcohol burner with stand), timer or watch with second hand, 1 dip net, 1 thermometer, 1 goldfish or minnow (mosquito fish work out well).

3. Procedure: Remember this experiment is a matter of life or death for the fish: use only clean glassware, no detergents; watch the temperature and have it no hotter than 35°C.



1. Fill the large containers about half full with tap water. Label them "A" and "B". Fill the baby food jar with water from the fish tank. Using a dip net, add one fish to the jar. Cap the jar and place it in container A.

2. After a minute, record the temperature in container A. Then determine the relative activity of the fish by counting the number of breathing movements (opening and closing of either mouth or gills) that occur in 20 seconds. Repeat this 3 times and then find the average breathing rate. Record this, and note any other activity of the fish.

3. Heat the water in container B to less than 35°C. Remove it from the heat. Place the jar with the fish in container B. After a minute, record the temperature of container B. Then determine the rate of breathing by counting the opening and closing of the mouth or gills in 20 seconds. Again, repeat this 3 times and find the average rate. Record this rate and note any change in the activity of the fish.

4. Remove the baby food jar and fish, allow water to cool, then put the fish into the "recovery tank" to rest.

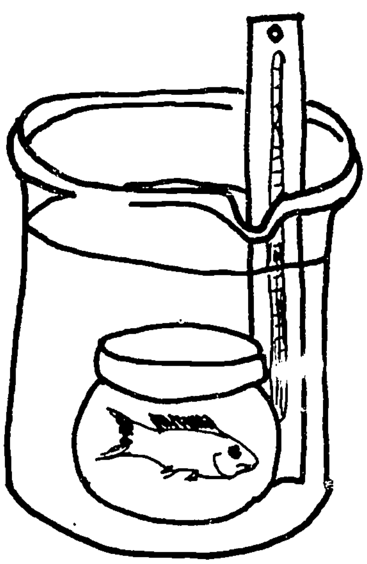
4. Discussion: 1. How did the breathing rate of the fish in warm water compare to that in the cooler water? (Increase in warmer water)

2. Did the fish seem more active in warmer or cooler water? (warmer)

3. A fish is cold-blooded which means that its body temperature adjusts to the same temperature as its surroundings. A warm-blooded animal is one whose body temperature stays about the same even when the temperature of the surroundings changes. Are you warm or cold-blooded? (warm blooded)

4. Tropical fish from the Gulf Stream populate the coast in the summer. What do you predict would be the effect of colder, winter water on the fish? How would the fish's activity probably change? (Low temperature water could kill fish or force it to migrate and slow down activity.)

5. Most animals, like fish, have a preferred temperature range in which to live. Some fish are much more sensitive than others to increases in temperature and die if the temperature increases slightly above their preferred range. Discuss why adding heat energy from power plants to rivers, lakes, bays, and streams can present real problems to fish and other animals. (Raises water temperature which can cause water to be too warm for organisms to tolerate and they would die. Abnormally warm water can upset reproductive cycles and affect growth of juveniles and larvae.)



b. Things to Do

Dancing Mothballs and Fish Buoyancy

(adapted from The American Biology Teacher, January 1975, Vol. 37(1): 49 by R. Postiglione)

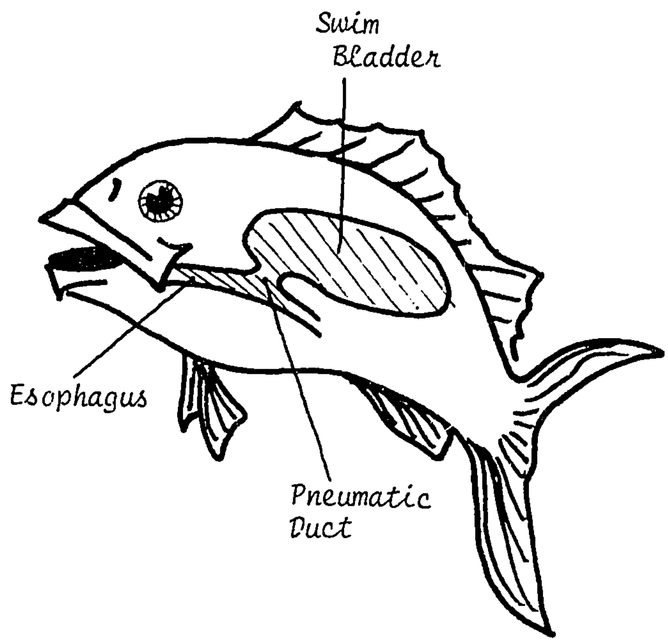
1. Objectives:
   1. To observe how gas bubbles can be produced and affect density of the object.
   2. To investigate how fish can use their gas bladder to maintain or change their position in the water.

2. Teacher Preparation: Collect 1 beaker or jar (1 liter); sodium bicarbonate; water; white vinegar; mothballs, and food coloring.

3. Procedure:
   1. Fill the jar half full of water and add a few drops of food coloring, 250 ml of white vinegar, 4-5 mothballs and then, 2-3 grams of sodium bicarbonate.
   2. Record the results (At this point, the mothballs will form bubbles on their surface and begin to rise. When they reach the surface, the bubbles will escape into the air and the mothballs will sink.)

4. Discussion:
   1. What happens on the surface of the mothballs? (Bubbles are formed)
   2. What causes the mothballs to rise? What happens to the overall density as the bubbles cling to the mothball? (The mothballs rise because the overall density of the combinations of mothball and gas bubbles is lowered. This same thing occurs when the fish takes air into its swim bladder.)
   3. Why does the mothball sink? (Because bubbles are released into the air when the mothball reaches the surface, increasing the density. This occurs when the fish releases air from its swim bladder.)
   4. How does the rising and sinking of mothballs apply to understanding of the fish's air bladder? (When the mothball or fish changes density, it will change its position by rising or sinking in the water column.)

5. What is an advantage to having a gas bladder? (Conserve energy. Sharks do not have a gas bladder and must swim to keep from sinking. Sharks do have a large oil-filled liver which gives them some buoyancy.) Nature has invented a marvelous ballast organ. Some fish have a swim bladder that helps the fish to float, sink or rise in the water. Some of them live at different levels in the water at different times of the day or year. The air bladder adjusts to these changes by releasing gas into the blood, or absorbing additional gas from the blood.



b. Things to Do

Gills - Multiple Uses and Design
Investigation of the Anatomy of the Gills of Fish

1. Background: Since most marine fish swim with their mouths open, and since water contains both oxygen and food, fish have structures called gillrakers to protect their gill filaments from clogging particles much as we have a valve to prevent food from clogging our windpipes. In carnivorous fish like bass, gillrakers are knobs on the gill arches, while in filter-feeding fish (herring and menhaden) gillrakers are fine sieves that strain plankton from the water for food.

2. Objective:
   1. To learn to dissect the gills of fish.
   2. To observe the differences in structure which enable different functions.

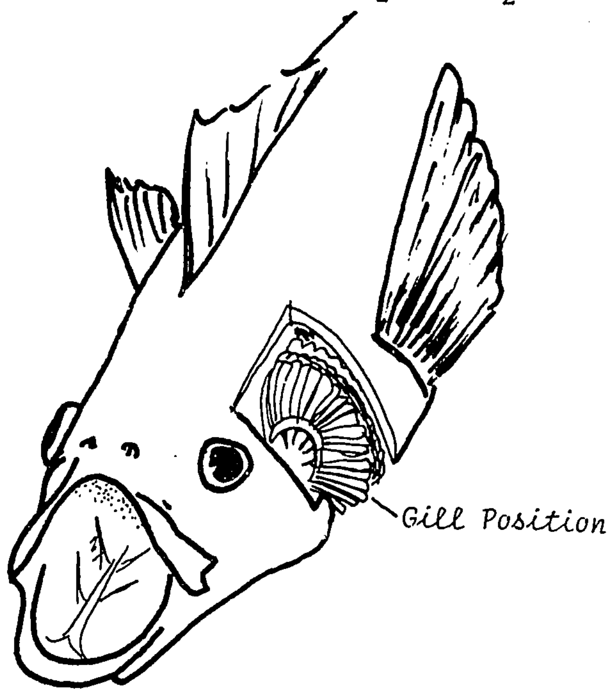
3. Teacher Preparation: This is a "dissecting lab" activity emphasizing only the head of fish. You could combine this with a whole fish lab or concentrate on gill structure. You will need to obtain fish heads of two types: a carnivorous fish like trout, mackeral, snapper, drum, grouper, bass, croaker, perch, or bluefish, etc.; and a filter-feeding fish like herring, shad, menhaden, mullet, anchovy (a common estuarine minnow like the silverside). A pair of scissors or dissecting blade plus tweezers will aid in removing the gills. Several gills will come from each fish head. Petri dishes or shallow bowls are needed to "float" the gill so the individual filaments can be observed. Dissection scopes, magnifying glasses will facilitate observations. (Seafood markets, seafood restaurants and local fishermen are good sources for supplies of fish heads.)

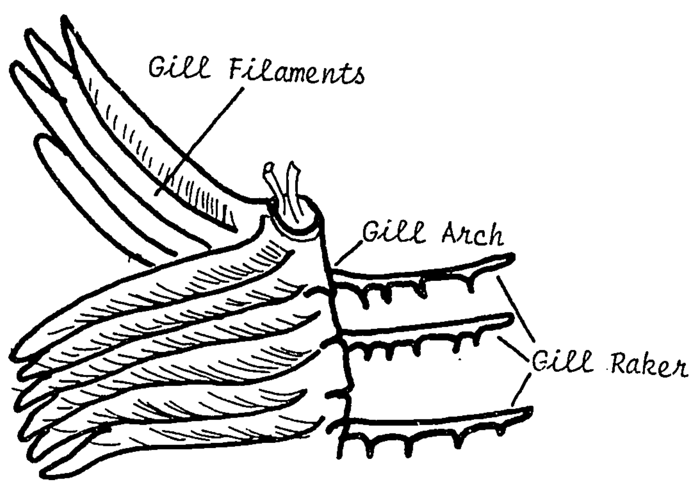
4. Procedure:
   1. Take the gills of the two fish which have been provided by your teacher. Put each in a separate bowl of water. Be sure to label which came from a carnivorous fish and which from a filter-feeding fish.

   2. Locate the following parts of the gills: gill-raker, gill arch, gill filaments. Sketch each of the gills and label the parts.

5. Discussion:
   1. Discuss the function of the gillraker, gill arch, and gill filaments. (gillraker - to strain particles from water. gill arch -

carries blood vessels to and from filament.)
gill filaments - blood vessels close to surface
and exchange of O_2 and CO_2 can occur.)





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b. Things to Do

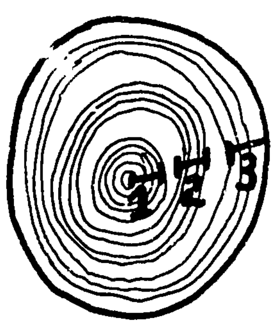
Detecting Age and Growth in Fish

1. Objective: To observe differences in the scales of fish; some of these differences reflect growth patterns.

2. Teacher Preparation: Obtain a fresh fish from the market (or catch your own!) and, if possible, obtain two sizes of the same species in order to compare age and growth. (Very old fish will have scales difficult to interpret as the scales will be thick and opaque.) Tweezers to remove scales (fingers will work), a pair of glass slides (1" x 3"), and a dissecting scope or low magnification microscope (10X to 40X) should be available for each group of students. (Hint: freshwater fish are often better than marine specimens in this exercise.)

3. Procedure:
   1. From the study fish, remove one scale intact, using tweezers or your fingers. Measure the length of the fish.
   2. Wet the scale and place it between two glass slides for examination.
   3. Sketch the scale and growth rings, noting any that are heavier in appearance. Recount the number of rings of the scale.

4. Discussion:



   1. The rationale for using growth rings on a scale is similar to using growth rings to determine the age of a tree. However, botanists have found that some trees under changes in soil moisture and temperature, can form more than one growth ring in a year. So ring counts do not always reveal true age. What factors could affect the growth rings on fish? (Sickness, temperature, especially abundant or scarce food.)
   2. In theory, a fish grows rapidly in summer and slowly in the winter. Why would this pattern occur? (More food in summer.)

Variation of this experiment: Take a number of the same species of fish which are different sizes (assume size is directly related to age). Measure the length of the fish and diameter of the scale and plot these results on a graph. Interpret the meaning of the graph.

b. Things to Do

Deep Sea Show

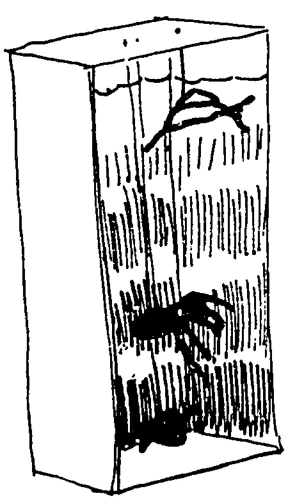
Objective: To allow for creativity in learning about nekton living in various depth of the ocean.

Teacher Preparation: This activity is more of a special project for a group of students. Materials can vary as to what is available. Basically a cardboard box of whatever you want from a refrigerator box to a produce box, construction paper, glue, scissors, string, paint, crayons.

Procedure: Turn the box on its side standing tall. Paint or paste in water color, light blue or green for surface, deeper blue near middle turning to black at the bottom. This gradation indicates absorption of light rays. Cut out models of fish and other creatures which inhabit different depths. Tie each to a string and suspend it from the top of the box at the suitable level. Some animals are capable of quite a bit of "vertical migration". You may wish to show this by pulling and lowering the animals to make your point. Squid, whales, and some crustaceans may migrate down to depths of 1000 m.

Discussion:

1. Why would most animals inhabit the upper levels of the ocean? (Most light allows most plants to grow providing food to other animals)



2. On what do deep animals feed? (This answer is still being studied by scientists. Many think deep animals depend on what drifts down to them. Some think food comes from organic molecules which clump up and become food sized particles)

3. Why are most mesopalagic animals luminescent? (To allow recognition of each other and of prey)

b. Things to Do

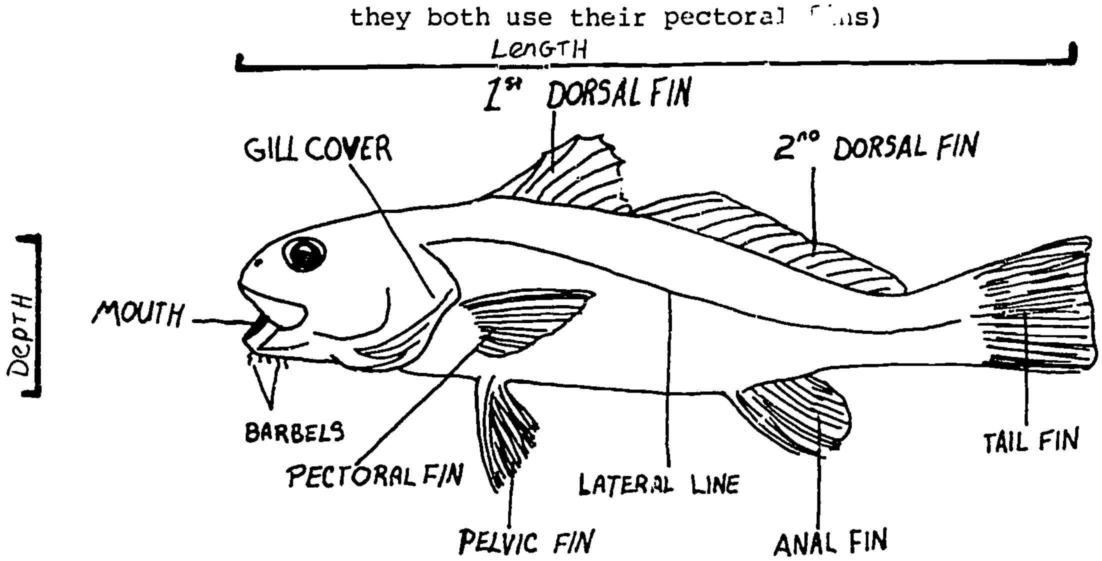
Dichotomous Key for Some North Carolina Fish

Objective: 1. To learn to use a dichotomous key
2. To identify some common North Carolina fish

Teacher Preparation: Duplicate the key and pictures of the fish. Review how to use the key.

Procedure: Using the key, identify the ten fish in Figure 1.

Discussion:
1. What survival adaptations do these fish exhibit?
   flounder - ability to burrow, camouflage itself on bottom
   file fish - green color, small mouth for picking small organisms off grass blades
   spade fish - mouth modified to pick and crunch attached organisms like barnacles
   eel - ability to burrow
   burrfish (alias puffer and porcupine fish) - inflate
   needle fish - mouth modified for surface feeding; body shape designed for speed
   stargazer - eyes on top of head so it can burrow and still see
   black drum - chin barbels feel bottom
   sea robin - modified fins for walking on bottom
   blue fish - modified mouth for attacking other fish (protruding lower jaw)
2. What body structures are clues to the habitat of the drum and star gazer? (Bottom habitat. Barbels on chin of drum and location of eyes on stargazer)
3. What do the burr fish and file fish have in common? (Mouth designed for picking, no speed in swimming as they both use their pectoral fins)



Dichotomous Key

1A. Both eyes on one side of head. /I. Flounder/ (Flounders live in shallow water often partly buried in the sand with the blind side down. They eat fish and small invertebrates such as shrimp. Flounders adapt their coloration to the bottom)

1B. Eyes on opposite side of head. (Go to 2)

2A. Body as deep as it is long (3)

2B. Body longer than deep (4)

3A. First dorsal fin modified into separate spine and mouth is beak-like. /B. File fish/ (Nibbles algae and crustaceans growing on pilings and wrecks and in marine grass flats)

3B. First dorsal fin normal; mouth not beak-like. /J. Spade fish/ (Nibbles algae and crustaceans from pilings, rocky patches and wrecks)

4A. Dorsal and anal fins continuous with tail. /G. American eel/ (Eels live in fresh water but lay eggs in the ocean; the young eels or elvers return to the rivers. Eels eat both plants and animals. They are very slippery, making it hard for birds and fish to catch them)

4B. Dorsal and anal fins not continuous with tail (5)

5A. Only 1 dorsal fin (6)

5B. Has first and second dorsal fins (7)

6A. Body covered with spines. /C. Burr fish/ (Burr fish eat mollusks and crustaceans, mainly hermit crabs. They defend themselves by puffing up)

6B. Body smooth. /D. Needle fish/ (Needle fish eat other fish which they catch crosswise in their long jaws. They swim and feed at the surface)

7A. Eyes and mouth pointed up. /H. Stargazer/ (Stargazers live buried in the sand with the eyes and mouth out. They have electric organs and can deliver a shock. They feed on fish)

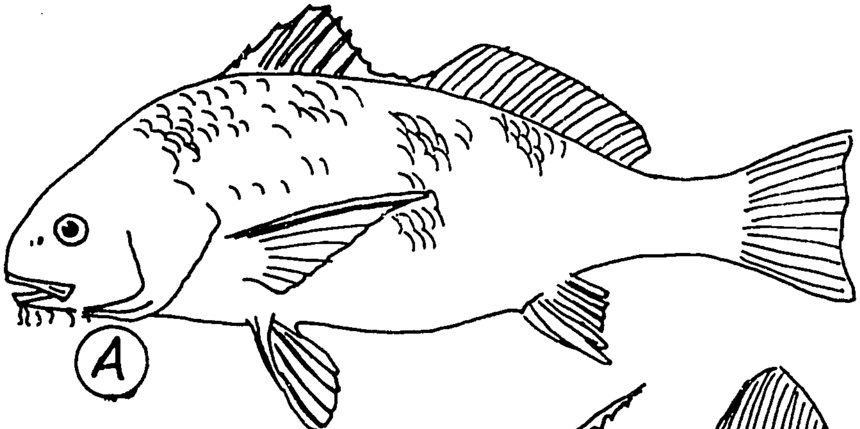
7B. Eyes and mouth not pointed up (8)

8A. Mouth has barbels on chin. /A. Black drum/ (Black drum feed on the bottom usually crushing mollusks and crustaceans. The barbels are a sense organ)

8B. Mouth without barbels. (9)

9A. Pectoral fins modified with three detached spines. /E. Sea Robin/ (It lives on the bottom propping itself up with its pelvic fins. Sea Robins eat crustaceans)

9B. Pectoral fin normal. /F. Blue fish/ (Blue fish swim in schools feeding on other fish. They often kill more than they can eat)



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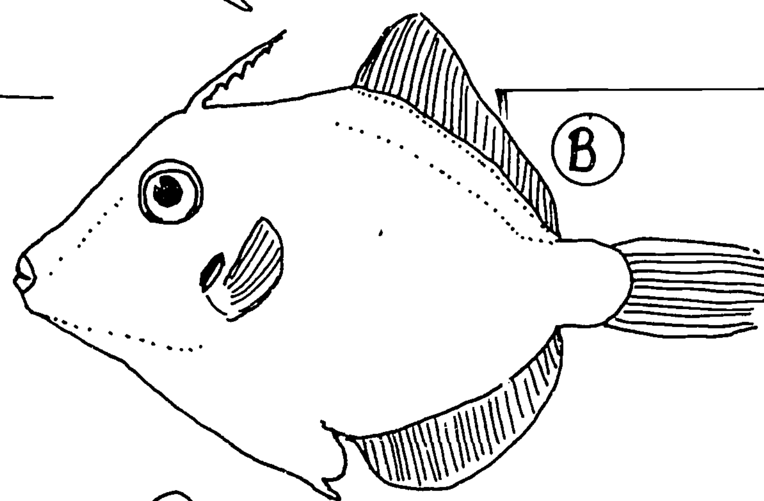

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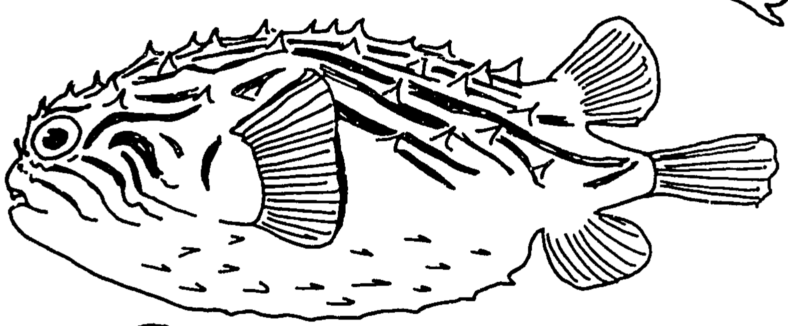

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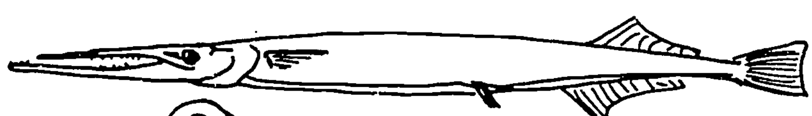

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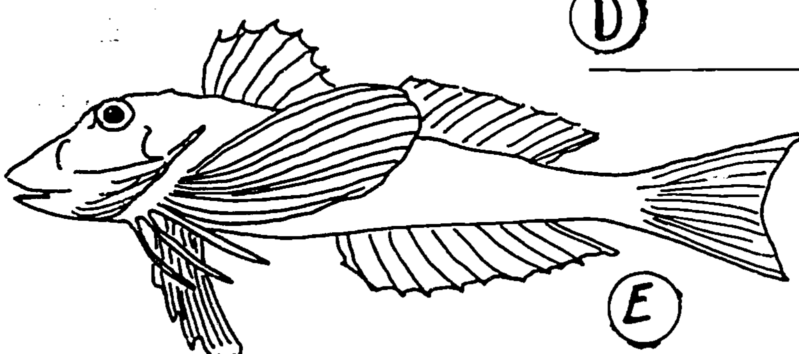

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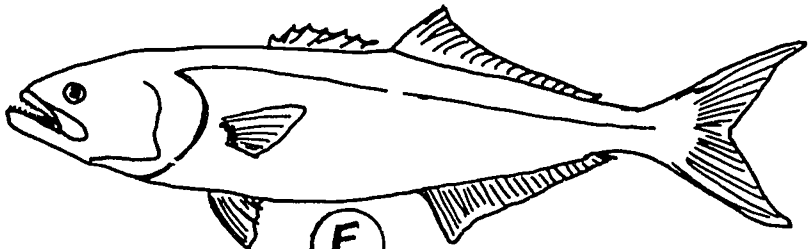

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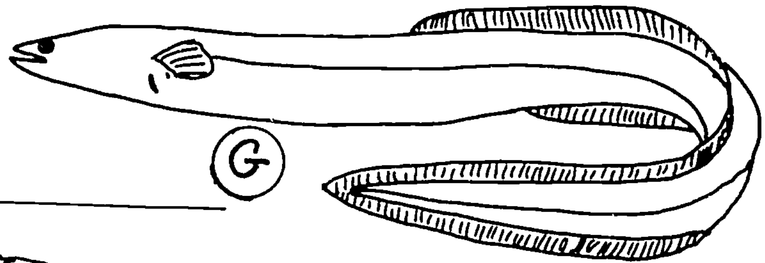

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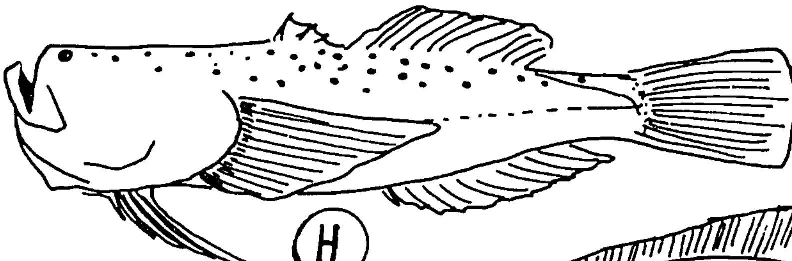

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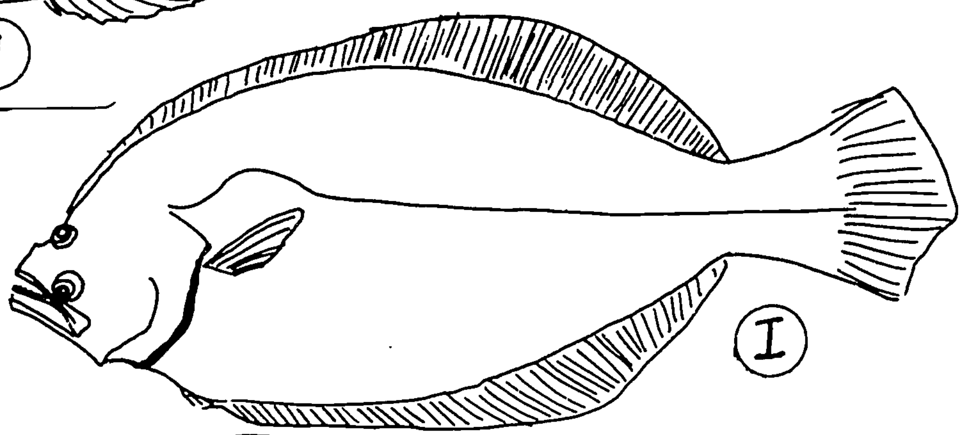

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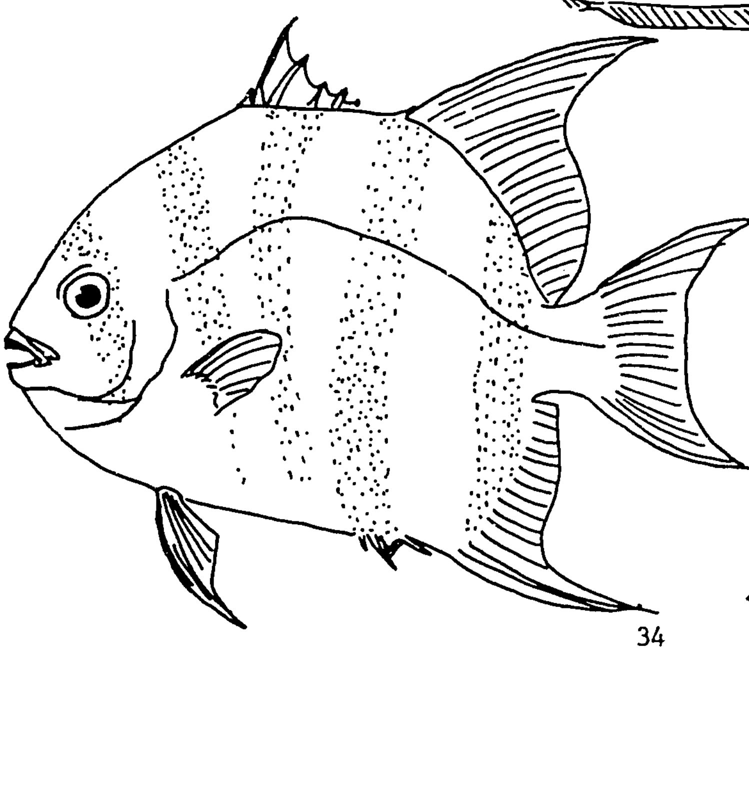

J

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b. Things to Do

Schooling Behavior in Fish

Objective: To investigate fish behavior.

Teacher Preparation: If possible, visit a large community aquarium to observe grouping tendencies in fish. You'll need one test aquarium, several fish (pet store or student supplies; some suitable breeds include: Zebra fish, Harlequin fish, Scissor tail, Rosy tetra, Tiger barb, Pristella, Brook stickleback, Three-spined stickleback), 2 jars with lids, and dip nets.

Procedure: <u>Experiment 1</u>

The tendency of a single fish to school with its own kind.

1. Draw two vertical lines on the aquarium front wall, dividing it into three equal parts.

2. Place equal numbers of the two species of fish in separate screw-top jars, one species per jar. The number of fish will depend on their size; eight to ten 3- to 5-cm long fish in a 4-liter jar is adequate (Fig. 1).

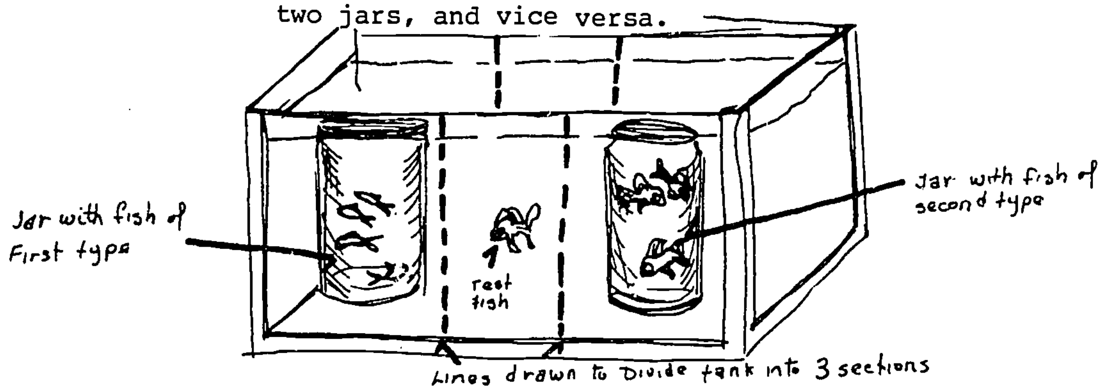
3. Place one jar containing a group of fish at each end of the aquarium.

4. Gently place a single fish of one of the two species (call it the Test Fish) in the center of the aquarium. Release the test fish carefully, making sure you do not direct it toward one of the jars at the start of the test. Record the following over a 15-minute period and enter your results.
   a. Time (in minutes) the test fish spends in each of the three areas.
   b. The number of times the test fish moves from one area to another.

5. Remove the test fish, reverse the positions of the jars, replace the test fish, and repeat the recording.

6. Remove the test fish, use one of the other species as a new test fish, and repeat steps 4 and 5.

During the four tests, make qualitative records of the responses of the test fish to fish in the two jars, and vice versa.



Experiment 2.

The effect of fish in a group on the behavior of an isolated individual.

1. Select the species that showed the strongest schooling tendencies in Experiment 1. Place the two jars in opposite ends of the aquarium. In one jar put two fish and in the other, six fish, all of the same species (Fig. 2).

2. Carefully release the same type fish in the center of the aquarium. Record for 15 minutes the following data and enter your results in the table.
   a. Time (in minutes) the test fish spends in each of the three areas.
   b. The number of times the test fish moves from one area to another.

3. Remove the test fish, reverse the positions of the jars, replace the test fish, and repeat the recordings.

4. Place equal numbers of fish in each jar, use a different individual as the test fish, and repeat steps 2 and 3.

Again, make qualitative records of responses shown by the test fish and the captive fish towards each other.

Discussion:

1. Did the test fish tend to school more with its own species than with other species? (Yes)

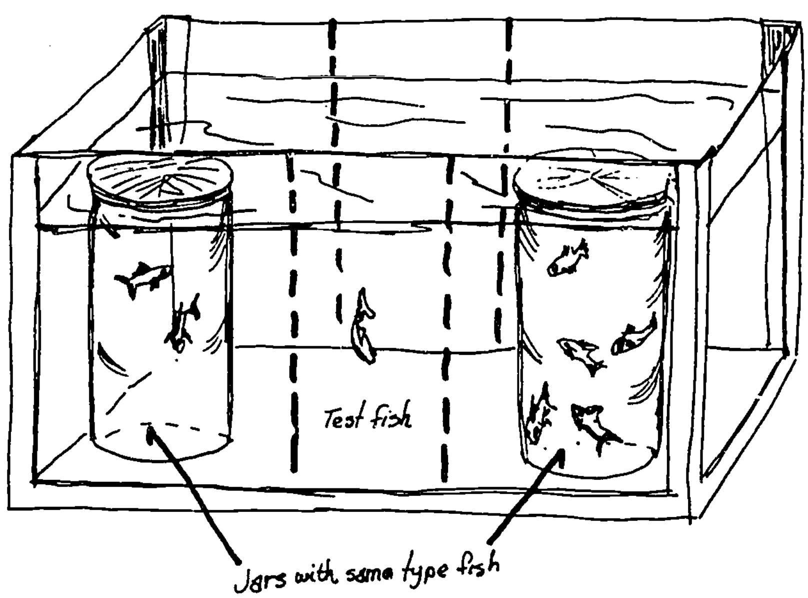
2. Did the test fish tend to school more with the large or with the small schools? (Depends on observations, usually larger schools)

3. In what other ways did the test fish react to the fish in the jars? (Your observations)

4. How did the enclosed fish react to the test fish? (Your observations)

5. Why do you think fish school? (Protection, feeding, reproduction)

Adapted from an article, "Schooling behavior in fish" by Miles H.S. Keenleyside of the University of Western Ontario.



b. Things to Do

Potato Fish

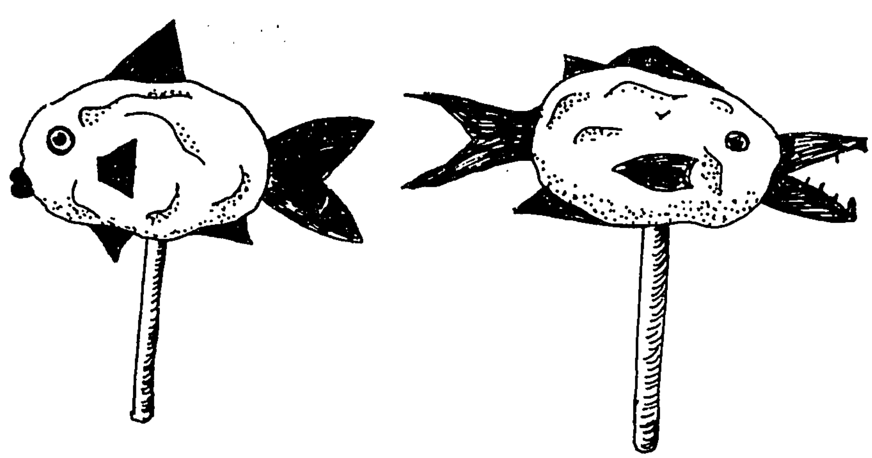
Objective: To design a fish with functional parts suited for its habitat; to learn the external parts of a fish.

Teacher Preparation: This activity can be demonstrated with you holding the potato (or piece of styrofoam cut into a fish shape) and asking for suggestions or can be done in small teams. The body shape is represented by a potato with fins, mouth, eyes, etc. represented by stiff pieces of cardboard or construction paper. These are stuck into the "fish". Before doing this, review the different types of fins, positions of mouths, and other adaptations.

Procedure:

1. Discuss where you want your fish to live, what it would eat, how it would protect itself from enemies. Write down the results of the discussion.
2. Cutting out fins, mouth, eyes place these on the potato in the shape and position which would allow this "fish" to survive in the habitat you have described.
3. When several of the "potato fish" have been finished, the students should compare and try to analyze the habitat of their friends' "potato fish".

Discussion: What characteristics are the best suited for defining where and how a fish lives? (body shape, fins, mouth design)



b. Things to Do

The Dangerous Animals' Message

Objective: To learn some facts about dangerous marine animals.

Procedure: Fill in blanks with name of animal. Place those letters above a number in proper position to spell out message.

Description: Name

1. This fish uses more than one poisonous spine as his defense.

___	___	___	___		___	___	___	___
	9				11			2

2. The lateral line on this fish looks pitted.

___	___	___	___	___	___	___	___
				4		12	

___	___	___
6		10

3. This fish is deadly in "schools".

___	___	___	___	___	___	___
	15		3		5	

4. The "pencil" shape of this fish helps to make him a fast, darting, swimmer.

___	___	___	___	___	___	___	___
						7	

5. This fish defends his home just by using his sharp teeth and powerful jaws.

___	___	___	___	___		___	___	___
							8	

6. This fish does not use his defense to get his food. He smothers his food.

___	___	___	___	___		___	___	___
16	1							

7. This fish was the star of "JAWS"

___	___	___	___	___	.
13	14				

Secret Message:

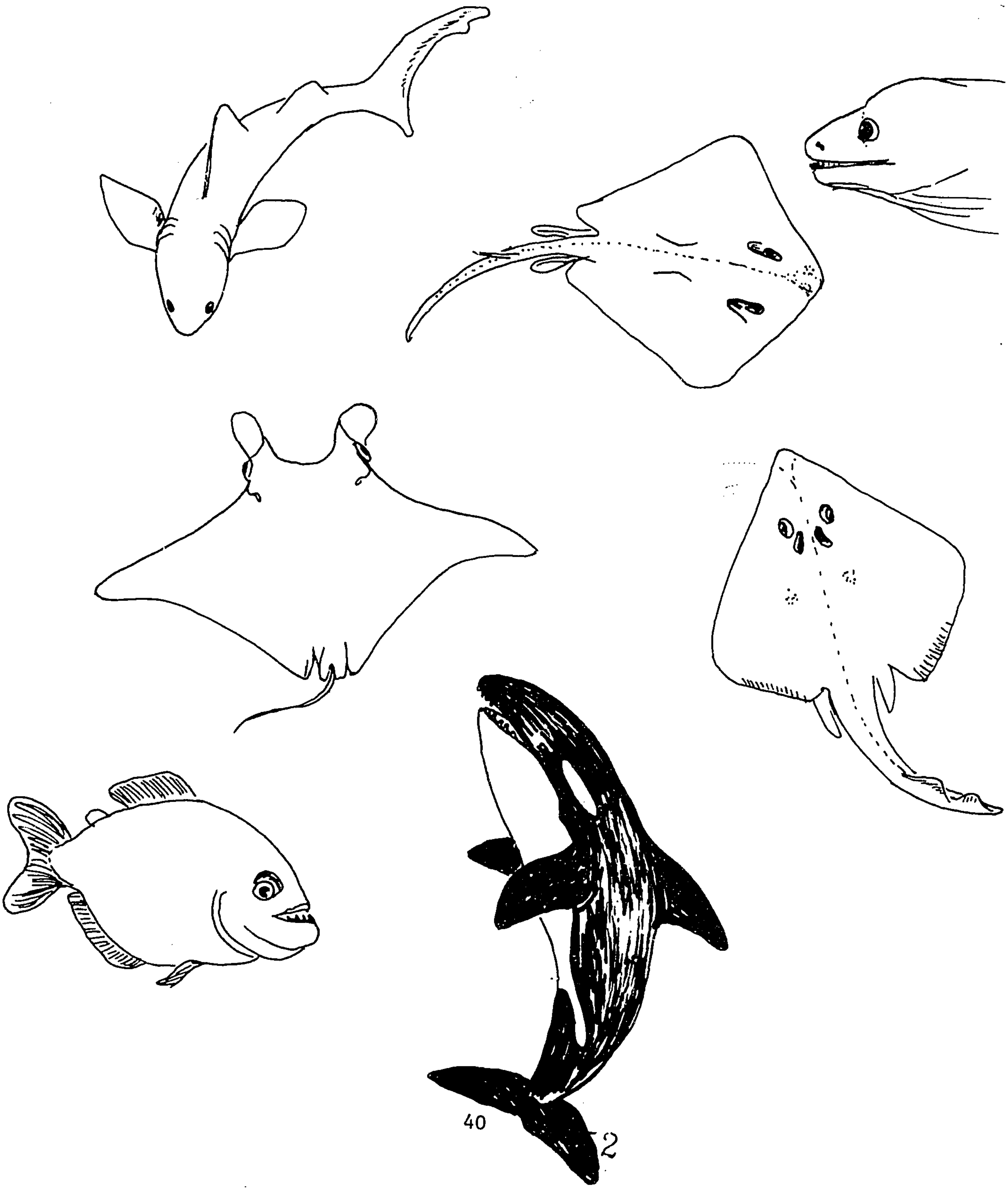
Did you know

___	___	___	___		___	___	___		___	___	V	___	___		___	___	___	___	
1	2	3	4		4	5	6		7	8		9	10		11	12	13	14	

___	___	a Manta Ray?
15	16	

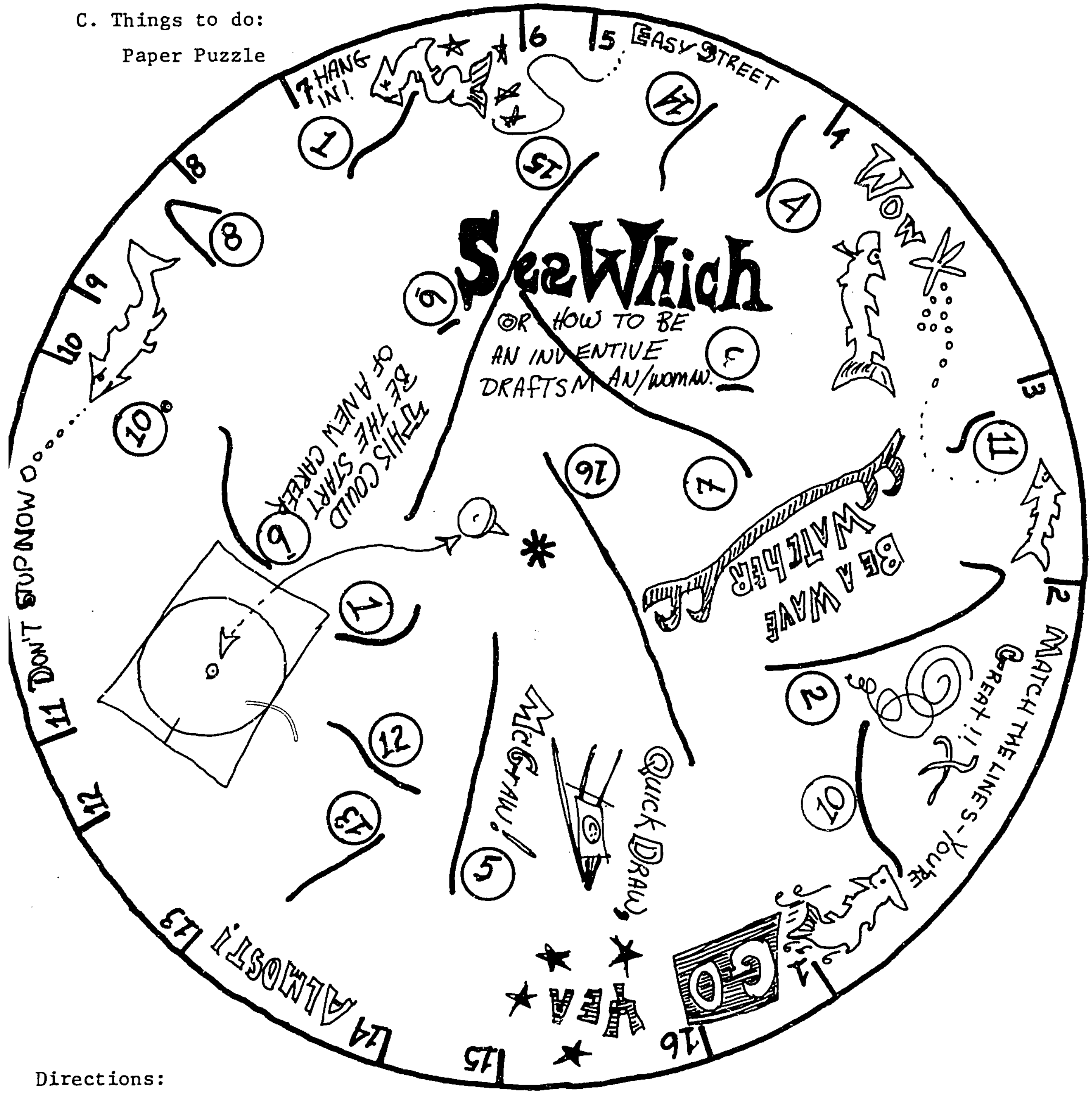
Choose the answers for the riddles from these fishes:

Lionfish
Red Tailed Catfish
Electric Eel
Baracuda
Shark
Sting Ray
Skate
Moray Eel
Manta Ray
Piranha
Tarpon
Killer Whale



C. Things to do:

Paper Puzzle



Directions:

1. Cut out circle.
2. Place circle on a sheet of paper with a piece of carbon paper in between (left-overs from duplicating masters work)
3. Thumb-tack "Sea Which" through center.
4. Pencil a mark on paper at top of circle.
5. Swivel circle until number 1 on circle edge is on the mark. Then trace over all thick solid lines marked "1".
6. Swivel circle to number 2. Repeat until all lines have been traced.
7. Lift circle and carbon and "Sea Which" you've got!

Concept 2

C. Things to do:

Paper Puzzle

Directions:
1. Cut out circle.
2. Place circle on a sheet of paper with a piece of carbon paper in between (left-overs from duplicating masters work)
3. Thumb-tack "Sea Which" through center.
4. Pencil a mark on paper at top of circle.
5. Swivel circle until number 1 on circle edge is on the mark. Then trace over all thick solid lines marked "1".
6. Swivel circle to number 2. Repeat until all lines have been traced.
7. Lift circle and carbon and "Sea Which" you've got!

d. Resources to Use

<u>Nekton</u>

Schwartz, F.J. and Jim Tyler. 1974. Marine Fishes Common to North Carolina. Write to:
NC Department of Natural and Economic Resources
Division of Commercial and Sports Fisheries
Raleigh, NC (one free)

Schwartz, F.J. and G.H. Burgess. 1975. Sharks of North Carolina and Adjacent Water. Write to:
NC Department of Natural and Economic Resources
Division of Commercial and Sports Fisheries
Raleigh, NC (one free)

Curtis, Brian. 1949. Life Story of a Fish - His Morals and Manners. Dover Publications, Inc. $5.95 (simple, yet thorough review of the fish)

Ross, Stephen. 1977. A Checklist of Marine Fish of Beaufort, NC $0.75

Project Jonah (whales)
Box 476
Bolinas, CA 94924 (free material)

Environmental Science. 1971. Probing Natural World/III.
ISCS Silver Burdett
General Learning Corporation
Morristown, NJ (excellent activities) $5.85

FISH - the Most Asked Questions. Reprint, April, 1973, National Oceanographic and Atmospheric Association, #1973-542-648126. Write to the U.S. Government Printing Office.

American Cetacean Society
National Headquarters
P.O. Box 4416
San Pedro, CA 90731 (free material)

Project Coast Material
#204 The Noisy Deep $0.80
#220 The Year of the Whale $0.85

Posters from Superintendent of Documents
Government Printing Office
Washington, D.C. 20402
Marine Fishes of the North Atlantic $2.80
Marine Fishes of the Gulf and South Atlantic $2.80
Marine Mammals $3.00

Films

And So Ends. . . . Pyramid, 25 minutes, color. (on whaling)

Aquatic Locomotion. Harper and Row, 17 minutes, color. (swimming animals on the Galapagos)

Attack Patterns of Sharks. Indiana University, 27 minutes, color.

Shark! MN11243 Navy

Desert Whales. Churchill, 22 minutes, color. (Cousteau)

Dolphins. MacMillan - Last of the Wild Series, 22 minutes

FISH - a Fish Inquiry. BFA, 9 minutes, color. (elementary, good)

Fish - Master of Movement. MacMillan, 12 minutes, color

The Green Sea Turtle. Churchill, 21 minutes, color. (Cousteau)

Portrait of a Whale. Modern Talking Picture Service, 12 minutes, elementary.

The Right Whales - An Endangered Species. National Geographic, 23 minutes, color. (excellent)

Swimmy. Connecticut Films, 6 minutes. (elementary animated film from the book Swimmy)

Whales, Dolphins and Men. Time-Life, 52 minutes, color. (excellent, elementary - high school)

Concept 3. North Carolina's intertidal organisms show striking adaptations to the environments in which they occur.

a. Background Reading

Organisms that live between the high and low tide levels of the seacoast face one of the most rigorous physical environments on the face of the earth. Not only must they tolerate alternating periods of immersion in sea water and exposure to air as the tides rise and fall, but they also must face great changes in temperature (tidal, daily and seasonal), wave energy (calm to storm conditions), and salinity (full strength sea water to fresh water during low tide rains). The organisms that inhabit this rigorous environment provide dramatic examples of adaptations demonstrating evolutionary solutions to environmental problems.

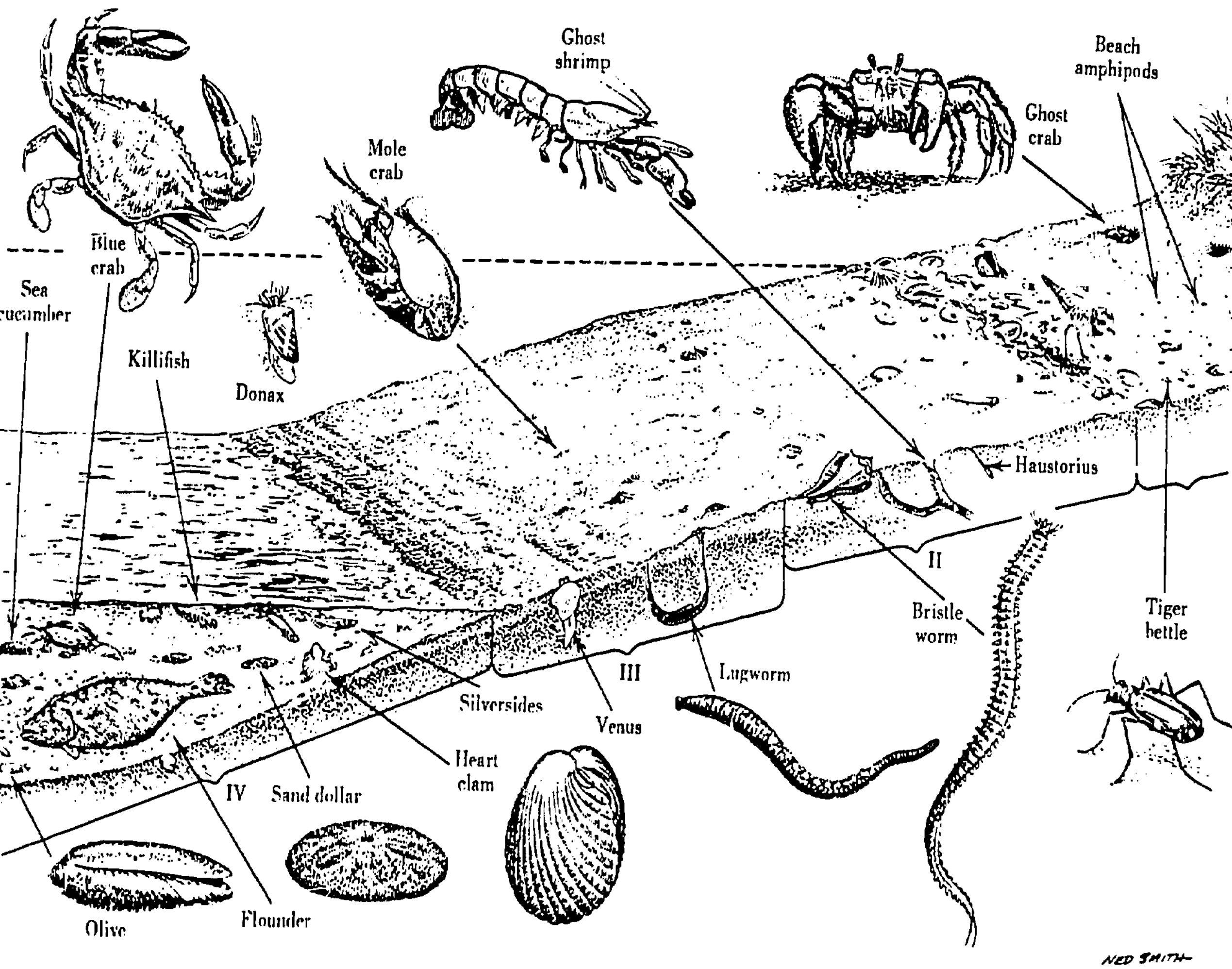
North Carolina's coastal zone contains a spectrum of intertidal benthic habitats including exposed beaches, sand and mud flats, and sheltered salt marshes. Organismal adaptations to these three habitats will be briefly discussed.

Sandy Beaches

Some of the organisms inhabiting sand beaches of North Carolina are illustrated in Figure 2. Some of these animals are of commercial importance (flounder, blue crab, clams); others are familiar to even casual beach visitors (sand dollars, heart clams, mole crabs, and sand pipers), and others are seen only by visitors who seek them out (Donax or coquina clams, bristle worms, ghost shrimp and ghost crabs). All of these animals are adapted to the environment in which they occur, but the adaptations are quite obvious for those living in the sand of intertidal zones.

Usually the most dramatic physical feature of the sand beach environment is the surf that breaks on its surface. Sand beach biota must tolerate the force of these waves and the shifting sands that they create. Thus, sand beach biota are good burrowers. The most obvious active burrower is the mole crab Emerita. These small crustaceans can be seen moving about rapidly within the wave's swash zone. When about to be stranded by the receding wave, they bury themselves rapidly in the water soaked sand. Similar behavior is illustrated by the Donax clam (coquina), although its small size makes it less obvious to casual observers. The similarity in the behavior of both clam and mole crab illustrate the efficiency of rapid burrowing as one solution to the problems of living in a sandy beach. Another, less easily observed solution to these problems is deep burrowing. This solution is demonstrated by both worms (lugworm) and crustacea (ghost shrimp). These animals usually live in protected beaches or sand flats, and their burrows are so deep (up to six feet for the ghost

FIGURE 2: LIFE ON A SANDY OCEAN BEACH ALONG THE ATLANTIC COAST



h strong zonation is absent, organisms still change on a gradient from land to sea. (I)Supratidal Zone: rabs and sand fleas; (II) Flat Beach Zone: ghost shrimp, bristle worms, clams; (III) Intratidal Zone: lugworms, mole crabs; (IV) Subtidal Zone: Blue crabs, sand dollars, silversides.

(From Smith, R.L., 1966. Ecology and Field Biology. Harper and Row. page 236.)

shrimp) that their presence is usually indicated only by the mouths of their burrows and the piles of characteristically shaped fecal pellets surrounding them. Dedicated collectors can capture these animals by digging deep holes, an exercise that will convince even the most doubting student of the lengths to which animals will go to escape the environmental rigors of the beach surface.

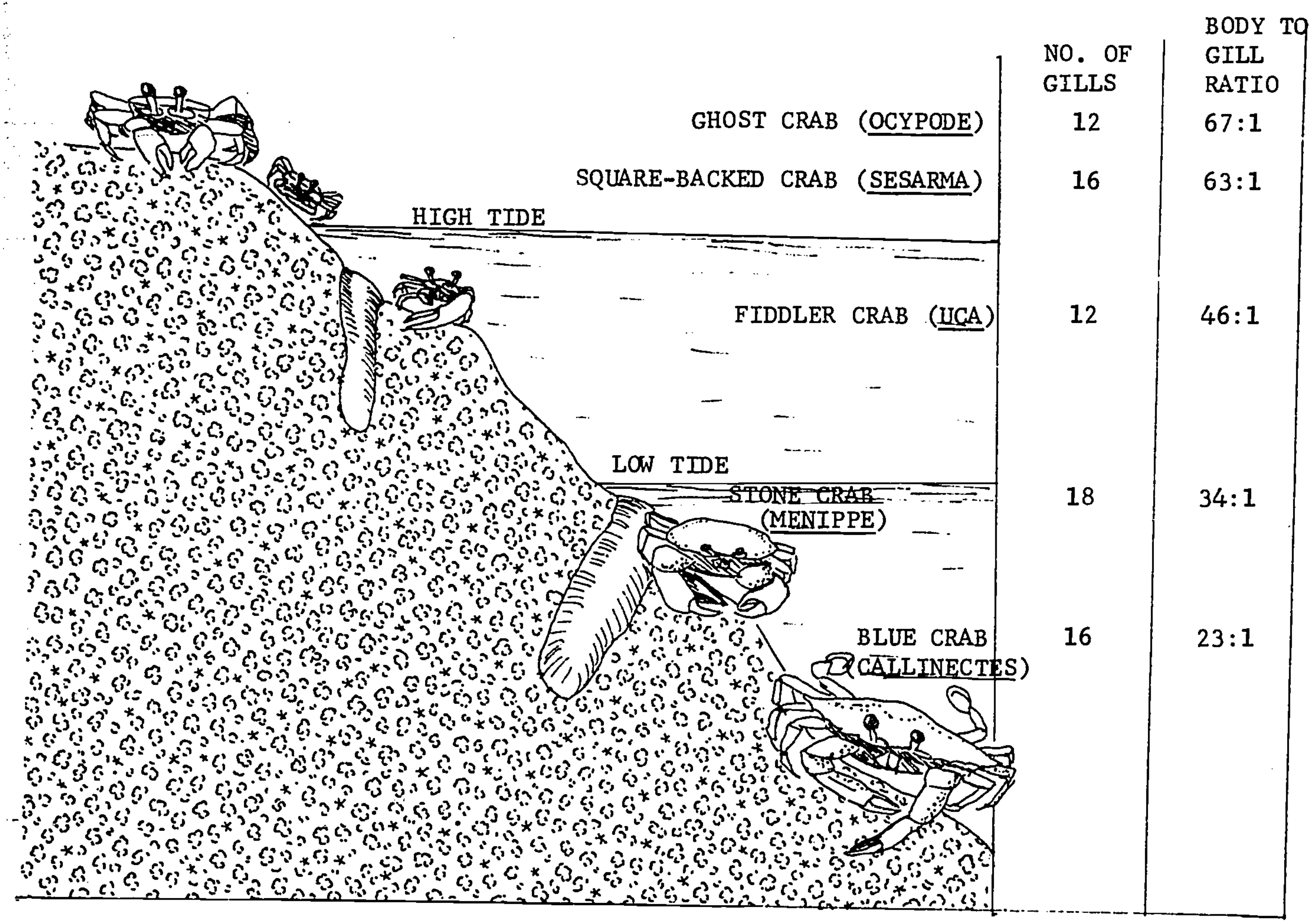
Sand and Mud Flats

Intertidal organisms that inhabit sand and mud flats show less obvious adaptations to their habitats than do the inhabitants of sand beaches. However, they do have adaptations to survive desication when they are exposed to the air at low tide and to cope with oxygen depletion in the water. One of these adaptations was demonstrated by Professor A.S. Pearse of Duke University who showed the relationship between the location of crabs in the intertidal zone and (1) the number of gills they possess and (2) the ratio between body and gill volume. This relationship is illustrated in Figure 3. Upon reflection, you can understand the problems aquatic animals have of water loss through the gills when exposed to air. (Humans lose water from their lungs also as seen by the condensation when you breathe on a glass on cold damp days.)

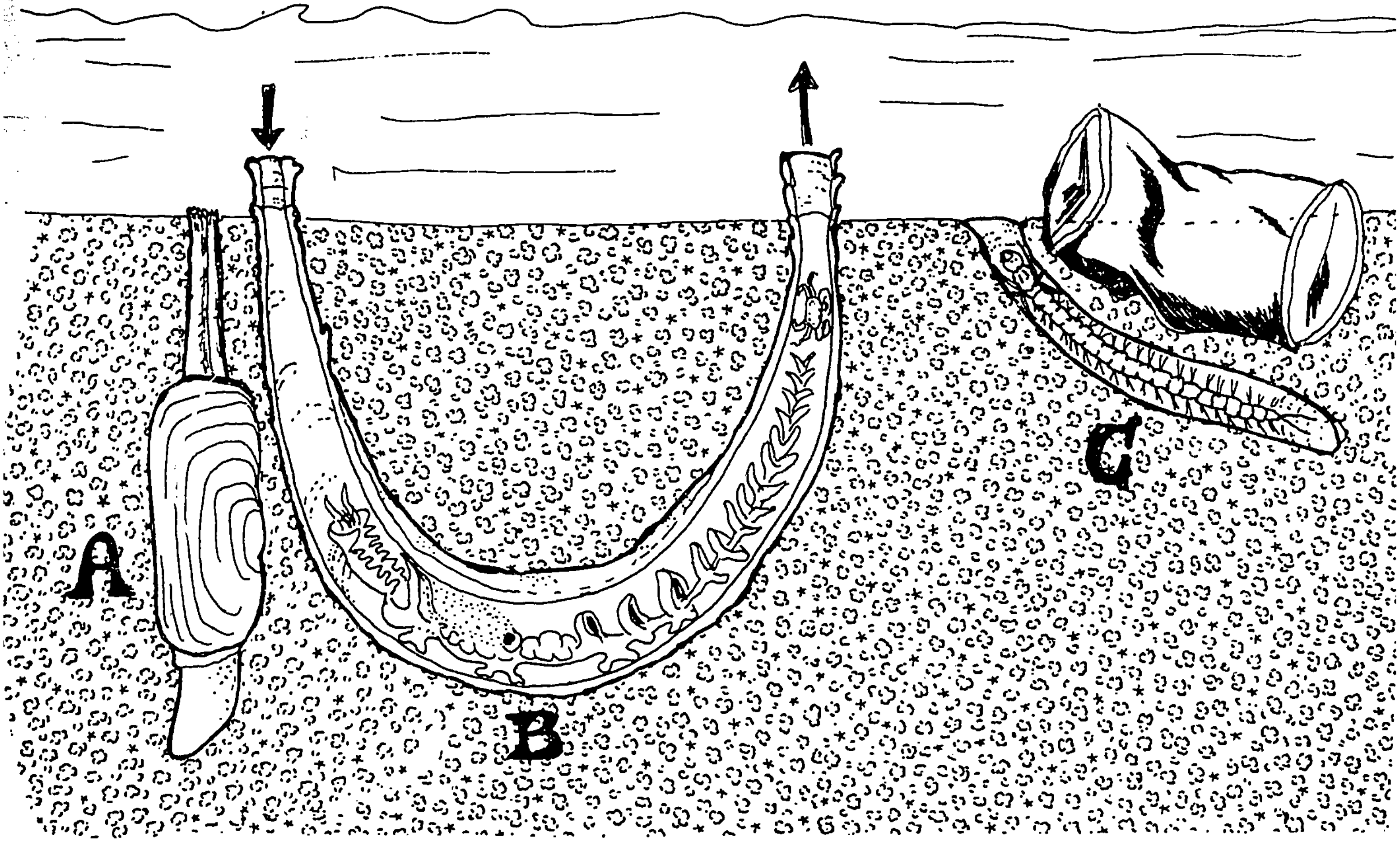
Crabs with fewer gills and a larger body volume to gill volume are better adapted to tolerate long periods of exposure than are those with many gills and a small ratio of body to gill volume. In addition, semi-terrestrial crabs have modifications for holding water in the gill chambers to allow them to tolerate terrestrial habitats. Another adaptation occurs in sand and mud flat animals which burrow for protection. They face the problem of obtaining oxygen as water in sediment usually has no available oxygen. Thus, clams have evolved long siphons which extend to the surface. Worms build tubes through which they create currents carrying oxygenated water. Both types of animals must "hold their breath" or close up during periods of low tide. (See figure 4).

Salt Marsh

Higher plants also illustrate adaptations to intertidal existence. The flora of North Carolina's salt marshes provide useful examples. For these plants, salt is the most obvious problem to living in the sea. Relatively few higher plants have solved this problem as there are only about 30 species that can live in sea water, but those that have solved the problem are often important producers of organic matter production in the coastal zone. The most striking feature of salt marshes is the zonation of plant species at different distances from sea water. The general pattern of this zonation is illustrated in Figure 5. This zonation reflects the tolerance of each species to inundation with sea water, i.e. those that live closest to the sea have evolved the best mechanisms for tolerating frequent sea water immersion, those that live closest to land have less effective



IGURE 3. GIL REDUCTION RATIO IN CRABS FROM TERRISTRIAL TO MARINE SPECIES (AFTER PEARSE) 1. Which crab is adapted to more exposure to air? 2. Which crab digs the deepest burrow? 3. Which crab swims the best?



A. RAZOR CLAM (Tagelus) SHOWING LONG SIPHONS AND FOOT FOR BURROWING.

B. PARCHMENT WORM (Chaetopterus) WITH BODY MODIFICATION FOR CREATING A CURRENT IN AND OUT OF THE U-SHAPED TUBE. NOTE THE COMMENSAL CRAB.

C. BLOOD WORM (Glycera) CREATING A CURRENT BY WAVING ITS FLESHY APPENDAGES (Parapodia)

IGURE 4. SAND FLAT ADAPTATIONS.

mechanisms. The best known of these adaptations is the presence of "salt excreting glands" in the salt marsh cord grass Spartina alterniflora. This plant usually occurs in areas flooded by water with a higher salt content than is found in its cells. Normally, in such a situation, water from inside the plant would tend to move outside by osmosis and the plant would die. Spartina alterniflora, however, has developed special "salt glands" on its leaves that help it to excrete excess salt and control the water content of its cells. This ability to live in salt water permits the establishment and expansion of this species into estuarine salt marshes.

Spartina alterniflora also has adaptations to allow its growth in oxygen-poor marsh muds. Roots demand oxygen for growth, but because little oxygen is found deeper than a few centimeters in the mud, the species has developed air passages in the stem to permit the diffusion of oxygen from the plant surface to the root system. Large gas spaces are also found in the roots.

Animals inhabiting the salt marsh exhibit adaptations similiar to those inhabiting the mud flat because of alternating wet and dry tidal periods. In fact, many of the same animals live in both areas, e.g. fiddler crabs, worms, and clams. Three species of snails, common to the salt marsh, occupy different zones due to their tolerance to submersion. The black mud snail (Ilyanassa) crawls on the muddy floor of marsh pools, scavenging detritus with particularly sensitive chemo-receptors. (If you go to the marsh, drop some dead fish on the mud during the lowering tide and watch the mud snails converge on it). The small brown snail (Melampus), an air-breather, inhabits drier areas of the salt marsh exclusively grazing on plant detritus. Marsh periwinkles (Littorina), also air breathers, are among the most easily observed snails as they migrate up and down blades of salt marsh cordgrass grazing on attached algae. Melampus snails, periwinkles, and mud snails all possess opercula or "trap doors", to prevent drying out and also provide protection.

Thus organisms have an array of adaptations enabling them to tolerate the rigorous conditions of the intertidal zone. These adaptations involve behavior (beach and marsh animals), morphology (intertidal crabs), and physiology (salt marsh plants).

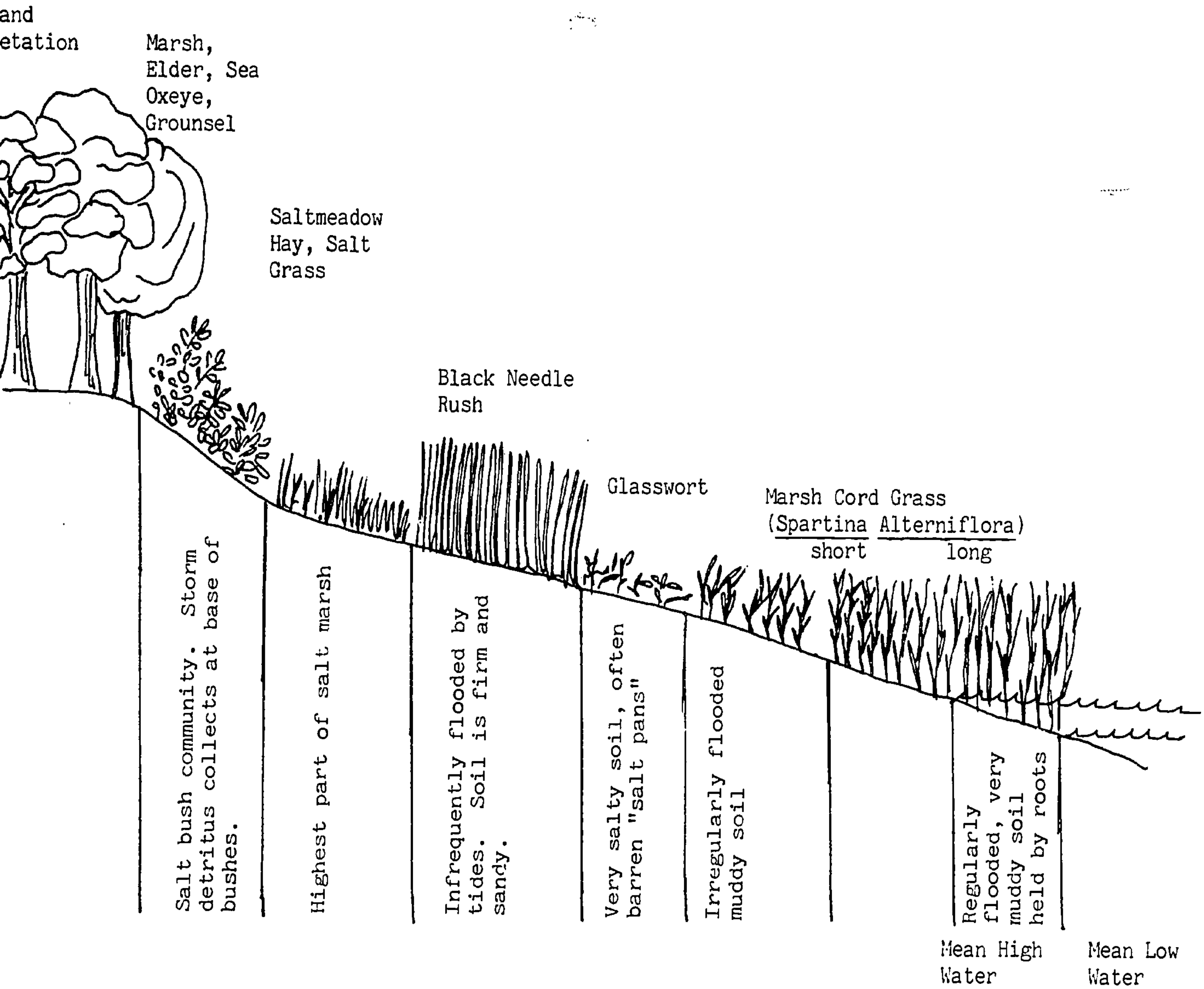


FIGURE 5: Idealized salt marsh zonation typical of North Carolina

b. Vocabulary

Crustaceans - a class of the Arthropods; these organisms consist of common marine animals, including shrimp, crabs, water fleas, barnacles, etc.

Desiccation - the tendency to dry up when removed from water for a period of time; this factor is extremely important for sea-dwelling crustaceans (ghost crabs, sand fleas, etc.) which must return to the ocean for water; these animals need water to moisten the gill-like lungs which they possess.

Flora - plant population of a given area; predominant marine flora are floating phytoplankton, attached nearshore algae, and marine grasses.

Oxygen Depletion - a state in which the normal amount of oxygen has been lost in a body of water by heat, respiration, decay,

Siphons - tube-like structures of many clams and snails which take water into their body where it is filtered for food and oxygen, and also pass out water with excretements.

G. Things To Do

What Shell is This?

Objective: To identify names of seashells by playing an identification game.

Teacher Preparation: Collect pictures of common North Carolina shells (obtain the pamphlet Sea Shells Common to North Carolina from the Sea Grant Office, NC State University, Raleigh, NC) or have students bring shells to class. Identify the shells and tell a little about each shell as you pass it around the class. Perhaps the students can pick a shell and do a short verbal report on it - where it lives, how it moves, what it eats. There are many shell books which hold fascinating information.

Procedure:

1. Arrange all the shells or pictures on a table easily viewed by all the students. Write the shells' names on index cards and have each child pronounce it as they look at the shells.

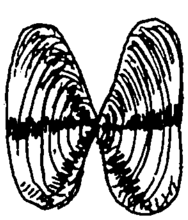
2. Review the shells. Hold up the index card, read the name, and have a child identify the shell, pronounce the name, and place the index card next to it.

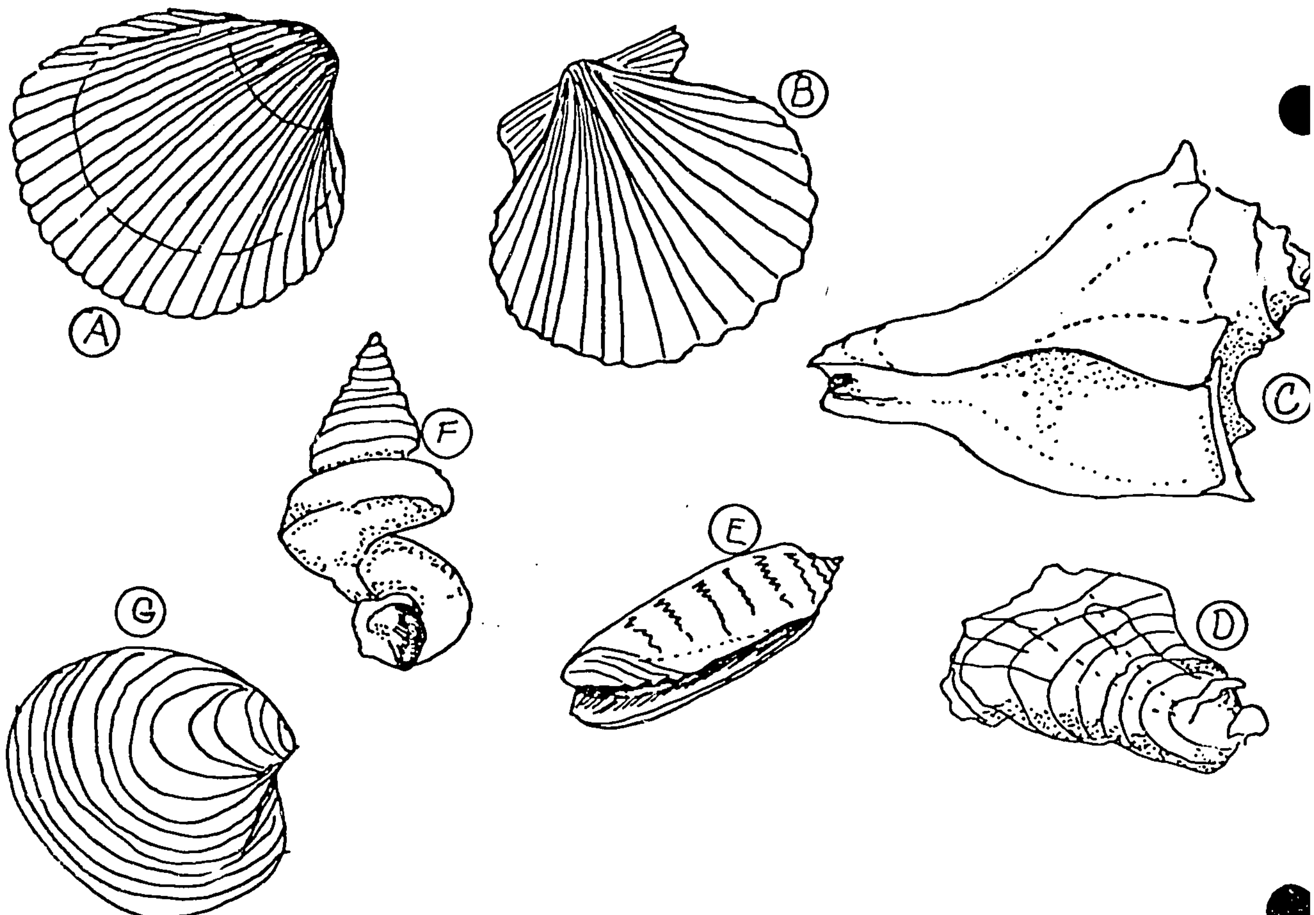
3. Divide the group into teams. Award one point for each correct identification. If a child fails to identify a shell correctly, the next child on the opposing team is given a chance. The team with the most points wins the game.

4. To emphasize the name, you could repeat the game without using the index card and have the child simply name the shell.

5. A paper and pen quiz can be given. Number each shell and have the students number their paper to correspond, filling in the names of the shells.

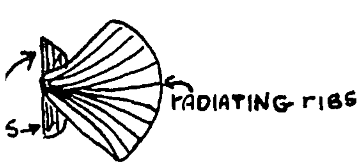
Discussion: Now that the students are familiar with the shells, have them point out things in common among the shells. For example, some belong to animals having only one shell (snails) while others have two shells (clam-type), all have growth rings, some have hinges in different places, some have decorations. With these observations, try to devise a key to identification. A sample is given below.

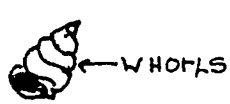




All Shells

- clam-like
  - radiating ribs
    - ears extension (B) Scallop
    - no ears (A) Cockle
  - nonradiating ribs
    - even rounded shape (G) Clam
    - very irregular shape (D) Oyster
- snail-like
  - whorls not connected (F) Wormshell
  - whorls connected
    - wide cavity for animal, knobs (C) Lightning Whelk
    - narrow cavity for animal, no knobs (E) Olive Shell





b. Things to Do

Clams and Scallops

Objective: To learn more about clams and scallops through models

Teacher Preparation:

1. Both the sheets referring to parts of a clam and the scallop are useful for disecting guides, to show the relationships between shell and internal organs, and also just to expose students to marine animals. Both animals are edible seafoods and students may have eaten clams either on half shell or in chowder and they may have eaten the large muscle of the scallop. For young children, these models can be simply cut out and transformed into a puppet by placing an accordion folded slip of paper in the middle. (Virginia Institute of Marine Science, Gloucester Point, Virginia published a story called Little Oyster which could be modified for either of these examples.)

2. Xerox carefully the back and front of the sheets on a single page being sure that the diagrams line up with one another as they do in the materials. Scissors, staplers, crayons are needed to color and put models together.

3. Order of putting together is shell outside; mantle, middle, and viscera inside.

Procedure: Key to Letters printed on the clam:

A. Right valve
B. Growth lines (like tree rings)
C. Inside right valve
D. Muscle attachment
E. Ligament holding two valves together
F. Mantle tissue which secretes shell
G. Siphons which bring water into shells for respiration and feeding.
H. Muscles
I. Foot which digs and moves clam
J. Gills which filter food particles and respire
K. Heart
L. Mouth
M. Stomach
N. Intestine
O. Viscera (gonads, kidneys, liver)

Key to Letters printed on scallop:

A. Left valve: top valve as you can see attached organisms.
B. Right valve. (If you hold scallop together with notched "ear" up, then valve to left is left valve)

C. Inside valve shell
D. Attachment muscle scar
E. Mantle tissue which secretes shell
F. Ligament holding two valves together
G. Sensory tentacles and blue eyes sensitive to light
H. Muscle
I. Gills which filter food particles and respire
J. Mouth
K. Vestigal foot, only used in very young scallops
L. Intestines
M. Heart
N. Reproductive organs -- gonads for both male and female

Discussion: (Both clams and scallops can be kept in a marine aquarium. Most of the following questions are best answered by observations, but the models help.)

Questions for Clam:

1. What is functions of clam's foot? (Mobility, digging)

2. How does a clam feed and breathe burrowed? (Through siphons extending to surface)

3. What part of a clam do we eat? (Whole soft body, fresh, steamed, or cooked in soups)

4. What eats clams besides people? (Starfish, stingrays, crabs, carnivorous snails)

Questions for Scallop

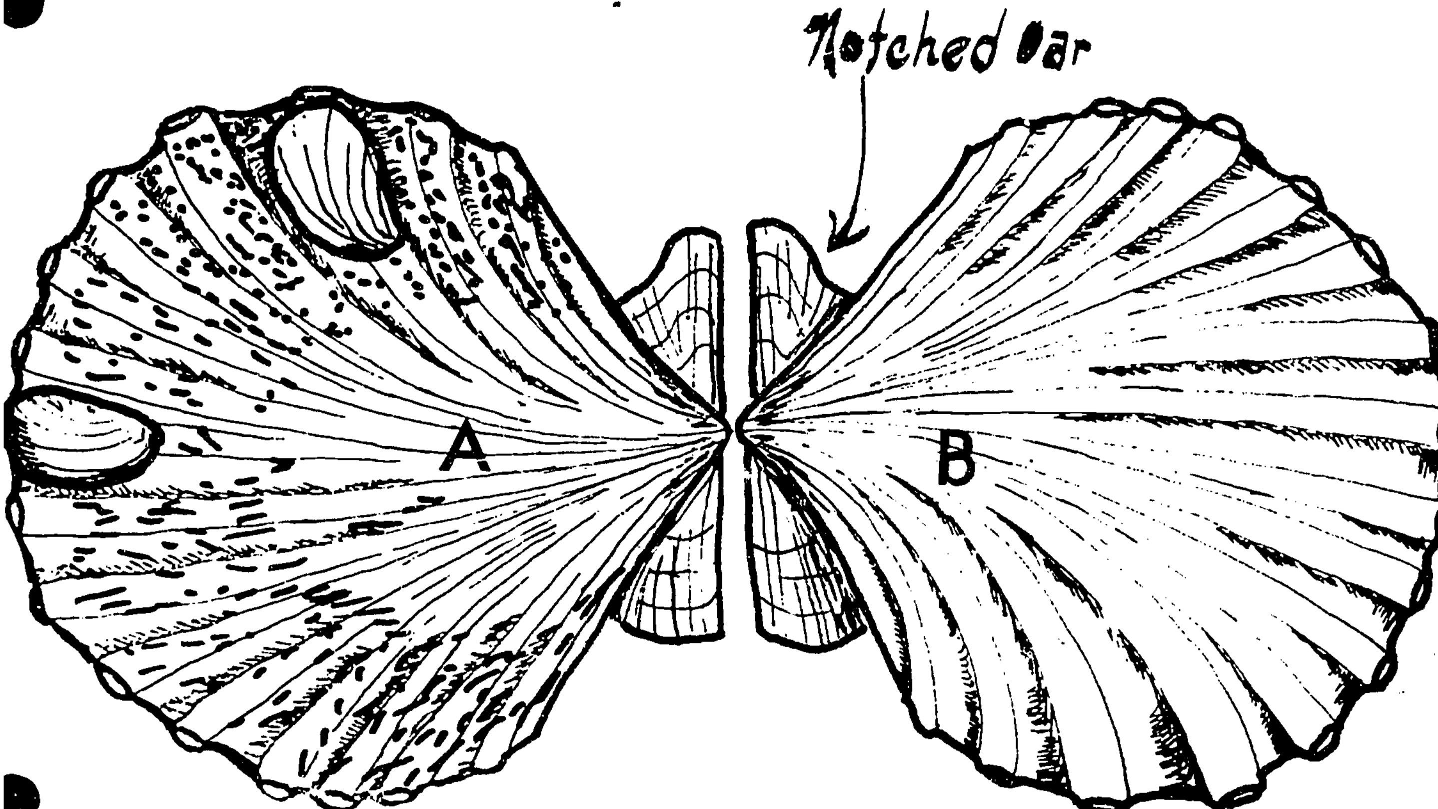
1. How does a scallop move? (Jet propulsion rapidly opening and closing its valves)

2. How can you determine top side of scallop? (Note growth of algae and fouling organisms on top side)

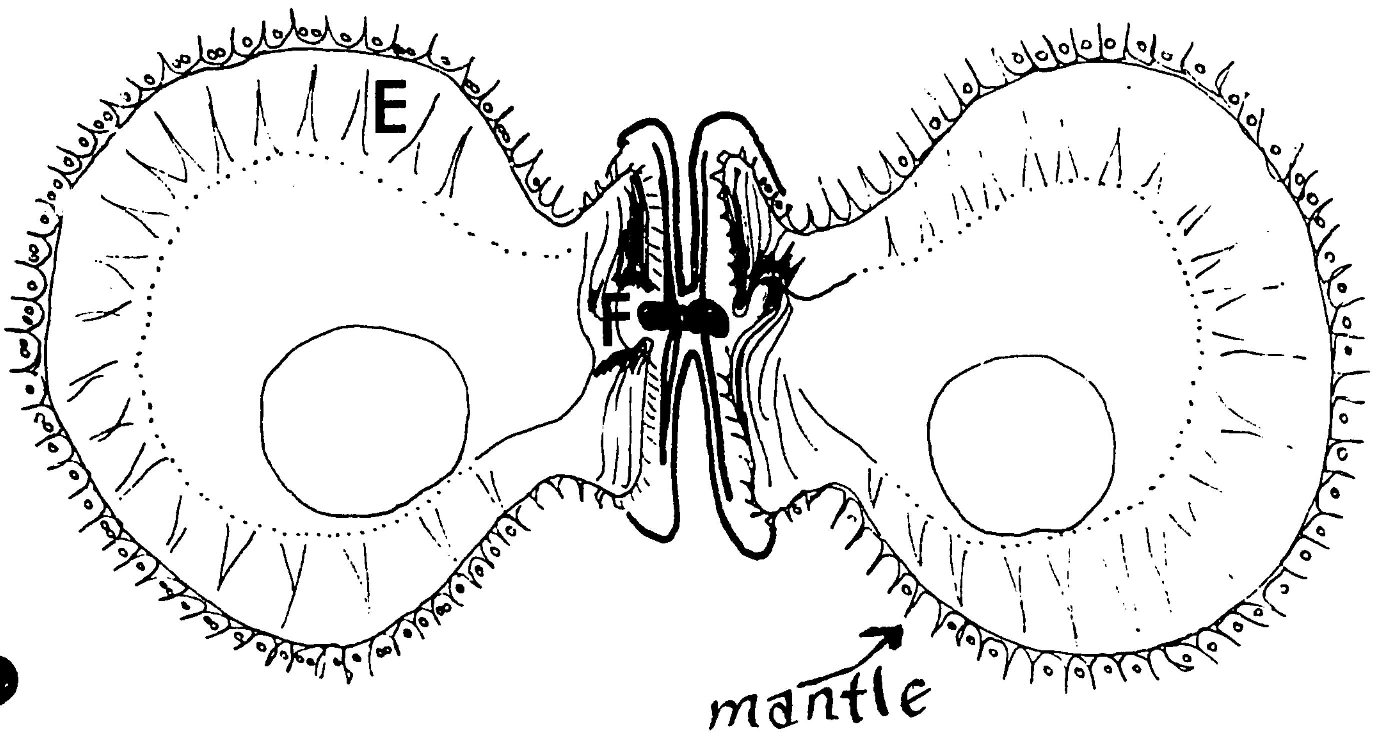
3. What part of a scallop do Americans eat? (Only muscle, Europeans eat whole animals)

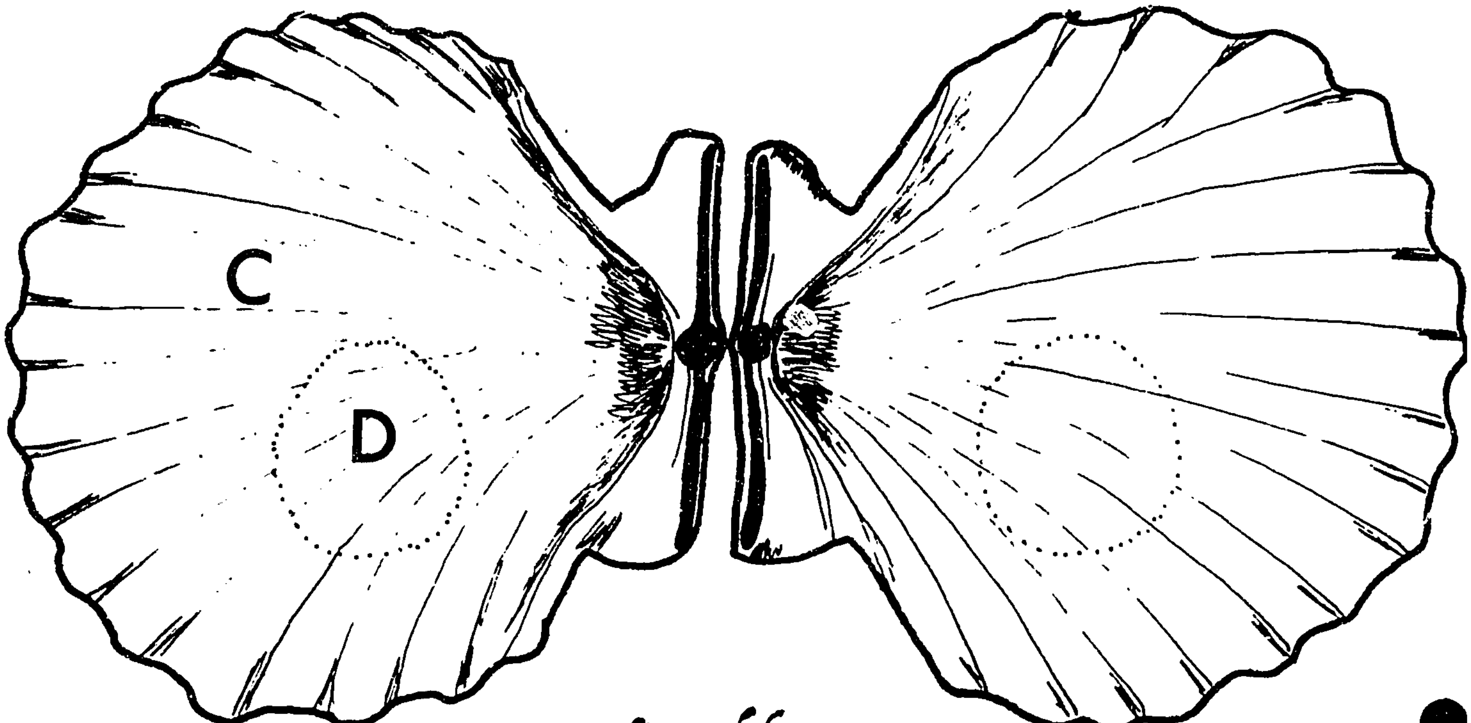
4. W[illegible] does a scallop eat? (Plankton)

5. Wr[illegible] eats a scallop? (Starfish, carnivorous snails, stingrays, some fish)

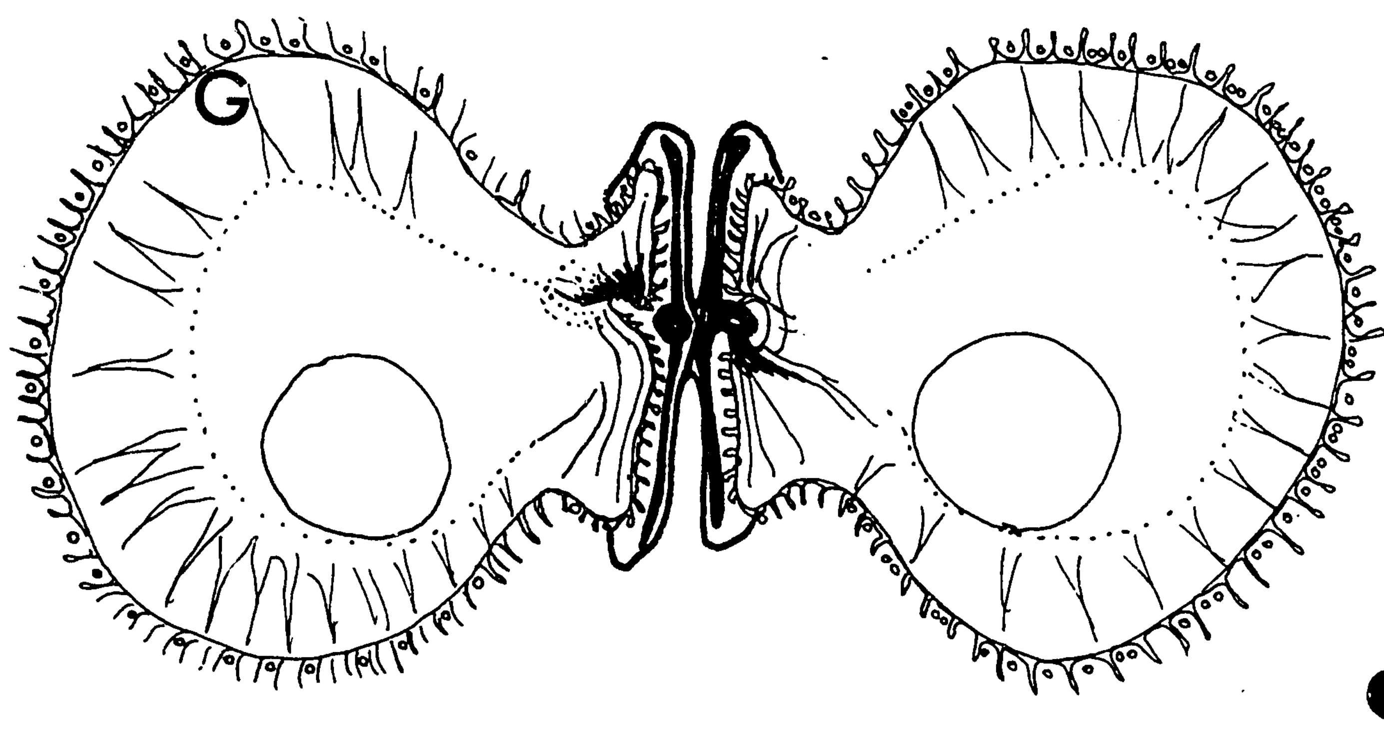


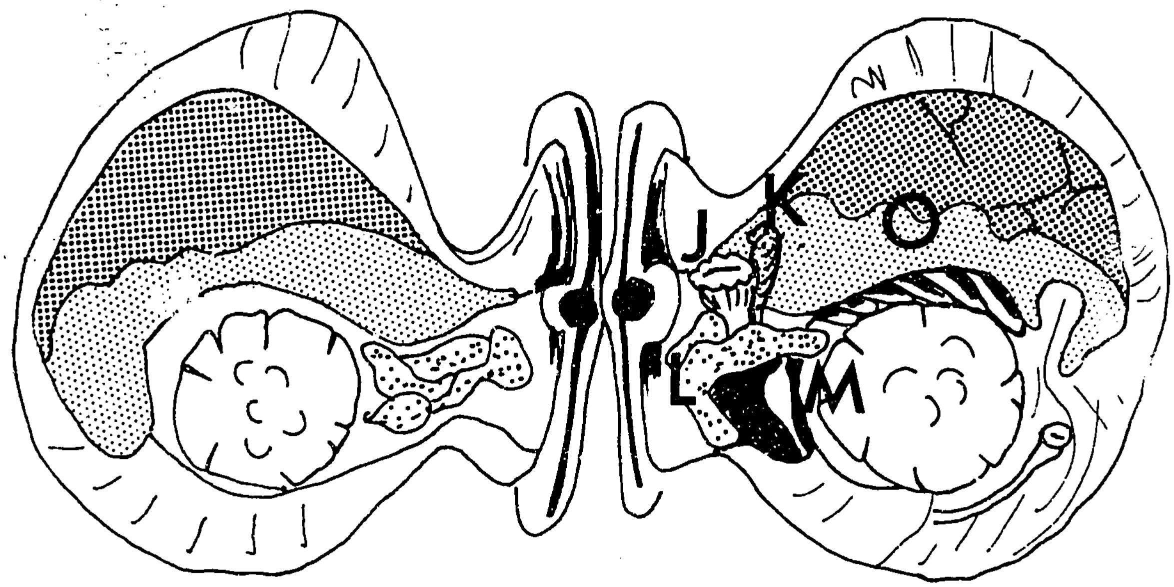
Scallop



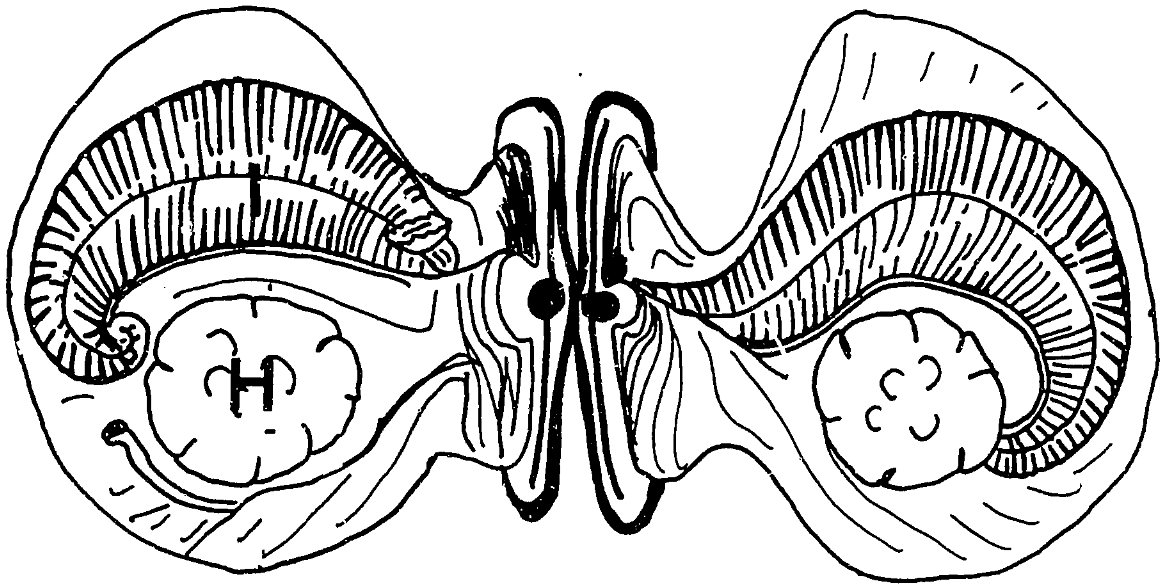


scallop





internal organs



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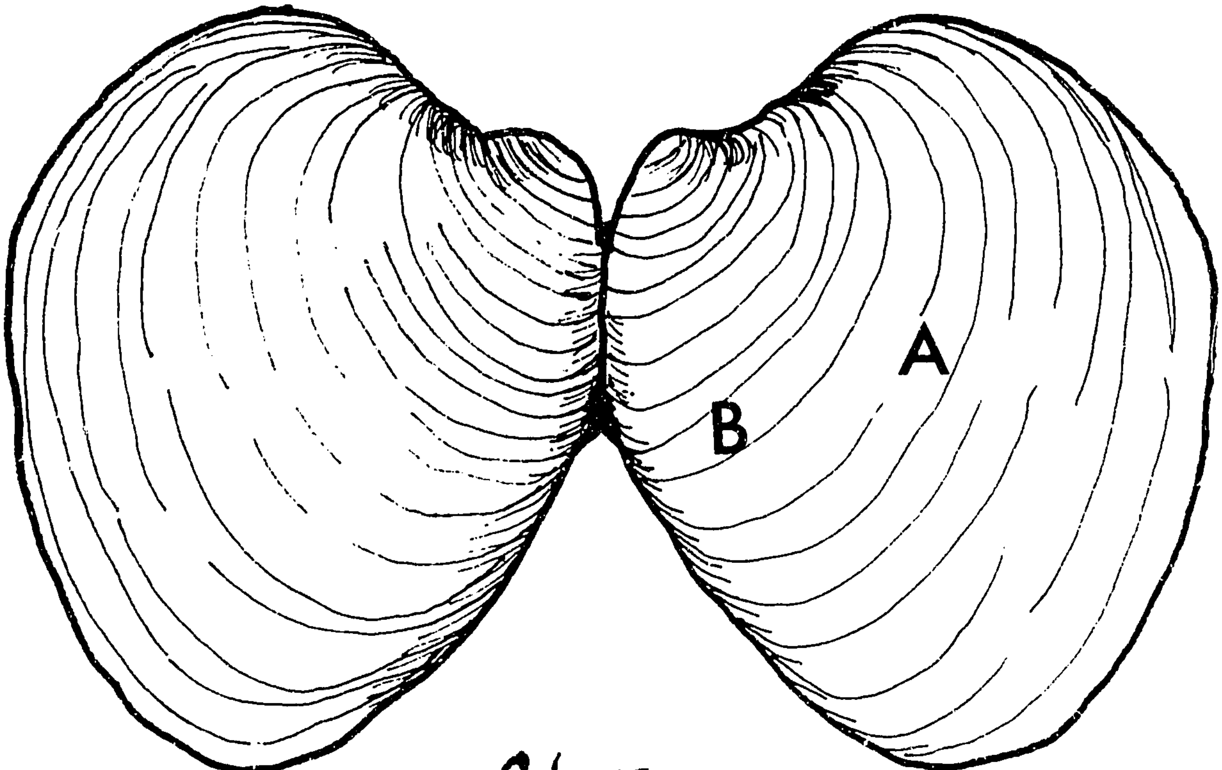
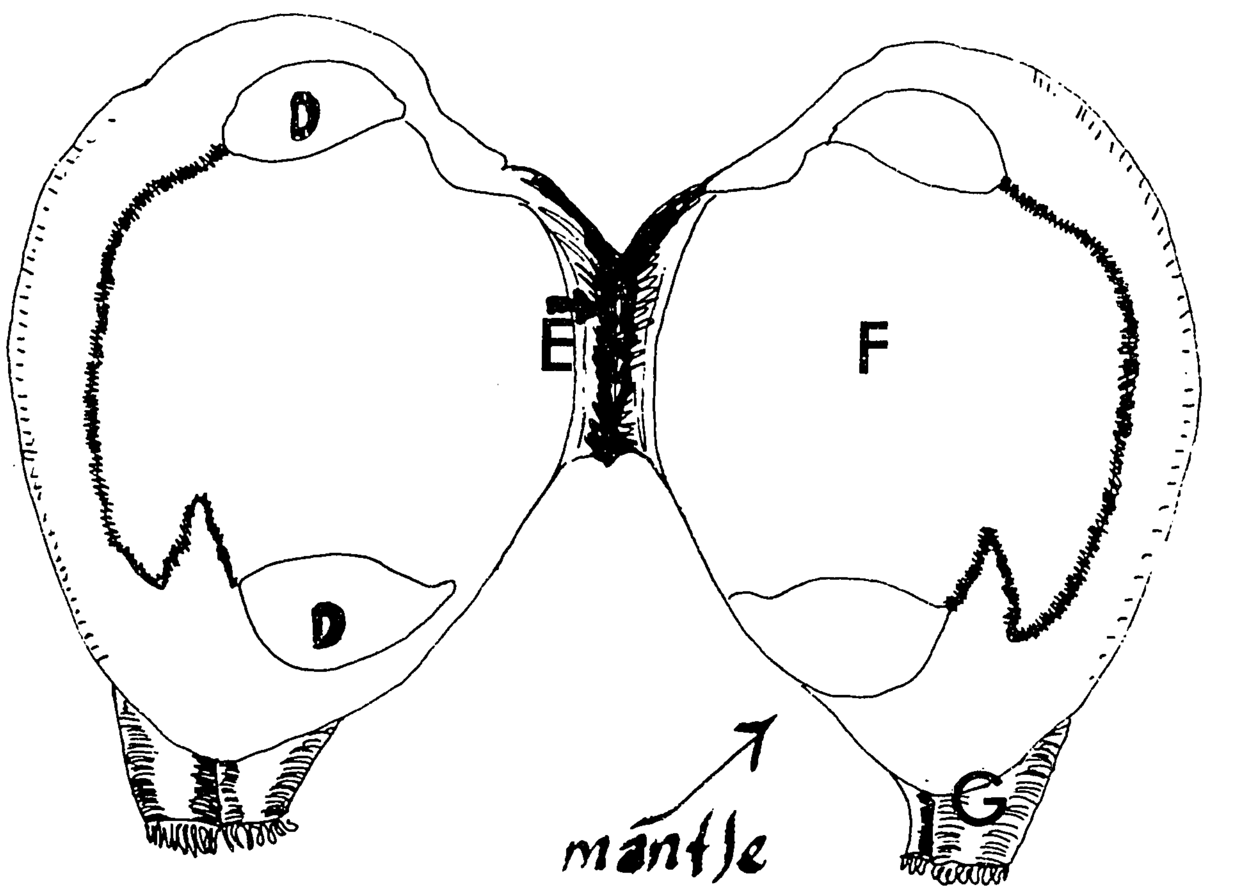
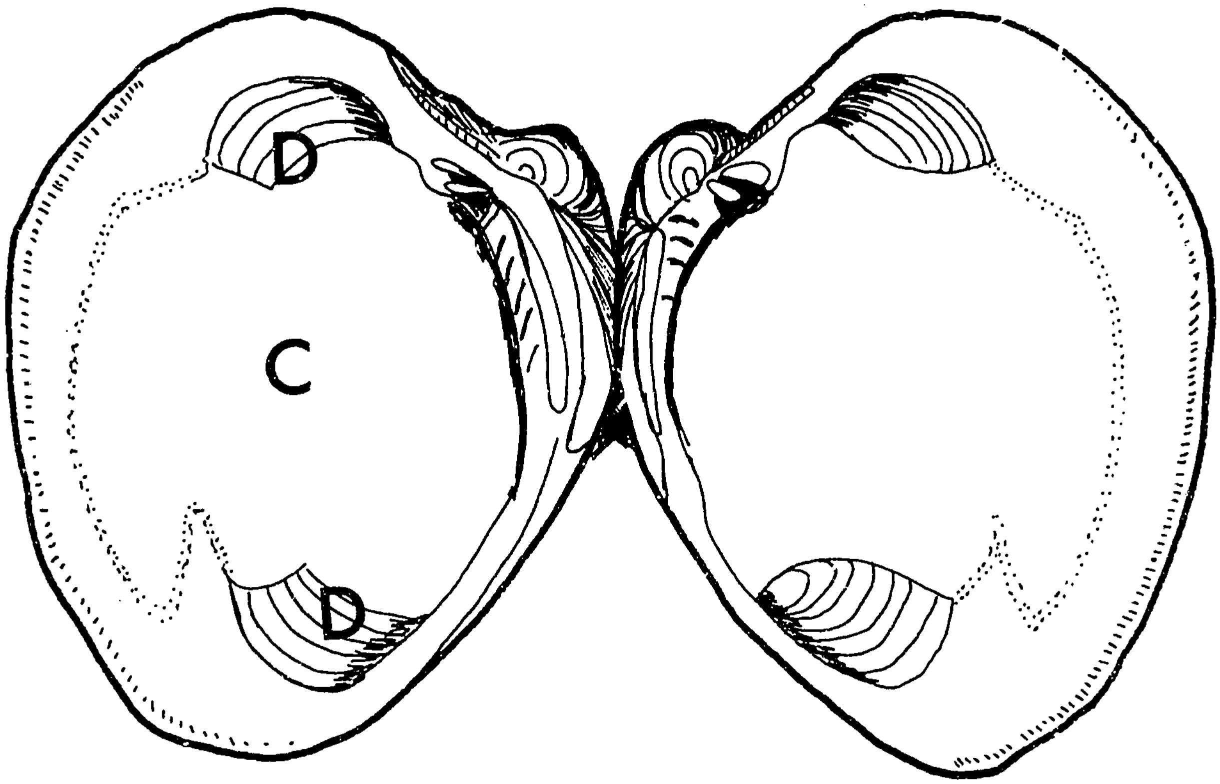


Clam

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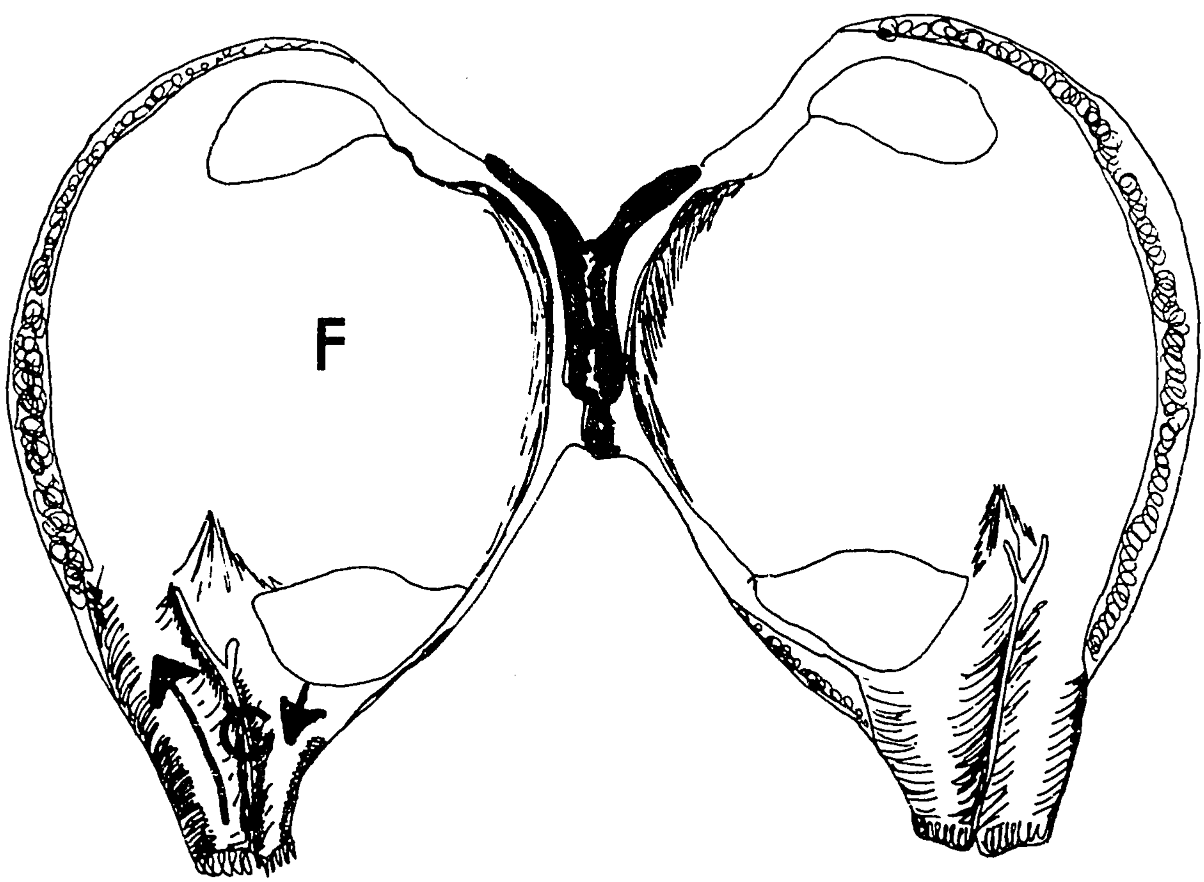
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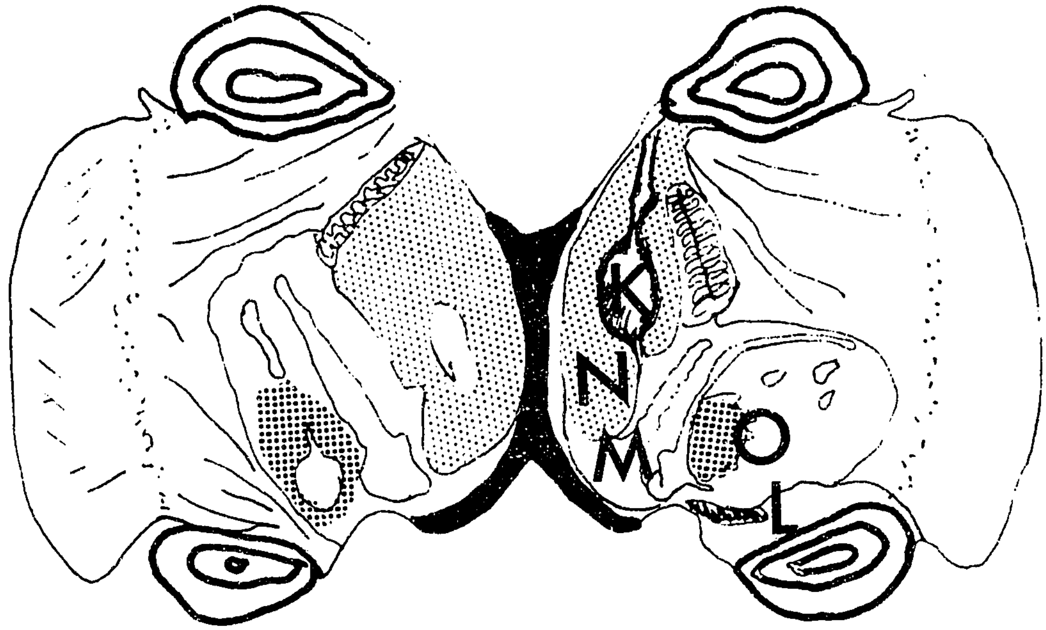
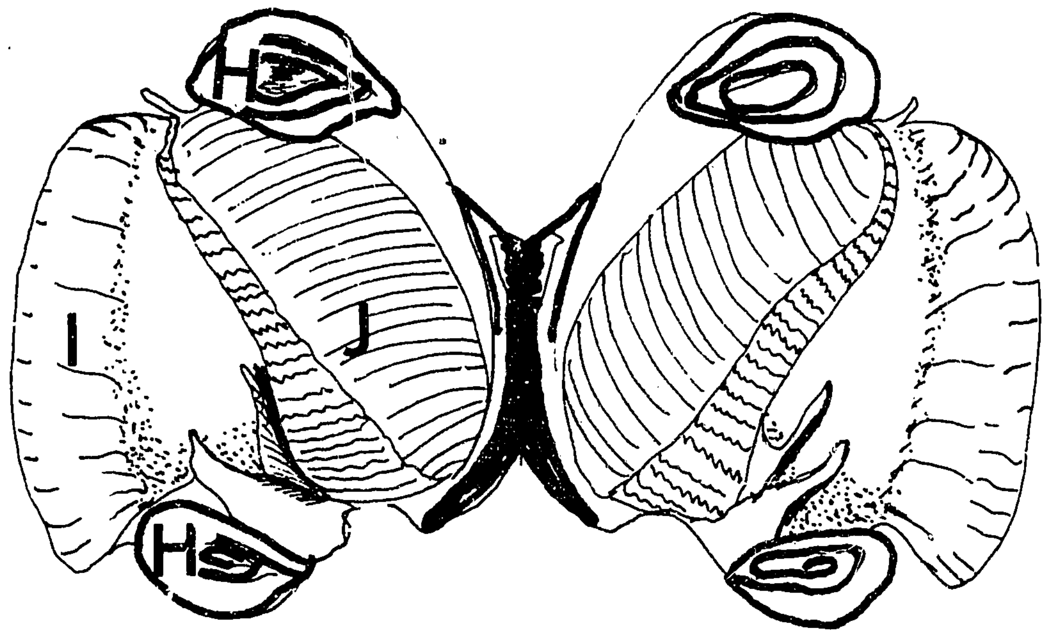


Clam
internal organs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b. Things to Do

Spineless Rummy
A Card Game

Objective: To familiarize students with the characteristics of invertebrate phyla.

Teacher Preparation: Cut out cards on the following pages, (xerox extras) and attach on cardboard or construction paper. You will need 24 cards for each set.

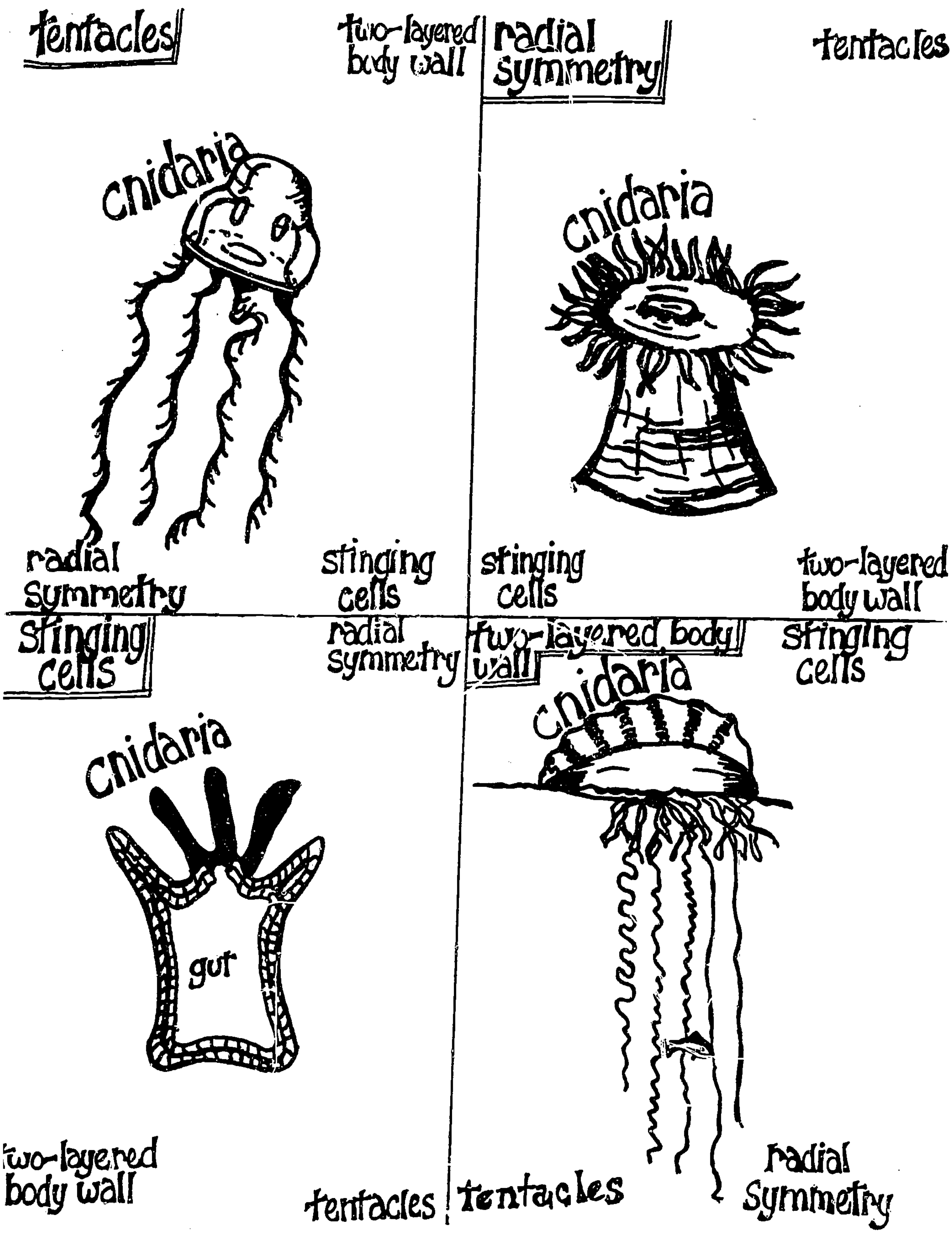
Procedure:

1. Two to five players

2. Deal out all cards

3. There are 4 characteristic cards for each of six marine invertebrate phyla. A player's goal is to get as many of these sets as he can. When he has three from one group he may lay them down. He can add others to it as he gets them. A complete set of 4 cards is 10 points and 3 cards is 5 points. Also, a player can get one point for every card he can play on someone else's stack. Such as, if player 1 lays down three PORIFERA cards and player 3 gets one, he may lay it down to match player one's stack. If a player is caught with any cards in his hand when game ends, he must take off one point for each.

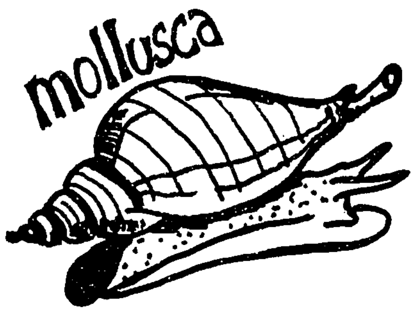
   Play proceeds in a clockwise direction with player one drawing a card from player two's hand, then player two from player three and so on. Game continues in this manner until a player is able to lay down all of his cards. At this point no other player may lay down cards. During play, a player may lay cards only when he has 3 from a phyla or one to match someone else's set.



tentacles
two-layered body wall
cnidaria
radial symmetry
stinging cells
radial symmetry
tentacles
cnidaria
stinging cells
two-layered body wall
stinging cells
radial symmetry
cnidaria
gut
two-layered body wall
tentacles
two-layered body wall
stinging cells
cnidaria
tentacles
radial symmetry

bilateral symmetry

foot



mantle

shell

shell

mantle

foot

bilateral symmetry

mantle

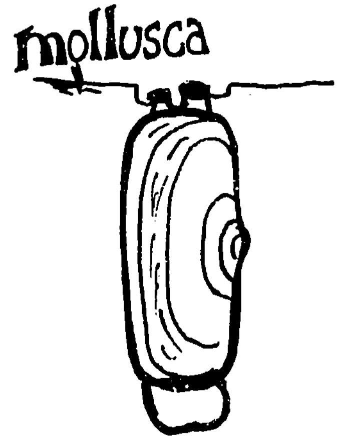
bilateral symmetry

shell

foot

foot

shell

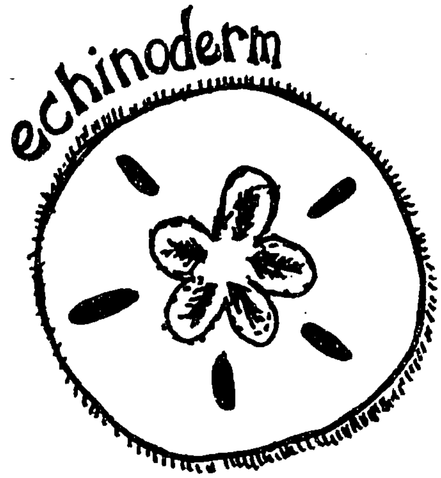


bilateral symmetry

mantle

Spiny

5-divisions



radial symmetry

tube feet

radial symmetry

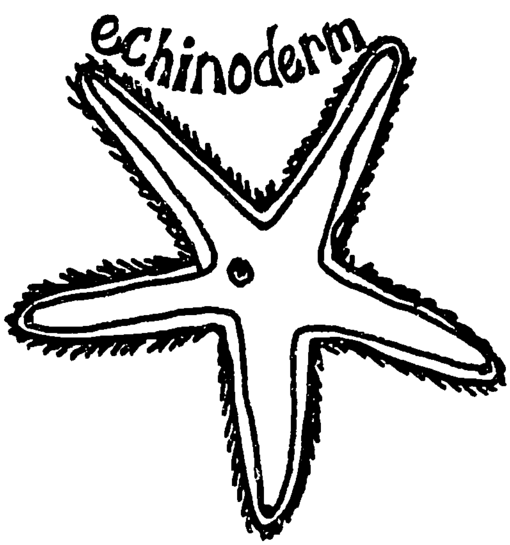
spiny

tube feet

5-divisions

tube feet

radial symmetry

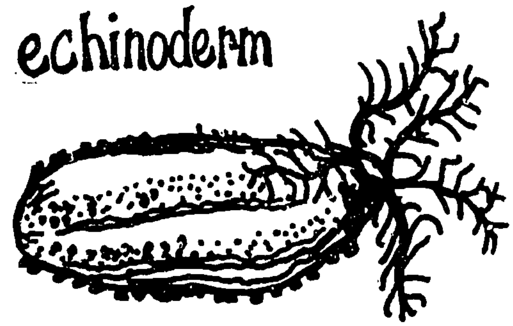


5-divisions

Spiny

5-divisions

tube feet



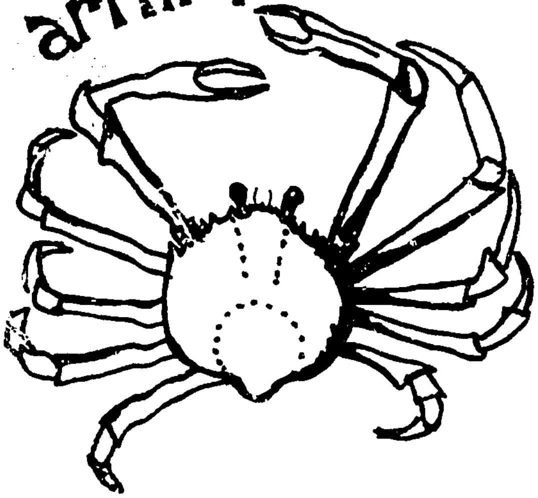
spiny

radial Symmetry

jointed legs

bilateral symmetry

arthropoda



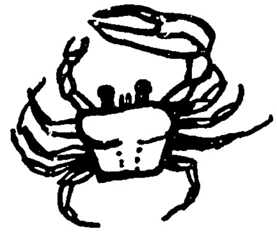
exoskeleton

antennae sense

exoskeleton

jointed legs

arthropoda



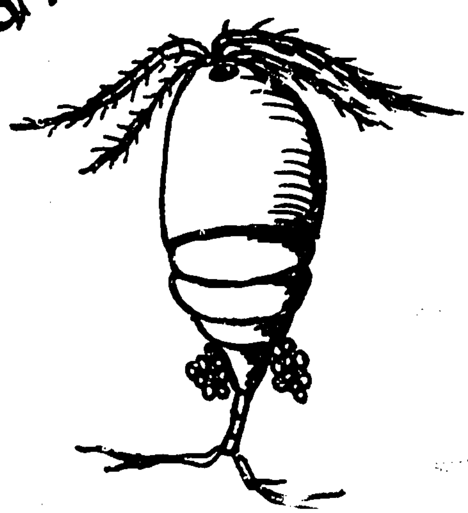
antennae sense

bilateral symmetry

antennae sense

exoskeleton

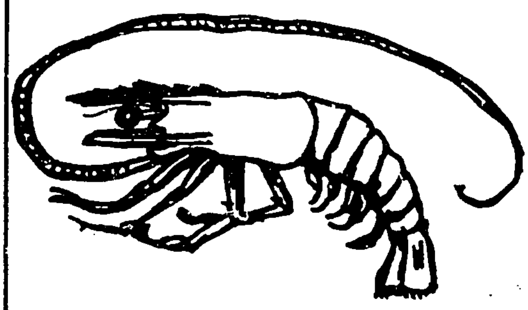
arthropoda



bilateral symmetry

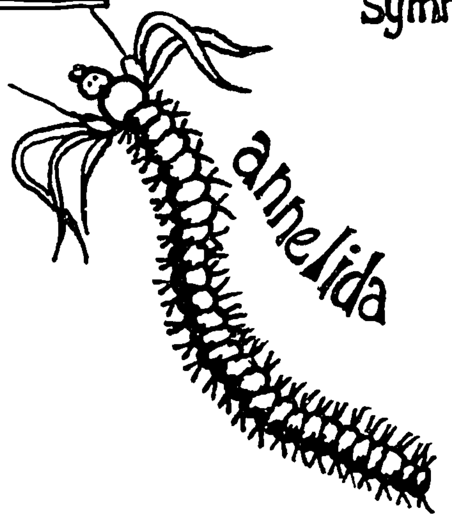
antennae sense

arthropoda



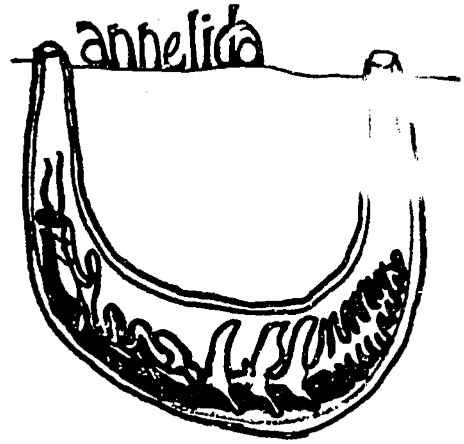
head

bilateral symmetry



segmented

head



segmented

parapodia

parapodia

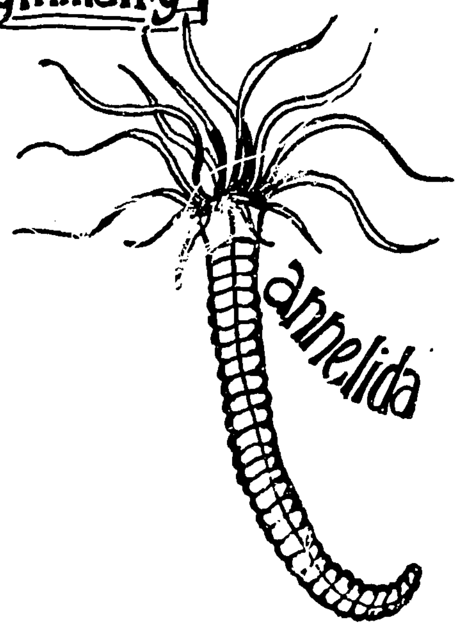
bilateral symmetry

parapodia

segmented

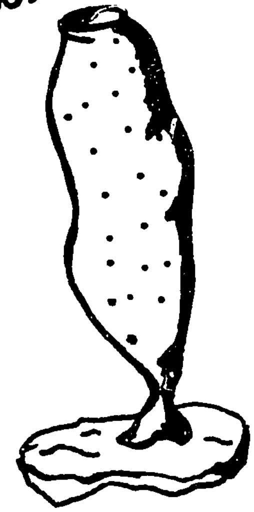
bilateral symmetry

parapodia



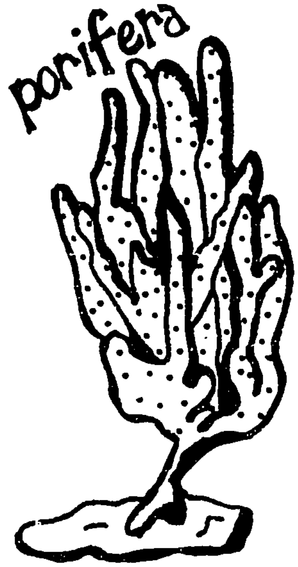
sessile asymmetrical

porifera



porous filter feeder

porifera

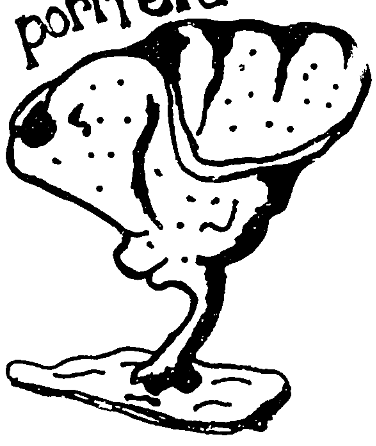


filter feeder porous

asymmetrical sessile

asymmetrical porous

porifera



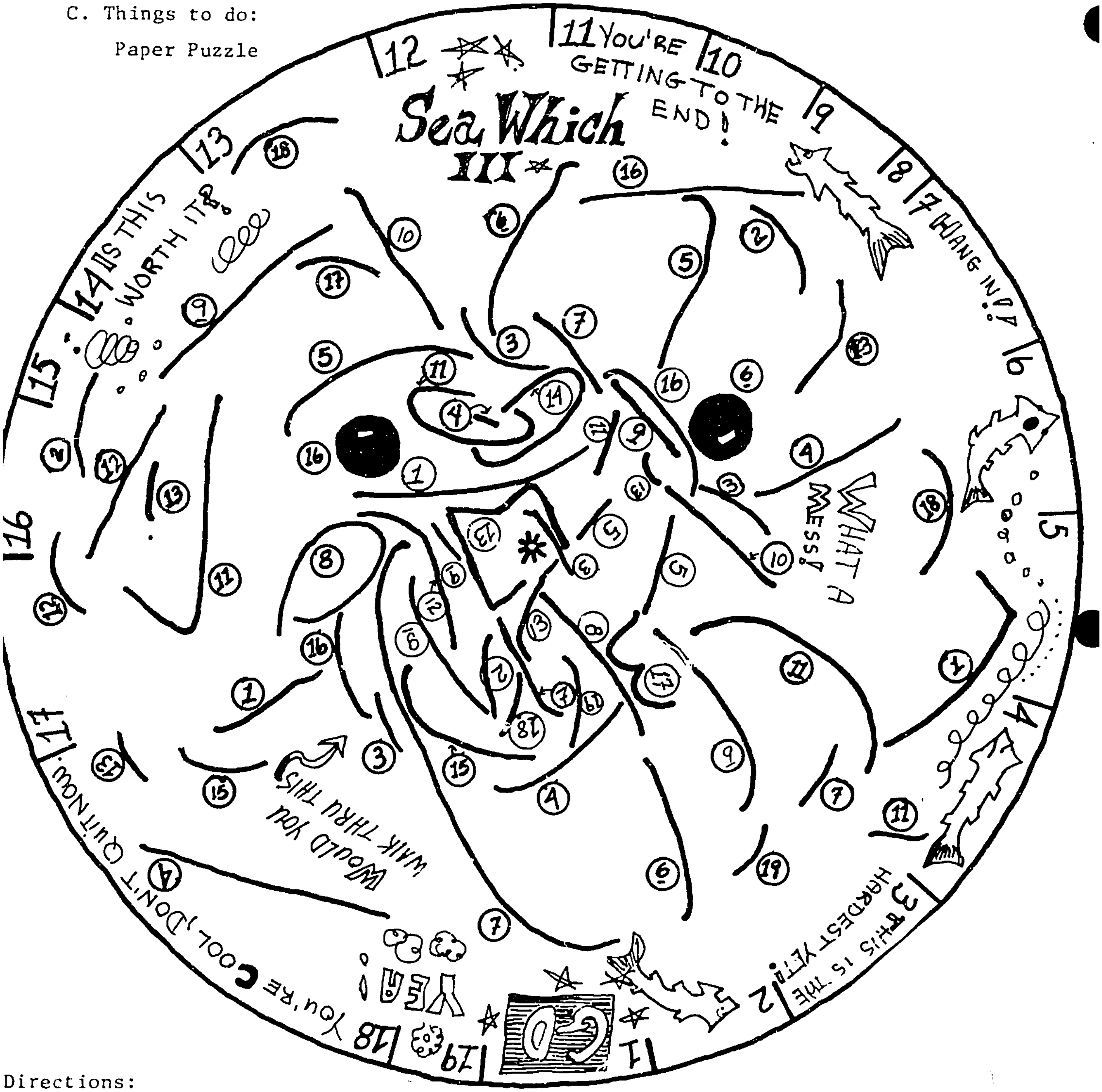
filter feeder sessile

porifera

Concept 2

C. Things to do:

Paper Puzzle



Directions:

1. Cut out circle.

d. Resources to Use

References

Porter, H.J. and Jim Tyler. 1976. Sea Shells Common to NC. Division of Commercial and Sports Fisheries, NC Department of Natural and Economic Resources, Morehead City, NC 28557. $0.50

Shepherd, Elizabeth. 1972. Tracks Between the Tides. Lothrop, Lee and Shepard Co., New York. $4.95

Gibbons, Ewell. Stalking the Blue-Eyed Scallop. David McKay Co., NY $2.95

Amos, W.H. 1966. Life of the Seashore. McGraw-Hill Book Co., NY $5.95 (excellent general reference)

The Mollusc and His Home by Wendy Beard (Poster). Write to:
Wetlands Institute
Stone Harbor, NJ

Stephen, William M. and Peggy Stephens. 1969. Hermit Crab, Lives in a Shell. Holiday House, NY

Holling, C. 1957. Pagoo. Houghton Mifflin Co., Boston. $7.95 (excellent 4-6 grade story of a hermit crab - good information)

Evans, S.M. and J.M. Hardy. 1970. Seashore and Sand Dunes. Heinemann Educational Books, 5 S. Union Street, Laurence, MA 01843. $2.50 good activities for biology to demonstrate physiology behavior.

Project Coast Material (see Appendix)
- 106 Teacher's Guide to Pagoo $5.10
- 101 Animals with Shells $0.50
- 109 The Not-so-common Oyster $1.70
- 111 The Horseshoe Crab $1.10
- 113 Animal Behavior - Mud Snail Responses $0.50
- 201 The Blue Crab $1.15
- 224 Observing Starfish - Water Vascular System $1.60
- 227 A Comparative Study of Clam and Squid $1.35

Poster: Superintendent of Documents
Government Printing Office
Washington, D.C. 20402
Mollusks and Crustaceans of the Coastal U.S. $3.20

Unit III

Concept 4. Plankton organisms are tiny, but are important to coastal zone ecology.

a. Background Reading

Plankton are small organisms that inhabit aquatic environments. Their small size keeps them from being obvious to casual visitors to the sea coast, but once seen, their strange shapes and adaptations are facinating and their role in the productivity and population dynamics of coastal zone ecosystems is so important that some mention of them is essential to any effort in marine education.

Plankton are drifters, plants and animals that move passively or very feebly with currents in the sea. Derived from the Greek word, "plantos", meaning wanderer, plankton vary in size, but are generally small. Plant plankton (phytoplankton) is often dominated by diatoms less than five microns in diameter (a micron is one millionth of a meter). Two common characteristics of plankton are their inability to control their movements against currents, and their habitat, typically in the upper regions of the water column. Plankton are divided into phytoplankton (plants) and zooplankton (animals). Further divisions are the holoplankton (permanent members of the plankton community) and meroplankton (temporary members such as larval stages of benthic invertebrates and fish).

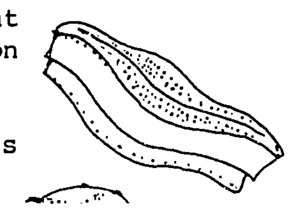
All of these organisms share certain general features: they are all small; they have flotation devices; most are transparent; and many have long body wall extensions that increase the surface to volume ratios of their bodies. These features hold true for both marine and freshwater plankton and can thus be demonstrated without access to ocean collections.

The importance of plankton in marine ecology involves both quantitative and qualitative features. Quantitatively, plankton are one increasingly important part of marine food chains as one moves offshore from the seacoast. Most food chains begin with plant photosynthesis in which sunlight and inorganic nutrients are converted into the organic matter of plant tissues. In the open sea, only the floating phytoplankton occur in the sunlit zone, thus phytoplankton are the major unit of primary production for the oceanic food chain. In shallow waters, however, sunlight reaches all the way to the sea floor so attached algae and rooted higher plants (eel grass and salt marsh species) become important contributors to food chain primary production. Qualitatively, plankton is important because of its nutritional role in marine food chains and its role in the reproduction distribution of marine organisms. There is evidence that phytoplankton are more easily digested, and thus more nutritious per unit weight.

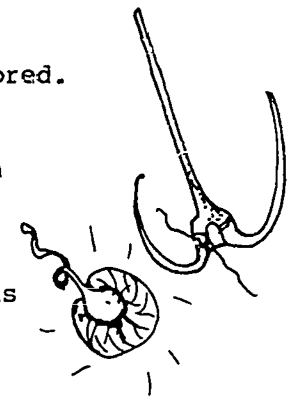
Plankton are also quantitatively important to nearshore ecology because a large fraction of the nearshore zooplankton community consists of larval stages of important nekton and benthic organisms. Thus survival and repopulation of many commercially important marine animals such as fish, shrimp, crabs, and oysters depend upon the success of the planktonic larval stage of their life cycle (meroplankton). Approximately 80% of all the sport and commercial catch on the east coast of the United States is of animals who spend some portion of their life cycle in nearshore and estuarine areas. The vast majority of these spend much of their nearshore life as meroplankton. These meroplanktonic stages are dramatically different from adults of the same species, both in their morphology and in their requirements for survival. The existence of commercial populations of marine species depends on maintaining conditions suitable for survival of both the adults and the meroplanktonic stages that lead up to the adult stage. At the moment scientists know far more about survival requirements of adults than of their meroplankton, i.e. young. From what is known, it appears that larvae can tolerate less pollution, less food scarcity, and, in general, less exposure to abnormal or unstable environments than can adults. This unsurprising fact lends increasing practical importance to studies of larvae in the light of potential pollution due to human development of the coastal zone.

Plankton play a dual role in considerations of marine pollution. Not only are meroplankton generally more susceptible to pollution than are adults, but also plankton can absorb non degradable pollutants like metals and particles which can become concentrated through the food chain. Phytoplankton form the link in the marine food chain that change inorganic nutrients to organic material. Zooplankton and other filter-feeding animals feed on phytoplankton and in turn are eaten by larger animals. Unfortunately, toxic slowly degradable substances such as pesticides, mercury, cadmium, and polychlorinated byphenyls (PCB's) can also be incorporated into the plant cell and thus be carried up the food chain where sufficient accumulation results in death of large animals. The classic example involves DDT, a pesticide running off from farms to water, being absorbed by phytoplankton, filter-feeders, fish, and finally fish-feeding pelicans. In California, pelicans nearly were eliminated from the state as DDT in their bodies upset their reproductive success.

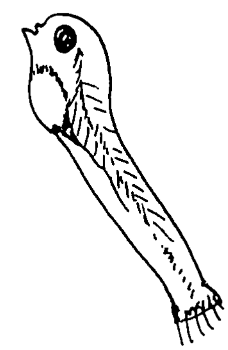
The exotic morphology of plankton makes them interesting to examine. Nearshore phytoplankton caught by normal plankton nets (cone-shaped nets of fine nylon cloth or stockings) are numerically dominated by diatoms and dinoflagellates. Diatoms are single-celled organisms with glass (silicon dioxide) sheletons made up of two valves. Some marine species are centric (circular, like a button) and some are



Dinoflagellates may be armored with plates or unarmored. Some species are luminescent while others are the causative organism of the Red Tide, an abnormal concentration of cells and their excretions that can kill fish. (Figure 6)



Phytoplankton must stay in the photic zone to survive, and even though they have little or no means of locomotion, they have evolved several adaptations to increase their buoyancy. Diatoms store oil in their cells and their specific gravity is thereby decreased. Many species have spines and cell wall extensions that increase surface area, and others link into spiral chains that increase their ability to remain within a specific mass of water.



Nearshore zooplankton caught by normal nets are usually dominated by holoplanktonic copepod crustacea although, in spring and summer, any of several types of meroplankton may dominate the catch. Other common holoplanktonic forms include the arrow worms, several types of jelly-fish-like animals and some protozoans. Meroplankton are very common in nearshore zooplankton samples and include larvae of many species of benthic invertebrates such as crabs, starfish, sea urchins, and mollusks plus eggs and larval stages of many fish. The abundance of zooplankton is related to their food supply, and since most are small, they feed either on small phytoplankton, higher plant fragments or on each other. Consequently, most zooplankton employ some mechanism for straining small particles from the water. The feathery antennae of copepods and modified mouth parts of crustacean larvae can strain phytoplankton. Arrow worms actively prey on small species of zooplankton.

Adaptations for the zooplankton include means for feeding, locomotion, and buoyancy. Elaborate appendages increase surface area and buoyancy while also aiding in feeding. Some jelly-fish have gas bladders which can be filled to increase buoyancy to rise and emptied to sink. Other jelly-fish and arrow worms with a gelatinous watery body increase buoyancy by eliminating heavy ions and replacing them with chloride ions. Storage of fats and oils also increase buoyancy.

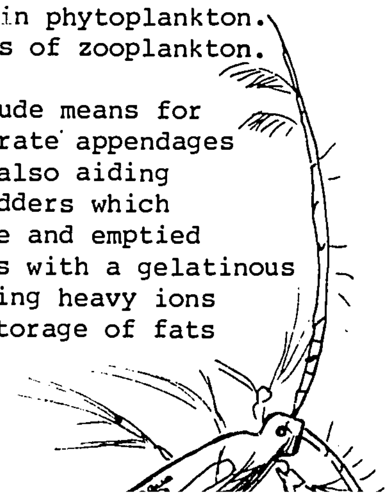
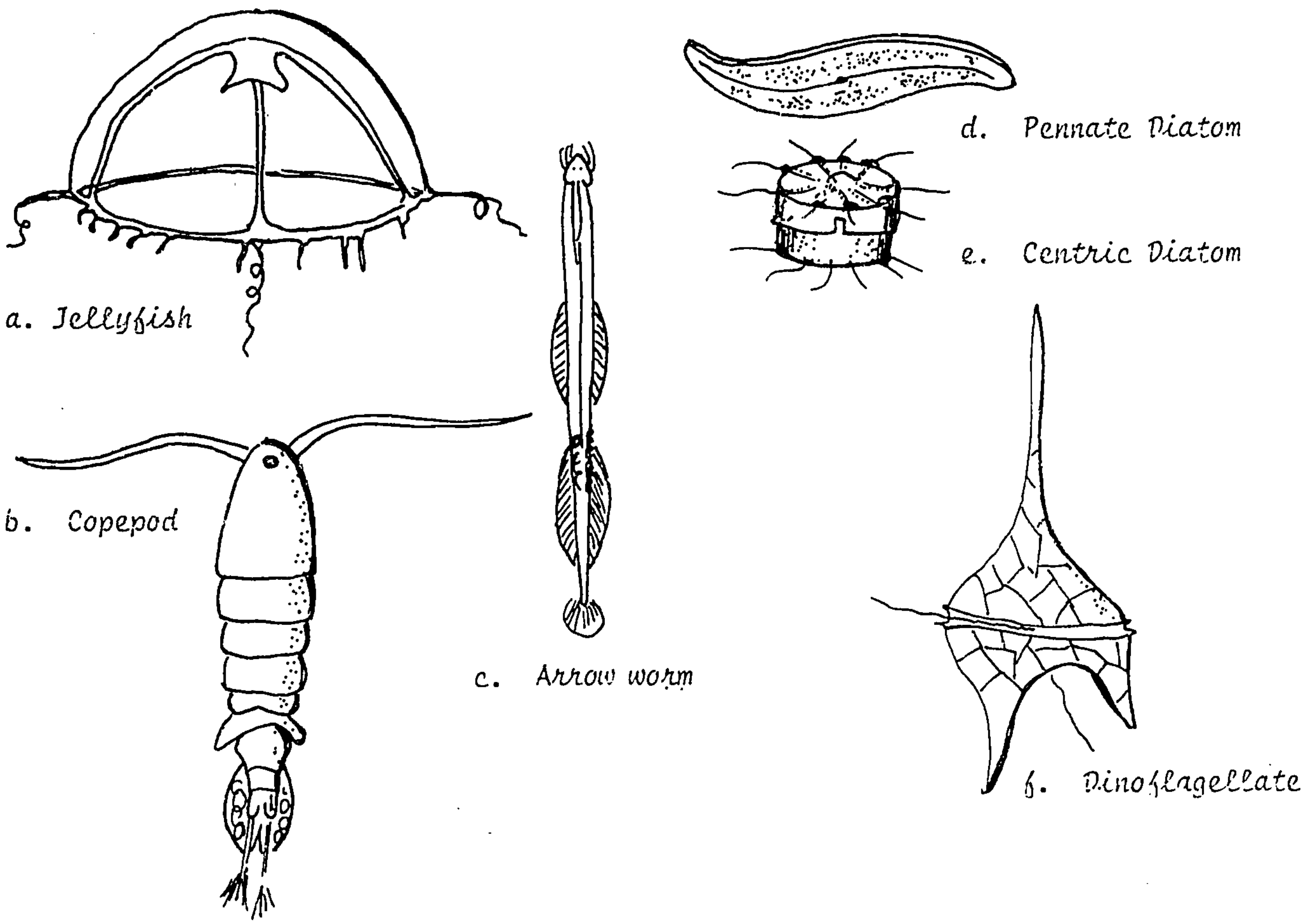
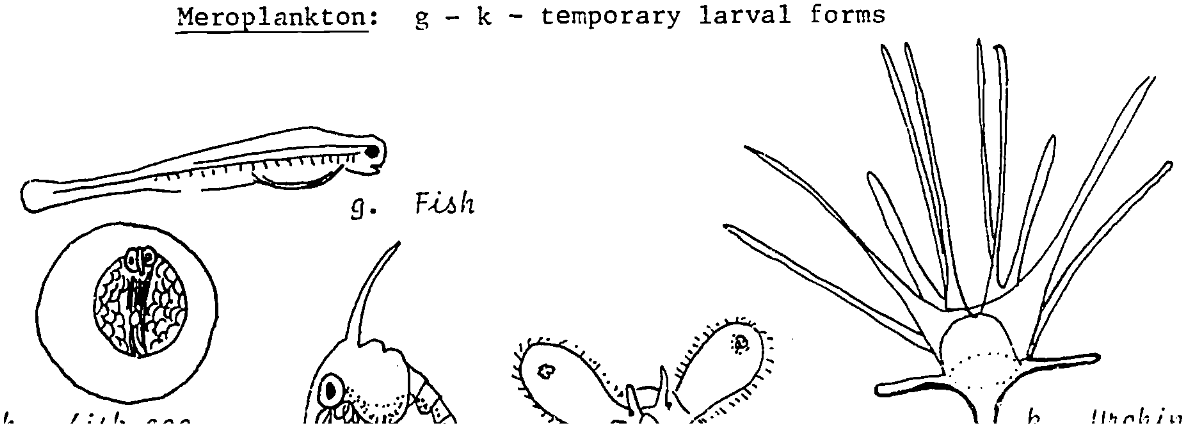


Figure 6. MARINE PLANKTON

Holoplankton: a - c - zooplankton
d - f - phytoplankton



Meroplankton: g - k - temporary larval forms



b. Vocabulary

Buoyancy - tendency of an object to rise or float. Plankton remain buoyant by several means: air bubbles trapped in their bodies; extensions to increase surface area; porous skeletons which weigh less.

Ecosystem - community of organisms interacting with each other and the environment in which they live.

Filter feeder - any organism which actively filters suspended material out of the water column by creating currents. Examples are tunicates, copepods, and oysters.

Flagella - fine, long threads which project from a cell and move in undulating fashion. Flagella are responsible for locomotion of small protozoans and reproductive cells.

Gas Bladders - gas filled organs providing buoyancy in fish.

Holoplankton - animals which spend their entire lives as plankton.

Luminescence - light emitted from organisms by physiological processes, chemical action, friction, electrical, and radioactive emissions. Luminescence in marine organisms is probably an adaptation for recognition, swarming, and reproduction.

Meroplankton - animals which are temporary members of the plankton.

Morphology - study of form and structure of individual plants and animals.

Photosynthesis - process of plants by which energy-rich organic compounds are made from water and carbon dioxide using sunlight as energy source.

Phytoplankton - tiny plants such as diatoms, floating passively in the upper 300 meters of the ocean or to the depths of sunlight penetration. "Grass of the sea".

Plankton - small plants and animals floating in the upper layers of the water column.

Population Dynamics - change in abundance in a species due to available food, predation, or competition.

Productivity - amount of organic material formed in excess of that

C. Things to Do

Plankton Bodies

Objective: To investigate how shape/surface area effect ability to float in order to understand how plankton maintain their position in the water column.

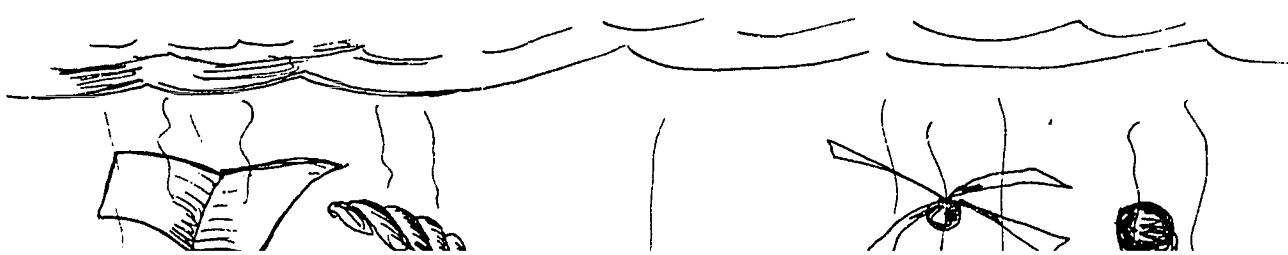
Teacher Preparation: Several jars or trays full of water; miscellaneous pieces of paper, metal, cloth, cardboard, glue and a timer (vegetable oil, optional)

Procedure:

1. Look at some pictures of plankton and observe their shapes. Discuss some of their modifications for floating.
2. Experiment with one type of material, e.g. paper, aluminum foil. Twist, glue, bend into different shapes and test its floating ability. (Avoid the structure being held up by water surface tension by wetting it completely.) Measure the time it takes for different shapes of the same material to sink to the bottom.
3. Some plankton produce oil and store it in their bodies. Try folding your material so it will hold a teaspoon of oil. How does this affect floatation?

Discussion:

1. What shapes enabled your material to float the longest?
2. Why are waves and surface currents important in keeping plankton afloat?
3. Why is it important for plankton, especially phytoplankton, to stay in the upper layers of the water column.

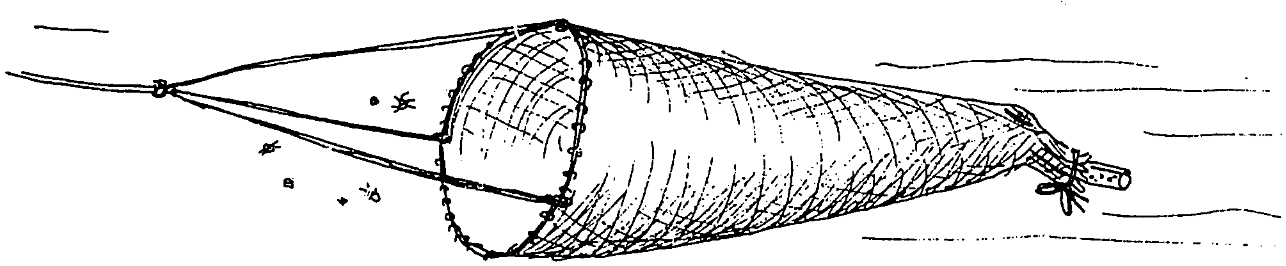


C. Things to Do

Objective: To make a plankton net.

Teacher Preparation: For each net, one leg of nylon hose, a wire coat hanger, string, small jar or lipped test tube.

Procedure: Construct the net as illustrated. The "catch bottle" at the toe is tied on. After the net is towed, wash the net and any contents down into the bottle, untie it, and observe the contents. A microscope is best to observe the tiny plankton although some are visible to the eye.



d. Resources to Use

Project Coast Materials

232 Diatoms: Nature's Aquatic Gem $2.70

Film

The Day the Tide Turned Red. MN-11395, Navy

Plankton - Life of the Sea. MN-10769, Navy

Ocean Phenomenon - Deep Scattering Layer. MN-10524, Navy

Plankton - National Geographic. 12 minutes, color. (excellent)

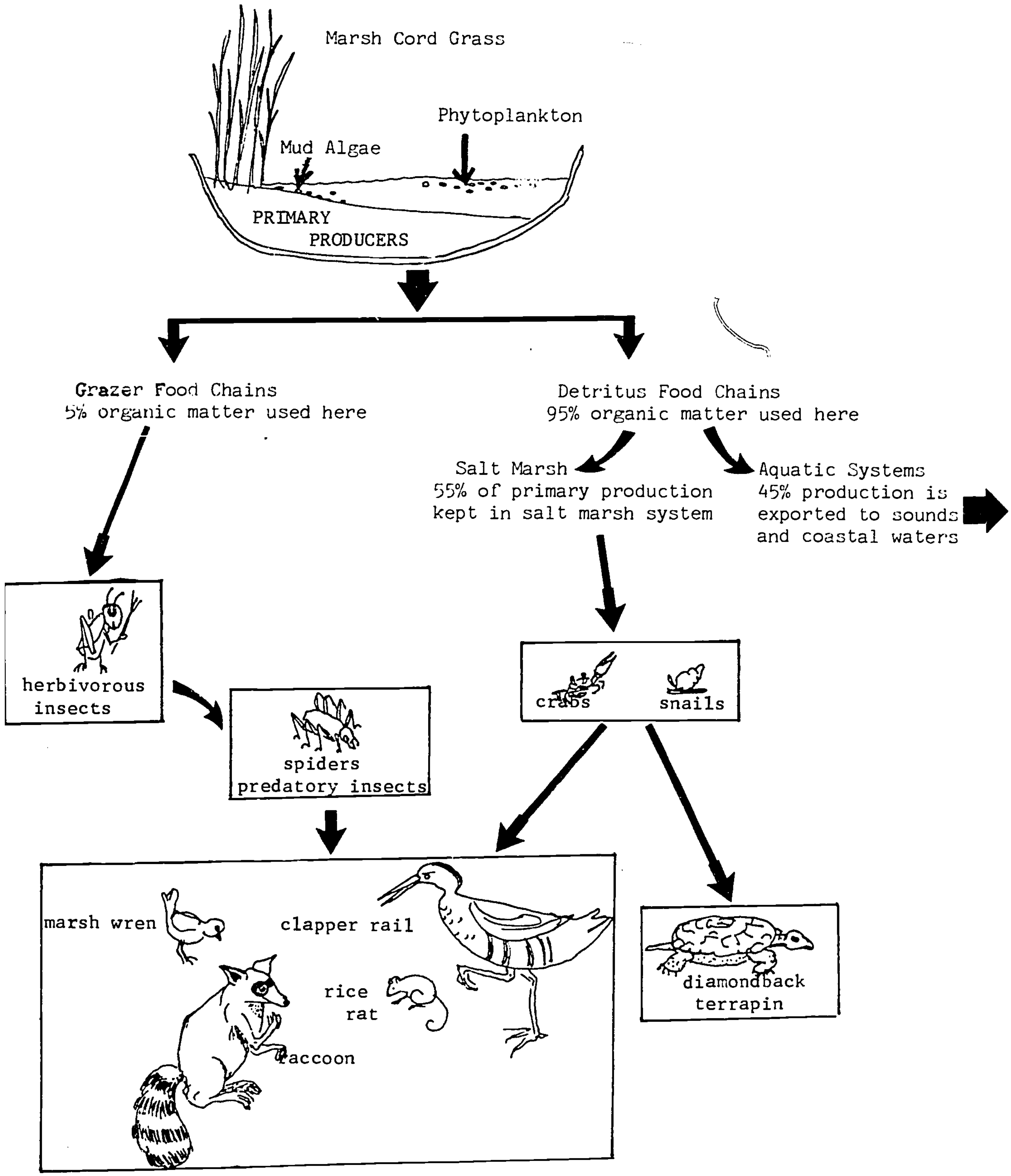
Unit III

Concept 5. Coastal organisms and habitats function together to form an ecological system.

In studying sea coast ecology, scientists tend to separate problems into units like marsh, beach, nekton, benthos. That approach has been followed in the development of these teaching materials. This separatist approach often makes it difficult "to see the forest for the trees". Studying the coastal equivalent of the proverbial "forest" is difficult, but marine ecologists who have done so now recognize three types of processes that link coastal habitats and organisms together into ecological systems: (1) the cycling of nutrients within the system; (2) the flow of energy through the system; and (3) the mechanisms that regulate the system's performance. This material presented in this concept is an effort to show how habitats and organisms operate together in a single system. Such an effort is necessary to the presentation of a balanced treatment of sea coast ecology.

(1) Nutrients are the chemicals needed to support plant or animal growth. Since animals ultimately derive their nutrition from plants, ecologists who study nutrient cycling usually focus their attention on major plant nutrients, i.e. phosphorous, nitrogen, and to a lesser extent silicon and sometimes carbon. The sources of nutrient supplies to the coastal zone ecosystem are varied and include land runoff, biotic excretion, chemical and microbiological degradation of deposited organic matter, and oceanic water masses that are brought onto the continental shelf by currents. The mixing and partitioning of nutrients from these sources is a key process in integrating coastal habitats and organisms into a unified ecological system. For example, a nutrient atom such as phosphorous from river runoff may be taken up by estuarine phytoplankton that serve as a food source for salt marsh mussels that excrete the atom onto the salt marsh surface, hence it may be taken up by sea grasses that eventually die, wash into sounds, and are deposited on the sea floor where microbial degradation liberates the phosphorous atom back into the water where it can be taken up by other phytoplankton that may serve as food for menhaden that migrate away from North Carolina to be caught and converted to fish meal that ultimately end up on someone's dinner table. Thus the use and reuse of an atom of phosphorous as it passes through a coastal ecosystem is a mechanism for linking organisms and habitats together. This linkage can be broken at any step, but there appear to be many linkages operating in parallel so that the general process of nutrient cycling continues even though specific pathways may be blocked. Thus nutrients that support ecological systems are always available, although changes in the kinds and amounts of nutrients may create changes in the

FIGURE 6: Production and Utilization of Organic Matter in the Salt Marsh



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photosynthesis). Energy, unlike nutrients, does not cycle from one component of an ecosystem to another; rather, energy flows from one ecosystem component to another and is degraded at each transfer until it reaches such a dilute state (heat) that it is no longer useful to biological systems. This can be demonstrated by trophic pyramids (Fig. 6).

Energy flow integrates ecosystems despite its unidirectional flow and dissipation through the food chain. Probably the best example of coastal habitat linkage is found in the energy production role of salt marshes. Salt marshes produce a crop of plants annually just like a hayfield. This crop is fertillized by nutrient-rich estuarine waters and harvested by tidal action at the end of the growing season. In Georgia and Louisiana, there is strong evidence that salt marshes are the major photosynthetic unit for the entire coastal ecosystem. This relationship is diagrammed in Figure 6 showing the flow of organic matter through, and away from, a Georgia salt marsh habitat. Note that 45% of the organic matter produced by pohotsynthesis in a salt marsh is exported from the marsh to the surrounding aquatic portions of the coastal ecosystem. This exported organic matter is a major contributor to the food chain of estuarine and nearshore waters, and thus serves as a mechanism linking these habitats together into a unified ecological system.

High salt marsh productivity described for Georgia and Louisiana does not occur uniformly in all salt marshes. There is now evidence that some salt marshes in New England and New York acutally take up more organic matter from their surrounding waters than they contribute. The marshes for which this is the case have artifically restricted tidal circulation and occur in areas of shorter growing season than in Georgia, but this new information needs to be considered when deciding if all marshes should be protected from development. In North Carolina, marshes low in the intertidal zone and regularly flooded by tides contribute organic matter to the surrounding waters whereas high, occasionally flooded marshes do not. The ecological role of these high marshes is not yet well understood.

(3) Mechanisms regulating an ecosystem's performance can include a wide spectrum of physical, chemical and biological phenomena. We cannot describe the entire spectrum of these phenomena here, but we can provide one obvious example of each type that operates to regulate the coastal ecosystem of North Carolina.

The most obvious physical mechanism regulating coastal ecosystems in North Carolina is the tide. Tidal range regulates the distribution of organisms in the coastal zone; tidal currents and ranges regulate the occurrence of such habitats as mud flats, sand flats, and marshes, and balance export and import of organic matter by influencing the energy available for "harvesting" marsh production.

The most obvious chemical mechanism regulating North Carolina coastal ecosystems is salinity, although dissolved oxygen and nitrogen supplies are almost equally important. Salinity regulates the distribution of organisms according to their salinity tolerance. This role extends from dune plant distribution (sea oats tolerate greater salt spray concentrations than do other dune species), through almost all aquatic organisms, to marsh plant distributions. The number of species occurring at points along an estuarine salinity gradient shows a marked decrease in the brackish water areas (Figure 7) because few organisms are able to tolerate the changeable salinity regimes of estuaries.

The most obvious biological mechanism influencing North Carolina's coastal communities is migration. Many more species utilize North Carolina's coastal habitats than are ever found there at any one time. Seasonal migrants include such commercially important species as menhaden, striped bass, bluefish, tarpon, and billfish. In addition, many motile species move around within the coastal ecosystem during the year utilizing different habitats at different times. The general migration pattern is onshore in the warm months, offshore in the cold. This pattern is found in shrimp, crabs, flounder, croaker and an array of non-commercial species. The importance of migration to the natural history of individual species has long been appreciated. However, scientists are just beginning to understand the role of predation in regulating the structure of ecological systems. Since most of the migrants in North Carolina's coastal ecosystem are predators, the recent appreciation of the importance of predation means that we are just beginning to understand the maintenance of our coastal ecosystem.

b. Vocabulary

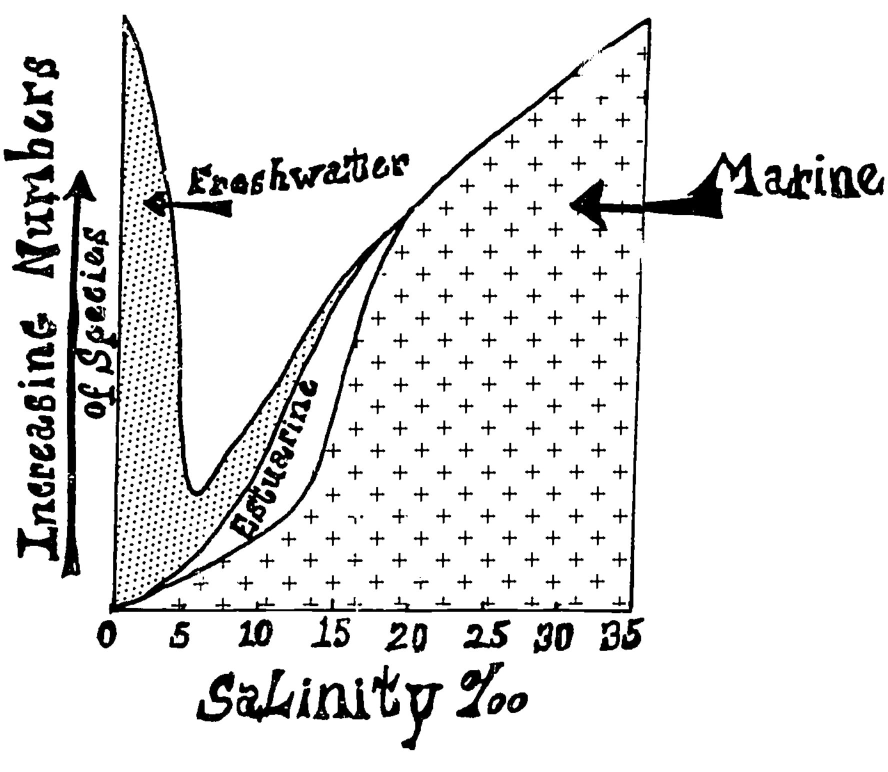
chemical and microbiological degradation - the process of breaking down organic matter, freeing elements such as phosphorus and nitrogen; usually involves bacteria.

marsh export and import - the release of organic matter to surrounding waters or up take of organic matter from the water by marshes.

nutrients - chemicals needed to support plant and animal growth; the main plant nutrients are phosphorus and nitrogen.

oceanic water masses - bodies of water that can be identified by their temperature, salinity, and chemical content.

Figure 7.



Comparison of the composition of fresh-water, estuarine, and marine species with increasing salinity.

C. Things to Do

Instructions for "EAT AND BE EATEN"
(A Food Web Card Game)

NUMBER OF PLAYERS - up to 6. Duplicate cards to have 64+ individual cards. (Paste on cardboard backs)

OBJECT - the first person to play out all of your cards wins.

THE CARDS - There are three types of cards in the deck - organism - sun - disaster. Each organism card represents an animal or plant found in the food webs of the North Carolina sounds. The organism which the card represents is pictured in the circle. On most cards there are lists of organisms in the lower left hand and right hand corners. These will tell you which organisms the main (pictured) organism eats or is eaten by. The organisms in the lower LEFT hand corner are eaten by the main organism (pictured), while the ones in the lower RIGHT hand corner eat the main organism (pictured).

When a green plant is the main (pictured) organism, the SUN is in the LEFT hand corner, giving energy to the plant. The arrows tell you which way the energy goes. An organism card cannot by played on another card unless it is listed in the lower RIGHT or LEFT hand corners of the card on which it is to be played.

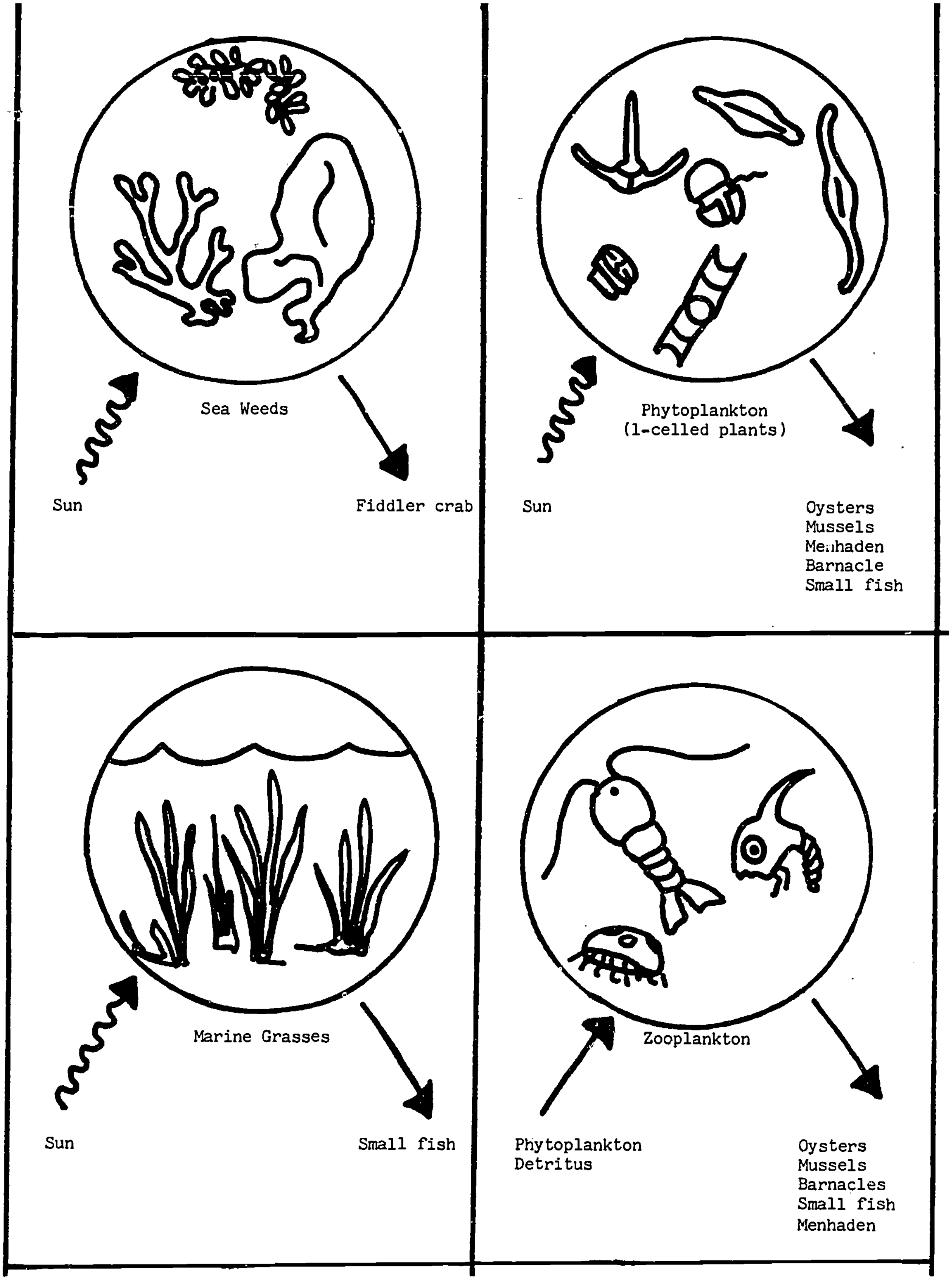
The sunshine card shows where all the energy of the food web comes from. The sun's energy passes first to green plants. Any plant organism card can be played on a sunshine card. The sunshine card can ONLY be played on a disaster card or on a plant organism card. The disaster card may be played on ANY card at any time during the game as long as it is the turn of the player holding the disaster card. The ONLY card that can be played on a disaster card is a SUNSHINE CARD.

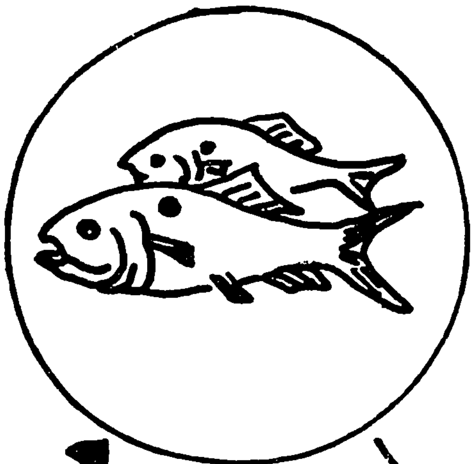
THE PLAY: Deal out six (6) cards to each of the players. Place the remaining cards face down on the table and turn the top card over, to start the playing stack. The top card showing is the card to be played on.

The player to the left of the dealer is the first to begin. To play a card from his hand, the player MUST have a card on which the main (pictured) organism is one of the organisms that is either eaten by or eats the main (pictured) organism on the top card of the playing stack.

In the event that a player does not have a card that either eats or is eaten by the main (pictured) organism of the top card, he must draw from the deck. If a card is drawn that can be played, the player does so and the play moves on to the next person to the left. If it cannot be played, he draws again. If after the third (3rd) draw the player has not drawn a suitable card, the play moves on to the next person.

Adapted for NC from Martin County Schools, Environmental Studies Center, 2900 NE Indian River Drive, Jensen Beach, Florida 33457.

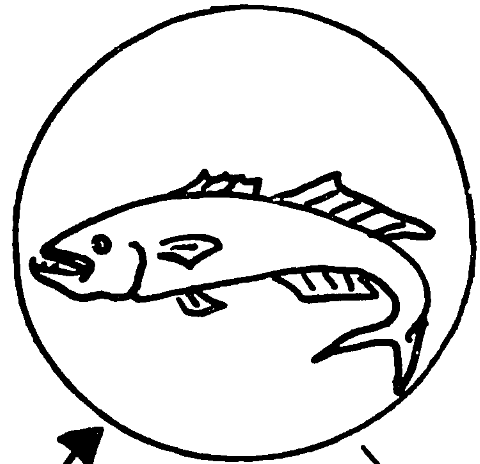

Sea Weeds
Sun
Fiddler crab
Phytoplankton
(1-celled plants)
Sun
Oysters
Mussels
Menhaden
Barnacle
Small fish
Marine Grasses
Sun
Small fish
Zooplankton
Phytoplankton
Detritus
Oysters
Mussels
Barnacles
Small fish
Menhaden



Menhaden

Phytoplankton
Zooplankton
Detritus

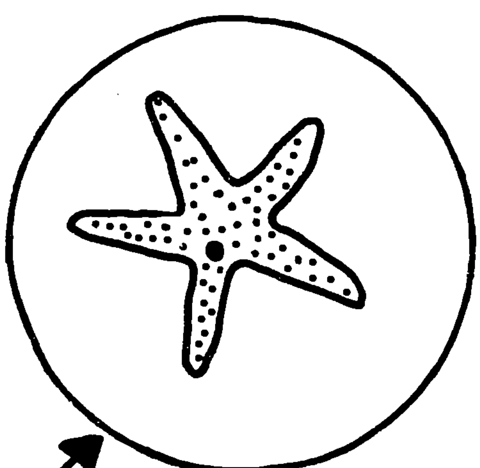
Blue Fish
Man



Blue Fish

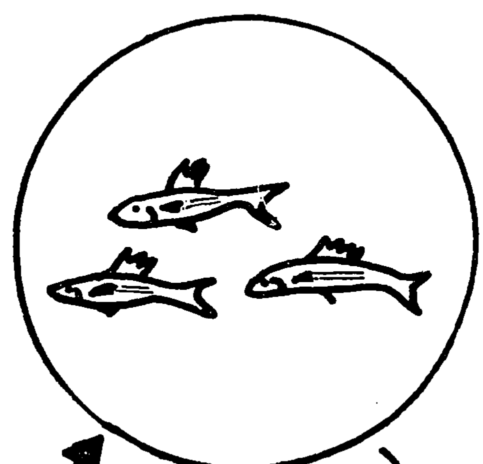
Menhaden
Small fish

Man



Star Fish

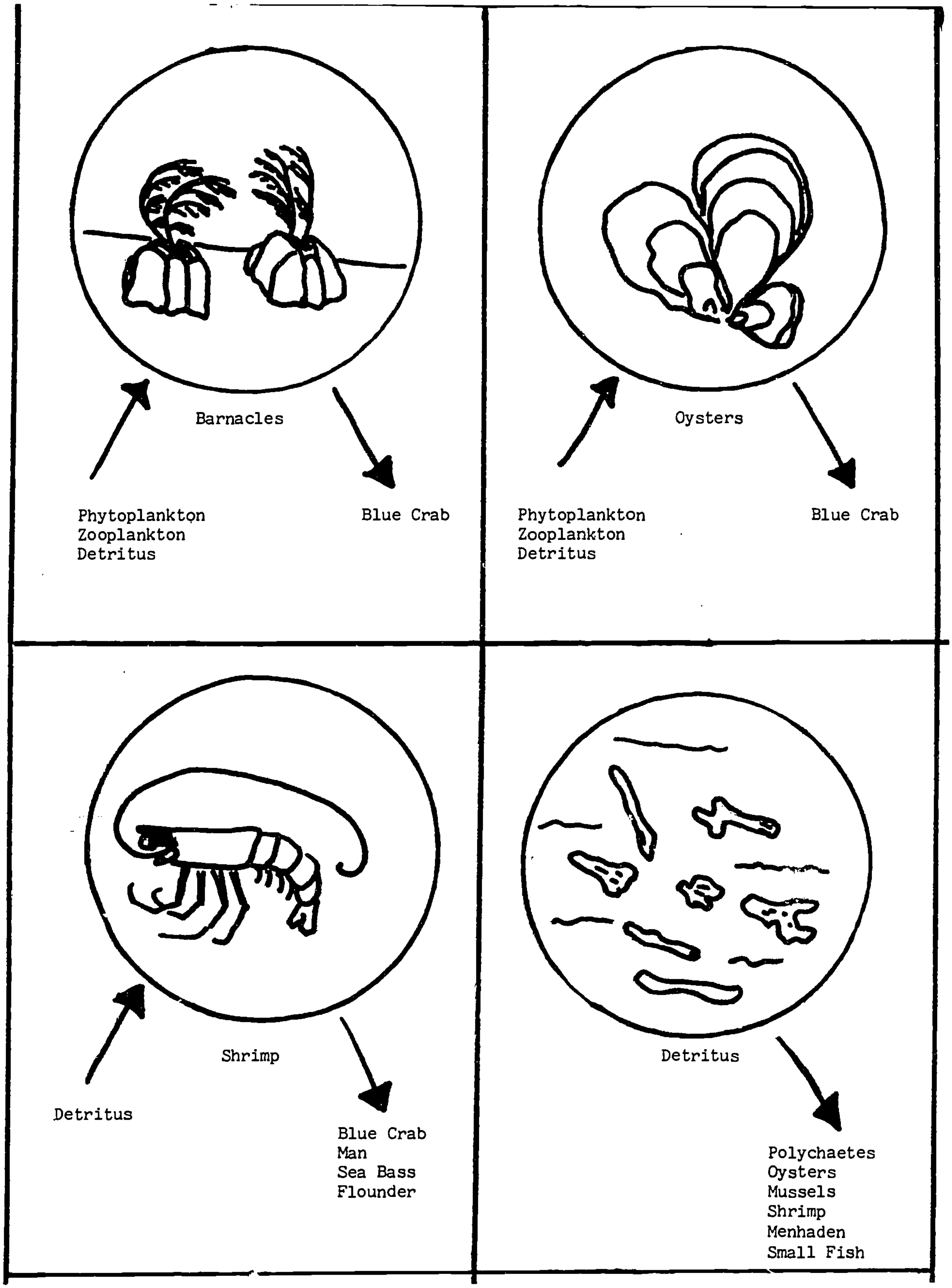
Mussels
Oysters

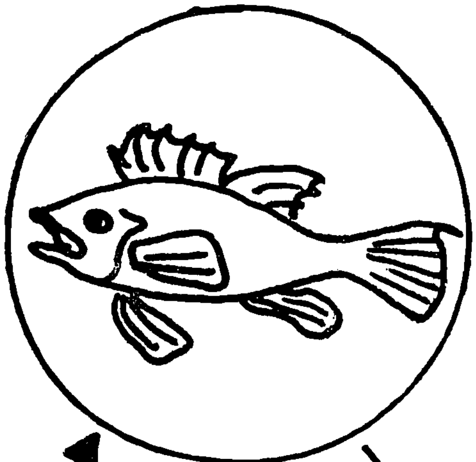


Small Fish

Phytoplankton
Zooplankton
Detritus

Flounders
Sea Bass
Blue fish

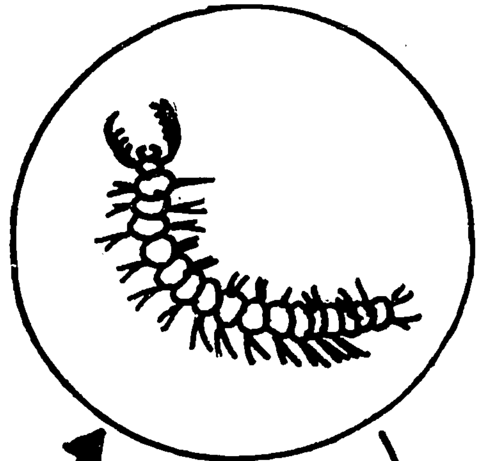

Barnacles
Phytoplankton
Zooplankton
Detritus
Blue Crab
Oysters
Phytoplankton
Zooplankton
Detritus
Blue Crab
Shrimp
Detritus
Blue Crab
Man
Sea Bass
Flounder
Detritus
Polychaetes
Oysters
Mussels
Shrimp
Menhaden
Small Fish



Sea Bass

Small fish
Shrimp
Polychaete worms

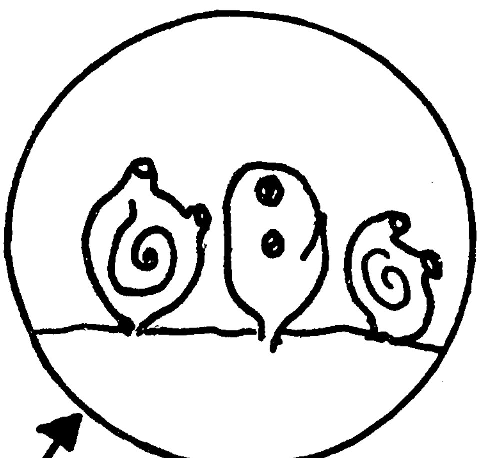
Man



Polychaete Worm

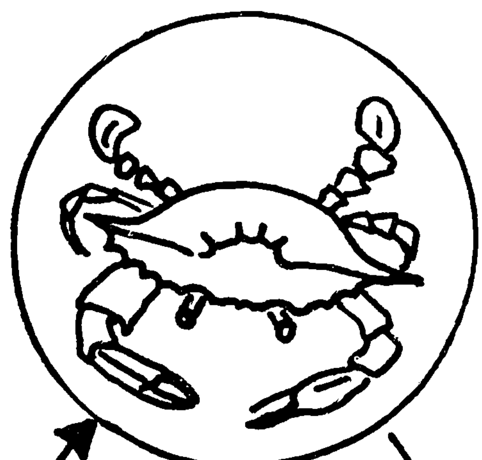
Detritus
Zooplankton
Phytoplankton

Small fish
Flounder
Sea Bass
Blue Crab



Sea Squirt

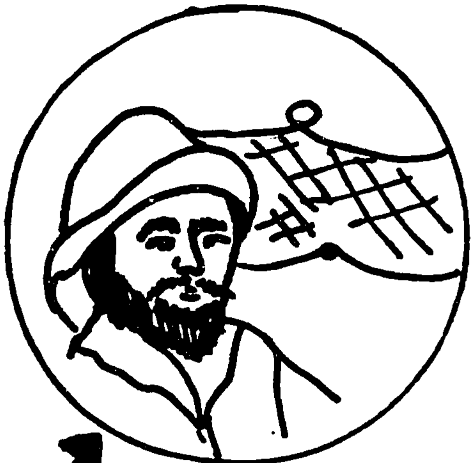
Detritus
Zooplankton
Phytoplankton



Blue Crab

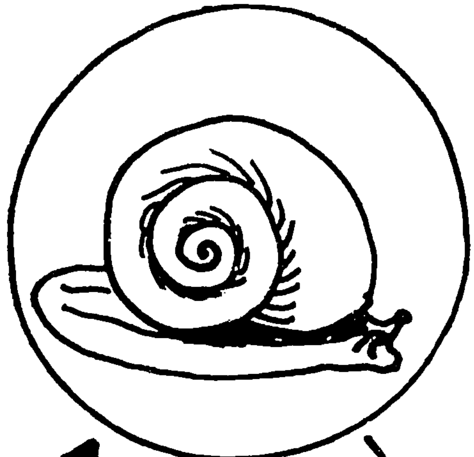
Shrimp
Polychaete worms
Mussels
Oysters
Small fish

Man
Sea Bass



Man

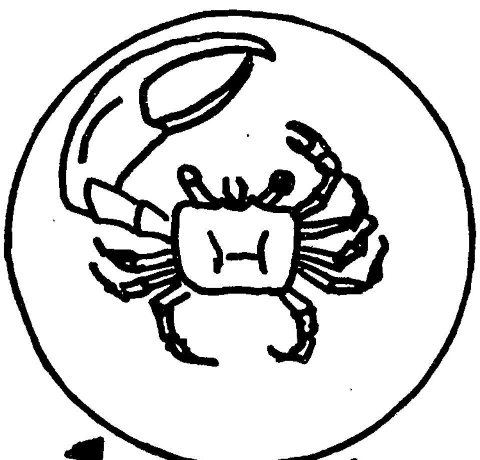
Oysters
Shrimp
Blue crab
Sea Bass
Menhaden
Blue fish
Flounders



Moon Snail

Oysters
Mussels
Detritus

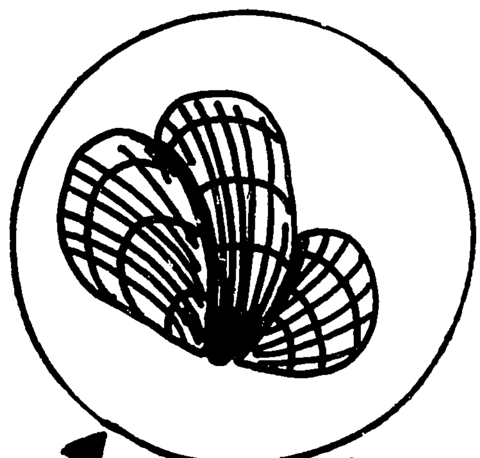
Blue Crab



Fiddler Crab

Detritus

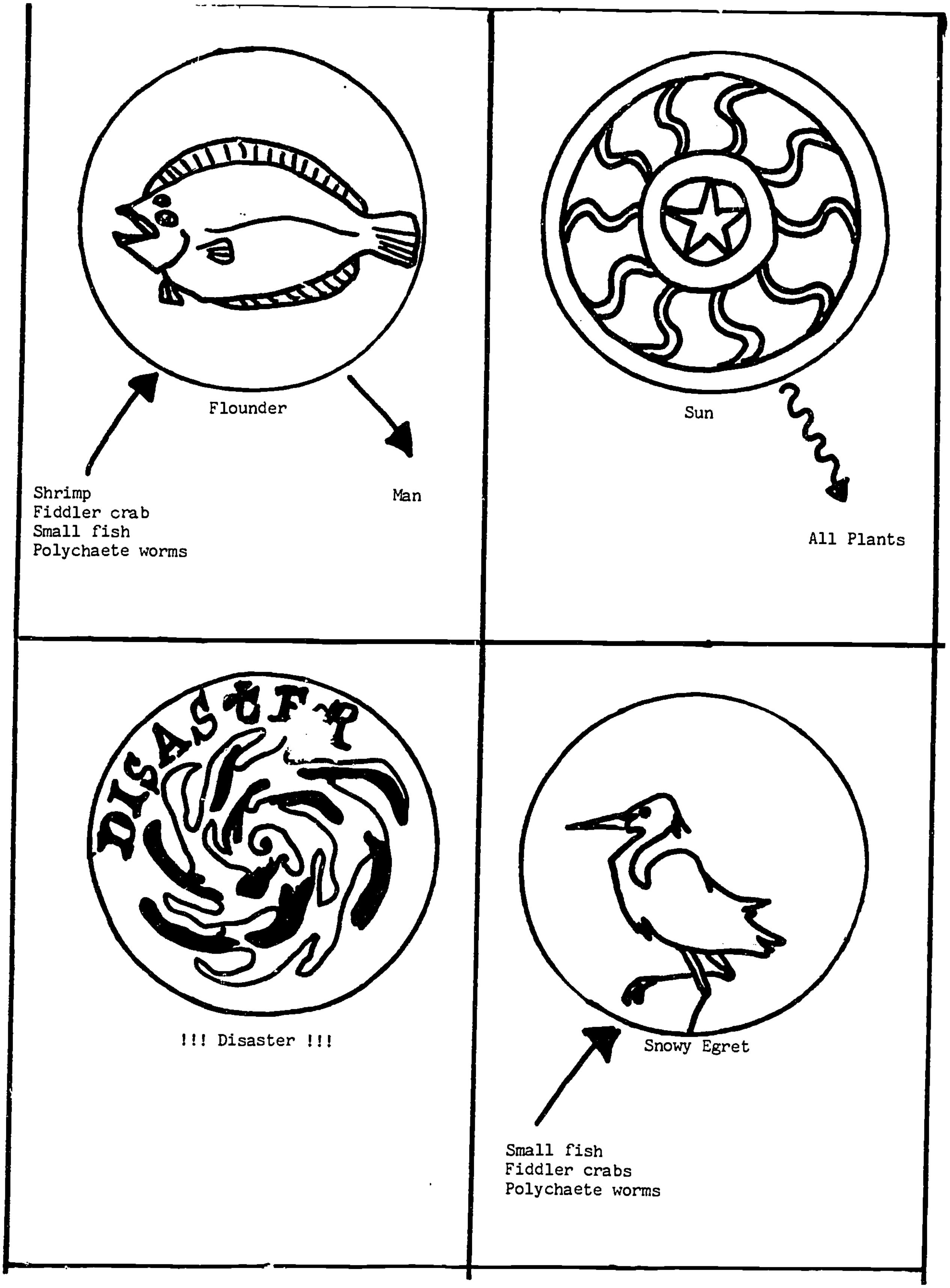
Egret
Blue Crab
Sea Bass
Flounder



Mussels

Phytoplankton
Detritus
Zooplankton

Blue Crab


Flounder
Shrimp
Fiddler crab
Small fish
Polychaete worms
Man
Sun
All Plants
!!! Disaster !!!
Snowy Egret
Small fish
Fiddler crabs
Polychaete worms

C. Things to Do

Objective: To learn to use a dicotomous key and to recognize some NC seaweeds

Teacher Preparation: Either duplicate pictures or collect seaweeds and let the class try to identify them using the key given here.

(Prepared by Joe Richardson, UNC)

Key to Common North Carolina Summer Algae

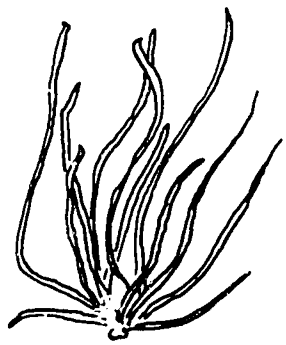
1a. GREEN - 2.
2a. Flat, sheet-like, thin - (ULVA)
3a. Tubular, branched or unbranched --- 3.

3a. Tubular, branched or unbranched, bright grass green; thin branches less than 5 mm thick --- (ENTEROMORPHA)
3b. Tubular, branched, spongy, dark green; thick branches 1 cm or more thick --- (CODIUM)
1b. BROWN RED or reddish --- 4.
4a. BROWN, with leaf-like blades --- 5.
5a. Entire plant flattened, no gas bladders --- 6.
6a. Flattened, dichotomously branched strap-like branches, with or without a midrid --- 7.
7a. No midrid --- (DICTYOTA)
7b. With a midrib --- (DICTYOPTERIS)
6b. Flattened, branching is more like splitting, no midrib, fan shaped with a circular margin; concentric rows on surface --- (PADINA)
5b. Plant composed of a stem-like axis from which leaf-like cenate blades and gas bladders (like berries) grow --- (SARGASSUM)
4b. RED or reddish, no leaf-like blades, much branched --- 8.
8a. Spiney axes; tips of branches often hooked; plant often growing on (epiphytic) or tangled with other algae (esp. Sargassum) --- (HYPNEA)
8b. Axes smooth; usually bright red; commonly drifting unattached --- (GRACILARIA)

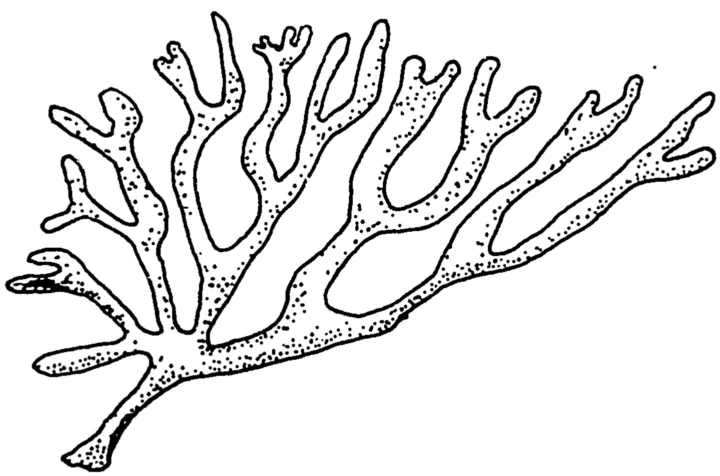
NOTE: This key includes only some of the common NC summer seaweeds.

COMMON SUMMER SEAWEEDS

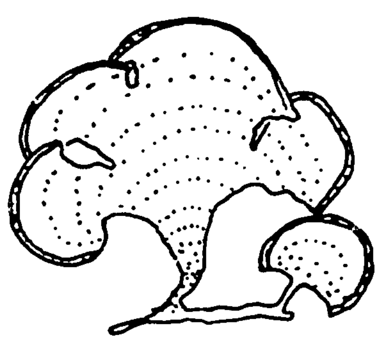
ULVA: "Sea Lettuce", Bright green seaweed, grows in intertidal zone or slightly below low tide level.



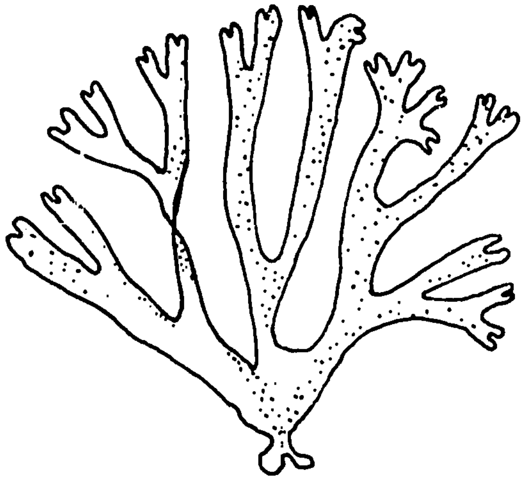
ENTEROMORPHA: "Mermaids' Hair", grass green seaweed, grows intertidally on shells, rocks or pilings, often near high tide level.



CODIUM: "Dead Man's Fingers", branched, dark green spongy seaweed, grows just below low tide level and may get quite long (15-18").

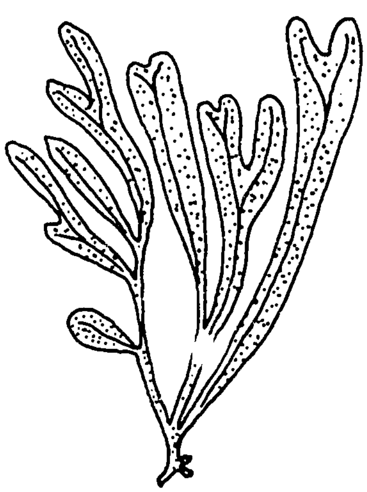


PADINA: Fan-shaped, warm water, brown seaweed found low in intertidal region.

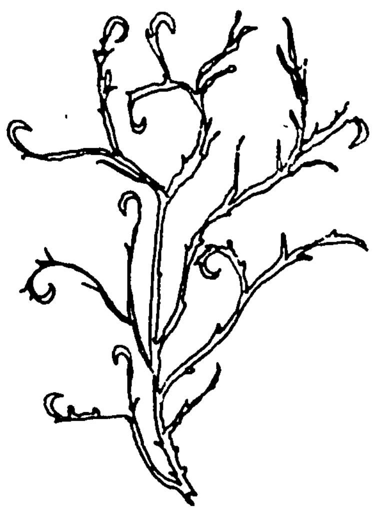


DICTYOTA: Strap-like, brown seaweed found in North Carolina only in summer. Sperm and egg are produced on separate plants that release on a single day during full moon.

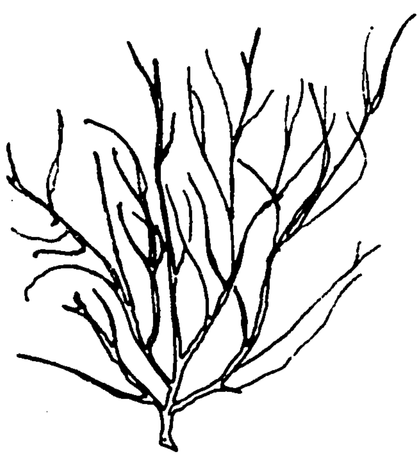
SARGASSUM: Floating brown seaweed characteristic of open sea, some times found ashore, or growing attached on jetties in North Carolina. Air bladders keep plants afloat.



DICTYOPTERIS: Brown seaweed with forked branching, prominent midribs. Attached by a felted spongy holdfast. Grows in deeper water, but common in beach drift. Distinctive odor.



HYPNEA: Purplish to straw color, often found tangled with other seaweeds as it has hooked, branched tips. One species produces a gelatin of economic importance.



GRACILARIA: Common, bright red North Carolina seaweed, often found washed ashore in tangled masses. Our species was source of agar during World War II.

C. Things to Do

Food Chain Connections - A Web of Life

Objectives: 1. To create a food web with students to demonstrate the complex nature of food/ecological relationships.

2. To review roles (niches) in nature.

Teacher Preparation: String or yarn cut into 8 feet lengths to tie your class of students together in a food web.

Procedure: 1. Review some of the eating habits of marine organisms (you can go to whatever degree of complexity you desire). You need to mention plants (producers) and animals (consumers) and mention levels of consumers (herbivores, carnivores).

2. Have the class suggest marine organisms and discuss what they eat. Write the names of these organisms on the board.

3. To begin the string, ask for one or two volunteers to be producers (seaweeds, algae). Give them each one end of a length of string. Ask other students to be some of the animals mentioned on the board. Ask who will eat the plants. Let the plant people hand the herbivores the other end of the string. Give lengths of string to the herbivores to hand to carnivores which would eat them. (At this point, the students should see that one organism may be the food for several others and that one organism may prey upon several others.)

Discussion: 1. When the possibilities of interacting have been exhausted and your room looks like a New Years's Eve spider web, ask the students to reflect how complex a real food web is.

2. You may want to use the web to show how a diverse ecology can withstand some pressure. (Remove one part and see how many other components are affected.)

d. Resources to Use

Coloring Books from the NC Marine Resources Centers. $0.25 each
(two books, one each for a primary level and for a middle school)

Project COAST Materials
#245 Food Webs in the Marine Habitat. $1.90

Films

Food Chains in the Ocean. 9 min., color, (BFA)

Great Barrier Reef. 58 min., color, (NBC)

Of Broccoli and Pelicans and Celery and Seals. 28 min., color, (NET)

Plankton. 12 min., color, (National Geographic)

Plankton to Fish: A Food Cycle. 10½ min., color, (Coronet)

References

Sumich, J.L. 1976. Biology of Marine Life. Wm. C. Brown Publishers, Dubuque, Iowa. Paperback, $9.95 (very good)

Outdoor Biology Instructional Strategies (BIS). Lawrence Hall of Science, University of California, Berkeley, CA. (OBIS is a series of activity cards designed to illustrate ecological concepts. The activities are creative, require little equipment and can be conducted with students of the middle grade level. Many of the activities reflect marine perspectives or can be modified to do so. Request information on these series.)

Marshall, Norman and Olga Marshall. Ocean Life - Macmillan Publishing Co., Inc. New York $5.95 (High school text)