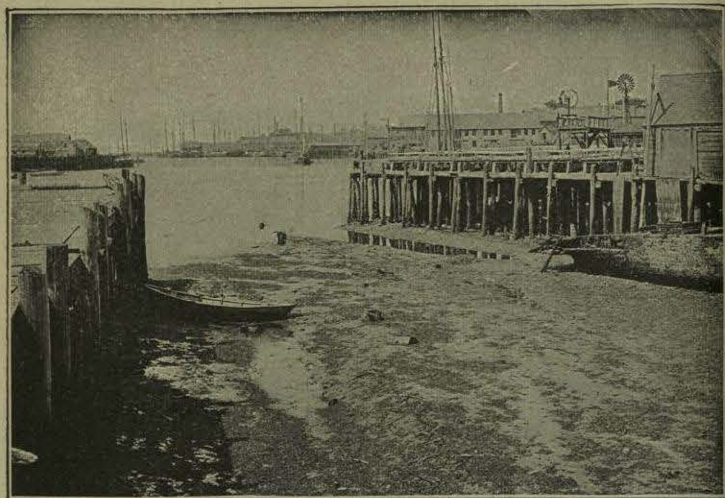

Fig. 330.—Low tide at Gloucester harbor, Mass., where the tide rises 8 or 10 feet. At high tide a fishing schooner (Fig. 341) can come in beside the wharf.

Fig. 331.—Low tide along the coast north of Boston, showing the seaweed mat which covers the rocky coast, protecting it from wave attack. At high tide the water reaches above the dark-colored zone of seaweed.

wave. These iceberg waves dash on the shores with great force, reaching several feet above the normal level of the waves.

A wave of high water accompanies hurricanes and other violent storms at sea (p. 271).

Summary. — *Waves are also started by earthquake shocks on the ocean bottom; by the breaking off or stranding of icebergs; and by violent storms at sea.*

135. Tides. — Twice each day (more exactly, every 12 hours, 26 minutes) the passage of tidal waves, formed by the attraction of moon and sun (Appendix E), causes the ocean surface to rise and fall (Figs. 328, 329). In the open ocean the difference in height between high and low tide, or the *tidal range*, is not over one or two feet; but, as the tidal wave approaches the coast, its height is increased (Figs. 330, 331) by the effect of the shallowing bottom.

In the ocean, and on open coasts, the tide is merely a rise and fall in the water level; but in bays and estuaries this change in level starts currents, which often move with great velocity. Such currents may move so rapidly that boats cannot make headway against them; indeed, in the Bay of Fundy the tide advances over the mud flats more rapidly than a man can run. From this it is evident why, as the tide rises and falls, it is said to "come in" and "go out." The rising tide is called the *flow*, the falling tide the *ebb*.

The advancing tidal wave is greatly influenced by the form of the coast. Ordinarily the tidal range is between 3 and 10 feet; but in narrowing, V-shaped bays the range is greatly increased, as in the Bay of Fundy in Nova Scotia and Ungava Bay in northern Labrador, where the tide rises from 30 to 50 feet.

On the other hand, where bays broaden out, bag-shaped, the tidal range is greatly diminished. For instance, the Atlantic tide, passing through the Straits of Gibraltar, produces practically no effect on the broad Mediterranean; but a very small local tide is developed in the Mediterranean itself. This almost complete absence of tide in the Mediterranean was of great impor-

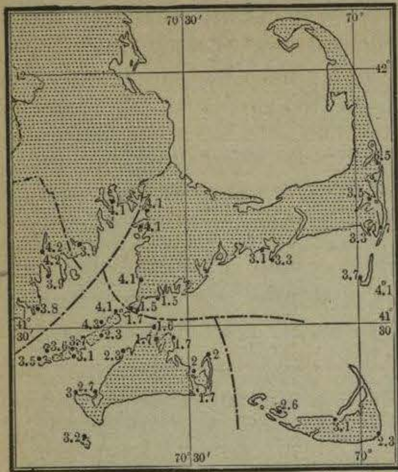

FIG. 332. — Range of tide, south of Cape Cod, indicated by figures. In Buzzards Bay it rises 4.1 feet; in Vineyard Sound, from 1.5 to 3.1; consequently rapid currents, or races, pass through gaps between the islands that separate the two bodies of water.

tance in the development of navigation in that inclosed sea (p. 377) and the growth of nations along its shores. With strong tidal currents to battle against, the movement of their small, open boats, propelled by oars, would have become a much more difficult task.

Along irregular coasts there are bays where the tidal range is greater than in neighboring parts of the coast. If there happens to be connection between two such places, rapid tidal currents, or *races*, will pass through the connecting straits. An illustration of this is found in southern Massachusetts, where rapid currents flow between Buzzards Bay and Vineyard Sound (Fig. 332). A similar current occurs at Hell Gate, in the narrow strait between New York Bay and Long Island Sound (Figs. 333, 334).

On entering some river mouths the tidal current changes to a wave, known as the *bore* (Fig. 323), which travels rapidly upstream. It is found in the Seine, Severn, Amazon, and several other rivers.

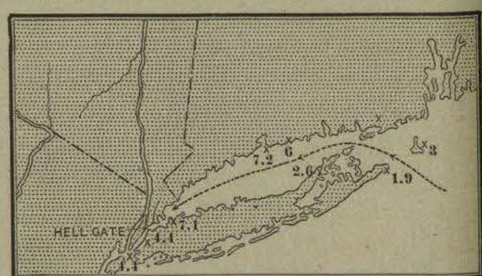

FIG. 333. — The height to which the tide rises on the two sides of Hell Gate, over which there are rapid tidal currents.

Not only does the tide vary from place to place, but also from time to time. At new and full

moon the tidal range is greater than during the quarters. Tides with high range are known as *spring* tides, those with low range, *neap tides* (Appendix E). The correspondence of spring and neap tides to phases of the moon, and the fact that two complete tides occur every 24 hours, 52 minutes (the period between two moonrises), long ago led to the discovery that the tides are due to some influence of the moon.

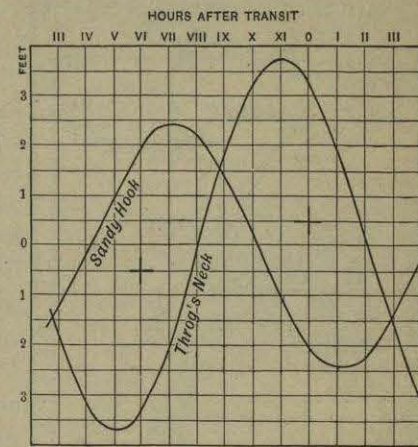

FIG. 334. — Diagram to show time of arrival and height reached by the tides on the two sides of Hell Gate. The currents at Hell Gate are therefore due to two causes: (1) the time of high tide differs on the two sides; (2) the tidal range differs.

Tides are of great importance along the coast. The tidal currents drift sediment about, thus helping to form sedimentary strata (p. 32). They also deposit sediment in harbors, and each year large appropriations are necessary for the purpose of removing such deposits. By these currents, too, a circulation is caused in harbors (Fig. 330), thus helping to remove the filth that necessarily finds its way into the ocean near large cities.

Tidal currents aid or impede vessels, according to their direction; and they sometimes drift vessels from their course, placing them in dangerous positions. Every now and then in foggy weather, when the land cannot be seen, vessels run aground, because the tide has drifted them out of their course. The captains of all large ships carry tide tables and charts to aid them in navigation. One use of these is to tell when the tide is high, for the entrances to many harbors are too shallow to admit large ships at low tide.

Summary. — *Every 12 hours, 26 minutes, the ocean surface rises and falls with the passage of a tidal wave. In the open ocean the range is a foot or two; along the coast from 3 to 10 feet; in V-shaped bays even 30 to 50 feet; but in large bays that broaden, the tide may be destroyed. Along irregular coasts the rise and fall of the tide cause currents, which may become very rapid races. Tidal currents move sediment about, helping to deposit sedimentary strata; they drift sediment into harbors; they keep the harbor water in circulation; they aid or impede navigation; and they sometimes place vessels in dangerous positions.*

Fig. 335. — The drifting of a wreck from March 13, 1888, till it went ashore January 25, 1889. Storm winds now and then caused the wreck to leave its general course in the ocean drift.

136. Ocean Currents. — The ocean waters are in constant circulation, not only along the bottom (p. 184), but also in well-defined surface currents (Fig. 335). The existence of ocean currents has been known for a long time; indeed, Columbus noticed them along the American coast, and Benjamin Franklin studied them and considered them the result of steadily blowing winds. It is now known that there are currents slowly sweeping through each of the oceans (Fig. 338).

Differences in temperature of the ocean water account for the settling of water in cold regions and its circulation along the sea bottom (p. 184). But it does not seem an adequate explanation for the surface currents.

The explanation that best accounts for surface currents is the effect of steadily blowing winds, as suggested by Franklin. By blowing on a pan of water with sawdust floating in it, a drift of water is seen to start; in like manner, winds blowing over lakes or ocean start a similar drift of surface water. Such wind-drift currents continue to move for some time after the wind dies down.

A comparison of the ocean-current chart (Fig. 338) and the wind chart (Fig. 408) shows that there is a close resemblance between the direction of ocean currents and regular winds. We will study the currents of the Atlantic Ocean to see how close this relationship is.

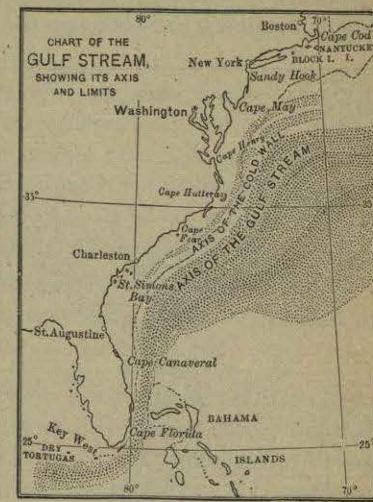

Fig. 336. — The Gulf Stream.

In the equatorial region there is a *drift*[1] of water, the *Equatorial Drift*, toward the South American coast. At the angle of South America it divides, the smaller portion going into the South Atlantic, the larger into the North Atlantic. This Equatorial Drift is exactly what we would expect to find, for the northeast and southeast trade winds blow steadily day after day, drifting the water westward before them.

After dividing on the coast of South America, the drift follows the coast for a while, then slowly swings to the right in the northern hemisphere, and to the left in the southern.[2]

[1] A slow current may be called a *drift*, a more rapid current a *stream*.

[2] This swinging is caused by the effect of the earth's rotation, which deflects all moving bodies, whether wind or water currents, from a straight course. In the northern hemisphere the moving body is turned to the right, in the southern hemisphere to the left.

Thus a great, slowly moving eddy is formed in each ocean. Floating seaweed (*Sargassum*) accumulates in the center of the eddy in such abundance that it has been called the *Grassy*, or *Sargasso, Sea*. Columbus encountered it, and his sailors, not knowing what it was, feared that the ships would run aground in it.

A portion of the *North Equatorial Drift* enters the Caribbean Sea, part coming out between the West Indies, part continuing on into the Gulf of Mexico (Fig. 337). The portion that enters the Gulf is warmed still more in that inclosed sea, and escapes, between Cuba and Florida, as a narrow and rapidly moving stream of warm water, known as the *Gulf Stream* (Figs. 336, 337). On the Florida coast it has a velocity of 4 or 5 miles an hour. The Gulf Stream rapidly broadens, a part of it joining the great *North Atlantic Eddy* that circles in the open ocean outside of the West Indies. This portion returns to once more form a part of the Equatorial Drift.

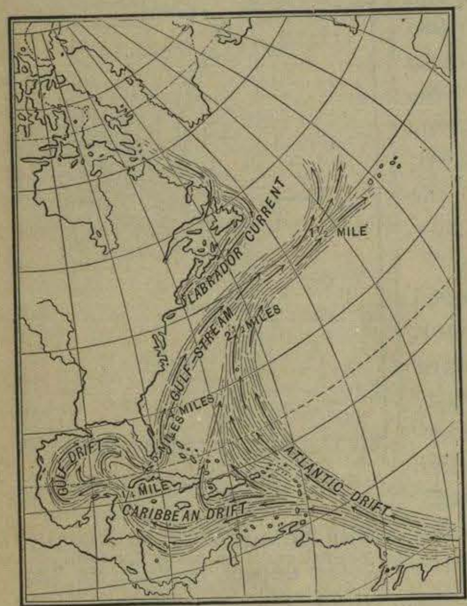

Fig. 337.—Diagram to show the currents of the western North Atlantic. Figures tell rate of movement in miles per hour.

A smaller portion of the Gulf Stream water, and some of the North Atlantic Eddy, drifts on into the region of the west winds, which drive it on toward the coast of northern

Europe, as the *West Wind Drift*. Thus water, warmed in the equatorial region, the Caribbean Sea, and the Gulf of Mexico, is carried to the European coast, and even into the Arctic. There is no similar stream in the South Atlantic, because there are no partly closed seas for the drift to enter.

Study the currents of the Pacific to see if the same great eddies are found there. Notice that in the Southern Ocean, where there are no continents to turn the currents, the West Wind Drift extends completely around the globe.

Besides these eddies, there are special currents, one of which, the *Labrador Current*, is of great importance to America. This is a cold current, descending from among the islands of the Arctic along the Labrador, Newfoundland, and New England coasts (Fig. 337). It keeps close to the American shores, being turned to the right by the influence of rotation. Thus, while warm water is drifted toward Europe, cold water flows down the American coast as far south as Cape Cod, where it disappears by settling and mingling with the warm water.

Summary. — *The surface currents are due to the drifting of water before steadily blowing winds. In each ocean there are great eddies, started by the trade winds, which cause an Equatorial Drift toward the west. This, dividing on the continents, follows the coast northward and southward for a while; then it is turned, by the effect of rotation, to the right in the northern hemisphere and to the left in the southern. Thus an eddy is caused in each ocean, both north and south of the equator. A part of the North Equatorial Drift enters the Gulf of Mexico and emerges as the warm Gulf Stream, a portion of which joins the eddy of the North Atlantic. A portion of the eddy, and of the Gulf Stream, is drifted by the west winds to the European coast, and even into the Arctic. In the southern hemisphere the West Wind Drift extends around the earth. The cold Labrador Current sweeps down the American coast from the Arctic, and, being turned to the right, is forced to hug the coast till it sinks.*

137. Effects of Ocean Currents. — The most important effect of ocean currents is on climate (p. 278). For instance, the warm water that is borne into the Arctic by the West Wind Drift, influences the temperature of northern Europe. Its effect was very well shown by Nansen's voyage toward the pole. He started into the Arctic north of Scandinavia, where the warm drift keeps the sea fairly clear of ice in summer (Fig. 338), and was able to push his ship far into the Arctic before he met with impassable ice.

Ocean currents aid or retard vessels, according to their direction; and, in their reckonings, navigators must make allowance for this influence. Columbus had much difficulty in navigating his small ships among the currents along the northern coast of South America. Currents have other important influences, for example, causing fogs (p. 247), drifting sea ice and icebergs, and bringing oxygen and food for many sea animals (pp. 196, 197).

Summary. — *Ocean currents affect climate, influence the movement of vessels, and are further important in causing fogs, drifting sea ice and icebergs, and bearing oxygen and food for sea animals.*

138. Ice in the Ocean. — Each winter a large part of the Arctic Ocean is frozen over, often to a depth of 5 or 10 feet. The tidal currents move the ice about, opening cracks or *leads*, and closing them again with so irresistible a force that the ice is broken and piled up in ridges of *pack ice* often 50 or 100 feet high. More than one Arctic ship has been crushed like an eggshell between these moving ice fields.

Nansen, Abruzzi, and Peary have all tried to reach the North Pole over this frozen sea; but the many leads, and the irregular surface of the ice packs, have proved such barriers to progress that no one has yet succeeded in reaching the pole.

In summer the ice breaks up, and the fragments drift southward till they melt. Each spring and early summer there is a steady stream of these ice fragments, or *ice floes*, passing down the Labrador coast in the Labrador current (Fig. 340).

Icebergs, discharged from the ice sheets of Greenland and other northern islands (p. 145), also drift in the Arctic waters (Fig. 339). They are huge floating islands of ice, sometimes rising more than

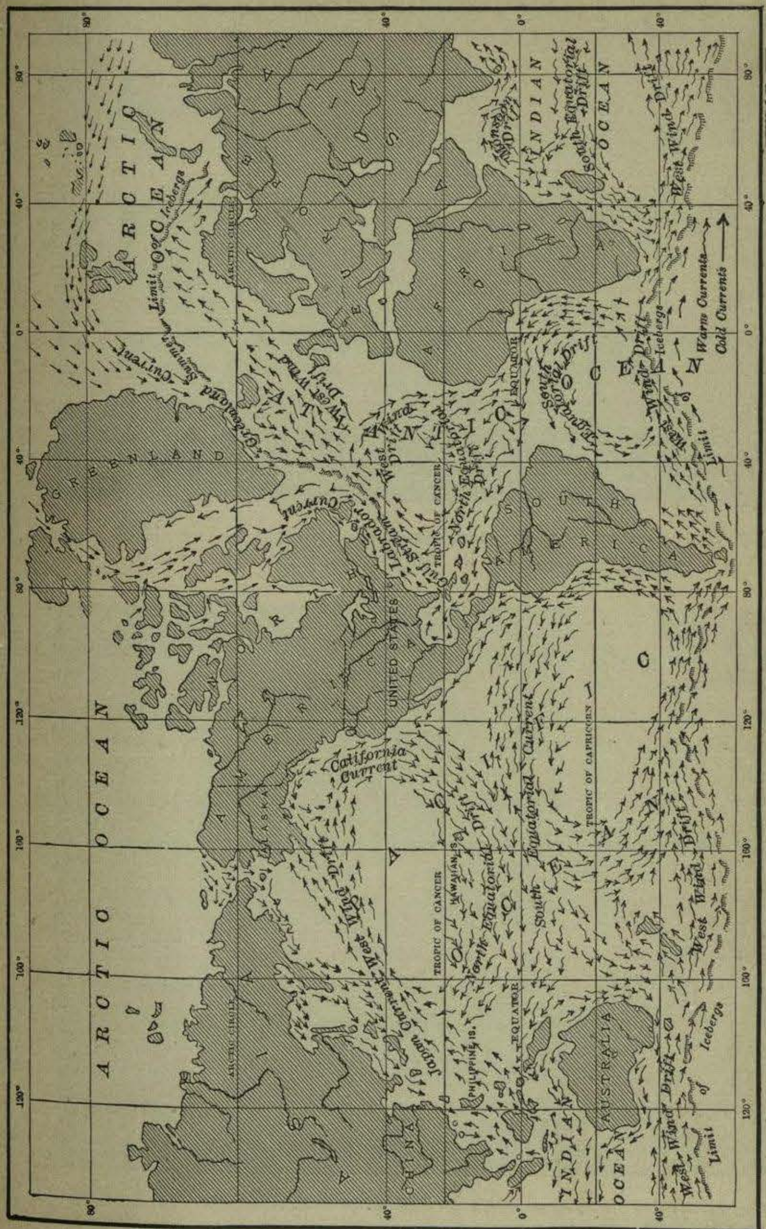

FIG. 338. — A chart showing the principal ocean currents and ocean drifts of the world. Study this map carefully. Make a sketch map somewhat like it. Compare the direction of the currents with that of the winds in Fig. 408.

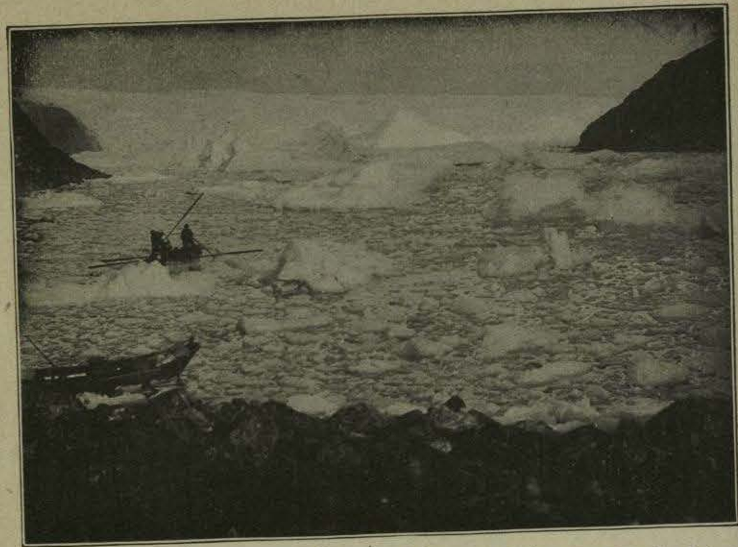

FIG. 339. — Glacier ice in Greenland (near Fig. 264), the Cornell glacier being directly opposite. The ice cliff, Fig. 265, is just over the boat.

FIG. 340. — Sea ice in summer in the Labrador Current off the coast of Baffin Land. The ship was held here for several days, then the ice was opened by tidal currents and the ship was able to leave.

100 feet above the water. Since ice floating in salt water has about seven parts below water to one above, some of these bergs extend 700 or 800 feet beneath the surface. They frequently run aground (Fig. 267), either breaking to pieces by the shock, or remaining aground till melting allows them to float away. So huge are these bergs that, before melting entirely, they may travel 1000 or 2000 miles, even down to the path followed by ocean liners. They are much dreaded, for even the largest ship may be destroyed by running into one.

Far greater icebergs are discharged from the Antarctic ice sheet, some of them rising 500 feet above the water and, consequently, measuring three quarters of a mile from base to top. They have steep sides and flat tops, and are sometimes several miles long.

Summary. — *The Arctic sea-ice, formed in winter, breaks up in summer, some of it drifting southward in the Labrador current. Huge icebergs, discharged from the Greenland ice sheet, drift in the Arctic, and still larger ones in the Antarctic.*

LIFE IN THE OCEAN.

139. Surface (Pelagic) Life. — The abundance of life in the ocean is marvelous. A pail of water dipped from the surface will contain thousands of individuals, mostly microscopic. These organisms are drifted about by winds and currents, and with them are many larger forms, some merely floating, some swimming. Pieces of floating wood have animals attached to them; and in the floating seaweed, many animals live in little worlds of their own.

The minute organisms are the source of food for many larger animals, even for the huge whales. Swimming with its mouth open, the whale strains the water to obtain its food, and thus the largest of animals feeds upon the smallest.

Among the many fishes are some, like the mackerel, which are valuable for food supply. For protection, the mackerel and some other fishes swim together in vast numbers, forming "schools" or "shoals."

Summary. — *Life is very abundant in the surface waters, both large and microscopic forms being present, the latter serving as a food supply for even the largest of animals, the whale.*

140. Life along Coasts (Littoral). — Along the coast line there is also abundant animal life; but it is more varied than in the open ocean, because the coast offers so many different conditions. Some of the littoral animals swim in the surf; others cling to the rocky coast; and others burrow in the sand or mud. Many kinds, such as clams, oysters, lobsters, and a large number of fishes, are valuable as food; others, such as sponges, precious corals, and pearls, are of value for other purposes.

Plants, as well as animals, abound on the seacoast. This is true in the mangrove swamps of the tropical zone (Fig. 379) and the salt marshes of the temperate zones (Fig. 378); it is also true of rocky coasts, to which seaweeds cling, covering the rock with a mat of plant growth (Fig. 331).

Fig. 341. — A Gloucester fishing schooner anchored on the Fishing Banks.

Some conditions are unfavorable to littoral life; for example, (1) frequent earthquake shocks, (2) the grinding of Arctic sea-ice, and (3) the grinding of moving sand and pebbles on the beaches. Other conditions are very favorable, especially the presence of food-bringing currents. Few parts of the earth have such an abundance and variety of animal life as the coral reefs (Fig. 380), which are bathed by warm ocean currents.

The influence of food-bringing currents is felt on those shallow banks, known as *fishing banks*, where large numbers of food fish live. This is well illustrated on the fishing banks off northeastern America, such as Georges and the Grand Banks of Newfoundland, which are bathed by the Labrador current. These are resorted to for cod, haddock, and halibut by fishing vessels from France, Newfoundland, Nova Scotia, and many New England ports, especially Gloucester, Mass. From a passing ocean liner, the schooners may be seen at anchor in the open ocean (Fig. 341), the men busily fishing, either from the sides of the vessel or from small, open dories. It is a hazardous calling, and many a fishing vessel has been sunk during the fierce storms, or crushed by the huge transatlantic liners. Every year, also, men in dories are separated from their vessels during fogs, which are frequent on the banks. They then drift about in the open ocean, often until they starve, or freeze, or founder.

Summary. — *Animal life along the coast is abundant and varied; there is also much plant life. Food-bringing currents especially favor life, as is illustrated on coral reefs and fishing banks, from which valuable food fish are obtained.*

141. Life on the Ocean Bottom (Abyssal). — Absence of sunlight prevents the existence of plant life in the deep sea; but, even at depths of two or three miles, there are animals on the ocean bottom (p. 174). These animals live in darkness, in water almost at the freezing point, and under a pressure of many tons.

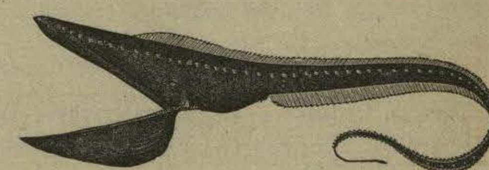

Fig. 342. — A deep-sea fish.

The conditions on the ocean bottom are very uniform: summer and winter are alike; day and night are dark; everywhere it is cold; and the sea floor is a monotonous expanse of ooze or clay. The nature of animal life varies with the depth because of differences in temperature; and where the water is very cold, animals are scarce and have little vitality. The supply of

FIG. 343.—A stalked crinoid from the deep sea.

oxygen, brought by the slowly moving bottom current (p. 184), and the supply of food, which settles down to the bottom as organisms at the surface die and slowly sink, also limit abyssal life.

Under such uniform conditions it is not strange that many peculiar forms of animal life should be found in the deep sea. Some of them, like the stalked crinoids (Fig. 343), belong to types once abundant, but now living only on the ocean bottom. There they have been able to survive, as in an asylum, while those which were out in the world, and exposed to the struggle that goes on there, have been exterminated.

Summary. — *There is wonderful uniformity of conditions in the deep sea, in which animals, but no plants, live. The abundance and distribution of animal life are influenced mainly by temperature, oxygen supply, and food supply.*

TOPICAL OUTLINE, QUESTIONS, AND SUGGESTIONS.

TOPICAL OUTLINE. — 124. **Oceanography.** — Definition; exploring expeditions; cables; sounding; water samples; ocean-bottom mud; temperature; dredging.

125. **Ocean Basins.** — General condition; deep-sea plains; deeps; elevations; Atlantic, — deepest point, volcanoes, mid-Atlantic ridge; Pacific, — volcanic chains, deepest point, other deeps; Arctic; Southern Ocean.

126. **Deposits on the Ocean Bottom.** — (A) *Rock fragments:* source; deposit; fossils. (B) *Ocean-bottom oozes:* absence of rock waste; area of ooze; materials in ooze; source of organisms; globigerina ooze; pteropod ooze; diatom ooze. (C) *Red clay:* solution of shells; insoluble parts; red color; slowness of accumulation; proofs.

127. **Land and Ocean-bottom Topography.** — Mountain folding and volcanic action; erosion; sediment; result of differences.

128. **Surface of the Sea.** — Sea level; effect of continents; of winds and storms; of deposit of sediment; of sinking ocean bottom.

129. **Composition of Sea Water.** — Original condition; increase in saltness; proportion of salt; other mineral substances; amount of salt; importance; carbonate of lime; presence of air; importance.

130. **Density and Pressure of Sea Water.** — (*a*) Density: average density; effect of fresh water; of evaporation. (*b*) Pressure: amount; reason for no effect on animals; animals brought to the surface; density of ocean-bottom water.

131. **Color and Light.** — (*a*) Color: entrance of sunlight; blue color; green color; Yellow River; Red Sea. (*b*) Light: darkness of ocean bottom; blind fish; phosphorescence on ocean bottom; at the surface.

132. **Temperature of the Oceans.** — From tropical to frigid zones; inclosed seas; decrease downward; ocean bottom; cooling of fresh and salt water; circulation; effect on animals; inclosed sea bottoms.

133. **Wind Waves.** — Cause; nature of movement; height; crest; trough; whitecaps; rate of movement; effects on vessels; use of oil; rollers; breakers; undertow; movement of rock fragments.

134. **Other Waves.** — Earthquake waves, — cause, size, effects, occurrence, distance of travel; iceberg waves; hurricane waves.

135. **Tides.** — (*a*) Nature of tides: time of passage; tidal range; increase on coast; movement in open ocean; currents on coast; flow; ebb. (*b*) Influence of coast: ordinary range; effect of V-shaped bays; of broadening bays; Mediterranean; races; examples; bore. (*c*) Influence of moon's phases: spring tides; neap tides; relation of tides to moon. (*d*) Effects of tides: on deposit of strata; on deposits in harbors; on circulation of water in harbors; on navigation.

136. **Ocean Currents.** — Early knowledge; effect of temperature differences; of steady winds; resemblance between winds and currents; a drift; a stream; Equatorial Drift; effect of continents; effect of rotation; Sargasso Sea; Gulf Stream; North Atlantic Eddy; West Wind Drift; Pacific eddies; West Wind Drift of Southern Ocean; Labrador Current; compare European and American coasts.

137. **Effects of Ocean Currents.** — Climate; Nansen's journey; effect on navigation; fog; ice; oxygen and food.

138. **Ice in the Ocean.** — (*a*) Sea ice: depth; leads; pack ice; travel over the ice; ice floes. (*b*) Icebergs: source; size; grounding; distance traveled; Antarctic bergs.

139. **Surface (Pelagic) Life.** — Abundance; modes of life; whales; mackerel.

140. **Life along Coasts (Littoral).** — Varied conditions; valuable animals; plant life; unfavorable conditions; favorable conditions; fishing banks, — location, food fish, fishing, dangers.

141. **Life on the Ocean Bottom (Abyssal).** — Plants; animals; surroundings; temperature; oxygen; food; survival of types.

QUESTIONS. — 123. In what ways is the ocean of importance?

124. What is oceanography? What expeditions have been engaged in deep-sea exploration? How is the depth of the sea learned? What facts are learned during a sounding? How is dredging carried on?

125. What is the condition of the ocean bottom? What irregularities occur? What irregularities are found in the Atlantic? In the Pacific? What is known of the Arctic and Southern oceans?

126. (A) What is the nature of the deposit near the coast? (B) Why is ooze deposited far from land? Of what is it composed? (C) What is the origin of red clay? Prove that it is forming slowly.

127. Why are land and ocean-bottom topography different?

128. What is sea level? How is this level changed?

129. What is the origin of the mineral substances in sea water? What mineral substances are there? How much salt is there? Of what importance is the carbonate of lime? The air?

130. What causes water to vary in density? What is the pressure on the ocean bottom? Why do not animals feel it? What would be the condition if the ocean-bottom water were compressed like the air?

131. What causes are there for the different colors of the ocean? What light is there on the ocean bottom?

132. What causes differences in temperature of the ocean-surface waters? What are the temperature conditions below the surface? Why is the bottom temperature lower than that in lakes? What is the cause of the slow circulation? What proof is there of it?

133. What causes waves? What is the real movement of the water? What causes whitecaps? How high may waves be? How fast may they move? What damage may they do to ships? How may this danger be lessened? What is the cause of rollers? What causes breakers? What is undertow? How are rock fragments carried away?

134. What causes earthquake waves? What are some of their effects? What other causes are there for waves?

135. To what height does the tidal wave rise? Under what conditions are tidal currents formed? What is flow? Ebb? What happens as tides enter narrowing bays? Where they enter broadening bays? Give an illustration. What causes tidal races? Give illustrations. What is the bore? What reasons are there for connecting tides with the moon? Name some important effects of tides.

136. What early knowledge of ocean currents was there? What effect have differences in temperature on ocean movements? What effect has the wind? Describe the system of currents in the Atlantic Ocean, and show how it is related to winds. Describe and explain the Gulf Stream. What is the Sargasso Sea? What currents are found in the Pacific? Other oceans (Fig. 338)? Describe the Labrador Current.

137. Name the important effects of ocean currents.

138. What are the characteristics of sea ice? Describe the icebergs of the Arctic. Of the Antarctic.

139. What are the conditions of pelagic life?

140. How do the conditions surrounding littoral life vary? In what situations are littoral plants found? What conditions oppose littoral life? What conditions favor it? Why are fishing banks the home of food fish? What dangers accompany the fishing?

141. What conditions influence life on the ocean bottom?

SUGGESTIONS. — (1) Prove that salt water is more dense than fresh, by putting shot in a bottle until it will barely sink in fresh water, taking care to cork it; then dissolve salt in the water and again put the bottle in it. (2) Cut a cube of ice and place it in fresh water. Measure the amount above and below water. Place it in salt water and measure again. What is the result? (3) In a large pan, or tub, of water place a bottle, partly submerged. Start waves by blowing on one end. Note how they travel beyond their source. Note the movements of the bottle as the waves pass under it. Have the students describe its movements. At one end of the pan make a shelving beach of sand, with a cliff at one end. Observe and describe the action of the waves as they approach the shore. What differences are there in the behavior of the waves on the beach and on the cliff? Are fragments removed? Where do they go? Make waves that advance diagonally on the shore and observe the movement of the fragments. To see this clearly, place at one point some colored objects, like bits of colored glass, and note how they move. (4) In the pan build a coast, roughly, like that of North and South America. Sprinkle sawdust on the water and blow over its surface from both sides of a line (the equator), to imitate the trade winds approaching the equator. Watch the drift of water. Do you see any resemblance to the ocean-current systems of the Atlantic? (5) Take the temperature at the bottom of the pan near the middle line, then place ice in the water as far away from the middle as possible. Be careful not to stir the water. After the ice has melted, again take the temperature under the middle line. What is the difference? It would be possible also to imitate the conditions in the Gulf of Mexico (p. 184). (6) If the school is by the sea, or even near a lake or pond, waves and wind-formed currents should be studied. Note their force, form, and effects. (7) If by the seashore, the tides should be studied. Observe time of low and high tides for three successive days. These facts may be obtained from an almanac, or better, from the *Tide Tables* published by the U. S. Coast Survey at Washington, the tables for the year, for the Atlantic (15 cents) and Pacific (10 cents) coasts. Observe the time of spring and neap tides. How do they compare with the phases of the moon? What is the range of the tide in each case? Are there any tidal currents near at hand? Are the tides of any importance in your harbor? That is, do they do any harm or good? (8) On cross-section paper, plot a curve to represent the high and low tide for a month (obtaining the facts from the Tide Tables). Let each of twelve students do a different month and then paste them all together. Above the curves indicate each quarter of the moon. Have the students study these to see how closely the phases of the moon coincide with variations in range of the tide. Let the vertical side of each square represent a foot of tidal rise, and the horizontal side, three hours of time. (9) On an outline map of the world sketch the ocean currents from the chart in the book (Fig. 338).

Reference Books. — Thompson, *Depths of the Sea*, 2 vols., Macmillan Co., New York, 1873, $7.50; *The Atlantic*, Macmillan & Co., London, 1877 (out of print); Agassiz, *Three Cruises of the Blake*, 2 vols., Houghton, Mifflin & Co., Boston, 1888, $8.00; Wild, *Thalassa*, Marcus Ward & Co., London, 1877, 12 shillings; Moseley, *Notes by a Naturalist*, Murray, London, 1892, 9 shillings; Sigsbee, *Deep Sea Sounding and Dredging*, U. S. Coast Survey, Washington, D.C., 1880; Tanner, *Deep Sea Exploration*, p. 1, 1892 Report, U. S. Fish Commission, Washington, D.C.; Darwin, *The Tides*, Houghton, Mifflin & Co., Boston, 1898, $2.00; *Tide Tables for the Year*, U. S. Coast Survey, Washington, $0.25; Pillsbury, *The Gulf Stream*, Annual Report, U. S. Coast Survey for 1890, Appendix 10, Washington, D.C.

CHAPTER XI.

SHORE LINES.

142. Importance of Shore Lines. — Some of the busiest centers of human industry are located on or near the seacoast. The great and increasing trade that uses the ocean as a highway converges toward these centers; and to and from them, by river, canal, and railway, there is a steady movement of goods for shipment or for distribution.

So important is the coast line that charts have been made of all parts of it that are reached by the vessels of commerce. Governments maintain bureaus, like the United States Coast Survey, whose duty it is to map the coast, to determine by accurate soundings the depth of water, and to detect and record all changes, such as shifting of channels, which might endanger ships. In addition, our government annually spends large sums of money for the improvement of harbors. This money is used in building breakwaters where no natural harbors exist; in dredging out the sand and mud that waves and currents deposit; and in building jetties and other structures to control the deposits of sediment and keep channels clear.

The approach to the coast, especially in times of storm and fog, is accompanied by so many dangers — from hidden reefs, islands, and projecting headlands — that all civilized nations spend large sums in the effort to lessen these perils. To warn sailors, or to guide them into port, lighthouses are built on exposed points and light-ships anchored on dangerous shoals; and, on the charts, the location and characteristics of these lights are shown. On approaching the coast at night, the first sign of land is the gleam of the lighthouse; and by the color, brilliancy, nature of