(Photo by Larry Ulrich/DRK Photo)

PART 2

Oceanography

EXERCISE 9

Introduction to Oceanography

The global ocean covers nearly three quarters of Earth's surface and **oceanography** is an important focus of Earth science studies. This exercise investigates some of the physical characteristics of the oceans. To establish a foundation for reference, the extent, depths, and distribution of the world's oceans are the first topics examined. Salinity and temperature, two of the most important variables of seawater, are studied to ascertain how they influence the density of water and the deep ocean circulation (Figure 9.1).

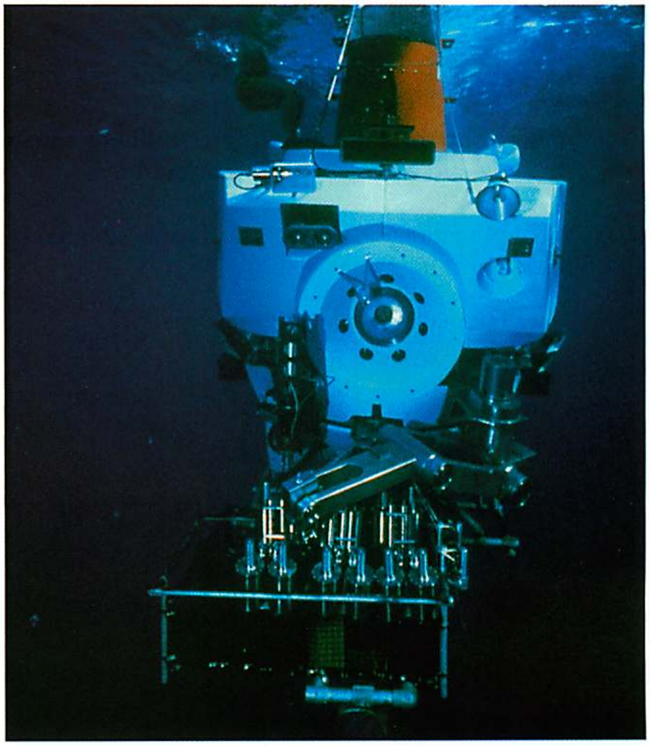

Figure 9.1 The deep-diving submersible *Alvin* is 7.6 meters long, weighs 16 tons, has a cruising speed of 1 knot, and can reach depths as great as 4000 meters. A pilot and two scientific observers are along during a normal 6- to 10-hour dive. (Courtesy of Rod Catanach/Woods Hole Oceanographic Institution)

Objectives

After you have completed this exercise, you should be able to:

1. Locate and name the major water bodies on Earth.
2. Discuss the distribution of land and water in each hemisphere.
3. Locate and describe the general features of ocean basins.
4. Explain the relation between salinity and the density of seawater.
5. Describe how seawater salinity varies with latitude and depth in the oceans.
6. Explain the relation between temperature and the density of seawater.
7. Describe how seawater temperature varies with latitude and depth in the oceans.

Materials

colored pencils
ruler

Materials Supplied by Your Instructor

measuring cylinder (100 ml, clear, Pyrex or plastic)
salt solutions
world wall map, globe, or atlas
ice
beaker
test tubes
dye
salt
rubber band

Terms

oceanography
continental shelf
continental slope
abyssal plain
seamount
deep-ocean trench
mid-ocean ridge
density
density current
salinity
submarine canyons
turbidity currents

Extent of the Oceans

1. Refer to a globe, wall map of the world, or world map in an atlas and identify each of the oceans

and major water bodies listed below. Locate and label each on the world map, Figure 9.2.

Oceans	Other Major Water Bodies	
A. Pacific	1. Caribbean Sea	11. Arabian Sea
B. Atlantic	2. North Sea	12. Weddell Sea
C. Indian	3. Coral Sea	13. Bering Sea
D. Arctic	4. Sea of Japan	14. Red Sea
	5. Sea of Okhotsk	15. Bay of Bengal
	6. Gulf of Mexico	16. Caspian Sea
	7. Persian Gulf	
	8. Mediterranean Sea	
	9. Black Sea	
	10. Baltic Sea	

Area

The area of Earth is about 510 million square kilometers (197 million square miles). Of this, approximately 360 million square kilometers (140 million square miles) are covered by oceans and marginal seas.

2. What percentage of Earth's surface is covered by oceans and marginal seas?

$$\frac{\text{Area of oceans and marginal seas}}{\text{Area of Earth}} \times 100$$

$= \_\_\_\_\_\_\_\%$ oceans

3. What percentage of Earth's surface is land?

_______ % land

Distribution of Land and Water by Hemisphere

Answer questions 4–7 by examining either a globe, wall map of the world, world map in an atlas, or Figure 9.2.

4. a. Which hemisphere, Northern or Southern, could be called the "water" hemisphere and which the "land" hemisphere?

"Water" hemisphere: ____________________

"Land" hemisphere: ____________________

b. The oceans become (wider, more narrow) as you go from the equator to the pole in the Northern Hemisphere. Circle your answer.

c. In the Southern Hemisphere the width of the oceans (increases, decreases) from the equator to the pole.

5. Follow a line around a globe, world map, and Figure 9.3 at the latitudes listed on the following page and estimate what percentage of Earth's surface is ocean at each latitude.

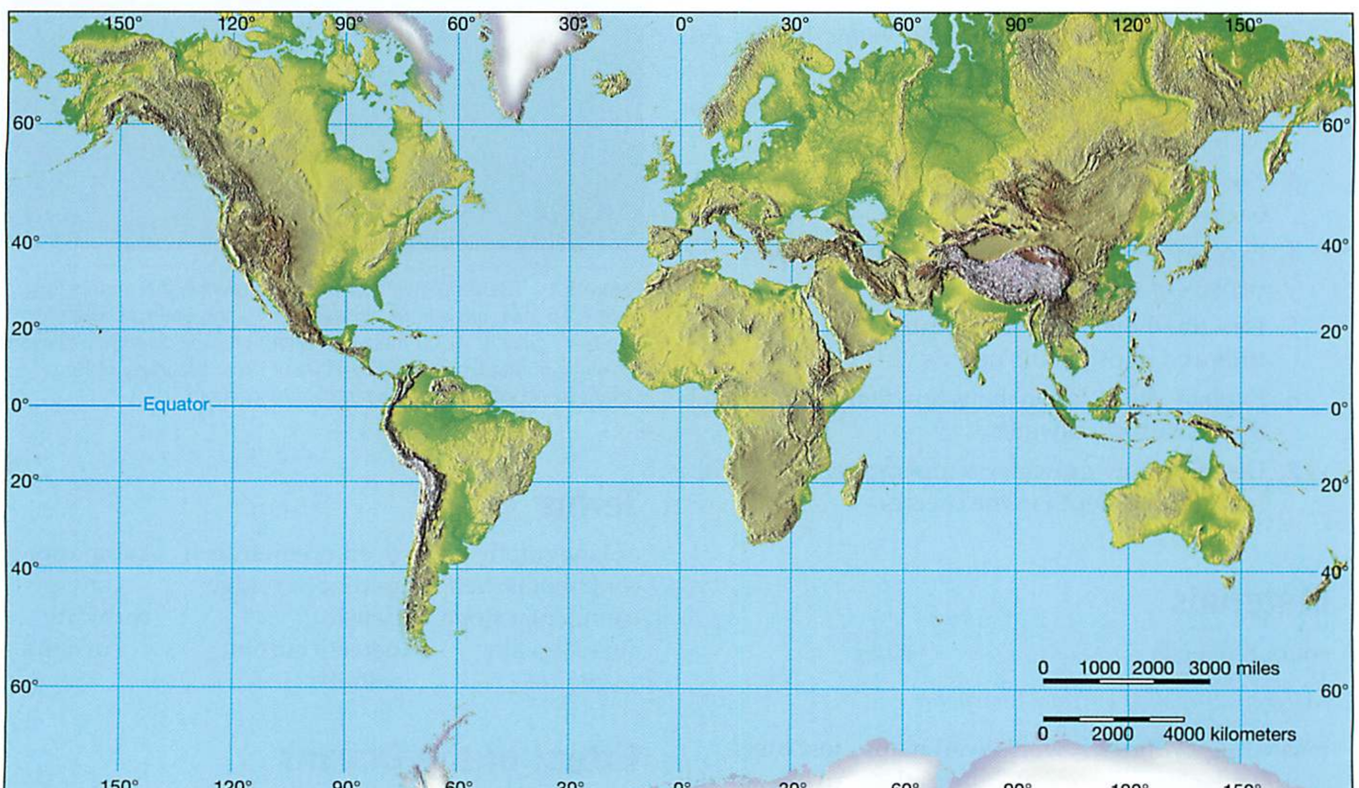

Figure 9.2 World map.

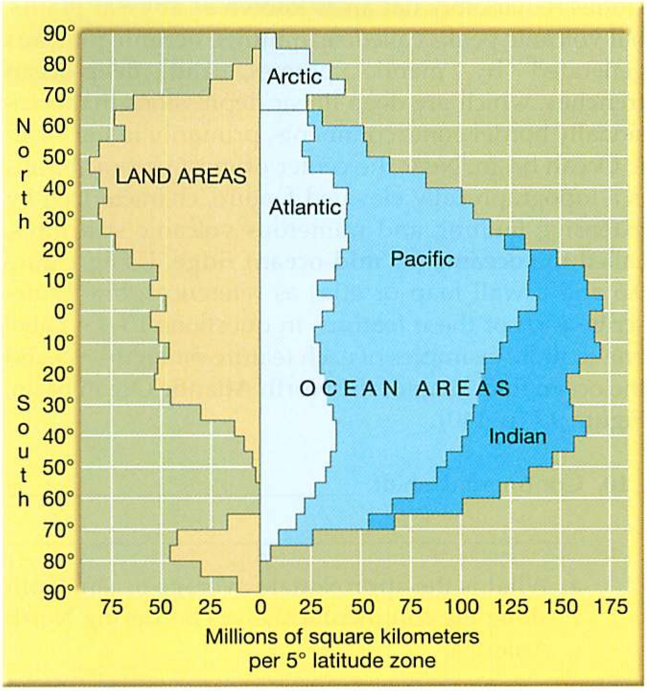

Figure 9.3 Distribution of land and water in each 5° latitude belt. (After M. Grant Gross, *Oceanography: A View of the Earth*, 2nd ed., Englewood Cliffs, NJ: Prentice-Hall, 1977)

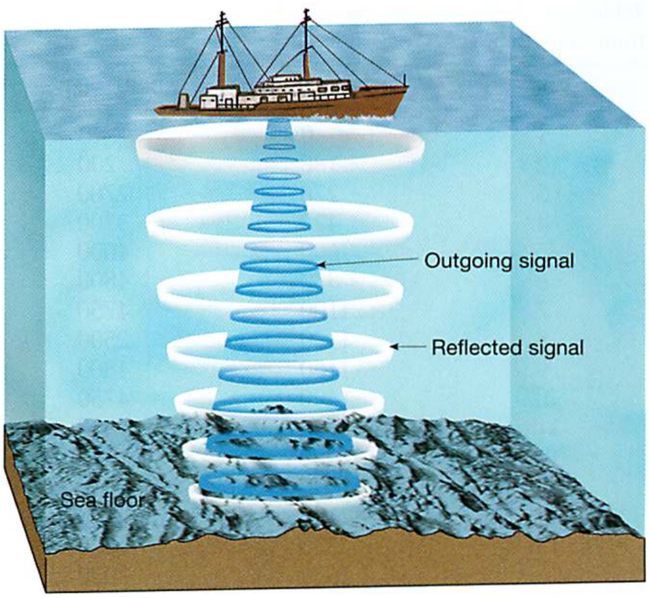

Figure 9.4 An echo sounder determines the water depth by measuring the time interval required for an acoustic wave to travel from a ship to the seafloor and back. The speed of sound in water is 1,500 m/sec. Therefore, depth = 1/2(1500 m/sec × echo travel time).

	NORTHERN HEMISPHERE	SOUTHERN HEMISPHERE
40°:	_______ % ocean	_______ % ocean
60°:	_______ % ocean	_______ % ocean

6. Which ocean covers the greatest area?

____

7. Which ocean is almost entirely in the Southern Hemisphere?

____

Measuring Ocean Depths

Charting the shape or topography of the ocean floor is a fundamental task of oceanographers. In the 1920s a technological breakthrough for determining ocean depths occurred with the invention of electronic depth-sounding equipment. The **echo sounder** (also referred to as *sonar,* an acronym for *so*und *n*avigation *a*nd *r*anging) works by measuring the precise time that a sound wave, traveling at about 1,500 meters per second in water, takes to reach the ocean floor and return to the instrument (Figure 9.4). Today, in addition to using sophisticated echo sounders such as *multibeam sonar,* oceanographers are also using satellites to map the ocean floor.

8. Using the formula in Figure 9.4, calculate the depth of the ocean for each of the following echo soundings.

5.2 seconds: _______________________

6.0 seconds: _______________________

2.8 seconds: _______________________

Ships generally don't make single depth soundings. Rather, as the ship makes a traverse from one location to another, it is continually sending out sound impulses and recording the echoes. In this way, oceanographers obtain many depth recordings from which a *profile* (side view) of the ocean floor can be drawn.

The data in Table 9.1 (page 138) were gathered by a ship equipped with an echo sounder as it traveled the North Atlantic Ocean eastward from Cape Cod, Massachusetts. The depths were calculated using the same technique used in question 8.

9. Use the data in Table 9.1 to construct a generalized profile of the ocean floor in the North Atlantic on Figure 9.5. Begin by plotting each point at its proper distance from Cape Cod, at the indicated depth. Complete the profile by connecting the depth points.

Table 9.1 Echo Sounder Depths Eastward from Cape Cod, MA

POINT	DISTANCE (KM)	DEPTH (M)
1	0	0
2	180	200
3	270	2700
4	420	3300
5	600	4000
6	830	4800
7	1100	4750
8	1130	2500
9	1160	4800
10	1490	4750
11	1770	4800
12	1800	500
13	1830	4850
14	2120	4800
15	2320	4000
16	2650	3000
17	2900	1500
18	2950	1000
19	2960	2700
20	3000	2700
21	3050	1000
22	3130	1900

Ocean Basin Topography

Various features are located along the continental margins and on the ocean basin floor (Figure 9.6). **Continental shelves,** flooded extensions of the continents, are gently sloping submerged surfaces extending from the shoreline toward the ocean basin. The seaward edge of the continental shelf is marked by the **continental slope,** a relatively steep structure (as compared with the shelf) that marks the boundary between continental crust and oceanic crust. Deep, steep-sided valleys known as **submarine canyons,** eroded in part by the periodic downslope movements of dense, sediment-laden water called **turbidity currents,** are often cut into the continental slope. The ocean basin floor, which constitutes almost 30% of Earth's surface, includes remarkably flat areas known as **abyssal plains,** tall volcanic peaks called **seamounts, oceanic plateaus** generated by mantle plumes, and **deep-ocean trenches,** which are deep linear depressions that occasionally border some continents, primarily in the Pacific Ocean basin. Near the center of most oceanic basins is a topographically elevated feature, characterized by extensive faulting and numerous volcanic structures, called the **oceanic** (or **mid-ocean) ridge**. Using Figure 9.6 and a wall map or atlas as references, briefly describe each of these features in questions 10–15. Label one or more examples of each feature on Figure 9.5 and the ocean floor map of the North Atlantic Ocean basin, Figure 9.7 (p. 140)

10. Continental shelf: ____________________

____

   a. What is the approximate average ocean depth along the continental shelves bordering North America?

   ____

   b. Write a brief statement comparing the width of the continental shelf along the east coast, west coast, and gulf coast of North America.

   ____

   ____

11. Continental slope: ____________________

____

   a. Briefly describe the origin of submarine canyons and label at least one on Figure 9.7.

   ____

   ____

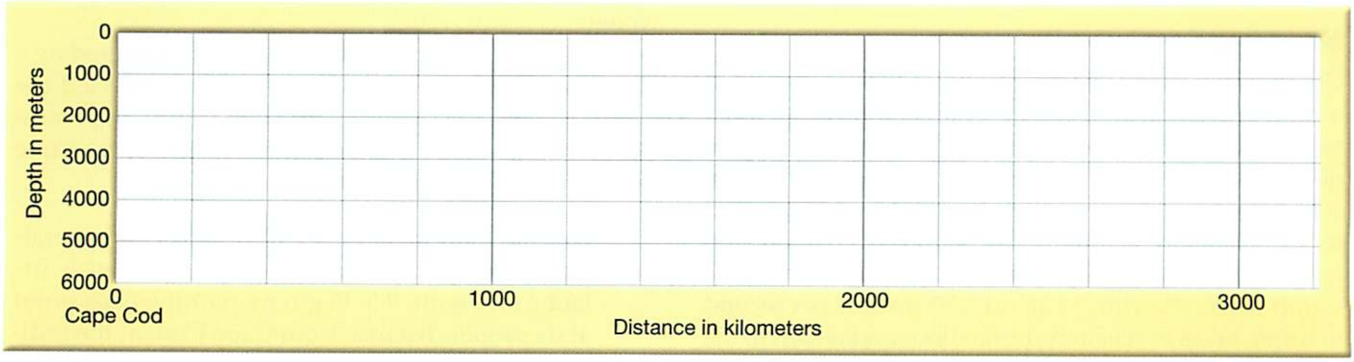

Figure 9.5 North Atlantic Ocean floor profile (exaggerated).

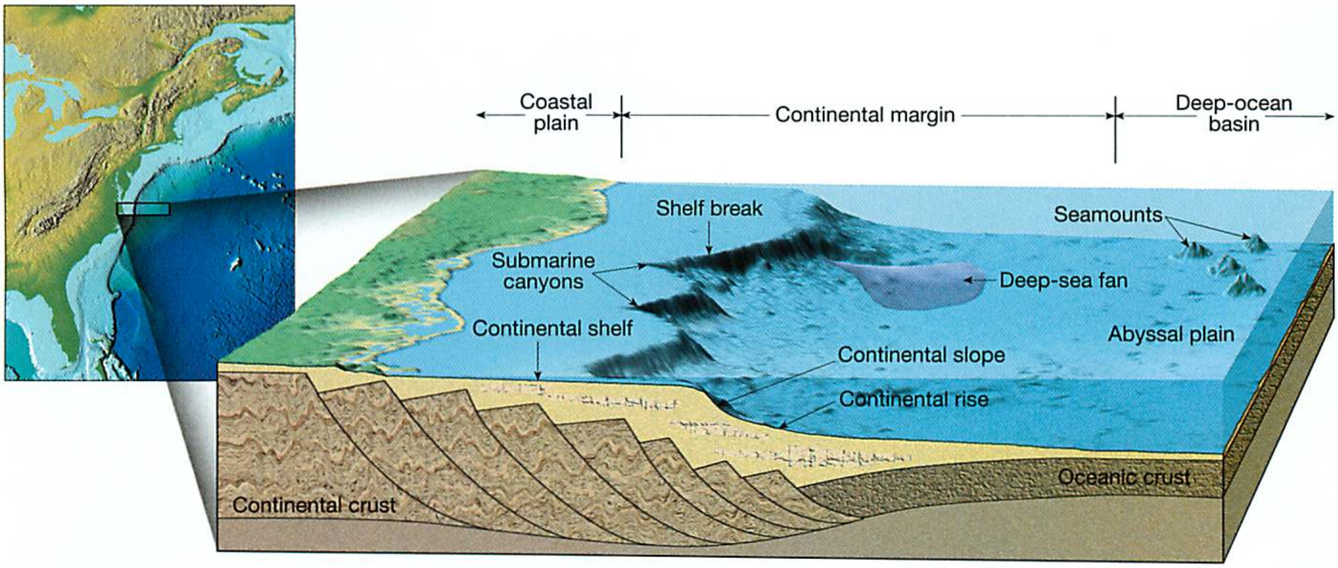

Figure 9.6 Generalized continental margin. Note that the slopes shown for the continental shelf and continental slope are greatly exaggerated. The continental shelf has an average slope of one tenth of 1 degree, while the continental slope has an average of about 5 degrees.

12. Abyssal plain: ______________________________

____

a. The general topography of abyssal plains is (flat, irregular). Circle your answer.

b. How do abyssal plains form and what is their composition?

____

____

13. Seamount: ______________________________

____

14. Deep-ocean trench (not shown on Figure 9.5):

____

____

____

a. Approximately how deep is the Puerto Rico trench?

______________ meters

b. Use a map or globe to locate three deep-ocean trenches in the western Pacific Ocean. Give the name, location, and depth of each.

Trench 1: ______________________________

____

Trench 2: ______________________________

____

Trench 3: ______________________________

____

15. Mid-ocean ridge: ______________________________

____

a. Examine the mid-ocean ridge system on a world map. Follow the ridge eastward from the Atlantic Ocean into the Indian Ocean and then into the Pacific. Describe what happens to the ridge along the southwest coast of North America.

____

b. Approximately how high above the adjacent ocean floor does the Mid-Atlantic Ridge rise?

______________ meters

16. Note that Figures 9.5 and 9.7 illustrate only the western side of the North Atlantic floor. Using a globe or map, write a brief statement comparing

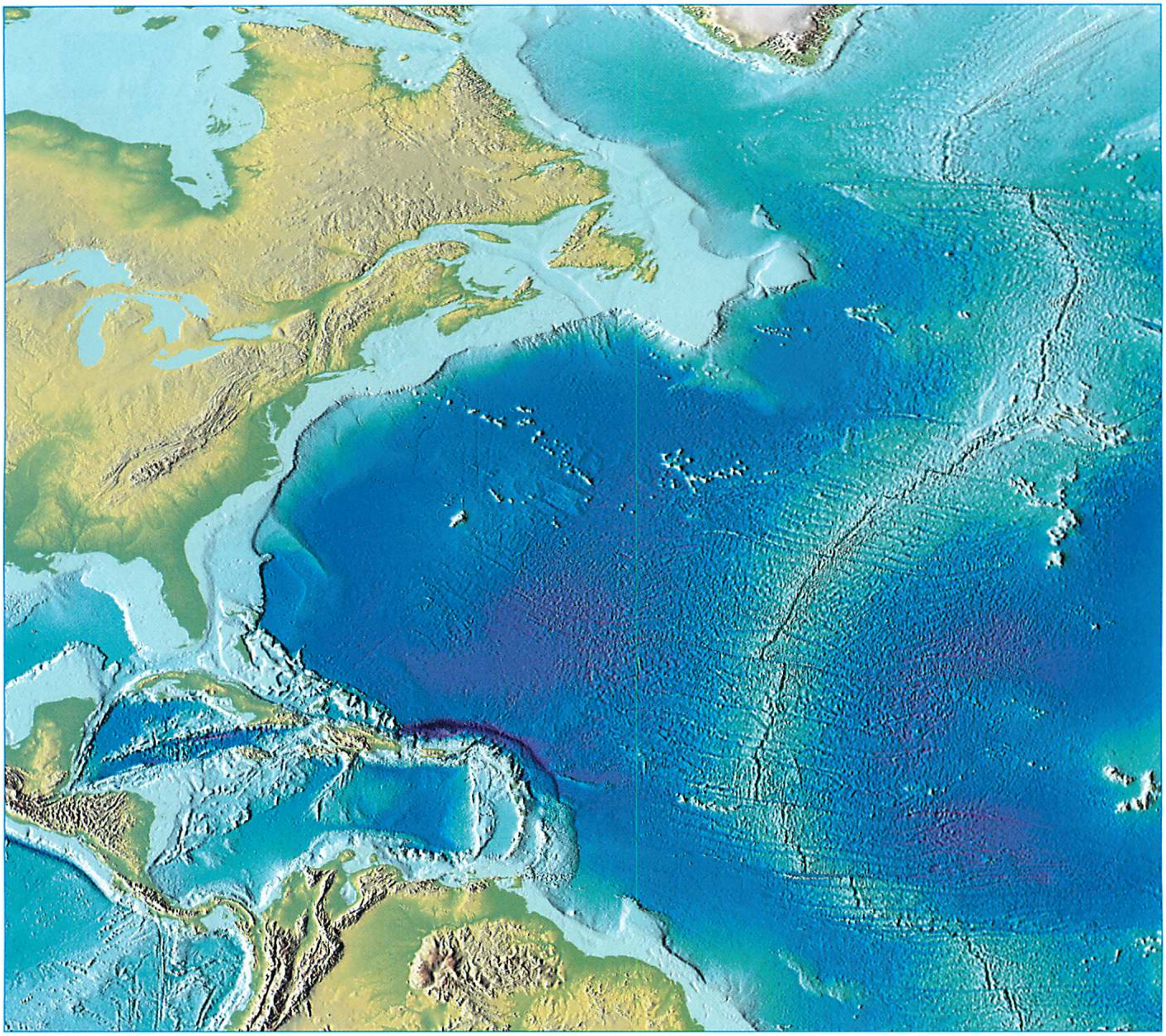

Figure 9.7 North Atlantic basin.

the topography of the North Atlantic Ocean floor east of the mid-ocean ridge to that on the west side.

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____

____

____

Characteristics of Ocean Water

Ocean circulation has two primary components: surface ocean currents and deep-ocean circulation. Both are examined with greater detail in Exercise 11, "Waves, Currents, and Tides." While surface currents like the famous Gulf Stream are driven primarily by the prevailing world winds, the deep-ocean circulation is largely the result of differences in ocean water **density** (mass per unit volume of a substance). A **density current** is the movement (flow) of one body of water over, under, or through another caused by density differences and gravity. Variations in **salinity** and temperature are the two most important factors in creating the density differences that result in the deep-ocean circulation.

Salinity

Salinity is the amount of dissolved solid material in water, expressed as parts per thousand parts of water. The symbol for parts per thousand is 0/00. Although

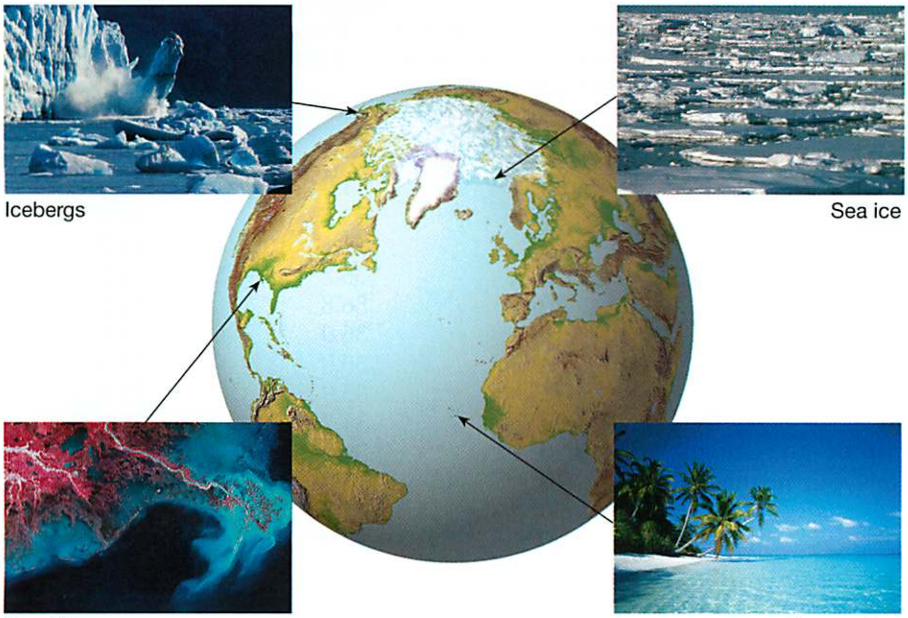

Figure 9.8 Processes affecting seawater salinity. Processes that *decrease* seawater salinity include precipitation, runoff, icebergs melting, and sea ice melting. Processes that *increase* seawater salinity include formation of sea ice and evaporation. Source: (upper left) Tom Bean/Tom and Susan Bean, Inc., (upper right) Wolfgang Kaehler Photography, (lower left) NASA Headquarters, (lower right) Paul Steel/Corbis/Stock Market.

there are many dissolved salts in seawater, sodium chloride (common table salt) is the most abundant.

Variations in the salinity of seawater are primarily a consequence of changes in the water content of the solution. In regions where evaporation is high, the proportionate amount of dissolved material in seawater is increased by removing the water and leaving behind the salts. On the other hand, in areas of high precipitation and high runoff, the additional water dilutes seawater and lowers the salinity. Since the factors that determine the concentration of salts in seawater are not constant from the equator to the poles, the salinity of seawater also varies with latitude and depth (Figure 9.8).

Salinity–Density Experiment

To gain a better understanding of how salinity affects the density of water, examine the equipment in the lab (see Figure 9.9) and conduct the following experiment by completing each of the indicated steps.

Step 1. Fill the measuring cylinder with cool tap water up to the rubber band or other marker near the top of the cylinder.

Step 2. Fill a test tube about half full of solution A (saltwater) and pour it slowly into the cylinder. Observe and describe what happens.

Observations: ______________________________

____

Step 3. Repeat steps 1 and 2 two additional times and measure the time required for the front edge of the saltwater to travel from the rubber band to the bottom of the cylinder. Record the times for each test in the data table, Table 9.2. *Make certain* that you drain the cylinder after each trial and refill it with fresh water and use the same amount of solution with each trial.

Step 4. Determine the travel time two times for solution B exactly as you did with solution A and enter your measurements in Table 9.2.

Figure 9.9 Lab setup for salinity–density experiment.

Table 9.2 Salinity–Density Experiment Data Table

SOLUTION	TIMED TRIAL #1	TIMED TRIAL #2	AVERAGE OF BOTH TRIALS
A			
B			
Solution B plus salt		XXXX	XXXX

Step 5. Fill a test tube about half full of solution B and add to it some additional salt. Then shake the test tube vigorously. Determine the travel time of this solution and enter your results in Table 9.2.

Step 6. Clean all your glassware.

17. Questions 17a and 17b refer to the salinity–density experiment.

a. Write a brief summary of the results of your salinity–density experiment.

____

____

b. Since the solution that traveled fastest has the greatest density, solution (A, B) is most dense. Circle your answer.

Table 9.3 lists the approximate surface water salinity at various latitudes in the Atlantic and Pacific Oceans. Using the data, construct a salinity curve for each ocean on the graph, Figure 9.10. *Use a different-colored pencil for each ocean.* Then answer questions 18–22.

Table 9.3 Ocean Surface Water Salinity in Parts per Thousand (0/00) at Various Latitudes in the Atlantic and Pacific Oceans

LATITUDE	ATLANTIC OCEAN	PACIFIC OCEAN
60°N	33.0 0/00	31.0 0/00
50°	33.7	32.5
40°	34.8	33.2
30°	36.7	34.2
20°	36.8	34.2
10°	36.0	34.4
0°	35.0	34.3
10°	35.9	35.2
20°	36.7	35.6
30°	36.2	35.7
40°	35.3	35.0
50°	34.3	34.4
60°S	33.9	34.0

18. At which latitudes are the highest surface salinities located?

____

19. What are two factors that control the concentration of salts in seawater?

_______________ and _______________

20. Refer to the factors listed in question 19. What is the cause of the difference in surface water salinity between equatorial and subtropical regions in the Atlantic Ocean?

____

____

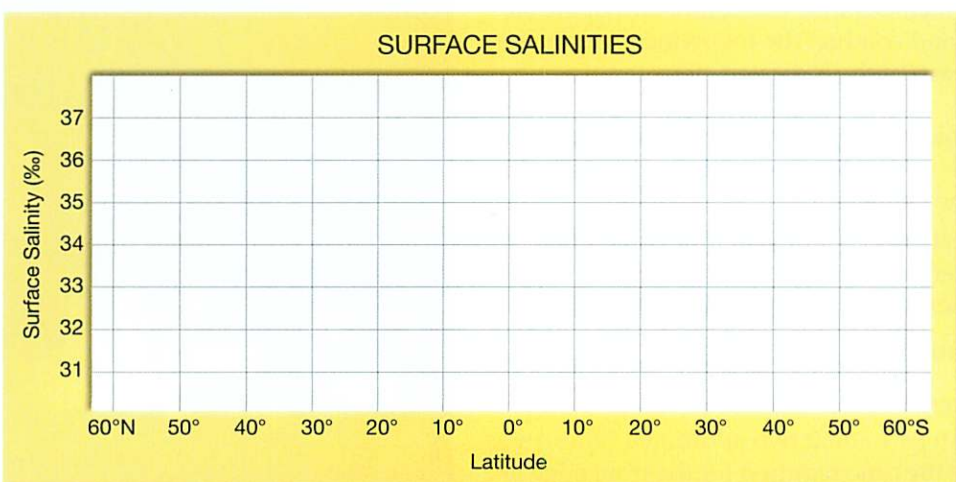

Figure 9.10 Graph for plotting surface salinities.

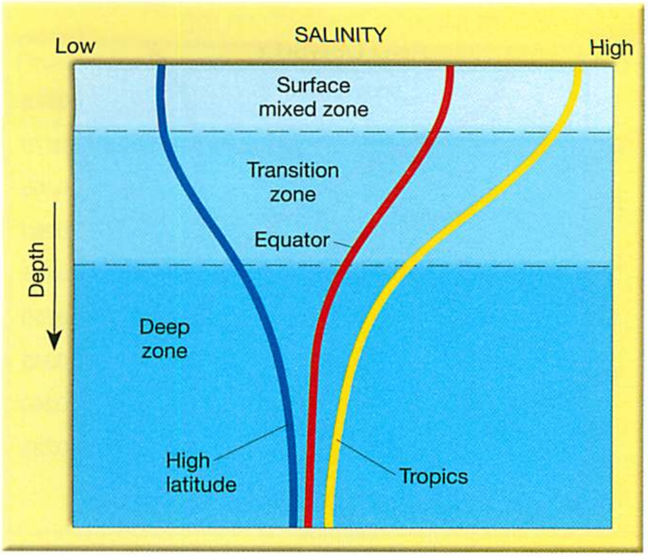

Figure 9.11 Ocean water salinity changes with depth at high latitudes, equatorial regions, and the tropics.

21. Of the two oceans, the (Atlantic, Pacific) Ocean has higher average surface salinities. Circle your answer.

22. Suggest a reason(s) for the difference in average surface salinities between the oceans.

____

____

____

Figure 9.11 shows how ocean water salinity varies with depth at different latitudes. Use the figure to answer questions 23–26.

23. In general, salinity (increases, decreases) with depth in the equatorial and tropical regions and (increases, decreases) with depth at high latitudes. Circle your answers.

24. Why are the surface salinities higher than the deepwater salinities in the lower latitudes?

____

The *halocline* (*halo*-salt, *cline*-slope) is a layer of ocean water where there is a rapid change in salinity with depth.

25. Label the halocline on Figure 9.11. Where does it occur?

____

26. Below the halocline the salinity of ocean water (increases rapidly, remains fairly constant, decreases rapidly). Circle your answer.

Ocean Water Temperatures

Seawater temperature is the most extensively determined variable of the oceans because it is easily measured and has an important influence on marine life. Like salinity, ocean water temperatures vary from the equator to poles and also changes with depth.

Temperature, like salinity, also affects the density of seawater. However, the density of seawater is more sensitive to temperature fluctuations than salinity.

Temperature–Density Experiment

To illustrate the effects of temperature on the density of water, examine the equipment in the lab (see Figure 9.12) and then conduct the following experiment by completing each of the indicated steps.

Step 1. Fill a measuring cylinder with *cold* tap water up to the rubber band.

Step 2. Put 2–3 drops of dye in a test tube and fill it half full with *hot* tap water.

Step 3. Pour the contents of the test tube *slowly* into the cylinder and then record your observations.

Observations: ____________________________

____

____

Figure 9.12 Lab setup for temperature–density experiment.

Notes and calculations.

Introduction to Oceanography

Date Due: ______________________

Name: ______________________

Date: ______________________

Class: ______________________

After you have finished Exercise 9, complete the following questions. You may have to refer to the exercise for assistance or to locate specific answers. Be prepared to submit this summary/report to your instructor at the designated time.

1. Give the approximate latitude and longitude of the centers of each of the following water bodies.

   Mediterranean Sea: ______________________

   Sea of Japan: ______________________

   Indian Ocean: ______________________

2. Write a brief statement comparing the distribution of water and land in the Northern Hemisphere to the distribution in the Southern Hemisphere.

   ____

   ______________________.

3. On the ocean basin profile in Figure 9.15, label the continental shelf, continental slope, abyssal plain, seamounts, mid-ocean ridge, and deep-ocean trench.

4. List the names and depths of two Pacific Ocean trenches.

NAME	DEPTH
__________	__________
__________	__________

5. Explain how an echo sounder is used to determine the shape or topography of the ocean floor.

   ____

   ____

   ____

   ____

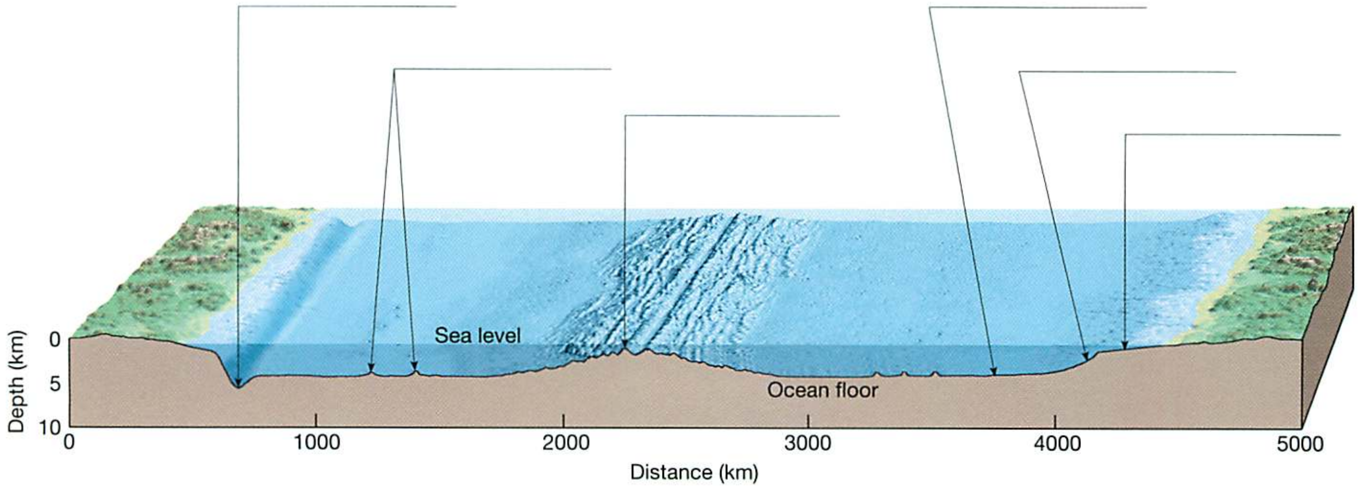

Figure 9.15 Hypothetical ocean basin.

6. The following are some short statements. Circle the most appropriate response.
   a. The higher the salinity of seawater, the (lower, higher) the density.
   b. The lower the temperature of seawater, the (lower, higher) the density.
   c. Surface salinity is greatest in (polar, subtropical, equatorial) regions.
   d. (Temperature, Salinity) has the greatest influence on the density of seawater.
   e. (Warm, Cold) seawater with (high, low) salinity would have the greatest density.
   f. Vertical movements of ocean water are most likely to begin in (equatorial, subtropical, polar) regions, because the surface water there is (most, least) dense.
7. Summarize the results of your salinity–density and temperature–density experiments.

   Salinity–density experiment: ______________

   ____

   ____

   ____

   Temperature–density experiment: ______________

   ____

   ____

   ____

8. Why is the surface salinity of an ocean higher in the subtropics than in the equatorial regions?

   ____

   ____

   ____

9. Given your understanding of the relation between ocean water temperature, salinity, and density, where in the Atlantic Ocean would you expect surface water to sink and initiate a subsurface flow? List the reason(s) for your choice(s).

   ____

   ____

   ____

   ____

10. Refer to the salinity–density experiment you conducted. Solution (A, B) had the greatest density. Circle your answer.
11. Describe the change in salinity *and* temperature with depth that occurs at low latitudes.

    Salinity: ______________________

    ____

    ____

    Temperature: ______________________

    ____

    ____

12. Are the following statements true or false? Circle your response. If the statement is false, correct the word(s) so that it reads as a true statement.

    T F a. The Atlantic Ocean covers the greatest area of all the world oceans.

    T F b. Continental shelves are part of the deep-ocean floor.

    T F c. Deep-ocean trenches are located in the middle of ocean basins.

    T F d. High evaporation rates in the subtropics cause the surface ocean water to have a lower than average salinity.