DOCUMENT RESUME

ED 225 841 SE 040 200

AUTHOR Pouler, Chris
TITLE Tides and Marshes.
INSTITUTION Maryland Univ., College Park. Sea Grant Program.
SPONS AGENCY National Oceanic and Atmospheric Administration (DOC), Rockville, Md. National Sea Grant Program.
REPORT NO UM-SG-ES-79-01
PUB DATE 79
GRANT NA81AA-D-00040
NOTE 48p.
AVAILABLE FROM University of Maryland Sea Grant Program, H.J. Patterson Hall, College Park, MD 20742 ($2.00).
PUB TYPE Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Biological Sciences; *Ecology; Elementary School Science; Elementary Secondary Education; Environmental Education; *Oceanography; *Science Activities; Science Education; *Secondary School Science; Wildlife
IDENTIFIERS Estuaries; *Marine Education; Marshes; *Tides

ABSTRACT

The Maryland Marine Science Education Project has produced a series of mini-units in marine science education for the junior high/middle school classroom. This unit focuses on tides and marshes. Although the unit specifically treats the Chesapeake Bay, it may be adapted for use with similar estuarine systems. In addition, the unit may be incorporated into existing life science courses using the Chesapeake Bay as a concrete example of working biological principles. The unit consists of the following components: (1) teacher's narrative, including background reading for the teacher on tides and marshes and comments on student attitudes (2) student activities, a section of 10 activities/games; and (3) a final section of resource materials. These include a student/teacher bibliography, list of various junior high/middle school science texts where the mini-unit may be incorporated, and list of films to supplement student activities. (Author/JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED222841

Tides and Marshes

U S DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it
Minor changes have been made to improve reproduction quality
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy

University of Maryland Sea Grant Program
Marine Science Education Project
Publication Number
UM-SG-ES-79-01

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Jack Greer

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

SE040200

Tides and Marshes

The Marine Science Education Project is grateful to all individuals who assisted in the development of the materials included in this publication. Special appreciation is accorded the following:

Selection and development of materials for
Tides and Marshes

Chris Pouler
Science Teacher
Eleanor Roosevelt High School
Greenbelt, Maryland

Technical Assistance

Nancy E. Thompson
Science Teacher
Thomas Johnson Junior High School
Lanham, Maryland

Barbara B. Dunne
Science Teacher
G. Gardner Shugart Junior High School
Hillcrest Heights, Maryland

Technical Assistance

J. Dewey Brown
Science Teacher
Wheaton High School
Wheaton, Maryland

Project Coordinators

Jack Wheatley
Associate Professor
Science Teaching Center
University of Maryland
College Park, Maryland

Emmett Wright
Assistant Professor
Science Teaching Center
University of Maryland
College Park, Maryland

Sea Grant Program
University of Maryland

Rita Colwell
Director

Jack Greer
Project Editor

Michael W. Fincham
Communications Coordinator

Halcyon Ahearn
Project Assistant

The reprint of this publication is made possible by grant #NA81AA-D-00040, projects #M-3 and #M-4, awarded by the National Oceanic and Atmospheric Administration to the University of Maryland Sea Grant Program.

The University of Maryland is an equal opportunity institution with respect to both education and employment. The University's policies, programs and activities are in conformance with pertinent federal and state laws and regulations on nondiscrimination regarding race, color, religion, age, national origin, sex and handicap. The University complies with Title VI of the Civil Rights Act of 1964, as amended, Title IX of the 1972 Education Amendments and Section 504 of the Rehabilitation Act of 1973.

Thanks to the Johns Hopkins University Press for granting permission to use maps and drawings from The Chesapeake Bay in Maryland, edited and illustrated by Alice Jane Lippson for the Natural Resources Institute of the University of Maryland. Except for the express purposes determined for this educational unit, no part of these maps or drawings may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, xerography, or any information storage and retrieval system, without permission in writing from the publisher.

INTRODUCTION

Estuaries form a fragile boundary between marine and freshwater habitats. Their value as shipping lanes, commercial fisheries, recreational areas, and breeding grounds for thousands of species of aquatic animals and plants remains incalculable. As with most estuaries, the Chesapeake Bay is suffering from overuse, its natural processes potentially changed by human manipulation. To help ensure wise handling of this valuable resource in the future, the Maryland public school system is educating the state's school population about the complex interrelationships between the Bay as an ecosystem and the Bay as a commercial, recreational and industrial commodity. In producing these curriculum materials, the goals of the Maryland Marine Science Project are to assist in this education, provide insights into those interrelationships, and encourage for the future a more informed and conscientious management of the world's most productive estuary, the Chesapeake.

The Maryland Marine Science Education Project is sponsored by the Science Teaching Center, the College of Education, and the Sea Grant Program of the University of Maryland. This cooperative effort of scientists, educators, and classroom teachers has produced a series of mini-units in marine science education for the junior high/middle school classroom. Although the curricular materials specifically treat the Chesapeake Bay, they may be adapted for use with similar estuarine systems. Teachers can also incorporate these units into their existing life science courses by using the Chesapeake Bay as a concrete example of working biological principles.

Each marine science mini-unit consists of the following components:

Teacher's Narrative, a brief content reading for the teacher on the subject of the mini-unit;

Student Activities, a section containing student activities and games related to the content of the mini-unit;

Resource Material, a bibliography for teachers and students, a list of resource people, additional suggestions for audio-visual aids and field-trip sites, and a list of various junior high/middle school science texts where the mini-unit may be incorporated.

The Teacher's Narrative provides content material for preparing the mini-unit, and the sections on Student Activities and Resource Materials include supplementary information for developing an interesting educational unit about the Chesapeake Bay.

Teacher's Narrative

ERIC

The Chesapeake Tidal-Marsh Ecosystem

Preface

The marshes along the Chesapeake Bay provide a place where land and estuary unite plants and animals in a highly productive ecosystem. In a daily drama, the slow ebb and flow of the tide makes special demands on the marsh landscape and its inhabitants. The purpose of the activities that follow is to provide students with an understanding of the tides and their effects on such salt marshes. The activities, which follow a general discussion, can be completed either by individual students or by a small group of students. Although instructions for students are given prior to each activity, the format is flexible so that teachers can supplement the information and give instructions that will provide the best chance for learning. Further, all activities do not need to be completed. Included as supplemental information in the workbook are (1) a selected bibliography, (2) a listing of where the activity might complement some of the existing life-sciences texts and curricula, and (3) a teacher's guide to the activities.

What Are Tides?

From antiquity, tides have captured the imagination of thinkers and the creativity of authors. Attempts by ancient scholars such as Aristotle (350 B.C.), Pytheas (325 B.C.), and Strabo (54 B.C.) to explain the existence of tides linked the tidal cycles to the phases of the moon. But it was not until the universal law of gravitational attraction was proposed by Sir Isaac Newton (1642-1727) that we had a mathematical model for some of the forces which cause tides. That model has undergone many changes over the years, and there are still many things we don't fully understand about tides.

A tide is the change in the water level of the earth's seas, caused by a complex relation between the gravitational pulls of the moon, the sun, and the earth itself, along with other forces related to the spinning of the earth and moon together and to the properties of the oceans themselves. The subject of tides is a very complicated one much pondered by physical oceanographers, but this booklet attempts to give a simple introduction to the subject, concentrating on the effects of the sun and moon on tides.

Tides usually fall within a certain range, called the tidal range, between the mean high water mark and the mean low water mark. Of course special circumstances can carry tides far above or below these average levels. The tidal range varies dramatically with different kinds of coastline in different parts of the world. These variations depend largely on the shape of a given tidal basin, especially the relation between the depth and breadth of that basin, but there are other factors as well. Differences can prove quite dramatic. Some areas see tides of only a few inches, while the rugged Bay of Fundy experiences tides of some 12 meters (40 feet).

Although the forces which act on tides are very complex, the two main influences that interest us here are gravity and centrifugal force. One way to explain centrifugal force is to fill a bucket with water and swing it around, showing how the water remains in the pail. Gravity, though a difficult concept, is easy enough to show by dropping a pencil. As Newton's Law points out, "gravitational attraction exists between any two objects." To understand how these two forces interact to create tides, refer to Figure 1.

The moon actually revolves around a barycenter located about 4,670 Km (about 2,900 miles) from the center of the earth. The barycenter can be explained as a kind of balancing point between the earth and the moon, the place where you would put a stick to balance two balls if they were connected by a rod, for example. This whole earth-moon system revolves around the sun while turning on the axis of the barycenter or balance point. Because it lies much farther away, the sun has less influence than the moon on tides (about 46% of the moon's effect), but its presence is very important. Figure 2 shows an oversimplified close-up of the moon's effect on tides; Figure 3 shows how the sun and moon cooperate to either augment or diminish tides.

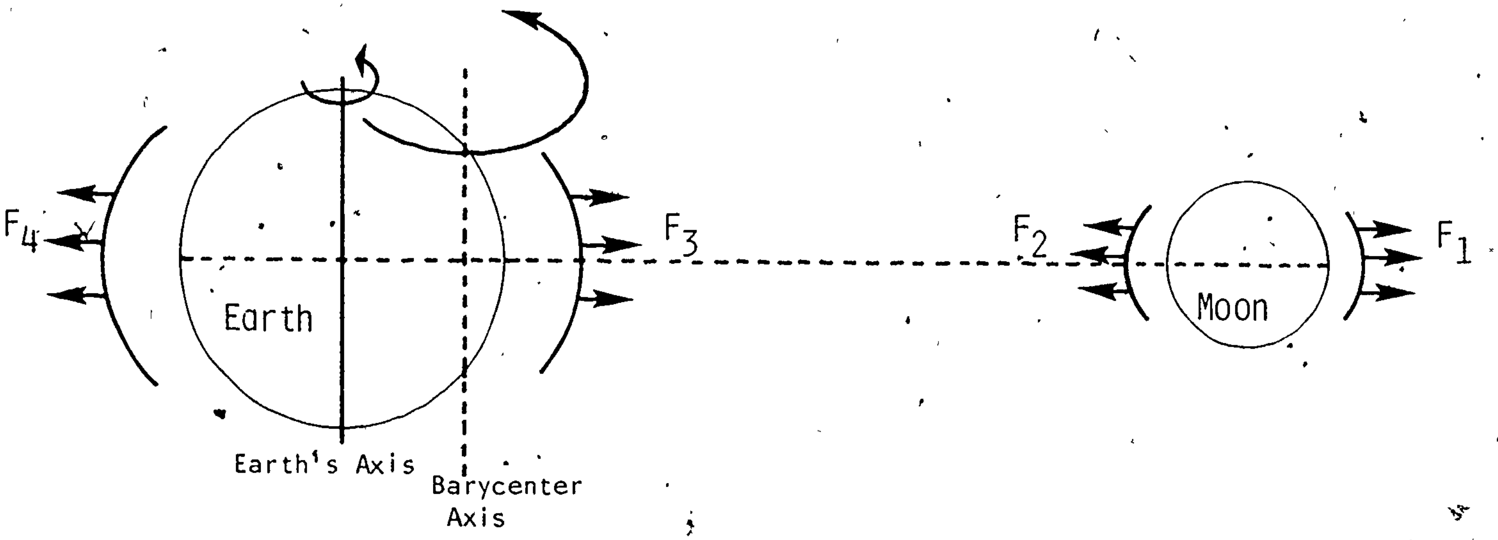
The time frame for tides, on one level, is very simple. The moon takes a little less than 30 days to circle the earth, and in that time (the basis for our calendar month) the moon grows nearer and farther from the sun. Though the actual distance from the sun may not seem to change very much, the relative position of the moon to the earth and sun makes a measurable difference for tides. When the moon is lined up with the pull of the sun, tides grow larger and are called spring tides. When the moon is at right angles to the pull of the sun on the earth, tides are generally diminished and are labeled neap tides.

Though the time between tides varies because of such factors as the relative movements of the earth and the moon, the common time given for average tidal period is 12 hours and 25 minutes. A tidal day is therefore 24 hours and 50 minutes, allowing for two lows and two highs where there are semidiurnal tides. The Chesapeake Bay experiences this kind of tidal pattern, though in some places on the globe tides may come only once a day, as happens along the Gulf of Mexico.

The reason the tidal day is 50 minutes longer than the 24-hour earth day is fairly simple. While the earth is spinning about its axis, turning day to night and back again, the moon is also moving around the earth. By the time the earth has completed one 24-hour rotation, the moon has ambled along about 12.2 degrees of the journey around its parent planet. To catch up to where the moon is, the earth must turn that additional 12.2 degrees, which takes about 50 minutes. Since the tidal day depends on the earth's relation to the moon, the tidal day ends up being 24 hours and 50 minutes.

There is also a certain amount of friction between the earth and sea water, which has some effect on the movement of tides, causing them to lag slightly behind the line of centers between the earth and the moon. This friction is actually slowly decreasing the earth's rotation on its polar axis.

Gravitational and Centrifugal Forces



The effects of gravity and centrifugal force on tides is actually quite complex and involves the pull of the sun on the earth, the pull of the moon on the earth, the pull of the sun on the earth-moon combination, and so forth. The above diagram gives a simplified idea of the relationships, where

F_1 = Centrifugal force acting outward on the moon due to the moon's rotation about the barycenter

F_2 = Inward-acting gravitational attraction pulling the moon's center toward the earth's center

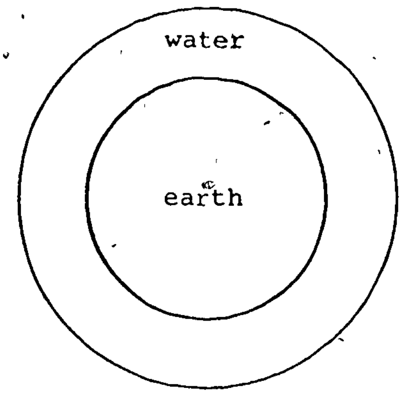
F_3 = Gravitational attraction pulling the earth's center toward the moon's center

F_4 = Centrifugal force acting to move the earth away from the moon due to the earth's rotation about the barycenter

FIGURE 1

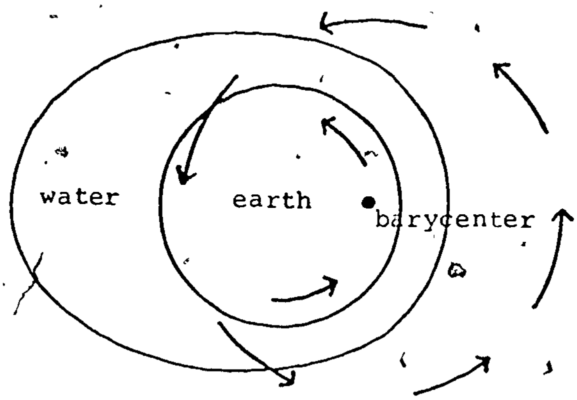
FIGURE 1 (CON'T)

Centrifugal force.



If there is no rotation, no bulge.

(And if there were no gravitational pulls from the sun or moon.)



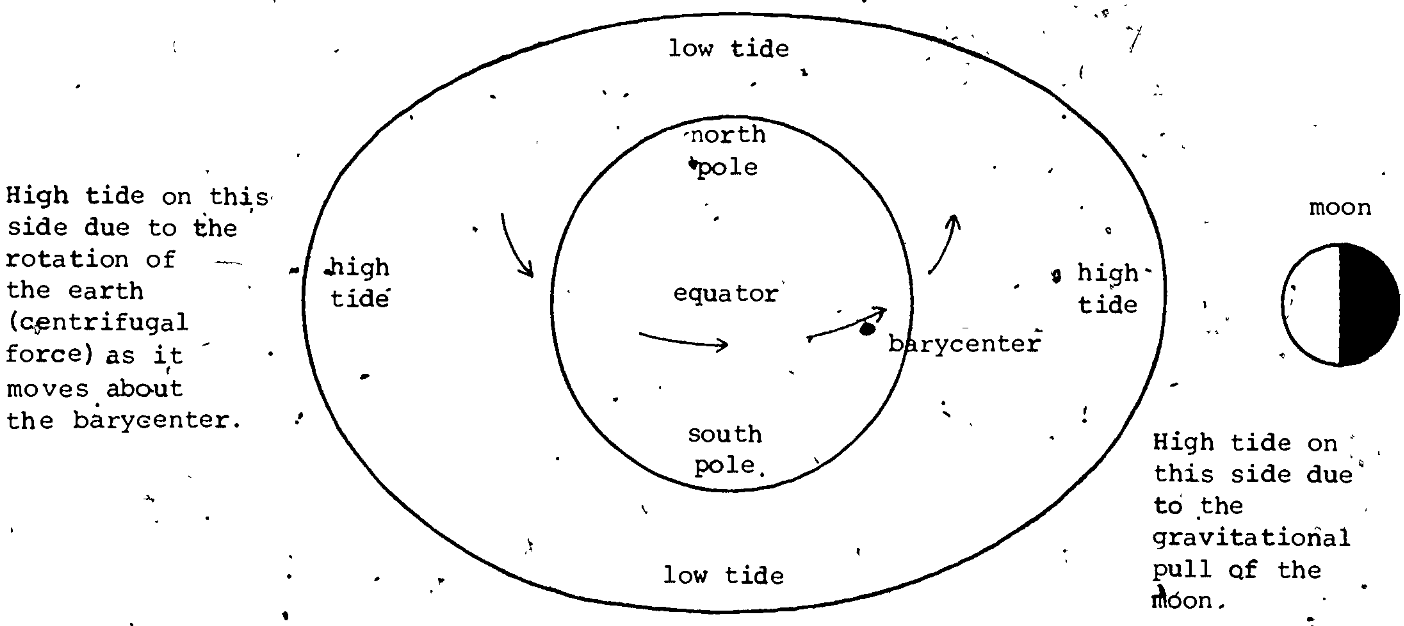
Rotation of earth* (arrows show path) causes a "tidal bulge" due to centrifugal force. (This is actually a complex interaction between gravitational pulls and centrifugal forces, very oversimplified here.)

(Moon)

* around the barycenter

FIGURE 2

The forces causing tides.



The forces causing tides are actually very complex and involve the gravitational influences of the sun, the moon, and the earth itself, as well as centrifugal forces generated by the earth-moon rotation around the barycenter. This diagram is a vast oversimplification.

(Note: Depending on the particular interests and abilities of the class involved, the teacher may want to relate these concepts to Einstein's theories of curved space.)

FIGURE 3

The lunar cycle.

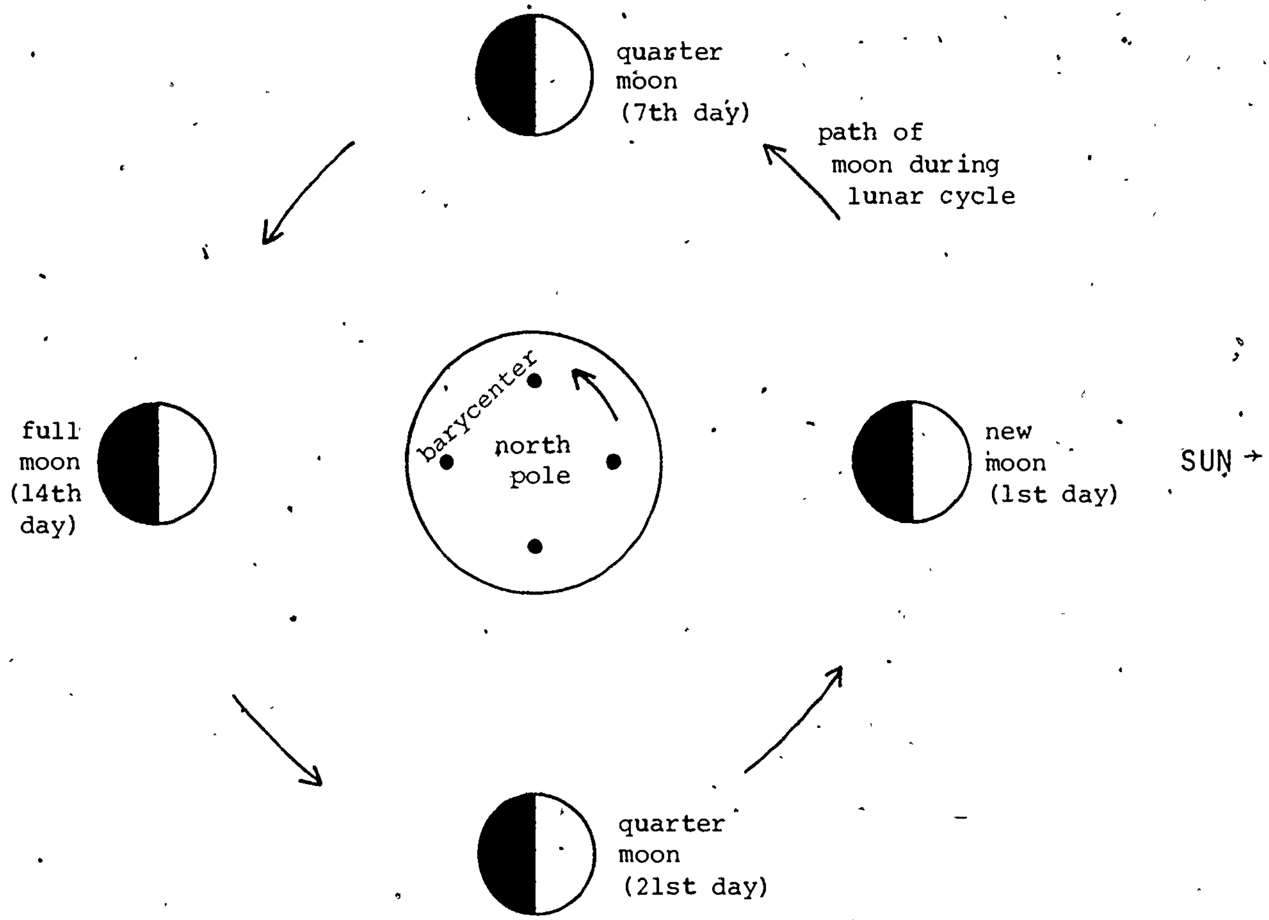
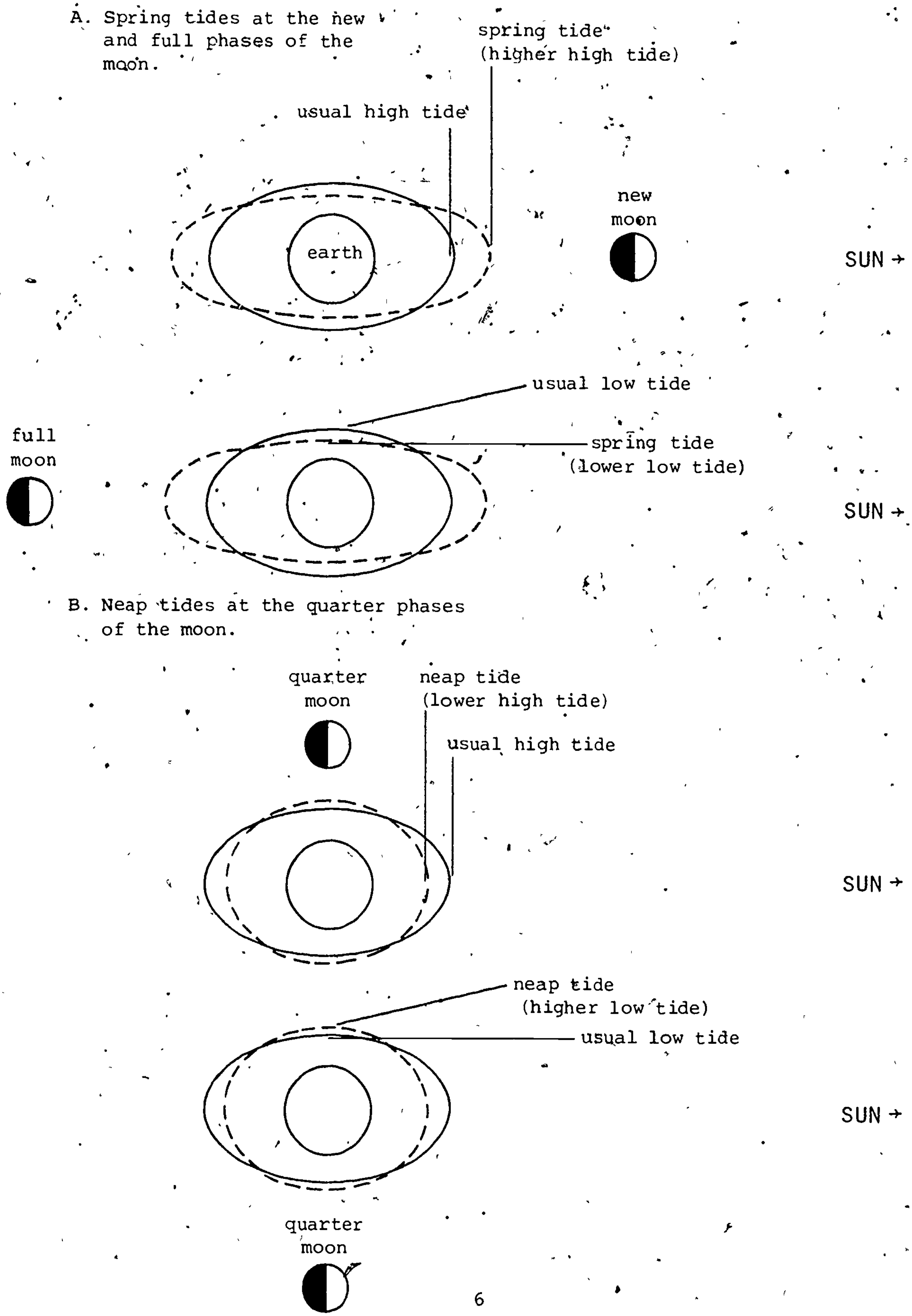


FIGURE 4

Spring and neap tides.



Tides and Marshes

Tides ebb and flow daily along the coastlines of the world. Perhaps the most pronounced effect occurs where large bodies of water exist. In Maryland, tides of the Chesapeake Bay have definitely influenced the flora and fauna of specific regions that have developed into marshes. A marsh is a productive ecosystem exhibiting diverse plant and animal populations. Formed in a quiet area, a marsh develops as a result of sediment which is trapped on its way to the Bay. Rivers leading to the Bay carry the sediment in their flow along the earth. For a marsh to form, a foundation must be built that is conducive to vegetative growth. Naturally, the first plant inhabitants must adapt to an aquatic environment that includes:

1. low light intensities due to a cover of water,
2. lack of free oxygen and carbon dioxide,
3. mechanical disturbances of tidal currents, and
4. changes in substratum.

Eelgrass (*Zostera*) is a perfect example of a plant well adapted to the marine environment. Eelgrass may be among plants which begin a marsh.

As eelgrass proliferates, the foundation of the marsh builds, and an above-water-level marsh evolves. Since this region is inundated at high tide, resulting vegetation must be able to tolerate flooding. Specific adaptations include tolerance to the following:

1. mechanical disturbance due to tides,
2. alternating high and low light intensities,
3. fluctuations in temperature,
4. alterations in free oxygen and carbon dioxide levels, and
5. changes in salinity.

Salt water cord grass (*Spartina alterniflora*) is the plant that clearly demarcates the low marsh zones along the Chesapeake Bay.

The marsh continues to develop into high and higher marsh zones. In these zones, submergence by water is not a problem except in areas close to the low marsh zones which are flooded by the spring tides, although there are a few environmental stress factors in the high marsh zone, such as the high salinity of the soil. A relative of cord grass, marsh hay (*Spartina patens*) has adapted and proliferates, as does black rush (*Juncus roemerianus*). In the higher high marsh, the environmental stress is less, and familiar plants, like blackberry and poison ivy, may be present. Figure 5 illustrates the marsh zones and the plants that have adapted to each zone.

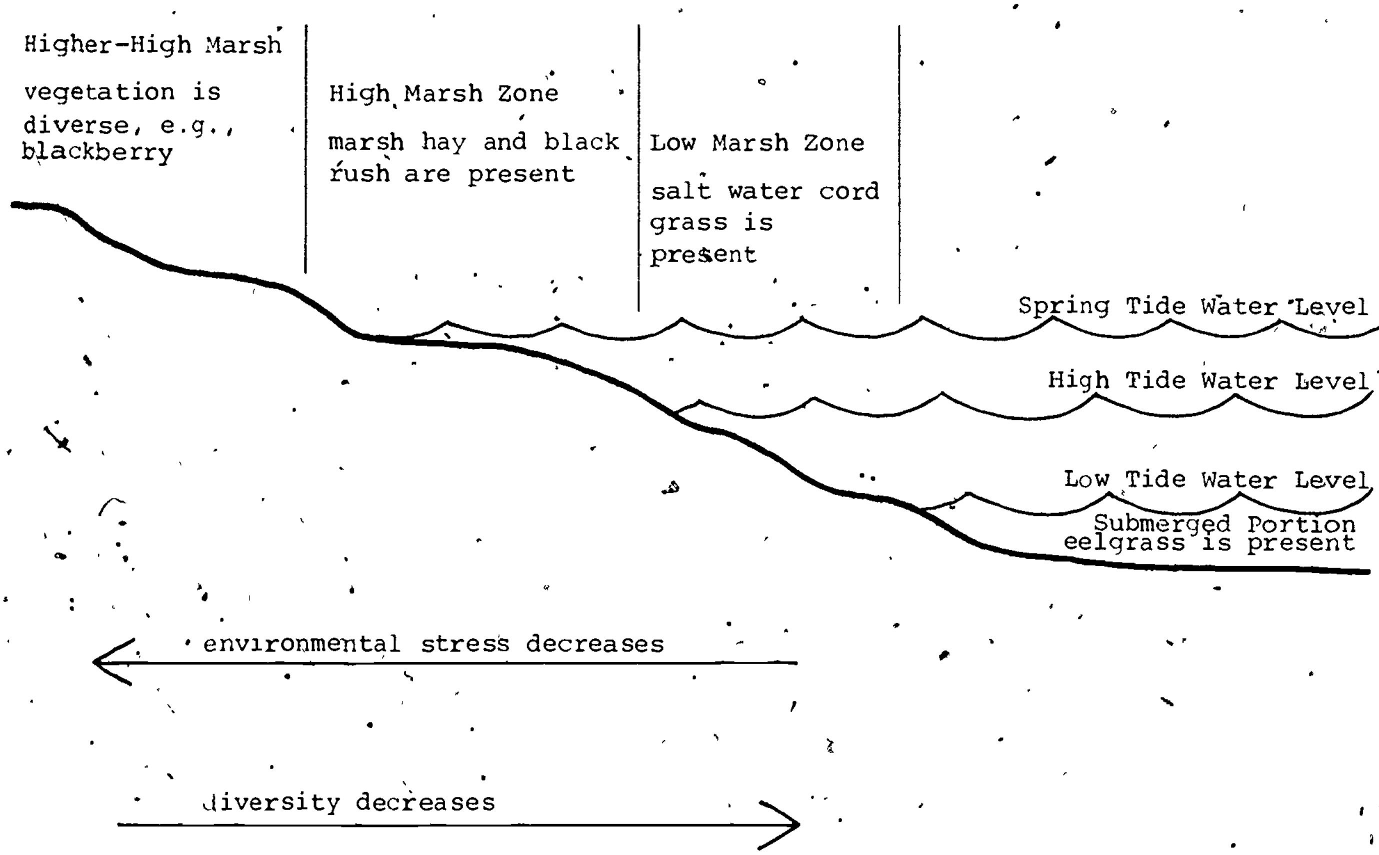
Since food abounds, many animals find the marsh a suitable habitat. From insects to crabs to racoons, the diversified animal population includes most phyla. The tide, however, necessitates modifications in living patterns. Insects must flee from the cord grass to plants of the high marsh as the tide enters. Racoons and muskrats also move to higher ground, though raccoons may take advantage of the high tide by building a nest that floats. Any fish stranded by the receding waters become the racoon's meal.

The high tide presents a different problem for endemic or confined aquatic species. With the high tide, large fish and other predators enter the marsh in search of small fish and crabs. Two varieties of crab have developed interesting escape tactics. One species of fiddler crab (*Uca pugilator*) arranges its burrow so the tide water collapses the entrance and, in the process, traps air in the burrow. The crab can then live in a cavern of oxygen until the tide ebbs. The squarebacked crab (*Sesarma cinereum*) climbs to the heights of the cord grass in order to avoid its predators.

Marshes, because they display this diversity of plants and animals, are interesting ecosystems. The tides have caused endless adaptations, and the result is a fascinating study in biology.

FIGURE 5

How tides influence marsh vegetation:



Guide to Student Activities

General Comments

The student activity section is composed of two parts--tides and the marsh. The section on tides is more extensive due to the complicated nature of the material. Ideas dealing with the revolution of the moon around the earth can be clarified by allowing students to use a globe. All the activities, of course, do not have to be completed. The activities may be conducted as a class exercise or an independent study experience. The text portion can be read by students, or you may prefer to explain the material and then give specific assignments. The key to successful understanding of the topics is flexibility to meet your needs. Review questions are located after an idea or concept has been introduced. Depending on your classes, you may prefer either a structured or a casual approach. Specific comments about each activity follow.

Activity 1

The purpose of this activity is for the student to:

1. learn to read a tide table,
2. record the times of the high and low tides for fourteen days, and
3. make some observations about tides.

A tide chart has been completed and appears on the following page. As you can see, the results are conducive to a discussion of tidal frequencies. Perhaps the major question will be: "Why is the time between tides not the same each day?"

What causes tides? You may wish to illustrate centrifugal force using a bucket that is half filled with water. (You may want to practice before demonstrating!) If students try the swinging activity, make sure they hold on tightly, since a flying bucket can be dangerous. This section contains several illustrations which might serve as useful transparencies.

Activity 2

This activity is intended to show students how one tide varies over a month. Students need to be aware of time as a twenty-four-hour process. Also, make sure they realize that the tide that begins in the morning on day one will eventually become the afternoon tide and then become again the morning tide.

Perhaps it might help to introduce students to the twenty-four-hour clock by asking them to plot their activities over a complete day. If students converge their lines to the center of the clock, the times will be easy to record. A sample clock appears following the tide chart.

TIDE CHART

Day	Date	High Tide	Low Tide	High Tide	Low Tide
Monday	September 11	1:29 am	8:09 am	1:15 pm	7:21 pm
Tuesday	September 12	2:32 am	9:15 am	2:30 pm	8:29 pm
Wednesday	September 13	3:31 am	10:11 am	3:39 pm	9:39 pm
Thursday	September 14	4:28 am	10:59 am	4:42 pm	10:44 pm
Friday	September 15	5:20 am	11:45 am	5:40 pm	11:43 pm
Saturday	September 16	6:06 am	12:26 pm	6:35 pm	
Sunday	September 17	6:52 am	12:40 pm	7:24 pm	1:06 pm
Monday	September 18	7:33 am	1:33 am	8:13 pm	1:47 pm
Tuesday	September 19	8:15 am	2:25 am	9:00 pm	2:27 pm
Wednesday	September 20	8:57 am	3:19 am	9:51 pm	3:06 pm
Thursday	September 21	9:37 am	4:04 am	10:43 pm	3:49 pm
Friday	September 22	10:22 am	5:06 am	11: 37 pm	4:33 pm
Saturday	September 23	11:13 am	6:05 am		5:23 pm
Sunday	September 24	12:31 am	7:10 am	12:11 pm	6:21 pm
Monday	September 25	1:30 am	8:12 am	1:16 pm	7:21 pm

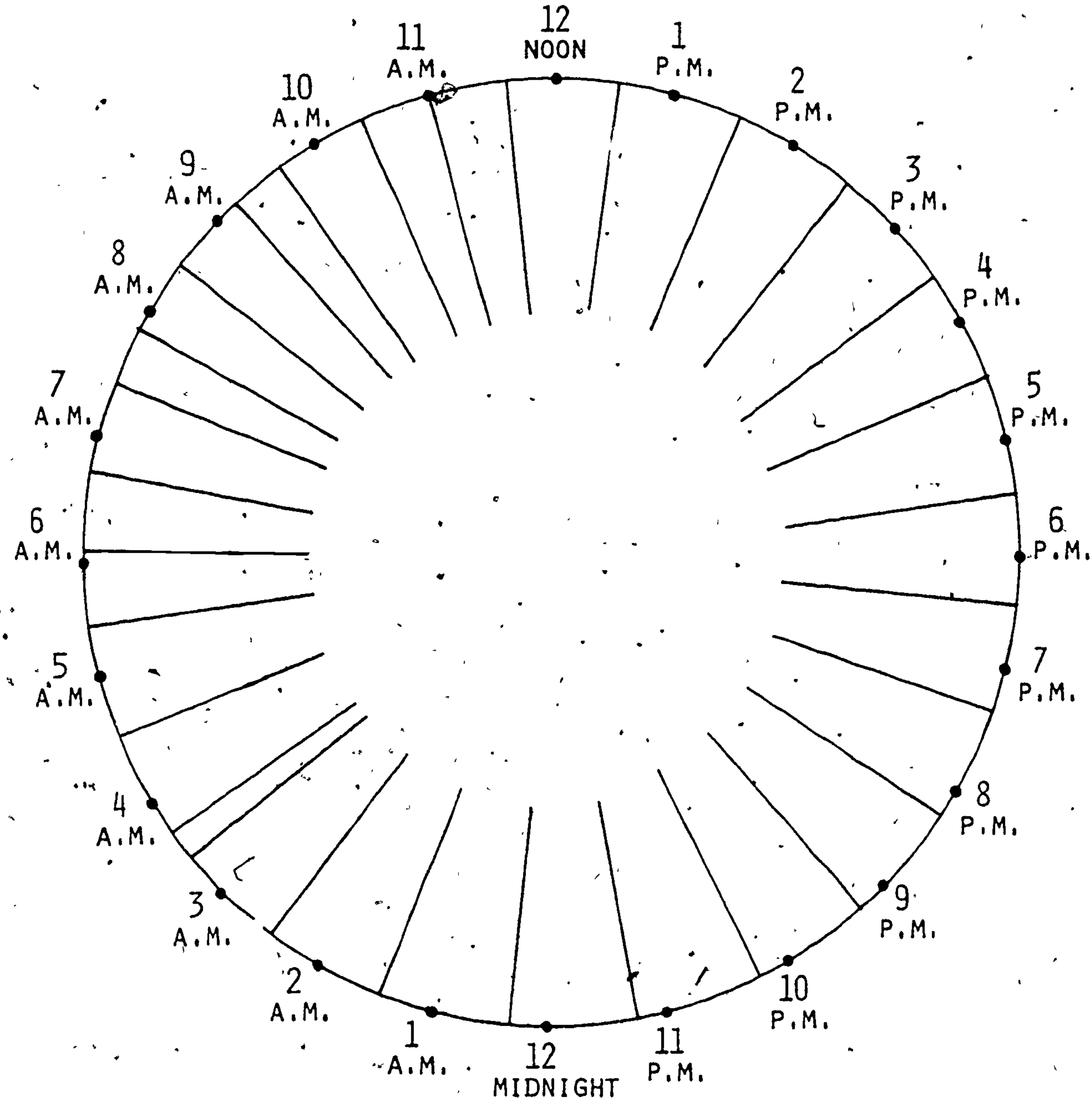
Review Questions

1. What is the relationship between the two high tides?
   (They are about 12 hours apart.)

2. What is the relationship between the two low tides?
   (They are about 12 hours apart.)

3. On the average, what is the time between the high tides and low tides?
   (The time is about 6 hours.)

TIDE CLOCK


12
NOON
1
P.M.
2
P.M.
3
P.M.
4
P.M.
5
P.M.
6
P.M.
7
P.M.
8
P.M.
9
P.M.
10
P.M.
11
P.M.
12
MIDNIGHT
1
A.M.
2
A.M.
3
A.M.
4
A.M.
5
A.M.
6
A.M.
7
A.M.
8
A.M.
9
A.M.
10
A.M.
11
A.M.

Since the review questions are also conducive to a discussion of tides, you may prefer to complete Activity 1 and Activity 2 together.

Spring and neap tides. This section may be difficult for all students to understand. Guidance and explanation may be necessary.

Key words. These are relevant words from the text concerning tides. They may be useful as a vocabulary exercise.

Activity 3

A road map that shows the Chesapeake Bay region (Delaware, Maryland, Virginia) is ideal for this activity. Students can supply the maps. This activity is designed to help students understand the continuous nature of tides. The four locations were selected because they are easy to locate and tide computation can be exact. Further instructions may be necessary for students to understand the time computations. The questions may provide the basis for further study. A completed chart appears below.

Location	time/day	time/day	time/day
Havre de Grace	5:18 am Mon	6:24 am Tues	7:20 am Wed
Baltimore	1:53 am Mon	2:59 am Tues	3:55 am Wed
St. Michaels	11:38 pm Sun	12:44 am Tues	1:40 am Wed
Taylors Island	10:33 pm Sun	11:39 pm Sun	12:35 am Wed

Computations*

	Havre de Grace	St. Michaels	Taylors Island
May 1	1:53 am	1:53 am	1:53 am
	+3:25	-2:15	-3:20
	4:78	11:38 pm	10:33 pm
	or 5:18 am		
May 2	2:59 am	2:59 am	2:59 am
	+3:25	-2:15	-3:20
	5:84	0:44	11:39 pm
	or 6:24 am	or 12:44 am	
May 3	3:55 am	3:55 am	3:55 am
	+3:25	-2:15	-3:20
	6:80	1:40 am	12:35 am
	or 7:20 am		

*Tide chart based on Baltimore tides. For other locations add or subtract:
Havre de Grace - add 3 hours and 25 minutes
St. Michaels - subtract 2 hours and 15 minutes
Taylors Island - subtract 3 hours and 20 minutes

Activities 4-6

These activities are further study ideas for interested students.

Activity 7

This activity is designed for students to read and complete the questions. Again, a road map of the Chesapeake Bay region is needed. You may want to use the questions as a reading activity, or you may want to discuss the material and then give specific instructions for a map-reading and identification exercise.

Review question #5 leads to Activity 8.

Activity 8

The activity is ideal for students to generate hypotheses and to obtain data for verification. Caution must be taken to ensure against exposure of the seeds to salt water. If salt water only is used to water the plants, the experiment should show no seed germination. Also, if large stock solutions are used, they should be stirred. Note: To make the proper percentage, take the appropriate number of grams of salt and place in 100 ml of water. This experiment will take up space and may be messy. Even if the results are not significant, worthwhile discussion should occur.

Activities 9-10

These are further study ideas for interested students.

Student Activities

ERIC

TIDES: THE RHYTHM OF WATER

Instructions

The following pages explain tides with questions and activities that will help your understanding. Your teacher will tell you which of the exercises to do, though you may want to do all of them.

A Dissappearing Act

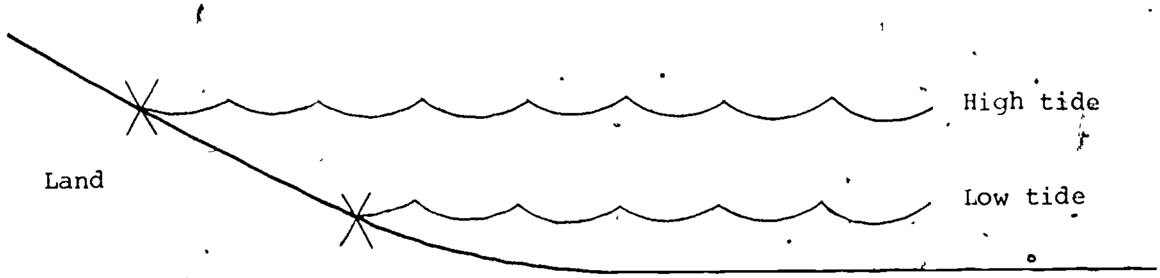
Have you ever sat along the beach or shore and watched the tide "come in" and "go out"? If so, you have seen the beach widen, only to be covered with water again in a few hours. This disappearing act is caused by a natural event called the tide.

Tides occur each day of the year at times that are as predictable as sunrise. As you proceed with these activities, you should begin to understand how and why tides occur.

What Are Tides?

Tide is a word that refers to water from a river, bay, or sea that covers a specific part of land for a few hours before it withdraws again. High tide occurs when the water covers the land, and low tide occurs when the water leaves the land.

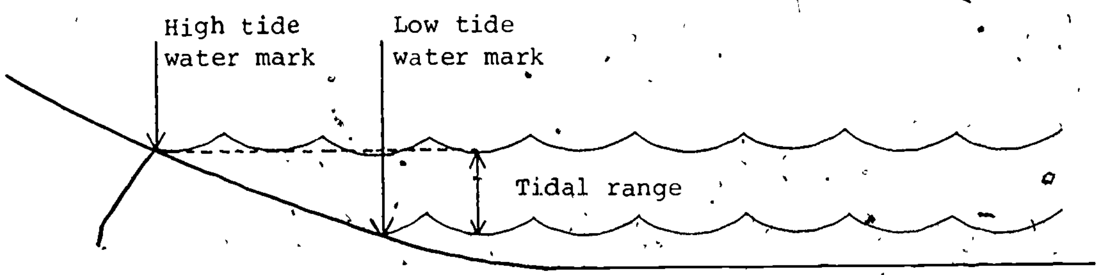
Figure 1. High and low tide water marks. Note that the land slopes into the water.



Since the water does not move from high to low tide all at once, the range of the tide is between the highest point the water reaches at high tide to the lowest point the water reaches at low tide. In other words, the range is the vertical distance between the high tide water mark and the low tide water mark. The tidal range may be only a few centimeters (or inches) in some areas. In other areas, like the Bay of Fundy in

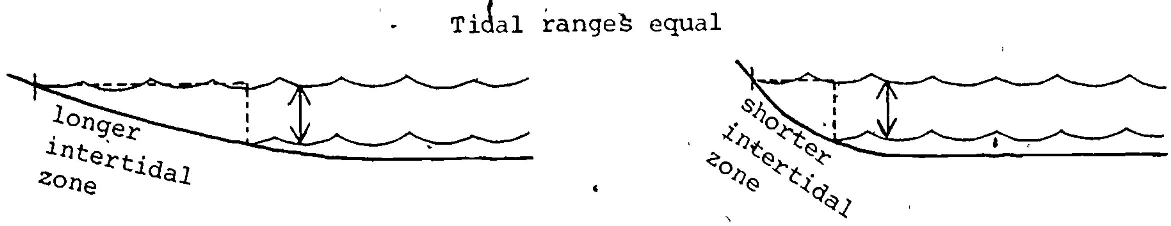
Canada, the tidal range can be as much as 12 meters (40 feet).

Figure 2. Tidal Range.



The land that is covered by the water of the tidal range is called the <u>intertidal zone</u>. When the land slopes sharply into the water, the intertidal zone is shorter than when the land slopes only slightly, even though the tidal range is the same. In some areas on earth the intertidal zone can stretch for more than 150 meters (or more than a mile).

Figure 3. Longer and shorter intertidal zones.



<u>Review Questions</u>

1. What is high tide?

2. What is low tide?

3. Why might we be interested in measuring tidal ranges and intertidal zones?

4. A seven meter pole is standing in the water. At low tide the water level is at two meters. At high tide the water level is at five meters. What is the tidal range?

Activity 1

Knowing about tides can be important. For example, people who work on the Chesapeake Bay need to know exactly when the high and low tides will occur so that they can plan to fish when the tide comes in, bringing a more plentiful catch, and to navigate with the help of the flow of the tide, not against the pull of the tide. What might happen to a boat safely docked at high tide in the Bay of Fundy? Fortunately, tides are predictable, since we can estimate when they will rise and fall. We predict the tides using a tide table.

The calendar below shows when high and low tides occurred each day in September, 1976. If you look at Monday, September 11, you will see that high tides occurred at 1:29 a.m. and 1:15 p.m. Low tides occurred at 8:09 a.m. and 7:21 p.m. On the tide chart on the next page, fill in the time of each tide for 14 days, beginning on September 11th. The times for the first day have been completed.

Instead of using the tide times on the calendar below, you might want to obtain the times of tides in your area each day for 14 days. The times of high and low tides are accurately predicted and printed in the newspaper and broadcast on television and radio each day because this information is so important to those who plan work or recreation on the water.

September CHESAPEAKE BAY TIDES

SUN	MON	TUE	WED	THU	FRI	SAT
					1 H 6:01a L 12:29a H 6:14p	2 L 12:07a H 6:33a L 1:00p H 6:54p
3 L 12:46a H 7:05a L 1:29p H 7:33p	4 L 1:28a H 7:36a L 1:59p H 8:12p	5 L 2:11a H 8:08a L 2:29p H 8:55p	6 L 2:57a H 8:44a L 3:01p H 9:40p	7 L 3:47a H 9:20a L 3:40p H 10:30p	8 L 4:43a H 10:04a L 4:27p H 11:25p	9 L 5:47a H 10:57a L 5:15p
10 H 12:24a L 6:57a H 11:59a L 6:15p	11 H 1:29a L 8:09a H 1:15p L 7:21p	12 H 2:32a L 9:15a H 2:30p L 8:29p	13 H 3:31a L 10:11a H 3:39p L 9:39p	14 H 4:28a L 10:59a H 4:42p L 10:44p	15 H 5:20a L 11:45a H 6:40p L 11:43p	16 H 6:06a L 12:26p H 6:35p
17 L 12:40a H 6:52a L 1:06p H 7:24p	18 L 1:33a H 7:38a L 1:47p H 8:13p	19 L 2:25a H 8:15a L 2:27p H 9:00p	20 L 3:19a H 6:57a L 3:06p H 9:51p	21 L 4:09a H 9:37a L 3:49p H 10:43p	22 L 5:06a H 10:22a L 4:33p H 11:37p	23 L 6:05a H 11:13a L 5:23p
24 H 12:31a L 7:10a H 12:11p L 6:21p	25 H 1:30a L 8:12a H 1:16p L 7:21p	26 H 2:25a L 9:05a H 2:26p L 8:23p	27 H 3:15a L 9:54a H 3:25p L 9:20p	28 H 4:02a L 10:32a H 4:21p L 10:15p	29 H 4:43a L 11:08a H 5:05p L 11:03p	30 H 5:22a L 11:43a H 5:48p L 11:48p

TIDE CHART

	Date	High Tide	Low Tide	High Tide	Low Tide
Monday	September 11	1:29 am	8:09 am	1:15 pm	7:21 pm
Tuesday					
Wednesday					
Thursday					
Friday					
Saturday					
Sunday					
Monday					
Tuesday					
Wednesday					
Thursday					
Friday					
Saturday					
Sunday					

Review Questions

1. What is the relationship between the two high tides?

2. What is the relationship between the two low tides?

3. On the average, what is the time between the high tides and low tides?

ERIC

What causes tides?

What would happen if you took a bucket filled with water and turned it over your head? Naturally you would get wet! But what would happen if your took a bucket of water and, grabbing the handle, swung it around and around with your arm so that the bucket rotated, passing upside-down over your shoulder? Even though the water was upside-down for a while, it would not spill. Ask your teacher to demonstrate. The water does not spill because a force you cannot see is caused by the rotating motion. This force is called centrifugal force.

Here is another example of centrifugal force that you can try. Join hands with a friend and begin to swing slowly in a circle. Hold on tightly and swing faster and faster. As you swing faster, you and your friend will begin to feel yourselves being pulled apart. It is centrifugal force, caused by your rotation, that pulls you away from each other. Centrifugal force also pulls the water toward the bottom of the bucket, holding it there even when the bucket is upside-down.

There are two properties of centrifugal force:

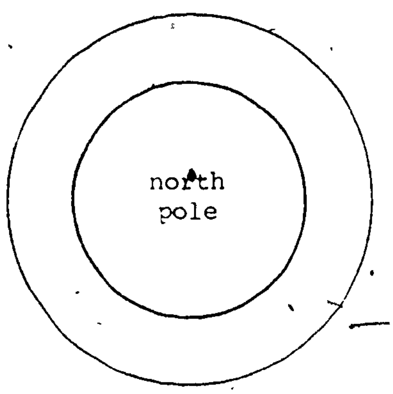
1. centrifugal force is present when an object spins or rotates, and
2. centrifugal force pulls an object away from a center of rotation.

Centrifugal force and gravity both pull on the land and the water alike, but since the water is more fluid it responds more visibly. Because of the way the moon and the earth affect each other as they spin around, centrifugal force causes the oceans to bulge slightly on the side opposite the moon. It's just as if two people were swinging each other around, and one person's coat bulged out in back.

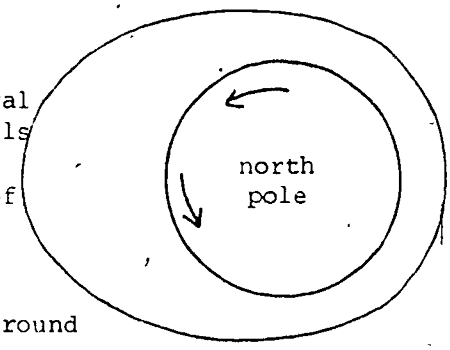
Although the effect of centrifugal force is really quite complicated on the real earth, Figure 4 shows a simple picture of what happens to the seas.

Figure 4.

If there were no rotation and no pull from the moon or sun, the seas would not bulge.



Centrifugal force pulls the seas because of the way the moon and earth revolve around each other.



The other cause of tides is the moon. If you stopped rotating the bucket as it was upside-down over your shoulder, the familiar force of gravity would be the cause of your getting wet. As you know, the moon, as well as the earth, has a gravitational force. Although the gravity of the moon is not strong enough to pull the land of the earth, the force is strong enough to pull the water on the earth's surface that is closest to it. As the moon revolves around the earth a tidal bulge occurs on the side of the earth facing the moon at that particular time.

The moon and centrifugal force are almost equally responsible for tides, though the effect of the moon is a little stronger. Figure 4 shows the tidal bulges which occur as a result of the centrifugal force of the earth's rotation and the gravitational force of the moon.

The earth experiences high tides directly beneath the moon and on the side directly opposite the moon. Low tides occur at right angles to the high tides. Figure 5 shows the position of the moon and the formation of low and high tides.

We said that the earth rotates on its axis once every 24 hours. The moon, though, revolves around the earth once every 28 days. As the moon travels slowly around the earth, the earth travels quickly by, so that in 24 hours, all of the surfaces of the earth have revolved past the influence of the moon's gravitational pull, and experienced the pull of centrifugal force on the side opposite the moon. The Chesapeake Bay, for example, experiences high tide as it passes under the moon, low tide when it has traveled one-quarter of a revolution past the moon, high tide again when it is farthest away from the moon, low tide again as it revolves back toward the moon, and high tide again as it comes back under the moon at the start of the next 24 hours. Like the Chesapeake Bay, most places on the earth experience two high tides and two low tides each day, called semidiurnal tides. (Diurnal tides--one high tide, one low tide--occur in some places on the earth where the water is so shallow and wide, or so enclosed by land, that only the double influence of centrifugal force and the gravity of the moon cause sufficient pull to create a tide.) Figure 6 illustrates semidiurnal tides.

We can see then that tides should occur every six hours. Though six hours is a good rough estimate, the time is actually a little longer than that. Remember that the moon takes 28 days to rotate around the earth. Since the moon is responsible for tides, it has been computed that high tides occur about 12 hours and 25 minutes apart. If a high tide occurred at 2:00 a.m. (in the morning), the next high tide would be at 2:25 p.m. (that afternoon).

Review Questions

1. Explain how high tides occur.

2. What is the role of centrifugal force in the forming of tides?

3. How does the moon cause tides?

4. How often does the moon rotate around the earth?

FIGURE 5

Low and high tides depend on the location of the moon also.

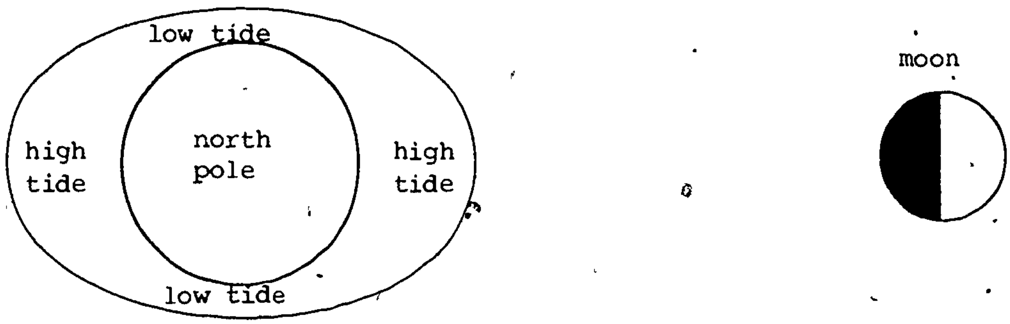
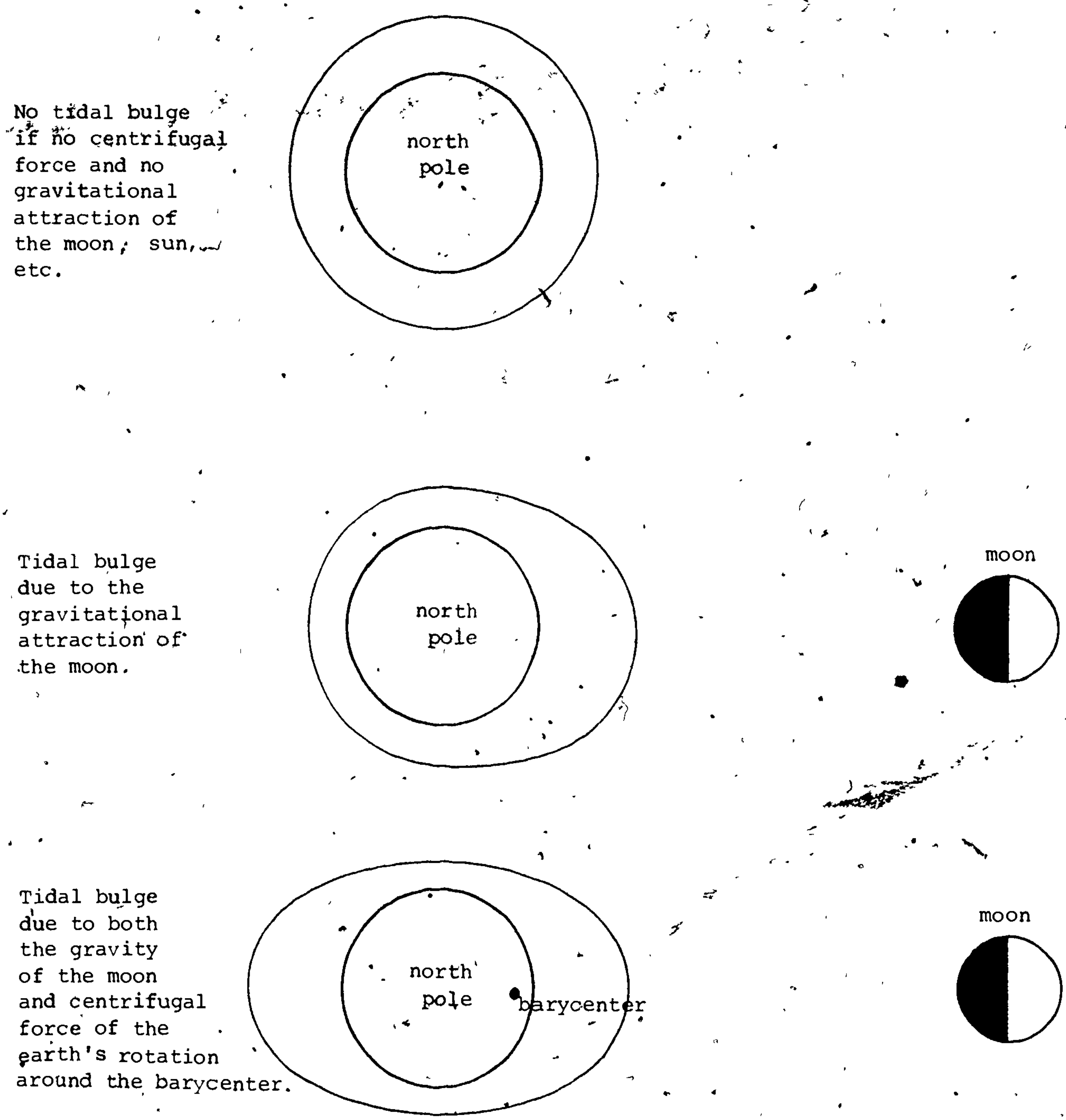


FIGURE 6

Tidal bulge due to the gravity of the moon and rotation of the earth



Activity 2

Usually there are two high tides each day. The rule of thumb is that high tides occur 12 hours and 25 minutes apart. This is because the moon passes the same spot every 24 hours and 50 minutes. If the morning high tide arrives at 8:00 a.m., it will occur at 8:50 a.m. tomorrow morning. Why? Using the tide table for June, find the morning high tide on June 1st. It should read 3:42 a.m. What time will this tide appear on June 2nd? Turn to the tide clock on the next page. The time, 3:42 a.m., of the June 1st morning tide has been recorded. For every day of June, record the time of the high tide that began on June 1st by drawing a line as shown on the clock and writing in the time of the tide and the day it occurred. (The times of high tide on June 12 and June 22 have already been entered for you.) When you have completed the tide clock, try to answer the review questions.

Review Questions

1. By how much does the time of high tide change each day?
2. Why does the time of the high tide change during the month?
3. Why is the time of the high tide about 50 minutes later each day during the month?

The moon revolves around the earth, while the earth revolves around the sun. Does this mean that the gravity of the sun also causes tides? Yes. Even though the position of the sun is constant, when the moon is lined up with the sun in certain ways, tides are affected.

Figure 7 shows the relationship between the sun, moon and earth. We can only see that part of the moon which is facing the sun. If the sun is shining on the half of the moon that we can see, we call it a full moon. If the moon is between the earth and sun, we call it a new moon, which is difficult to see. Locate the new and full moon phases in Figure 7.

A quarter moon exists when the moon is at right angles to the line of the earth and sun. Locate the two quarter phases of the moon in Figure 7. Since the moon rotates once around the earth in 28 days, a new moon occurs every 28 days.

Review Questions

1. If you see a new moon on November 8th, how many days later will you see a full moon? What will the date be?
2. At what phase is the moon directly in a line between the sun and the earth?
3. At what points during the moon's rotation cycle do you think the sun will affect the tides the most? Why?

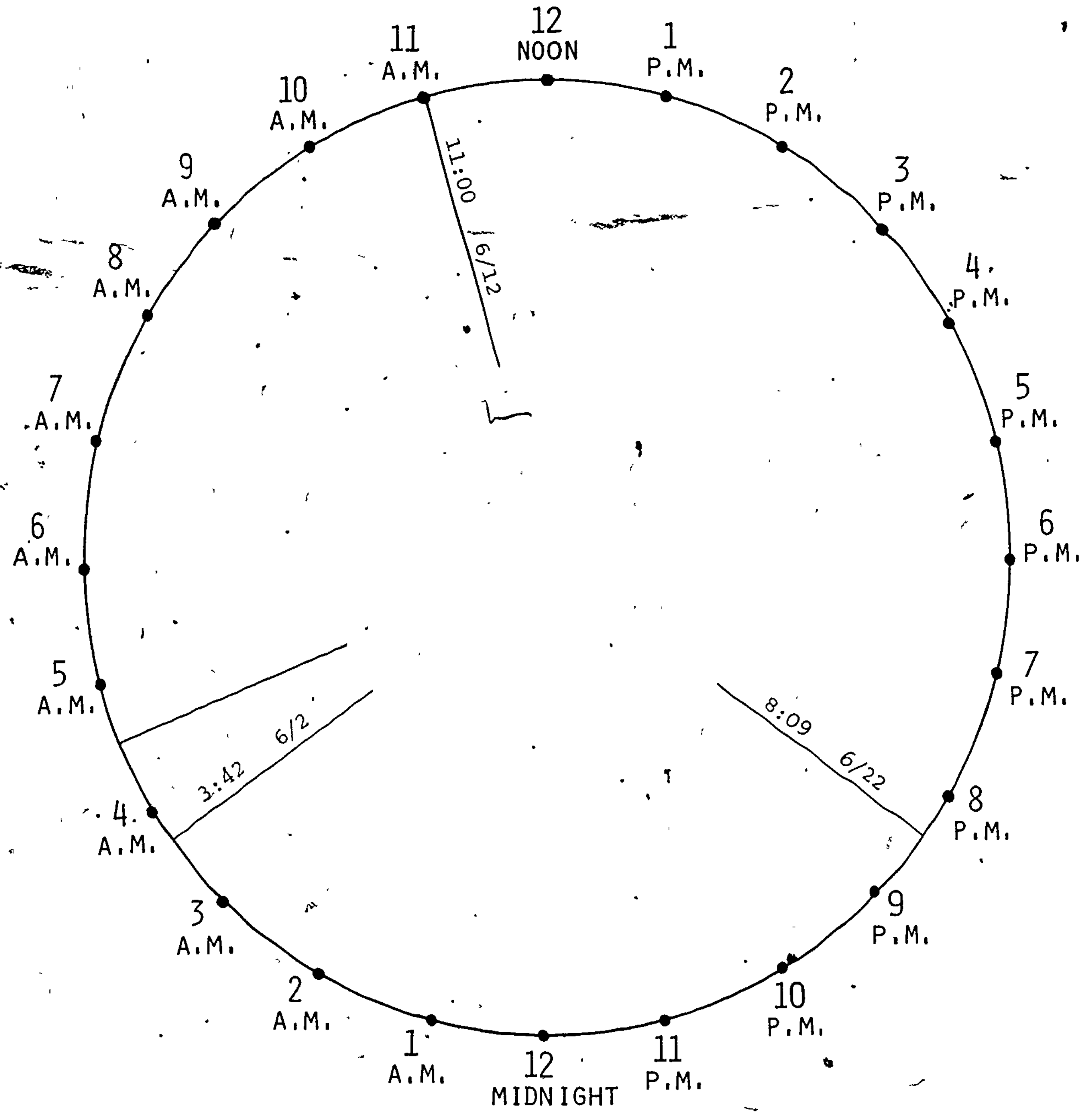
June Tide Table

June

CHESAPEAKE BAY TIDES

SUN	MON	TUE	WED	THU	FRI	SAT
				1 H 3:42a L 10:15a H 3:39p L 9:36p	2 H 4:34a L 11:14a H 4:31p L 10:18p	3 H 5:20a L 12:06p H 5:19p L 11:00p
4 H 6:01a L 12:51p H 6:01p L 11:40p	5 H 6:41a L 1:30p H 6:43p	6 L 12:57a H 7:19a L 2:02p H 7:24p	7 L 12:57a H 7:55a L 2:41p H 8:05p	8 L 1:36a H 8:29a L 3:16p H 8:46p	9 L 2:17a H 9:04a L 3:51p H 9:35p	10 L 3:03a H 9:40a L 4:27p H 10:26p
11 L 3:51a H 10:17a L 5:06p H 11:17p	12 L 4:48a H 11:00a L 5:45p	13 H 12:13a L 5:63a H 11:48a L 6:27p	14 H 1:09a L 7:02a H 12:37p L 7:12p	15 H 2:05a L 8:12a H 1:33p L 7:56p	16 H 2:59a L 9:22a H 2:31p L 8:44p	17 H 3:49a L 10:22a H 3:30p L 9:31p
18 H 4:38a L 11:19a H 4:26p L 10:21p	19 H 5:25a L 12:09a H 5:22p L 11:11p	20 H 6:12a L 1:01p H 6:17p	21 L 12:03a H 7:50a L 1:47p H 7:14p	22 L 12:56a H 8:38a L 2:36p H 8:09p	23 L 1:51a H 9:29a L 3:21p H 9:09p	24 L 2:50a H 9:29a L 4:10p H 10:09p
25 L 3:53a H 10:19a L 4:57p H 11:12p	26 L 5:02a H 11:10a L 5:46p	27 H 12:17a L 6:17a H 12:08p L 6:35p	28 H 1:22a L 7:34a H 1:04p L 7:25p	29 H 2:22a L 8:50a H 2:03p L 8:15p	30 H 3:21a L 9:59a H 2:59p L 9:01p	31

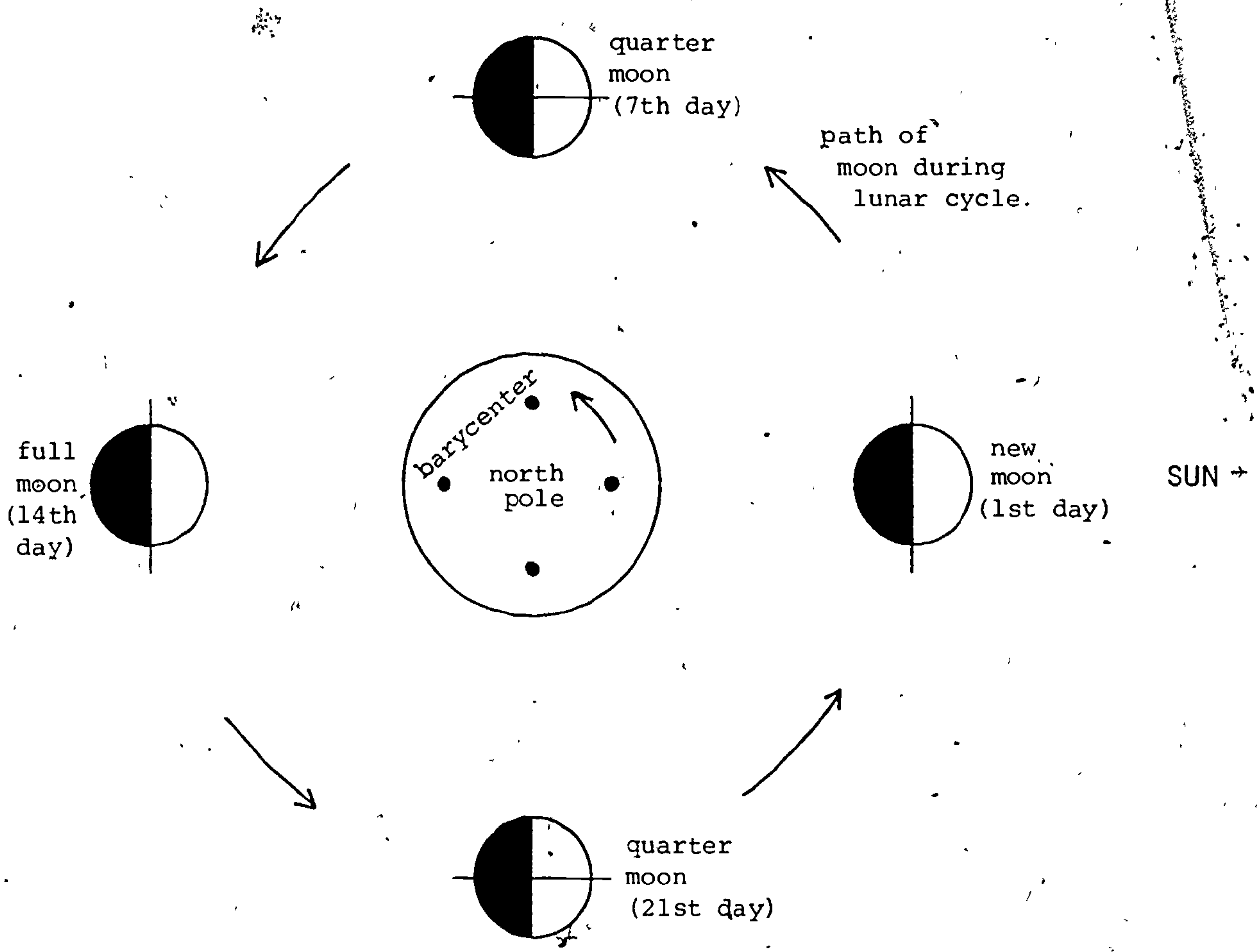
TIDE CLOCK


12
NOON
1
P.M.
2
P.M.
3
P.M.
4
P.M.
5
P.M.
6
P.M.
7
P.M.
8
P.M.
9
P.M.
10
P.M.
11
P.M.
12
MIDNIGHT
1
A.M.
2
A.M.
3
A.M.
4
A.M.
5
A.M.
6
A.M.
7
A.M.
8
A.M.
9
A.M.
10
A.M.
11
A.M.
11:00
6/12
3:42
6/2
8:09
6/22

3_

FIGURE 7

The sun, earth and moon.



The line drawn through the moon shows the part we can see. The moon is bright (visible) because the sun shines on it.

When the moon is in a direct line between the sun and earth, the result is an extremely strong high tide. These are called <u>spring tides</u>, and they occur during the <u>new</u> and <u>full</u> moon phases each month. The spring tides are stronger, which causes the tidal range to be greater. When the moon forms a right angle with the earth and sun, the result is a very weak low tide. These are called <u>neap tides</u>. Neap tides occur during the first and last quarter phases of the moon. Figure 8 shows the spring and neap tides. Study Figure 8 and see if you can explain spring and neap tides to a classmate.

<u>Review Questions</u>

1. During which phases of the moon will the high tide water mark be greatest?

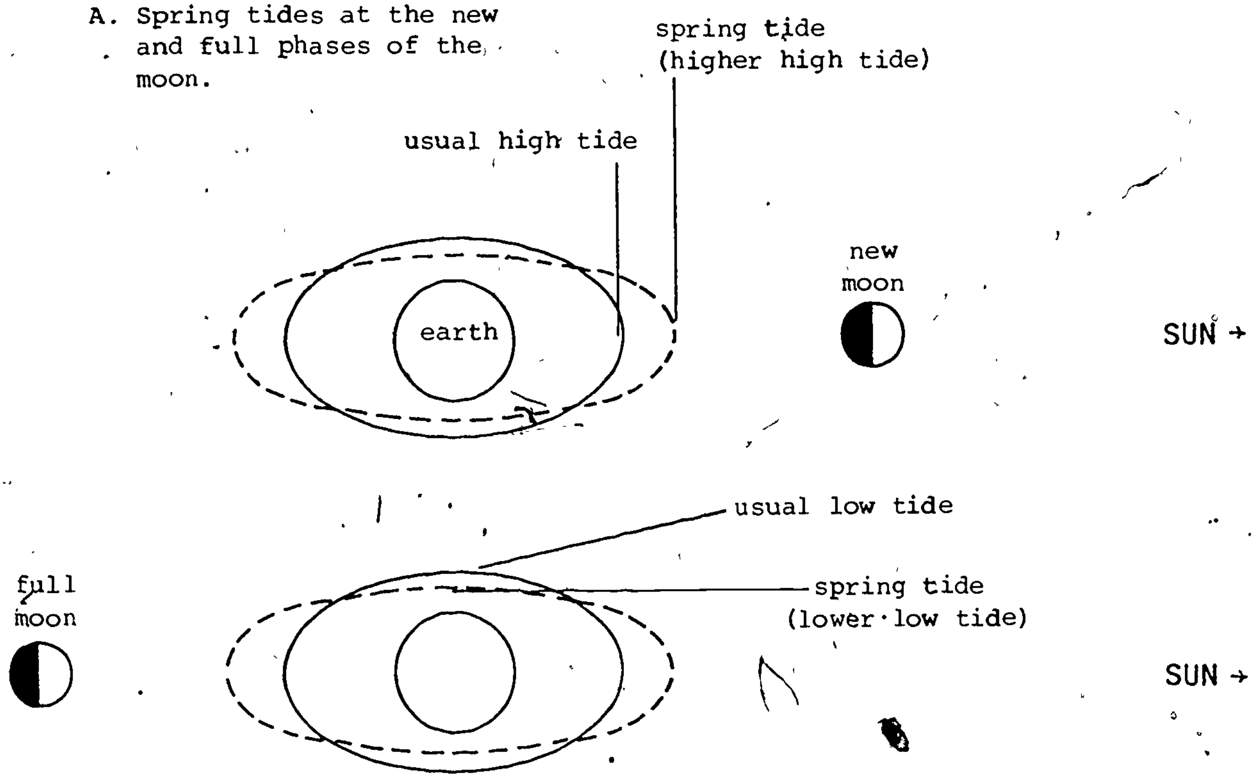
2. What causes neap tides?

3. What causes spring tides?

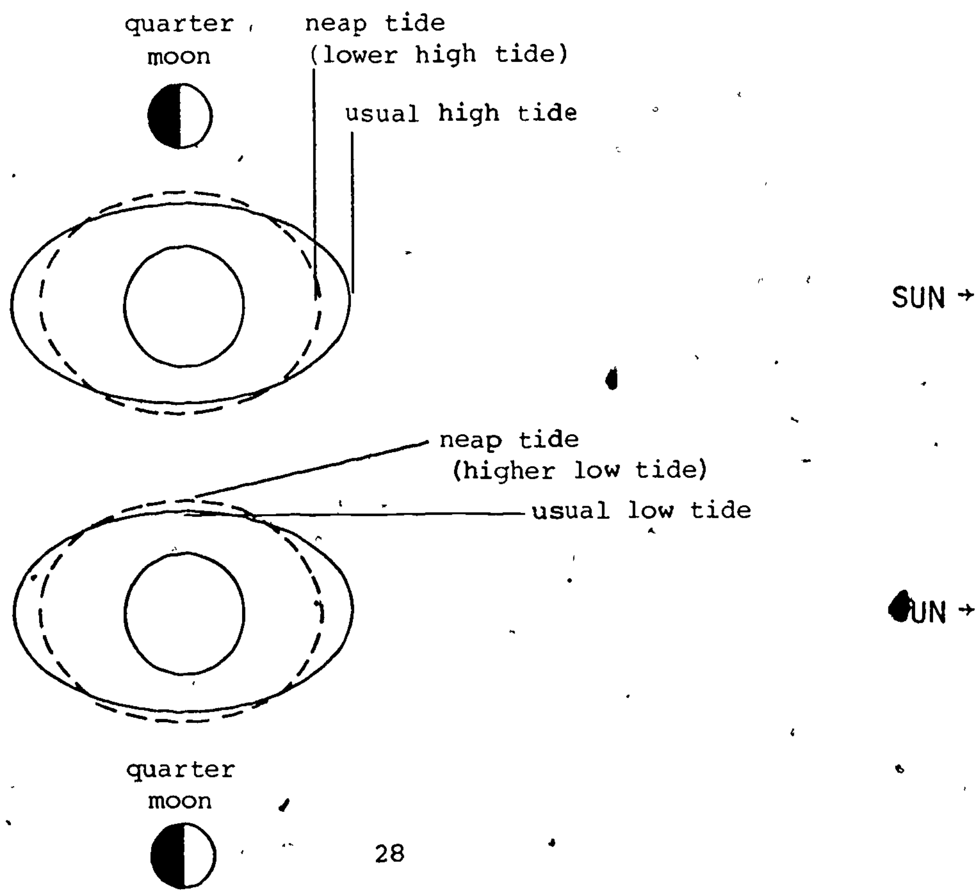
FIGURE 8

Spring and neap tides.

A. Spring tides at the new and full phases of the moon.



B. Neap tides at the quarter phases of the moon.



Activity 3

Look at a map of the Chesapeake Bay. Show where the Bay meets the Atlantic Ocean. In what direction would you expect the tide to move along the shores of the Chesapeake Bay? In this activity you will follow the tide "up" the Bay.

You will need to compute the time the morning (a.m.) high tides of May 1st, 2nd, and 3rd occur at four points along the Bay. You will probably find that the tide occuring late Sunday night at Taylors Island occurs early Monday morning in Baltimore. Since the times from the tide table on the following page refer to Baltimore, to obtain the times for the other locations you must add or subtract as follows:

(1) for Havre de Grace, add 3 hours and 25 minutes,
(2) for St. Michaels, subtract 2 hours and 15 minutes,
(3) for Taylors Island, subtract 3 hours and 20 minutes.

Using the May 1-3 times for the morning high tide, compute the times of high tide for each of these days at Havre de Grace, St. Michaels, and Taylors Island. The chart on the following page is already completed for May 1st.

Now find those four locations on your map and write the times next to each location. Then answer the review questions.

Review Questions

1. How does the tide change each day, at each location?

2. In what direction does the tide move?

3. What effect might the time of the tide have on fishing boats out on the Bay?

Tide Time Table

May

CHESAPEAKE BAY TIDES

SUN	MON	TUE	WED	THU	FRI	SAT
	1 H 1:53a L 7:58a H 2:15p L 8:37p	2 H 2:59a L 9:14a H 3:17p L 9:26p	3 H 3:55a L 10:20a H 4:13p L 10:12p	4 H 4:47a L 11:19a H 5:03p L 10:55p	5 H 5:35a L 12:10a H 5:40p L 11:35p	6 H 6:17a L 12:58p H 6:31p
7 L 12:12a H 7:00a L 1:41p H 7:12p	8 L 12:49a H 7:39a L 2:21p H 7:49p	9 L 1:29a H 8:17a L 3:03p H 8:30p	10 L 2:06a H 8:55a L 3:39p H 9:11p	11 L 2:46a H 9:34a L 4:20p H 9:53p	12 L 3:35a H 10:16a L 4:59p H 10:54p	13 L 4:27a H 10:59a L 5:45p H 11:47a
14 L 5:26a H 11:48a L 6:30p	15 H 12:48a L 6:32a H 12:41p L 7:16p	16 H 1:48a L 7:42a H 1:37p L 7:58p	17 H 2:40a L 8:48a H 2:32p L 8:46p	18 H 3:29a L 9:51a H 3:24p L 9:50p	19 H 4:15a L 10:44a H 4:13p L 10:11p	20 H 5:00a L 11:36a H 6:05p L 10:55p

Tide Chart

LOCATION	Time (Day)	Time (Day)	Time (Day)
Havre de Grace	5:18 am (Mon)		
Baltimore	1:53 am (Mon)		
St. Michaels	11:38 pm (Sun)		
Taylors Island	10:33 pm (Sun)		

Computations:

May 1 --

Havre de Grace

```
  1:53 am
 +3:25
  4:78 or 5:18 am
```

St. Michaels

```
  1:53 am
 -2:15
 11:38 pm
```

Taylors Island

```
  1:53 am
 -3:20
 10:33 pm
```

May 2 --

ERIC

Further Study about Tides

The following activities give ideas for reports or individual study.

Activity 4

Find out and then explain why the Gulf of Mexico has only one high tide each day along its coast.

Activity 5

Interview a person who works on the Bay and discuss the role of tides in his/her work.

Activity 6

Tides provide a way of life for certain forms of plants and animals who live in or near the Bay. Find out what forms of life depend on the tides and describe their habitats.

The Rhythm of Water

The ebb and flow of the tides, which once must have seemed a great mystery, have stirred the imagination of people for centuries. From ancient to modern writing, in prose and in poetry, one can find many references to the tides.

When you have finished these exercises, we hope you will understand the mystery of tides and how they work. You might think, too, about the different ways tides can affect people who live near or work on the water.

Activity 7: Marshes

What is a marsh? In the reading that follows you will learn what a marsh is and how it is formed. As you read along, answer the questions you find right on the page.

Bay Marshes

Although Maryland is one of the smaller states, it certainly has a diverse geography. To the north are the Cumberland Mountains, to the east the great Atlantic Ocean, and in the middle--the Chesapeake Bay. The Chesapeake Bay is important not only for its industry and for recreation, but also because of its unique ecology. What makes the Bay's ecology unique? Briefly tell what you know about the Bay's ecology. __________

____

____

____

Another name for the Bay is an estuary. An estuary is where fresh water from rivers mixes with tidal water leading to the ocean. Look at your map. Identify the metropolitan areas of Washington and Baltimore. Find your present location. Where is the Chesapeake Bay? Mark the point where the Bay and the Ocean meet. Now look at the rivers which enter the Bay. How many can you locate?_____ What is the difference between the water in rivers and the water in the Bay?____________________

River water, as it travels from the mountains toward the Bay, contains soil, rocks, and sediment. Suppose this solid material were trapped as it entered the Bay. What would happen?____________________

As the water from the rivers enters the Bay, sediment is sometimes trapped by the shape of the land and water currents. If the area is able to trap enough sediment, land is formed and plants begin to grow. As the area builds up more and more, more plants grow. Eventually, animals enter the area. The ecosystem that arises from the trapped sediment is called a marsh.

Look at the map of the Bay again. Circle those regions you think contain marshes.

Review Questions

1. What is the Chesapeake Bay?

2. How is a marsh formed?

3. Draw a picture of the formation of a marsh.

4. What types of plants would you expect to find in a marsh?

5. Tides cover part of the marsh each day. What adaptations must plants and animals make to protect themselves from tides?

ERIC

Activity 8

Salt Tolerance

The marshes along the Bay are called salt marshes because twice a day the high tide submerges part of the marshes, leaving a deposit of salt. To survive in a salt marsh, plants have to adapt to various salt concentrations. What effect does salt have on plants? In this activity, you will try to determine what effect salt has on the germination of seeds.

To compare your experiment to the conditions in the salt marshes, you must first consider how much salt is in the water of the Bay. The water you drink contains very little salt; in fact, we can consider that it contains zero percent (0.00%). Ocean water contains about 3.5 percent salt. Water in the Chesapeake Bay varies, but the average salinity is about 2.0 percent.

Materials:

1. Seven pie pans
2. Seeds that germinate easily (e.g. lima bean, radish)
3. Paper towels
4. Scale to weigh the amount of salt
5. Seven water containers

Procedure:

1. Place a paper towel in the bottom of each pie pan.
2. Place ten seeds on the towel in each pan and cover with another towel.
3. Prepare water of the following salinities:
   0.0% (control), 1.0%, 1.5%, 2.0%, 2.5%, 3.0%, 3.5%
   (A 1% solution is made with 1 gram of salt per 100 ml water.)
4. Mark each water container with the salinity percentage of its water.
5. Mark one pie pan to correspond to each salinity.
6. Water each marked pan of seeds with water of corresponding salinity. Water the seeds by lifting the top paper towels. Keep the seeds moist all the time. Always remove the top towel when watering.
7. Check the seeds for the next two weeks and write your observations on the chart given on the following page.
8. Answer the review questions.

Review Questions:

1. Did the seeds grow when salt was present? In what concentrations?

2. What types of plants could live in a salt environment?

Results: Complete the following chart each day for two weeks.

% SALT

DAY	0	1.0	1.5	2.0	2.5	3.0	3.5	

Further Study about Salt Marshes

Activity 9

Build a model of a marsh or make a drawing of a typical marsh of the Chesapeake Bay.

Activity 10

Explain the effect of the tides on a marsh in a report to the class.

ERIC

Resource Material

ERIC

SELECTED BIBLIOGRAPHY

Barnes, R.S.K. The Coastline. London: John Wiley and Sons, 1977.

Bishop, Margaret S., Phyllis G. Lewis, and Richmond L. Bronaugh. Focus on Earth Science. Columbus Ohio: Charles E. Merrill, 1972.

Davis, Richard A., Jr. Principles of Oceanography. Menlo Park, Cal: Addison-Wesley, 1972.

Friedrich, Hermann. Marine Biology. Translated by Gwynne Vevers. University of Washington Press, 1973.

Nybakken, James W. Readings in Marine Ecology. New York: Harper and Row, 1971.

Reid, George K. Ecology of Inland Waters and Estuaries. New York: Van Nostrand Reinhold Co., 1961.

Sherwood, Arthur W. Understanding the Chesapeake. Cambridge, Md.: Tidewater Publishers, 1973.

Teal, John, and Mildred Teal. Life and Death of the Salt Marsh. New York: Ballantine Books, 1972.

Weisberg, Joseph, and Howard Parish. Introductory Oceanography. New York: McGraw-Hill, 1974.

TOPIC INTRODUCTION REFERENCES

Abraham et al. Interaction of Man and the Biosphere. 1970.
With Section 8, "Ecological Interactions"

Carter et al. Life Science--A Problem-Solving Approach. 1971.
After Chapter 19, "Relationships Within a Community"

Fitzpatrick and Hole. Modern Life Science. 1974.
After Chapter 7, "The Natural Community"

Heimler and Lockard. Focus on Life Science. 1974.
With Chapter 24, "Ecology"

Morholt and Brandwein. Biology Patterns in Living Things. 1976.
After Chapter 5, "Planet Earth As Our Home"

Rasmussen et al. Man and the Environment. 1974.
After Unit 4, "Man Affects the Environment"

Stone and Sherman. Spaceship Earth--Life Science. 1975.
After Exercise 5, "Environments for Growing"

Tanzer. Biology and Human Progress. 1977.
After Chapter 9, "Ecology and the Future of Our World"

Thurber and Kilburn. Exploring Life Science. 1970.
After Chapter 2, "Man and His Environment"

Wong et al. Life Science. 1973.
After Idea 11

FILM SUPPLEMENTS

The following films may supplement the activities. Because of their popularity, they should be available from area school systems and local library systems.

1. Cry of the Marsh. 1969. 12 minutes, color, 16 mm.

2. One Day at Teton Marsh. 1966. 48 minutes, color, 16 mm.

3. Tides of Fundy. 1956. 14 minutes, color, 16 mm.

4. Waterman of Chesapeake. 1964. 28 minutes, color, 16 mm.