DOCUMENT RESUME

ED 239 870 SE 043 826

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TITLE Marine and Estuarine Ecology. Man and the Gulf of Mexico.
INSTITUTION Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Miss.
SPONS AGENCY National Oceanic and Atmospheric Administration (DOC), Rockville, Md. National Sea Grant Program.
REPORT NO ISBN-0-87805-201-1; MAGSP-82-007(1)
PUB DATE 84
GRANT NA81AA-D-00050
NOTE 94p.; For a related document, see SE 043 825.
AVAILABLE FROM University Press of Mississippi, 3825 Ridgewood Rd., Jackson, MS 39211.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS Animals; Classification; *Ecology; High Schools; *Marine Biology; *Marine Education; *Science Activities; Science Education; *Secondary School Science; Vocabulary Skills; Wildlife
IDENTIFIERS Alabama; *Coastal Zones; *Estuaries; Mississippi

ABSTRACT

"Man and the Gulf of Mexico (MGM)" is a marine science curriculum developed to meet the marine science needs of tenth through twelfth grade students in Mississippi and Alabama schools. This MGM unit, which focuses on marine and estuarine ecology, is divided into six sections. The first section contains unit objectives, discussions of the estuarine ecosystem and reasons for classifying organisms, and an activity on using a taxonomic key. The next five sections focus on: (1) plankton; (2) nekton; (3) intertidal organisms and their environment; (4) coastal habitats; and (5) coastal ecology. Each section includes a statement of concept(s) to be learned, objectives, vocabulary activities, vocabulary lists, and (with the exception of the section on nekton) one or more science activities. Objectives, procedures, and list of materials needed are provided for these activities which investigate: plankton bodies; osmosis; snails; population pressures and succession in a laboratory community; relationship of habitat to survival of an organism; diversity of organisms in an aquatic habitat; and the best use for a marsh beach. Activities involving the construction of a plankton net and an artificial ecological system are also included. (JN)

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Marine and Estuarine Ecology

SE 043 826

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Marine and Estuarine Ecology

Man and the Gulf of Mexico Series

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Published for the
MISSISSIPPI-ALABAMA SEA GRANT CONSORTIUM
by the
UNIVERSITY PRESS OF MISSISSIPPI
Jackson

Other titles in the
Man and the Gulf of Mexico Series

Marine Habitats
Diversity of Marine Animals
Diversity of Marine Plants

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University Press of Mississippi

Library of Congress Cataloging in Publication Data
Main entry under title:
Marine and estuarine ecology.
(Man and the Gulf of Mexico series)
Bibliography: p.
Includes index.
Summary: A high school textbook and workbook introducing marine and estuarine ecology, marine habitats, and the diversity of marine animals and plants.
1. Marine ecology—Mexico, Gulf of. 2. Estuarine ecology—Mexico, Gulf of. [1. Marine ecology. 2. Estuarine ecology. 3. Ecology. 4. Mexico, Gulf of] I. Irby, Bobby N. II. Series.
QH92.3.M37 1983 574.5'2636'0916364 83-19654
ISBN 0-87805-201-1

This publication is a part of an educational series sponsored by NOAA Office of Sea Grant, U.S. Department of Commerce, under Grant Number: NA81AA-D-00050, the Mississippi-Alabama Sea Grant Consortium, the University of Southern Mississippi and the University of South Alabama. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon.

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Preface

If the oceans of earth should die ... it would be the final as well as the greatest catastrophe in the troublous story of man and the other animals and plants with whom man shares this planet.

—JACQUES COUSTEAU

Cousteau's warning appropriately summarizes the need to include marine education in our curriculum today. The history of mankind is closely linked to the ocean. Man has always been awed by the vast expanse of the sea. It is ironic indeed that such a valuable resource has been neglected so long in education.

"Man and the Gulf of Mexico (MGM)" is a marine science curriculum developed for grades 10-12 with funds from the Mississippi/Alabama Sea Grant Consortium. The MGM materials were specifically designed to meet the need for marine science in all secondary schools of Mississippi and Alabama.

The MGM project was a two state effort, involving the University of Southern Mississippi, the University of South Alabama and the Gulf Coast Research Laboratory in cooperation with the Alabama and Mississippi State Departments of Education. Similarities among the coastal problems of the two states not only made this an appropriate arrangement, but also heightened the potential for success of the project. Additionally, the educational needs for increased dissemination of marine studies in the public schools of the sister states are equally urgent. Perhaps the most significant feature in the development of the MGM materials was the cooperation between university science educators, innovative secondary school science teachers and other resource personnel. These cooperative relationships were established at the outset of the project and continued throughout the duration of the curriculum development effort. The design, development, field testing, revision, and a second field test evaluation spanned four years of intensive and dedicated work.

During the initial phase of the MGM project, selected high school science teachers responded to a questionnaire designed to provide information concerning each teacher's impression of the importance of certain marine topics, each teacher's self-assessment of his/her knowledge of the same marine topics, and each teacher's preference in terms of curriculum format. Results of the survey were used to provide direction for the selection of topics and for the development of activities to be included in the materials. The completed materials include four units: **Marine and Estuarine Ecology, Marine Habitats, Diversity of Marine Animals,** and **Diversity of Marine Plants.** Field testing of the materials was conducted in eleven schools by biology teachers during 1980-81. Included were two inland and two coastal districts in Alabama and four inland and three coastal districts in Mississippi. Based on those classroom evaluations, the materials were thoroughly revised during the summer of 1981. The revised materials were then used in 35 schools throughout Alabama and Mississippi during the 1981-82 academic year.

The field-testing of the MGM materials in the classroom has demonstrated that the marine science materials are equally appropriate for both inland and coastal schools. Many teachers have successfully incorporated selected MGM materials into their existing courses of study in biology, while others have used the complete curriculum as a separate course in marine science. In either case, teachers have found the MGM Marine Science Curriculum enjoyable to teach and very informative.

Information and activities indexed and accumulated on microfiche through the Marine Education Materials System (MEMS) have been invaluable during preparation of the MGM units. Some of the activities and concepts included as a part of MGM were modified from resources in the MEMS collection. Appropriate credit is given to the original authors in the reference section of each MGM unit. We are particularly indebted to the following marine education curriculum projects for their contributions: "Man and the Seacoast", a project sponsored by the University of North Carolina Sea Grant College Program which resulted in the publication of the **North Carolina Marine Education Manual** series; "Project COAST", (Coastal/Oceanic Awareness Studies), funded by the Delaware sea Grant College Program; and the **Hawaii Marine Sciences Study Program** developed by the Curriculum Research and Development Group at the University of Hawaii.

We wish to acknowledge the cooperation that we have received from other marine education projects, the Alabama and Mississippi State Departments of Education, The University of Mississippi Law School, the National Marine Education Association, and many individuals who offered suggestions that were incorporated into the MGM materials. Our gratitude is also extended to Dr. J. Richard Moore for permission to include his plant key in the teacher supplement for **Diversity of Marine Plants**. We are indebted to the Department of Science Education at the University of Southern Mississippi for serving as a base of operation, allowing use of its equipment, and providing financial support. We especially would like to thank all of the dedicated Mississippi and Alabama teachers who worked so diligently on MGM materials. We hope that high school students and their teachers will continue to find that these efforts have been of value.

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MARINE AND ESTUARINE ECOLOGY

Objectives of *Marine and Estuarine Ecology*

1. To familiarize students with the complexities and dynamics of the marine environments.
2. To promote understanding of the diversity of the marine environments and their biological characteristics.
3. To develop an understanding of the interdependency of all living organisms upon one another.
4. To increase the student's appreciation of the values of the marine community both practically and aesthetically.
5. To instruct students in the manipulation of certain equipment used in marine biology.
6. To emphasize the idea of adaptation as a method of adjusting to the environment.
7. To aid students in developing the ability to record data in a logical manner and make inferences from it.

THE ESTUARINE ECOSYSTEM

An estuary is a partially enclosed body of water having a free connection with the sea. The sea water within the estuary is diluted with fresh water from its drainage area. Generally, salinity of the water is less than that of sea water, but it varies from time to time.

Estuarine organisms must be adapted in one way or another to tolerate varying salinities. There are a variety of habitats within an estuary and each habitat has its characteristic plants and animals. Estuarine communities consist of a mixture of species: those that normally occur in the area, species which come in from the sea, and a few which have the adaptation for penetrating to or from the freshwater environment.

Although the estuarine environment is changeable and difficult, it is very productive. The fresh water drainage brings down fresh supplies of nutrient salts. The estuaries are characteristically more productive than either the sea which borders one side of the estuary or the freshwater area on the other side. The main source of biological productivity is in the salt marshes. These provide a major source of food for the estuarine ecosystem. Dead marsh plants support huge populations of invertebrates which are preyed upon by fish and birds.

This study will examine some of the organisms that live within certain estuarine ecosystems. Emphasis is placed upon the adaptations that the organisms have made in order to survive in this environment and upon the limiting factors that are continually at work in the estuary. Finally, the interaction between an organism and its estuarine habitat is explored to point out that an ecological system results from living and non-living interactions within the estuary and, in more general terms, within the marine environment.

VOCABULARY

community—all of the populations of organisms in a particular area.

ecosystem—a community of organisms interacting with each other and the environment in which they live.

habitat—the place where an organism lives.

marsh—a tract of wet or periodically flooded treeless land, usually characterized by grasses, cattails, or other monocots.

nutrient salts—a particular class of chemical compounds which, when eaten by an organism, can be used in the growth process.

salinity—a measure of the total amount of dissolved salts in seawater.

WHY CLASSIFY?

We as humans are constantly placing our possessions in groups. Everything must be placed in some category. Thus, it is no different when it comes to living creatures. We first place all of those that are alike in one group and those that are different in other groups. Your school class is even grouped. All of the 10th graders are in one group and 11th graders in another class. You are grouped in this way by the number of years you have been attending school. As you can see, the criterion may be different in some instances and cause a change in the make up of a group. All students in your biology class are taking biology. Biology becomes the criterion in which all of the students in your class are alike. There may be 9th, 10th, 11th or 12th grade students in this class but in this instance grade level is not the characteristic that is important or similar.

Biologists are always looking for better ways to classify organisms that will be more relevant, and easier to understand by the user. Taxonomy is the term used to refer to the area of science dealing with the naming and classification of living organisms of a group, as well as the differences from other groups. Any good classification system will also provide the exact genus and species for each living organism. This will be the scientific name of the organism and there should not be any other organism with this name in the world.

In the accepted organizational plan, the largest and most comprehensive grouping is that of the kingdom. Organisms are then placed in subcategories called phyla. A phylum is then subdivided into classes.

The class is subdivided into orders, and the order is subdivided into families. The family is subdivided into genera (plural of "genus"), and the genus may be subdivided into species. The scientific name then is always composed of the genus and species. The genus is usually a noun and the species an adjective describing the noun.

Objective

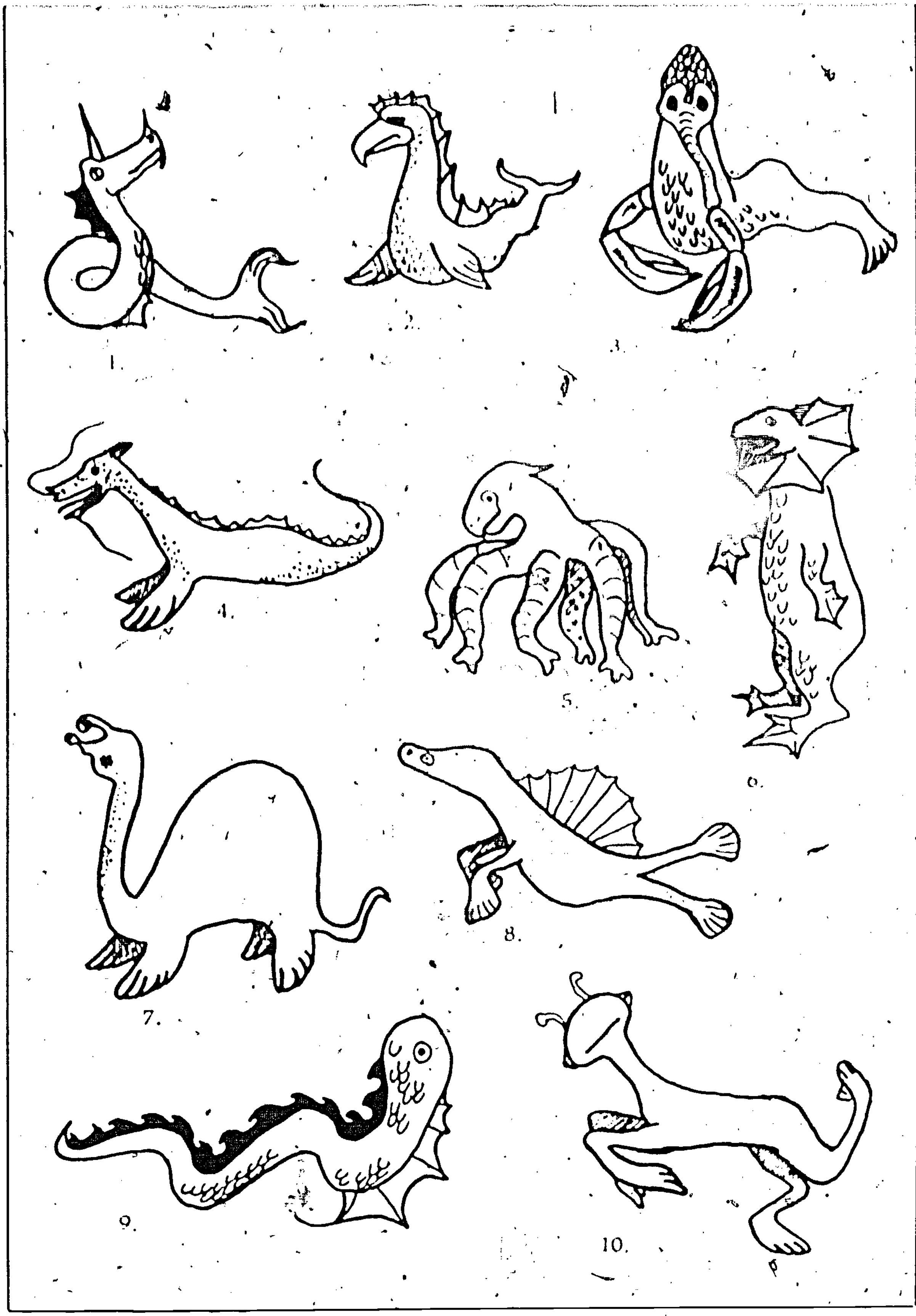
To classify a group of fictitious marine organisms in order to develop an understanding of how the classification system is used.

Materials

The attached page of fictitious marine animals.

Procedure

Before constructing your classification system, carefully examine all of the fictitious marine organisms. As you examine the organisms concentrate on their physical appearance. Try to observe and note like and unlike characteristics of the organisms. These characteristics are important in establishing the categories necessary for classification.


1.
3.
4.
5.
7.
8.
9.
10.

As a group, first complete Table 1 so that you will be able to classify each organism. For example: The kingdom criterion might be "plant-like or animal-like". Since all of the fictitious organisms exhibit "animal-like" characteristics, place them together as animals. For the next category you might separate the animals into "aquatic or terrestrial animals".

VOCABULARY

genus—a category of biological classification ranking between the family and the species.

species—a group of animals or plants which possesses in common one or more characteristics distinguishing them from other similar groups. Those organisms usually interbreed and reproduce their characteristics in their offspring.

taxonomy—classification of organisms, based as far as possible on natural relationships.

Table 1. Use your own system to classify the organisms on page 3
Now, classify each organism.

	Animal 1	Animal 2	Animal 3	Animal 4	Animal 5	Animal 6	Animal 7	Animal 8	Animal 9	Animal 10
Kingdom										
Phylum										
Class										
Order										
Family										
Genus										
Species										

1. Which organisms seem to be related the closest? ______________________

2. Which two organisms seem to differ the most? ______________________

3. Record your scientific name for organism 4, 6, 8, and 9.

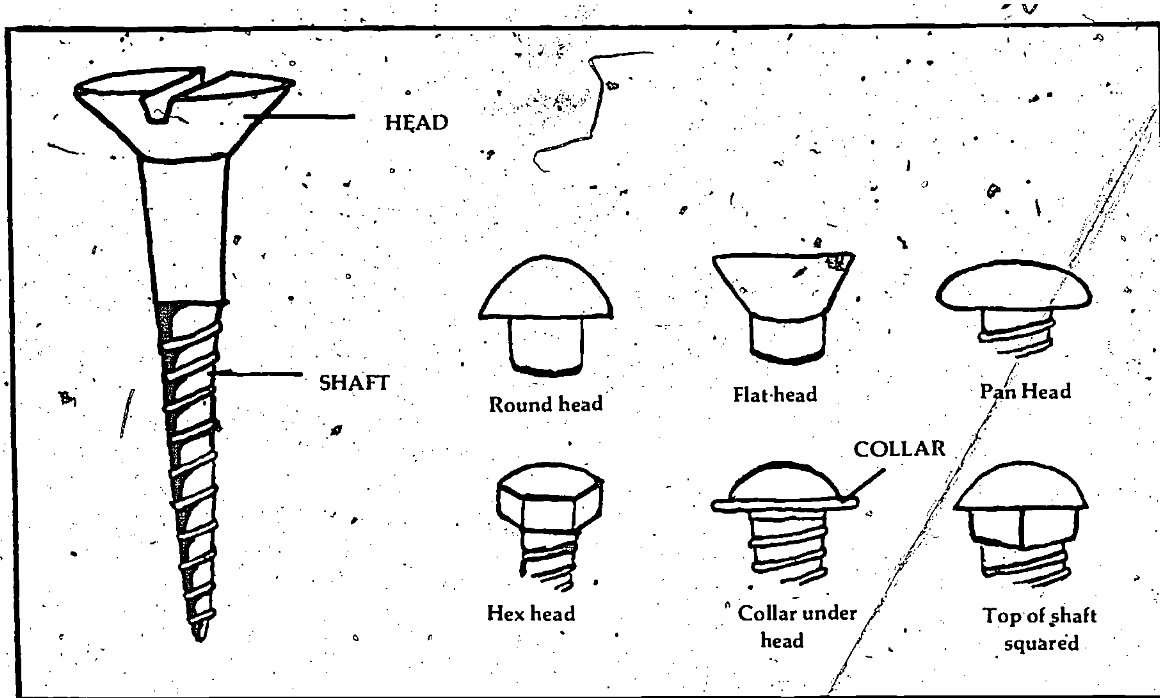
4. ______________________ 8. ______________________

6. ______________________ 9. ______________________

USE OF A TAXONOMIC KEY

Introduction

Many of the early biologists studied the structure of organisms. As a result of these studies, many of our methods of classification (taxonomy) of plants and animals are based on the structures of organisms.



Key to North American Screws

1.	a.	Sides of shaft (threaded part) parallel (no point)	2
	b.	Sides of shaft tapering to a point (as in 1)	6
2.	a.	Head with 1 or 2 slots	3
	b.	Head without a slot	5
3.	a.	Head rounded on upper surface	*Round-headed machine screw*
	b.	Head not rounded on upper surface	4
4.	a.	Head flat, six-sided	*Hex-headed machine screw*
	b.	Head flat, tapering to shaft	*Flat-headed machine screw*
5.	a.	Head six-sided flat on top	*Hex-headed machine screw*
	b.	Head flattened parallel to plane of long axis of shaft	*Thumb-grip machine screw*
6.	a.	Head with no slots	7
	b.	Head with 1 or 2 slots	8
7.	a.	Head curved into ring	*Eye screw*
	b.	Head with six sides & flattened collar	*Hex-headed metal screw*
8.	a.	Head with single slot or collar	9
	b.	Head with two slots at right angles to each other	11
9.	a.	Shaft with thread all the way up to the head, pan head	*Pan-headed metal screw*
	b.	Shaft with unthreaded area below head	10
10.	a.	Head flat	*Flat-headed wood screw*
	b.	Head rounded	*Round-headed wood screw*
11.	a.	Head flat	*Flat-headed metal screw*
	b.	Head not flat	12
12.	a.	Head round	*Round-headed metal screw*
	b.	Head pan	*Pan-headed metal screw*

In any plant or animal, there may be hundreds, even thousands, of characteristics which appear to separate it from all other organisms. Experience has shown, however, that most of these are not extremely important in determining the species of the organism. Usually only a few characteristics are valuable in determining the species. But if you were given an organism to classify, you would probably be both amazed and confused by the large number of characteristics that are present. Which characteristics do you use in classifying this organism? The answer is simple. You must center your attention on just a few, critical characteristics and disregard the others. Wouldn't it be nice if the plants and animals on earth only showed these critical characteristics? Unfortunately, plants and animals do not exist in this manner.

Man-made items sometimes are much simpler than those found in nature. This is true of some of the items in everyday use. Consider all the different types of spoons that help fill the drawers in any kitchen. Or the different kinds of nails, pipe fittings, pins, or bullets.

To make the job of learning to use a taxonomic key easier, we have chosen to work with screws. Screws are used for many purposes and come in many shapes and sizes. Each has a specific name, much like a plant or animal. The parts of a screw are extremely simple. There is an expanded portion called the head and a long, slender portion called the shaft. Screws can be separated from nails, for example, by the fact that the shaft is threaded, that is, it has a groove spiraling around it from its point toward the head.

Objectives

Each student shall be able to:

1. Use a key to separate organisms or items into categories based on known structure.
2. Define the following terms: taxonomy, taxonomic key.

Materials

Five of each of the following for a class of 20-25 students: round-headed machine screw, hex-headed machine screw, flat-headed machine screw, thumb-grip machine screw, eye screw, hex-headed metal screw (slotless and not), pan-headed metal screw, flat-headed wood screw, round-headed wood screw, flat-headed metal screw, round-headed metal screw, pan-headed metal screw (Phillips head and/or straight slot)

Procedure

Using your lab samples, identify one screw at a time. Read each couplet as a unit. If your answer to the first statement is "yes", go to the couplet indicated; if a name appears, you have identified your screw. If your answer to the first statement of the pair is "no", go then to the second statement of that pair. Your answer to this must be "yes". If you cannot give a positive answer to the second statement either, you are off the track. Return to the beginning of the key and start over, being very careful to read each statement accurately and to examine your screw meticulously.

After you have identified a screw, set it aside with its proper identification indicated. Take another screw and begin with the first couplet again. You must always begin with the first couplet.

VOCABULARY

taxonomic key—a table in which the distinguishing characteristics of a group of plants or animals are arranged so as to make it easier to determine their names.

taxonomy—classification of organisms, based as far as possible on natural relationships.

CONCEPT A

Plankton are generally tiny, but are important to coastal zone ecology.

Objectives

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

a. To give the general name for animal plankton and the general name for plant plankton.
b. To describe how plankton manage to float.
c. To provide at least one reason why plankton are important in fresh water and salt water.
d. To list the names of two organisms that would be placed in the "plant plankton" group.
e. To explain how a gas bladder works.
f. To list two characteristics that all plankton have in common.
g. To discuss a method that can be used to capture plankton for study.

PLANKTON

Plankton are generally 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 fascinating. 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 work, "plantos", meaning wanderer, plankton vary in size, but are generally small. Plant plankton (**phytoplankton**) is often dominated by **diatoms** less then 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 with access to ocean collections.

The importance of plankton in **marine ecology** involves both quantitative and qualitative features. Quantitatively, plankton are an 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, 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 and distribution of marine organisms. There is evidence that phytoplankton are more easily digested and thus more nutritious per unit weight, than is higher plant material produced by salt marsh species. For example, a common estuarine zooplankton crustacean (the copepod *Eurytemora affinis*) produces more eggs when grown on a diet of phytoplankton than when grown on a diet of salt marsh plant material. The qualitative significance of phytoplankton to egg production and other life cycle processes may ultimately show that phytoplankton are more important to nearshore food chains than currently conceived.

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 98% of all the sport and commercial catch on the coast of Mississippi is of animals that 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 the 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 changes **inorganic** nutrients to organic **material**. Zooplankton and other **filter-feeding** animals feed on phytoplankton and in turn are eaten by larger animals. Unfortunately, slowly degradable poisonous substances such as pesticides, mercury, cadmium, and polychlorinated biphenyls (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 involved DDT, a pesticide running off from farms to water, being absorbed by phytoplankton, filter-feeders, fish, and finally fish-feeding pelicans. In Mississippi, pelicans were eliminated from the state as DDT in their bodies upset their reproductive process.

The 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 mostly diatoms and dinoflagellates (Figure 1). Diatoms are single-celled organisms with glass (silicon dioxide) cell walls made up of two valves. Some marine species are centric (circular, like a button) and some on elongated (pennate). Diatoms are one of the most nutritious food sources for animals. Diatoms occur singly or in chains and can multiply up to three times a day under ideal conditions. **Dinoflagellates** are single-celled organisms that generally possess two whip-like **flagella** causing them to constantly spin as they move. 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 kill fish (Figure 2).

Phytoplankton must stay in the **photic zone** to survive, and even though they have little or no means of movement, they have evolved several adaptations to increase their **buoy-**

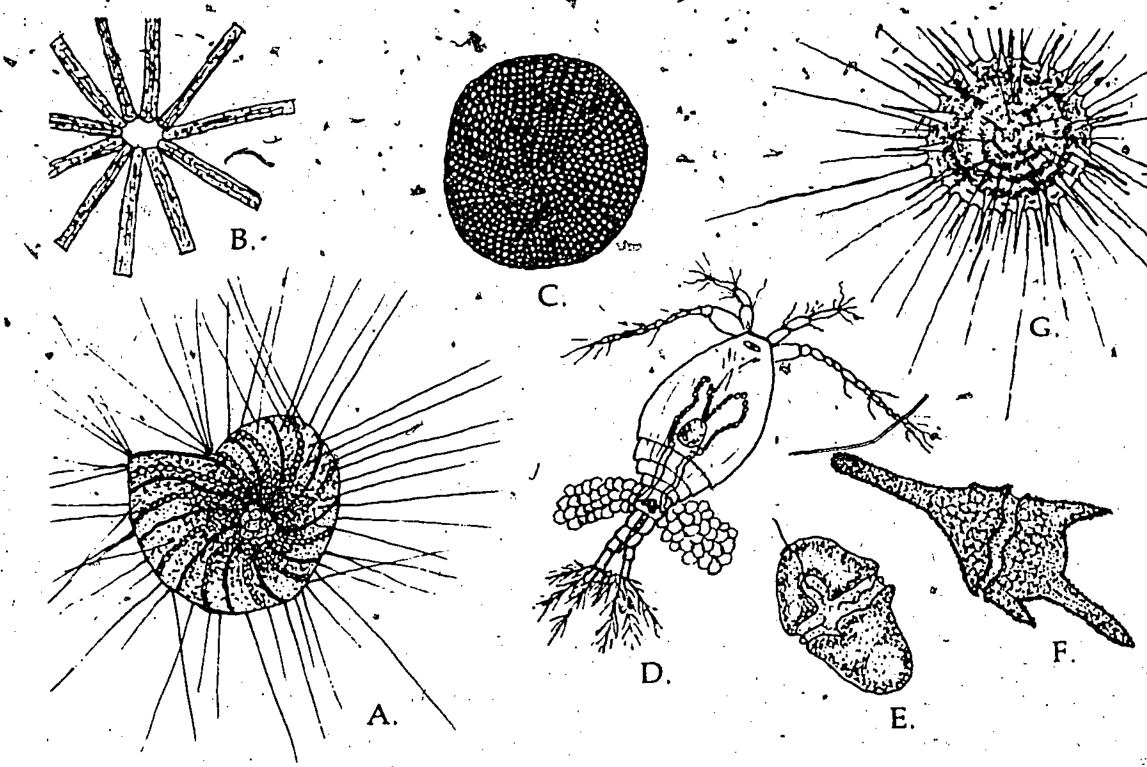


Figure 1. Organisms sometimes found in plankton tows. A, *Foraminiferan;* B-C, *Diatoms;* D, *Copepod;* E-F, *Dinoflagellates;* G, Radiolarian.

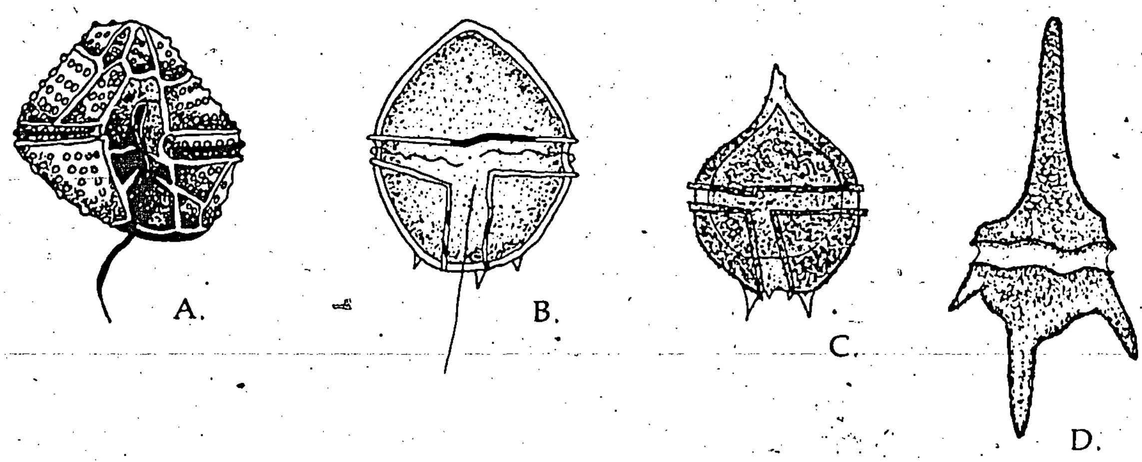


Figure 2. Representative dinoflagellates. A, *Gonyalux;* B, *Peridinium;* C, *Glenodinium;* D, *Ceratium.*

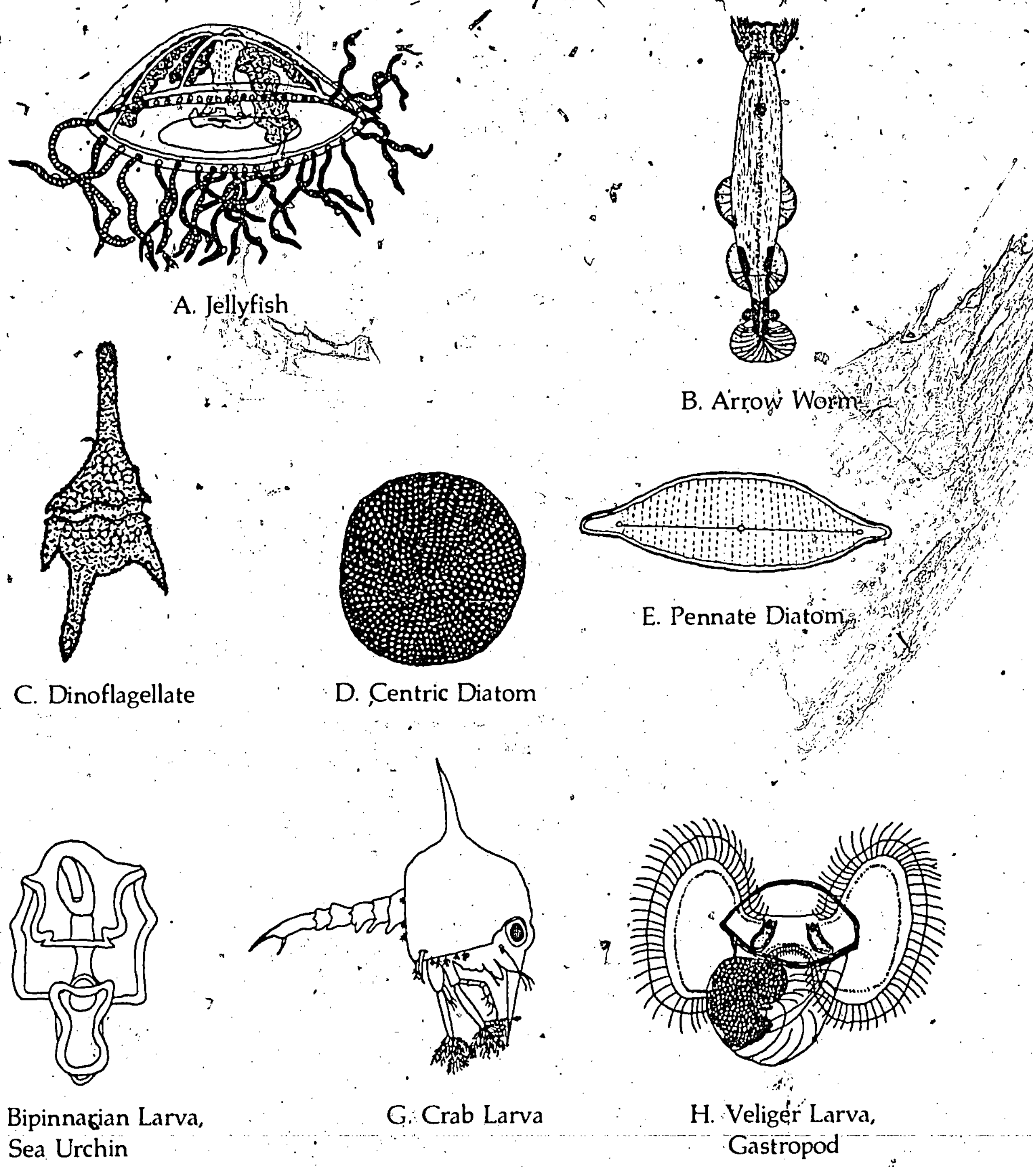


Figure 3. Holoplanktonic and meroplanktonic organisms. A-B, holoplanktonic zooplankton; C-E, holoplanktonic phytoplankton; F-H, meroplanktonic larval forms.

ancy. 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 (Figure 3). 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 of 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 increases buoyancy.

VOCABULARY

aquatic—living in water.

benthic organisms—bottom dwelling organisms.

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.

crustacea—a class of the arthropods; these organisms consist of common marine animals, including shrimp, crabs, water fleas, barnacles, etc.

diatom—single celled microscopic plants forming a major component of plankton.

dinoflagellate—single celled microscopic organisms possessing both plant and animal characteristics.

ecosystem—community of organisms interacting with each other and the environment in which they live.

environment—the surroundings of an organism.

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.

food chain—the transfer of the sun's energy from producers to consumers as organisms feed on one another.

gas bladders—gas filled organs providing buoyancy in fish organisms.

heavy ions—a group of charged atoms which have high atomic weights.

holoplankton—animals which spend their entire lives as plankton.

inorganic nutrients—substances which promote growth and development in organisms. Inorganic nutrients do not contain carbon.

larval stage—an immature stage in the life of an animal.
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.
marine ecology—study of the relationships between organisms and the ocean environment.
meroplankton—animals which are temporary members of the plankton.
morphology—study of form and structure of individual plants and animals.
nekton—those animals that are active swimmers, such as most adult squids, fish, and marine mammals.
organic material—any type material which contains the element carbon.
photosynthesis—process of plants by which energy-rich organic compounds are made from water and carbon dioxide using sunlight as the energy source.
photic zone—the portion of the ocean where light intensity is sufficient to accomodate plant growth.
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, competition.
primary production—the synthesis of organic material by plants.
productivity—amount of organic material formed in excess of that used for respiration. It represents food potentially available to consumers.
protozoa—single celled, nongreen, animal-like protists.
specific gravity—the ration of the weight of any volume of a substance to the weight of an equal volume of some other substance taken as the standard or unit.
valve—another name for "shell" in mollusks; in diatoms one half of the frustule.
water column—the area from the water surface to the bottom.
zooplankton—tiny animals that float in the upper portion of the water column, have extensive vertical migration patterns; and feed on phytoplankton.

VOCABULARY ACTIVITY FOR CONCEPT A

Hidden in the letters below are 10 vocabulary words that are used in concept A. The words may be written vertically (up and down), horizontally (across), upside-down, or diagonally. Try to find the 10 words.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
H	U	G	F	M	C	T	S	V	C	Z	P	E	P	F
E	O	U	C	Y	T	O	N	L	K	I	K	O	D	I
A	Y	E	A	T	O	Z	S	K	D	T	M	G	O	C
V	A	L	V	E	A	N	E	Y	O	G	F	P	A	A
Y	N	T	Z	F	C	O	O	N	S	A	L	M	C	D
I	C	O	J	Z	P	L	A	N	K	T	O	N	T	G
O	Y	I	M	P	A	T	A	I	E	N	E	A	O	H
N	E	B	T	W	P	O	I	U	R	C	L	M	R	G
S	A	L	L	A	Z	U	C	H	A	L	N	N	O	J
C	A	C	G	O	U	N	O	F	E	C	A	B	F	Z
D	E	C	T	F	J	Q	L	G	M	O	Q	Z	T	P
J	T	O	A	C	E	J	A	K	G	T	W	V	Z	Z
K	R	N	Y	G	O	L	O	H	P	R	O	M	C	M
P	A	C	B	E	F	G	S	H	C	T	L	Q	P	O

Answers: heavy ions, buoyancy, valve, aquatic, morphology, protozoa, plankton, ecosystem, nekton, flagella

VOCABULARY ACTIVITY FOR CONCEPT A

Below you will find a group of six scrambled vocabulary words that are used in concept A. Unscramble the letters of each word and write it in the blank provided. Notice that each word has one letter circled. If you write each one of these letters down in order you can spell the "mystery vocabulary word".

1. y v u c d p o r t i i t ____________
2. c n n o g r a i i t r n u t s e i n ____________
3. n u r s c e a t u a ____________
4. s i s e h t n y s o t o h p ____________
5. v m e t i n r n e n o ____________
6. k p m n a t n a l e o r ____________

What is the "mystery vocabulary word"? ____________

Here's a tougher one for you.

1. l v a r a l e t g a s ____________
2. c o g r a i n t r n u t s e i n ____________
3. e n a m r i o l e g o c y ____________
4. e t a l l e g a l f o n i d ____________
5. t c e n b h i ____________
6. e p i o h t e z o n ____________
7. c i f e p s i c v t g y a r i ____________
8. d o f o n a h c i ____________
9. r t l i e f r e d f e e ____________
10. n o t k n a l p o t y h p ____________
11. a t e w r m u c o l n ____________
12. a s g e r l a s d b d ____________

What is the "mystery vocabulary word"? ____________

Activity: CONSTRUCTION OF A PLANKTON NET

A plankton net is a device for concentrating small aquatic organisms for closer examination. The small organisms collected in a plankton tow will constitute an assemblage of organisms that go unnoticed by most individuals. Usually a microscope is needed to identify and examine these organisms. They are usually prolific in numbers and play a major role in food chains of any given ecosystem.

A net with very fine mesh is used in the plankton net because many of these tiny organisms would pass through an ordinary dip net. The plankton net is essentially a cloth funnel which allows water to pass through but retains the living organisms. The collected organisms will be found in the small glass or plastic bottle found at the bottom of the net.

Objective

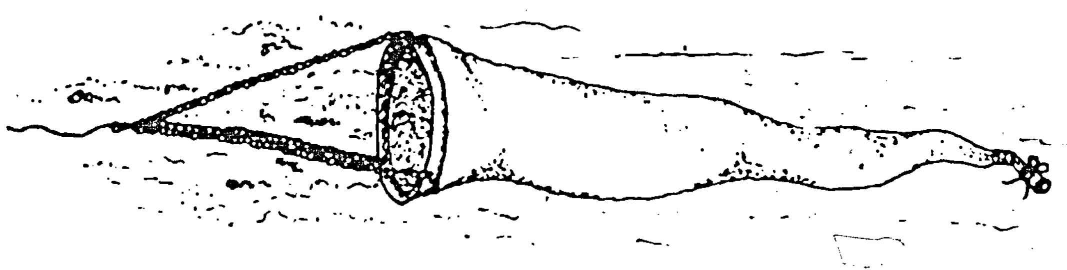
To make a plankton net.

Materials (for each net)

One leg of nylon hose, a wire coat hanger, string, small flask or bottle.

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.



Activity: PLANKTON BODIES

Objective

To investigate how shape/surface area affect ability to float. This will enable you to understand how plankton maintain their position in the water column.

Materials

Several jars or trays full of water, miscellaneous pieces of paper, metal, cloth, cardboard, glue, timer, (vegetable oil — optional).

Procedure

Examine the illustrations as pictured in Figure 1 of various plankton forms and observe their shapes. Discuss some of their modifications for floating.

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 materials to sink to the bottom.

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 flotation?

CONCEPT B

Free-swimming animals called nekton have made adaptations in body structure, feeding patterns, and swimming behavior in order to increase their chances of survival.

Objectives

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

a. To name four animals which are nektonic.
b. To demonstrate with hand motions, the swimming motions of fish, reef or grass flatfish, marine mammals, and octopuses.
c. To list the two basic feeding patterns used by fish.
d. To explain one change in the mouth parts of a bottom-feeding fish to help it collect food.
e. To discuss what happens when oxygen passes over the gill filaments of a fish.
f. To suggest a reason why the gill filaments of a living fish are very red.
g. To provide a listing of five ways in which nekton can protect themselves from being eaten.

NEKTON

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 counteract 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. Plants are not considered to be nekton. Nekton may have swimming powers to migrate long distances and traverse the water column from surface to ocean floor. Table 1 lists characteristics of some of the common groups of nekton while Table 2 shows vertical zonation of nekton.

Although nektonic animals include many diverse creatures, their 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

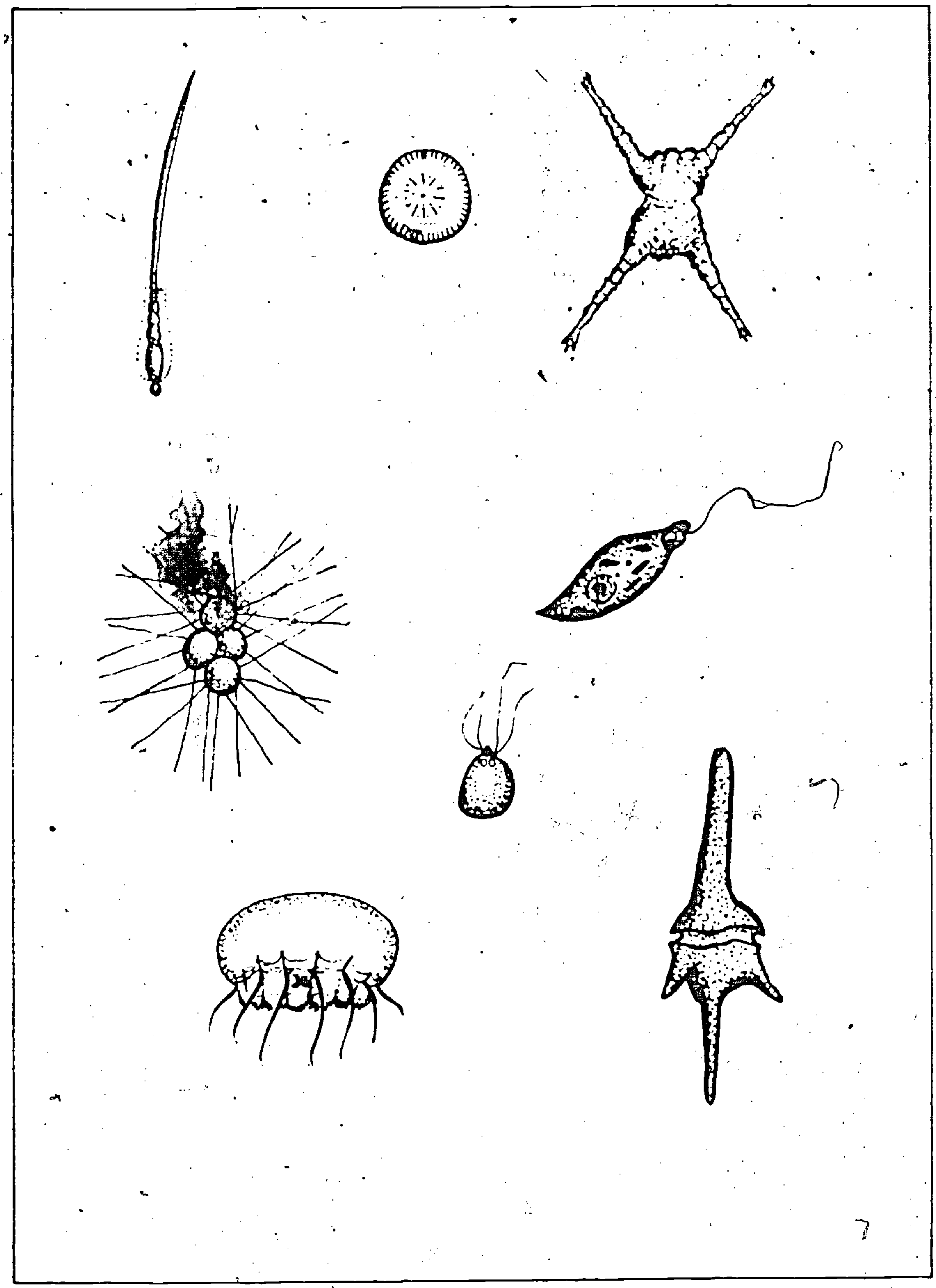


Figure 1. Planktonic forms.

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

Table 2. Vertical Zonation for Nekton

Zone	Depth (m)	Environmental Characteristics	Example	Animal Characteristics
Epi-pelagic	0-200	Lighted, variable temperatures	tuna, coastal fishes (See Figure 1A)	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 (See Figure 1B)	enlarged eyes, luminescent
Bathypelagic	2,000-6,000	No light, increased water pressure, colder	gulper eel, angler fish, squid (See Figure 1C)	small eyes, poor swimming muscles, flabby, few species and numbers.
Hadopelagic (trenches)		No light, most pressure, coldest 4°C	pelagic fish (benthic Tripod fish) (See Figure 1D)	

shape, enables the barracuda to have 45 mph bursts of speed and tuna to migrate thousands of miles (Figure 2).

(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 (Figure 3).

(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 seahorse'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 (Figure 4).

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, comblike filaments which collect plankton as the fish swim open-mouthed through the water. Baleen whales, e.g., blue whale, have brush-like **baleens** that 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. 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 which 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. Mouth modifications of fish are shown in Figure 5.

Adaptations of nekton for obtaining oxygen also provide good examples of classroom discussions of evolutionary processes and their results. Whales and porpoises have evolved modified nostrils on the top of the head. As a result, whales continue swimming while breathing through the "blowhole". These marine mammals 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 allows the animals to maximize submergence time. Together these adaptations allow marine mammals to spend long periods underwater, then surface briefly, exhale warm breath as a spout, inhale quickly, and begin another dive. 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 filaments. During passage over the gills,

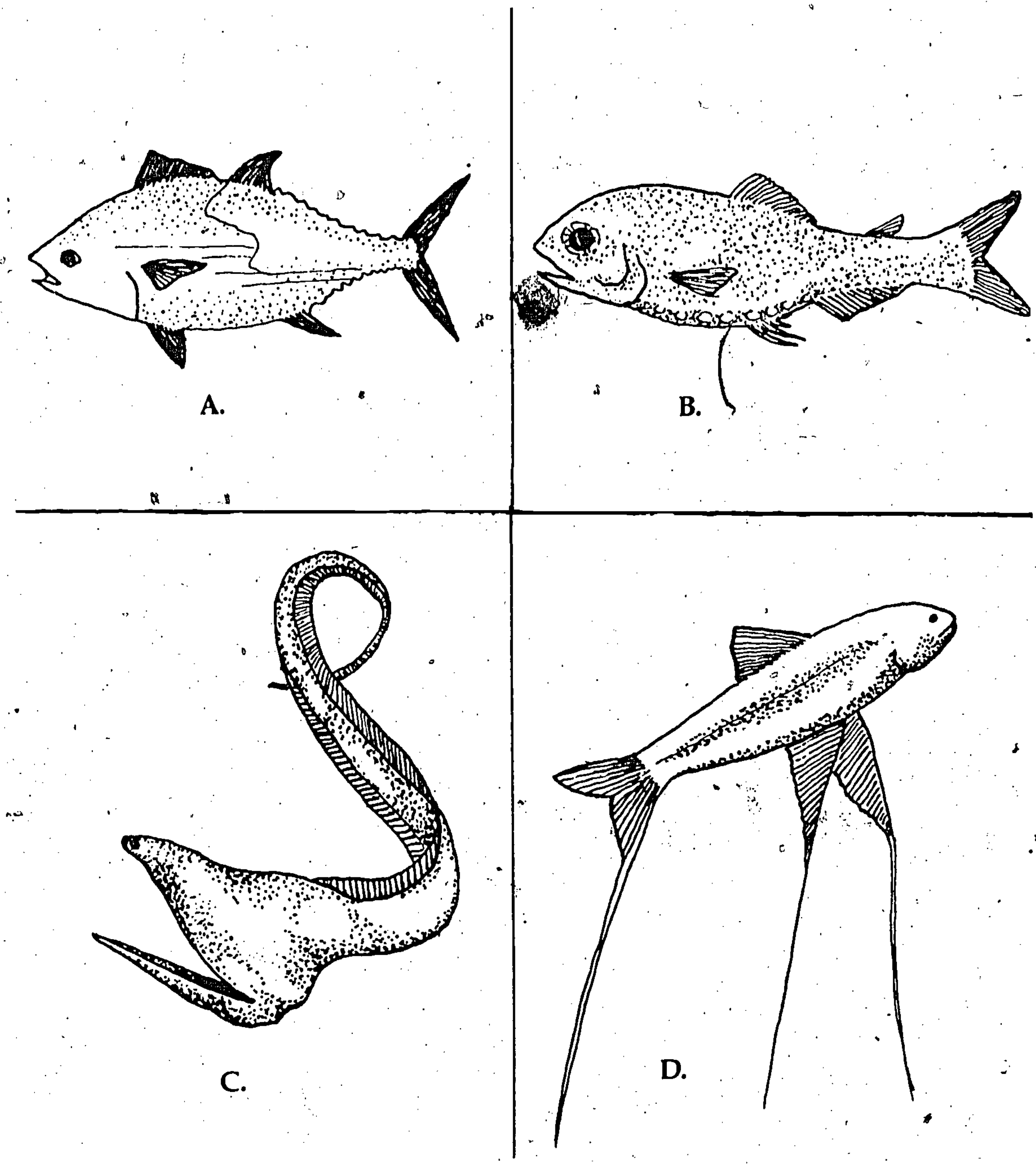


Figure 1. A, Tuna. B, Lantern Fish. C, Gulper eel. D, Tripod fish.

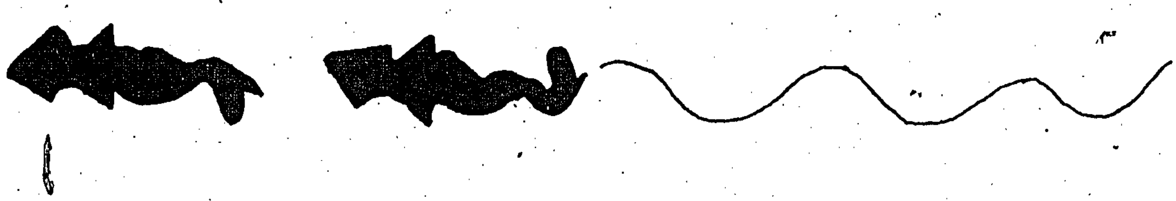


Figure 2. Lateral undulation.

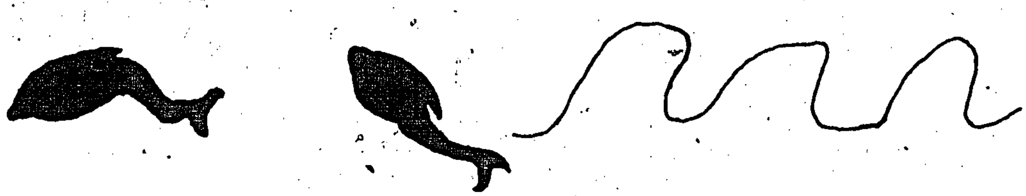


Figure 3. Dorso-ventral undulation.

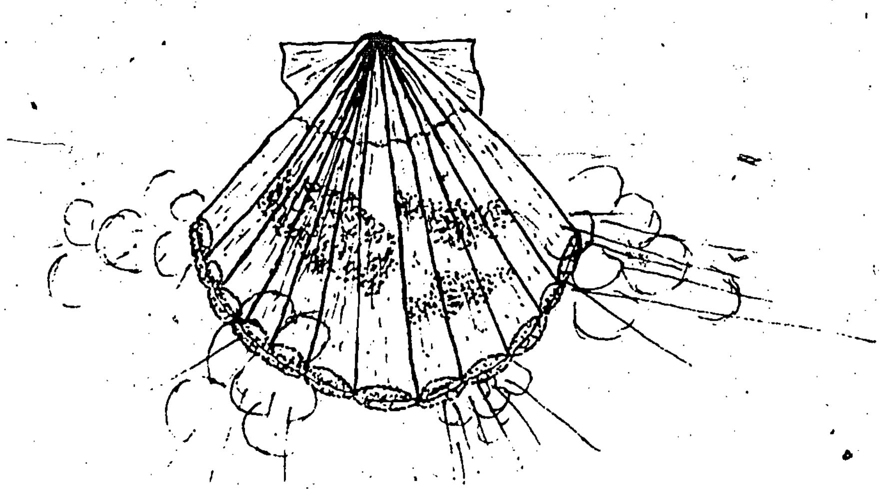


Figure 4. Principle of jet propulsion exhibited by scallop.

ERIC

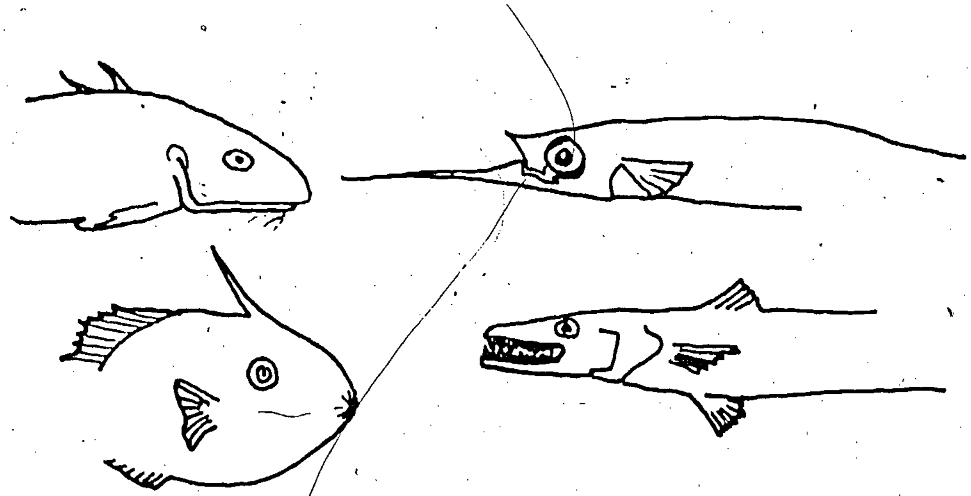


Figure 5. Modifications of fish mouthparts for feeding.

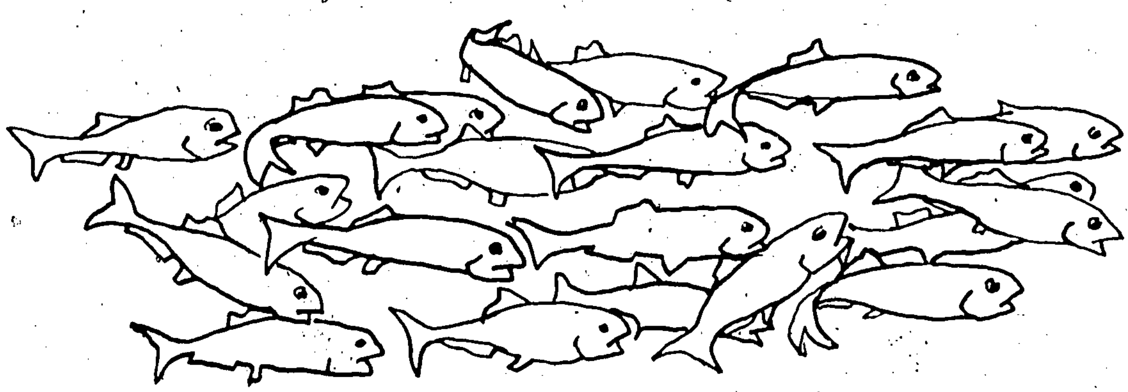


Figure 6. Schooling of fish.

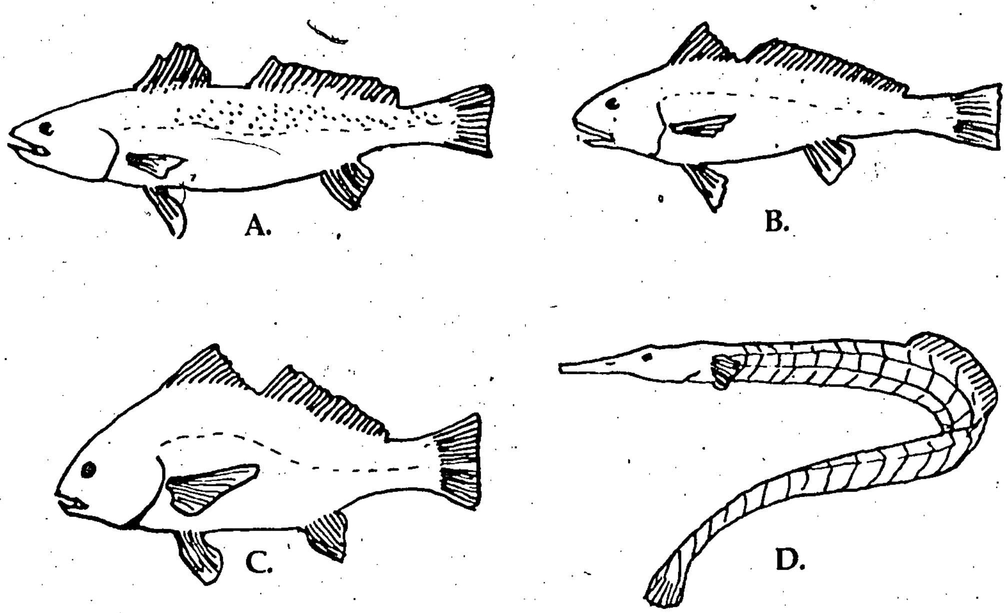


Figure 7. A, Mullet. B, Trout. C, Drum. D, Pipefish.

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 lack of oxygen, 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 wastes are passed. Sensitive equipment detects 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 most rapidly or are able to hide have the best offense/defense. Consequently, they can avoid predation and continue reproducing. Quickness (squid, pinfish), **schooling** (menhaden, silversides, herring), and burrowing (flounder, toadfish, stargazers, and skate) enable fish to avoid predation (Figure 6). **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) (Figure 7). 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.

Fish are the most abundant members of nekton. Gulf Coast fish assemblages are among the most diverse as both **tropical** and **temperate** organisms occur. 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, while others migrate south and others may die.

In addition to temperature distribution, **salinity** is also a major factor influencing the distribution of fish. Most fish are strictly marine and need salinity similar to that of the ocean 35‰. 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.

VOCABULARY

baleen—the horny material growing down from the upper jaw of large plankton-feeding whales, which forms a strainer or filtering organ.

cartilage—a strong, pliable supporting tissue in vertebrates.

coral reef—a chain or range of fragments of corals, coral sands, and the solid limestone resulting from their consolidation lying at or near the surface of the water.

countershading—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.

crustacean—a class of the arthropods; these organisms consist of common marine animals, including shrimp, crabs, water fleas, barnacles, etc.

diffusion—random movement of particles resulting in their movement from a region of greater concentration to a region of lesser concentration.

dissolved oxygen—oxygen which is found in a water solution. The amount of dissolved oxygen in water depends on the physical, chemical, and biochemical activities that occur in the body of water.

dorso-ventral undulation—the up-and-down vertical movement which is characteristic of marine animals.

estuary—a relatively small body of water that is set off from the main body of water and is affected by the rise and fall of the tide. Estuaries contain mixtures of fresh and salt water.

filter-feeding—the process of taking food from water as it flows through the animal's body.

gills—organs in fish and other aquatic animals which are modified for absorbing dissolved oxygen from water.

habitat—the place where an organism lives.

jet propulsion—propulsion in one direction by a jet of water that is forced in the opposite direction.

lateral undulation—the side-to-side swing of the animal's tail, usually including the sway of the whole body.

mollusks—soft-bodied, mostly marine animals, usually enclosed within a hard outer shell of calcium carbonate.

nekton—actively swimming animals, such as fish.

pelagic—inhabiting the open water of the ocean rather than the bottom or the shore.

plankton—drifting organisms in the sea.

predation—feeding of one organism upon another organism.

salinity—a measure of the total amount of dissolved salts in sea water.

schooling—a well-defined social organization of marine animals consisting of a single species with all members of a similar size.

scull—a method of maneuvering in which the fins or flippers are moved in a back and forth manner, similar to propulsion by use of oars.

sound—a body of water which occupies the area between a mainland and an island.

substrate—a surface available for living things.

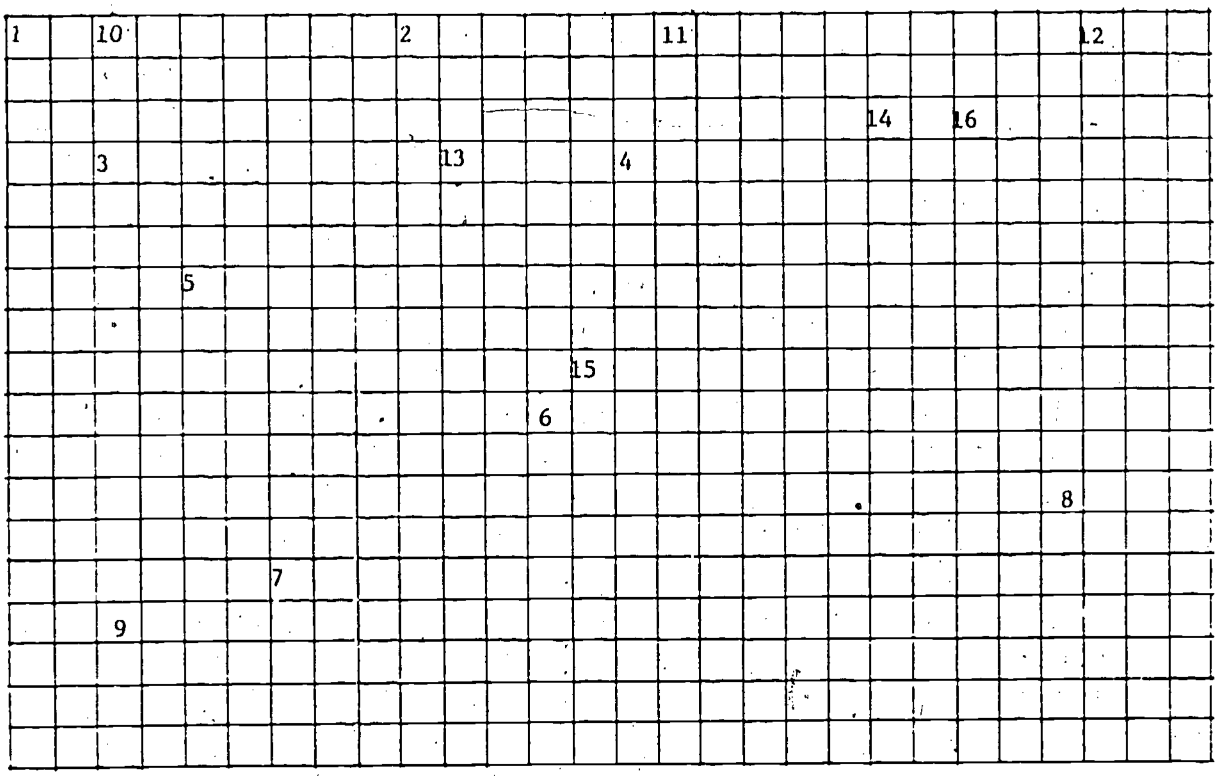
temperate species—organisms which are adapted to changing seasons.

tropical species—organisms living approximately between latitudes of 23° 30′ north and south of the equator; they are adapted to warm temperatures with little season differences.

water column—the area from the water surface to the bottom.

VOCABULARY ACTIVITY FOR CONCEPT B

The following activity is based upon key words taken from vocabulary definitions that you have studied in Concept B. Use these clues to solve the crossword puzzle.



ACROSS

1. Contains mixture of fresh and salt water
2. Method of movement
3. Feeding
4. From water surface to bottom
5. An organism's home
6. Supporting tissue
7. Class of arthropods
8. Absorb dissolved oxygen
9. Social organization of certain animals

DOWN

10. Adapted to warm temperatures
11. Open water of the ocean
12. Color pattern
13. Actively swimming
14. Chain of particular fragments
15. Filtering organ
16. Surface available for living things

CONCEPT C

Intertidal organisms are adapted to the environment in which they occur.

Objectives

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

a. To name four 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.
c. To compare and contrast methods by which sand and mud flat animals obtain oxygen while buried in the sand.
d. To explain how "salt glands" are useful to *Spartina*.
e. To prepare two wet mount slides without assistance from the teacher.
f. To explain how the process of osmosis operates.
g. To examine the characteristics and behavior of an organism that can be found in the intertidal zone—the snail.

INTERTIDAL ORGANISMS AND THEIR ENVIRONMENT

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 must also 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.

The Gulf Coast's coastal zone contains a variety of **intertidal benthic** habitats including exposed beaches, sand and mud flats, and sheltered salt marshes. Organismal adaptations to these three **habitats** will briefly be discussed.

Sandy Beaches

Some of the organisms inhabiting sand beaches of the Gulf Coast are illustrated in Figure 1. 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 of the **barrier islands** is the surf that breaks on its surface. This severe wave action is somewhat limited in the **sound** because of the presence of the barrier islands. On the protected beaches storms provide the most waves and do cause changes in the surface. Sand beach **biota** must tolerate the force of these waves and the shifting sands that they create. Thus, sand beach biota of the south beaches of the barrier islands are good burrowers. The most obvious burrower is the mole crab, *Emerita*. These small **crustaceans** can be seen moving about rapidly within the wave's wash 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 illustrates 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 crab). These animals usually live in protected beaches or **sand flats**, and their burrows are so deep (up to six feet for the ghost crab) 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.

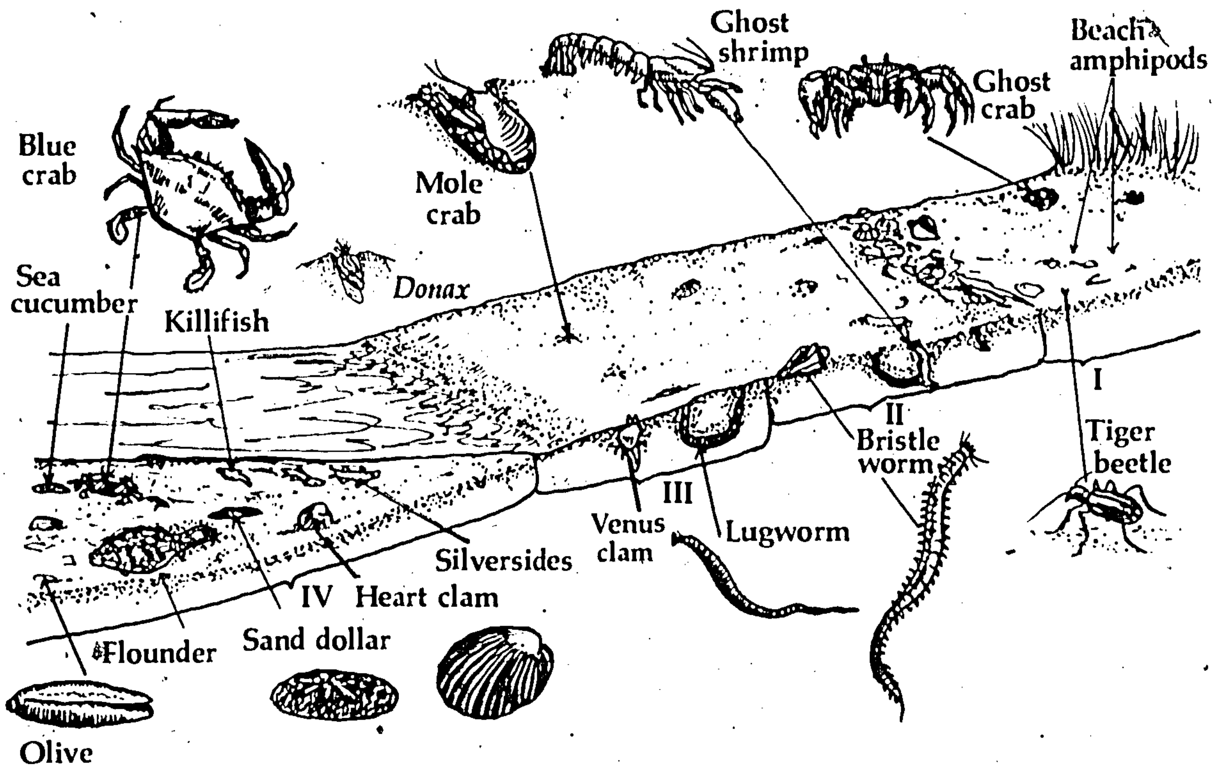


Figure 1. **Life on a sandy beach along the Gulf Coast. Although strong zonation is absent, organisms still change on a gradient from land to sea. (I) Supratidal Zone: ghost crabs and sand fleas; (II) Flat Beach Zone: ghost shrimp, bristle worms, clams; (III) Intertidal Zone: clams, lugworms, mole crabs; (IV) Subtidal Zone: blue crabs, sand dollars, silversides.**
Redrawn from Smith, R.L., 1966. *Ecology and Field Biology*. Harper and Row, p. 236.

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 desiccation 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 2. 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. You can understand the problem of water loss via gills that **aquatic animals** have 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.)

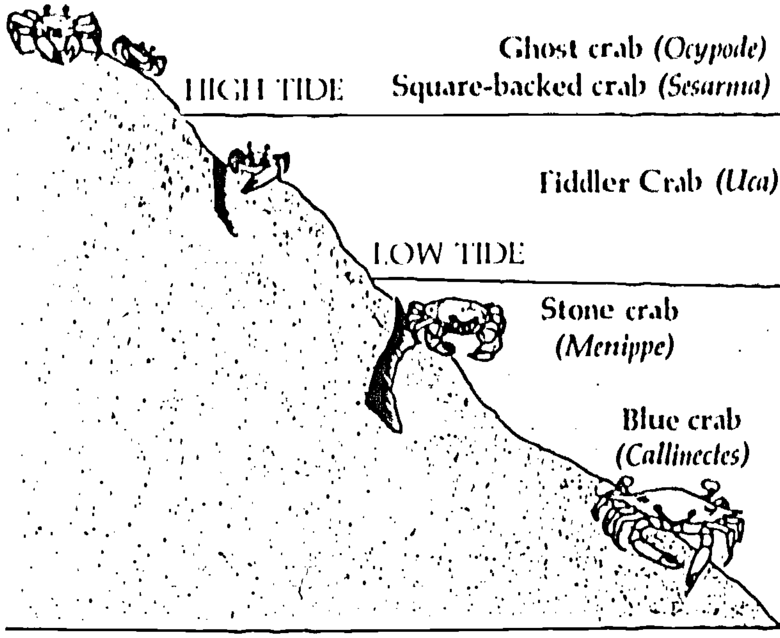
Another adaptation occurs in sand and mud flat animals which burrow for protection. They face the problem of obtaining oxygen as water in sediment usually has no available oxygen. Thus, clams have evolved long **siphons** which extend to the surface. Worms build tubes through which they create currents carrying oxygenated water. Both types of animals must "hold their breath" or close up during periods of low tide (Figure 3).

Salt Marsh

Higher plants also illustrate adaptations to intertidal existence. The **flora** of Gulf Coast **salt marshes** provides useful examples. Salt is the most obvious problem for organisms living in the sea. Relatively few higher plants have solved this problem as there are only 30 species that can live in sea water. Those that have solved the problem are often important sources 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 4. 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 mechanisms. The best known of these adaptations is the presence of "salt excreting glands" in the salt marsh cordgrass *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 formed 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 the 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 similar to those found in animals



	No. Of Gills	Body To Gill Ratio
Ghost crab *(Ocypode)*	12	67:1
Square-backed crab *(Sesarma)*	16	63:1
Fiddler Crab *(Uca)*	12	46:1
Stone crab *(Menippe)*	18	34:1
Blue crab *(Callinectes)*	16	23:1

Figure 2. Gill reduction ratio in crabs from terrestrial to marine species.
Adapted and redrawn from Mauldin, L. and Frankenberg, D., *Unit Three: Coastal Ecology.* 1978 (Marine Education Materials System, No. 000607.)

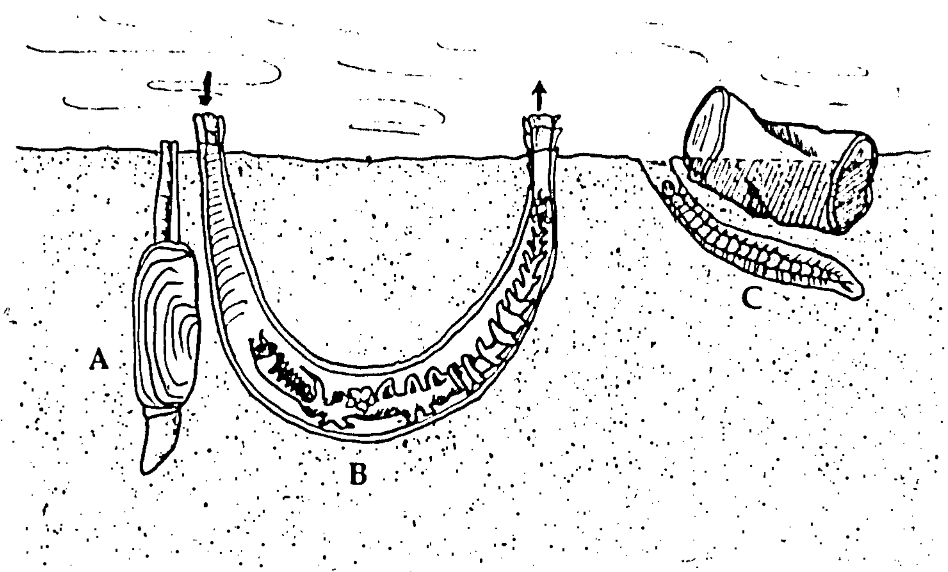


Figure 3. Sand flat adaptations. A, Razor clam *(Tagelus)* showing long siphons and foot for burrowing. B, Parchment worm *(Chaetopterus)* with body modification for creating a current in and out of the U-shaped tube. C, Blood worm *(Glycera)* creating a current by waving its fleshy appendages.
Adapted and redrawn from Mauldin, L. and Frankenberg, D., *Unit Three: Coastal Ecology,* 1978 (Marine Education Materials System, No. 000607).

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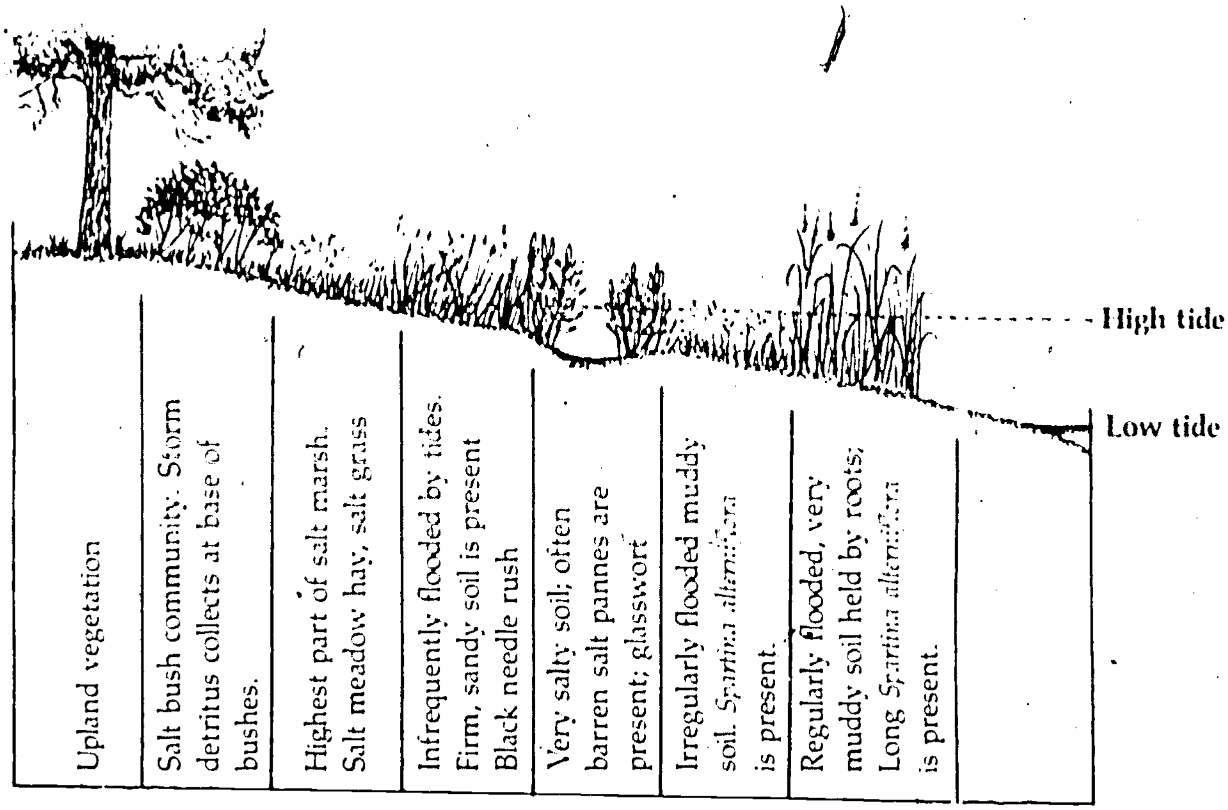

Figure 4. Idealized salt marsh zonation typical of the Gulf.

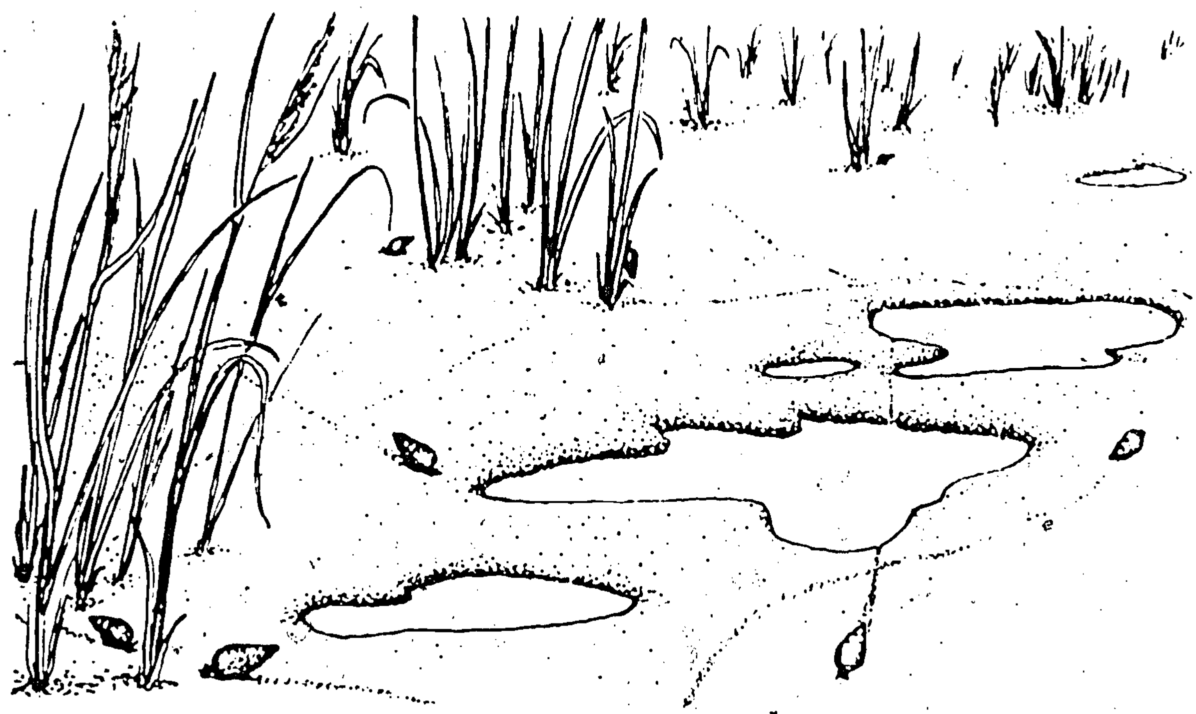

Figure 5. *Spartina alterniflora* and mud snails.

inhabiting the mud flat. This is due to alternating wet and dry tidal periods. In fact, many of the same animals live in both area, 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 common mud snail, *Nassarius*,* crawls on the muddy floor of marsh pools, scavenging **detritus.** (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** (Figure 5). *Melampus* snails, periwinkles, and mud snails all possess **opercula** or "trap doors" which 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).

VOCABULARY

algae—single celled or many-celled photosynthetic plants.
aquatic animal—an animal that lives in the water.
barrier island—a long, narrow island parallel to and not far from a mainland coast. The island is composed of material heaped up by ocean waves and currents.
benthic—living in or on the ocean floor.
biota—the community of organisms of a given region.
crustaceans—a class of the arthropods; these organisms consist of common marine animals, including shrimp, crabs, water fleas, barnacles, etc.
detritus—very small particles of the decaying remains of dead plants and animals; an important source of food for many marine animals.
diffusion—the transfer of substances along a gradient from regions of high concentration to regions of lower concentration.
estuary—a relatively small body of water that is set off from the main body of water and is affected by the rise and fall of the tide. Estuaries contain mixtures of fresh and salt water.
flora—plant population of a given area; predominant marine flora are floating phytoplankton, attached nearshore algae, and marine grasses.
gills—organs in fish and other aquatic animals which are modified for absorbing dissolved oxygen from water.
gill chambers—depressions in which gills are located.
habitats—places where organisms live.
intertidal—in the marine environment, the area of the shore that is periodically covered and uncovered by water.
morphology—a study of form and structure of individual plants and animals.
mud flats—a level tract of land at little depth below the surface of water, or alternately covered and left bare by the tide.
operculum—a hard covering of the gill chamber in fish; also, the plate which covers the opening of some snail shells.
osmosis—diffusion of material across a semi-permeable membrane.

oxygen depletion—a state in which the normal amount of oxygen has been lost in a body of water by heat, respiration, decay.

physiology—the study of function of parts of living things.

salinity—a measure of the total amount of dissolved salts in seawater.

salt marsh—flat land subject to overflow by salt water. The vegetation of salt marshes may consist of grasses or even shrubs.

sand flats—a level tract of land that is covered by sand. This land is only a little below the surface of the water, or it is alternately covered and left bare by the tide.

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 excrements.

sound—a body of water which occupies the area between a mainland and an island.

zonation of plant species—organization of a habitat into more or less parallel bands of plants as a result of differences in environmental conditions within the habitat.

VOCABULARY ACTIVITY FOR CONCEPT C

Using the letters of the alphabet given below, complete the words. All words are related to Concept C. Use each letter only once, placing it on a dash space. Cross off the letters as you use them to help keep track.

A A A A A A A A C E E E G H H I I I I I L L M N
O O O O O P P P R R R S S T T T T T U U U Y Z

1. _ L _ A E
2. G _ L _ S
3. _ _ U S _ A C E _ N S
4. S _ _ N D
5. _ H _ S I O L _ G Y
6. S _ L _ N _ T Y
7. _ _ _ N D F _ A T _
8. B _ _ T H I C
9. F L _ _ _
10. _ _ B _ T _ _ S
11. O _ _ _ C _ L _ _
12. B I _ _ _
13. D _ _ R _ T U S
14. _ _ N A _ I O N
15. S I _ _ O N S

Activity: OSMOSIS

When the **environment** is changed, how does this affect the kinds of organisms found in a **community?** This question can partially be answered by placing living organisms in an altered environment. Today, we shall place two different living plants in an altered chemical environment. We shall alter the environment by the addition of salt to an existing aquatic community. Then, we will observe the effect as demonstrated by the organisms being used.

In our investigation, we will be using sodium chloride as the **solute.** When a cell is placed in an environment where the solute outside of the cell is greater than within the cell, the available water will flow outside of the cell. This will cause immediate shrinkage of the **plasma membrane** and eventual death of the cell. This **osmosis** will be direct diffusion from a higher concentration of water molecules to a lower concentration of water molecules. When the plasma membrane shrinks away from the normal **turgid** condition it is called **plasmolysis.**

In this investigation, the quantity of salt will be varied to observe the effect of different quantities of solute on organisms. The variation of solute will simulate the variable salinity of **estuarine systems.** The organisms that are able to survive in changing environments must have mechanisms to compensate for these changes. This fact alone dictates the **diversity of living organisms** found in many communities.

The two plants selected for your study today are the elodea water plant and the white potato. The elodea plant will be used so that you will be able to verify the cellular effect of a changing environment and the potato will be used to permit you to quantify the effect on a larger organism.

Materials (group of 2 students)

Part I — 2 white potatoes, (6) 250 ml beakers, (100 ml) 5% sodium chloride solution, (100 ml) 10% sodium chloride solution, (100 ml) 12% sodium chloride solution, (100 ml) 15% sodium chloride solution, (100 ml) distilled water, balance, glass marking pencils or labels, paper towel, metric ruler

Part II — elodea sprigs, microscope, microscope slide, cover slip, water, medicine dropper, (5 ml) 5% sodium chloride solution, (5 ml) 15% sodium chloride solution, distilled water, paper towel

Part I

Take the potato and cut eighteen pieces that measure 2 cm x 2 cm x 1 cm each. Place the pieces in 6 stacks of three and weigh each stack. Now place each stack into a different beaker containing the specified solution. In the beakers place the following: in beaker 1 place 100 ml of distilled water, in beaker 2 place 100 ml of tap water, in beaker 3 place 100 ml of a 5% sodium chloride solution, in beaker 4 place 100 ml of a 10% sodium chloride solution, in beaker 5 place 100 ml of a 12% sodium chloride solution, and in beaker 6 place 100 ml of a 15% sodium chloride solution. Permit the potato slices to stay in the beaker about 25 minutes, then remove the potato slices and blot them quickly and weigh each stack. Record all data on the table accompanying the investigation. Indicate on the table the various changes if any occurred. Note any changes in the appearance and texture of the potato slices. __________

____

Explain ____

Do you think that the length of exposure time could have any effect on your potato investigation? ____

Why did the salt not move into the plant cell to counteract the rapid outward movement of water? ____

____

Data Table for the Change in Mass of the Potato Slices

	Beaker 1	Beaker 2	Beaker 3	Beaker 4	Beaker 5	Beaker 6
Initial Mass in grams						
Final Mass in grams						
Increase in Grams						
Decrease in Grams						

Does the amount or quantity of the solute seem to make a difference?

Explain how this kind of plant might survive in each of the six environments.

1. 100 ml distilled H_2O
2. 100 ml tap H_2O
3. 100 ml 5% NaCl soln.
4. 100 ml 10% NaCl soln.
5. 100 ml 12% NaCl soln.
6. 100 ml 15% NaCl soln.

Part II

Prepare a wet mount slide of a fresh elodea leaf. See illustration below. See Figure 1. On low power, find a section of the leaf where you can focus on individual cells, and then switch from low to high and center one complete cell if possible. Now place a drop of the 5% salt solution along one edge of the cover slip. Draw the sodium chloride across the slide by using a piece of paper towel on the edge of the opposite side of the cover slip. If you need more solute, use another drop as you develop your technique.

Observe the cellular structure microscopically as the solute moves across the viewing field.

What do you note? ______________________________

Now try to reverse the process. Can you think of a way? ______________________________

____

Try it. Did you cause a change in the cell? ______________________________

Name some of the cellular structures you were able to observe in the elodea leaf cell.

____

____

Now repeat the above investigation using the 15% sodium chloride solution. Were the results the same? ____________ Explain ______________________________

____

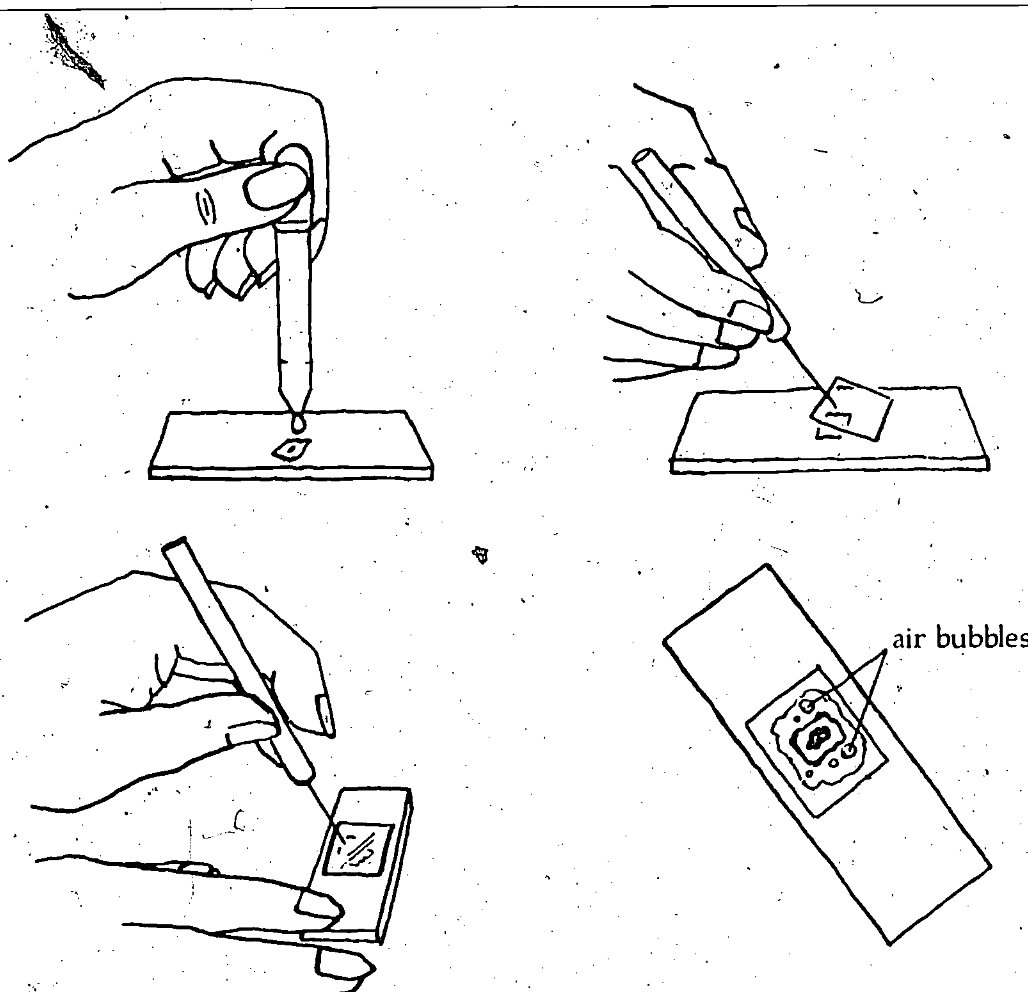

Figure 1. **Diagram of methodology used in preparing a wet mount. Exercise care in preparation of this slide so that air bubbles will not be trapped under the cover slip.**

VOCABULARY

community—a naturally occurring group of organisms living in a particular area.
diversity of organisms—the large number of different kinds of organisms that have varying characteristics found in a particular area.
environment—the surroundings of an organism.
estuarine ecosystem—a complex system of exchanges of materials and energy between living things and their environment, the estuary.
osmosis—diffusion of material across a selectively permeable membrane.
plasma membrane—the boundary which separates a cell from its environment.
plasmolysis—the shrinking of a cell due to loss of water.
solute—the dissolved substance in a solution.
turgid—a cell which is stiff due to the water pressure inside the cell.

Activity: SNAILS—COMMON INTERTIDAL INHABITANTS

Many snails may be found in the intertidal zone along the Gulf Coast. In this investigation you will be allowed an opportunity to collect some of these and study their ~~behavior.~~

Snails belong to the group of animals called mollusks that possess a single shell. Whelks, conches, and moon shells are found in water near the barrier islands. Less familiar, but extremely important ecologically, are the tiny hydroid snails that occupy estuarine mud flats in large numbers. The marsh periwinkle *(Littorina irrorata)* is very abundant along the coastline in *Juncus* and *Spartina* marshes.

Economically the most important gastropod is the oyster drill *(Thais haemastoma)*. This snail is a predator on the Mississippi oyster reefs. *Thais* requires a high salinity and when the salinity increases, the snail invades the reefs and causes extensive damage.

Snails are of significant trophic and economic importance. They provide part of the diet of many marine fish, birds, and mammals. Before you begin your study of snails, refer to the sketch of a snail in Figure 1. Note the important anatomical features. After familiarizing yourself with these features, go out and collect several snails. You should remember where you find them because they were probably found in their natural habitat. Place each snail in a different container for study purposes. Each group should have at least four different kinds of snails.

Materials (per student pair)

Part I: 4 different kinds of snails, 2 hand lens, 1 microscope, 4 snail containers, 2 culture bowls, 1 lettuce leaf, 1 metric ruler, 4 razor blades (single edge)

Part II: Littorina and various freshwater snails, 3 inch square glass plates, bottles of India ink, small paint brushes, glass or plastic containers large enough to hold a glass plate, varnish (optional)

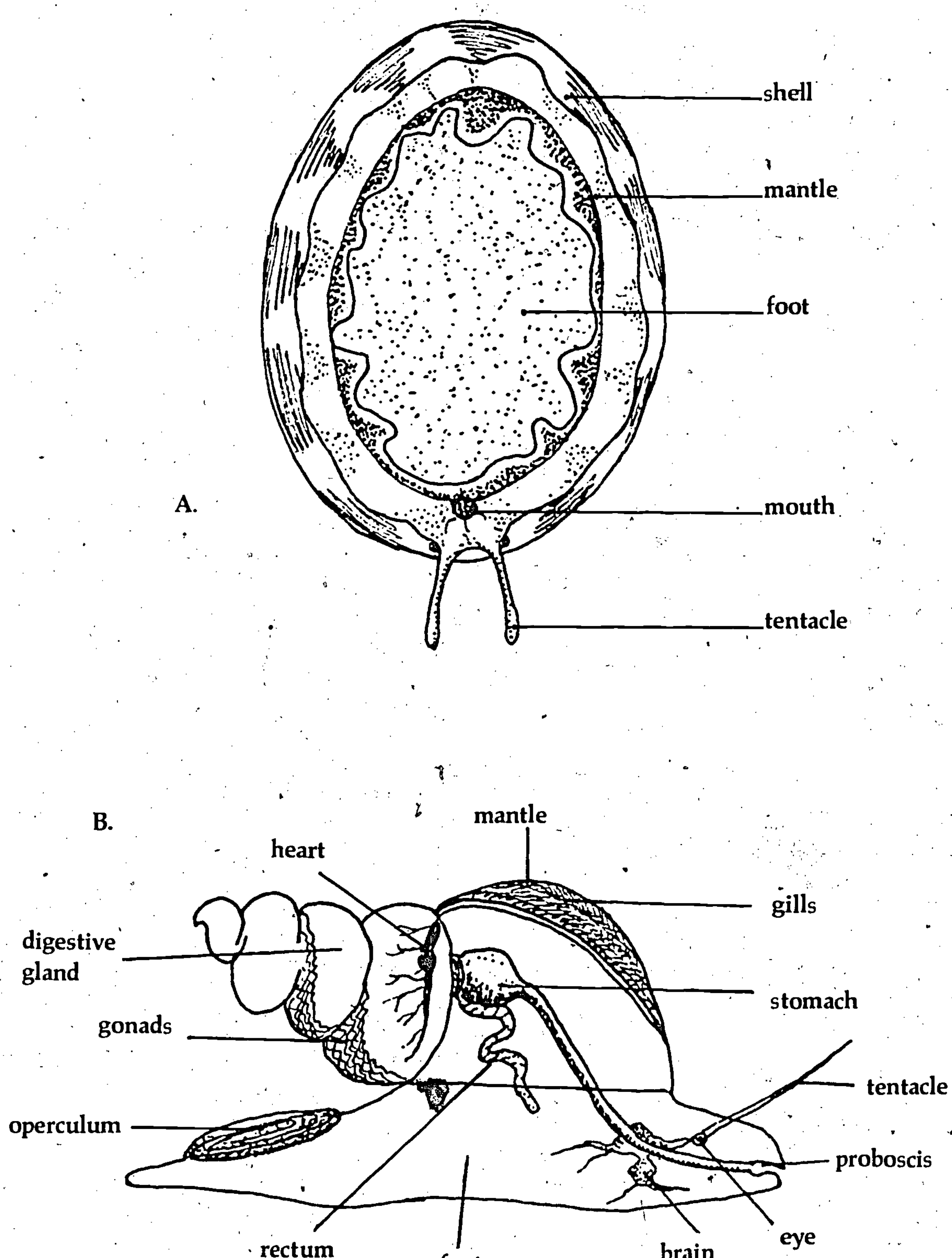

Figure 1. A, Ventral view of a snail. B, Cross-section of a snail.

Part I

Prepare a chart for your snails for easy recording of identifiable features that might be important in its survival. As you proceed through the investigation, record all material that might seem pertinent. Refer to the section at the end of this activity which provides pictures and descriptions of some of the snails that you may have collected for help in identification.

Snail Characteristics:

	Snail I	Snail II	Snail III	Snail IV
Natural Habitat				
Type of Shell				
Special Anatomical Feature				
Size				
Color				
Type of Spiral				
Niche				
Name: Common & Scientific				

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Part II

Take each snail out of its container and place it on a flat surface at your laboratory table. Leave it there for a few minutes. What do you observe:

Snail 1 ______________ Snail 3 ______________

Snail 2 ______________ Snail 4 ______________

Part III

Prepare a razor blade "cage" and place it in a container of water (Figure 2). The water level should be over the snail when it is placed on the wood surface of the cage. Fasten the razor blades with melted candle wax so that they extend about two millimeters above the flat surface of wood. See the diagram for correct construction of the razor blade "cage." Now place one of your aquatic snails on the wood space and observe the snail crawl out of the cage.

How did the snail get out of the cage? ______________

Explain how this must be possible. ______________
Try to observe the snail's foot and determine if this activity has harmed the snail in any way.

How do you account for this behavior? ______________

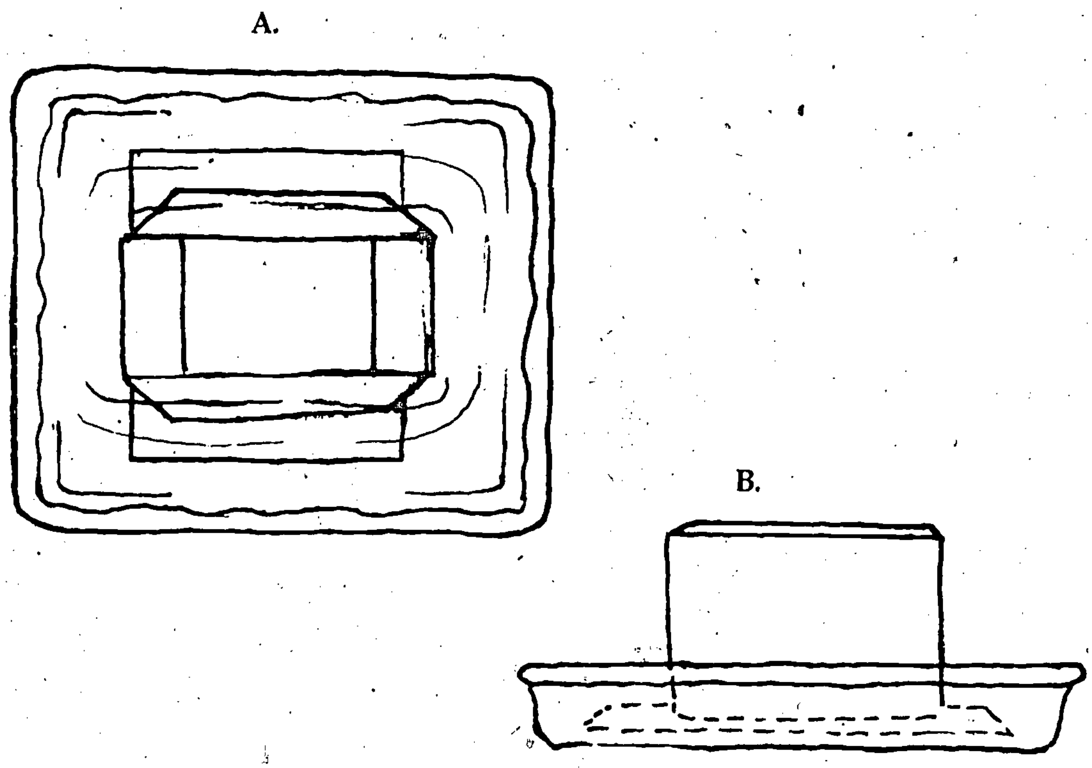


Figure 2. Razor blade cage. A, Top view. B, Cage placed in a pan.

Part IV

The **radula** is important to both **herbivorous** and **carnivorous** snails since it is used for obtaining food. This structure functions in a rasping fashion, that is, it dislodges food material along the surface of rocks or other materials by means of a scraping process. The food material collected in this manner is directed into the mouth of the snail. The radula is sometimes difficult to see in a living snail; however, we can observe the results of the action of the radula through preparation of "radula tracks". Obtain a piece of glass, a bottle of India ink, and a small paint brush from the supply table. Paint the piece of glass and allow it to dry thoroughly. Depending on the type snail you use, put the painted glass in a dish of salt water or fresh water. Place one or more snails on the surface of the glass. Make observations for the next 5-10 minutes or longer but do not disturb the snails unless they move off the glass plate. Describe what happens and then make a drawing of what you see.

Working with your partner and using the observations that you recorded, describe what the radula must look like within the actual living snail. ______________________

____

If you were to use a different snail in your experiment, what would the new radula tracks look like? Would they look the same as the previous set? ______________________

Upon what facts, observations, or other data do you base this conclusion? ____________

____

You may preserve your radula tracks by removing the glass plate from the water, allowing it to air dry, and applying varnish to the glass.

Part V

Place a piece of lettuce close to one of your **terrestrial** snails and try to determine if it will try to eat or not. How does the snail eat? ______________________

____

How does the snail use its small radula? ______________________

Watch the other structures as the snail eats. What do you observe? ______________________

______________________. There is a reddish bulblike structure inside the head just behind the jaws that you might see. This muscular swollen part of the digestive tract is called the **fuecal mass**. Watch it as the snail eats, if you can see it. What do you think it does?

____

Now pick up the snail and hold it close to the light with the shell opening toward you. Can you see any movement of the **gizzard?** It is a reddish four lobed structure containing sand grains. What do you think the function of the sand grains are? ______________________

Some marine snails have special **adaptive** structures that allow them to live in the marine environment. Can you name some of these adaptations? ______________________

____

You will find the descriptions of several of the more common marsh and coastal terrestrial snails in the following list.

Snail Descriptions

A. Flat-coiled Land Snail *(Polygra albolabris)*. (Figure 3A). This is one of several varieties of common flat-coiled land snails found in the United States. This species ranges over most of eastern and central United States, dwelling in moist woodlands. It is found in dark places such as on the undersides of tree trunks lying on the forest floor. These snails are reported to be vegetarians and use their rasp-like strap-shaped tongues (radula) in grinding up fragments of the plants on which they feed. Part of their **mantle cavity** is modified into respiratory organs. The scientific name of this species *(albolabris)* refers to the "white lip", the broad white margin around the opening of the shell. It would be interesting to gather a large number of your local flat-coiled snails to see how many distinctly different kinds you can find in your locality.

B. Salt Marsh Snail (*Melampus bidentatus*) (Figure 3B). The full-grown adults of this tiny kind of common snail are about 1 centimeter long. Young specimens show spiral stripes. These snails are found in numbers throughout marshes from Nova Scotia to Texas.

These snails are reported to crawl up the stems of swamp grasses to escape the rising tides. At low tide, numbers of snails may be seen moving over the mud during the warmer months of the year.

The scientific name of this species (*bidentatus*) refers to the fact that two tooth-like structures may be seen near the bottom of the shell on the inner lip or **columella.**

C. Common Mud Snail *(Nassarius vibex)* (Figure 3C). Adults of this snail are slightly more than ½ inch long. These snails are very common along the bay edges and subtidally. In some localities collectors find many shells of this snail washed up on the beach. This snail is reported to be a **scavenger** ordinarily. The shells of these small snails provide homes for hermit crabs that have recently settled from the plankton.

D. Lettered Olive (*Oliva sayana*) (Figure 3D). In addition to the moon snail, the lettered olive is a very common snail in the intertidal zone. *Oliva* forms a beautiful shell of shades of green and may reach a length of around 5 centimeters. This snail is predaceous, and glides along just beneath the surface of the sand. As they push the sand around their shells, they leave a trail. The front part of the large foot is modified for efficient burrowing. The lettered olive extends its foot and pulls the shell forward. As *Oliva* moves, its golden-patterned mantle almost completely covers the shell. This probably reduces friction with sand particles during movement and protects the shell from abrasion. This is another example of animal adaptations for population survival.

Oliva preys on small smooth-surfaced clams and *Donax* which it probably smothers with its large foot. The lettered olive lays its eggs on the surface of the sand in transparent capsules. The capsules, which contain from 20 to 50 eggs each, burst when the larvae emerge. (The eggs usually develop into larvae within a week.) After leaving the capsule, the larvae assume a planktonic existence until metamorphosing into adult lettered olives.

E. Oyster Drill (*Thais haemastoma*) (Figure 3E). There are many snails called **oyster drills**, but the most common along the northern Gulf Coast is *Thais haemastoma*. It can be found along the beaches of the sound as well as the beaches of the barrier islands. It can be seen during low tide as it moves about. When the snail is dead, the shell provides a home for one of the hermit crabs. *Thais* is best known as an oyster predator, but it will attack other bivalves as well. There are some differences in the shells of *Thais* organisms found in the Gulf. This has caused some zoologists to form subspecies. Because there are so many intermediate forms, it is doubtful if they should be given subspecies rank.

F. Common Atlantic Auger(*Terebra dislocata*) (Figure 3F). This organism possesses a very pretty little shell that washes up along the Gulf Coast very frequently. It crawls just under the sand surface and may leave a bulge in the sand surface. *Terebra* is a carnivorous snail and it apparently has a venom which it uses to capture its prey.

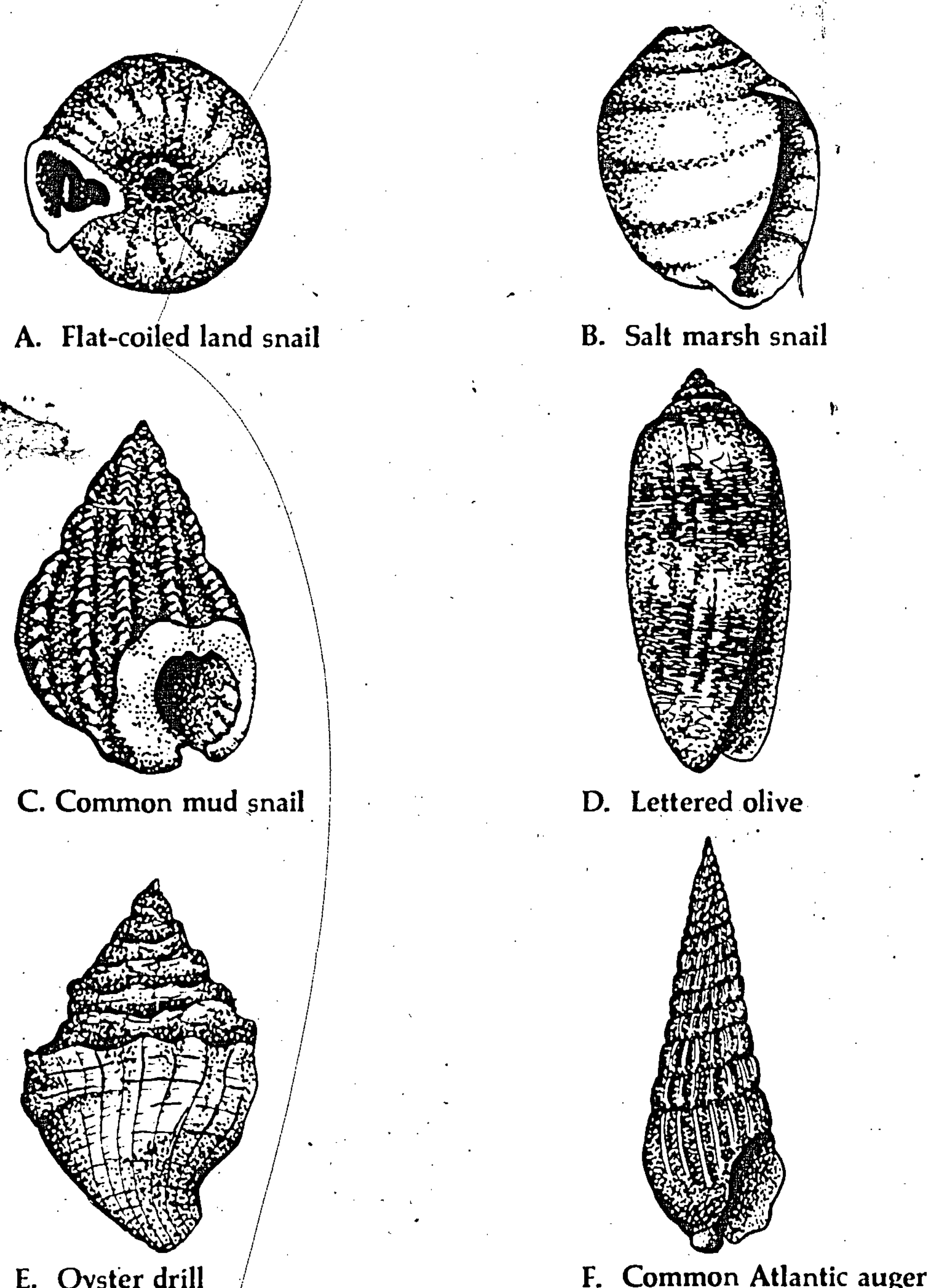


Figure 3. Common snails.

G. Periwinkle (*Littorina irrorata*) (Figure 4A). This snail lives in the intertidal zone where it is frequently found in great abundance clinging to the stems of the salt marsh plants. Its food consists of plant material. The edible snail of Europe is closely related to this species. This snail inhabits a range extending from New Jersey to the Gulf of Mexico. At some remote time in the past, possibly when climatic conditions were different, it survived farther north, and today its shell is commonly found in the **peat beds** of Connecticut on the Long Island Sound shore. Some claim this snail occurs north of New Jersey, but if this is so, it is quite possible the snail was reintroduced into the area along with seed oysters from the south.

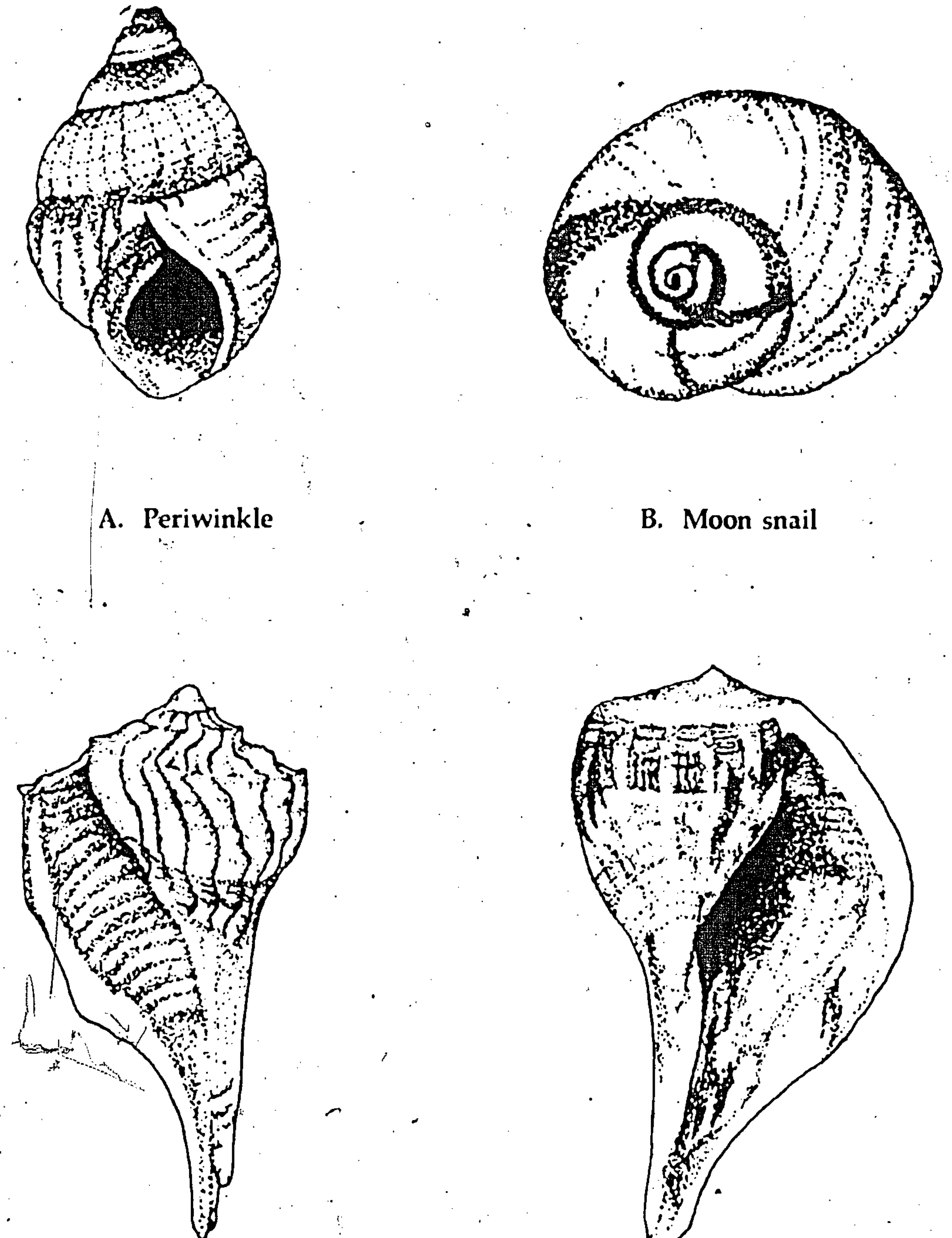
H. Moon Snail (*Polinices duplicata*) (Figure 4B). Full grown adults have shells about two inches high and three inches across. The foot of this snail is tremendous when expanded, and it permits rapid burrowing a few inches below the surface of sand. The foot covers an area almost four times that of the shell. This snail is a serious enemy of soft-shelled clams in New England where it is very common. When this snail expands its mantle, it covers its shell. This protects the smooth shell from corrosion. No living moon snail has "worn-out" shells like the common mud snail. Collectors find that many of the smoothest and most perfect shells come from snails that can cover their shells with their mantles. It is reported to be quite unselective in its food preferences, and frequently is reported a scavenger. It is sometimes **cannibalistic** since it will drill through the shell and eat its own kind. Curiously enough, this active snail is blind and yet it can certainly find its prey. This remarkable ability is probably due to a highly developed sense of taste.

I. Whelks (Figure 4C, 4D). There are some whelks that grow large in the Gulf. Two of these are *Busycon contrarium* and *Busycon spiratum*. They are easily distinguished one from the other because the direction of coiling of the shell is different. *Busycon contrarium* coils to the left; whereas, *Busycon spiratum* coils to the right, as most snails do. The bodies of the snails also differ. The flesh of *Busycon contrarium* is black.

These snails are carnivores and feed mainly on other small mollusks such as the jack-knife clam (*Ensis minor*) and the southern quahog (*Mercenaria comprechiensis*). The whelks wedge the shells open and gradually open the clam's valves. Once the valves of smaller clams are opened the whelks rasp the flesh away with their radulas.

These snails lay their eggs in disclike capsules. There may be as many as 50-175 capsules in a string. The string is attached in the sand and is thus anchored to the bottom. Sometimes these strings of capsules are stranded on the shore and beach combers call them a "mermaid's necklace". When the whelk eggs hatch, the young pass through all of their larval stages within the capsule. When the snails eventually emerge from the capsule, they resemble miniature adult organisms.

J. Quarter Deck Shell (*Crepidula fornicata*) (Figure 5A). Fully grown adults of this species are about 3.8 centimeters long. Shells of these snails are frequently washed up on sandy beaches, but quarter deck snails can only live under water. They live an inactive life attached to oysters or pilings, and feed in the same manner as oysters, filtering out the minute organisms in sea water. These snails are also called double-deckers from their habit of piling up, one on top of another, in chains of up to six or eight individuals. Another common name for this snail is boat shell or slipper shell. These snails were introduced into English waters from America, and became a serious pest by smothering oysters besides competing with them for the food supply. They are not considered important enemies of oysters in our area waters. This may



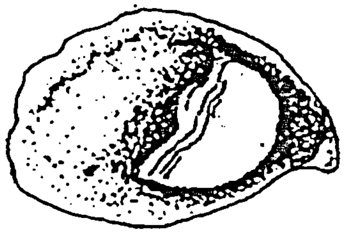
A. Periwinkle

B. Moon snail

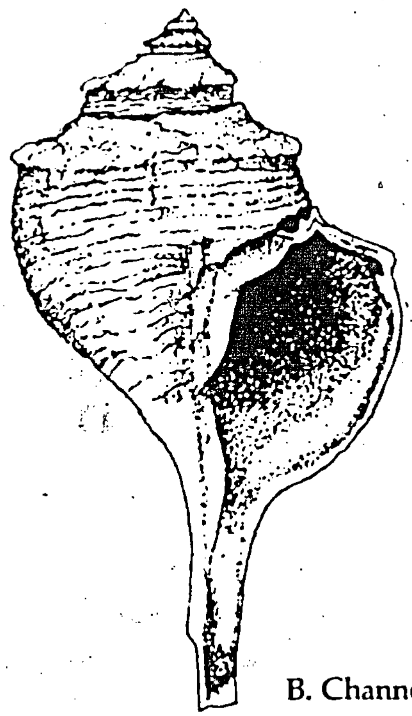
C. *Busycon contrarium*, a whelk

D. *Busycqn spiratum*, a whelk

Figure 4. Common snails.



A. Quarterdeck shell



B. Channeled whelk

Figure 5. Common snails

be because their numbers are checked by the oyster drills.

K. Channeled Whelk *(Busycon canaliculatum)* (Figure 5B). This large snail reaches a maximum shell length of 18 cm. The channel encircling the top of the shell along the **line of suture** gives this species its common and scientific name. These snails are reported to be aggressive feeders, overpowering and devouring **mollusks** nearly as large as themselves. Indian wampum was cut from a part of the shell of this snail. The channeled whelks live in marine waters from Cape Cod to Mexico. The flesh of the foot of this snail is very tough, but it is sweet and edible. Chopped up into small particles, the foot can be used in making an excellent chowder. Empty shells of the channeled whelk, the knobbed whelk, and the moon snail are used for housing by some of the larger hermit crabs of our waters. These snails are not common enough to be important pests of commercially valuable mollusks.

VOCABULARY

adaptation—the process by which a species becomes better suited to survive in an environment.
anatomy—the study of the structures of organisms.
bivalve—a mollusk possessing a shell of two valves hinged together; includes clams, oysters, and mussels.
cannibalism—the act or practice of any animal eating its own kind.
carnivorous—of or having to do with animals which prey on animals.
columella—in gastropod shells, the central axis of the shell around which the whorls are spiraled.
fuecal mass—a reddish bulblike structure inside the head of a snail just behind the jaws. This is part of the digestive tract.
gizzard—an organ in the digestive system of certain organisms which is modified for grinding food.
herbivorous—of or having to do with animals that are adapted to feeding on plants.
line of suture—a spiral line, or groove, where one whorl joins another.
mantle cavity—the space between the mantle and the rest of the body in mollusks.
mollusks—soft-bodied, mostly marine animals, usually enclosed within a hard outer shell of calcium carbonate.
niche—the particular way in which an organism obtains its food and reacts; an organism's way of life.
oyster drill—a shelled mollusk which obtains its food by drilling a hole in an oyster shell and digesting the oyster.
peat bed—partly decayed organic matter formed in boggy areas where high acidity and a lack or oxygen limits decomposition.
radula—a rasping tongue-like organ used by mollusks to graze algae and break up food.
scavenger—an animal which feeds on the dead remains of other animals and plants.
spiral—revolving; as lines going in the direction of the turning of the whorls of a snail shell.
terrestrial—living on land.

CONCEPT D

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

Objectives

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

a. To label a shore profile as supratidal, intertidal, or subtidal.
b. To label on a water column diagram where you would expect to find plankton, nekton, and benthos.
c. To list the two major types of coastal habitats.
d. To distinguish between epifauna and infauna.
e. To explain how the process of zonation helps marine organisms avoid competition.

COASTAL HABITATS

Coastal **habitats** occur at the **land/sea interface.** Differences in the physical, chemical, and geological conditions create the diversity of characteristic habitats. Along the Gulf Coast, 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; **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.

The Gulf Coast'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 by salinity, ranging from the open ocean (with salt concentration of 35‰) through **brackish** water (area where fresh water runoff dilutes sea water to about 10-20‰) 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 water). The organisms of benthic environments are divided into **epifauna** (living on or attached to the 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** in order to carry on these functions. For example, **menhaden** (Figure 2A) a type of schooling fish, have elaborate gills to strain food from the water while **copepods,** small planktonic crustaceans (Figure 2B), 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 parental care for the young. The body shape of planktonic animals shows 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 borrowing through the sea floor (Figure 2D and 2E).

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 (Figure 2C).

Another method for avoiding competition is **zonation. Intertidal** space provides a gradation of exposure to air and surf. On hard substrates (reefs or pilings), examination reveals

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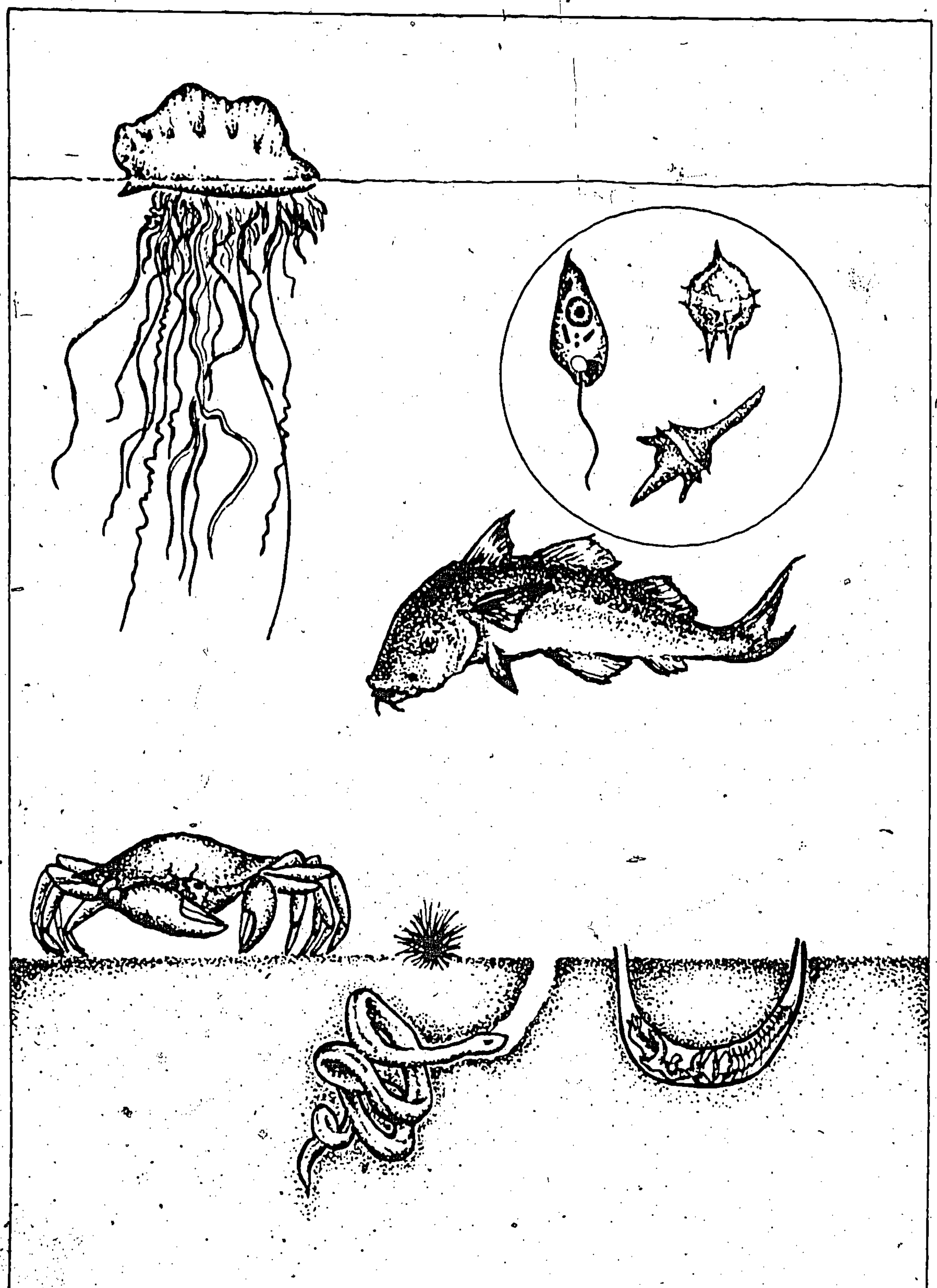

Figure 1. Marine benthic and aquatic habitats.

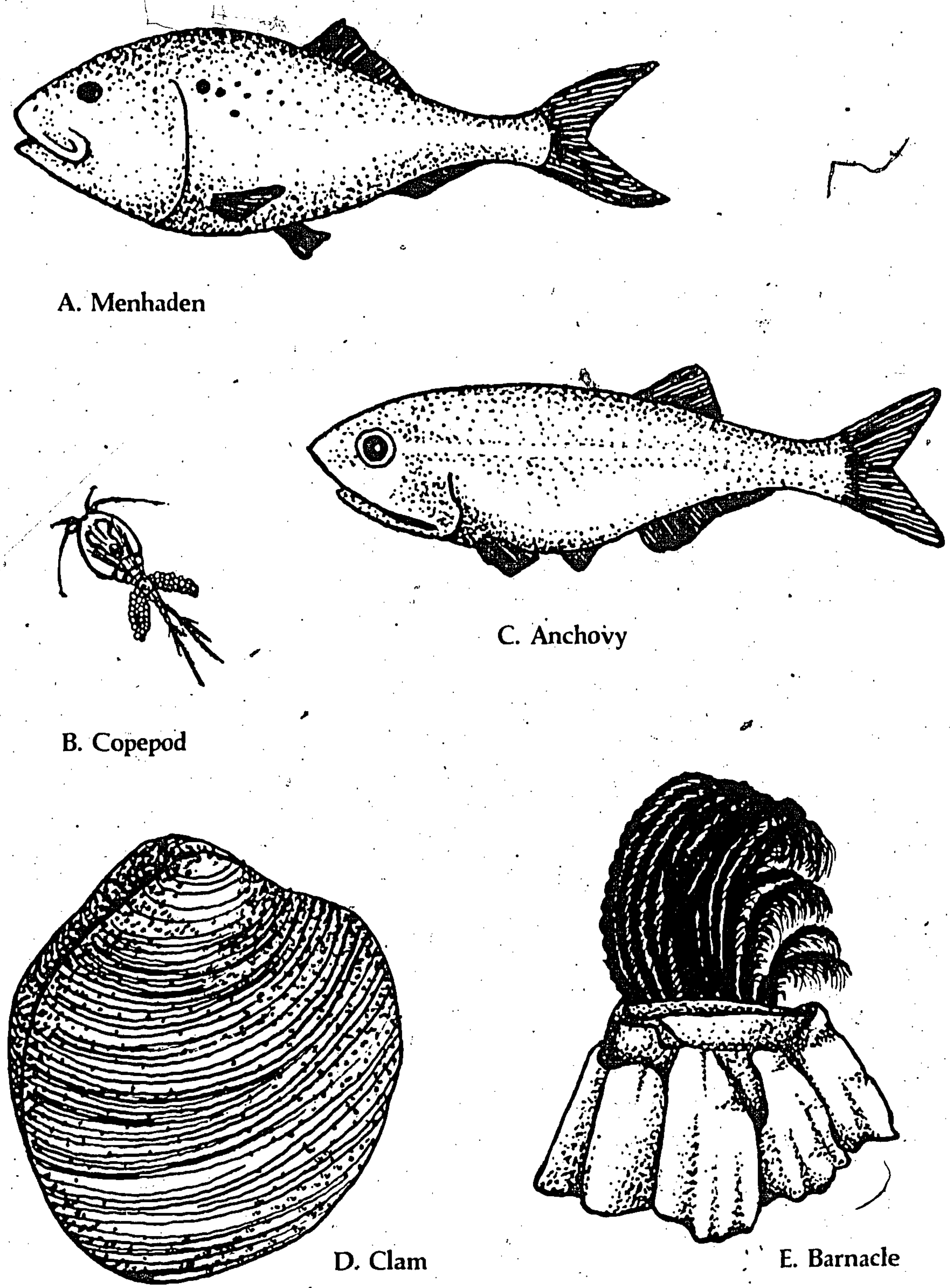

Figure 2.

that different animals live at different heights above the low tide line. On the Gulf Coast, 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 (Figure 3-4) that move up and down with the tide staying in the **swash zone** produced by breaking waves. Zone 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.

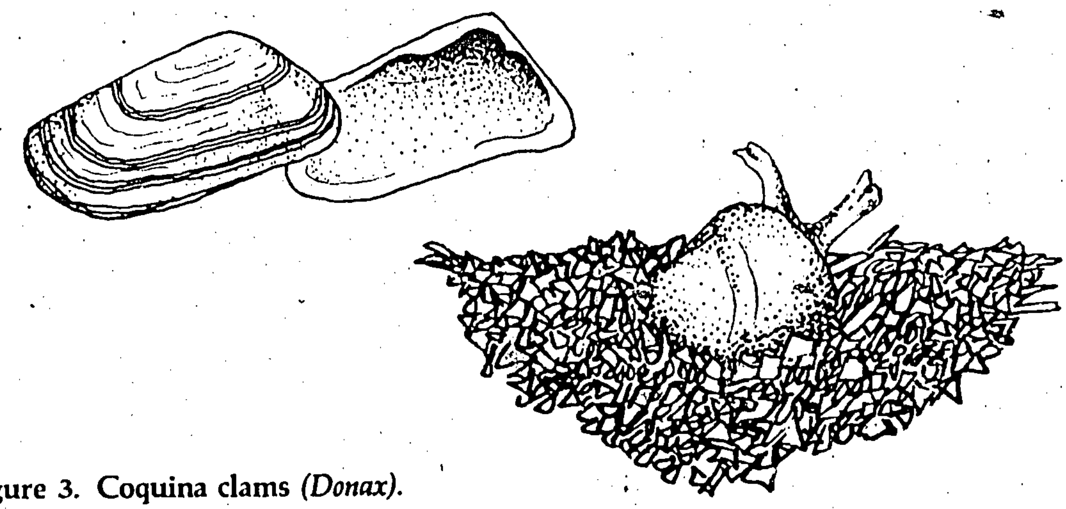

Figure 3. Coquina clams *(Donax)*.
These snails continuously burrow.

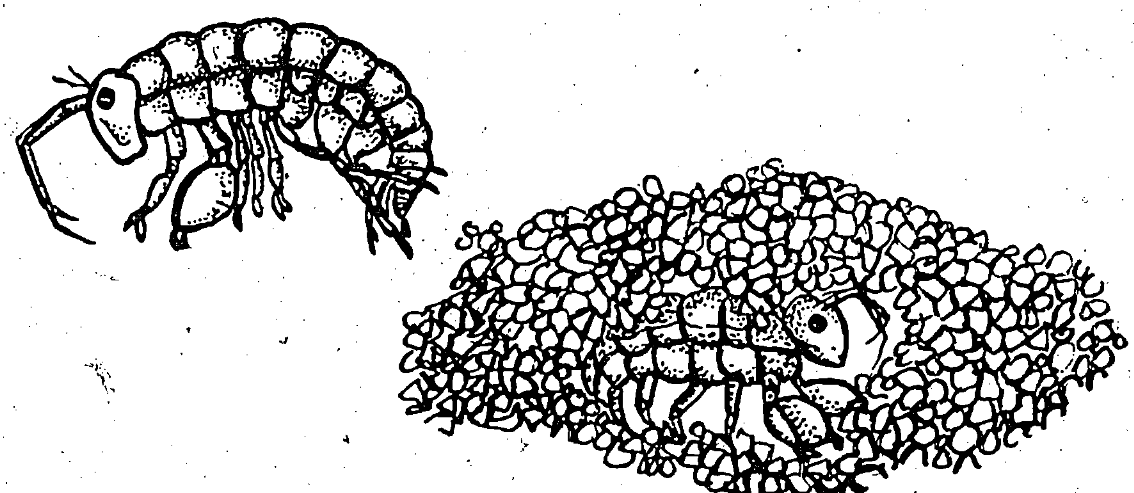

Figure 4. Beach hoppers. These organisms dig burrows for use in the day, but abandon them at night in order to search for food.

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.

buoyancy—the property of floating on the surface of a liquid.

copepods—a group of minute crustaceans that have rounded bodies and oarlike swimming antennae.

dune—a hill or ridge of sand piled up by the wind.

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

estuary—a relatively small body of water that is set off from the main body of water and is affected by the rise and fall of the tide. Estuaries contain a mixture of fresh and salt water.

filter-feeding—the process of taking food from the water as it flows through the animal's body.

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.

intertidal—in the marine environment, the area of the shore that is periodically covered and uncovered by water.

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

menhaden—a marine fish that has a large head, a deep compressed body, toothless jaws, and bluish silvery scales.

nekton—actively swimming animals such as fish.

oyster reef—a narrow ridge of rocks, shells or sand on which oysters attach for subsequent growth and development.

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

salinity—a measure of the total amount of dissolved salts in seawater.

salt marsh—flat land subject to overflow by salt water. The vegetation of salt marshes may consist of grasses or even shrubs.

sedimentary features—those features which are formed from deposits of sediment.

sound—a body of water which occupies the area between a mainland and an island.

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.

supratidal levels—the area of the beach that lies above the tide line.

swash zone—the section of the beach over which the sea washes.

water column—the area from the water surface to the bottom.

zonation—distribution of organisms along a gradient.

VOCABULARY ACTIVITY FOR CONCEPT D

The grids in these puzzles, when solved, will yield a defined term related to Concept D. The letters under the column below the grid go into the boxes directly above them. Your job is to decide which letter goes into which box. As you use a letter, cross it off. Note that some words are continued from one line to the next. The end of a word is indicated by a black square.

■	■								■				■			■			■	■	■
				■				■						■							■
W	I	T	E	N	T	H	E	C	O	H	E	S	N	T	B	O	T	O	O	M	
		B	H		T	H	I			C	A	A			O		D	T			

■	■									■			■		■						
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L	F	B	E	D	Y	A	T	D	N	E	H	I	E	A	A	R	L	R	W	N	A
A	H	S	S	D	H	T	D	O	T	T	P	S	S	O	M	P	A	E	R	G	E
D	N	D	A	N	L	A	H	S	E		I	A	C	S	S	M	R	A	I	S	E
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	T		N			I	N														

Activity: POPULATION PRESSURES AND SUCCESSION IN A LABORATORY COMMUNITY

Introduction

Most people in the United States have plenty to eat. In fact, we are confronted with a surplus of food crops. But in most parts of the world there is not enough food to go around.

Most people in the United States are not especially crowded by their neighbors. In fact, some states have large areas where settlement is invited because more neighbors would be welcome. But the world as a whole is already beginning to feel population pressures for space.

These matters of adequate food supply and living space are among the major problems which world governments must solve in the very near future. But scientists believe that among lower organisms food and space have been major problems for a much longer time than for man. Can we determine whether the number of individuals in a small laboratory community of plants and animals is governed by food supply and living space? Can we also find whether populations will change from one kind of organism to another if competition for limited food and room favors one organism over another?

Approach to the Problem

1. Fill a battery jar or similar convenient container about one-half to two-thirds full of dead grass and cover the grass with pond water. This mixture is called a hay infusion. Keep the battery jar covered with a glass plate. Why should it be kept covered? Keep a daily record of what you do and see starting with the day you set up the experiment.

2. Examine the jar every class period. Prepare a wet mount in the following manner: use a medicine dropper to transfer a drop of the culture to a slide and cover the slide with a cover glass (Figure 1.) Examine the wet mount with a microscope, changing the amount of light as you do. Do this twice a week or more often if you can.

At first you will see only bacteria, if anything at all. (1) What is the significance of bacteria in the water? (2) Do these bacteria appear suddenly in large numbers or do their populations increase gradually?

The next kind of organism to appear in the infusion will likely be an animal called a paramecium (Figure 2), but it may be some other ciliated protozoan. (3) Does the number of paramecia increase suddenly or slowly?

3. At about the time the paramecia become abundant, prepare three clean quart jars or similar containers by putting 1 gram of plain gelatin in the first, 3 grams in the second, and 10 grams in the third. If weighing in grams is impractical, the gelatin can be provided with sufficient accuracy by placing 1/4, 1½, and 5 level teaspoons of gelatin, respectively, in the three jars. Fill the jars with distilled or boiled pond or tap water to about an inch from the top and mix the gelatin with the water. Withdraw 30 ml of liquid from the hay infusion. Agitate it to distribute the organisms evenly and add 10 ml of this liquid to each jar and cover with a loose-fitting cap.

You now have three jars with equal quantities of water, i.e., equal living space, and essentially equal populations of bacteria and paramecia but with different amounts of food. Your problem is to see how food supply affects the numbers of organisms in a controlled habitat.

4. Notice which jar becomes cloudiest. (4) What causes the cloudiness? Stir the contents of

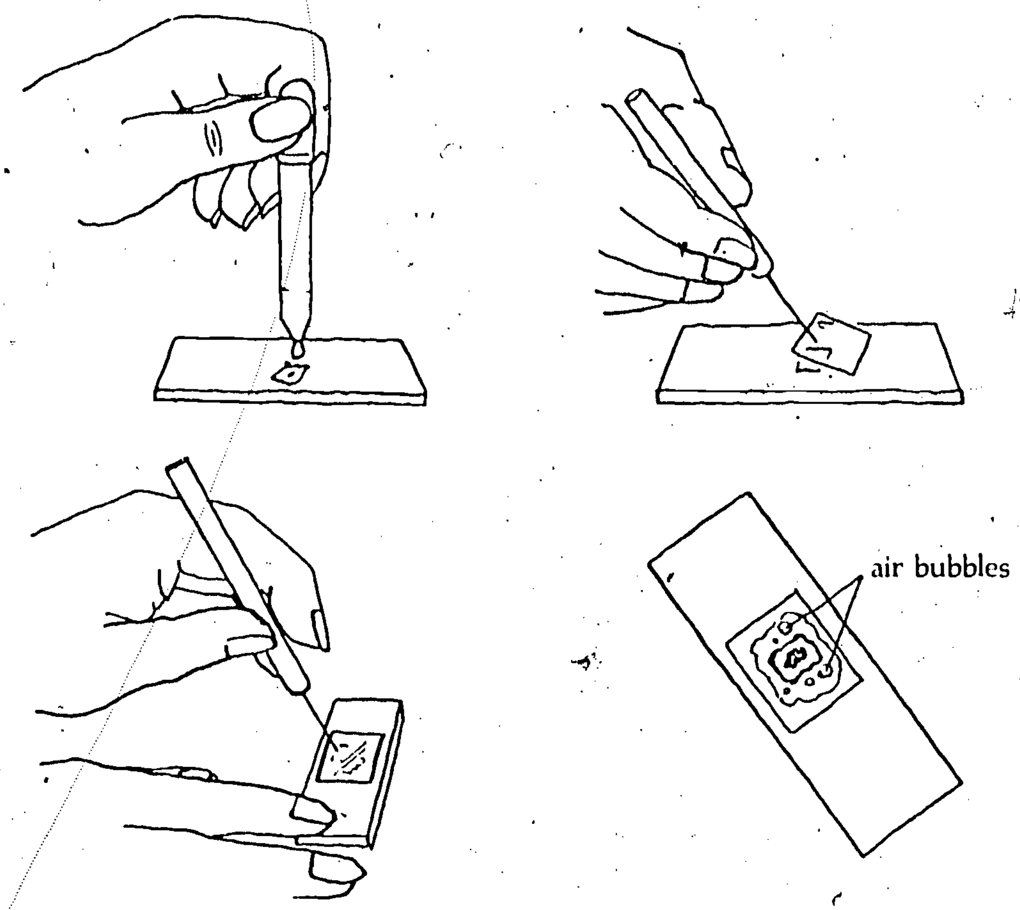

Figure 1. Technique used when preparing a wet mount. Exercise care in preparation of this slide so that air bubbles will not be trapped under the cover slip.

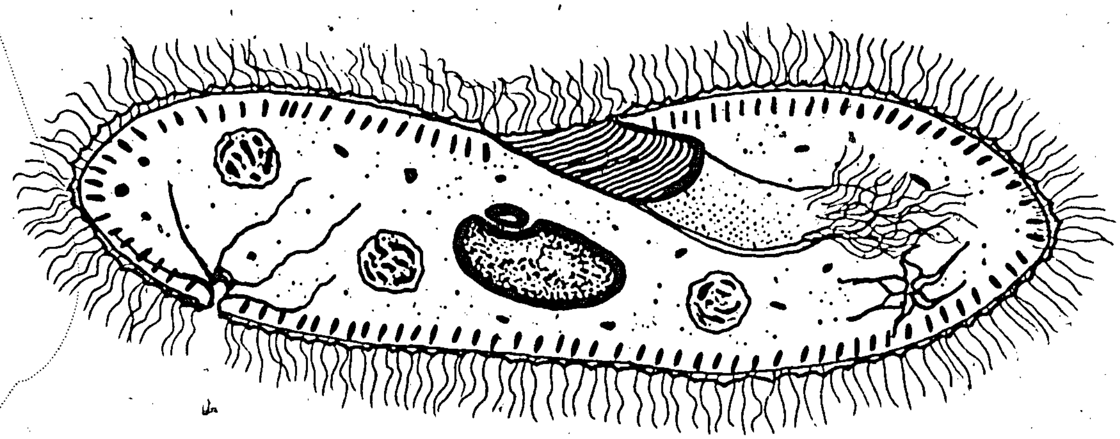

Figure 2. Paramecium.

each jar every day and examine a drop of the liquid from each jar with a microscope. Count the animals in each field and compare their numbers. If they move too fast to count, you may prepare traps of cotton fibers or use a drop of methyl cellulose on the slide. This will help to slow the organisms so that you can count them.

Conclusions

1. (5) What comparison can you make between the relationships of food, bacteria, and the animals and corresponding situations with humans, especially in countries such as India and China where large families are common?

2. (6) How many days passed before you noticed any life in the hay infusion? (7) How many days passed before the first animals began to disappear? (8) Would these animals be replaced by others? (9) Where did these organisms come from?

3. Most of the preceding questions can be answered directly from your observations. The rest of them can be answered by looking in reference books and by asking your teacher. Organize the data you have obtained into a scientific paper explaining the problem and its solution.

Activity: HOW IMPORTANT IS THE HABITAT TO SURVIVAL OF THE ORGANISM

Freshwater **habitats** include those found in running water and those found in standing water. The running water is usually identified as the freshwater stream; whereas, the standing water is identified as the pond. The water found in streams differs in several ways from that of marine water. Fresh water streams usually have a smaller volume, greater variations in temperatures, less salt or inorganic mineral content, greater light penetration, greater suspended material content and greater plant growth than the marine counterpart.

Just as found in the marine habitats, the organisms found in these freshwater habitats show many structural adaptations. Some of the more obvious **adaptations** would include organs for attachment such as suckers or specialized appendages, adaptive shapes for creeping under stones or a very streamlined body to withstand the strong stream currents.

The **diversity of organisms** found in each of the stream habitats is very great. In the rapids, such organisms as caddisfly, blackfly larvae, snails, darters, stone fly nymphs, or the water penny larvae may be found (Figure 1).

In the pool habitats a different **fauna** will be found. Various minnows, mussels, dragonfly nymphs, snails, crayfish, flatworms, leeches, and water striders will dominate as predictable species in slower water. Many of these organisms may even burrow into the mud or sand bottom.

Ponds will provide a third major freshwater habitat. In this body of water there will not be a visible current. The quantity of vegetation will vary, but it is almost always present in some quantities. The variety and quantity of plants will be much greater than in the other two freshwater habitats.

This large quantity of plant material provides an excellent habitat for many organisms. In this **environment** the **benthic** fauna may be characterized by large numbers of snails, mussels, larvae of flies, beetles, dragonflies, many kinds of crustaceans, and many kinds of frogs. The **nekton** or swimming organisms might include many varieties of water bugs,

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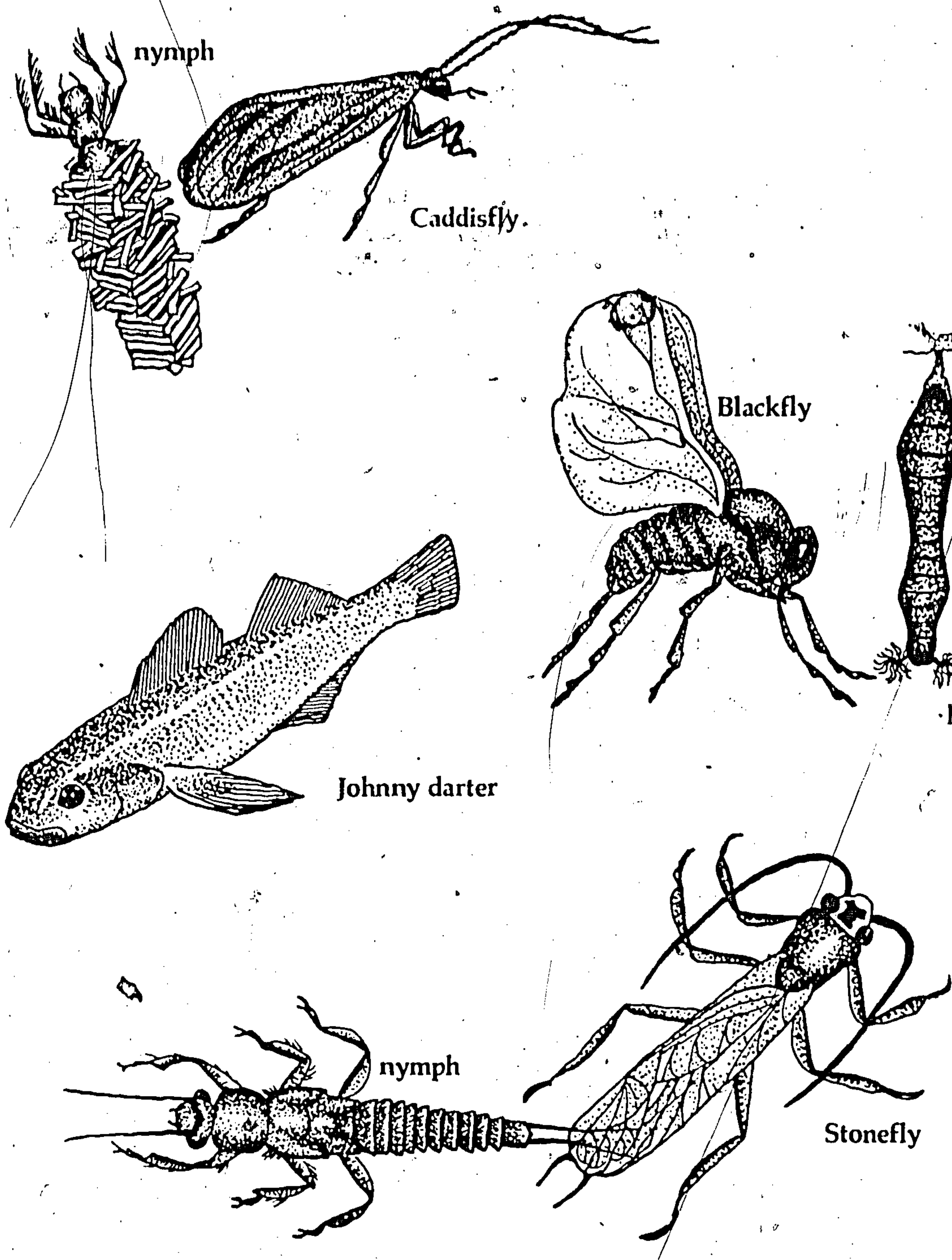


Figure 1. Organisms in the rapids.

turtles, and fish. Muskrats and beaver may inhabit some of the larger ponds. Because of the large quantity of plant food many birds will also be attracted to the pond habitat. The most characteristic birds would include the ducks and blackbirds.

A portion of the fauna and **flora** of all freshwater **communities** will always be the **plankton** organisms. These planktonic organisms will be microscopic plants and animals such as protozoans, crustaceans, rotifers, small worms, diatoms, and other forms of algae.

In the following activity you will observe some of the plankton forms found in a freshwater habitat close to your school.

Objectives

Each student should be able:

a. To identify four habitats in a local freshwater community.
b. To collect plankton samples from each of the habitats.
c. To identify dominant forms of plankton in each habitat.
d. To make comparisons of planktonic forms from each habitat.
e. To state adaptations that seem to be necessary for survival in each of the habitats.

Materials

plankton net (1 per class), glass container for plankton sample (2 per group), glass slides (4 per student), microscope (1 per student)

Procedure

Select the freshwater community. Divide the class into groups of four to speed up the plankton collection from each of the four habitats. The habitats to be examined will be: the shallow water zone where the water depth is around six inches, a rooted aquatic plant zone, the top zone of the open water, and the deep water zone in the open water area.

Each group should be assigned to make adequate collections from one zone. An adequate sample might be about four pulls of the plankton net. Each sample should be placed in a clean glass container and labeled as to the habitat sampled.

All samples should be returned to the laboratory and each person should be given a sample taken from each of the study sites. Using a clean dropper, samples should be taken and examined under the microscope. As organisms are identified each student is to complete the data table that is found on the following page.

Reference materials may be used in identification of unknown species. Many of the common planktonic forms are illustrated in this activity (Figures 2-5). Undue effort should not be placed on correct identification because the observable structural features will be more important in making comparisons in the various habitats.

This activity is not intended to determine exact quantities, thus under the "Frequency of Organisms" column you may use such words as very numerous, numerous, several, few, or very few.

DATA TABLE

Shallow water
6 inches or less

Sketch characteristic shape of organisms	Frequency of organism	Common name	Most unusual characteristic	Role in community
1				
2				
3				
4				
5				

Top of open water
first 6 inches

1				
2				
3				
4				
5				

Deep open water
below 6 inches

1				
2				
3				
4				
5				

ERIC

Portion inhabited by rooted aquatic plants

Sketch characteristic shape of organisms	Frequency of organisms	Common name	Most unusual characteristic	Role in community
1				
2				
3				
4				
5				

1. What seems to be the most common structure found in each of the habitats?

   Open water—top __________

   Open water—deep __________

   Shallow __________

   Rooted aquatic __________

2. How do you account for the survival of the most common organisms in each habitat?

   Open water—top __________

   Open water—deep __________

   Shallow __________

   Rooted aquatic __________

3. Do you feel that the organisms you found are structurally adapted to the habitat in which you found them? __________

4. What other factors may also play a role in the survival of an organism? __________

5. How do you think these organisms would differ from a marine plankton sample?

Why? ____

____

6. Why are plankton so important to any aquatic habitat? ____

____

____

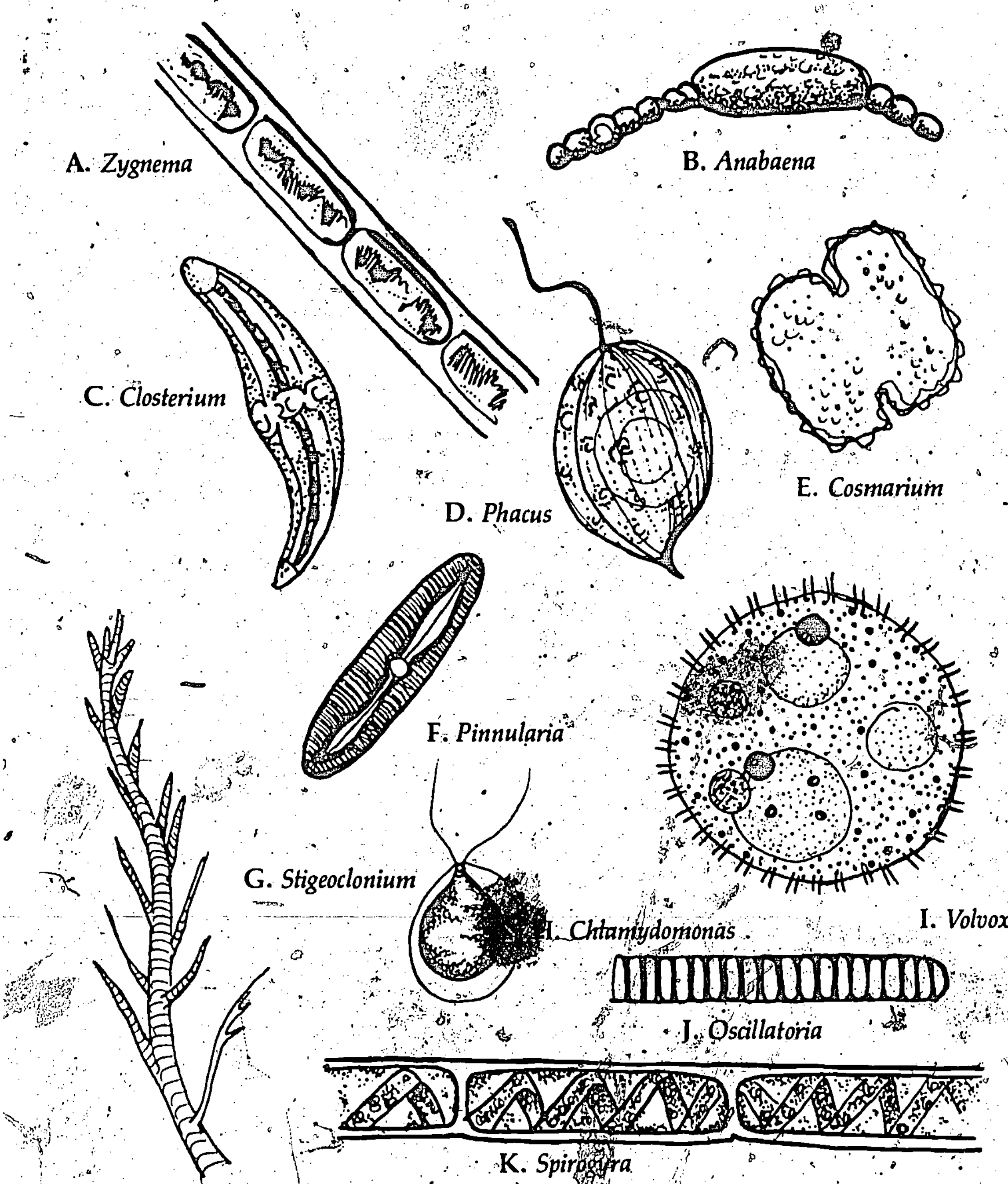


Figure 1. Planktonic forms.

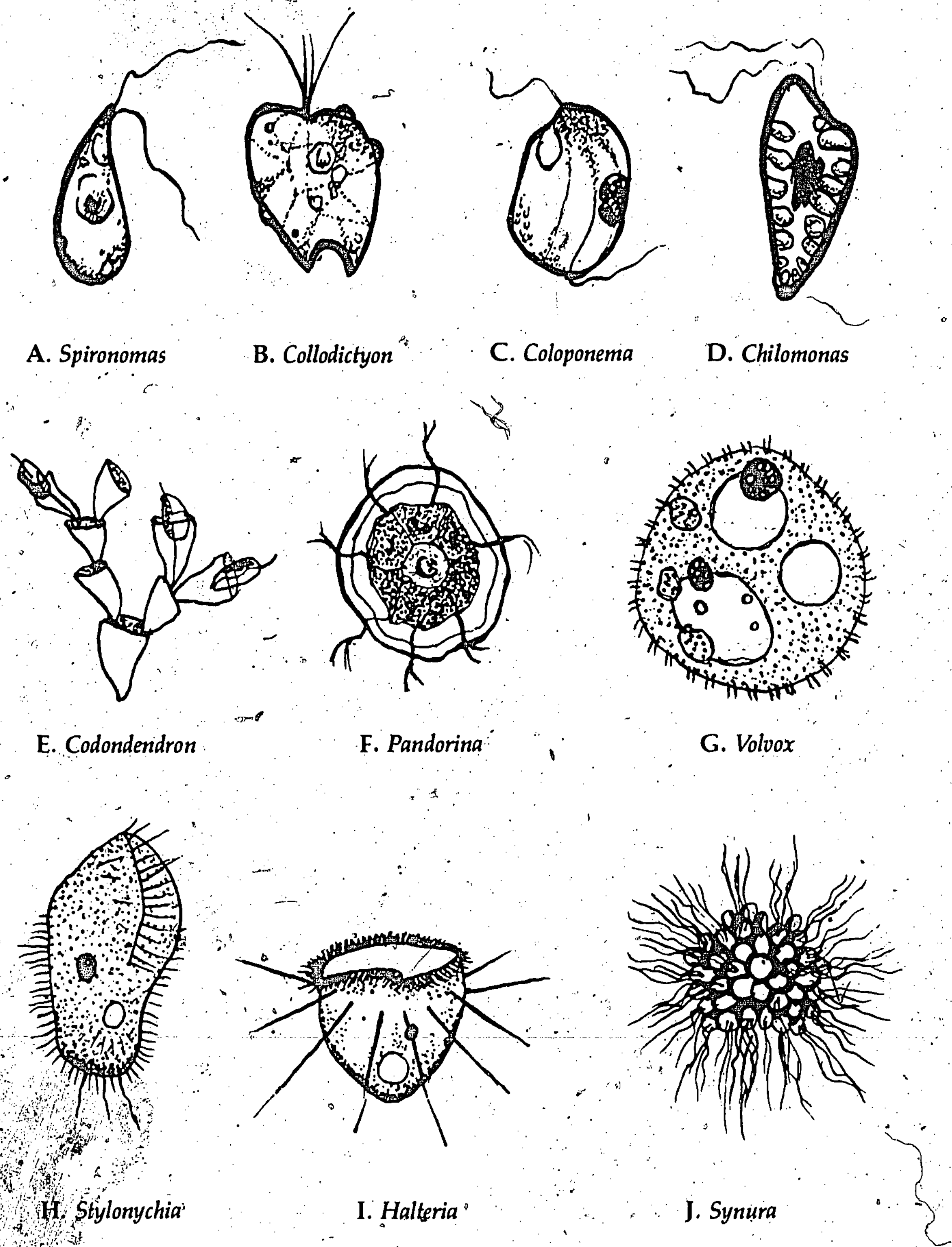


Figure 2. Planktonic forms.

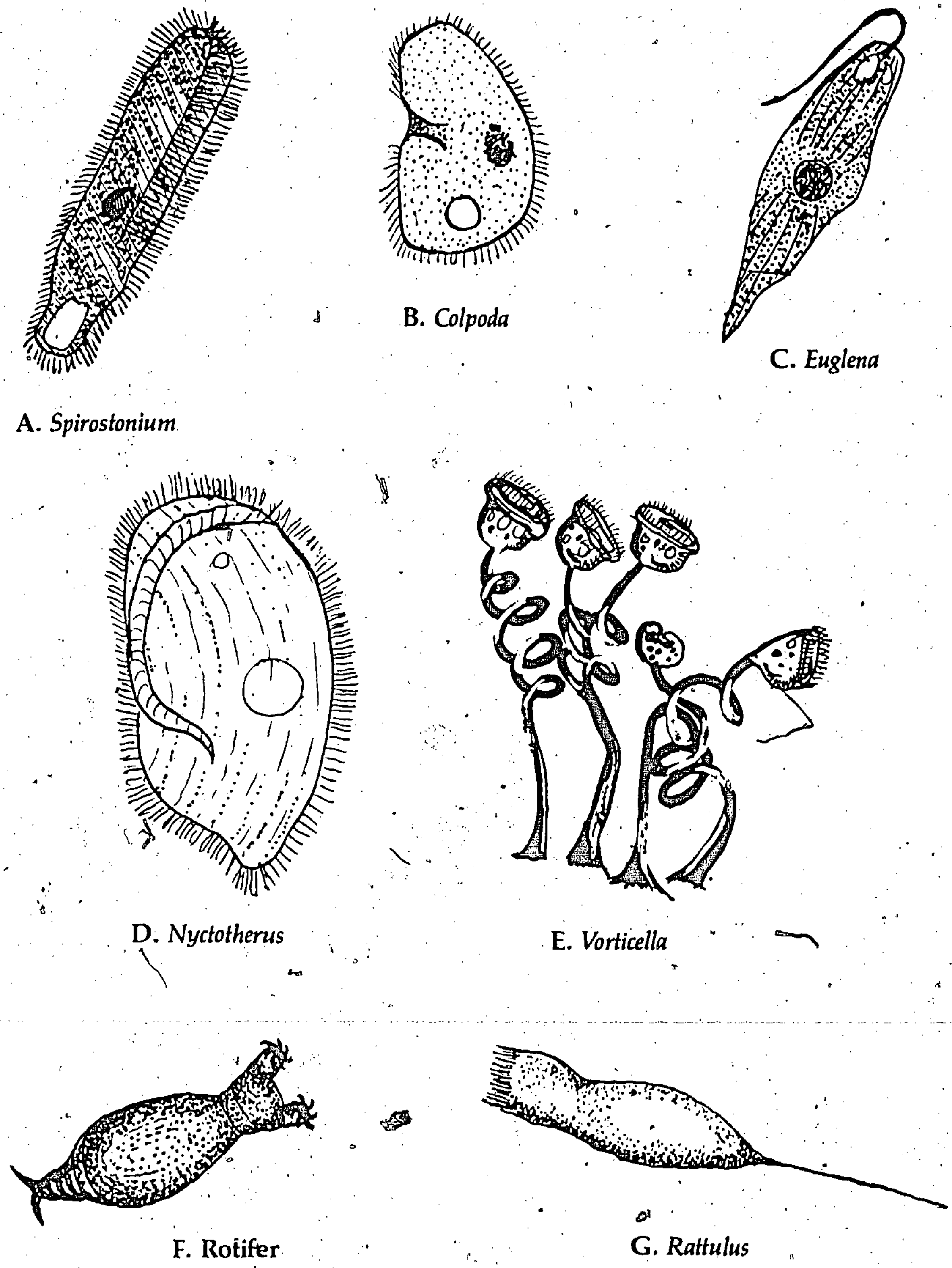


Figure 3. Planktonic forms.

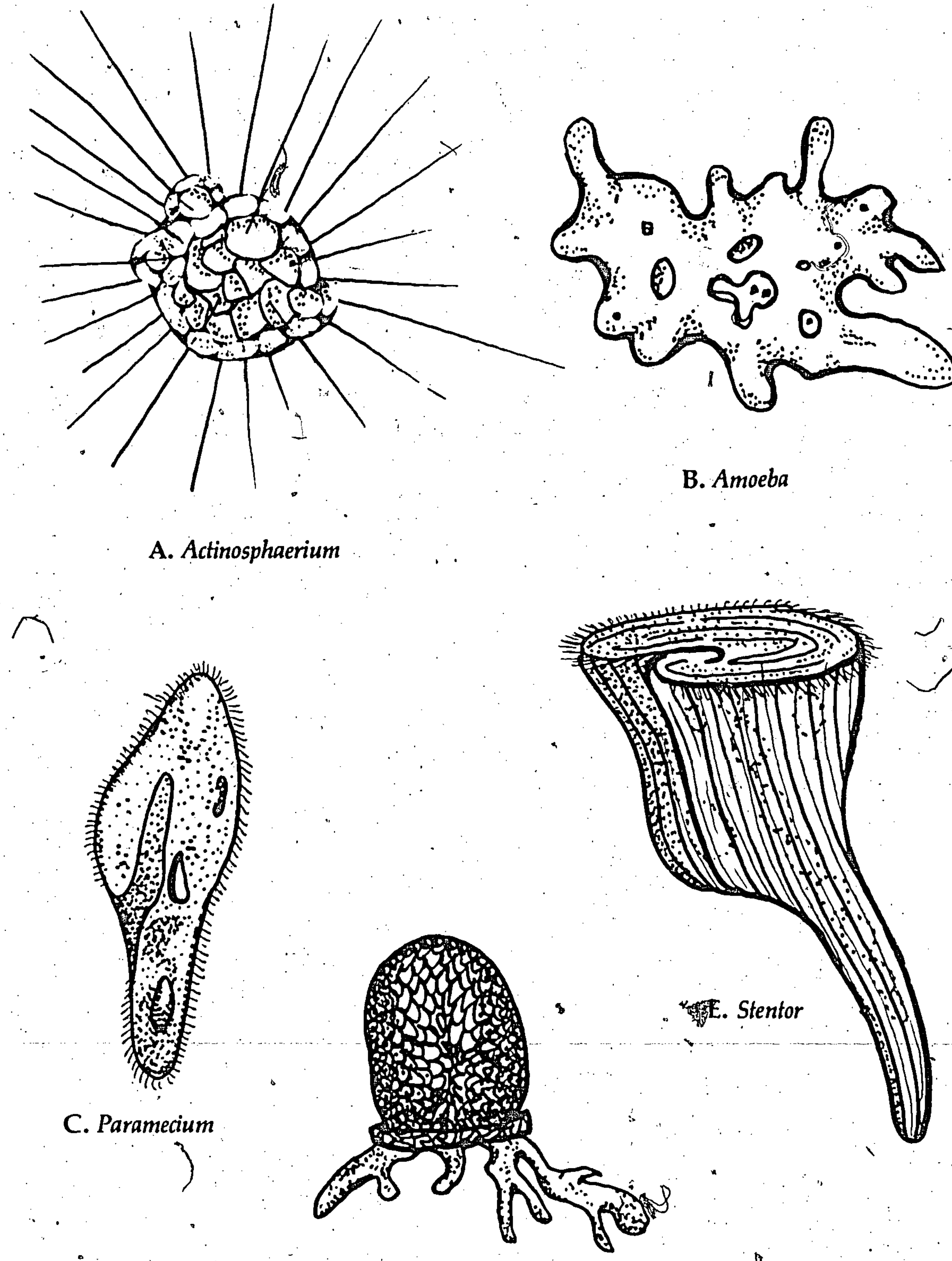


Figure 4. Planktonic forms.

adaptations—changes in the organism that allow it to survive in a particular environment.
benthic—having to do with the bottom.
community—all of the populations of organisms in a particular area.
diversity of organisms—the large numbers of different kinds of organisms that have varying characteristics found in a particular area.
environment—the surroundings of an organism.
fauna—the animal life occurring in a particular locality.
flora—the plants or plant life occurring in a particular locality.
habitat—the place where an organism lives.
nekton—those animals that are active swimmers such as most adult squids, fish, and marine mammals.
plankton—small plants and animals floating in the upper layers of the water column.

Activity: DIVERSITY OF ORGANISMS IN AN AQUATIC HABITAT

We are familiar with many frogs, turtles, minnows, crayfish, and microorganisms in fresh water **communities.** Are there other organisms also there, and if there are, what are they? These are questions that we may never have considered. There are many large organisms. Where do they get their food? These are some of the questions that may be answered as you participate in the following activity. You will be looking for other organisms that usually remain hidden due to their life style or adaptation for survival. These organisms may be larval stages of insects that you are very familiar with. You may be surprised at the creatures you find.

Objectives

To collect and identify macroscopic organisms found in a fresh water habitat.
To observe differences in organisms that may inhabit the same **habitat.**
To develop expertise in using the dip net to collect in an **aquatic** community.
To identify some of the interwoven links of aquatic **food webs.**

Materials (per group of 4 students)

1 dip net, 4 hand lenses, 2 containers for transport of organisms, 2 dissecting microscopes, reference books on aquatic organisms.

Procedure

Locate a water source which may be a pond or running stream. Take the dip net and pull it along the bottom until you have a sample of the mud and bottom debris and **detritus.** Toss the bottom sample up on the shore and sort through the debris for living creatures. In this activity you may find many different species, but any single habitat usually has its own unique **fauna.** You will make an effort toward identifying several of the **endemic** organisms to the particular water body.

Complete the data table as best you can. It may be necessary for you to use other reference books that will help you in a complete identification of the organisms which you find. You will find several organisms pictured in the exercise. This will help you find the correct category to which your specimen belongs (Figures 1 and 2).

DATA TABLE

Organisms that were taken from ______________ on ______________________ .

The condition of the water was ____ .

Specimen	Major Animal Group to which Animal Belongs	Approximate Size	Predominant Color	Number of Legs	Mouth Type	General Body Shape	Unusual Features

Were you able to observe gills of any sort on any of the specimens? ______________

Which ones? ____

Were the majority of organisms you found herbivores or carnivores? ______________

Why do you think so? ____

____

How do you account for the diversity of organisms found in this single habitat?

____

____

How do these organisms fit into the biological productivity of this water body?

____

____

VOCABULARY

aquatic—living in water.
community—all of the populations of organisms in a particular area.
detritus—very small particles of the decaying remains of dead plants and animals; an important source of food for many marine animals.
endemic—confined to a certain area or region.
fauna—the animal life occurring in a particular locality.
food web—an interlocking system of food chains. Since few animals rely on a single source of food and because no food source is consumed by only one species of animal, the separate food chains in every natural community interlock and form a food web.
habitat—the place where an organism lives.

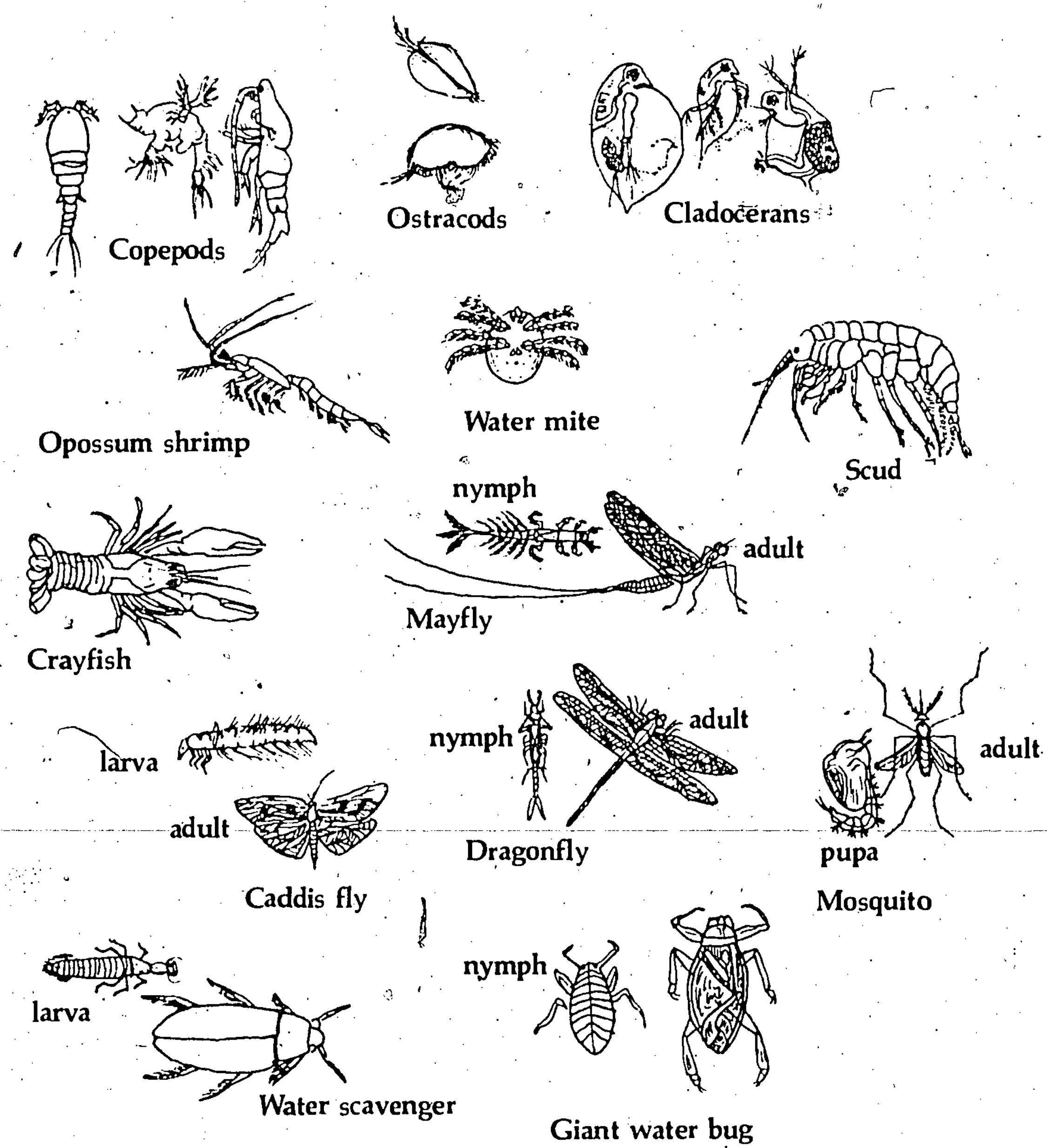


Figure 1. Common freshwater organisms.

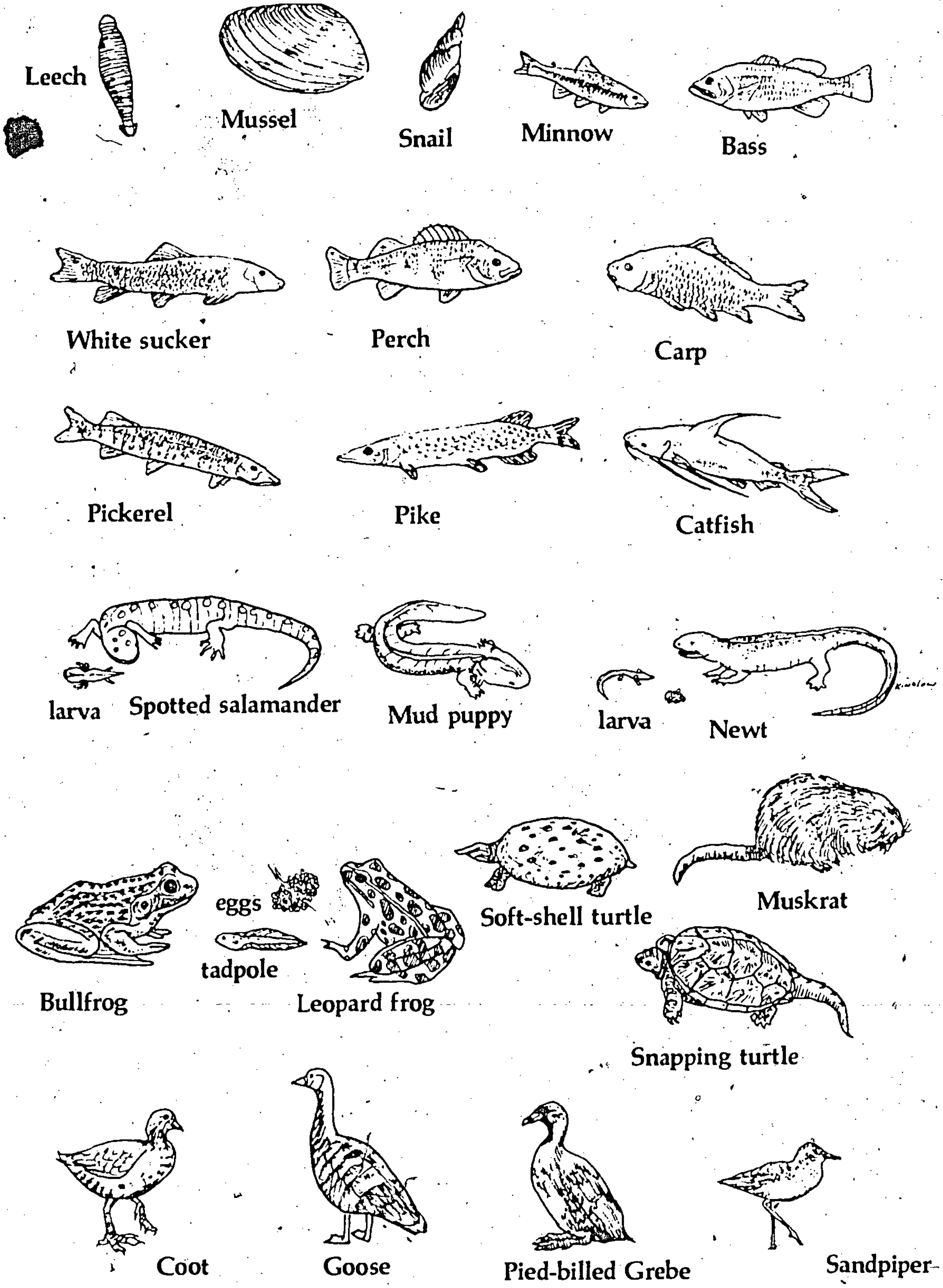


Figure 2. Organisms found in or around fresh water.

CONCEPT E

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

Objectives

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

a. To diagram a three unit food chain from a salt marsh, and three unit food chain from the open beach.
b. To diagram a ten unit food web of coastal organisms.
c. To name two types of food chains found in the salt marsh.
d. To list and describe two of the three types of processes that link coastal habitats and organisms into an ecosystem.
e. To describe two sources of nutrient supplies for an estuary.
f. To explain why the tide is such an important mechanism in regulating the coastal ecosystem.

COASTAL ECOLOGY

In studying sea coast **ecology,** scientists tend to separate problems into units like **marsh,** beach, **nekton, benthos.** 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. The 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., phosphorus, 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 phosphorus 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. Microbial degradation liberates the phosphorus atom back into the water where it can be taken up by other phytoplankton. They may serve as food for **menhaden** that migrate away from the Gulf Coast to be caught and converted to fish meal that ultimately ends up on someone's dinner table. Thus the use and reuse of an atom of phosphorus 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 ~~ecological~~ system.

(2) **Energy** is the capacity for doing work. In ~~biological~~ systems the most important energy sources are sunlight and its derivatives (the organic chemicals made from sunlight through **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.**

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 fertilized 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 1 showing the flow of organic matter through, and away from, a Georgia salt marsh habitat. Note that 45% of the organic matter produced by photosynthesis 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 actually take up more **organic matter** from their surrounding waters than they contribute. The marshes for which this is the case have artificially 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. On the Gulf Coast, marshes low in the **intertidal zone** and regularly flooded by the 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 spectrum of these phenomena here, but we can provide one obvious example of each type that operates to regulate the coastal ecosystem of the Gulf Coast.

The most obvious physical mechanism regulating coastal ecosystems of the Gulf Coast is 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. They balance **export and import** of organic matter by influencing the energy available for harvesting marsh production.

The most obvious chemical mechanism regulating Gulf Coast 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 area (Figure 2) because few organisms are able to tolerate the changeable salinity of estuaries.

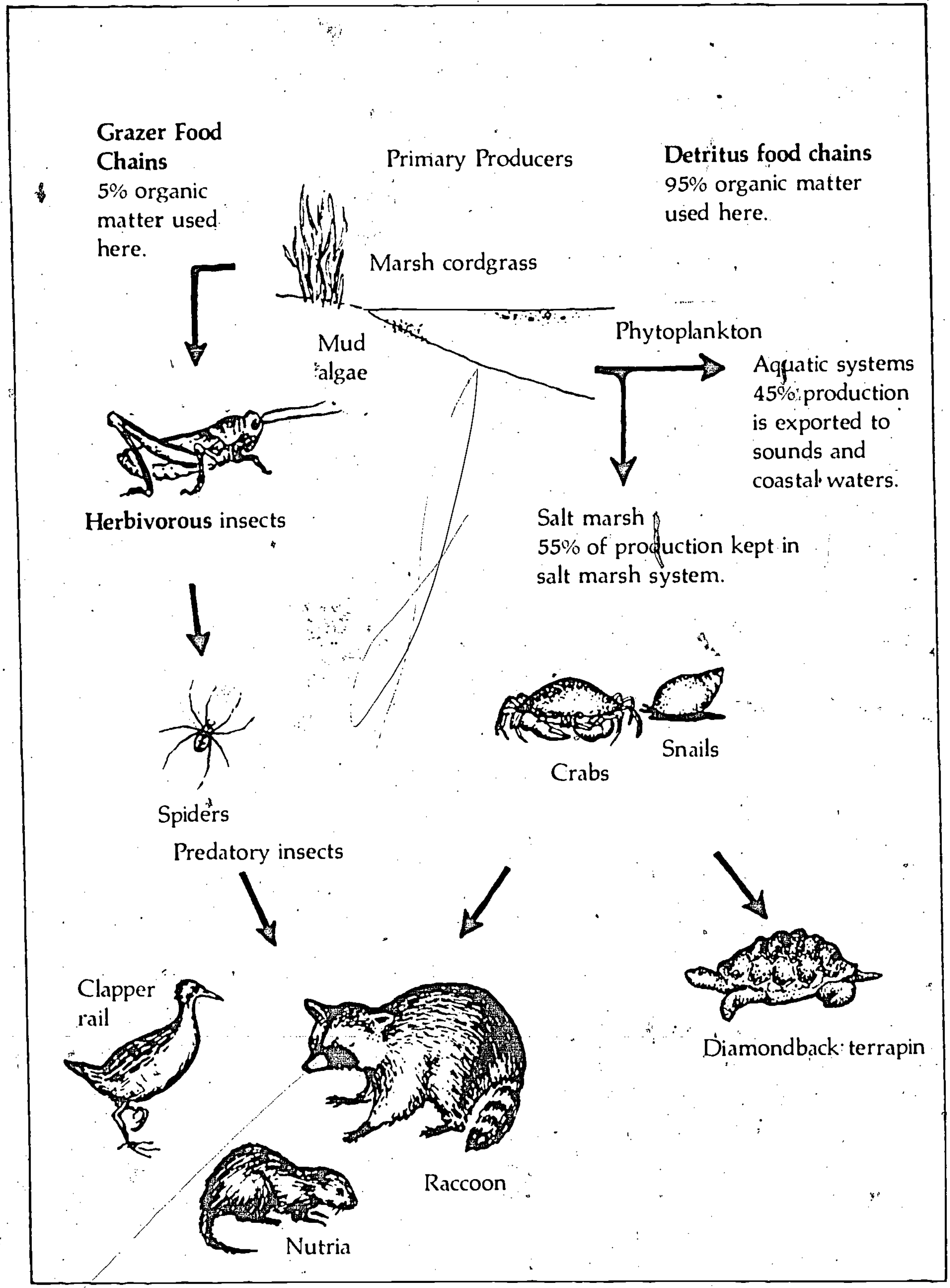


Figure 1. Production and utilization of organic matter in the salt marsh.

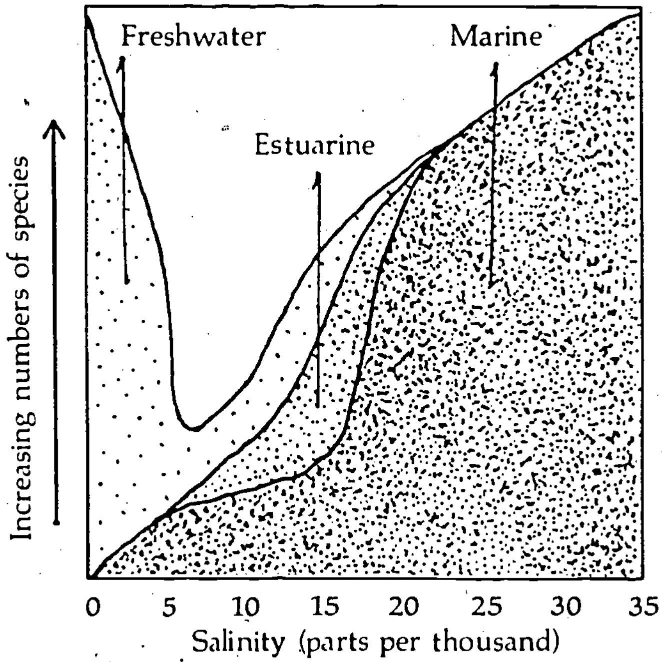


Figure 2. **Comparison of the composition of fresh-water, estuarine, and marine species with increasing salinity.**

VOCABULARY

benthos—bottom dwelling forms.

biotic—the community of organisms of a given region.

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

coastal zone ecosystem—a community of organisms found along the coast interacting with each other and the environment in which they live.

continental shelf—a zone adjacent to a continent or around an island, and extending from the lower water line to the depth at which there is usually a marked increase of slope to greater depth.

detritus food chain—a food chain in which accumulated organic detritus is decomposed by organisms such as bacteria and fungi. Excrements of animals as well as decaying plant and animal material are considered detritus.

dissolved oxygen—oxygen which is found in a water solution. The amount of dissolved oxygen in water depends on the physical, chemical, and biochemical activities that occur in the body of water.

dune—a hill or ridge of sand piled up by the wind.

ecology—the study of the relationship of living things to their surroundings.

energy—ability to do work and cause changes.

estuarine—pertaining to an estuary.

export and import—processes of taking living organic matter from a marsh and bringing organic matter into a marsh, respectively.

flow of energy—the movement of energy throughout an ecosystem.

grazer food chain—a food chain in which living plants or plant parts are consumed directly.
habitat—the place where an organism lives.
herbivorous—refers to organisms that are adapted to feeding on plants.
intertidal zone—in the marine environment, the area of the shore that is periodically covered and uncovered by water.
marsh—a tract of wet or periodically flooded treeless land, usually characterized by grasses, cattails, or other monocots.
menhaden—a marine fish that has a large head, a deeply compressed body, toothless jaws, and bluish silvery scales.
mud flat—a level tract of land at little depth below the surface of water or alternately covered and left bare by the tide.
mussel—a bivalve (2 shells) molluscan; clams, oyster, etc.
nekton—those animals of the pelagic division that are active swimmers, such as most adult squids, fishes, and marine mammals.
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 temperture, salinity, and chemical content.
organic matter—any type of material that contains the element carbon.
photosynthesis—process of plants by which energy-rich organic compounds are made from water and carbon dioxide using sunlight as the energy source.
phytoplankton—the plant forms of plankton. They are the basic synthesizers of organic matter (by photosynthesis) in the pelagic division. The most abundant of the phytoplankton are the diatoms.
productivity—amount of organic material formed in excess of that used for respiration. It represents food potentially available to consumers.
salinity—a measure of the total amount of dissolved salts in seawater.
sand flat—a level tract of land that is covered by sand. This land is only a little below the surface of the water, or it is alternately covered and left bare by the tide.
trophic pyramid—another way of representing a food chain, to take into consideration the volume of food consumed by each link in the chain.

VOCABULARY ACTIVITY FOR CONCEPT E

Listed below, in alphabetical order, is a group of "pseudo-syllables", that is, they are not true syllables. Figure out the words by using the definitions provided. You must then assemble the word using the "syllables" list. Write the completed words in the appropriate lines of the grid.

ar be bi di du ec en es es ha he hos ine is iv kt ne ne nt ogy ol ol on or os ot ox ph rb ss tat th tu ved yg yn

1.																	
2.																	
3.																	
4.																	
5.																	
6.																	
7.																	
8.																	
9.																	

Definitions:

1. Animals that are active swimmers.
2. Oxygen which is found in a water solution.
3. Bottom dwelling forms.
4. Pertaining to an estuary.
5. Process of plants by which energy-rich organic compounds are made from water and carbon dioxide using sunlight as the energy source.
6. A hill or ridge of sand piled up by the wind.
7. Animals that are adapted to feeding on plants.
8. The place where an organism lives.
9. The study of the relationship of living things to their surroundings.

Activity: CONSTRUCTION OF AN ARTIFICIAL ECOLOGICAL SYSTEM

Objectives

To prepare an artificial **terrestrial community** where typical nutritional interactions car be observed.

To identify the nutritional relationships found in a simple terrestrial community.

Any biological community will contain all elements of the **biotic pyramid** with the **niches** of the **ecosystem**. Even the simplest of communities will have expressed food relationships. The **producers, consumers,** and **decomposers** will interact to stabilize the community with time. Each organism that is found in the community fills a niche, interacts with other organisms, and becomes a member of waht is called the **food web.**

You will construct a terrestrial community and observe it over a period of several weeks. Observation of the selected organisms will be recorded to determine the niche of each.

Materials (per team of two students)

Large gallon jar, various types of soil, various types of organisms (both plants and animals)

Procedure

Select one of the gallon jars from the instructor's laboratory table and place it on your table. Into the jar place about 10 centimeters of a selected soil type. After selecting the soil, decide what kind of producers you want in your artificial community. You may decide to plant seeds and that will be satisfactory should you decide on this method. At the time you are selecting your producers, think about possible consumers you will place in your terrestrial community. Can you predict the niche of each organism that you have selected?

You are now to decide where you will keep your artificial community for the next three weeks. You will make observations and record data each day. Place as many organisms as you would like in your artificial community, but make accurate observations of each.

Make predictions for each of the selected organisms as to their nutritional demands and record your predictions in the following table.

Predictions of Nutritional Habits of Organisms Selected for Artificial Terrestrial Community

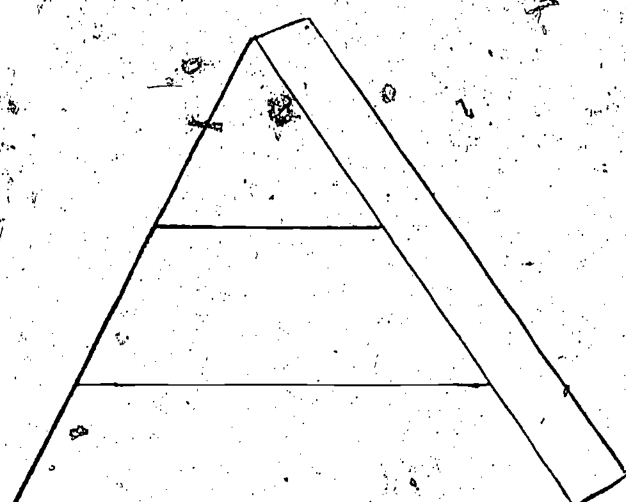
Name of Organism	Predicted Niche of Organism	Predicted Food Source
1.		
2.		
3.		
4.		
5.		
6.		
7.		

Date ______________________

Status of Organisms in the Terrestrial Community

	Name	No. Started	No. Today	Observations
Organism 1				
Organism 2				
Organism 3				
Organism 4				
Organism 5				
Organism 6				
Organism 7				
Organism 8				
Organism 9				
Organism 10				

After completion of the three week period, complete the biotic pyramid by placing the appropriate organism in the various levels of the pyramid.



List any abiotic factors that you consider were important in this community.

Would the same factors play a role in a marine ecosystem? ______

Explain ______

Construct a food web for your artificial community. How do you direct the arrow? ______

List two food chains that you were able to observe in this activity. ______

Now think about a marine **food chain.** List organisms for a marine food chain. ______

Different students selected different soils for their community. Did this factor have an effect on the organisms in those communities? ______

Explain ______

Do you suppose that there would be different organisms found in different marine aquatic communities? ______ Explain ______

biotic pyramid—a method of representing the ecological niches and food relationships among various organisms.
consumer—living things which obtain food from other organisms.
decomposer—organisms that break down the tissues and excretions of other organisms into simpler substances through the process of decay.
ecosystem—a community of organisms interacting with each other and the environment in which they live.
food chain—the transfer of the sun's energy from producers to consumers as organisms feed on one another.
food web—complex food chains existing within an ecosystem.
niche—the functional role of an organism as well as the set of physical and chemical factors which limit its range of existence.
producer—a living thing that can make its own food.
terrestrial community—all of the populations of organisms in a particular area that live on land.

WHAT IS THE BEST USE FOR MARSH BEACH

A Marine Environmental Simulation Game

During this investigation you are going to participate in a simulation game concerning land use in a hypothetical community, analyze what you have done, and present some ideas which will enable you to think critically about real environmental issues in your community. The techniques you are to use are those of simulating real issues, and combining the element of role-playing. You will assume the roles of decision-makers in a simulated environment and compete for certain objectives according to specified procedures and rules.

The major problem of this simulation activity will be: to decide what are some of the possible uses of the 3 mile (1250 acre) Marsh Beach which the city has recently purchased at a cost of $3 million.

Part I

For the next 10 minutes you are to read the background information for Seaport City, and list some possible uses of the vacant Marsh Beach area. The Marsh Beach area, which was held by the Lonely Estate Trust since its owner died in 1903, has been purchased by Seaport City to prevent it from falling into the hands of developers before the city planning board has an opportunity to decide how the property can best benefit the city.

Background Information Sheet: Seaport City

The population is 250,000 and rapidly increasing.

The city's boundaries are being extended, but the suburban fringe is expanding even more rapidly along the coast and up the river with industry moving in adjacent to the interstate highways.

The rapid growth is accompanied by demands for more housing, more jobs, additional municipal services, and recreational areas.

The city's harbor is the best within a hundred miles. Though its present harbor facilities are adequate, with good rail and highway links, the channel must be maintained by dredging and will not accommodate the new supertankers.

The surrounding coastal plain is glacial till and is mostly second growth hardwood forest with little timber value. There are a few scattered dairy and poultry farms, but most agricultural produce is shipped in from other parts of the country. The land to the north is hilly with coniferous forest.

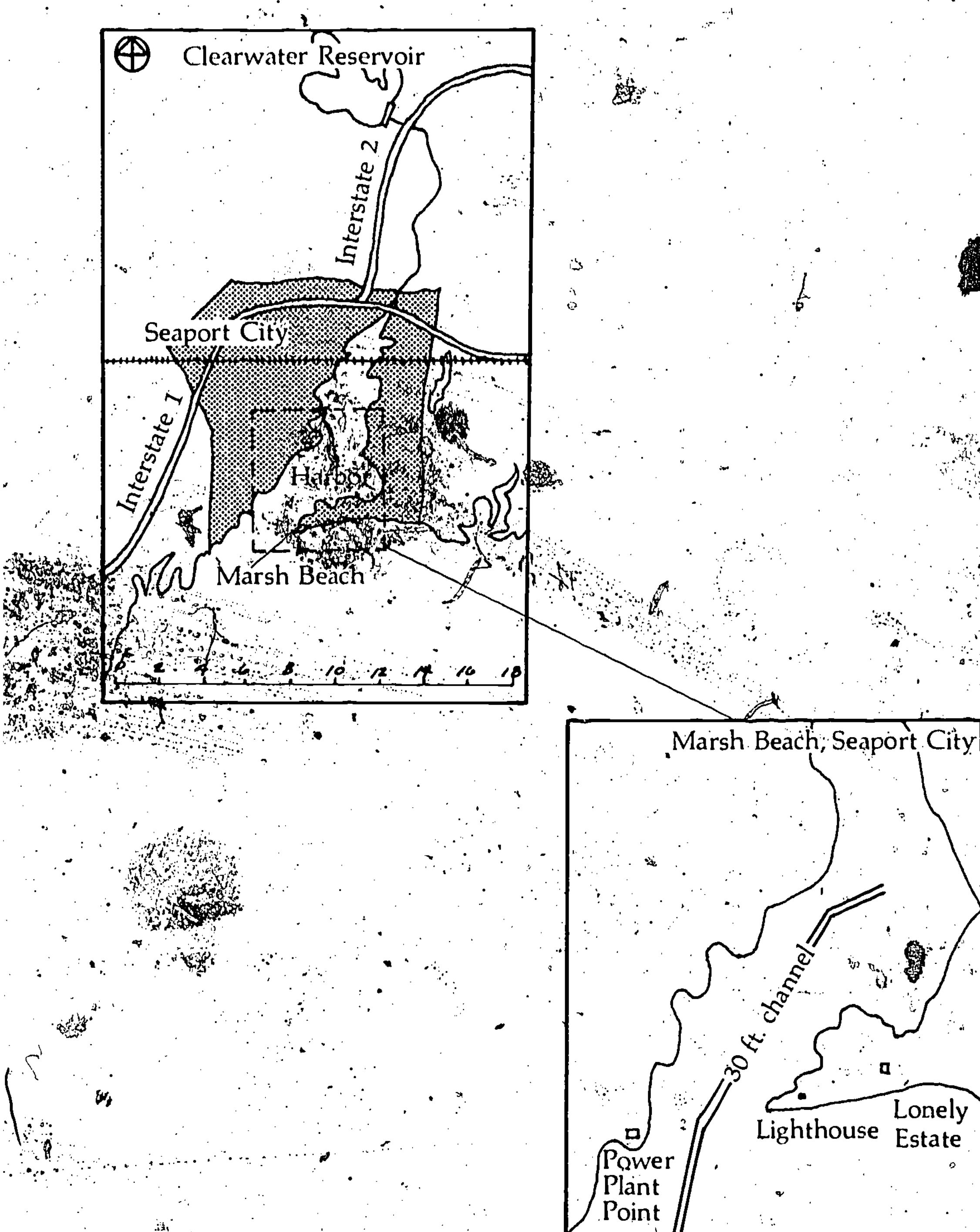
The Clearwater River is not navigable beyond the Old Mill Dam just north of Interstate 1. The city water supply comes from the Clearwater Reservoir which has a protected watershed. Below Interstate 2 the water is used by several industries as process water.

Offshore seismic surveys indicate the presence of possible deposits of sand and gravel and petroleum. Special interest groups are concerned with maintaining a scenic coastal environment and the coastal fisheries.

Present sewage treatment and solid waste disposal facilities are operating at maximum capacity.

The city planning board is going to hold a public hearing at which all interested groups will be given the opportunity to air their proposals for the utilization of the Marsh Beach area.

List possible uses of the Marsh Beach area below:



Your group should now, in a 10 minute period of time, analyze and list possible consequences of different land uses within your assigned land use category.

Use	Advantages to land/people	Disadvantages to land/people

Part III

Your group will now have 20 minutes to plan a strategy and develop a 3-minute presentation to be made at the next City Planning Board meeting. The presentation should be a proposal for developing the undeveloped Marsh Beach area. Your group must have a visual display such as a land use map drawing as a part of your presentation. More than one person in your group must help in making the presentation. On a separate sheet of paper, outline your group's presentation.

Part IV. Analyzing Characteristics of a Simulation Game

One group of people working with simulation games has identified at least three basic characteristics of most simulation games:

a. There is a problem to be solved.
b. The factors affecting the decisions are identifiable.
c. Groups or individuals with different interests who will be affected by the decision can be identified.

Let's see if the game we just played had these components:

a. What was the clearly defined problem in the Marsh Beach Simulation? ____________________

____

b. What factors influenced the decision in the Marsh Beach Simulation? ____________________

____

c. We assigned groups to fit each role in the Marsh Beach Simulation, but we all helped develop those roles from the items we listed on the chart. What group or individual roles were identified? How were they identified?

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