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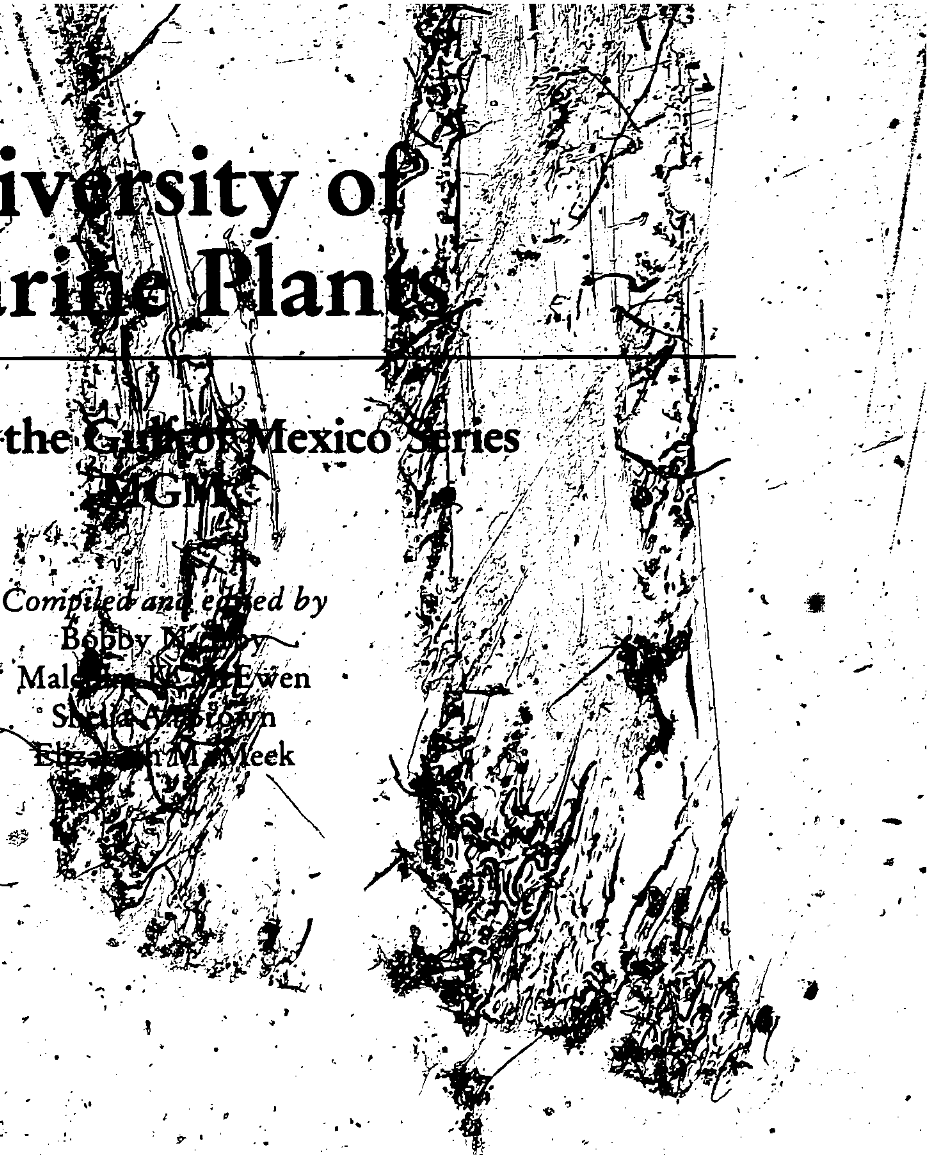
ABSTRACT

"Man and the Gulf of Mexico" (MGM) is a marine science curriculum series developed to meet the needs of 10th through 12th grade students in Mississippi and Alabama schools. This MGM unit on the diversity of marine plants is divided into 12 sections. The first section introduces the unit by providing objectives and activities on why people classify things and on the use of a taxonomic key. The next 11 sections focus on: photosynethesis; algae; green algae; brown algae; red algae; golden brown algae; dinoflagellates; blue-green algae; marine bacteria; sea grasses; and salt marshes. Each section includes a statement of the concept(s) to be learned, objectives, text material, and one or more science and/or vocabulary activities. Objectives, procedures, and a list of materials needed are provided for the science activities which focus on: plant pigments; photosynthesis and light; the role of carbon dioxide and oxygen in photosynthesis; diatoms; and the kinds of algae found around the coast of the United States. Additional activities include constructing a plankton net, pressing algae, identifying algae, staining bacteria, collecting and culturing marine bacteria, and taking a salt marsh field trip. (JN)



Diversity of Marine Plants

Man and the Gulf of Mexico Series (MGM)

Compiled and edited by
Bobby N. Irby
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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 [illegible] 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 this cirriculum 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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DIVERSITY OF MARINE PLANTS

Objectives of *Diversity of Marine Plants*

1. To familiarize students with the major divisions of algae found in the marine environment.
2. To emphasize diversity in form and size of the common marine algal groups.
3. To develop an understanding of how marine flora has adapted to survive in its environment.
4. To inform students about algal species found in the Gulf of Mexico.
5. To increase the student's appreciation of the interdependency of salt marsh flora and fauna.
6. To promote an understanding of the importance of marine flora to human affairs.
7. To inform students about vascular plants found in selected marine habitats of the Gulf Coast area.

INTRODUCTION

Marine and maritime plants belong to many divisions of the plant kingdom. Marine plants include **algae, sea grasses** and various **monocot** and **dicot** species found in salt marshes. The algae are **thallophytes** which do not have true roots, stems and leaves. Sea grasses are monocots which live in marine and estuarine waters. Like other monocots and dicots, sea grasses have **vascular tissue**. Thus, unlike the thallophytes, they have true roots, stems and leaves.

Algae are the simplest plants known to man. Their diversity in form and structure is obvious in the marine **environment**. Algae may exist as simple, single-cells (green and blue-green algae) or as large filamentous or branched multicellular plants as the **kelps**.

The importance of plants in any ecosystem, whether **aquatic** or terrestrial, must be emphasized. Plants, whether single-celled algae or multicellular grasses and trees, function as **primary producers**. As primary producers, green, chlorophyllous plants synthesize food and generate oxygen as a by-product of **photosynthesis**. The level of oxygen in the air we breathe and the food manufactured in plant **protoplasm** are essential to our very existence.

Bacteria and **fungi** are essential to any **ecosystem** (marine, estuarine, or terrestrial). These plant-like organisms perform diverse activities. They function as **decomposers** in their respective ecosystems. As decomposers, the bacteria and fungi break down the tissues and excrements of other organisms into simpler substances through the process of decay.

During the process, the bacteria and fungi absorb some of the decomposition products and release **inorganic nutrients.** The inorganic nutrients released into the environment can be recycled by primary producers.

VOCABULARY

Algae—unicellular or multicellular photosynthetic plants that do not have roots, stems, or leaves.
Aquatic—living in water.
Bacteria—a group of microscopic, one-celled protists.
Decay—the reduction of the substances of a plant/animal body to simple compounds.
Decomposers—organisms that break down the tissues and excretions of other organisms into simpler substances through the process of decay.
Dicot—a seed plant with two seed leaves (cotyledons).
Ecosystem—a community of organisms interacting with each other and the environment in which they live.
Environment—the surroundings of an organism.
Fungi—all nonvascular plants lacking chlorophyll, except bacteria and slime molds.
Inorganic nutrients—substances which promote growth and development in organisms. Inorganic nutrients do not contain carbon.
Kelp—large, tough, brown seaweeds.
Monocot—a flowering plant that develops a single seed leaf (cotyledon).
Photosynthesis—process of plants by which energy-rich organic compounds are made from water and carbon dioxide using sunlight as the energy source.
Primary producers—organisms that synthesize organic matter from inorganic substances; plants.
Protoplasm—refers to the complex, constantly changing system of substances that established the living condition.
Sea grasses—monocot plants living in marine waters.
Thallophytes—plants having a body without true roots, stems, and leaves.
Vascular tissues—specialized tissue for the transport of food, water and minerals (xylem and phloem).

WHY CLASSIFY?

We as humans are constantly placing our possessions into groups. Everything must be placed into some category. Thus, it is no different when it comes to living creatures. We first place all of those that are alike into one group and those that are different into other groups. Even your school class is 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. 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 ways to classify organisms that are relevant and easy 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. A system of classification should be devised to indicate similarities among the 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 in the world with this name.

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 a classification system can be used.

Materials

the attached page of fictitious marine plants

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.

As a group, first complete Table I 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 "plant-like" characteristics place them together as plants. For the next category you might separate the plants into "aquatic or terrestrial plants"; "herbaceous or woody". With careful observations you can devise a good system of classification based upon your observations. The criteria are abundant (leaf shape, fruit type, flower type).

VOCABULARY

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

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

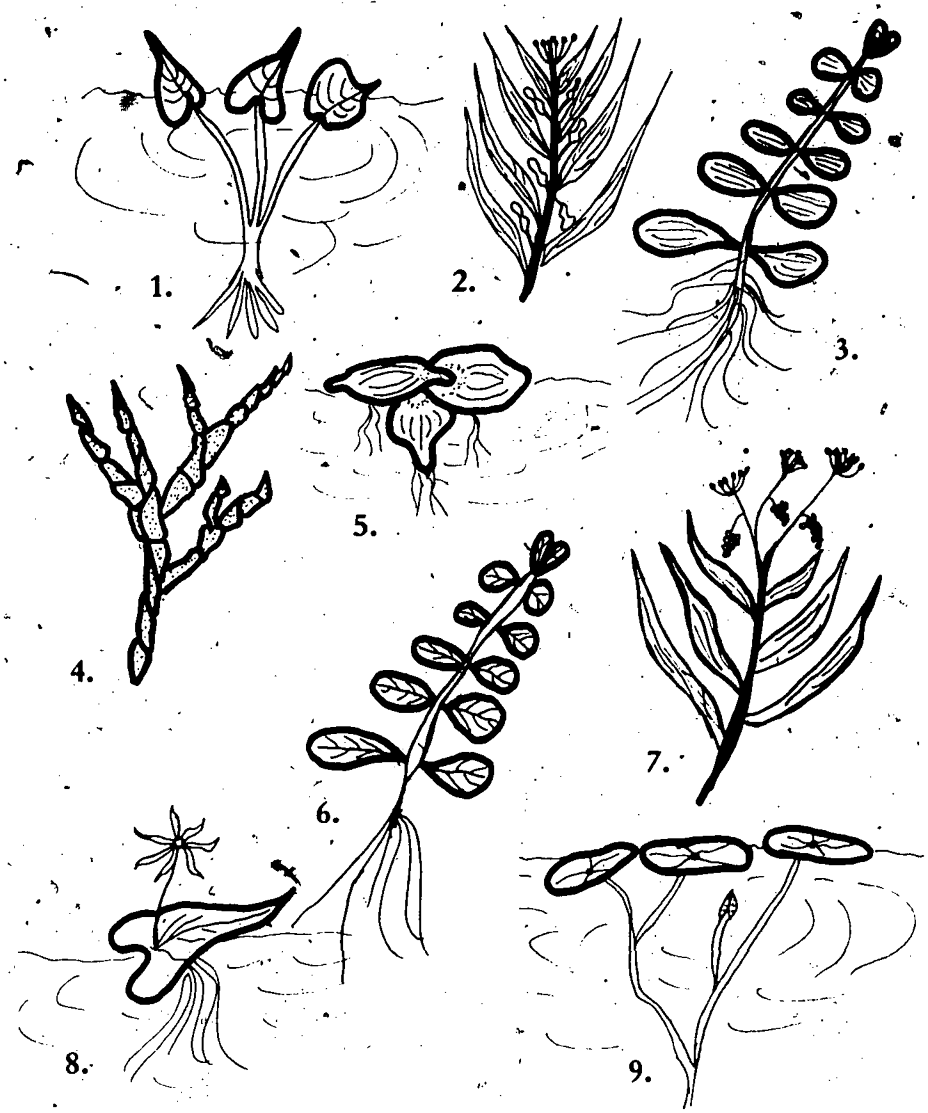

Table I.

Category	Criterion Used	Example
Kingdom	plant-like/animal-like	Plant
Division		
Class		
Order		
Family		
Genus		
Species		

Use your own system to classify the organisms which appear in the drawing. Place your responses in the accompanying data table.

	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9
Kingdom									
Division									
Class									
Order									
Family									
Genus									
Species									

1. Which organisms seem to be more closely related? ______
2. Which two organisms seem to differ the most? ______
3. Record your scientific name for organisms 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.

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

5 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,

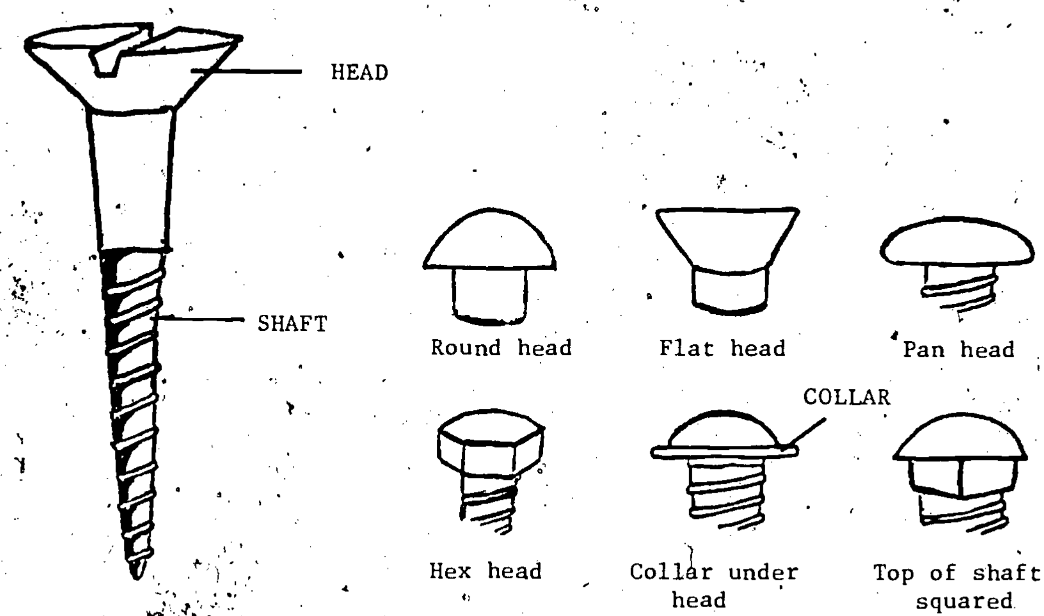

FIGURE 1

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*

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

Photosynthesis, an important series of chemical reactions, is the process by which plants synthesize organic food materials from inorganic materials.

Objectives

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

a. To explain the importance of plants in any ecosystem.
b. To give an overall reaction of photosynthesis.
c. To list the materials necessary for photosynthesis.
d. To list the products of photosynthesis.
e. To discuss a method that can be used to separate a mixture of chemical substances.

PHOTOSYNTHESIS

Green plants and certain bacteria are capable of converting inorganic materials into organic substances. These **autotrophs** are important to the **ecosystem** because their activity produces plant **protoplasm** and other products which are basic sources of energy and the building blocks for the synthesis of animal protoplasm. The process by which plants synthesize organic food materials from **inorganic materials** is called **photosynthesis.** In this process light energy is converted to chemical energy. Carbon dioxide and water are the inorganic substances plants use to produce **glucose.** Sunlight, **enzymes,** and **photosynthetic pigments** must be present for plants to convert carbon dioxide and water into glucose and oxygen.

$$6CO_2 + 6H_2O \xrightarrow[\text{enzymes}]{\text{solar energy}} C_6H_{12}O_6 + 6O_2$$

photosynthetic
pigment

Chlorophyll is the photosynthetic pigment which must be present for photosynthesis to occur. It is the major **catalyst** necessary for photosynthesis. A catalyst is a substance that affects a chemical reaction but does not enter into it chemically.

Both products of photosynthesis are important. Glucose is important because it is a food resource used by animals. Oxygen is important because it is utilized by plants and animals in the **respiration** of their food. Since the maintenance of adequate food supplies and atmospheric oxygen is essential to life, photosynthesis is considered the most important chemical process on earth.

VOCABULARY

Autotrophs—organisms capable of synthesizing protoplasm from inorganic substances.

Catalyst—a substance which regulates the rate of a chemical reaction without being used up in the reaction.

Chlorophyll—the green pigment present in plants needed for photosyn[illegible]

Ecosystem—a community of organisms interacting with each [illegible] nment in which they live.

E[illegible]—[illegible]otein-like catalyst produced by living cells.

Glucose—a simple sugar, $C_6H_{12}O_6$, also termed dextrose or grape sugar.

Inorganic materials—substances (nutrients) which promote growth and development in organisms.

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

Photosynthetic pigments—chlorophylls, xanthophylls and carotenes found in plastids; they are involved in photosynthesis.

Protoplasm—refers to the complex, constantly changing system of substances that establishes the living condition.

Respiration—a series of complex oxidation-reduction reactions whereby living cells obtain energy through the breakdown of organic materials and in which some of the intermediate materials can be utilized for various syntheses.

Activity: PHOTOSYNTHESIS AND LIGHT

Objective

To observe the effects of light and dark on a green plant.

Materials

2 corn or bean seedlings per student pair (that have been previously germinated and are at present from 3–4 inches above soil level), 4 rulers, marking pens, test tubes, test tube racks, aluminum foil, *Elodea*, paper

Procedure

A. Terrestrial Plant—Each student pair should obtain two plants. Label one plant "A" and the other "B". Count the number of leaves on each plant. Measure the approximate height of each plant. Record your data. Place plant "A" in a closet or any area where light exposure is poor. After 3–4 days, examine each pot. Measure the height of each and count the number of leaves on each plant.

Record your data.

Data Sheet—Photosynthesis and Light

	Plant "A"		Plant "B"	
	Day 1	Day 4	Day 1	Day 4
Number of Leaves				
Plant Height				
Color of Leaves				

COMMENTS

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What color are the leaves and stems of the plant grown in the light?______________________

____

Do the leaves and stems of the plant grown in the dark differ from those of the plant grown in the light?____

How do they differ?____

____

Which leaves appear to have more chlorophyll?___________________________________

____

Is there a difference in height between plant "A" and "B"?________________________

What might have caused the difference?____________________________________

____

B. Aquatic Plant—Each student pair should obtain two 2–3" segments of *Elodea*. Place each segment into a test tube containing water. Label tubes "A" and "B". Cover plant "B" in aluminum foil. Place each tube in a rack side by sid[illegible] the r[illegible] in [illegible] window or any area exposed to light. After 4–5 days remove the *Elodea* from the test tubes. Lay the plants side by side on a piece of white paper.

Does the color vary between the plants?____________________________________

____

Does the size vary?____

______________________________________Why?_________________________

____

Do the leaves vary?____

Can you explain why the plants vary?______________________________________

____

____

Is light essential for plant survival?____

____

____

Activity: THE ROLE OF CO_2 AND O_2 IN PHOTOSYNTHESIS

Objective

To note the significance of certain gases to photosynthesis.

Materials

beakers, test tubes, *Elodea*, Bromthymol blue, straws.

Procedure

Students should work in pairs.

A. Each student pair should obtain three test tubes. Fill each tube with water. Label the tubes "A", "B", and "C" respectively. In tube "A" place a sprig of *Elodea*. To each tube add 3–4 drops of bromthymol blue. With a straw, blow into tubes "A" and "B" until a color change occurs. Leave tube "C" alone.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

neutral blue — acid yellow-green

Set the tubes in a well lighted area. Observe the tubes for the next hour at 15 minute intervals. Record your data.

	Tube "A"	Tube "B"	Tube "C"
Time	*Elodea* + H_2O + CO_2 + bromthymol blue	H_2O + CO_2 + bromthymol blue	H_2O + bromthymol blue
0			
15 min.			
30 min.			
45 min.			
1 hr.			

What gas is necessary for photosynthesis to take place? ________

What is an indicator? ________

What color was tube "A" after you blew CO_2 into it? ________

What happened to cause a color change in 1 hour? ________

Is carbon dioxide used in photosynthesis? ________

Did tube "C" change colors? ________ Why? ________

Did tube "B" change colors? ________ Why? ________

What gas is a product of photosynthesis? ________

Write an equation to represent photosynthesis.

B. Place a 4–5" sprig of *Elodea* into a test tube. Fill the tube with water. Shake the tube to rid it of any bubbles. Fill a beaker ⅓ full with water. Place your thumb over the top of the test tube, invert it, and place it into the beaker of water. Remove your thumb. The test tube now becomes a gas trap (Figure 1). Place the tube and beaker into a well lighted area for 1–2 hours. Observed the setup periodically throughout the time span.

Do you see any air bubbles forming? ________

If so, what gas is being evolved? ________

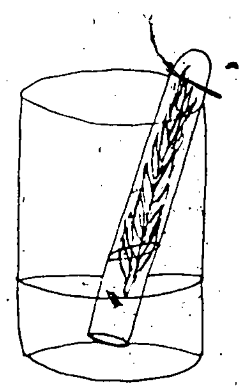


Figure 1. Gas Trap

VOCABULARY ACTIVITY FOR CONCEPT A

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

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

Answers: photosynthesis, autotrophs, ecosystem, catalyst, enzyme, chlorophyll, glucose, pigment, inorganic, organic

CONCEPT B

Algae represent one group of plants that do not possess true roots, stems or leaves and exist in a variety of sizes and forms adapted for survival in their environment.

Objectives

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

a. To list the characteristics of thallophytes.
b. To differentiate between procaryotic and eucaryotic cells.
c. To name an algal group which has procaryotic cells.
d. To name an algal group which has eucaryotic cells
e. To differentiate between the term annual and perennial.
f. To list various forms of algae.
g. To list three habitats of algae.
h. To list two physical factors which affect growth.
i. To list two adaptations of the seaweed thallus to the environment.
j. To state various characteristics used to divide algae into major divisions.
k. To discuss the importance of algae to the ecosystem.
l. To state the economic importance of algae.

ALGAE

Diversity among marine plants is quite obvious within the **thallophyte** group called **algae**, the grasses of the sea. Algae exist in more forms than any other group of living things.

Algae are the simplest plants. The blue-green forms are composed of **procaryotic** cells; all other forms are composed of **eucaryotic** cells (Figure 1). Structural characteristics range from the microscopic, unicellular forms (*Pleurococcus*) to those with millions of cells, such as the giant kelp (Figure 2). **Chlorophyll** and other pigments are localized in **chloroplasts** of distinct size and shape which vary from genus to genus. The most primitive algae are **flagellated** (Figure 2).

Algae are found in many curious and sometimes beautiful shapes. Some forms resemble trees and some exist in colonies encased within a gelatinous substance. *Cladophora* is representative of the threadlike alga, while *Ulva* somewhat resembles a ribbon. *Enteromorpha* has separate layers of cells which give it a hollow effect. Some are **annuals**, others **perennials**, so they look different during different seasons.

Algae produce their own food by photosynthesis, and they are nourished by substances suspended within the water which surrounds them. These plants must not be exposed to air over a very long period of time, for they will wilt.

Water is by far the most common **habitat** of algae, but they may also be found on tress, rocks, in animal bodies and other places. Algae are worldwide in distribution and different species are endemic to certain environments. **Each** ocean has its own distinctive **flora**, and if one species of algae is represented by a very high percentage in one ocean, it will hardly be found, if at all, in the others. Of all the algae found in the coastal waters of the United States, only 10% is found on both coasts.

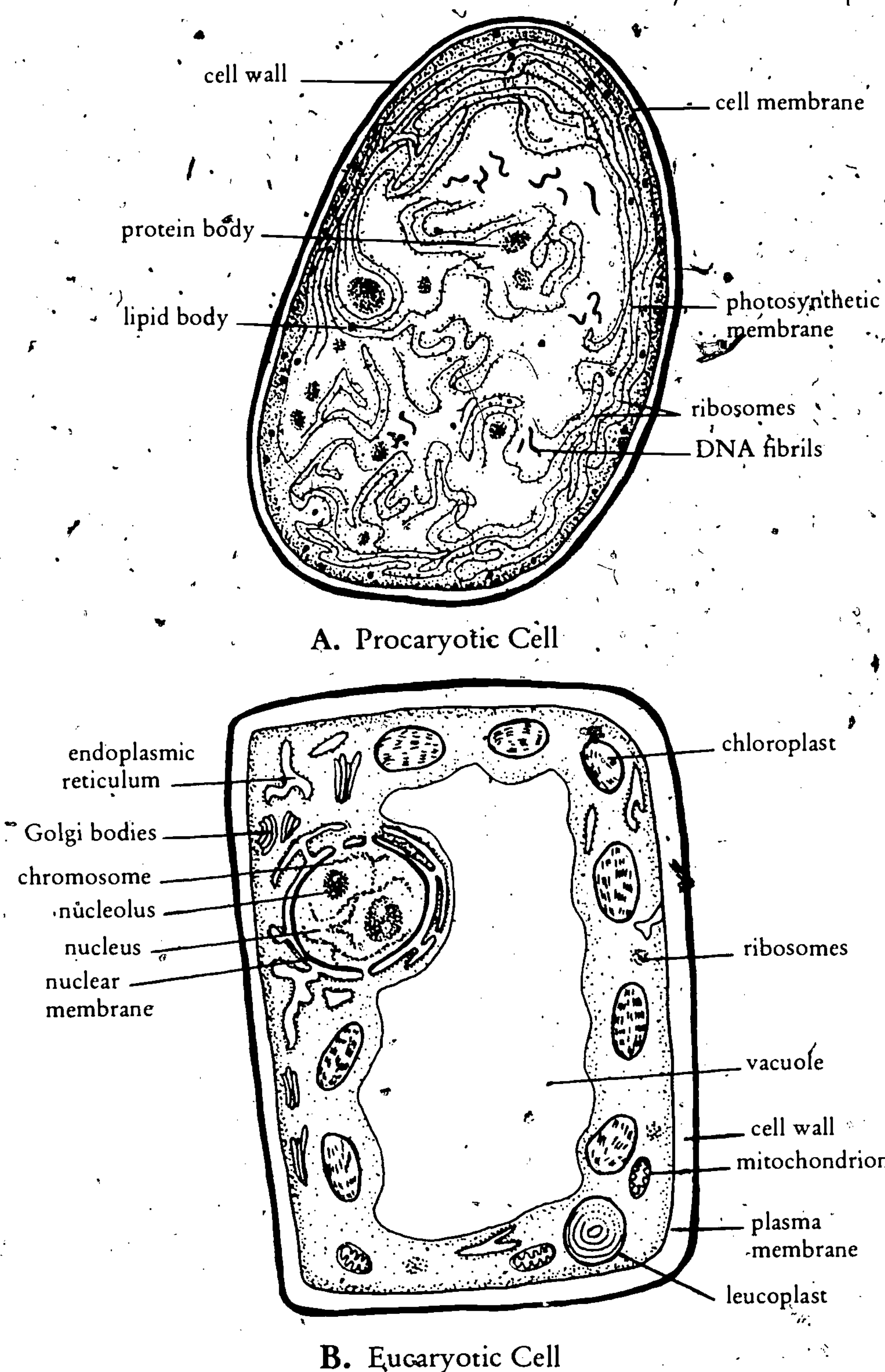
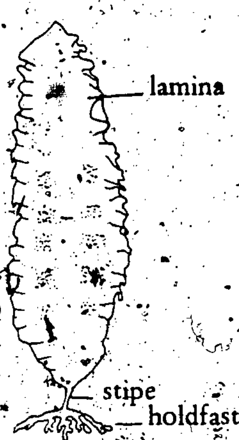


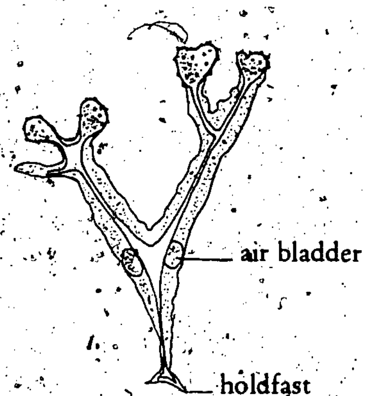
Figure 1. Typical procaryotic (A) and eucaryotic (B) cells.

A. Single-cell with gelatinous sheath

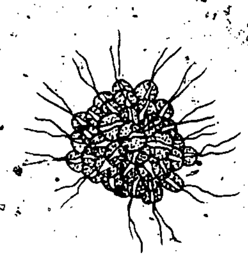
B. Filamentous alga in gelatinous sheath



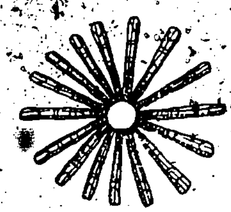
C. Multicellular kelp with ribbon-like blade



D. Multicellular branched thallus with air bladders

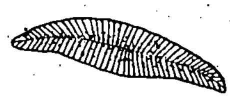


E. Flagellated colonial alga



F. Nonflagellated colonial alga

G. Unicellular dinoflagellate



H. Unicellular diatom; nonflagellate

Figure 2. Variation in body form of the algae.

Physical factors such as differences in salinity, temperature, available light, pollution, water currents, waves, and shoreline type dictate how well an organism will live. A very harsh environment may even limit the presence of some organism in specific localities.

Usually marine algae are limited to the coastlines of the continents because of the light factor. These plants may possess very highly adaptive anatomical features that allow them to exist in this shoreline environment which is constantly being washed by wave action. Many plants will be torn loose and can be found floating in the upper waters almost any place in the world.

Algae will not be found in the deeper habitats because the light intensity is not great enough to sustain photosynthetic activity necessary for food production.

We can divide the coastline into three areas that will support algae. The **subtidal** area is below the low tide level and here the extremes in light, heat and violent wave action are held to a minimum. The **intertidal** area is exposed for about a 12-hour period of drying and a similar submergence once a day along the Gulf Coast. The **supratidal** area is the area above the highest tide that receives the spray from the high tides. The subtidal and intertidal areas usually support the greatest algal populations.

If there are alterations along the shoreline such as concrete pilings or other objects, there may be additional areas where algae may be found. These areas are usually very rich in algal flora.

Seaweeds represent the large marine algae. These look somewhat like the higher land plants, but they are quite different in that they do not have roots, stems, or leaves. Seaweeds are well adapted for the marine habitat. They usually grow near the shore where they attach themselves to rocks, other objects, or to the bottom by **holdfasts** which look like roots (Figure 2). Their bodies are generally quite flexible, and some have air floats that help them stay near the surface in order to get sufficient light for photosynthesis through the shallow water.

Each part of a seaweed has very specific functions (Figure 2). The body, or **thallus**, may consist of a simple filament, a branched filament, a hollow tube or bladder, a bushy tuft of cylindrical or flattened branches, or a simple or compound blade, sometimes called a **lamina.** Attached to the thallus is the stemlike **stipe.** The stipe varies among species, but in each it is highly adapted for its important role of holding the plant together against the force of moving water (Figure 2C, D). Some species have floats, called **bladders** which help them stay afloat in order to receive enough light. At the other end of the stipe the aptly named holdfast does just that, holds the plant tightly to its anchor. Unlike a root, it does not transport water and nutrients. In sand and mud habitats, such as those found in the Gulf of Mexico, some plants have holdfasts that surround and attach to sediment particles to form an anchor within the loose substrate.

Algae are of enormous importance to the ecosystem. They produce five times more matter than land plants, and this matter is food for a great variety of animals, from the protozoa to humans. About ninety percent of the **photosynthesis** on earth is carried out by algae, so they are great producers of oxygen, too. Algae also are contributors to human knowledge of biological processes, for their simplicity of structure lends itself well to laboratory study.

The algae are organized into divisions based on differences in cell type, photosynthetic pigments, nature of food stored, and other characteristics relating to morphology and motility. Table 1 lists various characteristics used to distinguish the divisions of algae.

TABLE 1

The Divisions of Algae and Their Differentiation (Bold, 1973).

DIVISION	Common Name	Cell Type	Food Stored	Pigments
Cyanophycophyta	Blue-green algae	Procaryotic	Cyanophycean Starch	Chlorophyll *(a,b)* Carotene (2) Xanthophyll *Phycocyanin *Phycoerythrin
Chlorophycophyta	Green algae	Eucaryotic	Starch	*Chlorophyll *(a,b)* Carotene (3) Xanthophylls (4)
Phaeophycophyta	Brown algae	Eucaryotic	Mannitol (laminarin)	Chlorophyll *(a,c)* Carotene (1) Xanthophylls (6) *Fucoxanthin
Chrysophycophyta	Golden algae	Eucaryotic	Oil (Chrysolamminarian)	Chlorophyll *(a,c,e)* *Carotene (1) *Xanthophylls (2)
Pyrrhophycophyta	Dinoflagellates	Eucaryotic	Starch & Oil	Chlorophyll *(a,b)* Carotene (1) *Xanthophylls (several)
Rhodophycophyta	Red algae	Eucaryotic	Floridean Starch	Chlorophyll *(a,d, c)* Carotene (1) Xanthophyll (several) *Phycocyanin *Phycoerythrin

*Impart color to the algae.

VOCABULARY

Algae—unicellular or multicellular photosynthetic plants which do not have roots, stems or leaves.
Annual—a plant which completes its life history within a year.
Bladders—"air bladders", "floats"; structures on certain algae which increase buoyancy so that the algae can float on or in the water. They are morphological adaptations to insure that the plants are exposed to sunlight for photosynthetic processes.
Chlorophyll—the green photosynthetic pigment found in plants.
Chloroplast—a membrane-bounded area of cytoplasm containing photosynthetic membranes (lamellae).
Ecosystem—a community of organisms interacting with each other and the environment in which they live.
Eucaryotic cell—cell having membrane bound organelles (nuclei, Golgi apparatus, mitochondria).
Flagellated—bearing flagella; whiplike projections of cytoplasm used in locomotion by certain organisms or sex cells.
Flora—the plants or plant life occurring in a given locality. The predominant marine flora are floating phytoplankton, attached near shore algae, and marine grasses.
Habitat—the place where an organism lives.
Holdfast—an attaching organ of some algae.
Intertidal zone—in the marine environment, the area of the shore that is periodically covered and uncovered by water.
Lamina—a simple leaf-like structure; the thin layered thallus of some algae.
Perennials—plants living three or more seasons.
Photosynthesis—process of plants by which energy-rich organic compounds are made from water and carbon dioxide using sunlight as the energy source.
Procaryotic cell—cells lacking membrane-bounded nuclei, plastids, Golgi bodies and mitochondria. Blue-green algae and bacteria possess procaryotic cells.
Seaweed—large, marine algae such as the kelps.
Stipe—the portion of a kelp between the blade and base (holdfast).
Subtidal zone—the area of the beach that lies below the high tide line.
Supratidal zone—the area of the beach that lies above the high tide line.
Thallophyte—a plant having a body without roots, stems, or leaves.
Thallus—a plant body with no true roots, stems, or leaves; the flattened body of some lower plants.

Activity: **Plant Pigments**

Marine algae and terrestrial plants contain chlorophyll, carotene, and xanthophyll pigments. These pigments can be easily extracted from plant tissues and separated from each other. The pigments differ in color which allows for easy identification.

Objective

To extract plant pigments from live tissue and separate them into groups based on color.

Materials

paper clips, test tubes, corks, test tube racks, strips of chromatography or filter paper, scissors, pencils, blender or mortar and pestle, developing solution (8% acetone, 92% ether), spinach leaves or algae, toothpicks, ethyl alcohol (95%)

Procedure

A. Pigment extraction
   1. Place the plant materials in a blender.*
   2. Estimate the plant volume.
   3. Add 3–4 volumes of the extracting solution (95% alcohol).
   4. Blend for approximately 2 minutes. Plant materials should appear homogenized.
   5. Allow the plant debris to settle. Pour the supernant (the upper layer) through general purpose filter paper to remove the plant debris.
   6. This supernant contains the photosynthetic pigments. Store the pigment in the refrigerator in the dark until you are ready to use the material. Be sure to use a covered container.

B. Certain pigments can be separated from each other due to their differential solubility in various organic solvents.
   1. Place about 1 inch of the chlorophyll extract in a test tube.
   2. Add an equal amount of ether to the tube.
   3. Shake the tube and set it aside.
   4. Allow the layers to separate.

Which layer is on the top, alcohol or ether? ____________________
In which layer is the chlorophyll? ____________________ How could you tell? ____________________
What pigments are in the other layer? ____________________
Why were you able to separate the pigments this way? ____________________
____

C. Plant pigments can also be separated by paper chromatography.
   1. Cut a strip of chromatograph paper or filter paper large enough to hang in a test tube from a paper clip inserted into a cork without touching the sides or bottom of the test tube (Figure 1).
   2. Mark the paper at approximately ¾ of an inch from the bottom of the paper with a pencil. (Only use a lead pencil. Ink will travel up the paper with the solvent.)
   3. By using a tooth pick, place a drop of pigment extract on the pencil mark. Let dry and repeat several times.
   4. Add about ½ inch of the ether-acetone solution to the test tube.
   5. Hook the strip of paper on the clip.
   6. Carefully place the paper into the test tube. Be sure the pigment spot does not touch the developing solution in the test tube.
   7. If necessary adjust the hook to avoid the pigment spot from entering the solvent.
   8. Periodically check the set-up. Watch the developing solution rise and the separation of the pigments.

*If you do not have a blender, the plant material can be ground in a mortar and pestle to which some sand has been added. Add some alcohol and empty into a container covered with aluminum foil. Add 3–4 volumes of alcohol and let steep overnight.

Figure 1.

9. When the solvent edge reaches the hook area remove your chromatogram from the tube. Note the colors.

What colors do you see? ______________________________

What pigment does each color represent? ______________________________

____

What pigment traveled the farthest? ______________________________

____

Which pigment traveled the shortest distance? ______________________________

____

VOCABULARY ACTIVITY FOR CONCEPT B

Hidden in the letters below are 10 vocabulary words related to Concept B. The words may be written vertically (up-and-down), horizontally (across), backwards, or diagonally. Try to find the 10 words.

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

Answers: algae, chloroplast, flora, seaweed, thallophyte, stipe, procaryote, bladder, chlorophyll.

VOCABULARY ACTIVITY FOR CONCEPT B

Below you will find scrambled vocabulary words that are related to Concept B. Unscramble the letters of each word and write it in the blank provided. Notice that some words have letters circled. If you write each of these letters down in order you can spell the "mystery" vocabulary word.

1. s a d h f o t l ____________
2. e g a l a ____________
3. t o r a l t i l ____________
4. e r d b a d l ____________
5. n a n a l u s ____________

What is the "mystery" vocabulary word? ____________

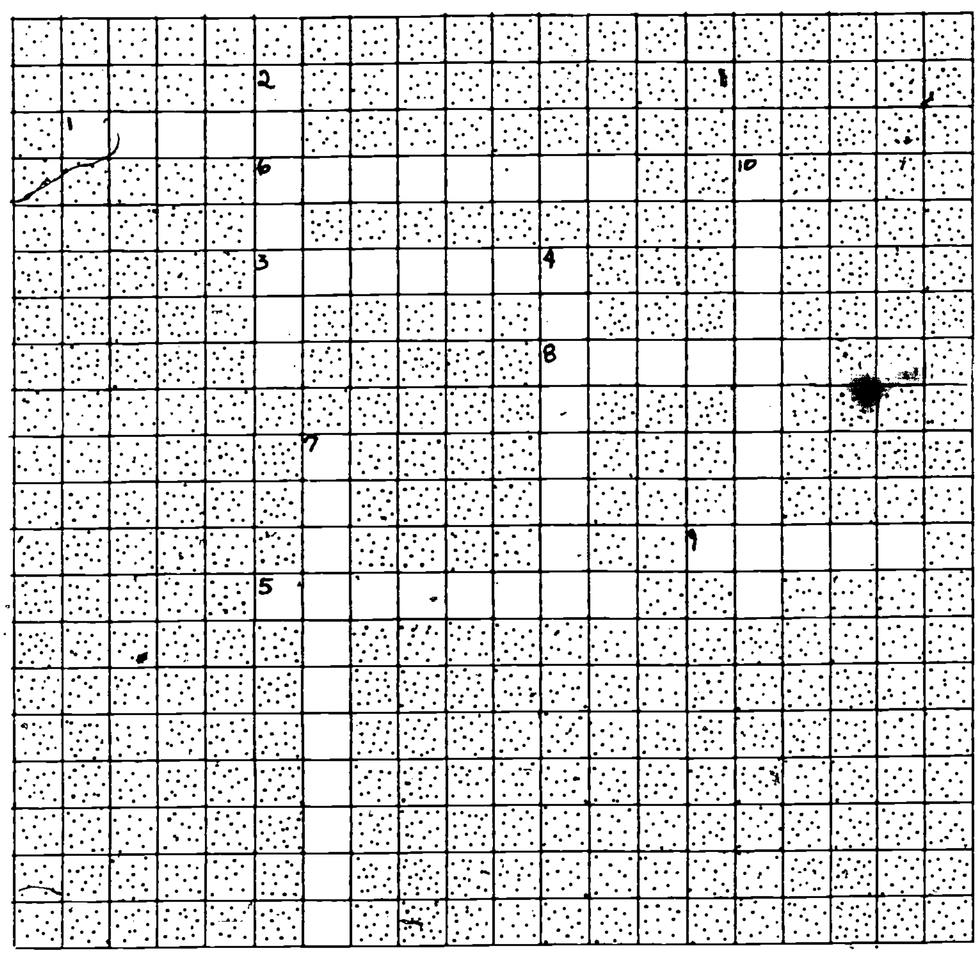
1. t i p s e ____________
2. b i h a t a t ____________
3. g e l a a ____________
4. m a l n i a ____________
5. l a t r i t o l ____________
6. s a d f h o t l ____________
7. r c a p o r o y t e ____________
8. s u l h a t l ____________
9. l o p c h y r o h l l ____________
10. h o t o p y n s t h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

What is the "mystery" vocabulary word? ____________

VOCABULARY ACTIVITY FOR CONCEPT B

Try to work this crossword puzzle by using Concept B vocabulary words.

1. Plant life of a given area.
2. The place where an organism lives.
3. A plant body without true roots, stems, and leaves.
4. Large marine algae as the kelps.
5. An adaptation of the thallus of some algae used for attachment.
6. Structures found in some algae which increase buoyancy, floats.
7. A green photosynthetic pigment.
8. A plant that completes its life history in one year.
9. The portion of a kelp between the blade and holdfast.
10. Does not have membrane-bounded organelles.



CONCEPT C

The green algae are a diverse group of eucaryotic algal forms which have a grassy-green color and store starch as a food reserve.

Objectives

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

a. To name the food reserve of green algae.
b. To explain the life history of one green alga.
c. To state the dominant pigment in green algae.
d. To state the importance of green algae to the ecosystem.
e. To name general habitats of green algae.
f. To give two human uses of green algae.
g. To identify two genera of algae found in the Gulf of Mexico.

GREEN ALGAE

Green algae belong to Division Chlorophycophyta (Greek, *chloros*, green and *phykos*, seaweed and *phyton*, plant).

Quite descriptively named, members of this division are grassy-green in color due to the photosynthetic pigments chlorophyll *a* and *b*. Diversity of form and size makes this one of the most attractive and interesting of all groups of marine flora. These organisms vary in size from microscopic *(Chlamydomonas)* to unusually large (*Codium magnum*, of Mexico) forms, which sometimes attains a length of more than 8m. Most species are small, unnoticed, except as floating masses of "green scum" or as clustered growths on rocks and other objects. Some forms require microscopic examination to determine species, but most genera can be determined, even by an amateur, by size, shape, and locality.

The structure and life cycles of the green algae are similar to those of higher plants. Each cell has at least one **chloroplast,** the site of **photosynthesis.** Food is stored as **starch.** Like bryophytes and vascular plants, green algae have firm cell walls. For these reasons, many scientists believe they are directly related to the evolutionary line from which the bryophytes (mosses) and vascular plants (ferns and flowering plants) arose.

There are at least 7,000 known species of Chlorophycophyta. While most are aquatic, only about 13% are marine. Members of this division are very common along the whole Atlantic coast. Some species of green algae are found where freshwater and saltwater mix, and several freshwater species are common to the Gulf coastal region. Members of Chlorophycophyta are rarely found below a depth of 10 m because of their requirement of light.

Members of this division are very important to the ecosystem. As primary producers, green algae are vital elements of food chains. They provide food for many animals, both microscopic and macroscopic. They benefit man both directly and indirectly. Some forms of green algae are consumed by humans in salads and some are eaten as marine vegetables. Some forms are valued as livestock food. Green algae are also extremely important for their release of oxygen, a by-product of photosynthesis.

Sometimes green algae are considered a nuisance, for they form an algal slime on boats, rocks, piers, and other objects. But their positive value far outweighs the inconveniences they cause.

Green algae reproduce by both **sexual** and **asexual means**. Filamentous forms may reproduce asexually by **fragmentation** of filaments. **Two types of asexual spores** are produced by certain species. The motile spores bear **flagella** and are called **zoospores. Aplanospores** are nonmotile. Spores are produced either by simple differentiation of the contents of a vegetative cell, or by modification of a vegetative cell into a **sporangium.**

Sexual reproduction in green algae involves the union of **gametes** which may be motile or nonmotile. Typically, marine algae possess flagellate gametes. **Isogamy** is a type of sexual reproduction in which cells of equal sizes (**isogametes**) fuse. When flagellated sex cells of unequal size (**heterogametes**) unite, the fusion is called **anisogamy.**

The life history of *Ulva*, the sea lettuce, is representative of marine forms in the division (Figure 1). An **alternation of generation** occurs between an asexual generation and a sexual generation. The asexual plant is **diploid** and is called a **sporophyte.** The sexual plant is **haploid** and is called a **gametophyte.** The alternation is called **isomorphic** since both the gametophyte and sporophyte are identical in appearance. The sporophyte (2n) produces zoospores (4 flagella) by meiosis which develop into male or female plants (n). The gametophytes produce **biflagellated** gametes (n) of different sizes (heterogametes). The male plants produce small gametes, while female plants produce larger gametes. Therefore, *Ulva* is unisexual. Three types of plants are produced; a diploid sporophyte, a haploid female gametophyte, and a haploid male gametophyte.

Green algae are primarily a freshwater group. There are only a few marine planktonic members. Most members are macroscopic algae. Species found in the Gulf of Mexico are shown in Figure 2.

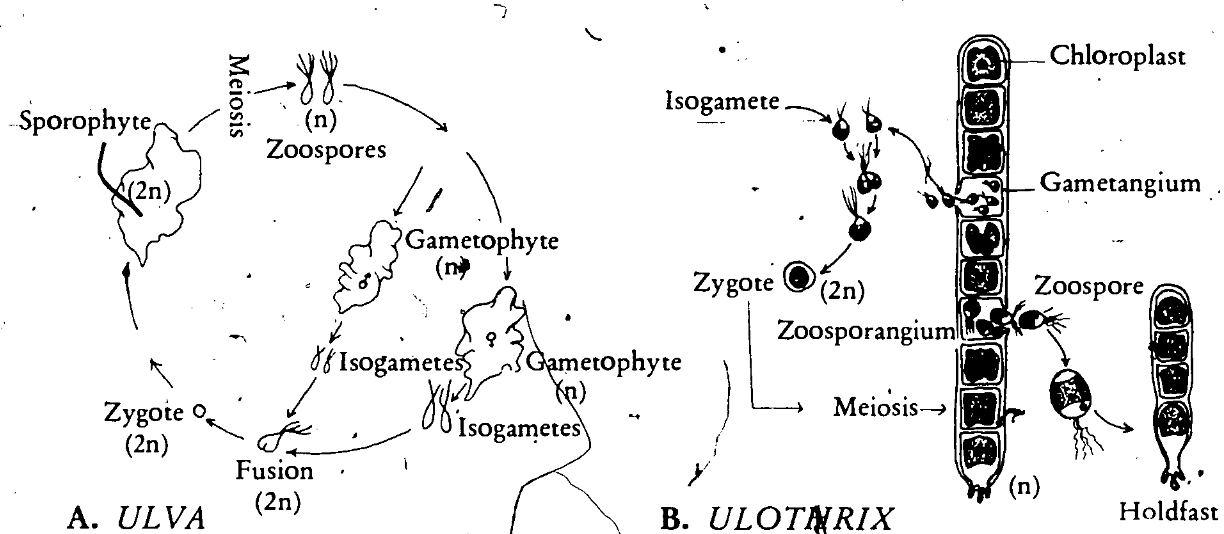


Figure 1. Modes of reproduction of two green algae. (Adapted from Muller, 1969 and Abbott, 1978)

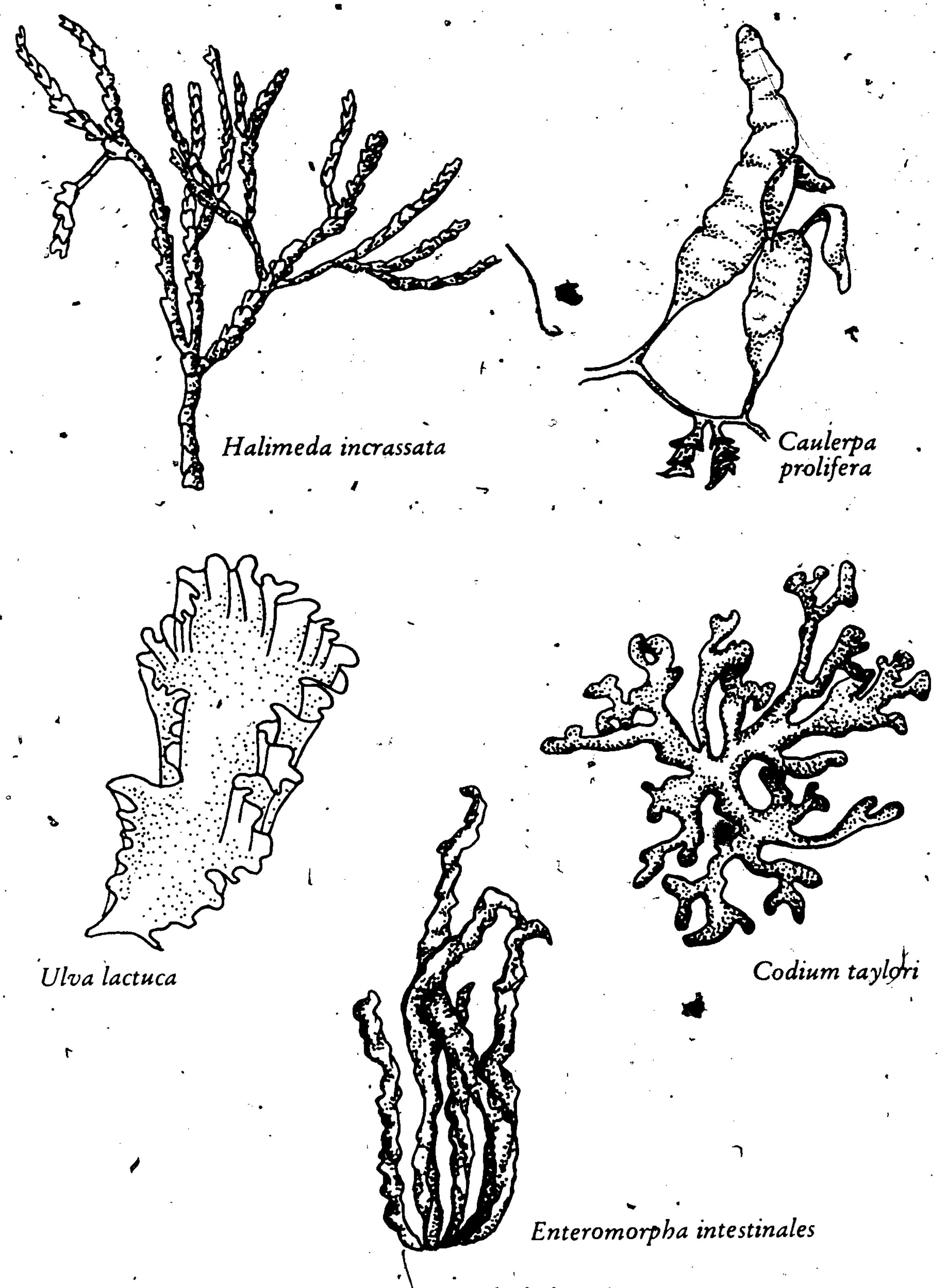


Figure 2. Several green algae common to the Gulf of Mexico.

VOCABULARY

Alternation of generations—a type of life cycle in which the asexual reproductive stage alternates with the sexual reproductive stage.

Anisogamy—a type of sexual reproduction in which unlike gametes fuse.

Aplanospore—a nonmotile spore in algae.

Asexual reproduction—reproduction without the joining together of two cells.

Biflagellate—having two flagella.

Chloroplast—a cell plastid containing chlorophyll on the lamellae.

Diploid—term used to denote a cell and/or organisms containing a full set of homologous pairs of chromosomes.

Flagellum—a whiplike projection of cytoplasm used in locomotion by certain organisms or sex cells.

Food chain—sequence of organisms (producers, consumers, and decomposers) through which energy and materials may move in a community.

Fragmentation—an asexual type of reproduction whereby pieces of an organism may break off and develop into a whole organism.

Gametes—male or female reproductive cells; sex cells.

Gametophyte—the stage that produces gametes in an organism having alternation of generation.

Haploid—a term used to denote a cell and/or organism containing only one chromosome of each homologous pair.

Heterogametes—male and female gametes that are unlike in appearance and structure.

Isogametes—male and female gametes which are structurally alike.

Isogamy—a type of sexual reproduction which results from the fusion of like gametes (isogametes).

Isomorphic—having identical morphology.

Photosynthesis—the process by which certain living plants combine carbon dioxide and water in the presence of chlorophyll and light energy to form carbohydrates and release oxygen.

Sexual reproduction—that involving the union of two gametes.

Sporangium—a structure that produces spores.

Spore—an asexual reproductive cell.

Sporophyte—the stage that produces spores in an organism having alternation of generation.

Starch—a complex, insoluble carbohydrate built up from molecules of glucose.

Unisexual—having separate sexes; male and female.

Zoospore—a motile, asexual reproductive cell formed by nonmotile organism.

VOCABULARY ACTIVITY FOR CONCEPT C

Hidden in the letters below are 10 vocabulary words related to Concept C. The words may be written vertically (up-and-down), horizontally (across), backwards, or diagonally.

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

Answers: aplanospore, zoospore, sporangium, isogamete, marine, isomorphic, fragmentation, diploid, unisexual, haploid.

VOCABULARY ACTIVITY FOR CONCEPT C

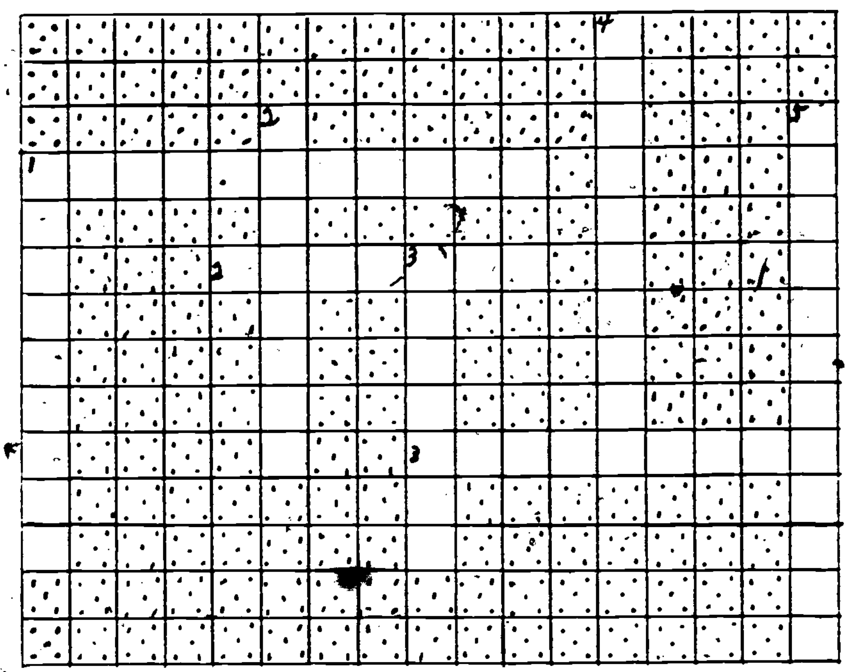
Below is a crossword puzzle containing words associated with the reproduction terminology of green algae.

DOWN

1. Sexual reproduction with fusion of unlike gametes.
2. A motile, asexual body.
3. Reproduction without the fusion of two gametes.
4. A plant that produces spores.
5. Having two flagella.

ACROSS

1. Nonmotile spore
2. Fusion of like gametes.
3. Having one sex; being of one sex.



CONCEPT D

Brown algae are macroscopic thallophytes which store laminarin as a food reserve. They are brown due to the presence of fucoxanthin, a brown xanthophyll pigment, which masks the green of chlorophyll in the plants.

Objectives

Upon completion of this concept the student should be able:

a. To name two characteristics of the Division Phaeophycophyta.
b. To describe how the kelps float.
c. To describe the typical habitat of brown algae.
d. To list three economical uses of the brown algae and their components.
e. To identify, recognize and give the function of the anatomical features of the brown algae.
f. To give two examples of brown algae found in the Gulf of Mexico.
g. To state the importance of brown algae to the ecosystem.

BROWN ALGAE

The brown algae belong to Division Phaeophycophyta (Greek, *phaios,* brown, *phykos,* seaweed and *phyton,* plant).

Brown algae, true to their name, are usually a deep, rich brown. This color is attributed to an accessory pigment, **fucoxanthin,** which masks the presence of chlorophyll. However, in some species, the pigmentation makes brown algae hard to identify, for it may have a greenish brown color.

Cytologically, the brown algae resemble the green algae. Both have well-defined cell walls and distinct organelles. Reserved food is not easily observed, because it is in a dissolved state as a carbohydrate (**laminarin**) or as an alcohol (**mannitol**).

No other group of algae exhibits the range in form, size or complexity of structure as these algal forms. Brown algae range in size from microscopic, filamentous forms less than 2 mm in length to giant **kelp** which may have **fronds** more than 100 m long. Most are macroscopic; no unicellular, colonial, or unbranched filamentous species are known. Some of the brown algae, such as *Sargassum,* approach the vascular plants in complexity of organization of vegetative parts.

The brown algae are almost entirely **marine.** Of the 1,500 known species, less than 1% are freshwater dwellers. A few genera are entirely restricted to the warm seas, but in general the brown algae are cold saltwater plants. Although brown algae are characteristic of exposed shores, they also occur in some areas as conspicuous salt-marsh plants.

Structurally, some of the brown algae have the most complex plant bodies of all the algae. The typical **thallus** consists of a **holdfast,** a **stipe, air bladders,** and **blades** (Figure 1). The holdfasts allow for attachment to rocks or reefs of the intertidal zone or oceanic bottom. The air bladders are flotation devices which allow the kelp blades to float on or in the surface water where sufficient light for photosynthesis exists.

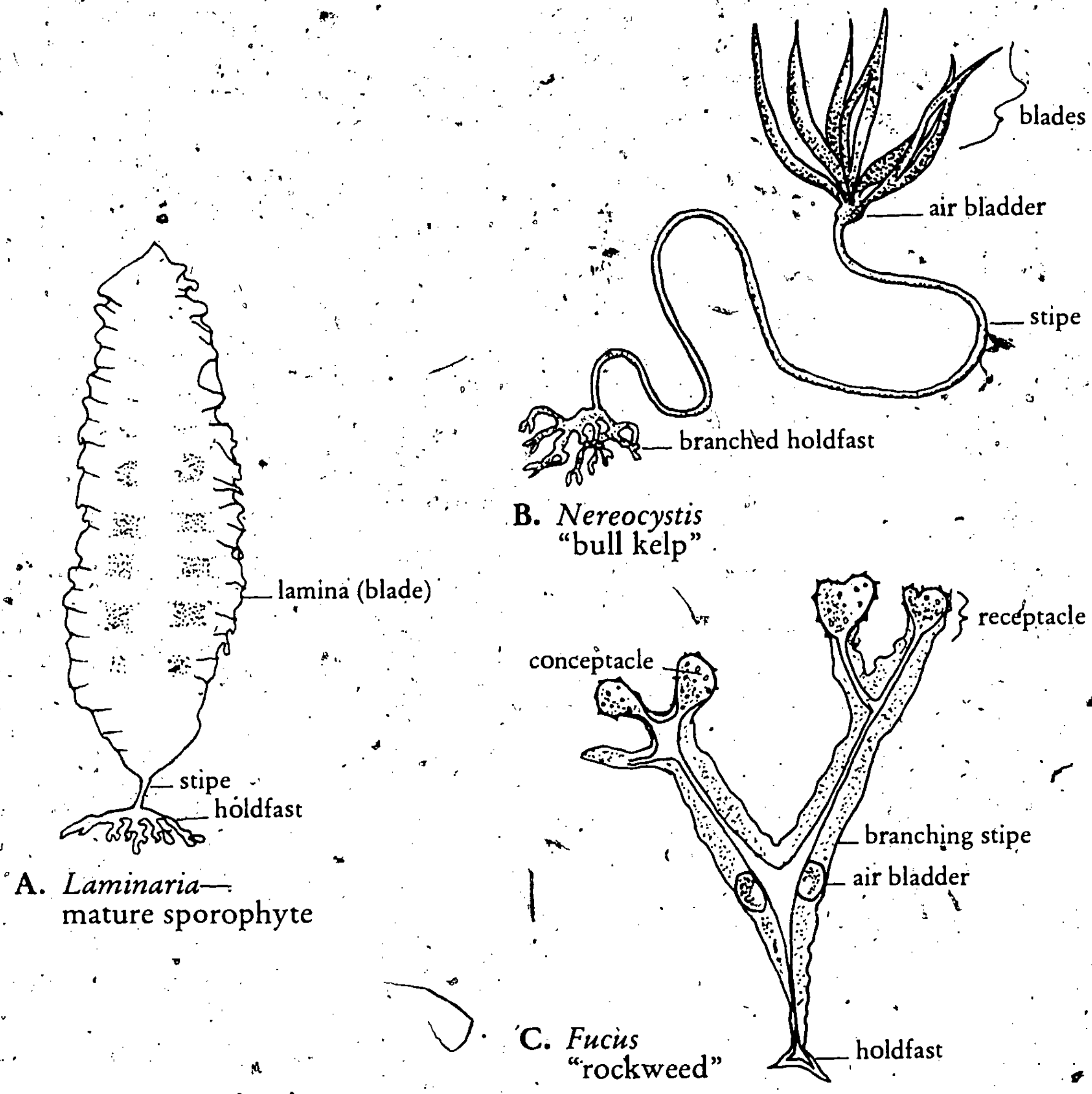


Figure 1. Habit sketches of three brown algae showing modifications and environmental adaptations. (Adapted from Muller, 1969).

Most brown algae reproduce by alteration of generations, involving both sexual and asexual forms. Brown algae are important to the ecosystem for they provide food, shelter, spawning grounds and a substrate for many marine animals.

Economically, too, this group is very important. Kelp is farmed in some parts of the world and processed as food for humans and other animals. Brown algae are also used for fertilizer. A large industry has grown from extracting a cell wall component called **algin** from which salts known as **alginates** are manufactured. These are used in the manufacture of soaps, paints, leather finishers, insecticides, toothpaste, lipsticks, and medicines. Algin is also used as a stabilizer in food products and as a clarifying agent in the production of beer.

Several species of brown algae are important to the Gulf of Mexico. Among the forms found in the Gulf of Mexico are *Dictyota dichotoma, Ectocarpus conderroides, Ectocarpus siliculosus, Sargassum fluitans, Sargassum natans,* and *Sargassum filipendula* (Figure 2).

These species attach to rocks, shells and other permanent structures. *Sargassum fluitans* and *S. natans* are **pelagic** species which drift into the Gulf of Mexico from the Sargasso Sea. The Sargasso Sea is a water mass bisected by the Tropic of Cancer in the western Atlantic Ocean. The abundance of *S. fluitans* and *S. natans* in the Gulf of Mexico probably depends on the amount of disturbance inflicted by tropical storms and hurricanes on floating masses of this seaweed in the Sargasso Sea. Entire plants and plant fragments are torn loose and carried away by tides and currents.

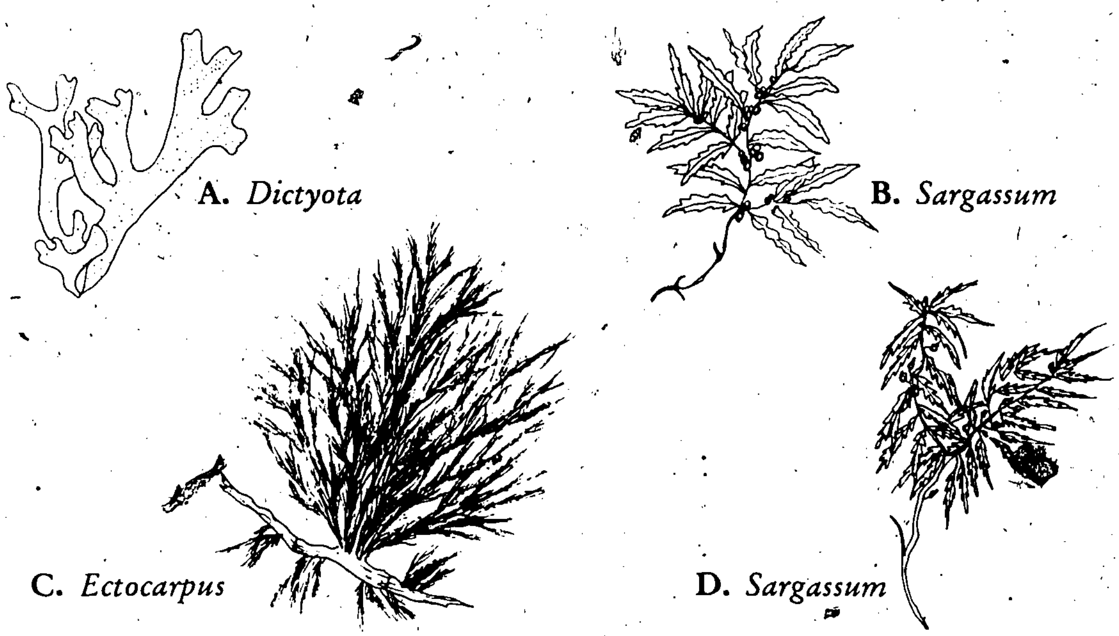


Figure 2. Habit sketches of some genera of brown algae found in the Gulf of Mexico.

VOCABULARY

Air bladders—structures on certain algae which increase buoyancy so that the algae can float on or in water.

Algin—a gelatinous compound found in brown algae. It is used in plastics and as a food emulsifier and thickener.

Alginates—salts extracted from brown algae; yarn made from algin.

Blade—in algae, the leaf-like expanded portion of the thallus.

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

Frond—leaf-like thallus of algae.

Fucoxanthin—a xanthophyll pigment produced in brown algae (Phaeophycophyta) and golden-brown (Chrysophycophyta).

Holdfast—an attaching organ in certain algae.

Kelp—any one of the large, tough, brown seaweeds.

Laminarin—a storage product of brown algae; a polymer of glucose and mannitol.
Mannitol—an alcoholic storage product of brown algae.
Marine—growing within the influence of the sea or immersed in its water.
Pelagic—living or occurring in the open sea.
Stipe—the portion of a kelp between the blade and holdfast or base.
Thallus—a plant body without true roots, stems or leaves.

VOCABULARY ACTIVITY FOR CONCEPT D

Complete-A-Word

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

A B ~~C~~ D E E F ~~G H I~~ I K L L M M N N O O P R S S S T U U X Y.

1. __ L __ AE
2. __ __ IP __
3. __ R __ N __
4. __ __ ADE
5. __ EL __
6. __ A __ INE
7. E __ O __ __ ST __ M
8. T __ A __ L __ __
9. __ AN __ __ T __ L
10. F __ __ O __ A __ TH __ N

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.

■	■	■	■						■			■		■					
■						■									■				
		■		■					■										
A	S	N	A	A	L	O	C	N	M	P	M	U	L	S	I	U	I	E	D
	I		O	U	F	G	O	O		I	O	U	A	D	G	F	S	E	R
					S		I	D		E	S		N			E	L	A	T

B	R	O	W	O	L	A	M	I	A	P	R	O	D	U	I	T		A	F
		S	T	N	R	A	L	E	N	A	R'	I	N		C	S		O	
						A	G	G		E									

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

CONCEPT E

The red algae of the Division Rhodophycophyta are a diverse group of thallophytes which contain phycoerythrin and phycocyanin pigments and store floridean starch.

Objectives

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

a. To name two pigments other than chlorophyll found in red algae.
b. To describe a habitat where red algae are found.
c. To name ~~the food~~ reserve of red algae.
d. To distinguish a coraline algae from a noncoraline algae.
e. To list two ways man uses red algae and their products.

RED ALGAE

Red algae are members of Division Rhodophycophyta (Greek, *rhodon*, red, *phykos*, seaweed and *phyton*, plant).

Algae in this division range in color from pink to rosy-red to reddish purple. Their color is a result of two factors. First of all, there is the presence of a substance called **phycoerythrin**, a red protein pigment whose presence masks the color of **chlorophyll**. Secondly, a blue pigment called **phycocyanin** is also present. The abundance of these pigments varies inversely with the intensity of light. So red algae near the surface are lighter in color than the dark red species found in deep water. Sometimes totally green species are found, but it is not usually difficult to separate these from members of the Divisions Chlorophycophyta and Phaeophycophyta.

There is great diversity in size and form among members of this division. There are only two known genera which are unicellular, and very few colonial forms are known to exist. Most red algae are composed of filaments but sometimes this trait is concealed because the filaments may be pushed together very tightly. Some filamentous species are quite delicate. Other species look like long thin sheets; many are coarse and ropelike. The longer species of fleshy red algae occur in cool, temperate regions. In tropical seas, however, the red algae are mostly small filamentous plants. They grow more deeply submerged than the brown and green algae and are almost exclusively **marine.**

A number of red algae become heavily encrusted with calcium carbonate. These **coraline algae** are very important in the building of coral reefs in warm water. These algae usually form the principal cementing agents in the reefs.

About 98% of the 4,000 known species of the Division Rhodophycophyta is marine. Unlike the brown algae, the red algae are most commonly found in temperate and tropical waters. Various species of these algae occur from the highest **intertidal zones** to the lowest limits of light penetration (175 m). Their accessory pigments, phycoerythrin and phycocyanin are able to absorb light of short wavelengths and transfer the energy to the chlorophyll pigment for photosynthesis. Red algae usually grow attached to rocks or other algae. There are few floating forms.

Cellular structure of red algae includes typical organelles, such as plastids and nuclei. The cell wall may be transparent. The reserve food is a nonsoluble carbohydrate called **floridean starch,** which is not associated with plastids.

Both sexual and asexual reproduction occur in red algae. However, sexual reproduction is more common and is generally more complex than in the brown and green algae.

Red algae are an important part of **food webs** in saltwaters. Some species are harvested as a direct food source. This is particularly true in the Orient where they are eaten raw as marine vegetables and also used in soups.

Economically the red algae are important, mainly because of their extracts. The extracts **agar agar** and **carrageenin** are **polysaccharides.** They are used widely as gel-forming substances.

Several species of red algae are important plants in the **ecosystem** of the Gulf of Mexico. *Gracilaria foliifera, Agardhiella tenera, Spyridia filamentosa,* and *Hypnea musciformis* are red algae which form extensive seaweed beds in Mississippi (Figure 1). These **macrophytic** algae form lush growths amid sea grasses to create a **habitat** and nursery area for a diverse group of marine animals. Thus, they help in providing food and shelter for marine organisms.

VOCABULARY

Agar agar—a gel-forming polysaccharide derived from some red algae. It is used to make solid culture media in microbiology.

Carrageenin—a polysaccharide extracted by hot water from certain red algae, composed of galactose and sulfate groups.

Chlorophyll—the green pigment present in plants needed for photosynthesis.

Coraline algae—those encrusted with calcium carbonate. They aid in reef building.

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

Floridean starch—the stored food product of red algae. It is a polysaccharide found outside of a plastid.

Food web—an interlocking system of food chains. Since few animals rely on a single source of food and because no food is consumed by only one species of animal, the separate food chains in every natural community interlock and form a web.

Habitat—the place where an organism lives.

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

Macrophytic—big plant; not microscopic.

Marine—growing within the influence of the sea or immersed in its water.

Phycocyanin—a blue protein pigment of blue-green and red algae.

Phycoerythrin—a red protein pigment of blue-green and red algae.

Polysaccharide—any carbohydrate that can be decomposed into two or more simple sugars by hydrolysis.

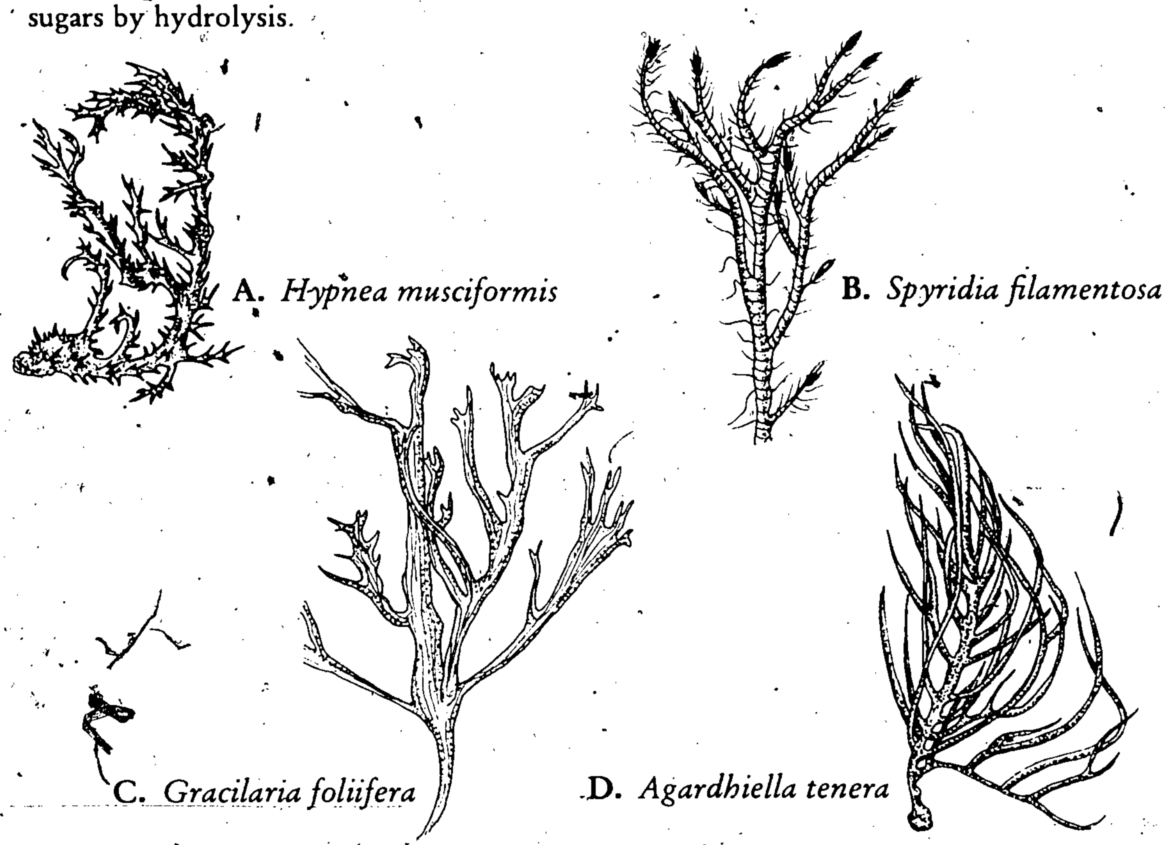


Figure 1. Species of red algae common to the Gulf of Mexico (Adapted from Dawes, 1974).

VOCABULARY ACTIVITY FOR CONCEPT E

Listed in alphabetical order below is a group of syllables which are not true syllables. Figure out the words according to the definitions given. Cross off the syllables as you use them. Place the words in the grid.

ag ar at bit car ch co co co ean en er es fl ge ha hr hy id in in li lo ma ne ne od op or ph ph phy ra ra rh ri ro yt yt yll

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

Definitions:

1. A gel-forming polysaccharide derived from red algae.
2. Plants of the Division Rhodophycophyta.
3. The stored food product of red algae.
4. Algae encrusted with calcium carbonate.
5. Hot water extract of red algae.
6. The place where an organism lives.
7. A red protein pigment of algae.
8. Growing immersed in sea water.
9. Green pigment of plants.

Activity: Pressing Algae

A great variety of algae are found along the seashore. If you press and mount algae as you collect them, you learn more about them. Mounted algae also make attractive decorations.

Materials

shallow pan (cafeteria trays work well), waxed paper, typing paper, blotter paper, newspaper, mounting paper, hollow-type cardboard, two pieces of plywood, two belts or a length of rope

Procedure

1. Float the algae in the shallow pan so you can arrange the fronds (leaves). Then slip a sheet of typing paper under the algae and carefully lift it out of the water. If this proves too messy, place the algae on the typing paper and arrange the fronds as best you can.

2. Transfer the specimen to waxed paper by putting a piece of waxed paper on each side of the specimen.
3. Next place a layer of blotter paper and then a layer of newspaper on each side of the specimen to absorb excess moisture from the plant.
4. Put a sheet of cardboard on each side of the papers. Use hollow-type cardboard to allow for air circulation.
5. Repeat these steps for each specimen you want to press.
6. After you have prepared all the specimens for pressing, place one piece of plywood on each side of the stack and secure tightly with the belts or ropes.
7. Set the plant press near a heater or in any other area where there is circulating air.
8. Change the layers of blotter paper and newspaper once a day so drying is thorough.
9. When the plants are completely dry, glue them to a piece of mounting paper and label. Be sure to list the name of the plant, the place of collection, and the date.

Activity: Kinds of Algae Found Around the Coast of the United States

Many species and forms of algae occur in different locations around the coast of the United States. Various abiotic factors influence the presence or absence of these organisms. Some of these factors include type of substrate, temperature, sunlight, salinity, and water currents.

Hardly any species can be found universally. Many of the larger macroscopic forms are very common and are worthy of further examination. Even though they are macroscopic they are major producers in the habitat in which they live.

In the following activity you will try to identify some of the macroscopic forms of algae found around the coastline of the United States. Some of these forms are found along the Gulf Coast and your instructor will emphasize these. There will be preserved specimens of the examples used in today's activity lying on the front laboratory table. When you have difficulty, please feel free to examine these specimens.

Procedure

Identify each picture and place the correct name under each illustration. Use the key each time. This will improve your ability to successfully utilize biological keys in making correct identifications of unknown organisms. A short description of many forms of marine algae follows the algae key. This should be of benefit to you as you complete this activity.

Special Note: The algae labeled A, B, and C are green in color. The algae labeled D, E, and F are brown in color. The algae labeled G, H, I, J, K, and L are red and purplish-red.

KEY TO SELECTED GENERA OF MARINE ALGAE

(Adapted from: Humm, Harold J. *Key to the Genera of the Common Marine Alge of Tidewater Virginia.* 1967 (Marine Education Materials System, No. 000049).

1A. Individual plants microscopic, although plant masses are usually visible to the unaided eye; color green, blue-green or blackish-green . . . . *Cyanophycophyta*

1B. Individual plants macroscopic and visible to the unaided eye, although some are very tiny 2
    2A. Plants usually some shade of red in color, but some are yellow-brown, olive-green, purplish-green, or purple .... *Rhodophycophyta*
    2B. Plants brown or green 3
3A. Plants some shade of brown .... *Phaeophycophyta*
3B. Plants green .... *Chlorophycophyta*

Chlorophycophyta

1A. Plants in the form of a flat sheet 2
1B. Plants flattened and very elongated, or not flattened 3
    2A. Sheet two cells in thickness .... *Ulva*
    2B. Sheet one cell in thickness .... *Monostroma*
3A. Plants consisting of a hollow tube, the wall one cell thick; the tube either collapsed or inflated .... *Enteromorpha*
3B. Plants filamentous 4
    4A. Filaments much-branched .... *Cladophora*
    4B. Unbranched single row of cells 5
5A. Individual filaments microscopic, forming patches on pilings and rocks in the intertidal zone .... *Ulothrix*
5B. Filaments, coarse .... *Chaecomorpha*

Rhodophycophyta

1A. Plants in the form of a flat sheet 2
1B. Plants not in the form of a flat sheet 3
    2A. Plants rose red, with a conspicuous midrib in the center of the blade .... *Grinnellia*
    2B. Plants purple to brownish-red, very thin, strictly intertidal, especially on oysters, without a midrib .... *Porphyra*
3A. Plants delicately filamentous, the main axes of no greater diameter than an ordinary pin 4
3B. Plants not delicately filamentous, coarser, at least in the main axes 6
    4A. Plants monosiphonous, uncorticated .... *Callithamnion*
    4B. Plants corticated or polysiphonous 5
5A. Plants polysiphonous but not corticated .... *Polysiphonia*
5B. Plants monosiphonous and corticated .... *Ceramium*
    6A. Branches of the plant bearing an abundance of fine, red filaments .... *Dasya*
    6B. Branches of the plant without fine, red filaments 7
7A. Tips of all branches with a tiny tuft of colorless filaments .... *Chondria*
7B. Tips of branches without filaments 8
    8A. Plants consisting of a series of hollow, barrel-shaped segments .... *Champia*[5]
    8B. Plants not consisting of barrel-shaped segments 9

9A. The ultimate **branchlets** monosiphonous with corticating cells at the nodes only, the main axes completely corticated . . . . *Spyridia*
9B. Both ultimate branches and other axes many cells thick. 10
10A. Plants red to yellowish-red color; the branches with a hollow center having fine filaments in the hollow . . . . *Agardhiella*
10B. Plants with cells in the center, not hollow, usually a purplish-green in color. 11
11A. Branches not flattened and bearing many small spine-like branchlets; the main branches often ending in a hooked tip . . . . . *Hypnea*
11B. Branches sometimes flattened, the ultimate branches not fine or spine-like. . . . . *Gracilaria*

Phaeophycophyta

1A. Plants delicately filamentous, but often large. . . . . *Ectocarpus*
1B. Plants not filamentous. 2
2A. Plants consisting of a broad flat, elongated blade, long stipe and a large **holdfast**. . . . . *Laminaria*
2B. Plants not consisting of a flat blade 3
3A. Plants Terete, hollow, and unbranched 4
3B. Plants branched and not hollow (except for air bladders) 5
4A. Plants with constrictions, sex organs in large patches or covering the surface . . . . *Scytosiphon*
4B. Plants without constrictions, sex organs in spots or small patches . . . . *Asperococcus*
5A. Plants very soft, gelatinous, slippery, the main axis 305 mm in diameter; usually on eel grass. . . . . *Eudesme*
5B. Plants rigid, larger, and with some type of air bladder. 6
6A. Main axes and branches flattened, air bladder **intercalary** 7
6B. Air-bladders spherical, terminal on short stalks; plants with leaf-like appendages. . . . . *Sargassum*
7A. Branches strap-shaped and with a prominent midrib. . . . . . *Fucus*
7B. Branches only a little flattened and not divided into a midrib and blade . . . . *Ascophyllum*

Cyanophycophyta

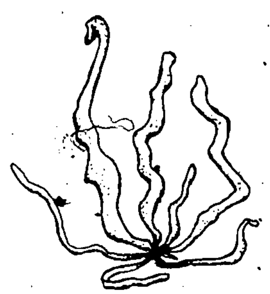
1A. Plants single-celled and solitary, or in colonies of various form; not filamentous, the cells coccoid (except in that part of *Entophysalis* that penetrates shells or limestone where filaments are produced because of the habitat) 2
1B. Plants producing filaments, the cells not coccoid 3
2A. Cells spherical (except where adjacent cells have flattened sides), single, or embedded in groups within a common gelatinous **sheath**. . . . . *Anacystis*

2A. Cells somewhat elongate or pear-shaped, often in strata or cushions, the cells in one mass variable in size .... *Entophysalis*
3A. Filaments without an obvious gelatinous sheath 4
3B. Filaments with a sheath........ 5
4A. Filaments forming a regular spiral, very small .... *Spirulina*
4B. Filaments not in the form of a spiral 5
5A. Filaments 3–5 microns in diameter, tip of filament with a short taper and tending to be bent slightly........ *Oscillatoria*
5B. Filaments 6 microns or more in diameter........ *Lyngbya*

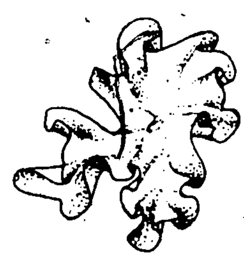
VOCABULARY

Air bladder—structures on certain algae which increase buoyancy so that the algae can float on or in water.
Axis (plural-axes)—a straight line with respect to which a body or figure is symmetrical.
Blade—in algae; the leaf-like expanded portion of the thallus.
Branchlet—a small terminal branch.
Coccoid—related to or resembling a coccus (sphere).
Cortex—the outer tissue of a thallus usually including surface cells.
Corticated—provided with a cortex, often by secondary growth from the axis.
Filaments—a thread of cells.
Gelatinous sheath—a sheath of gelatin which encloses a filament or mass of cells.
Holdfast—an attaching organ in certain algae.
Intercalary—arranged in the same series, as spores or heterocysts occuring in the same series of vegetative cells rather than being terminal or lateral; interposed.
Midrib—a vein-like or rib-like structure running up the middle of a blade.
Monosiphonous—a single row of cells.
Polysiphonous—provided with transverse tiers of parallel vertically elongated cells of approximately equal length.
Stipe—a stalk-like structure; the portion of a kelp between the blade and the holdfast.
Strata—layers.
Terete—circular in cross section.
Uncorticated—without a cortex.

A. ____________



B. ____________

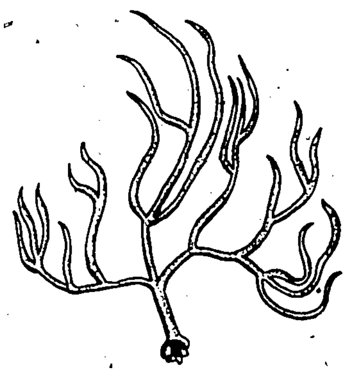


C. ____________

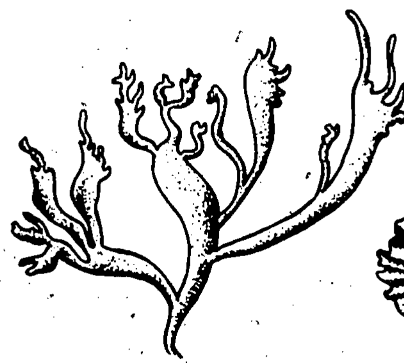
D. ______________________

E. ______________________

F. ______________________



G. ______________________



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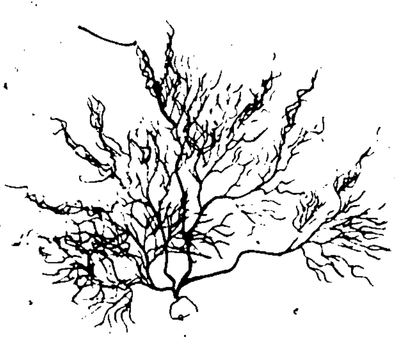

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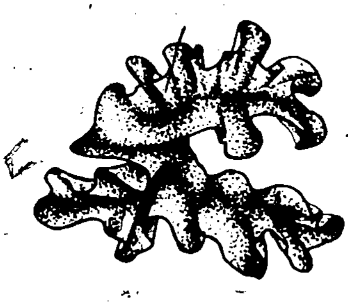


L. ______________________

Chlorophycophyta (Green Algae)

Ulva lactuca (Sea Lettuce)

1. Bright green-flattened sheets, variable in shape
2. Two cell layers thick
3. Holdfast inconspicuous
4. One to three yards wide, tears and fragments easily
5. Often floating along bottom
6. Abundant in shallow bays and shoreline area

Entermorpha intestinalis (Link Confetti, Intestine-like Seaweed)

1. Bright green
2. Single cells arranged in circular tube
3. Tubular, inflated above-tapering below, intestine like
4. Solitary or gregarious
5. Free floating or attached

Entermorpha linza

1. Similar to *Enteromorpha intestinalis*
2. Blade flatter, often with a crisp margin

Bryopsis plumosa

1. Color: light to olive green
2. Three to four inches tall
3. Plants erect—tufted
4. Occurs as feathery clumps in warm shallow areas

Cladophora expansa

1. Bright green color
2. Plants usually tufted, tangled mass twisted together
3. Often forming cushions of considerable extent

Rhodophycophyta (Red Algae)

Porphyra umbilicalis (Laver)

1. Color: variable—pink to rosy purple
2. Four inches to two feet long by three to four inches wide
3. No midrib present
4. Strap shaped to semi-circular, resembles *Ulva* or Sea Lettuce

5. Can resist drying on beach for short periods
6. Abundant in early spring to June
7. Well know edible algae. High protein and vitamin B & C content.
8. Popular English food. When boiled, the resulting jelly is covered with oatmeal and fried. This is called "Laver Bread."

Daysa pedicellata (Thick Seaweed)

1. Color: light to deep red purple
2. Six to eighteen inches tall
3. Feathery, alternately branched, often denuded below
4. Small disc-like holdfast

Grinnellia americana (Grinnell's Seaweed)

1. Plants usually simple pink blades
2. Prominent midrib
3. Dark nodular sporangia scattered on blade appear as dark spots
4. Occur in warm quiet water at moderate depths
5. Occurs in circular clusters, often torn free and floating in drift

Ceramium strictum (Transparent *Ceramium*)

1. Color: deep red
2. Thallus filamentous, branched
3. Filaments beaded or chainlike
4. Claw-like branchlets at ends or terminal portions of branches often closed
5. Loose filamentous red masses
6. Often found attached to other algae
7. Abundant in shallow bays and drift zone in summer

Ceramium diaphanum (Transparent *Ceramium*)

1. Color: deep red
2. Similar to *Ceramium strictum* terminal claws more open
3. Distribution and occurrence same as *Ceramium strictum*

Ceramium rubrum (Common Red Seaweed or Pottery Seaweed)

1. Color: deep red
2. Filaments similar to *Ceramium strictum* but without crossbands
3. Claws reduced, dull
4. Filamentous branched red mass
5. Distribution and occurrence same as *Ceramium strictum*

Polysiphonia dinudata

1. Color: red—brown
2. Mass slippery to the touch
3. Branched filamentous dark red masses
4. Resembles wet auburn hair
5. In water a loose filamentous ball

Gracillaria foliifera

1. Color: dull purple to faded brown
2. Lower part slender
3. Branching with branched flat and expanded
4. Disc-like holdfast
5. Plant often coarse
6. Four to eleven inches tall
7. Attached to pebbles and shells
8. Serves as an attachment for other algae

Agardhiella tenera

1. Color: deep rose to pinkish
2. Plant translucent, firm, and fleshy
3. Alternately branched
4. Branches tapering at tip
5. Projecting nubs often present
6. Disk-like to fiberous holdfast
7. Plant slippery
8. Seldom found with other algae attached

Phaeophycophyta (Brown Algae)

Fucus vesiculosis (Pop-weed, Rockweed)

1. Color: olive brown
2. Plant branched erect, grows to two to three feet
3. Air bladders present usually in pairs on either side of midrib
4. Bladder-like reproductive receptacles at terminal ends, single, paired or forked
5. Prominent midrib with wide margin, denuded below
6. Circular disc-like holdfast
7. Often attached to rocks and pilings in intertidal zone

CONCEPT F

The golden-brown algae are a diverse group of algae which store oils and leucosin and have fucoxanthin masking the chlorophyll pigments.

Objectives

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

a. To name storage products of diatoms.
b. To list two habitats of golden-brown algae.
c. To give the two types of diatoms based on symmetry.
d. To discuss locomotion in diatoms.
e. To recognize centrate and pennate diatoms.
f. To discuss reproduction in diatoms.

GOLDEN-BROWN ALGAE

The golden-brown algae belong to the Division Chrysophycophyta (Greek: *chrysos*, golden and *phyton*, plant). Many members of this division are unicellular organisms that are very important members of **phytoplankton.**

Most species of the golden-brown algae are **diatoms** belonging to the Class Bacillariophyceae (Figure 1C). Diatoms are represented by unicellular and colonial genera. There are at least 40,000 known species, but some scientists believe there may be many more.

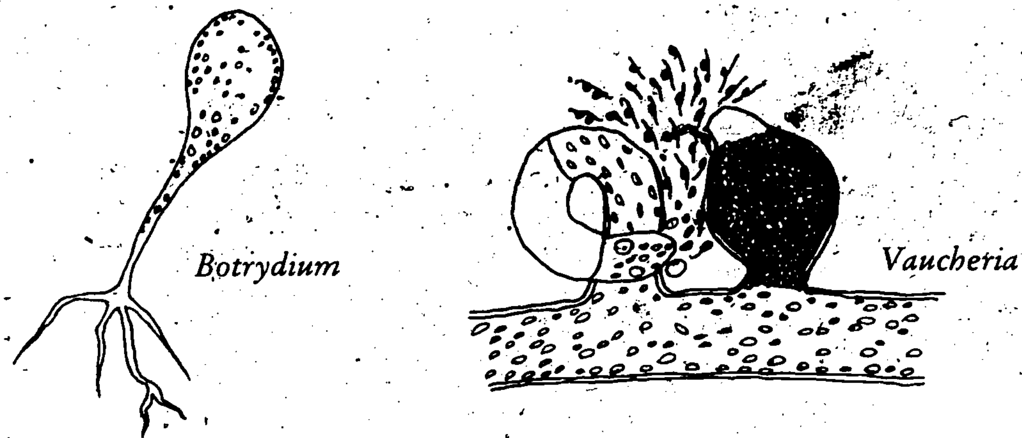
These organisms occur in both fresh and salt water. Most are **planktonic,** but some are bottom dwellers or grow on other algae or plants. They are found wherever there is sufficient light, water, nutrients and carbon dioxide.

Freshwater habitats of diatoms are diverse and include cold streams, hot springs, polluted pools and polluted ditches. Sometimes a large number of species are found in one area. Most saltwater diatoms are found in the coldest seas; they occur in both the Arctic and Antarctic Ocean. One liter of seawater may contain as many as 10,000,000 diatoms. They sometimes form a brown coating on ice floes. Some diatoms burrow in mud; some are found in the seabed, but most occur near the surface of the water. Some are found attached to seaweeds while others are found in the stomachs of mollusks, holothurians, and other sea creatures.

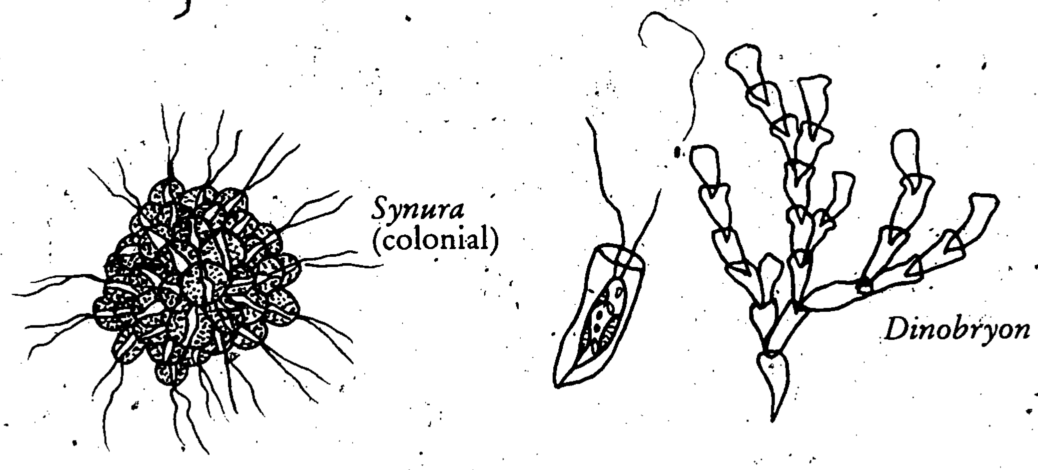
Some species of diatoms can survive for a long time without water and can be revived after a long period of dormancy. Diatoms occur in a great variety of shapes—pinwheel, spiral, star, rod, cigar, drum, triangle, and many others. Some form ribbon-like colonies while others occur in zigzag chain-like configurations.

Diatoms have double shells of opaline silica called **frustules.** These shells fit together, one on top of the other, like a carved pillbox. The upper valve is called the **epitheca** and fits over the lower valve, the **hypotheca** (Figure 2). The fine, delicate markings on the shell are used to identify species.

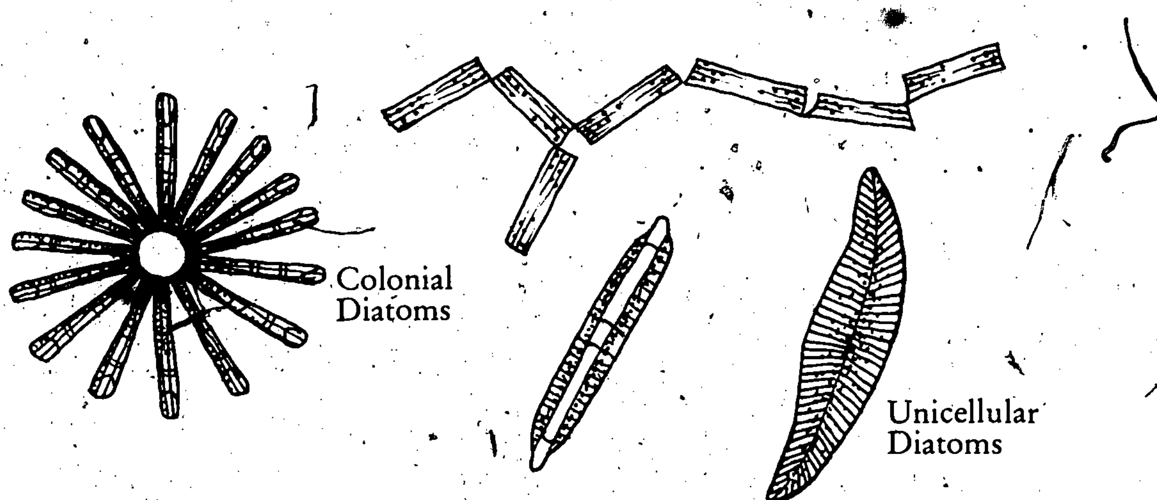
The major orders of diatoms are identified on the basis of symmetry. In Centrales (centric diatoms) the shells have an ornamentation that is concentric about a central point. There may be rows of spaces or spines that radiate with perfect symmetry. Members of



A. Class Xanthophyceae (yellow-green algae)



B. Class Chrysophyceae (golden-brown algae)



C. Class Bacillariophyceae (diatoms)

Figure 1. Representatives of the three classes of the Division Chrysophycophyta (Adapted from Abbott, 1978; Griffith, 1961; Smith, 1950).

order Pennales (pinnate diatoms) have markings that are **bilaterally symmetrical** or **asymmetrical.**

Diatoms exhibit considerable diversity in form within as well as outside the shell. There is great variation in position and size of **chromatophores.** The color of chromatophores, which contain **fucoxanthin,** depend in part on the intensity of light. So diatoms may range in color from brown to olive green or yellow. Food, the product of photosynthesis, is stored as oil droplets and as **leucosin.** No starch is found in diatoms. The oil droplets increase **buoyancy.**

Despite the fact that they lack the usual forms of locomotion (cilia, flagella, or other organelles) many species of pennate diatoms are motile. This locomotion results from a controlled secretion that occurs in response to stimuli. Movement is quite limited, so even motile diatoms are usually at rest. These motile diatoms possess thickenings in their frustules called nodules. One nodule is found at each end of the cell and one is found at the midpoint. They are called **polar nodules** and **central nodules,** respectively (Figure 2). The three nodules are connected by a long slit called the **raphe.** The raphe is visible in the valve view. The raphe is occupied by streaming cytoplasm in direct contact with the external environment. Some scientists have reported that an adhesive is secreted from the raphe and its subsequent hydration accounts for diatom movement.

Reproduction in these organisms is quite unusual. The two halves of the pill-box-like shell separate. The nucleus divides, and each new nucleus migrates into one of the valves. The new diatoms then secrete a new inner valve. The new diatom formed from the inner half of the parent shell is slightly smaller than the other, and this continues in each division until the shell becomes too small to hold the necessary parts (Figure 3). So occasional sexual reproduction is essential. During sexual reproduction of pennate diatoms, cells come together, cover themselves in a gelatinous material, and exchange chromosomes. Later the fertilized protoplasm breaks out of the parent shell and develops into a new diatom, full-sized. Some diatoms divide every four to eight hours, a reproduction rate that can result in one billion new diatoms in ten days.

Diatoms are sometimes referred to as the "grasses of the sea", for they are at the base of the food chain for many animals which vary from **zooplankton** to whales. It has been estimated that it takes several hundred billion diatoms to feed a humpback whale for just a few hours, and that it takes one half ton of diatoms to produce one pound of seal flesh. There is probably more available food in the form of diatoms than in any other organism on earth. Oxygen released during photosynthesis is also an important factor to the ecosystem.

Economically, too, diatoms are important to humans. Their siliceous shells, piled up over millions of years, form a fine crumbly substance called **diatomaceous earth** which is used in several industries. These include the making of paint, silver polish, filters, and insulating materials.

The oil droplets stored as reserve food by diatoms, may become increasingly important to humans. Bodies of organisms that died centuries ago have been acted upon by biologic and geologic forces and the oil droplets have coalesced beneath the sea into pools of petroleum. These pools may be important energy sources for the future.

Members of the Class Chrysophyceae of the Division Chrysophycophyta were formerly thought to be primarily a freshwater group (Figure 1B). However, they have been found recently to be an important part of the marine plankton. Some scientists believe that members of this class, and not the diatoms, are the major food producers of the oceans. There are about 1,100 known species within this class.

There is a great deal of diversity among these algae. Some have no cell walls, while in others well-defined cell walls are quite evident. Some have superficial or internal skeletal structures which are quite elaborate.

Yellow-green algae are members of the Class Xanthophycea. Not all scientists agree on the classification of these algae. Until recently they were classified as a part of the Division Chlorophycophyta, for they resemble many of the green algae in structure. Here we include these organisms as part of the Division Chrysophycophyta. The yellow-green algae are different from members of Chlorophycophyta and Chrysophycophyta, largely in the type of pigments which they contain. Most of the 450 known species of this class are freshwater organisms.

Diversity in structure is one of the fascinating factors within this division. It includes those which are unicellular, motile, nonmotile, and **amoeboid.** There are species which occur in colonies. In some members of this division the cell wall is quite well defined, while others are **coenocytic.**

The principal method of reproduction is by cell division, but various types of spores may be formed.

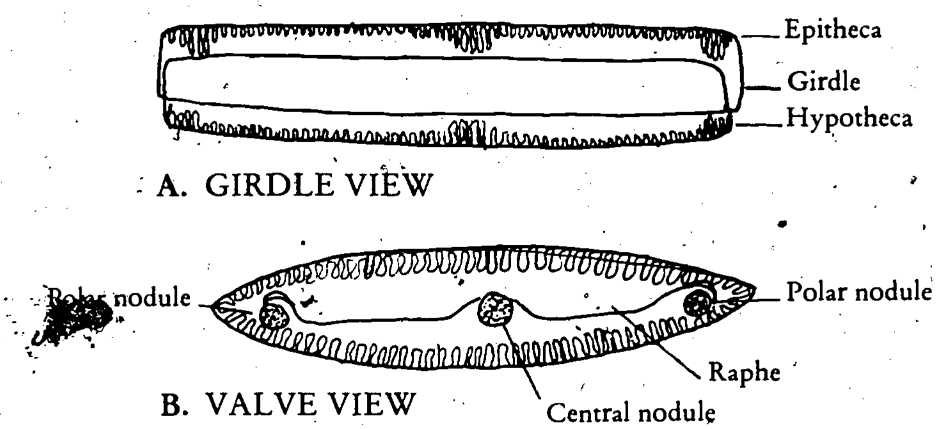


Figure 2. Valve & girdle view of a typical pennate diatom. (Adapted from O'Neil)

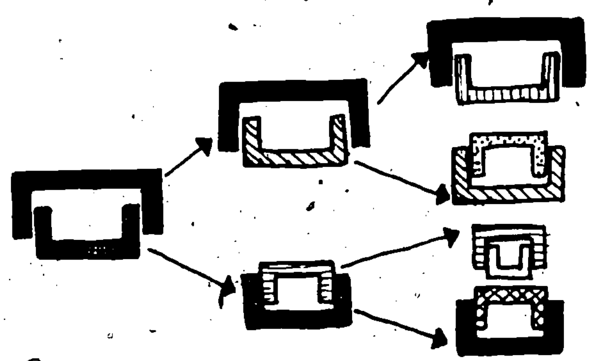


Figure 3. Cell division in diatoms. Note that some of the resultant diatoms are smaller than others. (Adapted from Muller, 1969).

Yellow-green algae have a place in the ecosystem, for they are producers. Reserve food is stored as leucosin, so these algae are a part of the food chain. Oxygen, released during photosynthesis, is also an important contribution to the ecosystem.

Some golden-brown algae have two **flagella** and are quite mobile while others are amoeboid and have no flagella. It is difficult to distinguish some golden-brown algae from an amoeba except for the presence of **chloroplasts**. Some scientists believe that these two organisms are closely related. Reproduction in golden-brown algae is largely asexual.

The Gulf of Mexico is not rich in yellow-green algae. Only one species, *Vaucheria thuretti* is listed as being of importance to this region (Figure 1A). This alga is found forming a matted growth on mud or other surfaces in salt marshes and mangrove swamps. It is a **littoral** plant.

VOCABULARY

Amoeboid—of or like an amoeba.
Asymmetrical—having no symmetry.
Bilaterally symmetrical—the condition of having distinct and similar right and left sides.
Buoyancy—the power to float; tendency to rise.
Central nodule—a thickening at the midpoint of diatom frustules.
Chloroplast—a specialized cytoplasmic body containing chlorophyll; plastid.
Chromatophore—one of the specialized pigment-bearing bodies in the cells of plants; chloroplasts or chromoplast.
Coenocytic—being a multinucleated mass of protoplasm lacking internal walls.
Diatomaceous earth—deposits of diatom frustules or their fossil remains. It is used as absorbents and abrasives.
Diatom—single celled microscopic plant forming a major component of plankton.
Epitheca—the larger of the two valves in the diatom frustule.
Flagella—fine, long threads which project from a cell and move in undulating fashion. Flagella are responsible for locomotion in some plants and animals and reproductive cells.
Frustule—the siliceous cell wall of diatoms; value.
Fucoxanthin—a xanthophyll pigment produced in brown algae and golden-brown algae.
Hypotheca—the smaller valve of a diatom frustule.
Leucosin—(chrysolaminarin) a polysaccharide composed of glucose and produced and stored by golden-brown algae.
Littoral—an area extending from shoreline to the edge of the continental shelf or to the 200 meter depth line.
Phytoplankton—the plant forms of plankton. They are the basic synthesizers of organic matter.
Plankton—small plants and animals floating in the upper layers of the water column.
Polar nodule—one of two thickenings of the diatom frustule located at the end of the shell.
Raphe—a longitudinal fissure in the frustules of motile pennate diatoms.
Valve—one-half of a diatom frustule.
Zooplankton—tiny animals floating in the upper water column feeding on phytoplankton, some weak swimmers.

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 goes 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

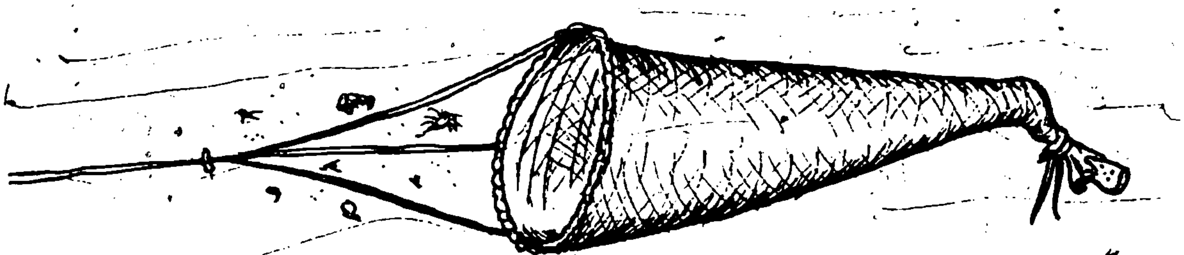
- To make a plankton net.

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 end 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: **Diatoms**

Objective

To collect and examine planktonic, edaphic (soil), and epiphytic diatoms from a pond or beach area. This will enable you to obseve first hand the various types of diatoms.

Materials

Field materials: frozen juice cans with both ends removed, plastic wrap and tape, large water containers, small collecting jars, plankton net, forceps, razor blades or scalpel for scraping

Lab materials: filter paper, medicine dropper or pipettes, glass slides and coverslips, microscopes

Procedures

Collecting Planktonic Diatoms. Obtain a plankton net and tow the net through the water. The diatoms, along with other planktonic organisms, will collect in the "bucket" at the end of the net. Place the plankton into a small collecting jar for storage until you return to the lab. Carefully label your containers with your name, the date, and collection site.

If plankton nets are not available, diatoms can be obtained by collecting a large water sample. A large, plastic gallon jar can be filled with surface water from your chosen habitat. Cover the jar after it has been filled to prevent leakage and evaporation of the fluid. Label the container with your name, the date, and collection site. In the laboratory, filter the water. The diatoms will be left on the filter paper. Observe them with a microscope. If soluble filter paper was used, dissolve the paper and collect the diatoms. Make wet mounts from your samples for observation under the microscope. Are most of the diatoms centrate or pennate? Using Figure 1, see if you can name some diatoms. If so, make a list of them.

Collecting Epiphytic Diatoms. Epiphytic diatoms grow on other plants. They can be collected by squeezing fairly large samples of the plants to which the diatoms are attached. As you squeeze the plants, collect the liquid dripping from them into small collecting jars. Another method is to scrape the stems and leaves of the aquatic plants with a scalpel or a razor blade. Place the scrapings in small, labeled collecting jars. After returning to the lab, prepare slides of the collected diatoms and observe them. Determine whether the diatoms are centric or pennate.

Collecting Edaphic Diatoms. Edaphic diatoms live on the mud or sand surfaces. A frozen juice can with both ends removed can be used to obtain cores of the substrate which border the water's edge. Push the can into the sediment and remove it with the soil inside. Seal both ends with plastic wrap and tape to prevent evaporation. Beware! Label the ends of the core so that you can identify the top surface. Collect some habitat water along with the cores.

Immediately upon returning to the lab, filter the habitat water. Soak a piece of filter paper in water and place it over the top of the core. Let the filter paper sit on the core overnight. By that time nearly 90% of the live diatoms should have moved onto the filter paper. Examine them on the filter paper. With a medicine dropper or squeeze bottle, rinse the diatoms off the filter paper with some of your filtered habitat water. Make a slide and observe the diatoms.

How did the diatoms move from the soil to the filter paper? ______________________

____

Note the types of diatoms found. Does the method of collecting limit the types found? ____

____

Why? ____

____

Examine your diatoms. Do they have cilia or flagella? ____________________________

Compare diatoms which appear to move with those which do not. Do those that move have any special shape or structures which permit them to move? ____________________

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If so, describe the shape of structure? ____________________

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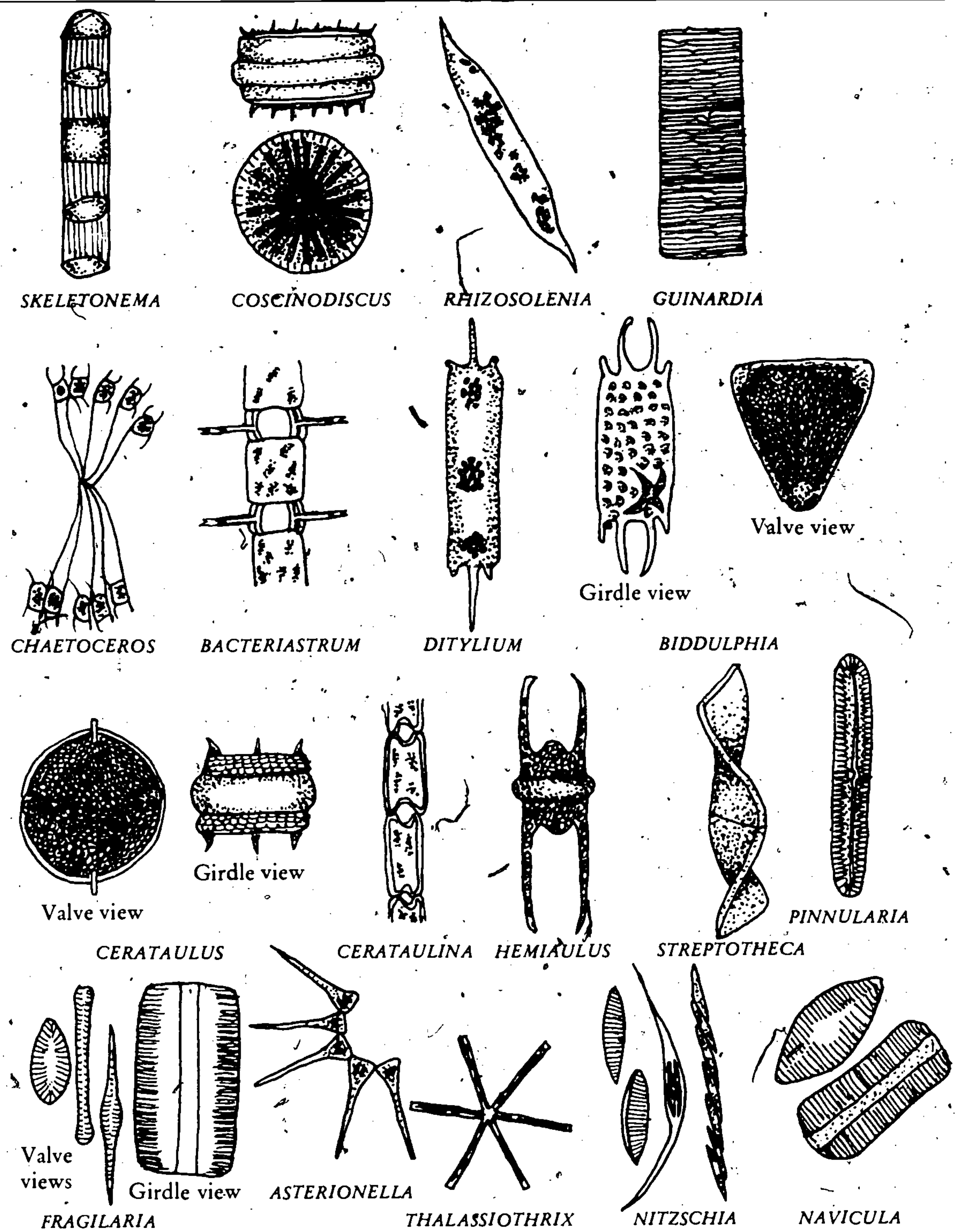


Figure 1. Common diatoms (Adapted from Griffith, 1961).

CONCEPT G

Dinoflagellates are microscopic organisms which have both plant and animal characteristics.

Objectives

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

a. To give animal and plant characteristics of dinoflagellates.
b. To name two pigments unique to the dinoflagellates.
c. To name food storage products of dinoflagellates.
d. To describe locomotion in dinoflagellates.
e. To name at least two ways dinoflagellates meet their nutritional needs.
f. To state the cause of "red tides".
g. To state a contribution to the ecosystem by dinoflagellates.
h. To state a significant economic aspect of dinoflagellates.

DINOFLAGELLATES

Dinoflagellates are members of Division Pyrrhophycophyta. The organisms which belong to the Class Dinophyceae are known as the "spinning flagellates". They are common to marine and freshwater habitats. These organisms have two **flagella.** A short **transverse flagellum** lies along a horizontal groove called the **girdle.** This flagellum wraps around the organism and creates sideways motion. The longer **longitudinal flagellum** lies in a vertical groove called the **sulcus.** The longitudinal flagellum trails behind for forward motion. Both flagella arise from **flagellar pores** (Figure 1). The beating of both flagella causes the organism to spin like a top.

A look at these tiny organisms under the microscope could be rather frightening if one forgets their size. There are many which are quite bizarre in appearance, with stiff cellulose plates forming a wall which may look like part of an ancient coat of armor. Many species have **trichocysts,** and some have stinging bodies, **cnidoblasts.** Coloration varies, but most are yellow-brown or yellow-green. Carotenoid pigments mask the chlorophyll. Two pigments, **peridinin** and **dinoxanthin,** are peculiar to this group.

Dinoflagellates have a number of characteristics, in addition to locomotion, which leads to the question of whether they should be classified as plants or as animals. Some contain **chlorophyll** and are **autotrophic.** In those which are **heterotrophic,** structural characteristics cause them to be classified with other members of Pyrrhophycophyta. Many dinoflagellates are **parasitic** or **commensalistic** with certain tropical species. Some heterotrophic forms feed upon other dinoflagellates.

There are at least 1,100 known species of this class, and about ninety-three percent are marine. They are found in all but the coldest seas.

Sexuality has been observed in only a few species of Dinophyceae. Reproduction is largely by longitudinal cell division, with each daughter cell getting one of the flagella and a portion of the **theca** (cell wall). It then constructs the missing parts in a very intricate sequence. Under certain conditions, numbers may increase to as much as 60,000,000 organisms per liter of water.

A very fast and large increase of these organisms in a given area, a **"bloom"**, can result in a phenomenon called "red water" or **"red tide"**. The water will be red or brown in color, with a brilliant night-time **luminescence,** called the "burning of the waves".

Dinoflagellates produce a water soluble poison, and a red tide can result in the killing of hundreds of thousands of fish and other marine animals. Poisonous dinoflagellates are ingested by higher animals, and so they are a contaminating factor in **food chains.** Certain genera, *Gonyaulax* and *Gymnodinium,* are known to produce an extremely powerful nerve **toxin.**

Some regions experience this disaster fairly often. During the winter and spring of 1974, the west coast of Florida was very hard hit. This was its twenty-fifth red tide in one hundred thirty years. In the fall of 1972, the first red tide in recorded history hit the lower New England coast. Twenty-six people were poisoned from eating contaminated shellfish. This caused a setback in the shellfish industry in that area, and it took several years to recover.

Factors involved in causing red tides are poorly understood. Nutrient and trace metal levels, sewage runoff, ocean salinity and temperature, winds, light, and other factors seem to play some sort of role in red tide development. Red tides are carefully monitored by checking the level of toxicity of sample organisms. Satellites are now being used in efforts to track these devastating phenomena.

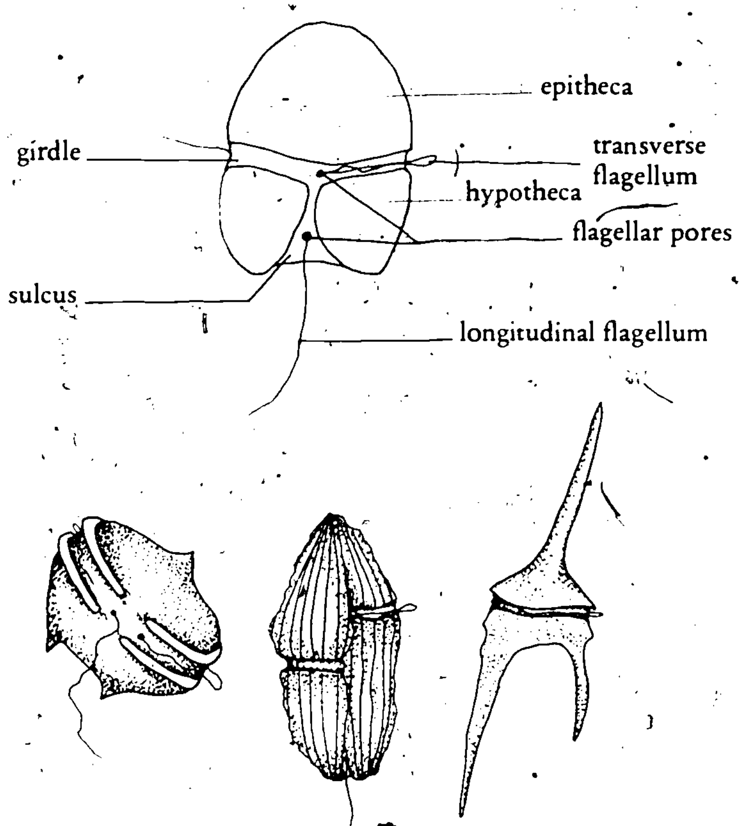


Figure 1. External structures of dinoflagellates and common examples (Adapted from Parmer)

Dinoflagellates, regardless of problems caused by a few genera, are still an important part of the **phytoplankton** of the seas. In this role, they are a significant part of food chains and **food webs.**

VOCABULARY

Autotrophic—capable of synthesizing protoplasm from entirely inorganic substances.
Bloom—a rapid and often unpredictable growth of a single species in an ecosystem.
Chlorophyll—the green pigment present in plants needed for photosynthesis.
Cnidoblast—the cell in which a nematocyst is developed.
Commensalistic—living in or on another, with only one of the two benefiting.
Dinoflagellate—a single celled, microscopic organism possessing both plant and animal characteristics.
Dinoxanthin—a xanthophyll pigment peculiar to the dinoflagellates.
Flagella—fine, long threads which project from a cell and move in undulating fashion. Flagella are responsible for locomotion of small organisms and reproductive cells.
Flagellar pore—in dinoflagellates, a pore of the theca from which a flagellum arises.
Food chain—the transfer of the sun's energy from producers to consumers as organisms feed on one another.
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.
Girdle—in dinoflagellates, the horizontal groove the transverse flagellum lies in.
Heterotrophic—unable to synthesize organic molecules from inorganic molecules; nutritionally dependent on other organisms or their products.
Longitudinal flagellum—in dinoflagellates, the flagellum which lies in the sulcus; allows for forward motion.
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.
Parasitic—living in or on the body of another for a period of time and getting nourishment from other organisms called a host.
Peridinin—a xanthophyll peculiar to the dinoflagellates.
Phytoplankton—the plant forms of plankton.
Red tide—a bloom of certain dinoflagellates (*Gonyaulax* and *Gymnodinium*) in which concentrations of poisonous substances are released into the water.
Sulcus—in dinoflagellates, the vertical groove in which the longitudinal flagellum lies.
Theca—cell wall.
Toxin—a poisonous substance produced by bacteria and other organisms that acts in the body or on foods.
Transverse flagellum—in dinoflagellates, the flagellum which lies in the girdle; allows for sideways movement.
Trichocysts—sensitive protoplasmic threads in some protozoans which are concerned with protection.

Activity: What Kinds of Algae Can Be Found in My Area

Seaweeds, as they are called in the marine environment, or pond scum, as they are called in the freshwater environment, can be found in just about all habitats. They may constitute a major food source for the herbivores or first level consumers of a water community. These very important plants go unnoticed unless they become so plentiful that they become a nuisance and interfere with the life styles that people enjoy. Without an adequate diversity and quantity of aquatic plants many food chains cannot exist. As you explore some of the algal species endemic to your area, think of how these small organisms play an important role as the producer link in the food chains of the body of water you are sampling.

Objectives

To collect algal specimens of your local area.
To place the collected algal specimens in the proper algal grouping.
To examine microscopically the collected organisms to observe similarities and differences.

Materials (for every two students)

1 wooden or plastic slide box with top and bottom removed, 18 clean glass slides, string, wire (about 8 feet in length), nail

Select the water supply to be sampled and determine where the samples are to be taken. Some students may want to sample the top six inches of water column, while others may want to sample lower in the water column.

Take the slides and place them in the slide slots in groups of two. Leave a space between the first pair of slides before placing the second pair in the box. After all slides have been placed in the box, tie a string around the entire container so that the slides will not fall out. Tie the wire onto the slide box and allow it to hang in the water to the desired depth. Complete the data sheet and check your algal samples to determine growth patterns and diversity at your sampling site. It is suggested that you leave the samples in water a few days before checking them. Give the algae a chance to grow then decide the time interval between checking of the sampler (Figure 1).

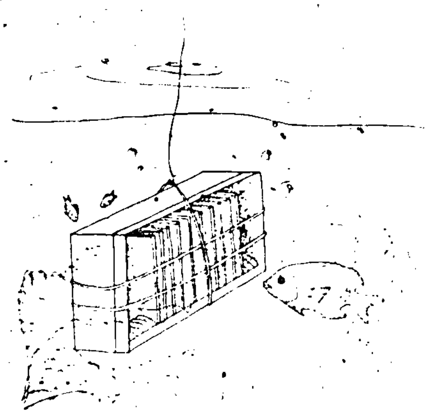


Figure 1. Algal sampler

L

DATA SHEET

Selected water sampling site ____________________

Length of time between checking of the samples ____________________

Date sampler placed in the water __________ to the depth of ____________________

General observation of the sampling site include:

Macroscopic : ____________________

____

____

____

Microscopic: ____________________

____

____

____

Date	Quantity of Organisms	Diversity of Organisms	New Organisms	Organism no longer present

Date	Quantity of Organisms	Diversity of Organisms	New Organisms	Organism no longer present

Date	Quantity of Organisms	Diversity of Organisms	New Organisms	Organism no longer present

Date	Quantity of Organisms	Diversity of Organisms	New Organisms	Organism no longer present

1. Did you expect to collect different kinds of algae? ______
   How many different types of algae did you collect? ______
   ______
2. Did your classmates seem to collect the same species as you were able to collect? Explain. ______
   ______
3. Make a list of the algal species collected during this investigation and the specific site or habitat in which it was collected.

Name	Habitat collected	Abundance

4. Can you explain why you were not able to collect all of these species in your algal sampler? ______________________________
____

5. What are the major pigments of the algal species that you have collected?

Alga	Major pigment
______	______
______	______
______	______
______	______

6. See if you can design an experiment to check the affect of various kinds of pollution on the algal species that you have collected.

VOCABULARY ACTIVITY FOR CONCEPT G

Below you will find scrambled vocabulary words related to Concept G. Unscramble the letters of each word and write it in the blank provided.

1. s u u c l s ______________________
2. h e c t a ______________________
3. i n i n i d p e r ______________________
4. i x n o t ______________________
5. o b o l m ______________________
6. i d o n a n x i n t h ______________________
7. r i g d e l ______________________
8. f l l l a a g e ______________________
9. t e l a l e g a l f o n i d ______________________
10. h h o l o p c i t y ______________________

VOCABULARY ACTIVITY FOR CONCEPT G

Listed in alphabetical order below is a group of syllables which are not true syllables. Figure out the words according to the definitions given. Cross off the syllables as you use them. Place the words in the grid.

ce cen cn cus di di fla gel ho id la la lo lu mi nes nin no ob pa pe phy ra ri si sul st te tic tic

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

1. Light produced by physiological processes.
2. The cell in which a nematocyst is developed.
3. The vertical groove in which the longitutinal flagellum lies in dinoflagellates.
4. A xanthophyll peculiar to the dinoflagellates.
5. A condition of living in or on another living thing for a period of time and getting nourishment from the other organism called the host.
6. Refers to plants that manufacture their own food; autotrophic.
7. A single-celled organism possessing both plant and animal traits; has two flagella.

CONCEPT H

The blue-green algae, by virture of their procaryotic cells, are the simplest and most primitive algae containing chlorophyll.

Objectives

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

a. To give a characteristic of blue-green algae which links them to bacteria.
b. To name two accessory pigments which mask chlorophyll.
c. To name a unique food storage product of blue-green algae.
d. To list several habitats of blue-green algae.
e. To recognize some coastal and estuarine genera of the Division Cyanophycophyta.
f. To state a contribution to the ecosystem by blue-green algae.

BLUE-GREEN ALGAE

Blue-green algae, unlike other algal forms, are composed of **procaryotic** cells. They do not have membrane bounded organelles. This and certain other traits have caused scientists to classify these organisms with bacteria in the Kingdom Monera. However, they are considered algae, and as such will be included in this discussion on the diversity of marine plants. (They were formerly classified as the algal Division Cyanophycophyta; Greek, *kyanos*, blue and *phyton*, plant).

There are believed to be about 1,500 species of blue-green algae which are widely distributed in both fresh and saltwater. They are found in such widely differing **habitats** as boiling springs and the frigid lakes of Antarctica, where they abound. However, they are not found in acidic waters where **eucaryotic** algae are abundant.

Blue-green algae are not always blue-green, but may be red, black, purple, blue, yellow, or red. The Red Sea was named because of the dense **blooms** of one genus which frequently occur in it. Of course, these organisms contain chlorophyll, but the green color of **chlorophyll** is masked by **phycocyanin,** a blue pigment, and **phycoerythrin,** a red pigment, which cause the variation in color. All blue-green algae are microscopic as individuals, but they are sometimes found in masses which may grow to as much as 1 m in length. Some of these organisms are unicellular, others are filamentous, a few form branched. filaments, and a very few form plates or irregular colonies (Figure 1).

While the cellular organization of blue-green algae is much like that of bacteria, their color and overall structure led to their historical grouping with algae.

Cells of this group lack any type of locomotive organelle, but some filamentous blue-green algae can move. This may be a simple gliding motion, or it may consist of rotation around a longitudinal axis.

Unicellular blue-green algae reproduce by simple cell division. Colonial and filamentous forms reproduce by fragmentation. Sexual reproduction has not been observed for the blue-green algae.

The blue-green algae are important to the **ecosystem** in several ways. Capable of **photosynthesis,** they are **primary producers,** providing both food and oxygen. **Cyanophycean starch** is produced and stored by blue-green algae. Some species can **fix nitrogen,** and are valuable to crop production. Blue-green algae are found living **symbiotically** with amoebae, protozoa, some diatoms, and other algae, as well as with some forms of higher plants. They also may serve as the photosynthetic component in **lichens,** and sometimes occur in some bryophytes and vascular plants. On the other hand, these algae may be hosts for certain fungi and viruses.

Some species of this group are responsible for a skin irritation called swimmers' itch. One group is believed to cause a chemical toxicity in certain fish.

Some species of Cyanophycophyta found in the coastal and estuarine waters are represented in Figure 1.

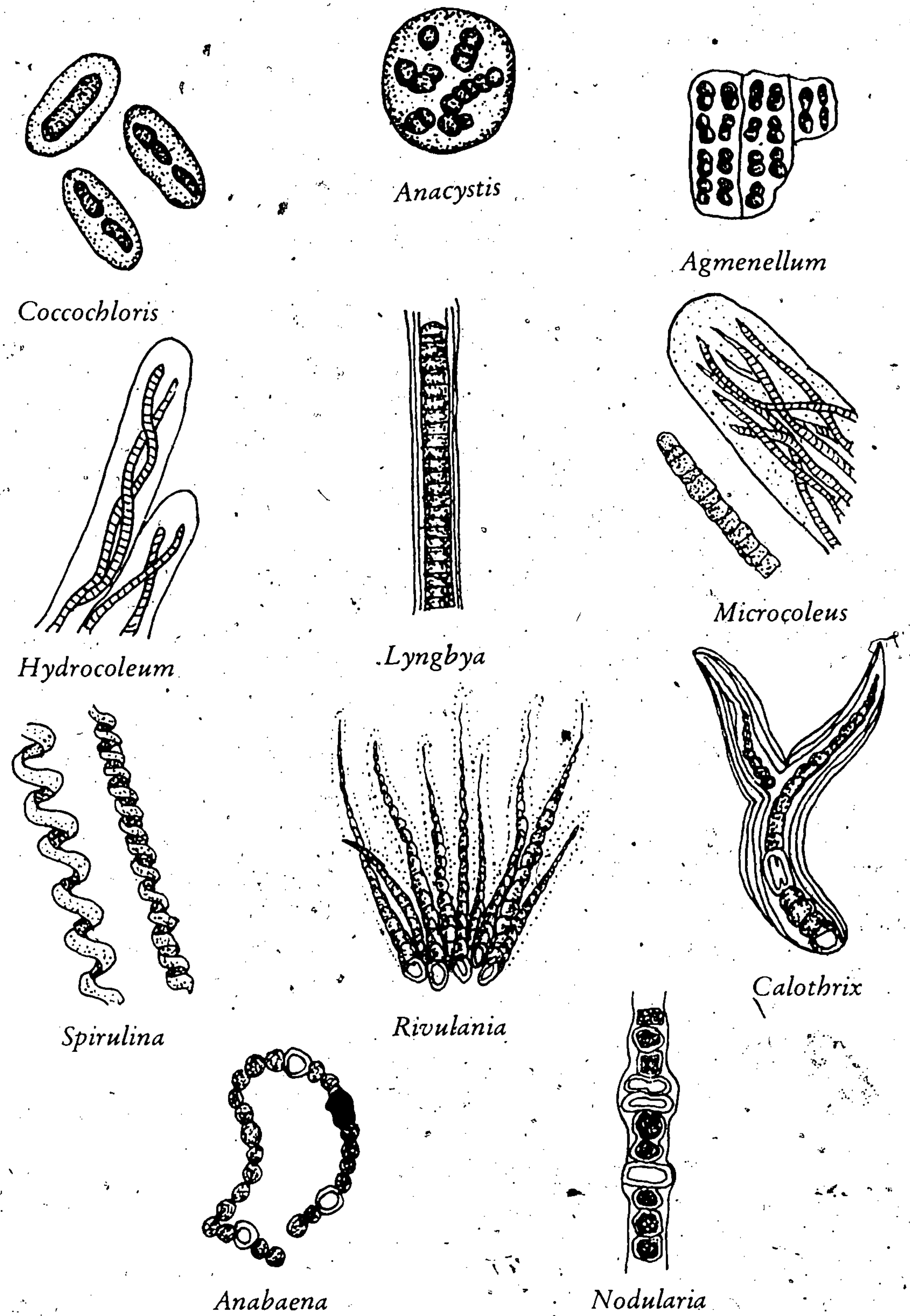


Figure 1. Various species of blue-greens found in estuarine areas. (Adapted from Griffith, 1961).

VOCABULARY

Bloom—a rapid and often unpredictable growth of a single species in an ecosystem.

Chlorophyll—the green pigment which is present in plants and is needed for photosynthesis.

Cyanophycean starch—the glycogen-like storage product of blue-green algae.

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

Eucaryotic—pertaining to organisms having membrane bound organelles.

Habitat—the place where an organism lives.

Lichen—a plant composed of an association of certain algae and fungi that live together symbiotically.

Nitrogen fixation—use of gaseous nitrogen in metabolism.

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

Phycocyanin—a blue protein pigment of blue-green and red algae.

Phycoerythrin—a red protein pigment of blue-green and red algae.

Primary producers—organisms that create new organic matter from inorganic substrates; plants.

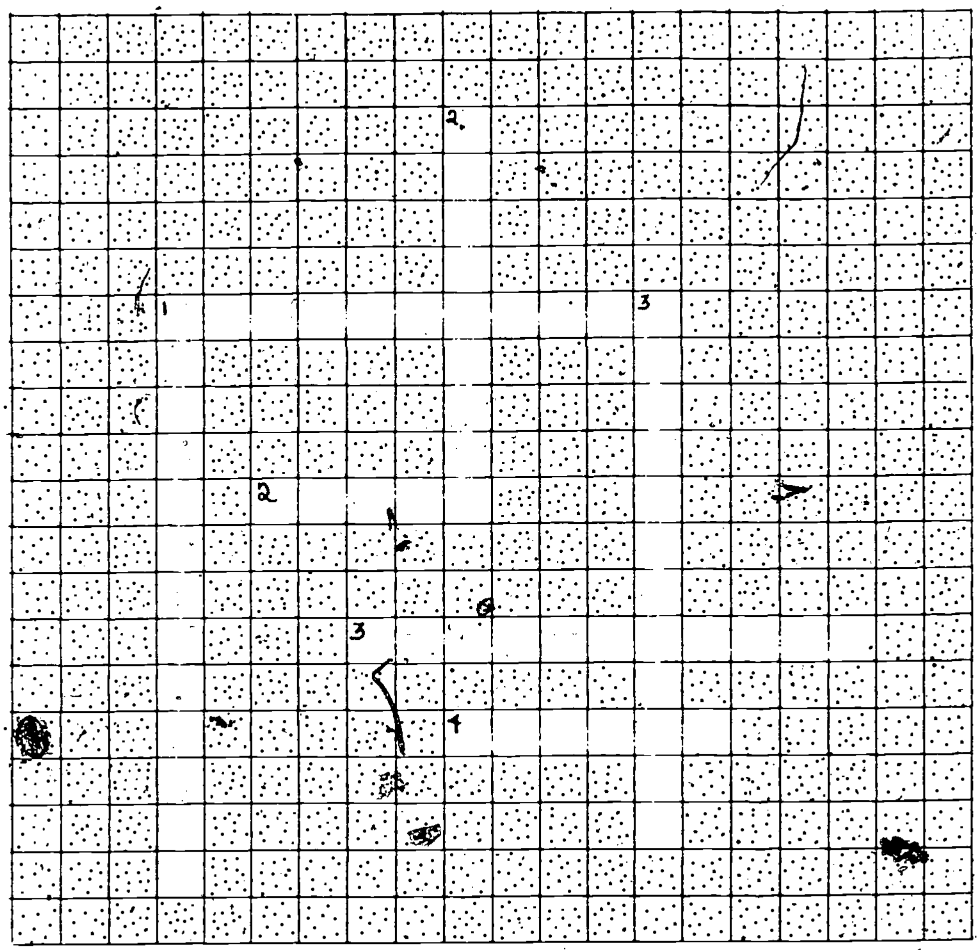
Procaryotic—organisms lacking membrane-bounded nuclei, plastids, golgi bodies and mitochrondria.

Symbiotic—pertaining to a relationship in which two organisms live together in close association.

VOCABULARY ACTIVITY FOR CONCEPT H

Below is a crossword puzzle containing words associated with Concept H. Clues for the puzzle are given below.

ACROSS
1. A cell type which has no membrane-bounded organelles.
2. A rapid increase in a single species.
3. A blue protein pigment of algae.
4. Algae and fungi living symbiotically as a plant.



DOWN
1. A red plant pigment.
2. A community of organisms interacting with their environment.
3. The starch of blue-green algae.

VOCABULARY ACTIVITY FOR CONCEPT H

Hidden in the letters below are 7 vocabulary words related to Concept H. The words are written vertically (up-and-down), horizontally (across), backwards, or diagonally. Try to find the words.

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

Answers: symbiotic, procaryote, phycoerythrin, phycocyanin, lichen, cyanophycean, bloom.

CONCEPT I

Marine bacteria are procaryotes which influence the physical, chemical, biological, and geological processes in the oceans and estuaries.

Objectives

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

a. To discuss the process of mineralization of organic matter.
b. To explain the significance of decomposers to the ecosystem.
c. To list three characteristics of marine bacteria.
d. To name the three types of marine bacteria.
e. To differentiate between cocci, bacilli, and spirilla bacterial forms.
f. To give one beneficial and one harmful result of bacterial activity.

MARINE BACTERIA

Marine bacteria are widely distributed in the sea. They can be isolated everywhere in oceans, estuaries and salt marshes. Populations are largest near shore where water is rich in **organic nutrients.** The greatest bacterial densities have been located at mud-water interfaces. It has been estimated that 50,000 to 100,000 bacteria per milliliter can be contained in shoreline waters.

Bacteria's rôle as **decomposers** in marine and **maritime** environments is most significant. Bacterial activities, which breakdown accumulated organic matter from the remains of plants and animals, and their subsequent release of chemical constituents in the form of simple soluble inorganic matter, are of paramount importance to the **ecosystem.** This process is called **mineralization of organic matter.** In the process of mineralization, nitrates, phosphates, and other nutrients necessary for the growth of **primary producers** are recycled for plant utilization. Mineralization of organic matter occurs at the bottom of the sea (mud-water interface) where **organic detritus** accumulates and in upper oceanic waters just below the level at which the greatest concentration of phytoplankton are found. Here dead and dying plants and animals settle and are subjected to bacterial action.

The bacteria also contribute to the ecosystem by serving as an important food source for many **filter** and **deposit feeders.** Bivalve mollusks, copepods, annelids, rotifers and protozoans are some organisms which feed on bacteria.

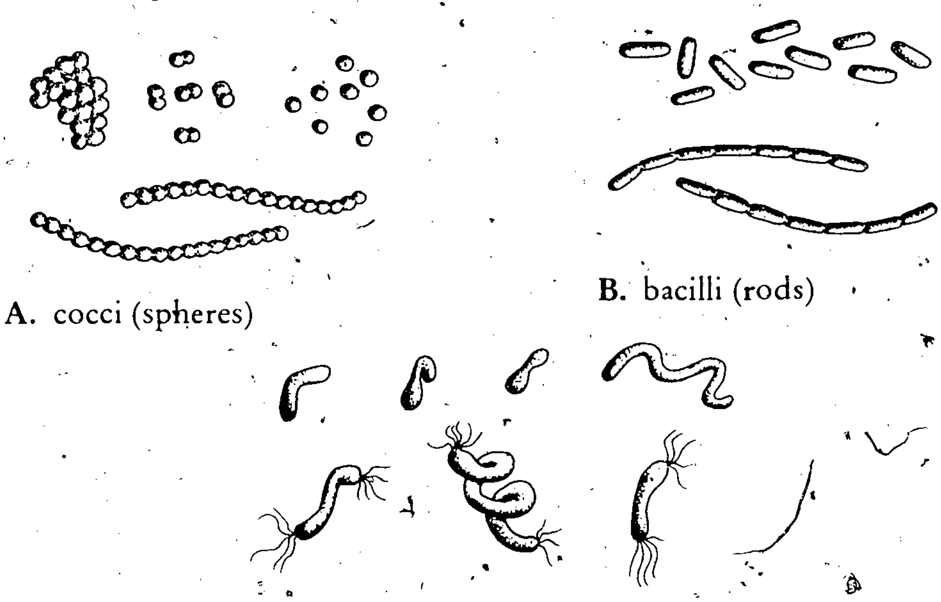
During times of high metabolic activities, marine bacteria can deplete oxygen in surface waters and bottom sediments. This oxygen depletion causes the death of many organisms. The lack of oxygen can also cause significant geological changes to occur. The sea floor and its characteristic "ooze" can be altered as bacteria hasten the consolidation and **lithification** of sedimentary materials. It has been observed that the alteration in the proportion of chemical elements of organic sediments by bacteria form petroleum-like deposits in the sea.

Like all bacteria, marine bacteria are **procaryotes**. They do not survive unusual environmental stresses. Most are **nonsporogenous** rods or spirals. They are usually smaller than non-marine forms. Most move by flagella (Figure 1). The stationary types attach themselves by **pili,** mucus slime or "holdfasts". Marine species are highly pigmented. Cultures can be pink, brown, yellow, green, or orange. Many are **luminescent** and give off a greenish color in the dark.

The majority of marine bacteria (Figure 1) fall into the three types listed below:

1. Myxobacteria—single celled; pointed rods; capable of movement; colony lacy; flame shape.
2. Eubacteria—a) cocci (singular, **coccus**) nonmotile, clusters or in groups of eight.
   b) bacilli (singular, **bacillus**) with or without spores, (*Pseudomonas; Photobacterium*—luminescent).
   c) spirilla (singular, **spirillum**)—flagellate.
3. Spirocheta—large slender helical; common in marine muds; most anaerobic (*Cristispira*).

Marine bacteria are responsible for the rapid spoilage of seafood. The deterioration of nets, ropes and cables is the result of bacterial activity.



A. cocci (spheres)

B. bacilli (rods)

C. spirilla

Figure 1. Bacterial cell types. (Adapted from Muller, 1969).

VOCABULARY

Bacillus—a rod shaped bacterium.
Bacteria—microscopic plant-like organisms.

Coccus—a spherical bacterium.

Decomposer—an organism that breaks down the tissues and excretion of other organisms into simpler substances through the process of decay.

Deposit feeder—an animal which engulfs masses of sediments and processes them through its digestive tract.

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

Filter feeder—any organism which actively filters suspended material out of the water column by creating currents.

Lithification—consolidation into rock either from molten lava or from a state of loose aggregation as sand or gravel.

Luminescent organisms—those which emitted light by physiological processes, chemical action, friction, electrical, radioactive emissions.

Maritime—relating to or bordering on the sea.

Mineralization of organic matter—the process of breaking down the accumulation of organic matter represented in the bodies, secretions, feces, skeletons, and other remains of plants and animals, releasing their chemical constituents in the form of simple soluble inorganic ions.

Nonsporogenous—does not produce spores.

Organic detritus—very small particles of the decaying remains of dead plants and animals; an important source of food for many marine animals.

Organic nutrient—a carbon containing substance which promotes growth and development in organisms.

Pili—thread-like projections from an organism used for attachment.

Primary producer—an organism that creates new organic matter from inorganic substrates; plants.

Procaryote—an organism lacking membrane—bounded nuclei, plastids, golgi bodies and mitochondria.

Spirillum—a spiral or corkscrew-shaped bacterium.

Activity: Staining Bacteria

Objective

To observe the variety of bacterial cell types.

Materials

broth cultures of bacteria, slides, microscopes, inoculation loops or round wooden sticks 6–8" long, crystal violet stain*, alcohol lamps or Bunsen burners, paper toweling

Procedure

1. Place one or two drops of the culture onto a clean slide by using a loop or wooden stick.
2. Using the loop or stick, spread the liquid over a 2 cm area.

*Dissolve 2 grams of crystal violet in 20 ml of 95% ethyl alcohol. To this, add 80 ml of distilled water.

3. Let the slide air dry.
4. Heat-fix by quickly passing the area of the slide with the bacterial film through the flame three or four times FILM SIDE UP! **DO NOT "COOK"** the bacterial film.
5. Let the slide cool to room temperature.
6. Hold the slide, film side up, over a sink. Add 3–4 drops of crystal violet to the bacteria.
7. Let stain stand for 15–30 seconds.
8. Rinse stain off with a slow stream of water.
9. Press the end of the slide to a piece of toweling to remove excess water.
10. Remove remaining water by gently blotting the slide. **DO NOT WIPE.**
11. Let slide dry before examining under the miscroscope.
12. Place the stained bacterial slides under the microscope. Coverslips are not necessary. Focus on the bacteria with your low power objective. Look for tiny purple specks. Bring the specks into sharp focus. Swing the high-power objective into place and refocus with your fine adjustment knob. Observe the size, shape, and arrangement of cells. Draw typical cells below.

Were most of the cells rods (bacilli) or spheres (cocci)?
Did you note size variation between the cells or cell groupings?

Suggested Demonstration

If an oil-immersion microscope is available, students should observe the bacterial cells at higher magnifications.

Preparation of Broth Cultures

Dissolve a gram of peptone in 100 ml of distilled water or 1 bouillon cube in a pint of distilled water. Fill several screw-cap tubes or test tubes with cotton plugs ¾ full with the broth. To obtain a variety of bacterial cell types, expose some tubes to the air and place soil in the others before capping or plugging. Within 2–3 days you will have adequate cultures. Note that sterile technique is not necessary.

Activity: Collecting and Culturing Marine Bacteria

Objectives

To collect and isolate some common pond or marine bacteria.
To observe the growth patterns of these organisms on artificial media.

Materials

autoclave, home pressure cooker, or oven; distilled water, habitat water (filtered), disinfectant, nutrient agar or gelatin, peptone (bouillon cubes), screw cap test tubes, inoculating loops (Q-tips), Bunsen burners or alcohol lamps, cooler, petri dishes (disposable sterile, if possible), single-edge razor blades

Procedure

A. Collection of seawater samples
   1. Wash, rinse (distilled water) and dry several screw-cap test tubes. **Loosely** screw caps on the tubes.
   2. Autoclave at 15 psi for 25 minutes or wrap in foil and place in an oven of 350°F for 1 hour or more.
   3. After sterilization and cooling, the tubes are ready.
   4. Hold the tube under the water at the desired water level. Remove the cap with one hand and tilt the tube with the other hand. This allows the tube to fill easily.
   5. When tube is ¾ full, recap the tube while under the water.
   6. Remove tube from water, label, and place in a cooler until culturing the sample.

B. Collection of sediment samples
   1. Prepare several tubes as described in "A".
   2. Wrap several single-edged razor blades in foil individually and sterilize as mentioned in "A".
   3. At the sampling site (beach or edge of pond), dig some of the substrate up with the sterile razor blade.
   4. Fill a sterile screw-cap test tube ⅓ full with your substrate material.
   5. Place well labeled sample tubes in a cooler.
   6. Collect some habitat water in a sterile container. This water should be autoclaved at 15 psi for 25 minutes or boiled for 10 minutes.

C. Preparation of media
   Sea-Agar
   1 liter filtered sea water
   10 grams peptone
   15 grams agar
   20–25 sterile plates (disposable or oven sterilized at 350°F for 1 hour)

Add the ingredients and heat until dissolved (100°C). Pour about 125 ml of the hot liquid medium into 250 ml flasks. Plug with cotton wads. Autoclave for 25 minutes at 15 psi. Cool to 60°C and pour plates. Invert plates after media solidifies. Preparation of media and pouring of plates should be done prior to class.

If you do not have an autoclave or pressure cooker, other kitchen materials can be used to make the media. An artificial medium can be made with gelatin and bouillon cubes. Sterilize petri dishes as explained above. Then boil 2½ pints of your habitat water (freshwater for pond sample, salt water for marine samples) in a pot with 3 bouillon cubes. Remove fats and oils. Dissolve 8 envelopes of gelatin in it. Add a pinch of salt. Divide the gelatin-bouillon mixture among 60 petri dishes. Immediately cover the dishes. After medium solidifies, invert plates so that water droplets will not fall onto the medium.

D. Streaking plates

1. Each student pair should obtain three petri dishes; one for a control, one to streak with the water sample, and one to streak with sediment sample. Label the plates with sample designation and your name.
2. Light the burner and flame the loop. Remove the cap of the water sample and flame the mouth. If inoculation loops are not available, the students can streak the plates as described below with Q-tips which have been individually wrapped in foil and sterilized in an oven at 150 F for 1 hour.
3. Insert the loop (Q-tip) into the water and withdraw a loopful of the sample. Try not to touch the sides of the tube as you remove the loop. Flame the mouth of the tube and screw cap back on. If a Q-tip was used, it will be necessary to press excess water off on the sides of the test tube.
4. "Mop" with Q-tip or "streak" with the loop carefully over the surface of the media (Figure 1). **Do not** break the surface of the medium.
5. Replace lid of the petri dish. Flame loop.
6. Invert plate and incubate at room temperature for 3–4 days.
7. For the sediment sample, add sterile habitat water until the tube is ⅔ full. Screw cap on the tube and shake 20–30 times. Allow the sediment to settle.
8. Repeat steps 2–6.

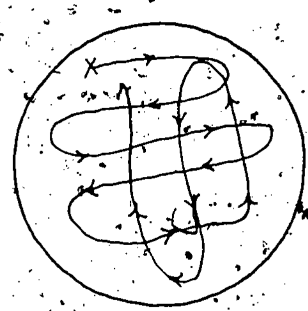


Figure 1.

9. Make daily observations and record the following data: number of colonies, color, size of colonies, and shape of colonies.

	Plate 1 Control				Plate 2 Water Sample				Plate 3 Sediment Sample			
	Day				Day				Day			
	1	2	3	4	1	2	3	4	1	2	3	4
Number of colonies												
Color(s) of colonies												
Size of colonies												
Shape of colonies												
Roughly sketch two different colonial types												

E. Smears for staining

1. After 4 days, place a drop of water on a slide.
2. Flame the inoculating loop and pick off a small amount of a chosen colony with the loop and mix it with the water drop on your slide.
3. Flame the loop. Let the slide air dry, heat fix, and stain.
4. Repeat for as many different types of colonies as possible.
5. Observe the stained slides under the microscope. Make rough sketches of the cells you have stained.

6. Describe the colonial characteristics and cellular characteristics for each bacterium you have stained.

VOCABULARY ACTIVITY FOR CONCEPT I

The grids in these puzzles, when solved, will yield a defined term related to Concept I. 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.

■	■	■								■				■	■				■
■	■							■	■									■	■
		S	H	A	C	I	D	L	I	B	A	C	E	E	R	I	O	D	
			B	A	P	E	L				A	R	T			R	A		

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

■	■	■							■									■	■
■						■					■								
			■	■								■							■
■			■		■								■						
■	■	■	■	■															■
T	B	D	E	A	K	R	D	A	R	B	A	S	M	E	A	I	A	R	A
	B	R	M	A	O	I	N	O	C	I	S	I	C	A	T	M	L	I	D
	E	Y		A	[illegible]	P	G	E	W	N	L	A	T	C	T	T	O	N	
					R	I	N	E	N	A	C	C	Z	C	U	L	U	E	
							R	O		E				A	R	I	E		

VOCABULARY ACTIVITY FOR CONCEPT I

Hidden in the letters below are 7 vocabulary words related to Concept I. The words may be written vertically (up-and-down), horizontally (across), backwards, or diagonally. Try to find the 8 words.

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

Answers: bacillus, bacteria, coccus, procaryote, lithification, mineralization, nonsporogenous.

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CONCEPT J

Sea grasses are submerged monocots which stabilize the bottom sediments, contribute food, and provide a habitat and refuge for marine organisms.

Objectives

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

a. To name three sea grasses of the Gulf of Mexico.
b. To give two modifications of the plant body of sea grasses.
c. To list two ways the sea grasses benefit their ecosystem.
d. To discuss how sea grasses differ from algae.

SEA GRASSES

There are many flowering plants closely associated with the marine environment. Their range extends from the mangrove thickets of the tropics to the salt marshes of temperate regions. However, few of these qualify as seaweeds, for most do not grow wholly submerged. There are eight genera, including about fifty species, which fall into the sea grass category. These are not true grasses, but are members of the pondweed families. Many sea grasses are tropical in origin, and several species are found along the Gulf Coast of the United States.

The **monocots** called sea grasses resemble true grasses in their general structure. They have long leaves, rhizomes, and fibrous root systems. Many scientists theorize that sea grasses evolved from freshwater monocots that spread from rivers into the oceans.

Sea grasses are **hydrophytes**, plants that grow underwater. Consequently, their tissues are not as complex as those of the true grasses. For example, in sea grasses the **vascular** system is poorly developed, and the **cuticle** and **stomata** are lost from the epidermal layer. Reproduction is highly specialized.

The ecological role of these plants is very important in the **sublittoral** environment. The spreading of rhizomes and roots forms sediment traps and helps to stabilize sandy bottom sediments.

These grasses also serve as a food source. Their **productivity** may be even greater than that of benthic algae. They provide food directly and indirectly for many animals.

Another important contribution of sea grasses to the ecosystem lies in the fact that they provide a habitat and refuge for great numbers of organisms, including shrimp, crabs, scallops, and many fish. Their great value as nursery areas for animals can hardly be estimated. These plants also serve as a substrate for many invertebrate species and for algae. Starfish, sea urchins, soft corals, and sea biscuits are among other animals using these grasses for shelter. Sea grasses occur from mean low tide to thirty meters in depth.

Mississippi Sound makes up a large portion (678.8 square miles) of the territorial marine waters under the jurisdiction of the state of Mississippi and also is part of the coastal waters of Alabama. This body of water is partially separated and protected from the open Gulf of Mexico by a chain of barrier islands.

More than half of the sea bottom of Mississippi Sound is composed of mud, especially near the mainland. Toward the barrier islands, the bottom becomes sandy. Shell reefs occur in both the eastern and western Sound and in various locations along the mainland. The amount of shells mixed with the bottom sediments varies.

Extensive submerged beds of sea grass occur on the sandy bottom, especially near the barrier islands. In 1969, the Gulf Coast Research Laboratory mapped the bottom of the Sound under the jurisdiction of Mississippi and found approximately 20,000 acres (31.2 square miles) covered by marine sea grasses and algae. Scientists believe that the total area of sea bottom covered by vegetation may fluctuate from year to year and over a period of several years.

Five species of sea grass are found in Mississippi Sound. They are shoal grass *(Halodule beaudettei)*, widgeon grass *(Ruppia maritima)*, turtle grass *(Thalassia testudinum)*, manatee grass *(Cymodocea filiformis)*, and *Halophila engelmannii* which has no common name (Figure 1). Being tropical in origin, the sea grasses in local waters add a dimension of tropical diversity to the sound.

Thalassia testudinum (turtle grass) is the most common sea grass. It has broad, strap shaped leaves, 4–9 mm wide and 5–30 cm long, rounded at the apex. The stem is a persistent rhizome, and leaves arise in clusters from **nodes**. Turtle grass is found from mean low tide to a depth of 30 m. Flowering is rare, and reproduction is usually vegetative.

Cymodocea filiformis (manatee grass) is often found mixed with *Thalassia* at a depth of 2–15 m. **terete** leaves grow to 35 cm in length with a diameter of about 0.5 cm. The sheaths and bases are pointed. Sexual reproduction is rare; vegetative growth is the primary means of reproduction.

Figure 1. Genera of sea grasses common to Mississippi Sound. A, *Halophila*. B, *Halodule*. C, *Ruppia*, D, *Thalassia*.

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Ruppia maritima (widgeon grass) differs from other local sea grasses in that it has no stalk. The narrow, flat, pointed leaves arise from a simple to much branched partly upright rhizome which is poorly attached to the substrate. These plants are basically a freshwater species, but they are found growing on mud and sand in the littoral and upper sublittoral zones. Flowering is common, and sexual reproduction occurs more frequently in this sea grass than in many other species.

Halophila engelmannii has, as its most distinguishing characteristic, elliptical leaves which are arranged in rosettes at the tip of the short stem. This leaf consists of a whorl of five leaflets. Leaves are 1–3 cm long and have faint, central veins. Rhizomes are creeping and scaly. This species is found in depths of less than 5 meters, growing with *Thalassia* and *Cymodocea*. Sexual reproduction is rare.

Halodule beaudettei is a marine perennial. The leaves are slender giving a linear appearance. The leaves develop from the nodes of submersed rhizomes. Rooting is from the nodes. The apex of each leaf has three points. Each point represents an extension of the three veins, the midrib and two marginal veins.

These plants propagate and spread primarily by vegetative growth, through the production of extensive rhizome systems. Rhizomes are horizontal stems which grow in the sandy sea bottom. The plants adjust to sediment deposits and erosion by upward or downward growth of the rhizome apex or growing point. The erect stems of *Hadodule beaudettei* elongate vertically to adjust to sediment deposition.

Rhizomes and roots form extensive masses and tend to stabilize the sandy sea bottom. Organic material also accumulates in some beds of grasses and, in time, the shells of scallops, clams, and conchs (sea snails) become abundant. Beds are often formed of only one plant species and they may range in area from a few to several hundred square feet. Shoal, turtle and manatee sea grasses do not usually intermix, but *Halophila* grows intermixed with turtle or manatee grass.

As mentioned before, sea grasses and marine algae support various animal populations (Figure 2). As many as 300 or more species, including more than 100 known invertebrate species, occur in Mississippi waters. The population of certain species varies widely from a few individuals to hundreds of animals per square meter of vegetation.

Many kinds of clams (20 species) and snails (45 species) are known to occur. Sea grass beds are also habitats for numerous crustaceans (50 known species), including the blue crab (*Callinectes sapidus*) and the brown shrimp (*Penaeus aztecus*) during some stage of their life cycles. Some 24 other species of crabs and four other species of shrimp are found among sea grasses. Sponges, bryozoans, corals, sea whips, sea anemones, horseshoe crabs, starfishes, sea cucumbers, and annelid worms (Polychaeta) are also found here. In some years the sea hare (*Aphysia willcoxi*) and the sea pork (*Amaroucium stellatum*) also inhabit these beds.

Beds of marine vegetation provide a source of food to small organisms and also protect them from predators and the physical forces of the sea. Some animals feed directly on the sea grasses, others feed on the phytoplankton (minute, drifting plant life) in the waters, and others on the algae which grow attached to the sea grasses or on associated shell fragments. Some animals feed upon other animals within the community and thus the food chains and webs begin. The leaves of the sea grasses buffer violent waves and currents and reduce their destructive forces.

Figure 2. Animal diversity associated with sea grass beds.

Invertebrates are the primary assemblage of animals found among the sea grasses. There is some evidence that the species found vary from one sea grass bed to another, which seems to indicate that the characteristics of the beds formed by the various species of sea grasses are important to the particular animals associated with them.

Unvegetated sandy areas adjacent to sea grass beds may have a few species of animals and algae common to the sea grass beds, but both numbers and diversity are greatly reduced. Areas of muddy bottom are equally lacking in algal and animal species. Comparing these readily observable facts, it has been concluded that the large number of animals found in sea grass and algal beds is dependent upon the presence of vegetation. The abundance of animals is strikingly noticeable, especially in summer months. In comparison to other marine, estuarine, freshwater or terrestrial communities, sea grass beds are probably the most diversified and among the most productive in the world.

The presence and abundance of small animals attract many fish, making the sea grass beds of Mississippi coastal waters excellent areas for sportfishing. Fishes such as flounder, ground mullet, striped mullet, redfish, sheepshead, spade fish, white and speckled trout are very abundant around sea grass beds. Sharks and rays are often found in the vicinity of grass beds, and occasionally mackerel and lemon fish. However, mackerel and lemonfish along with blue fish are found generally in deeper waters along the south side of the barrier islands and further south in the open Gulf.

Magnificent pipefish and seahorses are found among the blades of the sea grasses. The sea robin, file fish, sea bass, cowfish and puffers are only a few of the interesting and beautiful fishes associated with these undersea meadows.

Environmental Disturbances

Large-scale environmental disturbances, such as hurricanes, and prolonged periods of low saline water are known to affect sea grass and algal beds. When the acreage of sea bottom covered by sea grasses and algae is reduced, it probably causes a reduction in the density and diversity of animal populations associated with them. The reduction in the small animal abundance may cause the populations of certain sportfishes to shift to other locations for food.

Thus, large recurring weather cycles are important to the environmental conditions affecting these beds of vegetation. In past years, sea grasses and marine algae may have occupied much more sea bottom than that recorded in 1969. During periods of drought, when coastal waters are maintained at relatively high salinities, sea grasses and marine algae are probably more abundant. As the marine flora develops, subsequently the marine faunal community increases also in density and diversity resulting in concentrations of sportfishes. Supported by the U.S. Army Corps of Engineers, the Gulf Coast Research Laboratory has developed techniques that could be used to extend barren sea bottom areas to potentially productive areas. Simple anchoring devices constructed from wire mesh and iron rods were used to hold portions of sea grass to the bottom until they became established.

At present there are limitations to the application of these techniques. However, considerable potential exists for management of sea grass and algal beds. It may be feasible to transplant certain species of plants in areas disturbed by channel maintenance, pipelines and other coastal engineering projects, in addition to areas destroyed by natural disasters.

To suggest that man's efforts can produce results that mimic nature would be bold. But the natural establishment of sea grass can be significantly aided and put into motion by man through transplanting programs which should contribute beneficial effects on the marine environment.

VOCABULARY

Cuticle—a waxy material (lipid) which covers the outer surface cells of leaves and some other plant parts to reduce water loss.
Hydrophyte—partially or wholly immersed water plant; dwelling in wet places or water.
Monocot—a flowering plant that develops a single seed leaf (cotyledon), floral parts in three or multiples of three.
Node—the region of the stem where one or more leaves are attached.
Productivity—amount of organic materials formed in excess of that used for respiration. It represents food potentially available to consumers.
Rhizome—a horizontal underground stem.
Rosette—a cluster of radiating leaves.
Sea grass—a grass-like monocot which grows in brackish or marine water.
Sheath—the basal part of a leaf or a collar-like outgrowth at a node wrapped about a stem.
Stomata—the pores or openings between two guard cells in the epidermis of a plant.
Sublittoral zone—that benthic region extending from mean low water to a depth of about 200 meters or the edge of a continental shelf.
Terete—round in cross section.
Vascular system—the conducting tissue (xylem and phloem).

CONCEPT K

Salt marshes are productive communities of monocot and dicot plants which demonstrate zonation in flora.

Objectives

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

a. To name causes of zonation in the marsh.
b. To discuss the importance of salt marshes to the ecosystem.
c. To differentiate between halophytes and pseudohalophytes.
d. To give generic examples of marsh plants common to the Gulf Coast.
e. To list two ways transpiration is reduced by salt marsh plants.
f. To describe a typical grass flower.
g. To cite a challenge that salt marsh plants face daily.

SALT MARSH COMMUNITES

Salt marsh communities are found in the littoral zone in regions of low wave energy. These plant communities are formed along stable or emerging shorelines in the temperate regions of the world.

Along much of the coast of the Gulf of Mexico, salt marsh communities have formed and are forming in areas where accumulation of sediment in sea grass communities permits a stand of smooth cordgrass to develop. As sediments increase, this grass may move in if the soil contains a sufficient amount of organic material.

In many **salt marsh** communities, algae form a mat on the mud, on plant stems, and on shells. The lower littoral zone of tide channels is primarily exposed bare mud. Saltwater algae may be found in tide channels, while certain freshwater species are present in brackish regions of tidal channels.

From an ecological standpoint, salt marshes are tremendously important. They are sites of the production of many tons of **organic matter,** providing food for countless numbers of organisms. These areas act as a **buffer zone** between saltwater and land vegetation. Certainly one of the greatest values of the salt **marsh** to the **ecosystem** is that it provides the **habitat** for many species of algae, seed plants, invertebrate animals, and a large number of birds.

It is important that this value be stressed, for humans, too, have come to value the salt marsh as a habitat. Many areas have been filled and houses have been built, destroying the natural setting which is so vital to the **flora** and **fauna** of marshes.

Salt marsh plants are classified into two categories based upon their habitat. The first category includes the **halophytes.** These are plants which grow and complete their life cycles in areas of high salt content. Plants of the second category are called "false halophytes" or **pseudohalophytes.** Pseudohalophytes are those plants which appear in high salt habitats for short periods of time or occupy local nonsalty **ecological niches** in an overall saline environment.

Halophytic and pseudohalophytic plants are widely distributed in many ecological and climatic regions. However, they share uniformity in taxonomy, structure, and behavior. Often the same genera or species of plants can be found in subtropical, tropical, or temperate regions.

Plants in the salt marsh are usually found in distinct zones (Figure 1). These zones are believed to be the complicated result of elevation, soil type, salinity, temperature, and the amount of water the plants get from the tides. The most abundant grass on the muddy low sections of the salt marsh is the salt marsh cordgrass, *Spartina alterniflora.* It usually grows taller near the water, and its growth looks stunted farther away from the water. The salt meadow cordgrass, *Spartina patens,* is found higher in the marsh where the soil is sandy. *S. patens* is narrow-leafed and does not grow as tall as *S. alterniflora.*

In some salt marshes the black needle rush, *Juncus roemerianus,* grows in clumps or may cover an entire marsh. On drier **hammocks** where water seldom reaches, wax myrtle *(Myrica cerifera),* yaupon holly *(Ilex vomitoria),* and cotton seed bush *(Baccharis halimifolia),* are very common. These grow to be large bushes and make excellent shelter and nesting sites for birds, mice, rat, and other animals.

There are many other plants scattered throughout the marsh. Glassworts, *Salicornia,* are fleshy, green plants with rounded leaves. They are usually found in the sandy areas of the marsh where salinity of the soil is very **high.** Spike grass *(Distichlis spicata)* and the sunflower-like sea ox-eye *(Borrichia frustescens)* are also found in the sandy areas of the marsh (Figure 1).

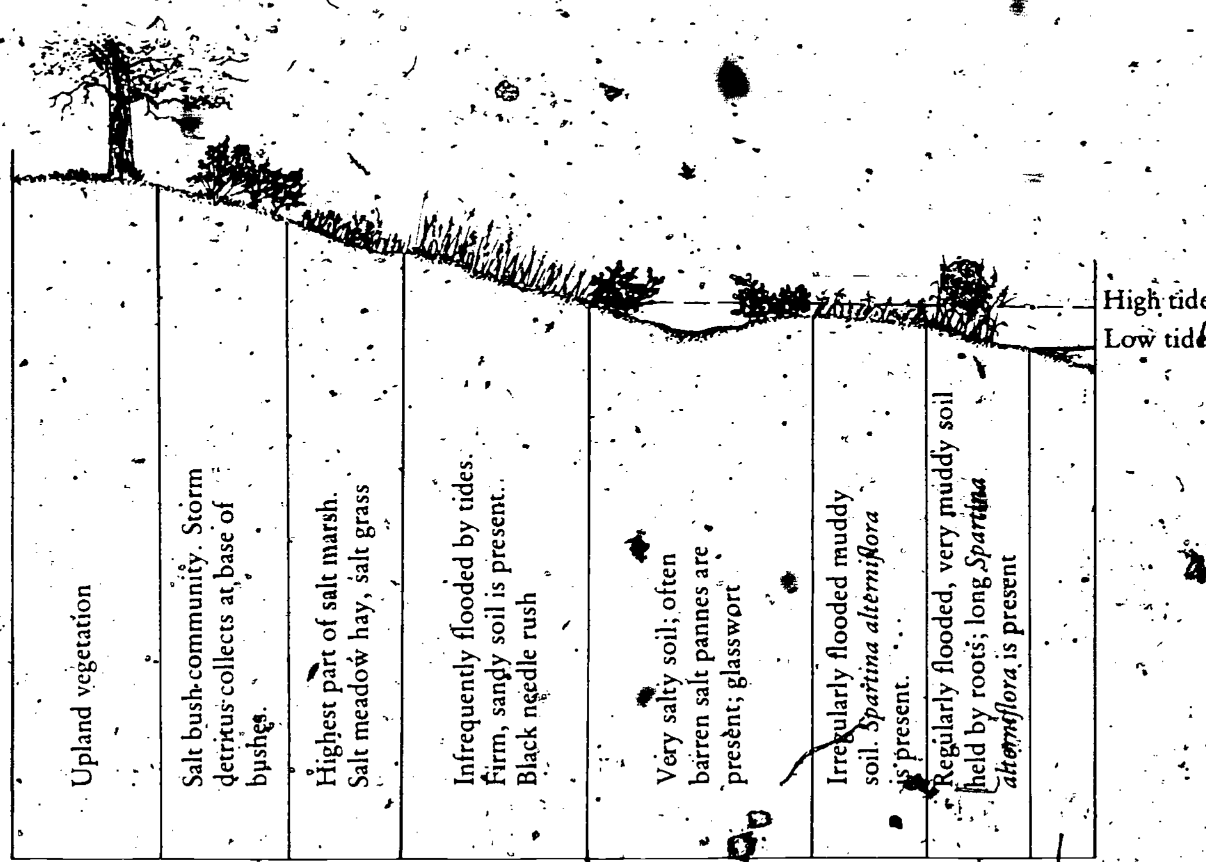


Figure 1. Idealized salt marsh zonation typical of the gulf. (Adapted from Mauldin and Frankenburg, 1978).

Most of the dominant salt marsh plants look like "grasses". Actually, these plants belong to three different **monocot** families. These are the true grass family (Poaceae), the rush family (Juncaceae), and the sedge family (Cyperaceae). Leaf, stem, and flower characteristics are used to distinguish between the three families. The flowers are highly modified from the typical **complete flower** of **angiosperms** (Figure 2) and are in **inflorescences** (a cluster of flowers).

Grasses are herbs which have flat or round stems called **culms**. The stems are hollow except at the **nodes**. The leaves alternate along the stem (2-ranked) and have **parallel venation**. Each leaf has two parts, a **sheath** and a **blade**. The sheath surrounds the culm and appears to be a tube split down one side. This is called an open sheath. The blade can be flat, folded, or strap-shaped. The grass leaf has a small appendage called a **ligule** at the junction of the blade and sheath. The ligule is thin and sometimes reduced to a ring of hairs. (Figure 3).

Grasses have small inconspicuous flowers. Each flower contains a single **pistil** with a single ovary, two **styles** each with a feathery **stigma**, and three **stamens** with delicate **anthers**. Each flower is borne in the **axil** of a small green **bract** called the **lemma**. Subtending and enveloping the flower is a second bract called the **palea**. The flower, palea and lemma together are called a **floret** (little flower). Florets alternate on an axis called the

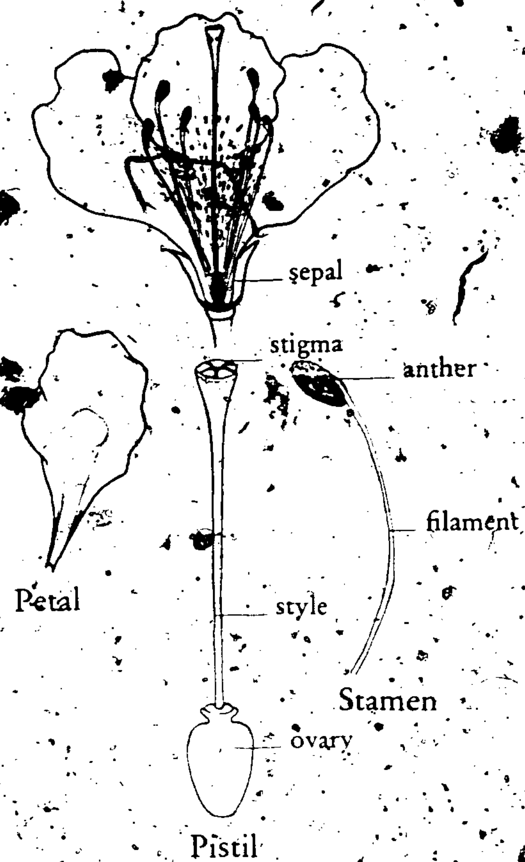


Figure 2. Typical angiosperm flower.

rachilla. At the base of the rachilla are two bracts without flowers called **glumes.** Two glumes, a rachilla, and the florets together form a grass **spikelet** (Figure 3).

The sedges (Cyperaceae) resemble the grasses upon casual inspection. The stems have solid culms, usually triangular in shape. The leaves have channeled blades and closed sheaths fused to the stem. The leaves alternate on the stem (3 ranked). Ligules are usually absent.

The inflorescences of sedges are borne in spikelets on one side of the culm. Each flower consists of a single pistil with two or three stigmas and one to three stamens. Each flower is borne in the axil of overlapping scales (Figure 4).

The rushes (Family Juncaceae) are often mistaken for grasses and sedges. The flower, however, has 3 **sepals** and 3 **petals.** The sepals and petals are stiff, dry, scale-like structures. In addition to petals and sepals, each flower has a single pistil with 3 stigmas and 3 or 6 stamens. The leaves do not have ligules. All inflorescences are terminal off an erect stem. Some species have an erect bract called the **involucral leaf** which appears to be an extension of the stem (Figure 5).

Salt marsh plants live in the intertidal zone. Therefore, the plants are subjected to conditions which challenge their very existence. These plants have to overcome problems associated with saltwater. In the marsh, plants are either in constant contact with the water or they are submerged twice daily due to tidal fluctuations. Also, the soil of most marshes is anaerobic (lacks oxygen). These salt marsh plants have developed anatomical, mor-

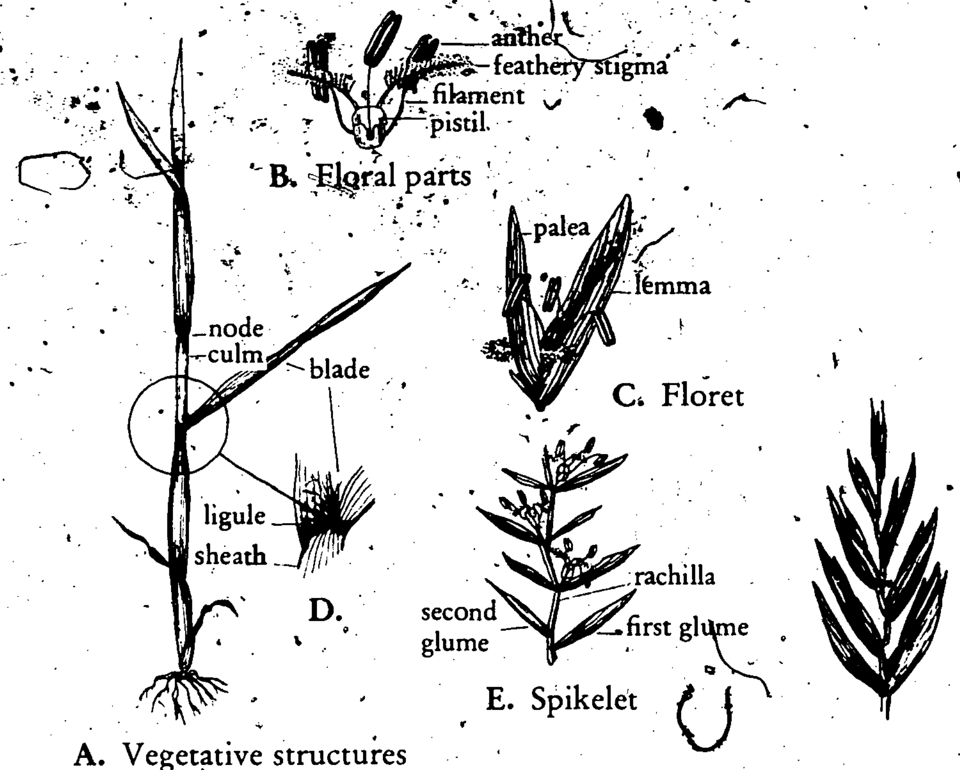


Figure 3. Habit sketch of a typical grass, Family Poaceae. (Adapted from Chase, 1968; Fassett, 1972).

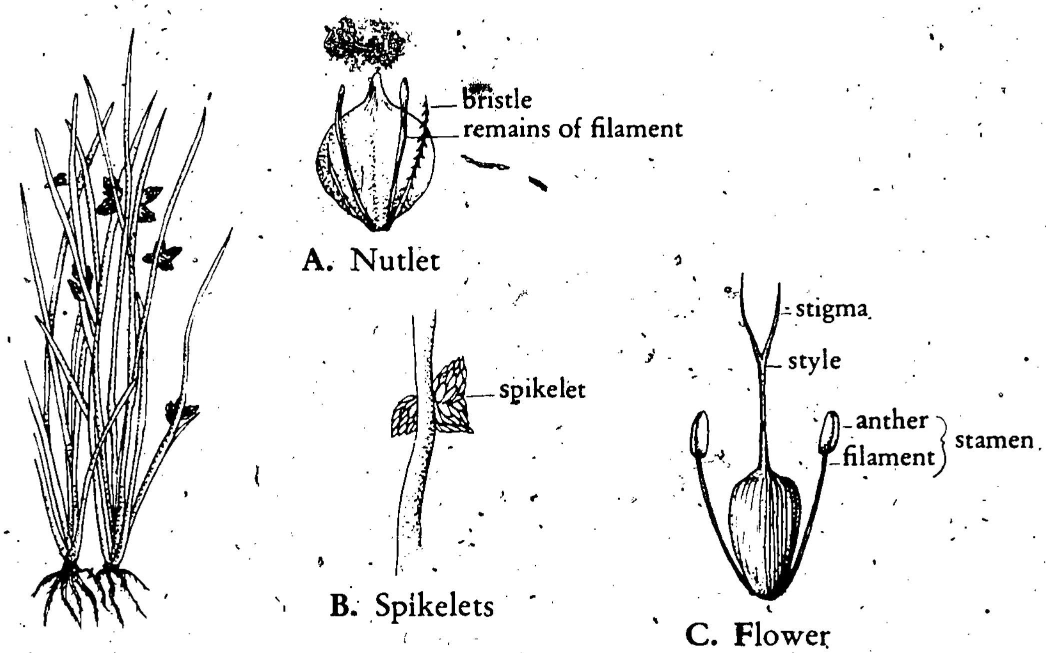


Figure 4. Habit sketch of a sedge showing nutlet, spikelets and flower. (Adapted from Chase, 1968; Fassett, 1972).

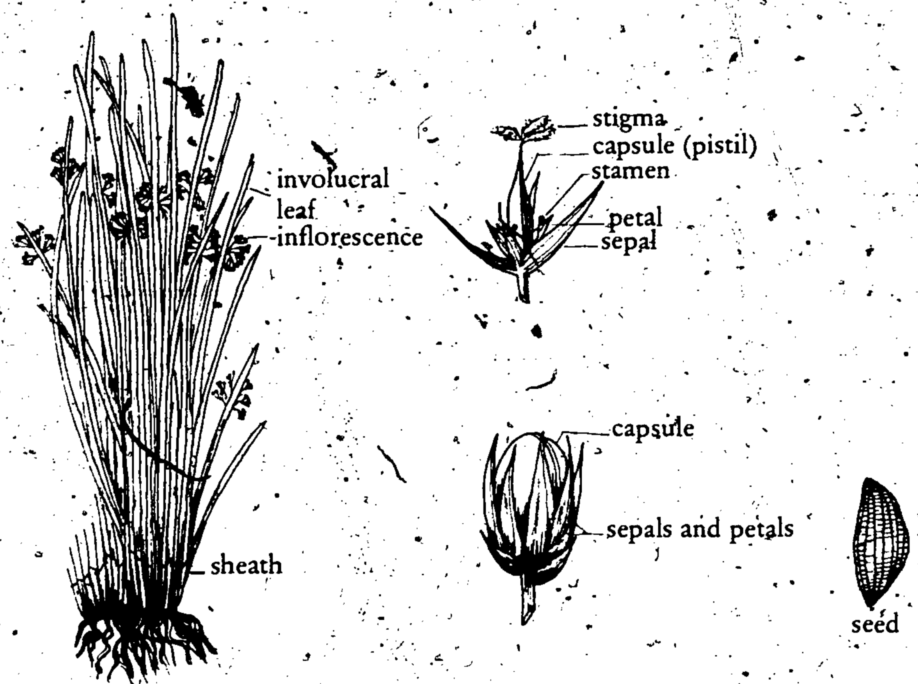


Figure 5. Habit sketch of a *Juncus* showing the vegetative and floral parts. (Adapted from Chase, 1968, Fassett, 1972).

phological, and physiological **adaptations** which allow them to tolerate the challenges of their habitat.

Salt water is "physiological dry". This can best be demonstrated by placing a plant cell in saltwater. Water inside the cell diffuses via **osmosis** through the cell membrane into the saltwater causing the cell membrane to shrink away from the cell wall. Eventually, the cell would die without the water it needs for cellular activities. Similar osmotic pressure is placed on salt marsh plants by the environment. Some plants like *S. alterniflora* actually take in salt with water and actively excrete the salt via **salt glands** located on the surfaces of the leaves and stems. Salt crystals can often be seen on some plants in the marsh.

Water conservation is essential to plants in a "physiological dry" environment. Therefore, water loss by **transpiration** must be reduced. This is achieved in various ways by marsh plants. Most plants have sunken **stomata,** fewer stomata per unit area than inland plants, thick **cuticles,** succulent plant bodies and **trichomes** (hairs) on stems and leaves.

Plants which have developed **succulence** are fleshly plants. In effect, these plants have diluted the effects of "toxic ions" associated with excessive salts by increasing their volume to surface area ratio.

Many salt marsh plants are **pubescent.** Over stems and leaves many hairs called trichomes have developed. These trichomes give the plants a greyish-green appearance. These hairs reduce transpiration in three ways. First, the hairs reduce air movement directly over leaf and stem surface; therefore, they help reduce transpiration. Secondly, the hairs increase back radiation from the plant surfaces creating an insulated zone between the hair surface and plant surface. In effect, the plant surface is at a lower temperature than the atmosphere. Again, transpiration is reduced. Thirdly, the trichomes prevent the spray of seawater from making direct contact with the live plant surfaces.

Oxygen is rare in the soils of the salt marsh. This is due to several factors. The soil is flooded daily by tides and the air spaces of the soil are filled with water. Gases diffuse slowly through water. Also, bacterial activity in the area is great and oxygen consumption by them occurs at the soil surface. This creates a problem for the roots which do have an oxygen requirement for growth. They will suffocate if deprived of oxygen.

The plants have adapted by developing a system of hollow tubes which run from the leaves to air spaces in the roots and **rhizomes**. The oxygen is, therefore, piped from the stomata of the leaves, through the stems to the roots and rhizomes by diffusion.

VOCABULARY

Adaptation—the process by which a species becomes better suited to survive in an environment.

Angiosperm—a flowering plant.

Anther—the pollen-bearing part of a stamen.

Axil—the upper angle between an organ and the axis which bears it.

Blade—the lamina, or expanded part of a leaf.

Bract—a leaf reduced to a scale.

Buffer zone—an area resistant to change.

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

Complete flower—having sepals, petals, stamens, and pistils.

Culm—the above-ground stem of grasses or grasslike plants.

Cuticle—a waxy material (lipid) which covers the epidermal cells of leaves and some other plant parts to reduce water loss.

Diffusion—the transfer of substances along a gradient from regions of higher concentrations to regions of lower concentrations.

Ecological niche—the particular way in which an organism obtains its food and reacts; an organism's way of life.

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

Fauna—the animal life occurring in a particular locality.

Flora—plant populations of a given area; the plants or plant life occurring in a particular locality.

Floret—one of the flowers in a close inflorescence of small flowers, such as in the spikelet of a grass.

Glume—a member of a pair of bracts subtending the spikelet of the grasses.

Habitat—the place where an organism lives.

Halophyte—a plant of salty or alkaline soils.

Hammock—an elevated tract in a plain or swamp, often densely covered with hardwood trees.

Inflorescence—an axis bearing flowers; cluster of flowers.

Involucral leaf—in rushes; a bract which appears to be an extension of the stem beyond the inflorescence.

Lemma—the o[illegible] (abaxial) bract subtending a floret in the flower of a grass

Ligule—the [illegible]rgence from the top of the [illegible] at the base [illegible]he blade.

Littoral zone—an area extending from shoreline to the edge of the continental shelf or to the 200 meter depth line.
Marsh—a tract of wet or periodically flooded treeless land, usually characterized by grasses, cattails, or other monocots.
Monocot—a flowering plant that develops a single seed leaf (cotyledon).
Node—point of leaf attachment.
Organic matter—any type of material that contains the element carbon.
Osmosis—diffusion of material across a semi-permeable membrane.
Palea—the upper bract of two sterile bracts, subtending a floret.
Parallel venation—the veins are so placed relative to one another that they approximate parallel lines.
Petal—unit of the corolla of a flower.
Pistil—one of the essential organs of a flower, consisting of a stigma, style, and ovary.
Pseudohalophyte—"false" halophyte.
Pubescent—hairy; the general term for hairiness.
Rachilla—the axis of a spikelet in grasses and in some sedges.
Rhizome—a horizontal, underground stem.
Salt gland—a specialized gland located on the surfaces of certain salt marsh plants which excretes excessive salt from the plant.
Salt marsh—flat land subject to overflow by salt water.
Sepals—one of the segments of the calyx of a flower.
Sheath—a basal part of a leaf or a collar-like outgrowth at a node wrapped about a stem.
Spikelet—the segment of the inflorescence of grasses enclosed by a pair of glumes.
Stamen—the pollen bearing organ; consists of a filament (stalk) and the anther.
Stigma—that part of the pistil that receives the pollen and in which pollination is effected.
Stomata—pores regulating the passage of air and water vapor to and from the leaf.
Style—a short or long, simple or branched stalk arising from the ovary and bearing the stigma or stigmas.
Succulent—fleshly; composed of soft, watery tissue.
Transpiration—the loss of water in vapor form from a plant.
Trichomes—hairlike structures.

Activity: Salt Marsh Field Trip

Objectives

To observe the zonation of salt marsh plants.
To observe the diversity of salt marsh flora and fauna.
To determine the effects of salinity on floral zonation.

Materials

boots, old shoes or waders, buckets, collection jars, plastic bags (various sizes), shovels, plant presses, salinity test [illegible]ipment, graph paper, measuring tapes, transect poles (6 feet high), [illegible] neets, preservatives

Procedure (Field)

1. Students should work in groups of four to five. Each group should obtain two poles and a ball of cord to make their transect line.
2. The transect line should be established perpendicular to the wave-shore interface. This is accomplished by placing one pole into the substrate at the water's edge and the second pole at the top of the marsh. Tie the cord from pole to pole to establish the transect line.
3. Every five meters along the transect line, each student group should note and collect animal and plant specimens. Also, water samples should be collected at each interval. It will be necessary to label your material carefully.

Procedure (Laboratory)

1. In the lab, press plants and preserve animals. Try to identify the plants and animals with available materials.
2. Determine the salinity of the water samples which were taken along your transect.
3. Each student should prepare a diagram of their transect on graph paper showing the variation, if any, in the flora, fauna, and salinity. Study your graph and determine if there was any apparent zonation in the flora and fauna of the marsh for a class discussion.

DATA SHEET

(Salt Marsh Field Study)

Date________

Location________

Salinity ‰	Plants	Animals

VOCABULARY ACTIVITY FOR CONCEPT K

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

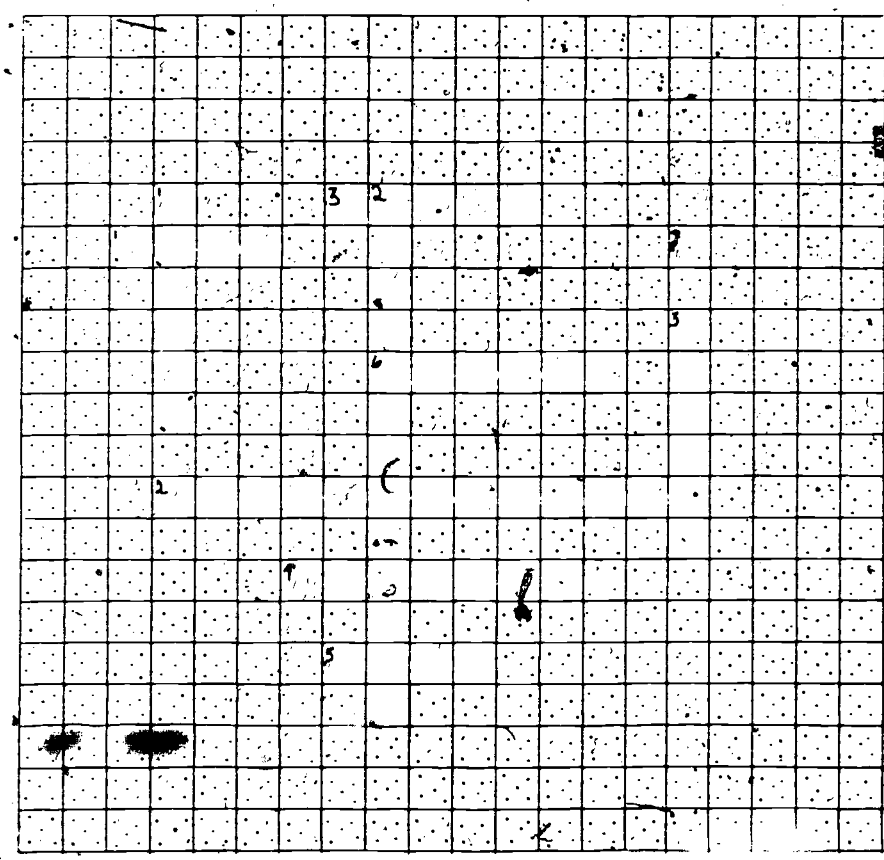
A	B	E	F	M	N	O	P	N	O	E	I	U	R	S	R	U	V	W	O
W	E	R	T	Y	U	I	O	C	V	B	O	E	R	M	O	A	W	E	P
E	R	T	M	O	P	R	S	O	S	A	P	F	O	U	R	S	T	U	V
O	S	T	A	M	E	N	R	M	O	U	I	P	Q	W	E	T	Y	I	C
B	T	V	C	O	T	W	E	L	R	T	C	I	G	O	P	Q	R	M	N
T	Y	Z	E	M	Y	C	V	A	B	A	X	C	L	D	F	G	H	J	P
Q	L	M	O	E	H	A	Z	P	C	M	V	Y	U	U	O	A	I	E	D
A	E	R	T	U	P	X	C	E	D	M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

Answers: blade, halophyte, inflorescence, lemma, glume, stamen, style, sepal, succulence, osmosis

VOCABULARY ACTIVITY FOR CONCEPT K

Try to complete the crossword puzzle using vocabulary words from Concept K.

DOWN
1. Resistant to change.
2. The loss of water in vapor form from a plant.
3. "Little flower"; a flower of a grass.



ACROSS
1. Name for the stem of a grass or sedge.
2. A cluster of flowers on an axis.
3. Stalk bearing the stigma of a plant.
4. A waxy substance on the epidermis of some plants.
5. A place on a stem where leaves are attached.
6. Receives pollen; part of the pistil.

VOCABULARY ACTIVITY FOR CONCEPT K

Below you will find a group of 7 scrambled words which are used in Concept K. Unscramble the letters of each word and write it in the blank provided. Notice that each word has one letter circled. If you write one of the letters down in order you can spell out the "mystery word".

1. d e o n ____________________
2. l e y s t ____________________
3. m a t s i g ____________________
4. t l o f e r ____________________
5. t p i l s i ____________________
6. r l x a ____________________
7. l a s t ____________________

What is the "mystery word"?

COMMON GULF OF MEXICO SALT MARSH PLANTS

Monocots

Grasses

Smooth cordgrass, *Spartina alterniflora*, grows in the lower littoral to sublittoral zones, forming a fringe around the salt marsh. This grass may grow to a height of 2 m, but shorter plants are also found. The leaves are tough, flat, broad and green. The spikelets alternate. Another common name for *S. alterniflora* is salt marsh grass (Figure 1).

Slender cordgrass, *Spartina patens*, is sometimes called saltmeadow grass. Often it is found mixed with the black rush, or forming continuous, dense stands in the mid-littoral to upper littoral zones of salt marshes. Stems may be 0.5 to 2 m tall, while the leaves are about 1 cm wide. Leaf color varies from bright green to a duller shade. *S. patens* rises from a mat of last year's growth, and may be recognized from a distance by its tousled appearance (Figure 2).

Big cordgrass, *Spartina cynosuroides*, can attain a height of 4 m or more. It is the largest of the "Spartinas" found growing in low saline marshes. The leaves are toothed, long and tapering with blades 7.5 dm long and 4 cm wide (Figure 3).

Salt grass, *Distichlis spicata*, is also called spike grass. It is quite common in the upper littoral regions of the Gulf Coast salt marshes. Spike grass favors the wetter places, and it grows in compact colonies. It is a very obvious grass as it creeps low to the substrate with rigid, erect stems and overlapping leaf sheaths. The leaves are flat and light green in color (Figure 4).

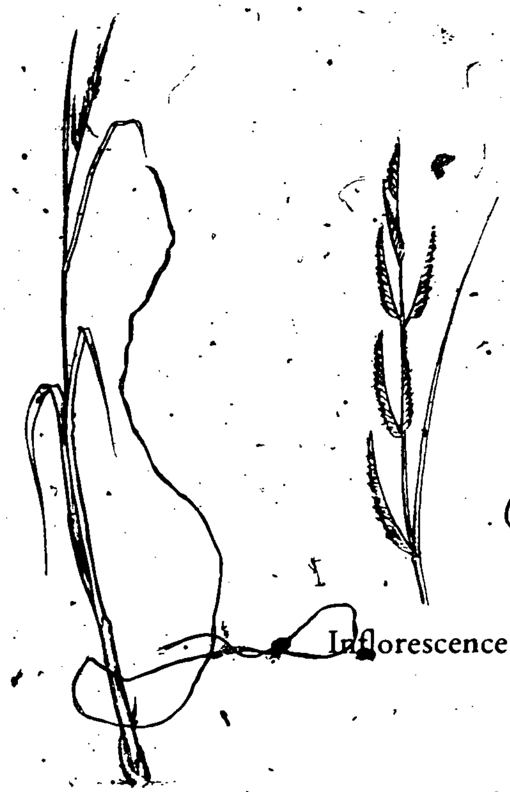


Figure 1. Habit sketch of the salt marsh grass, *Spartina alterniflora,* with an enlarged inflorescence.

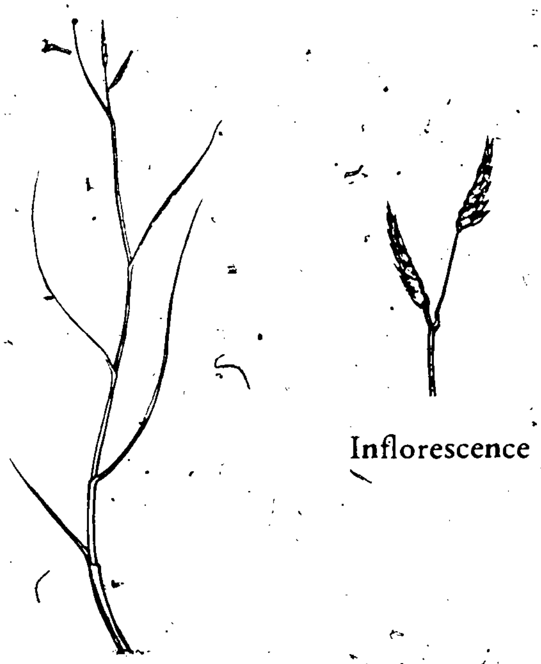


Figure 2. Habit sketch of the slender cordgrass, *Spartina patens,* with an enlarged inflorescence.

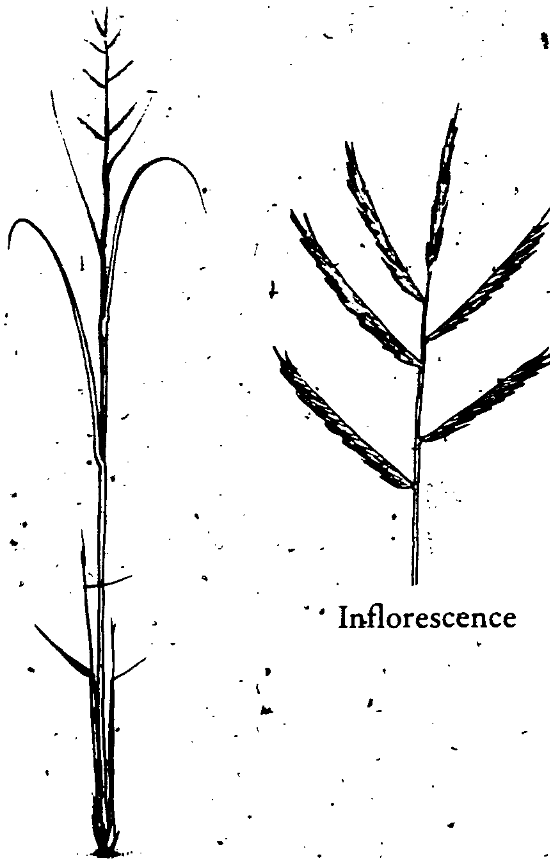


Figure 3. Habit sketch of the big cordgrass *Spartina cynosuroides* with an enlarged inflorescence.

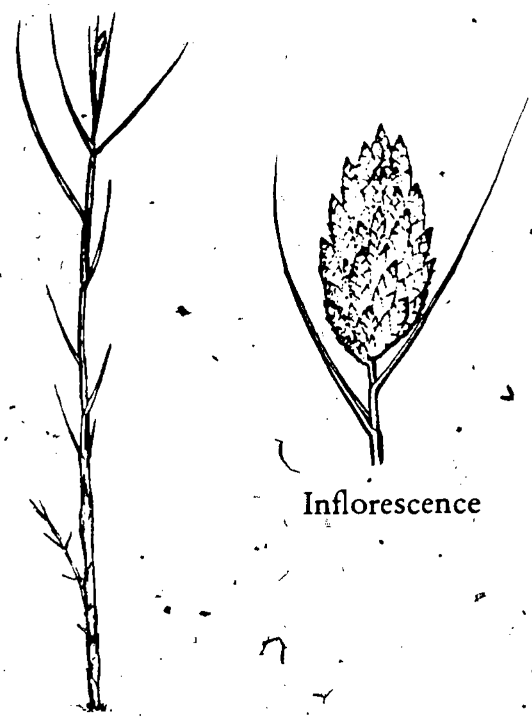


Figure 4. Habit sketch of the salt grass *Distichlis spicata* with an enlarged inflorescence.

Reed grass, *Phragmites communis*, is a tall (4 m) coarse grass with feathery seeds. The leaves are flat approximately 5 dm long and 3 cm wide (Figure 5).

The switch-grass, *Panicum virgatum*, grows in tufts. It can attain a height of 10 dm. The blades are 4–15 mm wide and as long as 3.6 dm. The ligules are densely ciliated. The inflorescence is branched with delicate florets. The grains are purplish (Figure 6).

The grass *Panicum repens* is found along the beaches and edges of marshes of the Gulf Coast. It has short (30–80 cm) culms. The blades are flat and folded. The inflorescence is open (7–12 cm) with distinct branches (Figure 7).

Sedges

The three-way sedge, *Dulichium arundinaceum*, has a round, hollow stem and attains a height of 2–8 dm. The leaves are alternate (3-ranked) with conspicuous sheaths. In the axil of the upper leaves the inflorescences are borne in racemes of spikelets (Figure 8A).

Spike rushes, *Eleocharis*, have solitary spikelets at the end of the stems. The leaves do not have blades. The blades are represented at the base of the stem as sheaths (Figure 9).

Another common sedge to the salt marshes along the Gulf Coast is *Fimbristylis castanea*. It grows in the upper littoral zones of the salt marsh and along protected sandy, brackish regions. This sedge is small, reaching a height of only about 1 m. It is a deep green perennial. The leaves are narrow with rigid blades 2–4 dm in length. The golden brown fruit is comprised of spikelets in rosette form (Figure 8B).

Four sedges of the genus *Scirpus* common to the Gulf are *Scirpus olneyi*, *Scirpus validus*, *Scirpus robustus*, and *Scirpus americanus*. These plants have sheaths at the base of their stems. The inflorescences are terminal with 4 or more involucral bracts.

S. robustus differs from the others by having several foliaceous bracts (Figure 10).

S. olneyi and *S. americanus* (Figure 11) have triangular stems and spikelets in sessiled clusters with single involucral bracts. They are differentiated by the fact that the involucral bract of *S. olneyi* is less than 2 cm and *S. americanus* is longer than 2 cm.

S. validus (Figure 12) has spikelets in branched clusters. The culm is round, not triangular like *S. olneyi* and *S. americanus*.

Beak rushes, *Rynchospora*, (Figure 13) have leaves shorter than their culms. The inflorescences bear spikelets which are ovoid or lanceolate. The spikelets are numerous and have leafy involucres.

Saw grass, *Cladium jamaicense*, (Figure 14) is a tall sedge (3 m). It is a coarse plant with long leaves (1 m). It gets its name from the rough, serrated leaf margins which easily cut human skin. The spikelets are clustered at the end of the culm.

Rushes

Black rush, *Juncus roemerianus*, (Figure 15) is one of the most important members of the salt marsh community, for it is quite prolific and occupies a great deal of space. This plant dominates the mid-littoral zone. Members are stiff, rigid, and about 1.5 m tall. They occur in large tufts and are gray green to black in color. The leaves are nearly cylindrical, but taper at the end. The stems separate, arising almost singly. In mass, *J. roemerianus* appears very dark in color because of its black fruits which ripen early in summer and last into autumn.

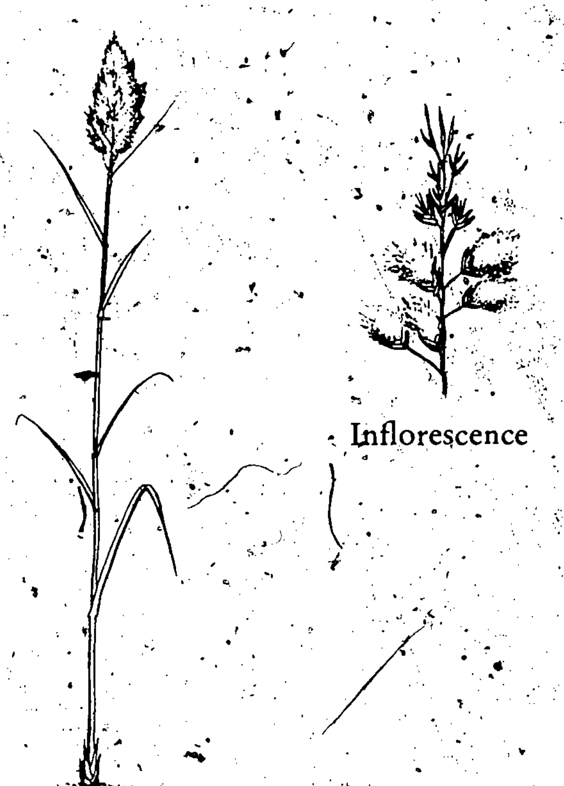


Figure 5. Habit sketch of the reed grass *Phragmites communis* with an enlarged inflorescence.

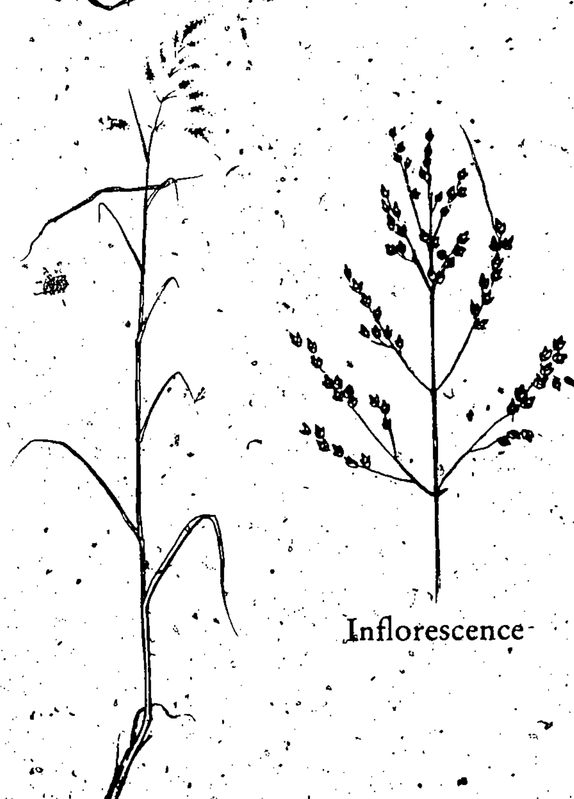


Figure 6. Habit sketch of the switch-grass *Panicum virgatum* with an enlarged infloresc-ence.

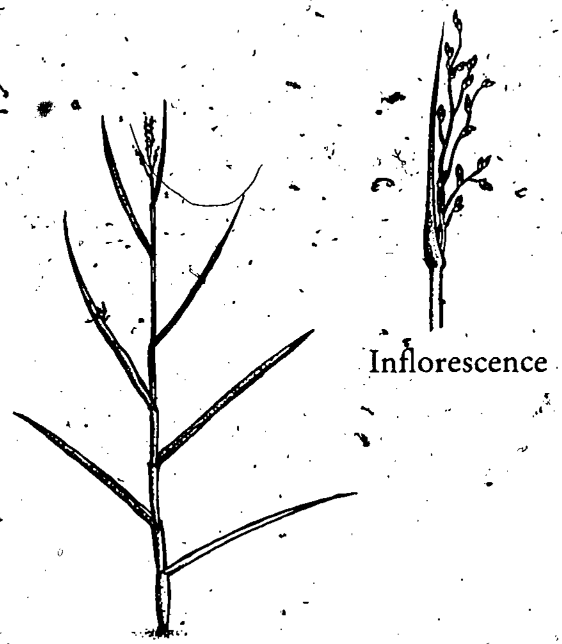


Figure 7. Habit sketch of the marsh grass *Panicum repens* with an enlarged inflorescence.

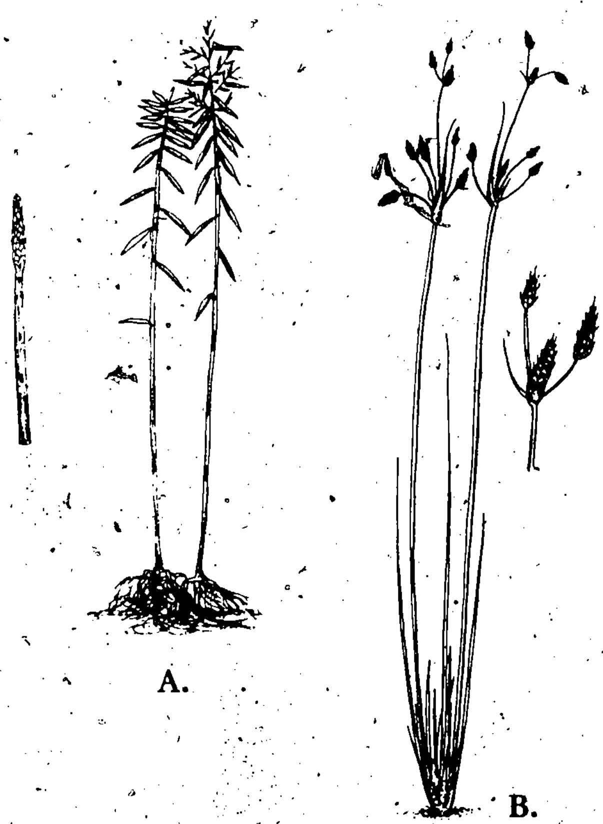


Figure 8. Habit sketches. A, three-way sedge *Dilichium arundinaceum*. B, *Fimbristylis*.

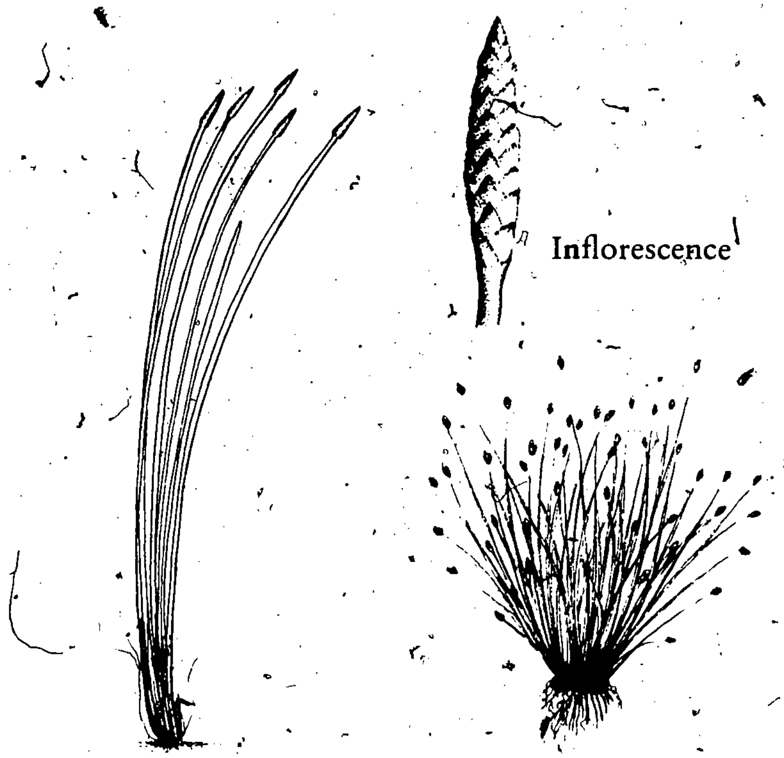


Figure 9. Habit sketches of spike rushes of the genus *Eleocharis*.

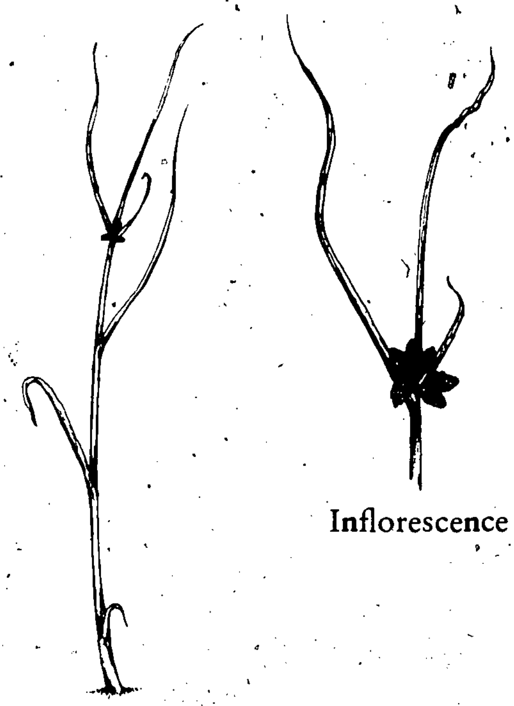


Figure 10. Habit sketch of the sedge *Scirpus robustus* and the inflorescence showing the foliaceous bracts.

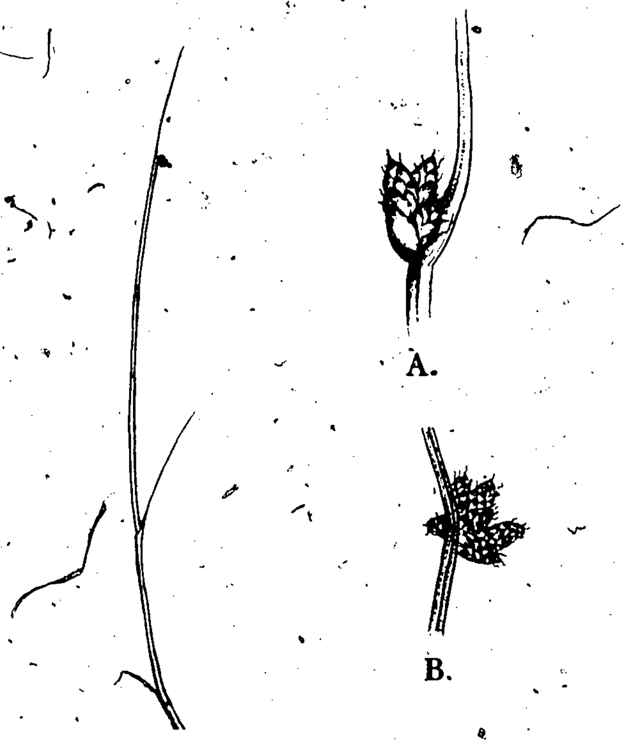


Figure 11. Habit sketch of *Scirpus americanus.* A, Inflorescence of *S. americanus.* B, Inflorescence of *S. olneyi.*

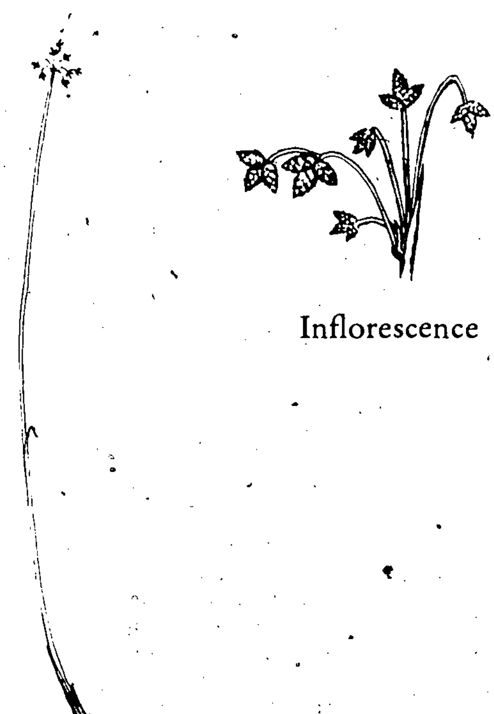


Figure 12. Habit sketch of the rush *Scirpus validus* with an enlarged inflorescence.

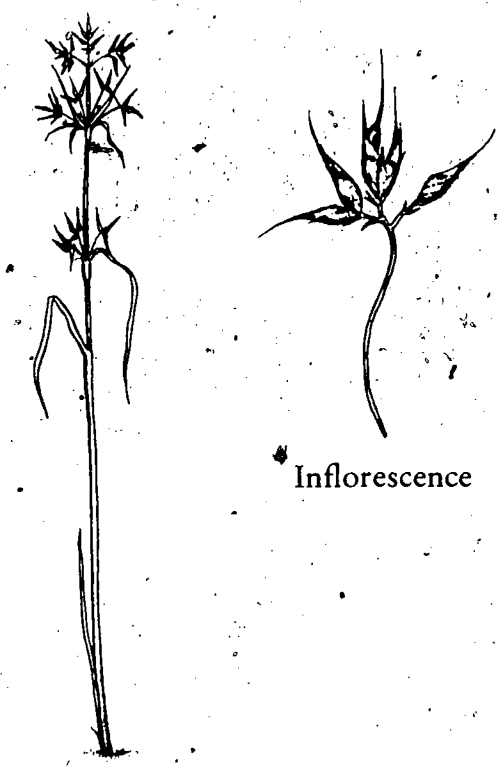


Figure 13. Habit sketch of a beak rush of the genus *Rynchospora* with an enlarged inflorescence.

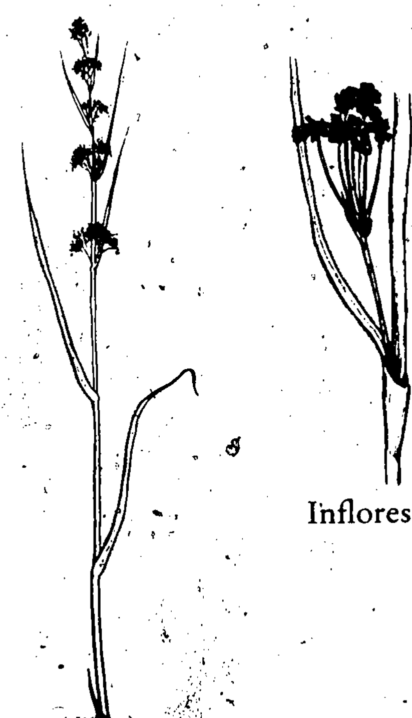


Figure 14. Habit sketch of the saw grass *Cladium jamaicense* with an enlarged inflorescence.

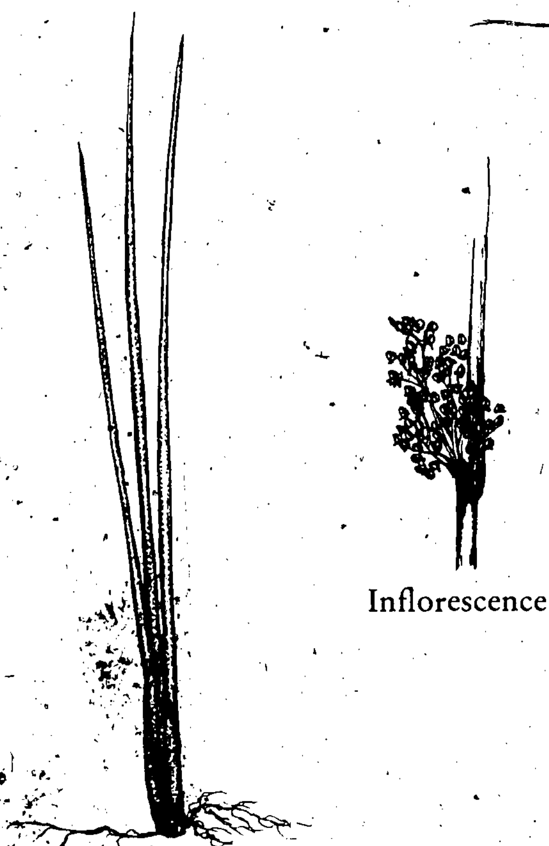


Figure 15. Habit sketch of *Juncus roemerianus* with an enlarged inflorescence.

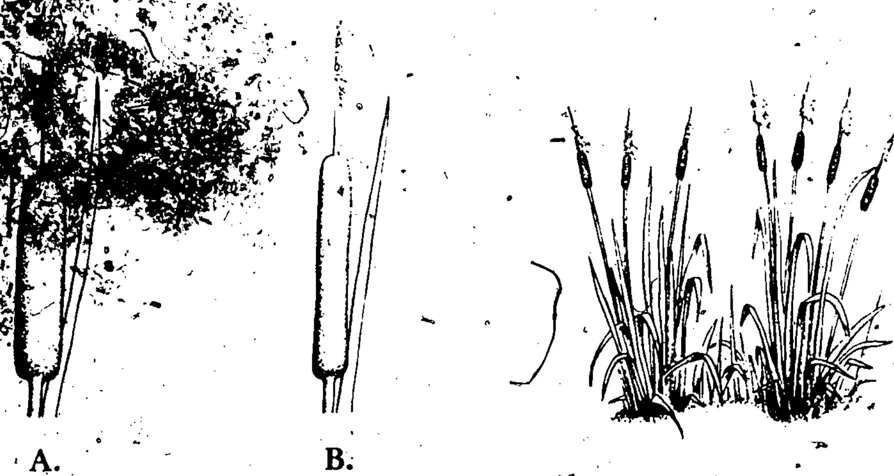


Figure 16. Habit sketch of the cattails. A, Inflorescence of *Typha latifolia*. B, Inflorescence of *Typha angustifolia*.

Cattails

There are two cattail species found along the Gulf Coast, *Typha latifolia* and *Typha angustifolia* (Figure 16). They can appear in any wet area. The inflorescences are borne in brown, cyclindrical spikes. The plants are monecious with unisexual flowers. The female flowers (pistillate flowers) are located on the lower portion of the spike and the male flowers (staminate flowers) are located on the upper portion.

The common cattail, *T. latifolia*, has stout stems and flat leaves about 4 cm wide. There is no gap between staminate and pistillate flowers. If a gap does exist, it is only slight. The narrow-leaved cattail, *T. angustifolia*, has narrow leaves about 0.5–1.2 cm. The spike is narrow and has a distinctive gap between the upper male portion (staminate) and the lower female flowers (pistillate flowers).

Pipeworts

Pipeworts, *Eriocaulon septangulare*, (Figure 17) are often called bog buttons because of white to cream colored flowers in button-like heads at the tips of slender stalks. The stems are erect rarely more than 10 cm tall. The leaves are arranged in rosettes approximately 2–8 cm long. The leaves are round in cross section. They are long and slender tapering to a point.

Dicots

Saltworts *(Batis maritima)* are strongly scented shrubs, typically found in the maritime providences in the upper littoral region of the salt marsh. The plants are succulent, have gray green leaves on a stiff, erect stem. The leaves are opposite and quite hairy. The flowers are formed in bracts, and a cone shaped configuration results from the inflorescence (Figure 17).

Salicornia virginica (Figure 18), the woody glasswort, is given that name because it makes a crunchy sound when stepped upon. This perennial, fleshy marsh dicot grows from a woody, creeping main stem. These plants have short, erect stalks which range from 5 to 20 cm in length. Leaves are arranged in opposite pairs and they are wrapped around the stem. This causes the stem to look as if it is succulent and lifeless. Flowers of *S. virginica* are embedded in the upper joints of their spike like stems. These marsh plants are found in the upper to mid-littoral zones of salt marshes, and they also occur in mangrove swamps.

Salicornia bigelovii is another glasswort found in brackish marshes. It remains green through autumn with stiff ascending branches which may attain a height of 1–2 dm tall. Unlike *S. virginica*, *S. bigelovii* is an annual (Figure 18).

There are two members of the mallow family which are found in areas along freshwater or upland margins of salt marshes. The rose mallow or marsh mallow, *Hibiscus moscheutos* has large blossoms (15 to 20 cm wide) ranging from white to pink. The seashore mallow *Kosteletskya virginica* has triangular to ovate or triangular to lanceolate leaves. The flowers are pink, lavender, or white. The flowers are much smaller (4.5–5 cm wide) than the marsh mallow (Figure 19).

There are several species of smartweeds, *Polygonum*, (Figure 20) common to the tidal marshes. These are herbaceous annuals or perennials. The plants are difficult to identify to species if mature fruits are not available. A distinctive characteristic of these plants is the

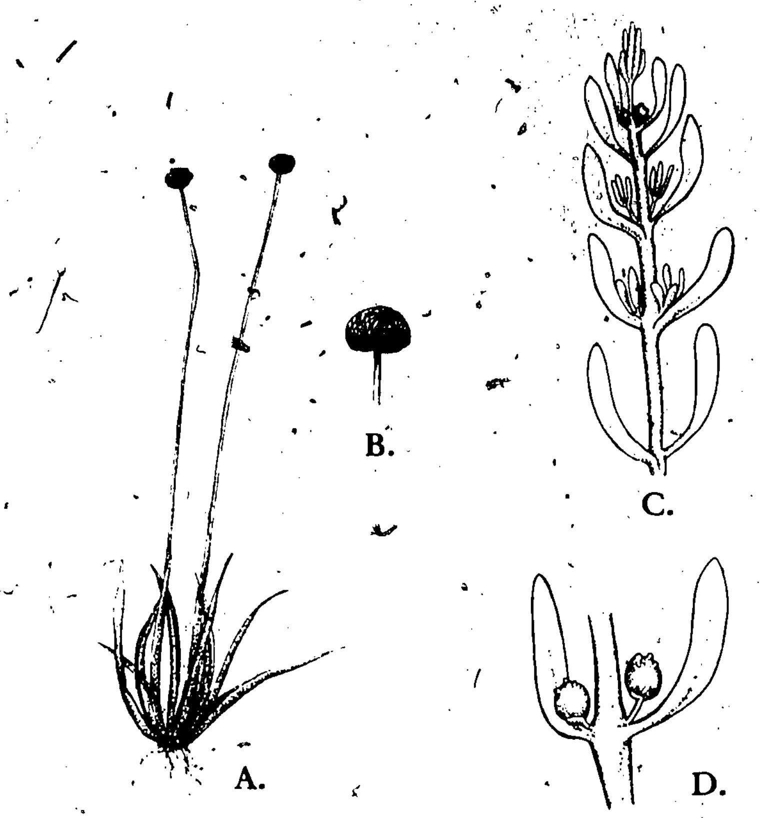


Figure 17. A, Habit sketch of *Eriocaulon*. B, Flower of *Eriocaulon*. C, *Batis mar:* D, Enlargement showing fruits of *Batis maritima*.

Figure 18. A, Habit sketch of *Salicornia virginica*. B, Habit sketch of *Salicornia bigelovii*.

Figure 19. A, Habit sketch of the marsh mallow *Hibiscus moscheutos*. B, Flower of *H. moscheutos*. C, Habit sketch of seashore mallow *Kosteletskya virginica*. D, Flower of *K. virginica*.

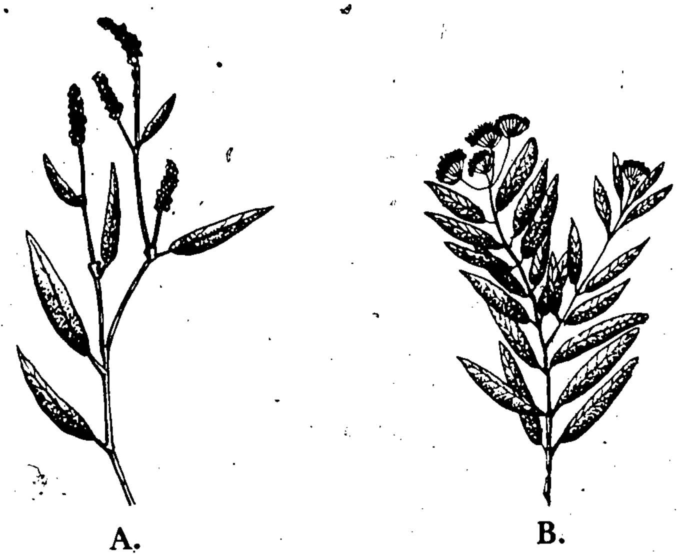


Figure 20. A, *Polygonum* (smartweed). B, *Asclepias* (swamp milkweed).

conspicuous sheath at the base of the petioles. The lanceolate to linear leaves are alternate on the stem with smooth edges. The plants grow trailing, scrambling or erect. Flowers are green with white to pink borders.

The swamp milkweed, *Asclepias lanceolata,* (Figure 20) is an erect plant with branching stems and grows as high as 15 dm. The leaves are opposite, usually lanceolate. The flower is an umbel 2–5 cm wide. The flower is distinct in that the corolla has reflex lobes and is a vivid deep rose. It can be identified by its milky sap.

There are five composites commonly found in or bordering marshes of the Gulf Coast. These are *Iva frutescens, Baccharis halimifolia, Boltonia asteroides, Bidens, Borrichia frutescens.*

Iva frutescens (Figure 21) is called the marsh elder. It is an erect shrub (1–2 m tall). The stems are hairy and branch freely. The leaves are hairy, opposite and lanceolate. The flowers are cream colored. It grows best in brackist marshes along the drainage ditches

The groundsel tree, *Baccharis halimifolia,* (Figure 21) is a shrub with fleshy, toothed leaves. The leaves alternate on stems which range from 1–4 m tall. The leaves are elliptic to ovate with serrate apexes. The flowers are yellowish with purplish bracts.

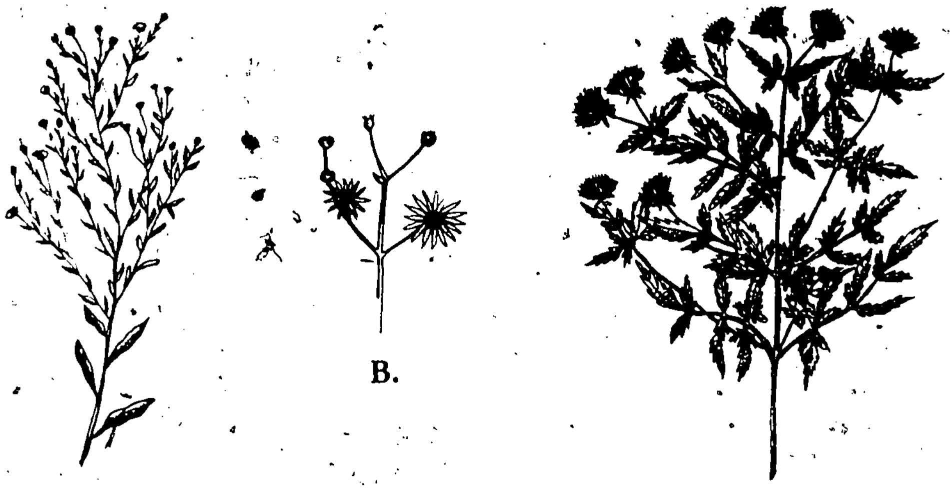
Boltonia asteroides (Figure 22) is a perennial herb with freely branching stems. The leaves are alternate and variable in size. Typically the leaves are linear. The heads have yellow disc flowers and white to lavender ray flowers.

The beggar ticks of the genus *Bidens* (Figure 22) are herbaceous plants with erect or trailing stems. The leaves are opposite. Some species are sessiled and do not possess petioles. The leaves are serrate. Some species have dissected leaves. The ray flowers are yellow or white and the disc flowers are yellow.

The sea ox-eye, *Borrichia frutescens,* (Figure 23) is a shrub which can acquire a height of 3–8 dm. It is characteristic of the maritime zone and is commonly found in the upper littoral regions of salt marshes. The fleshy, finely toothed leaves are about 7 cm in length. They grow on erect stems which become woody. Stems are erect bearing obvate to oblanceolate leaves. The leaves are opposite about 3–8 cm long and 0.8–3 cm wide. The flowers are yellow.

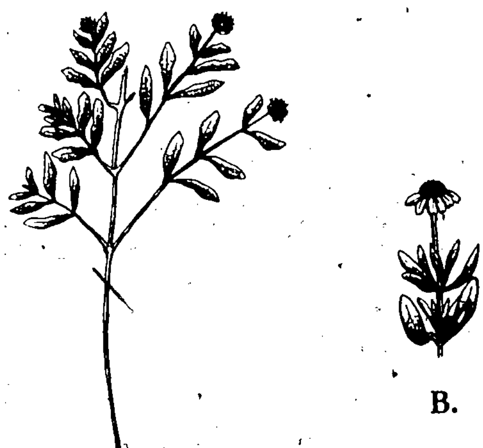
A. B.

Figure 21. A, *Iva frutescens.* B, *Baccharis halimifolia.*



A. B. C.

Figure 22. A, *Boltonia asteroides*. B, Flower of *B. asteroides*. C, *Bidens*.



A. B.

Figure 23. A, *Borrichia frutescens*. B, Enlarged inflorescence of *B. frutescens*.

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