Oceanography

Ocean Facts

Area:

about 140 million square miles (362 million sq km), or nearly 71% of the Earth's surface

Average Depth:

12,200 feet (3,720 m)

Deepest point:

36,198 feet (11,033 m) in the Mariana Trench in the western Pacific

Mountains:

The mid-ocean ridges form a great mountain range, almost 40,000 miles (64,000 km) long, that weaves its way through all the major oceans. It is the largest single feature on Earth.

Highest Mountain:

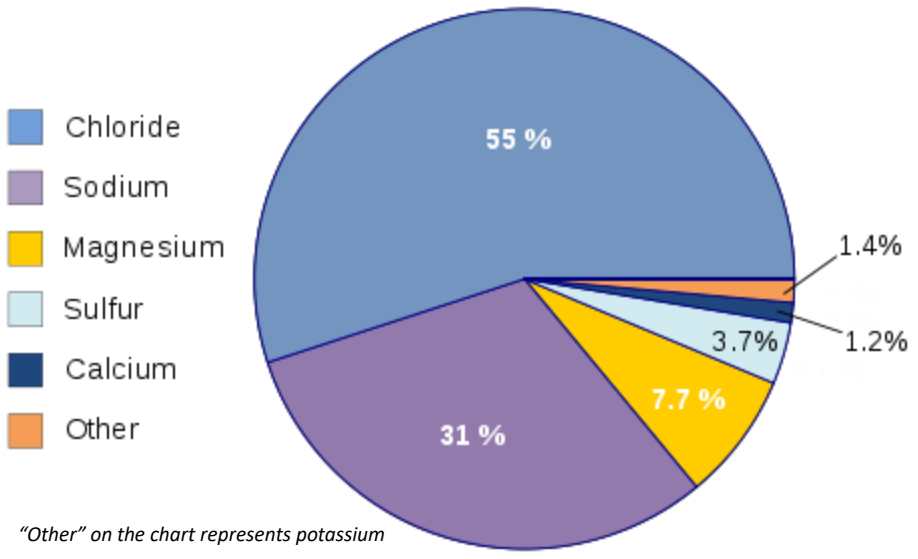
Mauna Kea, Hawaii, rises 33,474 feet (10,203 m) from its base on the ocean floor; only 13,680 feet (4,170 m) are above sea level.

Temperature:

The average temperature of all ocean water is about 3.5° C.

Composition of Ocean Water

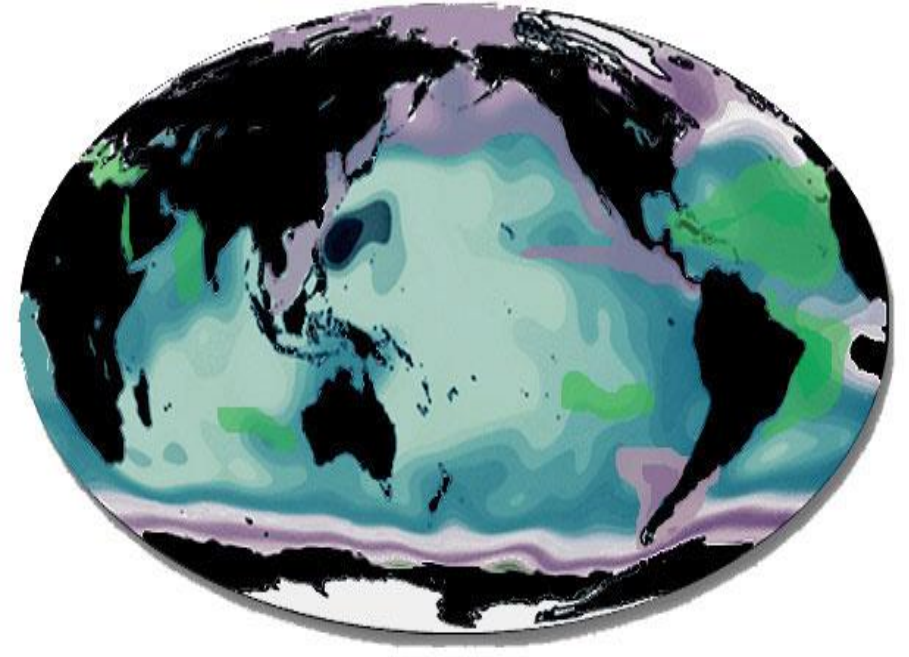
Almost anything can be found in seawater. This includes dissolved materials from Earth's crust as well as materials released from organisms. The most important components of seawater that influence life forms are salinity (amount of salts in the ocean water), temperature, dissolved gases (mostly oxygen and carbon dioxide), nutrients, and pH.



"Other" on the chart represents potassium

An average ocean water sample of one kilogram in mass contains about 35 grams of dissolved salts. Ions of sodium and chlorine make up the largest percentage. Only six ions make up more than 99 percent of the total dissolved load of ocean water.

Oceanographers report salinity (total salt content) and the concentrations of individual chemical constituents in sea water -- chloride, sodium, or magnesium for example -- in parts per thousand, for which the symbol o/oo is used. That is, a salinity of 35 o/oo means 35 pounds of salt per 1,000 pounds of sea water.



The salinity map showing areas of high salinity (36 o/oo) in green, medium salinity in blue (35 o/oo), and low salinity (34 o/oo) in purple.

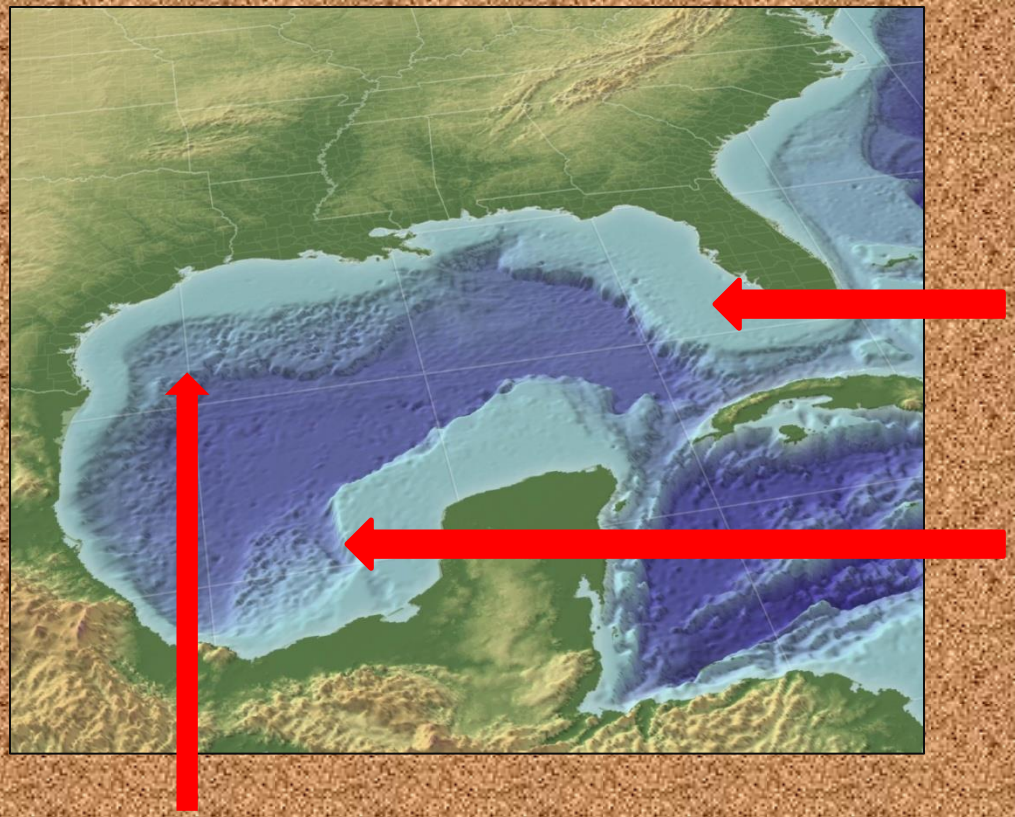
Salinity is rather stable but areas in the North Atlantic, South Atlantic, South Pacific, Indian Ocean, Arabian Sea, Red Sea, and Mediterranean Sea tend to be a little high (green). Areas near Antarctica, the Arctic Ocean, Southeast Asia, and the West Coast of North and Central America tend to be a little low (purple).

The salinity of ocean water varies. It is affected by such factors as melting of ice, inflow of freshwater from rivers, evaporation, rain, snowfall, wind, wave motion, and ocean currents that cause horizontal and vertical mixing of the saltwater.

Topography of the Ocean Floor

Over half a mile taller, from base to summit, than Mt. Everest, Mauna Kea in Hawaii is more than 6 miles tall from its base on the ocean floor, to its summit two miles above the surface of the Pacific Ocean. This island mountain is only one of many features found on the ocean floor. Besides being the base for islands, the ocean floor also includes continental shelves and slopes, submarine canyons, mid-ocean ridges, trenches, abyssal hills, abyssal plains, volcanoes, and seamounts.

As the continent ends and we approach the ocean, we see some drastic changes in the Earth's geology. This transitional area is known as the continental margin**.** This area includes the continental shelf, the continental slope and the continental rise.



CONTINENTAL SHELF: The continental shelf is a broad, relatively shallow submarine terrace of continental crust forming the edge of a continental landmass.

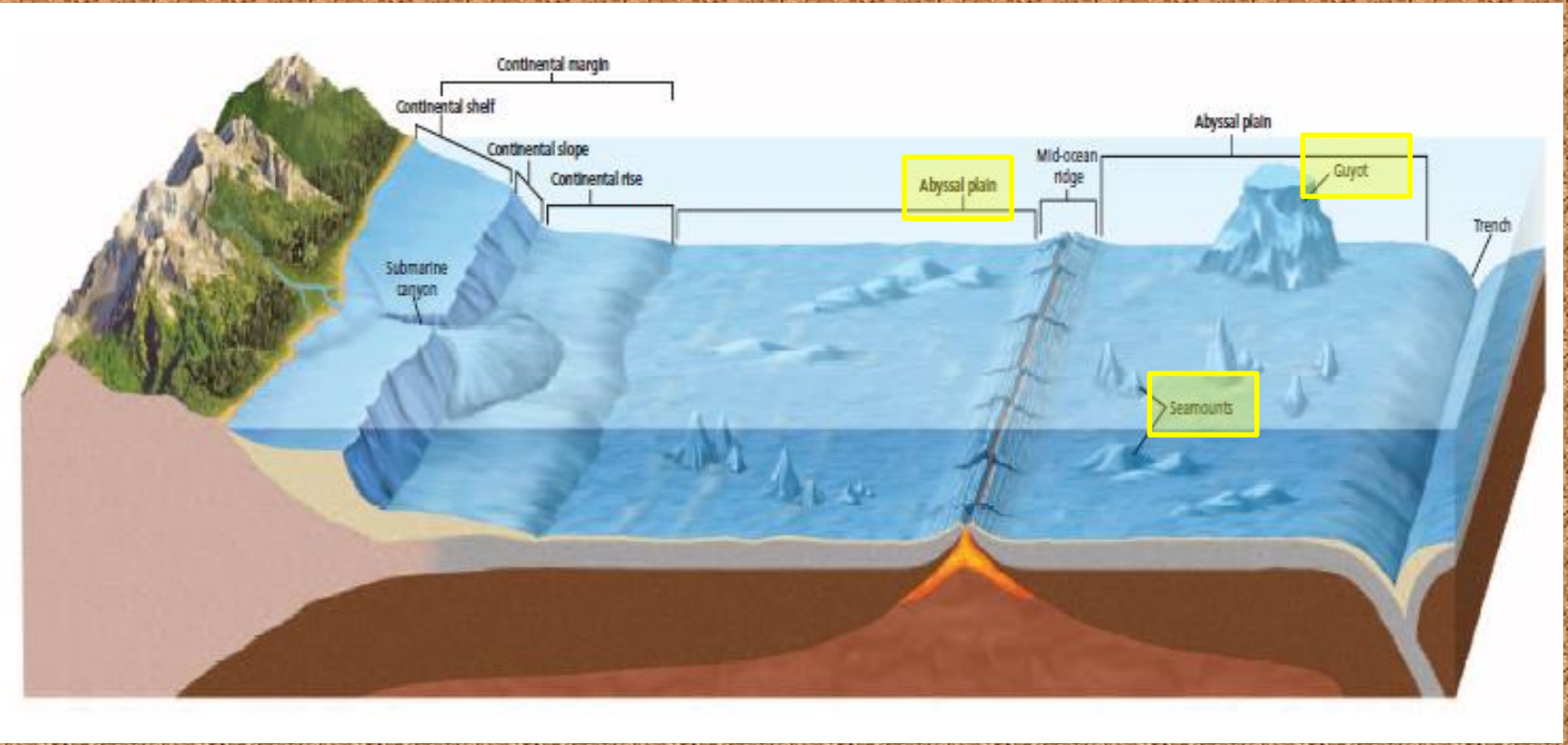
CONTINENTAL SLOPE: The continental slope marks the boundary between the continental type granite crust and the oceanic basaltic crust. Occasionally, you will observe deep "V" -shaped valleys cut into the hard rock of the continental slope. These are called submarine canyons. Geologists speculate that these canyons are formed due to seismic activity, or perhaps eroded into the rock of the slope by powerful ocean currents.

CONTINENTAL RISE: At the bottom of the continental slope, one will find the continental rise, an underwater hill composed of tons of accumulated sediments.

ABYSSAL PLAIN: The abyssal plain is an extremely flat area of the sea floor.

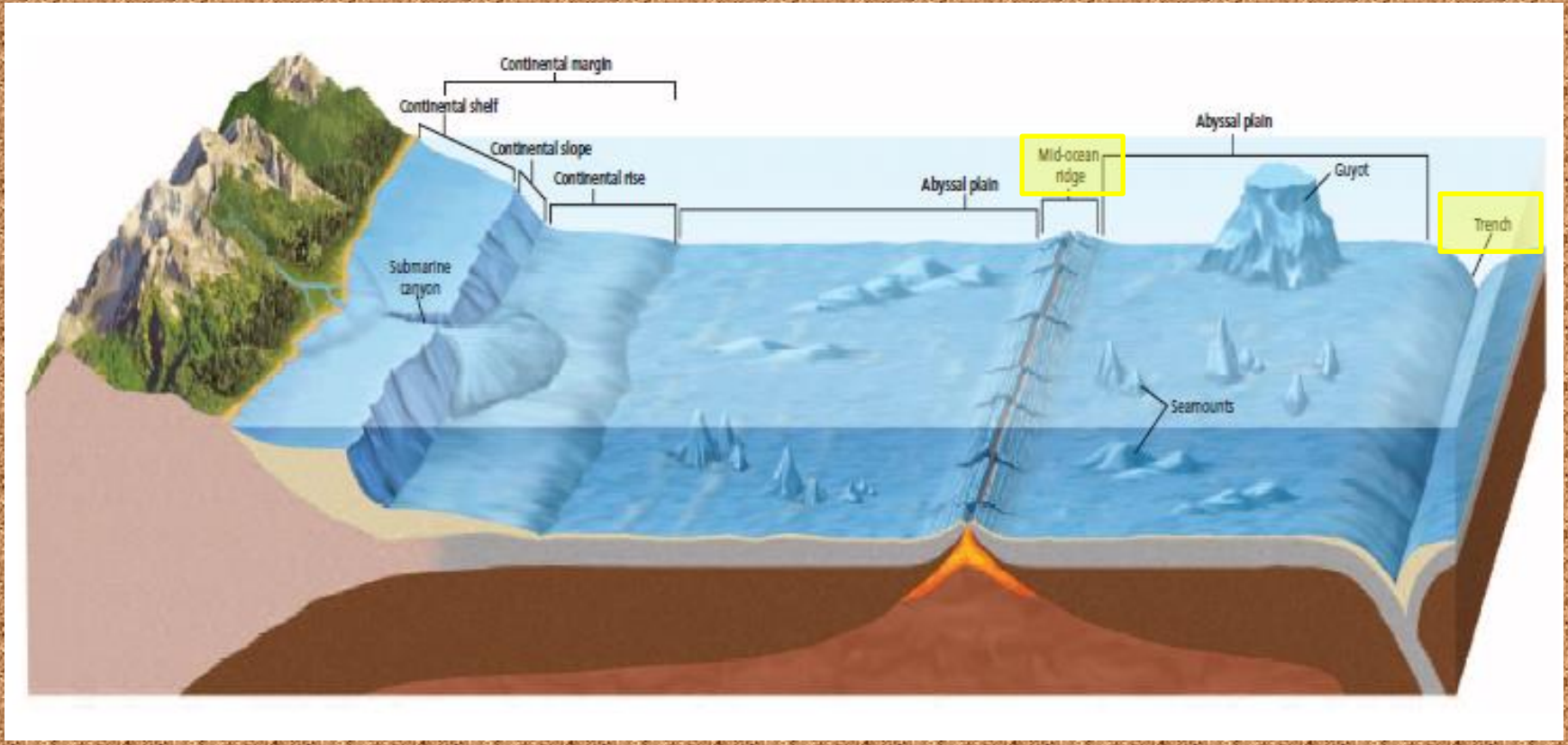
SEAMOUNT: Seamounts are underwater, volcanic mountains that occasionally will rise to the surface of the ocean. If they do rise to the surface, they are called islands.

GUYOT: A guyot is a flat-topped submarine mountain that once emerged above sea level as a volcanic island, and then re-submerged when volcanic activity ceased and wave erosion wore away the peak.

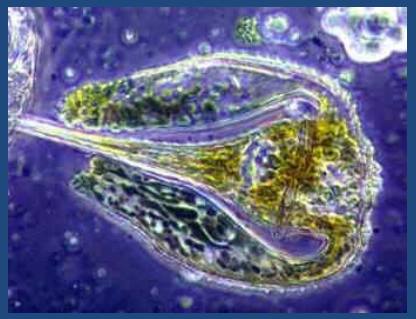


TRENCH: A deep-sea trench is a narrow, elongate, v-shaped depression in the ocean floor. Trenches are the deepest parts of the ocean

MID-OCEAN RIDGE AND RIFT VALLEY: A mid-ocean ridge is an underwater mountain system that consists of various mountain ranges, typically having a valley known as a rift valley running along its spine.



Oceanic Life



- Plankton
  - Weakly swimming, free-floating organisms carried by the currents

- Nekton
  - strongly swimming consumers

- Benthos
  - bottom dwellers

Plankton

- Weakly swimming, free-floating organisms carried by the currents

- Three major types:
  - phytoplankton (plant plankton, producers, support most aquatic food chains and food webs)
  - zooplankton (animal plankton, primary consumers (herbivores), single-celled protozoa to large invertebrates such as jellyfish)
  - ultraplankton (extremely small, photosynthetic bacteria)

Nekton

- Strongly swimming consumers

- Examples: fish, turtles, whales, squid

Benthos

- Live on the bottom of freshwater or saltwater
- Examples: barnacles, oysters, worms, lobsters, crabs, starfish

Marine Life Zones

Saltwater oceans cover about 71% of the earth.

<u>Oceans have three major life zones</u>:

1. Intertidal zone
2. Neritic (coastal) zone
3. Open sea (open ocean) zone

Intertidal Zone

The area of shoreline between low and high tides is called the intertidal zone.

This is not an easy place to live. Organisms must be able to avoid being swept away or crushed by waves, and avoid or cope with being immersed during high tides and left high and dry (and much hotter) at low tides. They must also survive changing levels of salinity when heavy rains dilute salt water. To deal with such stresses, these organisms hold on to something, dig in, or hide in protective shells.

Some shorelines are rocky and some are sandy.

Neritic or Coastal Zone

The warm, nutrient-rich shallow water that extends from the low-tide mark on land to the gently sloping, shallow edge of the continental shelf (the submerged portion of the continent).

This zone has numerous interactions with the land and thus human activities easily affect it.

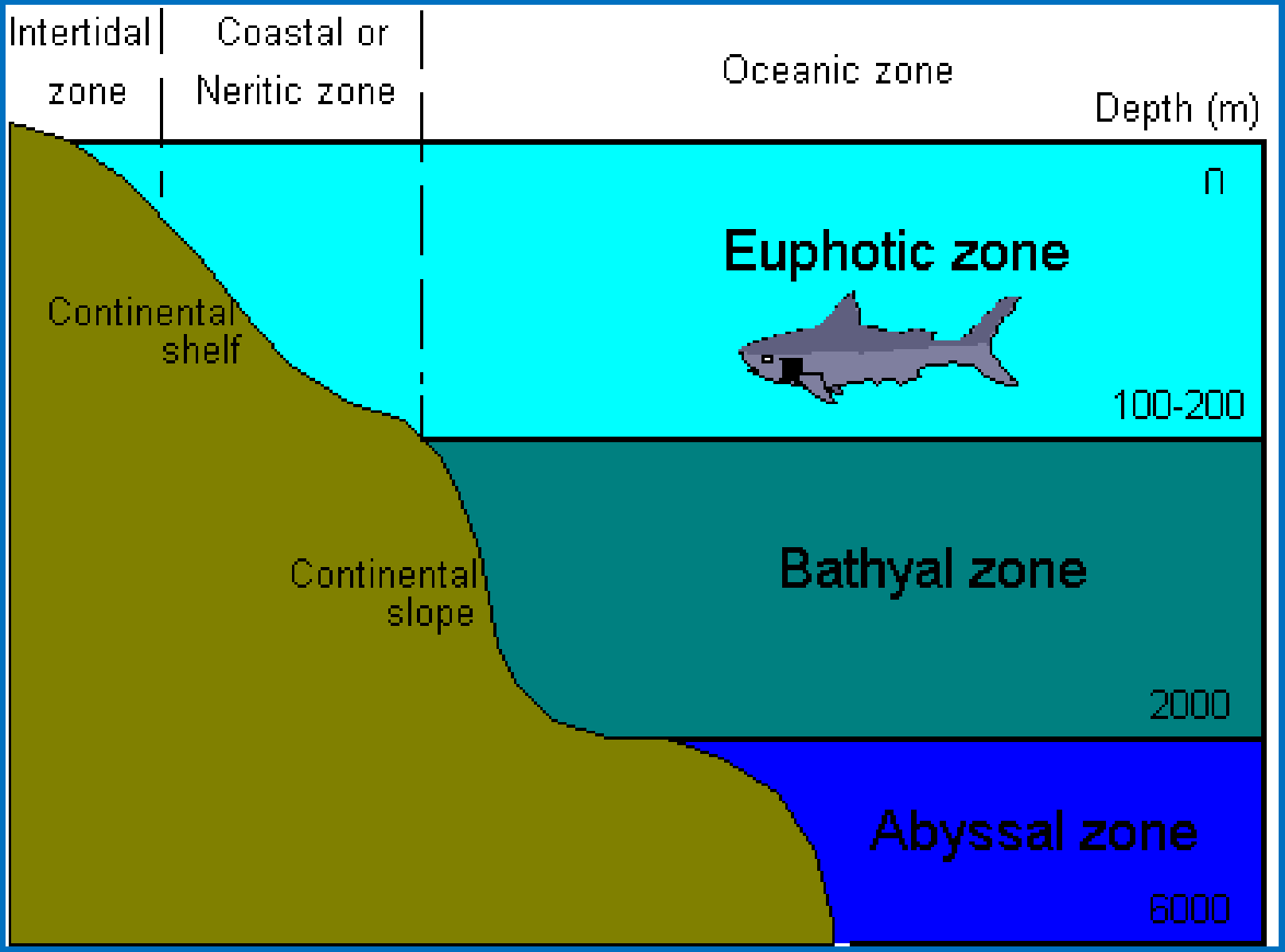
Although it makes up less than 10% of the world's ocean area, the coastal zone contains 90% of all marine species and is the site of most large commercial marine fisheries.

Open Sea (Open Ocean) Zone

The open ocean consists of a brightly lit surface layer (**euphotic**), a dimly lit middle layer (**bathyal**), and a dark bottom zone (**abyssal**).

The sharp increase in water depth at the edge of the continental shelf separates the coastal zone from the vast volume of the ocean.

The open ocean zone is divided on the basis of the penetration of sunlight.


Intertidal zone
Coastal or Neritic zone
Oceanic zone
Depth (m)
0
Euphotic zone
Continental shelf
100-200
Continental slope
Bathyal zone
2000
Abyssal zone
6000

Euphotic Zone

The lighted upper zone of the open ocean where floating drifting phytoplankton carry out photosynthesis.

Nutrient levels are low (except around upwellings).

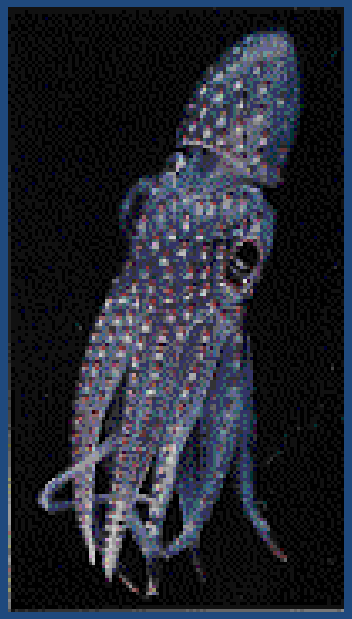
Dissolved oxygen levels are high due to photosynthesis.

Large, fast-swimming predatory fish such as swordfish, sharks, and blue fin tuna populate this zone.

Bathyal Zone

The dimly lit middle zone that does not contain photosynthesizing producers because of the lack of sunlight.

Various types of zooplankton and smaller fish populate this zone.



Abyssal Zone

Dark , very cold, and has little dissolved oxygen

There are enough nutrients on the ocean floor to support about 98% of the species living in the ocean.

Most organisms of the deep waters and ocean floor get their food from showers of dead and decaying organisms (marine snow) drifting down from upper lighted levels of the ocean.

Coral Reefs

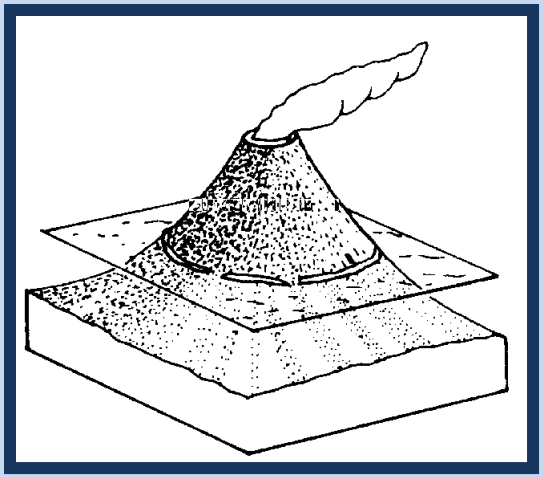
Coral reefs form in clear, warm, coastal waters of the tropics and subtropics.

These reefs are vulnerable to damage because they grow slowly and are disrupted easily. They thrive only in clear, warm, are fairly shallow water of constant high salinity.

Corals can live only in water with a temperature of 18-30 degrees Celsius (64-86 degrees Fahrenheit). Coral bleaching can be triggered by an increase of just 1 degree Celsius (1.8 degrees Fahrenheit) above this maximum temperature.

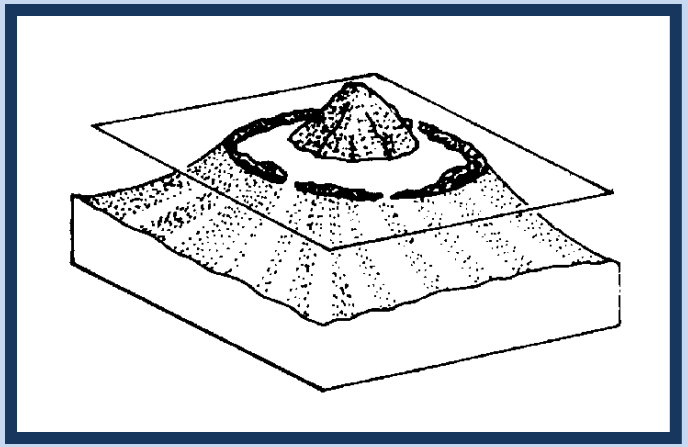
Types of Coral Reefs

1. Fringing Reef



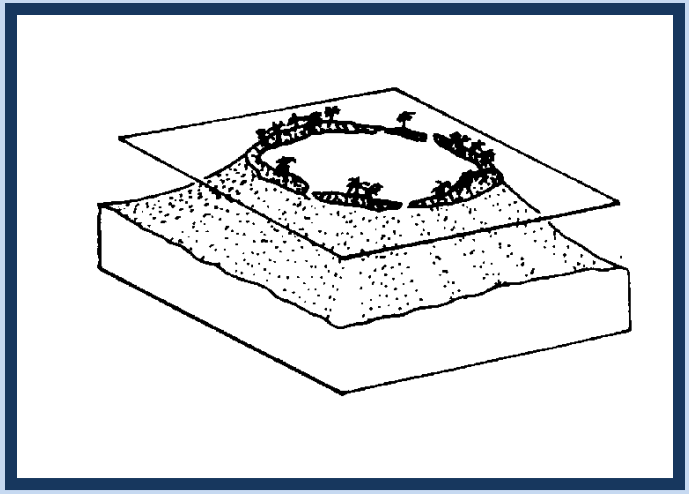
Types of Coral Reefs

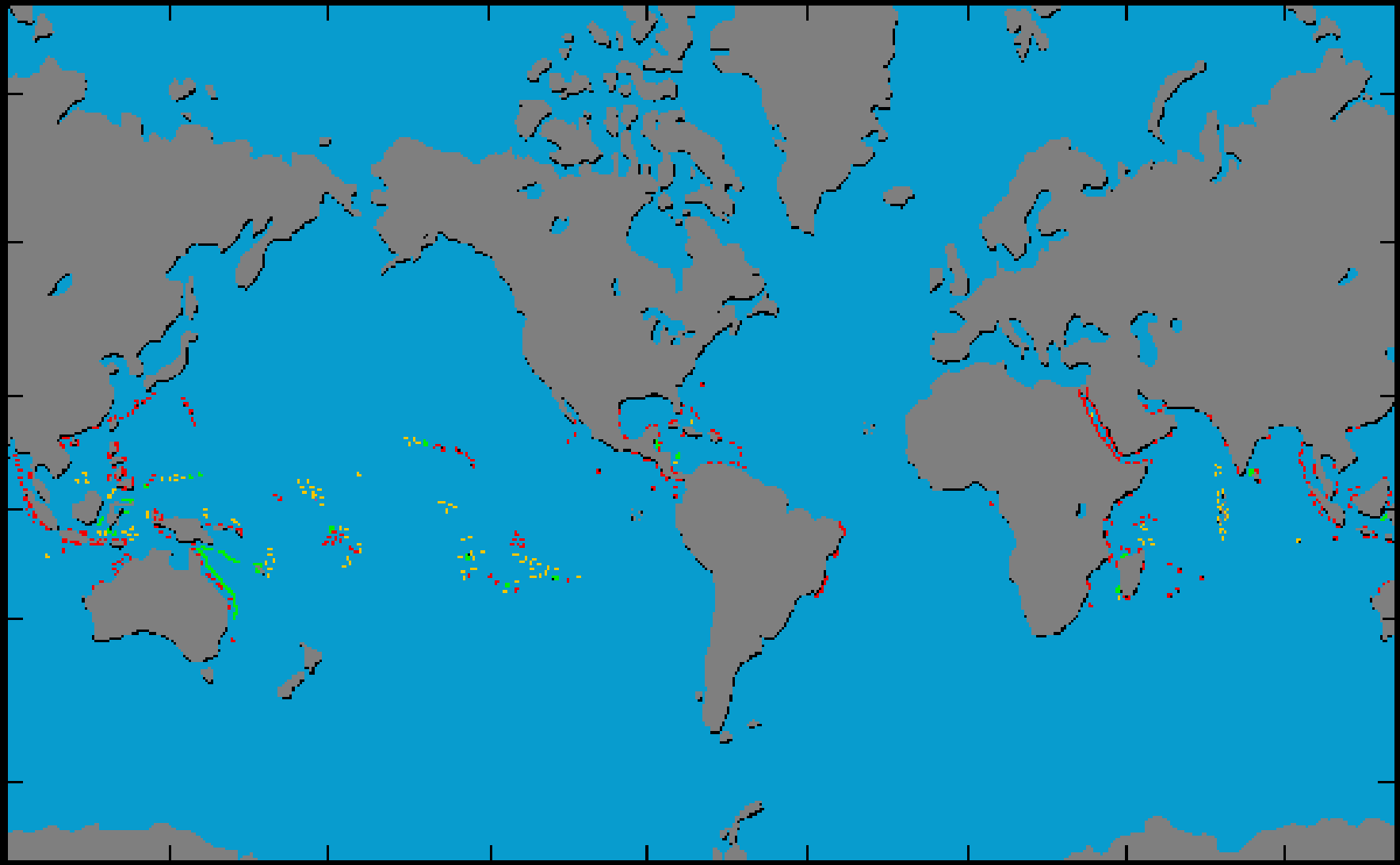
2. Barrier Reef



Types of Coral Reefs

3. Atoll





Red - Fringing

Green - Barrier

Yellow- Atolls

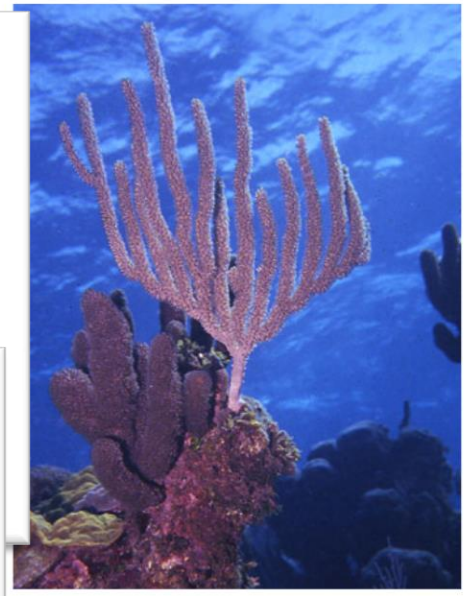
The biodiversity of coral reefs can be reduced by natural disturbances such as severe storms, freshwater floods, and invasions of predatory fish. Throughout history, coral reefs have been able to adapt to such natural changes.

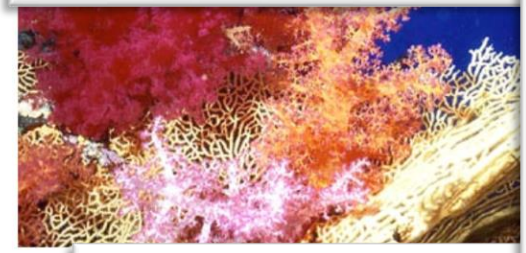
Click picture above for a 4 minute coral video.

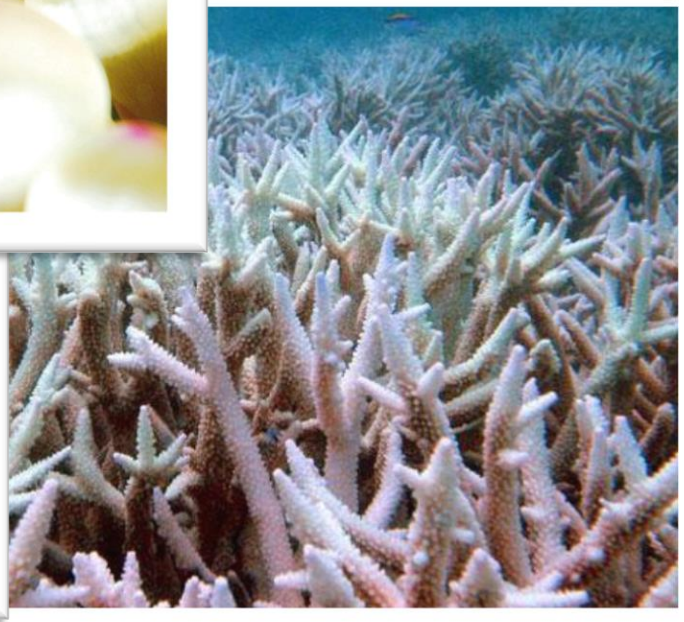
Today the biggest threats to the survival and biodiversity of many of the world's coral reefs come from sediment runoff and other human activities.

Good news: There is growing evidence that coral reefs can recover when given a chance. When localities or nations have imposed restrictions on reef fishing or reduced inputs of nutrients and other pollutants, reefs have rebounded.

Some 300 coral reefs in 65 countries are protected as reserves or parks, and another 600 have been recommended for protection. Protecting reefs is difficult and expensive.

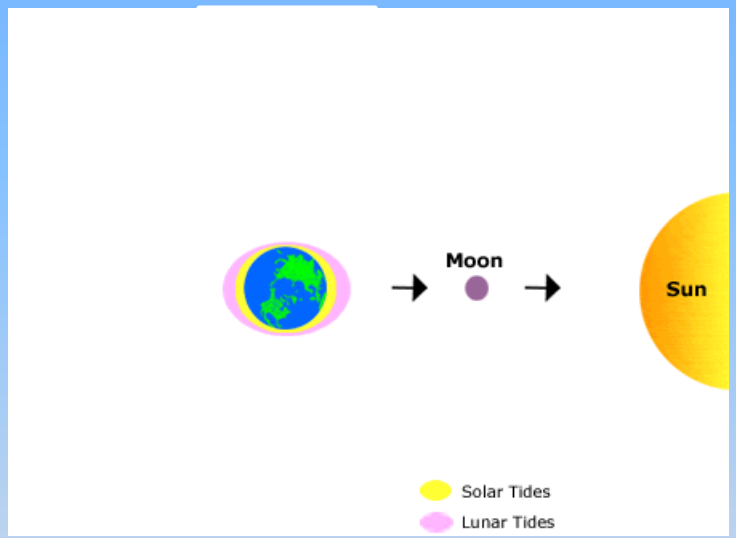






Tides

Tides are the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the Moon and the Sun and the rotation of the Earth.



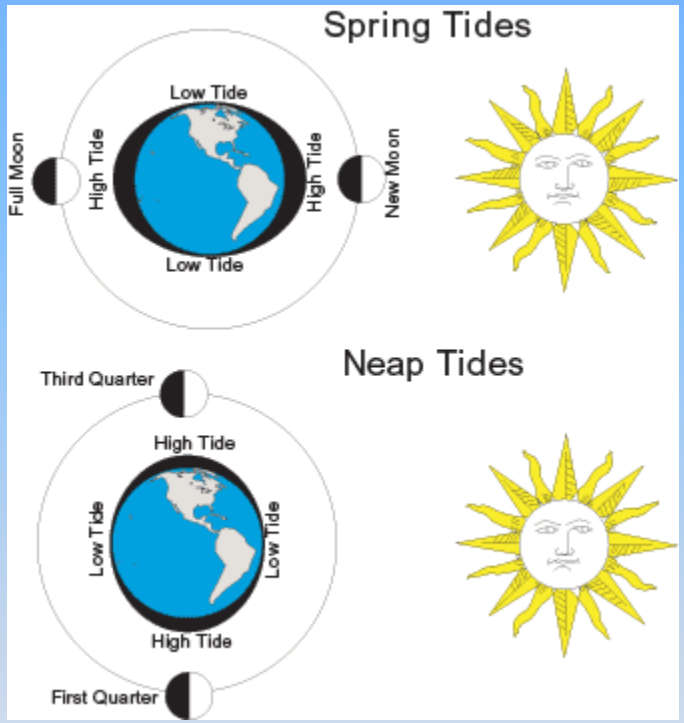
Most places in the ocean usually experience two high tides and two low tides each day (semidiurnal tide), but some locations experience only one high and one low tide each day (diurnal tide). The times and amplitude of the tides at the coast are influenced by the alignment of the Sun and Moon, by the pattern of tides in the deep ocean and by the shape of the coastline.

Special Types of Tides

There are two special types of tides: **spring tides and neap tides**.

When the sun, moon, and Earth are in a straight line alignment (at the time of the new or full moon), the solar tide has an additive effect on the lunar tide, creating extra-high high tides, and very low, low tides — both commonly called **spring tides**.

One week later, when the sun and moon are at right angles to each other (at the time of the first or last quarter moon), the solar tide partially cancels out the lunar tide and produces moderate high tides known as **neap tides**.



Click picture above for a 13 minute video by Neil deGrasse Tyson on tides.

During each lunar month, two sets of spring and two sets of neap tides occur.

Name: _____ Date: _____ Period: _____

PowerPoint Notes Handout: Oceanography

Ocean Facts

- *Area:* about 140 million square miles (362 million sq km), or nearly _____% of the Earth's surface
- *Average Depth:* _____ feet (3,720 m)
- *Deepest point:* 36,198 feet (11,033 m) in the _____ in the western Pacific
- *Mountains:* The mid-ocean ridges form a great mountain range, almost 40,000 miles (64,000 km) long, that weaves its way through all the major oceans. It is the largest single feature on Earth.
- *Highest Mountain:* Mauna Kea, _____, rises 33,474 feet (10,203 m) from its base on the ocean floor; only 13,680 feet (4,170 m) are above sea level.
- *Temperature:* The average temperature of all ocean water is about _____° C.

Composition of Ocean Water

Almost anything can be found in seawater. This includes dissolved materials from Earth's crust as well as materials released from organisms. The most important components of seawater that influence life forms are _____ (amount of salts in the ocean water), _____, dissolved gases (mostly oxygen and carbon dioxide), nutrients, and _____. An average ocean water sample of one kilogram in mass contains about _____ of dissolved salts. Ions of _____ and _____ make up the largest percentage. Only six ions make up more than 99 percent of the total dissolved load of ocean water.

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The salinity of ocean water varies. It is affected by such factors as _____, inflow of _____ from rivers, evaporation, _____, snowfall, wind, wave motion, and ocean currents that cause horizontal and vertical mixing of the saltwater.

Topography of the Ocean Floor

Over half a mile taller, from base to summit, than Mt. Everest, Mauna Kea in Hawaii is more than 6 miles tall from its base on the ocean floor, to its summit two miles above the surface of the Pacific Ocean. This island mountain is only one of many features found on the ocean floor. Besides being the base for islands, the ocean floor also includes continental shelves and slopes, submarine canyons, mid-ocean ridges, _____, abyssal hills, abyssal plains, volcanoes, and _____.

As the continent ends and we approach the ocean, we see some drastic changes in the Earth's geology. This transitional area is known as the _____**.** This area includes the continental shelf, the continental slope and the continental rise.

CONTINENTAL SHELF: The continental shelf is a broad, relatively _____ submarine terrace of continental crust forming the edge of a continental landmass.

CONTINENTAL SLOPE: The continental slope marks the boundary between the _____ type granite crust and the _____ basaltic crust. Occasionally, you will observe deep "V" -shaped valleys cut into the hard rock of the continental slope. These are called _____. Geologists speculate that these canyons are formed due to seismic activity, or perhaps eroded into the rock of the slope by powerful ocean currents.

CONTINENTAL RISE: At the bottom of the continental slope, one will find the continental rise, an underwater hill composed of tons of _____.

ABYSSAL PLAIN: The abyssal plain is an extremely _____ of the sea floor.

SEAMOUNT: Seamounts are _____ that occasionally will rise to the surface of the ocean. If they do rise to the surface, they are called _____.

GUYOT: A guyot is a _____ submarine mountain that once emerged above sea level as a volcanic island, and then re-submerged when volcanic activity ceased and wave erosion wore away the peak.

TRENCH: A deep-sea trench is a narrow, elongate, _____ depression in the ocean floor. Trenches are the deepest parts of the ocean

MID-OCEAN RIDGE AND RIFT VALLEY: A mid-ocean ridge is an _____ that consists of various mountain ranges, typically having a valley known as a rift valley running along its spine.

Oceanic Life

1. Plankton: Weakly swimming, _____ organisms carried by the currents
   Three major types:

   - _____ (plant plankton, producers, support most aquatic food chains and food webs)
   - _____ (animal plankton, primary consumers (herbivores), single-celled protozoa to large invertebrates such as jellyfish)
   - _____ (extremely small, photosynthetic bacteria)

2. Nekton: _____ consumers examples: _____

3. Benthos: _____ examples: _____

Marine Life Zones

Saltwater oceans cover about _____% of the earth.

Oceans have _____major life zones:

1. **Intertidal zone**
   The area of shoreline _____is called the intertidal zone. This is not an easy place to live. Organisms must be able to avoid being swept away or crushed by waves, and avoid or cope with being immersed during high tides and left high and dry (and much hotter) at low tides. They must also survive changing levels of salinity when heavy rains dilute salt water. To deal with such stresses, these organisms hold on to something, dig in, or hide in protective shells. Some shorelines are rocky and some are sandy.
2. **Neritic (coastal zone)**
   The warm, nutrient-rich shallow water that extends from the _____ on land to the gently sloping, shallow _____ (the submerged portion of the continent). This zone has numerous interactions with the land and thus human activities easily affect it. Although it makes up less than 10% of the world's ocean area, the coastal zone contains 90% of all marine species and is the site of most large commercial marine fisheries.
3. **Open sea (open ocean) zone**
   The open ocean consists of a brightly lit surface layer (_____), a dimly lit middle layer (_____), and a dark bottom zone (_____). The sharp increase in water depth at the edge of the continental shelf separates the coastal zone from the vast volume of the ocean. The open ocean zone is divided on the basis of the penetration of sunlight.

   Euphotic Zone
   The _____ upper zone of the open ocean where floating drifting phytoplankton carry out photosynthesis. Nutrient levels are low (except around upwellings). Dissolved oxygen levels are high due to photosynthesis. Large, fast-swimming predatory fish such as swordfish, sharks, and blue fin tuna populate this zone.

Bathyal Zone

The _____ middle zone that does not contain photosynthesizing producers because of the lack of sunlight. Various types of zooplankton and smaller fish populate this zone.

Abyssal Zone

_____, _____, and has little dissolved oxygen. There are enough nutrients on the ocean floor to support about 98% of the species living in the ocean. Most organisms of the deep waters and ocean floor get their food from showers of dead and decaying organisms (marine snow) drifting down from upper lighted levels of the ocean.

Coral Reefs

Coral reefs form in _____, _____, coastal waters of the tropics and subtropics. These reefs are vulnerable to damage because they grow slowly and are disrupted easily. They thrive only in clear, warm, are fairly shallow water of constant high salinity. Corals can live only in water with a temperature of 18-30 degrees Celsius (_____ degrees Fahrenheit). Coral bleaching can be triggered by an increase of just 1 degree Celsius (1.8 degrees Fahrenheit) above this maximum temperature.

Types of Coral Reefs

1. _____
2. _____
3. _____

The _____of coral reefs can be reduced by natural disturbances such as severe storms, freshwater floods, and invasions of predatory fish. Throughout history, coral reefs have been able to adapt to such natural changes.

Today the biggest threats to the survival and biodiversity of many of the world's coral reefs come from _____ and other _____. Good news: There is growing evidence that coral reefs can recover when given a chance. When localities or nations have imposed restrictions on reef fishing or reduced inputs of nutrients and other pollutants, reefs have rebounded. Some 300 coral reefs in 65 countries are protected as reserves or parks, and another 600 have been recommended for protection. Protecting reefs is difficult and expensive.

Tides

Tides are the _____ of sea levels caused by the combined effects of the gravitational forces exerted by the Moon and the Sun and the rotation of the Earth. Most places in the ocean usually experience two high tides and two low tides _____ (semidiurnal tide), but some locations experience only one high and one low tide each day (_____ tide). The times and amplitude of the tides at the coast are influenced by the alignment of the _____ and _____, by the pattern of tides in the deep ocean and by the shape of the coastline.

Special Types of Tides

There are two special types of tides: _____ tides and _____ tides. When the sun, moon, and Earth are in a straight line alignment (at the time of the new or full moon), the solar tide has an additive effect on the lunar tide, creating extra-high high tides, and very low, low tides — both commonly called spring tides. One week later, when the sun and moon are at right angles to each other (at the time of the first or last quarter moon), the solar tide partially cancels out the lunar tide and produces moderate high tides known as neap tides. During each lunar month, _____ sets of spring and _____ sets of neap tides occur.

The Tides: A Balance of Forces

Despite the fact that tides are a phenomenon familiar to most individuals, the driving forces behind the tides tend to be considered somewhat mysterious and confusing. Misconceptions about what causes tides abound and most people have only a vague awareness that the Moon is somehow involved. A global view of the tides can help explain the complex actions and interactions of the forces involved in tide formation.

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The tides can be viewed as one global wave with two crests (or tidal bulges) and two troughs (or tidal troughs). Each crest

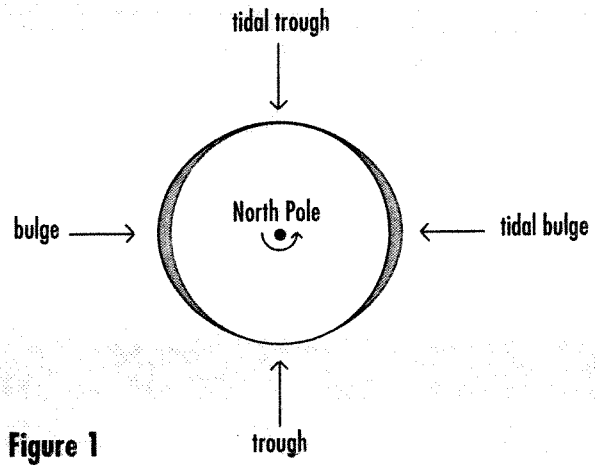


Figure 1

and trough runs the length of Earth from the North Pole to the South Pole. One bulge is always oriented toward the Moon, the other always away from the Moon. The global wave rotates slowly as Earth rotates much more rapidly underneath it. The different speeds of rotation makes the wave appear relatively stationery, and this view is therefore called the static model of tides. Figure 1 represents a simplified version of the static model.

To observers on Earth, the tidal bulges are experienced as high tides, the tidal troughs as low tides. The tides change as Earth rotates beneath the global wave. Because it takes 24 hours for Earth to make one complete rotation (360°) on its axis, it might be predicted that consecutive high or low tides would occur exactly 12 hours apart (the time it would take for Earth to complete one-half a rotation (180°) from one tidal bulge or trough to the other). In reality, the period between consecutive

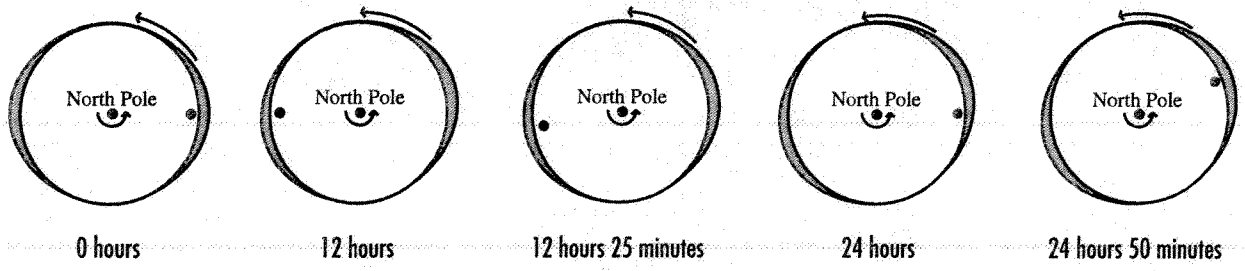
high or low tides is approximately 12 hours, 25 minutes. The period is 25 minutes longer than predicted because of the rotation of the global wave. The global wave rotates because the tidal bulge facing the Moon is drawn by the Moon's gravity as the Moon revolves around Earth. Because the wave rotates in the same direction as Earth but more slowly, it takes longer than 12 hours for a location on Earth to rotate from one point directly beneath a tidal bulge or trough to the next.

An analogy can help provide a clearer picture of this situation. Imagine that two people—a runner and a walker—are standing still at the same point on an oval, quarter-mile track. The runner can run around the track in one minute; the walker goes much more slowly. They both start around the track at the same instant and in the same direction—one running, the other walking. In one minute, the runner will be back at the starting point; but he will not have caught up with the walker, who has also moved around the track from the starting point. More time will be required for the runner to catch back up with (or "lap") the walker.

Similarly, on Earth, a location that experiences a high tide at 2:00 a.m. will rotate halfway around Earth in 12 hours. During that time, the global wave will have rotated to a much smaller degree in the same direction. Some extra time (25 minutes) will therefore be required for the location to move beneath the other tidal bulge and experience its second high tide. High tide will occur at 2:25 p.m. rather then 2:00 p.m. At 2:00 a.m. the next day, the location will have made one complete rotation, but the tidal bulge on that side of Earth will have continued to rotate away from its original position. The location will therefore not experience its next high tide until 2:50 a.m., 12 hours and 25 minutes after its previous high tide or 24 hours and 50 minutes after its initial high tide. See Figure 2.

Two concepts from physics are helpful in explaining tides. Newton's law of universal gravitation states that any two objects are attracted to each other by a force—gravity—that is directly proportional to the product of their masses and inversely propor-

Figure 2
Note: The dot along the edge of Earth in the figure represents the position of the observer.



tional to the square of the distance between them. The greater the mass of an object, the greater its gravitational attraction; the greater the distance from an object, the smaller the effect of its gravity. Newton's law of inertia states that a body at rest tends to stay at rest, and a body in motion tends to stay in motion, in a straight line, unless acted upon by an outside force. These two phenomena—gravity and inertia—work together to create the tides.

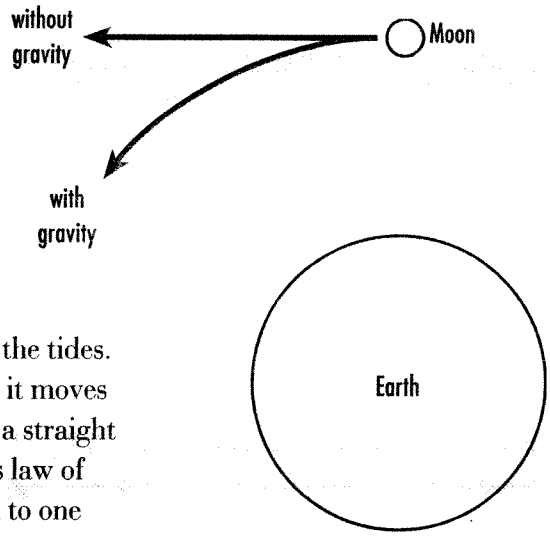


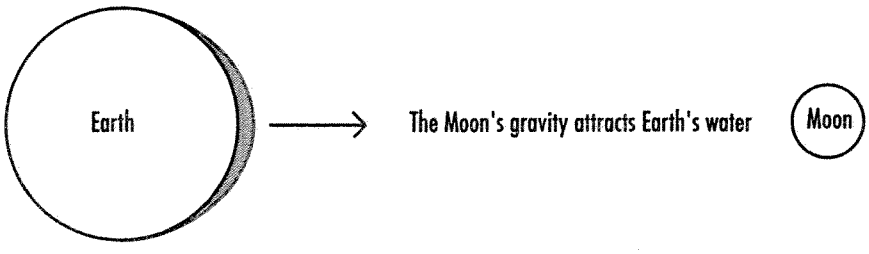
Figure 3

According to Newton's law of inertia, the Moon, as it moves through space, has a tendency to continue its motion in a straight line and bypass Earth. However, according to Newton's law of universal gravitation, Earth and the Moon are attracted to one another due to gravity. Since Earth has much greater mass than the Moon, the effect of Earth's gravity is stronger. It acts in conjuction with the Moon's inertia to keep the Moon in orbit around Earth. Without the effect of Earth's gravity, the Moon would fly off in a straight line tangent to its orbit around Earth. See Figure 3.

The Moon also exerts a gravitational attraction on Earth. Land masses and the ocean are both affected by the Moon's gravity, but because water is more easily deformed than land, land masses are affected to a lesser degree and ocean water moves over the area of Earth facing the Moon. In this way, the Moon's gravity causes the tidal bulge which is oriented toward the Moon. See Figure 4.

It is commonly thought that the center of the Moon's orbit around Earth is in the center of Earth where Earth's center of mass and axis of rotation are located. In reality, Earth and the Moon together form a two-body system which rotates on an axis located at the center of mass of the system. The center of mass of the Earth/Moon system is distinctly different from Earth's center of mass. It is located within Earth, rather than at the center of Earth. This is because Earth is so much more massive than the Moon. The analogy of a seesaw can help make this point clearer.

Figure 4



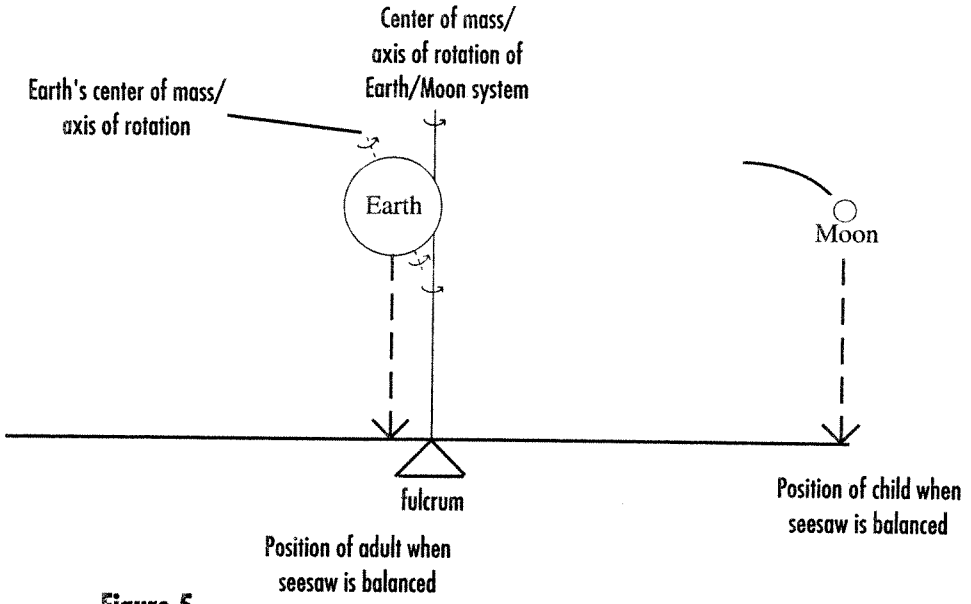


Figure 5

If an adult and a small child are on a seesaw, the adult must sit much closer to the fulcrum in order for the seesaw to be balanced. Similarly, if Earth and the Moon were placed on a seesaw, the fulcrum would have to be located within Earth for the two to balance. See Figure 5.

As the Earth-Moon system rotates about its axis, Earth, like the Moon, has an inertial tendency to continue in a straight line through space. Everything on the planet, including its ocean, is also subject to the effect of inertia. While Earth's gravitational attraction for the ocean keeps it from flying off the planet, it does move away from Earth somewhat because of its fluid nature. This is what creates the tidal bulge on the side of Earth opposite the Moon. The bulge is shown in an exaggerated way in Figure 6.

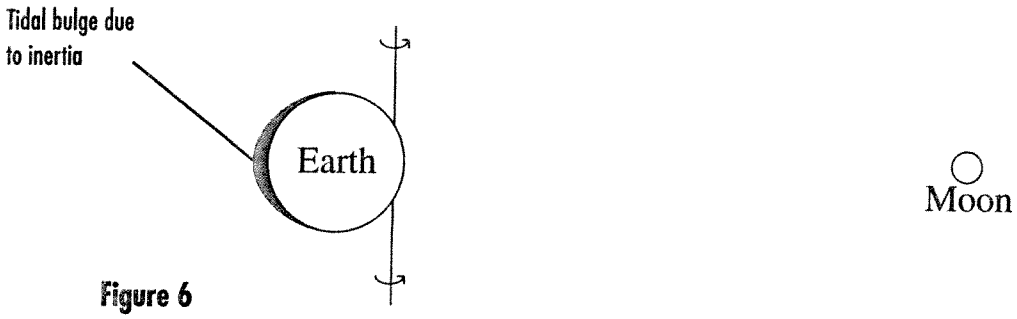


Figure 6

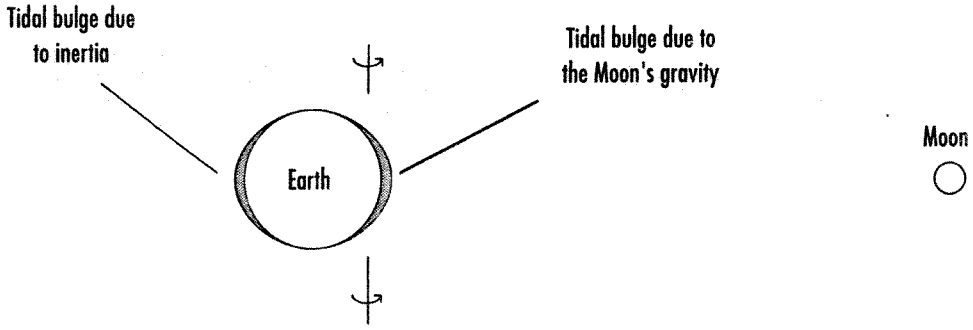


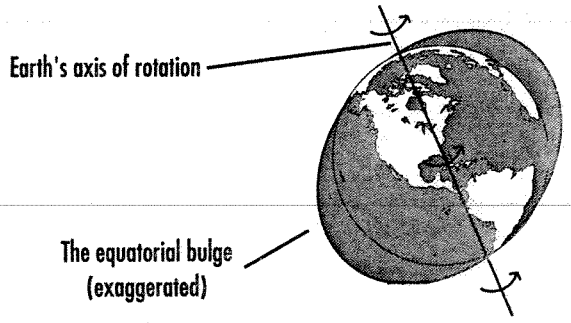
Figure 7

The inertia of the Earth/Moon system contributes to the tidal bulge on the Moon side of Earth as well, but to a much smaller degree. Because the Moon side of Earth is very close to the center of mass of the Earth/Moon system, the force of inertia there is much less. Activity 15, *Tides Mobile* explores this difference.

In summary, the two tidal bulges on Earth result, for the most part, from two different factors. The bulge on the side of Earth facing the Moon is due primarily to the effect of the gravitational attraction of the Moon on Earth's water. The bulge on the opposite side of Earth is due primarily to the inertial tendency of water to travel in a straight line away from Earth as the Earth/Moon system rotates. See Figure 7.

The tidal bulges associated with the rotation of the Earth/Moon system should not be confused with the equatorial bulge that results from the rotation of Earth on its own axis. The equatorial bulge, although caused by inertia, is not a tide. It is a constant effect that occurs uniformly around the planet's equatorial regions. See Figure 8.

Figure 8



The ocean is also affected by the gravitational attraction of the Sun. While the effect is less than half that of the Moon's, it does becomes evident roughly four times a month—at new moon, first quarter, full moon, and third quarter. At new moon, the Sun's gravitational attraction works in conjunction with the Moon's to cause an exceptionally high tide.

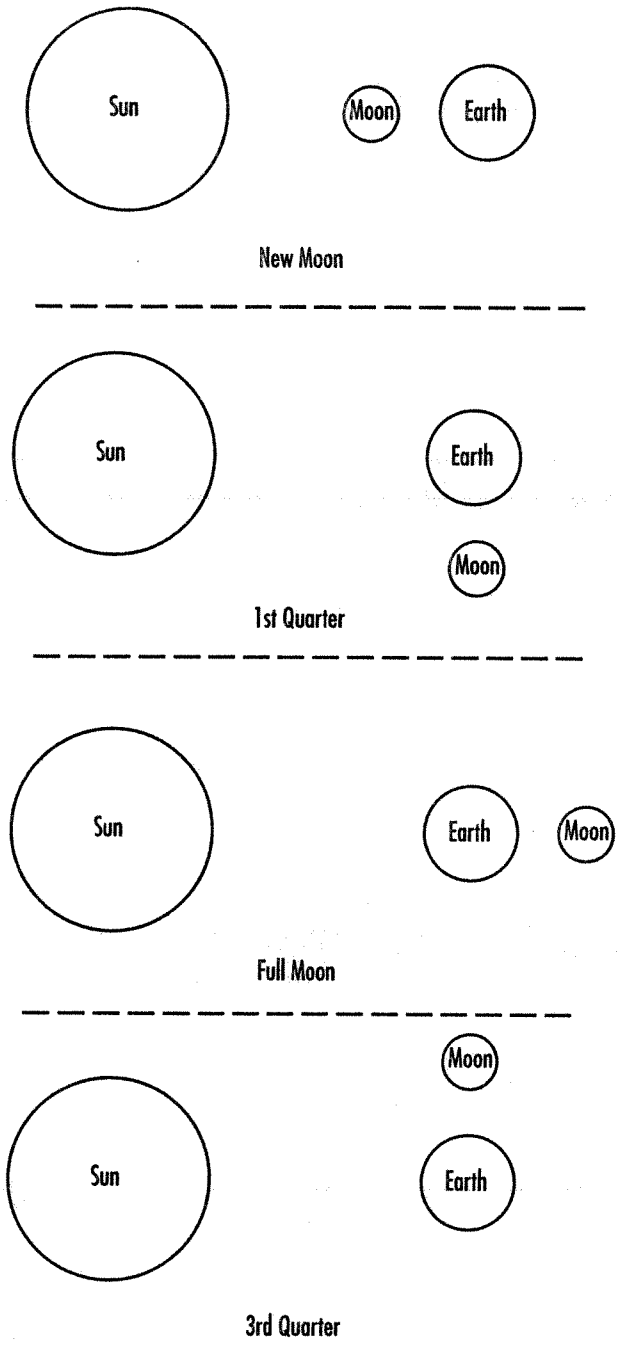


Figure 9

The high tide associated with a new moon is called a **spring tide,** because the ocean "springs" away from Earth even more than usual. At full moon, the Sun's gravitational attraction adds to the bulge on the side of Earth opposite the Moon, creating a second spring tide. At both first and third quarter, the Sun's gravitational attraction pulls water away from the normal tidal bulges and diminishes them. This creates the very moderate high and low tides referred to as **neap tides.** Spring and neap tides each occur twice every 29.5 days. See Figure 9.

Coastal locations of the world experience tides as rhythmic fluctuations in sea level. At high tide, the sea level rises; at low tide, the sea level falls. Not all locations experience the same pattern of tidal activity, however. Most locations on the eastern coast of North America, for example, experience diurnal tides—two high tides and two low tides every 24 hours and 50 minutes. Mixed tides—where there is a *high* high tide, a *low* high tide, a *high* low tide, and a *low* low tide every 24 hours and 50 minutes—occur along the west coast. Locations on the Gulf coast of Florida have a daily tide—one high tide and one low tide every 24 hours and 50 minutes.

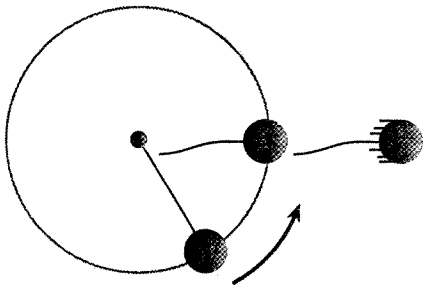
Variations in tidal patterns result from the fact that the depth of the ocean is not uniform in all locations. Coastal ocean basins oscillate at frequencies either operating in conjunction with or opposing those of the basic tide producing forces. Just as the water in a bathtub sloshes back and forth at a frequency characteristic of its shape and bottom contour, the ocean water in coastal basins "sloshes" back and forth at a frequency unique to each basin. The coastal basin that affects most of the North America's eastern coastline has an oscillation period of about 24 hours and 50 minutes and therefore tends to reinforce tidal action. The reinforcing action is best seen in Canada's Bay of Fundy where oscillation and tidal periods reinforce each other to produce differences in sea level of up to 18 meters between high and low tides. Off the coast of California, the coastal basin oscillates in such a way as to reinforce every other tide, thereby creating the *high* high and *low* low tides. In

the Gulf of Mexico, the basin oscillates once every 24 hours, thereby creating a single high tide and a single low tide each day.

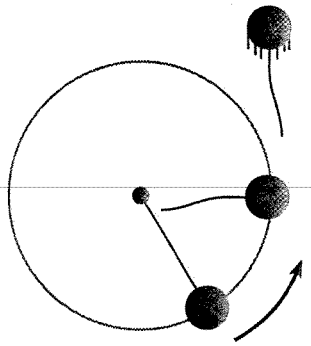
A common misconception about tides that has even been perpetuated through some textbooks is that centrifugal force is in part responsible for their creation. The concept of centrifugal force is actually a myth. It is described as a force which pulls an object out away from the center of its circular orbit. The tidal and equatorial bulges are attributed to this nonexistent force through the assertion that water is being pulled away from Earth as Earth rotates. While the assertion that water tends to move away from Earth is true, the conclusion that centrifugal force causes the tendency is incorrect. If centrifugal force was at work, the water would tend to move along a radial path away from Earth; but the real tendency of water is to move along a path tangent to Earth. This tendency results from inertia, as previously described. Centrifugal force is not a real force, but a perceived effect. Some physics writings dispel the myth of centrifugal force and point out how it is misleading (see references below). The following is an excerpt from one such text (Giancoli, 1980, page 66):

> "There is a common misconception that an object moving in a circle has an outward force acting on it, a so-called centrifugal ("center-fleeing") force. Consider, for example, a person swinging a ball on the end of a string around his head. If you have ever done this yourself, you know that you feel a force pulling outward on your hand. The misconception arises when this pull is interpreted as an outward "centrifugal" force pulling on the ball which is transmitted along the string to the hand. But this is not what is happening at all. To keep the ball moving in a circle, the person pulls inwardly on the ball. The ball, then, exerts an equal and opposite force on the hand [Newton's third law—for every action, there is an equal and opposite reaction], and *this* is the force your hand feels. The force *on the ball* is the one exerted *inwardly* on it by the person. For even more convincing evidence that a centrifugal force does not act on the ball, consider what happens when you let go of the string. If a centrifugal force were acting, the ball would fly outward. But it does not; it flies off tangentially, in the direction of the velocity it had at the moment it was released, since the inward force no longer acts." (See Figure 10.)

Figure 10



Radial path suggested by "centrifugal force"



Actual (tangential) path

In teaching students about tides, it is very important that such misconceptions as centrifugal force be addressed. The difference between centrifugal force and inertia can be shown clearly through a simple demonstration. A student is given a ball attached to a string and asked to swing it about his or her head like a sling and to aim it at a target directly in front of him or her. The student soon discovers that centrifugal force is indeed a misconception. If the string is released when the ball is directly in front of the student (as centrifugal force suggests is necessary in order to hit the target), the ball will miss the target completely. With practice, the student will learn where the string must be released in order for the ball's tangential path to lead to the target.

In summary, while the tides are sometimes attributed to the effect of centrifugal force, this force is a misconception. The tides are actually generated by complex interactions of the forces of gravity and inertia inherent in the rotating Earth/ Moon system. They can be viewed as a global wave under which Earth rotates, with crests experienced as high tides and troughs as low tides. The tides are reinforced or diminished by factors such as the natural oscillation of coastal basins and the gravitational effect of the Sun.

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Taffel, Alexander. 1981. *Physics: Its methods and meanings*. Boston: Allyn and Bacon.