

Key Concepts

Major Concept (I) *Our solar system began to form out of a rotating disk of gas and dust about 5 billion years ago.*

Related or supporting concepts:

- The present view of the beginning of the solar system suggests that a cloud of gas and dust, or nebula. A shock wave from a nearby exploding star flattened the nebula into a disk and gave it spin. The density of the matter in the disk was greatest at its center and decreased toward the edges.
- The sun formed at the center of the disk where the temperature was highest and the planets formed at greater distances away from the center.
- The compositions of the planets differ because of a natural sorting of elements in the cloud with distance from the center.
- The temperature of the early earth was probably quite high due to the:
 - a. gravitational capture of particles that released heat on impact,
 - b. increased pressure on the interior of the planet as it continued to grow, and
 - c. capture of radioactive elements that gave off heat when they decayed.
- During the first few hundred million years, the internal temperature rose high enough to melt iron and nickel. These heavy metals sank to form the core of the planet and displaced lighter material that rose to form chemically differentiated shells.
- Partial melting early in the earth's history would have released water molecules bound into rocks and minerals. This water was expelled at the surface, along with other gases, through volcanic activity to form the early oceans and atmosphere.
- The early atmosphere did not have any oxygen. The oxygen released from the interior of the planet would have combined with metals at the surface to produce oxides.
- It wasn't until large amounts of oxygen were produced after plants formed that it began to accumulate in the atmosphere.

Major Concept (II) *There are a variety of lines of indirect evidence that allow us to estimate the age of the earth as being about 4.6 billion years.*

Related or supporting concepts:

- The original crust of the earth that would have formed early in its history has been destroyed or covered by active volcanism and tectonic processes. This is a reflection of the geologically active nature of the planet. Consequently, the oldest surface rocks we have found, slightly over 4 billion years old, give us a minimum age for the earth rather than an actual age.
- Indirect evidence of the age of the earth includes:

- a. the dating of moon rocks at a little more than 4.4 billion years,
 - b. the dating of meteorites at 4.5 to 4.6 billion years, and
 - c. theoretical calculations of the age of the sun as being roughly the same as meteorites.
- We can determine the age of rocks that contain radioactive isotopes of elements that decay at constant, known rates. This is called radiometric dating.
 - If a rock contains atoms of a specific radioactive isotope, half of them will decay into another element, called the daughter product, in a period of time called the half-life of the isotope.
 - An example of this type of process would be Uranium²³⁵ and its daughter product Lead²⁰⁷ with a half-life of 704 million years. A rock that initially contained 100 atoms of U²³⁵ and no Pb²⁰⁷ would have the following numbers of the two elements after the indicated elapsed times:

<u>U²³⁵</u>	<u>Pb²⁰⁷</u>	<u>Time (m.y.)</u>
100	0	0
50	50	704
25	75	1408
~12	~88	2112
~6	~94	2816
~3	~97	3520

- There are several different "parent-daughter" radioactive pairs that occur in rocks. Each of the pairs has its own specific half-life, some quite long and others very short. Pairs with long half-lives are best for dating very old rocks while those with short half-lives are best for younger rocks. Ideally, an assigned date for a rock will be based on the use of more than one radioactive pair so that a check can be made on accuracy.

Major Concept (III) *Geologic time is often difficult to grasp because of how long it is compared to all of human history (to say nothing of the incredibly brief time span of a single human life).*

Related or supporting concepts:

- Just as we divide time into segments like years, months, and days to identify both duration and some sense of position, we divide geologic time as well. The longest division is called an eon. Eons are divided into eras, eras are divided into periods, and periods into epochs.
- The geologic time scale and the history of evolution of lifeforms is given in table 2.1 and illustrated in figure 2.2 in the text.
- The eras, in order of most distant past to most recent time, are:
 - a. Precambrian,
 - b. Paleozoic (ancient life),

- c. Mesozoic (intermediate life), and
- d. Cenozoic (recent life).
- The divisions of geologic time were originally decided upon on the basis of the appearance and disappearance of specific fossils.
- The development of radiometric dating techniques allowed geologists to assign absolute dates to the different time divisions.
- Because of the difficulty we typically have in comprehending time spans as great as billions of years, it is often easier to imagine that the earth is much younger, say tens of years old, and then consider what major events occurred in that period of time. Suppose, for example, that rather than the earth being 4.6 billion years old, it is only 46 years old. The following things have happened over the last 46 years:
 - a. There is no remaining record of what happened during the first 3 years.
 - b. The earliest history preserved can be found in some rocks of Canada, Africa, and Greenland that formed 43 years ago.
 - c. The first primitive living cells of bacteria-type organisms appeared sometime between 35 and 38 years ago.
 - d. The production of oxygen by living cells began about 23 years ago, half the age of the earth.
 - e. It took roughly 8 years for enough oxygen to accumulate in the atmosphere to support large numbers of complex, oxygen-requiring cells. This occurred about 15 years ago.
 - f. Eleven years later, or roughly 4 years ago, oxygen reached its present concentration in the atmosphere.
 - g. The first invertebrates (animals without backbones) developed 7 years ago.
 - h. The first vertebrates (animals with backbones) appeared 5 years ago. At the same time, the first fish swam in the oceans and corals appeared.
 - i. Three years, eight and one-half months ago the first sharks swam in the oceans.
 - j. Three years, three and one-half months ago reptiles roamed the land.
 - k. Two and one-half years ago a massive extinction killed 96% of all life.
 - l. Twenty-seven months and 10 days ago the dinosaurs appeared. Three and one-half weeks later the first mammals developed.
 - m. Eighteen and one-half months ago the first birds flew and five months later there were flowering plants.
 - n. 237 days ago a second extinction killed off the dinosaurs and many other organisms.
 - o. 211 days ago mammals, birds, and insects became the dominant land animals.
 - p. A little less than 6 days ago: the first member of the genus *Homo* appeared.
 - q. 30 minutes ago: modern civilization began.
 - r. 1 minute ago: the industrial revolution began.

Major concept (IV) *The earth has a roughly spherical shape, bulging slightly at the equator, with a surface that is remarkably smooth.*

Related or supporting concepts:

- The earth is not a perfectly rigid body. As a result, its rotation causes it to bulge outward at the equator and be slightly flattened at the poles (see fig. 2.3).
- Approximate values for the following figures are:
 - a. average radius = 6371 km or 3959 mi
 - b. equatorial radius = 6378.4 km or 3963 mi
 - c. polar radius = 6356.9 km or 3950 mi
 - d. (equatorial - polar) radius = 21.5 km or 13 mi
- The unequal distribution of continents and ocean basins results in a further deformation of the planet from a perfect sphere to a shape that is similar to a pear.
- Although it seems as if the difference in elevation from the highest point on land to the deepest place on the sea floor is very large, it is really quite small compared to the size of the earth. The difference in surface elevation is less than 20 km compared to Earth's radius of over 6000 km.
- If the earth were reduced to the size of a basketball or a grapefruit, its surface would be about as smooth as they are.

Major Concept (V) *Positions on the earth are determined by latitude and longitude.*

Related or supporting concepts:

- A grid of lines can be placed over the surface of the earth to serve as a reference system to determine location. There are two sets of lines that intersect one another to define latitude and longitude.
- Lines of latitude are drawn as circles parallel to the equator (see fig. 2.4). These circles have steadily decreasing diameters as they get closer to the poles. Lines of latitude are also called parallels because all of the circles are in planes that are parallel to one another.
- Latitude is 0° at the equator and increases to 90° at the poles. From this it should be clear that latitude is measured as an internal angle from the center of the earth away from the equator.
- By convention, latitudes south of the equator are negative and north of the equator are positive.
- One degree of latitude is equal to 60 nautical miles.
- Lines of longitude are sometimes called "great circles" because they are drawn by constructing circles perpendicular to the equator, that pass through both poles (see fig. 2.6). In this way, each circle has a diameter that is the same as the diameter of the earth.
- Lines of longitude segment the planet in a way that is similar to the sections of an orange.
- Lines of longitude are also called meridians. The distance between meridians corresponds to an angle from the center of the earth between an arbitrarily chosen

"prime meridian," which is at 0° by definition, and a second meridian measured along the equator.

- The prime meridian passes through both poles and Greenwich, England (see fig. 2.5).
- Longitude can be measured from 0° - 360° moving eastward from the prime meridian, or from 0° to +180°E and 0° to -180°W.
- The actual distance between meridians decreases away from the equator and becomes zero at the poles, where all meridians converge.
- Each degree of latitude or longitude can be divided into 60 minutes (60¢) and each minute into 60 seconds (60²).

Major Concept (VI) *Differences in longitude can be related to differences in time between two locations because of the rotation of the earth.*

Related or supporting concepts:

- The earth rotates on its axis once every 24 hours. It follows therefore that it rotates through 360° of longitude each 24 hours. This is equivalent to (15° of longitude/1 hour) or (15¢ of longitude/1 minute of time).
- The time at 0° longitude, or at Greenwich, England is called Greenwich Mean Time (GMT). It is also known as Universal Time (UT) or ZULU (Z) time.
- The international date line is on the opposite side of the earth from Greenwich, England or the prime meridian. It corresponds to the 180° meridian.
- Because we know the rate of rotation of the earth, we can determine our longitude simply by knowing the difference in time between our location and Greenwich, England. For example:

<u>Greenwich time</u>	<u>Our time</u>	<u>Our longitude</u>
10 A.M.	8 A.M.	30° W
9 A.M.	1 P.M.	60° E
5 P.M.	11 A.M.	90° W

Major Concept (VII) *Maps and charts are used to illustrate characteristics of Earth's surface.*

Related or supporting concepts:

- Maps and charts illustrate three-dimensional shapes on two-dimensional surfaces.
- Surface features on land are often illustrated with maps.
- Seafloor features are often illustrated with charts. Charts are also used to illustrate features in the sky.
- Three-dimensional features can never be perfectly illustrated on two-dimensional maps and charts. As a result, there is always some distortion of real features.
- Different map projections will produce different types and degrees of distortion. When choosing a specific projection you need to carefully consider which one will

- produce the least distortion of the features you are interested in.
- There are three basic types of projections (see fig. 2.8):
 - a. cylindrical,
 - b. conic, and
 - c. tangent plane.
 - The sea floor is often illustrated using a bathymetric chart (see fig. 2.9). Contour lines on a bathymetric chart connect points of equal depth.
 - A chart that shows regions of varying depth by variations in color, shading, or perspective drawing is called a physiographic map (see fig. 2.10).
 - Three-dimensional, color images are generated by computer from detailed sonar data (see fig. 2.11).

Major Concept (VIII) *Physical, biological, and chemical processes on the planet are all influenced by temporal changes or cycles that occur with different periods and are due to the earth's rotation on its axis and its movement around the sun.*

Related or supporting concepts:

- There are two natural periods that influence processes on the earth. These are caused by the daily rotation of the planet on its axis which gives us night and day, and the yearly rotation of the earth around the sun which gives us the changing seasons.
- We experience seasonal variations in climate because the rotational axis of the earth is tilted away from a line drawn perpendicular to the plane of its orbit around the sun by $23\frac{1}{2}^{\circ}$ (see fig. 2.12).
- The tilt of the earth results in an annual migration of the apparent position of the sun in the sky from being directly overhead at noon somewhere between $23\frac{1}{2}^{\circ}$ S and $23\frac{1}{2}^{\circ}$ N throughout the year. Outside of this band of latitude centered on the equator, the sun will never appear to be directly overhead even when it has risen in the sky to its highest point at noon.
- The Northern Hemisphere is tilted toward the sun during Northern Hemisphere summers and is warmer because the intensity of solar radiation is greater at the surface when the sun's rays are more nearly perpendicular to the surface. At this time the Southern Hemisphere experiences its winter as it is tilted away from the sun.
- There are four parallels of latitude that have special names; these are:

<u>Latitude</u>	<u>Name</u>
$66\frac{1}{2}^{\circ}$ N	Arctic Circle
$23\frac{1}{2}^{\circ}$ N	Tropic of Cancer
$23\frac{1}{2}^{\circ}$ S	Tropic of Capricorn
$66\frac{1}{2}^{\circ}$ S	Antarctic Circle

- On the summer solstice, which usually occurs around June 22, the sun will be directly overhead the Tropic of Cancer and there will be 24 hours of daylight above the Arctic Circle. This is the day with the longest period of daylight in the Northern Hemisphere and the shortest in the Southern Hemisphere. The sun will not rise at all at latitudes farther south than the Antarctic Circle.
- On the autumnal equinox, on about September 23, the sun will be directly overhead the equator and the amount of daylight will be the same everywhere.
- On the winter solstice, around December 21, the sun will be directly overhead the Tropic of Capricorn and there will be 24 hours of daylight above the Antarctic Circle and perpetual darkness above the Arctic Circle. This will be the day with the longest period of sunlight in the Southern Hemisphere and the shortest in the Northern Hemisphere.
- On the vernal equinox, roughly March 21, the sun will have moved northward again to stand directly over the equator.
- The greatest annual change in climate occurs at mid-latitudes in what are called the temperate zones. At low latitudes it is relatively warm throughout the year and at high latitudes it remains fairly cold.
- The orbit the earth takes around the sun is elliptical, so the distance between the earth and the sun changes through the year. The distance is greatest during the Northern Hemisphere summer and least during the Northern Hemisphere winter. It is important to remember that the seasons are not due to the variable distance from the sun (otherwise we should expect summer in the Northern Hemisphere when we are closest to the sun in the end of December), but rather they are controlled by what hemisphere is tilted toward the sun's rays.

Major Concept (IX) *The earth is essentially a closed system. As such, all of the water available to the planet moves through different reservoirs where it is stored for varying periods of time before moving on.*

Related or supporting concepts:

- Water can be found in all three states of matter in the earth system: solid (ice), liquid, and gas (water vapor).
- At any given time a water molecule will be located in a specific reservoir. Examples of reservoirs include the atmosphere, rivers, lakes, the oceans, glaciers, and groundwater, to name a few.
- Water will not remain indefinitely in a single reservoir; rather, it will be cycled from one reservoir to another by such processes as evaporation, precipitation, transpiration, sublimation, and runoff.
- Transpiration is the release of water by plants. Sublimation is a phase change of water from solid to gas, or from ice to water vapor.
- The cycling of water from one reservoir to another is called the hydrologic cycle. The hydrologic cycle can be seen diagrammatically in figure 2.13 in your text.

- In the simplest possible description, the movement of water from one reservoir to another can be described in part by the following table:

<u>Reservoir</u>	<u>Water lost via</u>	<u>Water gained via</u>
continents	evaporation runoff transpiration sublimation	precipitation
oceans	evaporation	precipitation runoff sublimation
atmosphere	precipitation	evaporation transpiration sublimation

- The amount of water stored in different reservoirs can vary greatly. The largest volume of water is stored in the oceans (about 97%) and the least amount is stored in rivers (about 0.0001%). Take a look at table 2.2 for more information on the relative volume of water stored in different reservoirs.

Major Concept (X) *The largest water reservoir in the earth system, in terms of the volume of water stored, is the oceans.*

Related or supporting concepts:

- Roughly 71 percent of the surface of the planet is covered by the oceans. This leaves only 29 percent covered by the continents.
- The surface area of the oceans is approximately 139 million square miles or 361 million square kilometers.
- The volume of water held in the oceans is an incredible 1.37 billion cubic kilometers. This amount of water is so great that it is difficult to grasp.
- If the earth was a smooth ball without any continents to interrupt the oceans and a flat sea floor, the water held in the oceans would cover the globe to a uniform depth of about 1.7 miles (2680 meters or 8800 feet).
- Adding all of the rest of the water trapped in other reservoirs would raise the level of this global sea by 63 meters to about 2743 meters or 9000 feet.

Major Concept (XI) *The continents are not uniformly distributed on the earth. In addition, the percentage of the planet's surface at any given elevation is not constant.*

Related or supporting concepts:

- As mentioned previously, continents cover about 29 percent of the earth's surface. Roughly 70 percent of all land is found in the Northern Hemisphere, and most of it at mid-latitudes.
- Take a look at figure 2.15 to see the distribution of land and water with latitude.
- The only latitude band where there is more land than water, with the exception of Antarctica, is between 45° - 70°N.
- The Southern Hemisphere is dominated by oceans while most land is in the Northern Hemisphere (see fig. 2.15).
- The percent of land and sea floor, as well as the percent of the total surface area of the planet, that is at any specific elevation above or depth below sea level is shown in figure 2.16. This plot is called the hypsographic curve.
- Among the things we can learn from the hypsographic curve are:
 - a. mean elevation of land = 840 m
 - b. mean depth of the oceans = 3795 m
 - c. about 20 percent of land is higher than 2 km above sea level
 - d. about 85 percent of sea floor is deeper than 2 km below sea level
- The highest elevation on land, Mt. Everest at 8850 m, is closer to sea level than the deepest spot in the oceans, the Challenger Deep of the Mariana Trench at 11,030 m.
- The great difference in height between the continents and the sea floor is due to the large difference in the types of rocks that make up continents and sea floor. Continental rocks have a lower density than seafloor rocks.

Major Concept (XII) *The world's seawater can be divided into four oceans: the Pacific, the Atlantic, the Indian, and the Arctic (see fig. 2.17).*

Related or supporting concepts:

- The Pacific, Atlantic, and Indian oceans all join in the Southern Hemisphere around Antarctica.
- The Pacific Ocean is the largest ocean with a surface area that is slightly larger than the Atlantic and Indian Oceans combined. The Pacific also holds the greatest volume of water and has the greatest average depth.
- The Pacific Ocean was named by Ferdinand Magellan in 1520 for the calm water he encountered while crossing it.
- There are roughly 25,000 islands in the Pacific Ocean, most of which are in the Southern Hemisphere.
- There are a number of marginal seas around the edges of the Pacific Ocean including the Celebes Sea, Coral Sea, East China Sea, Sea of Japan, Sulu Sea, and Yellow Sea.
- The Atlantic Ocean is unique in that it extends the greatest distance north and south. It is a relatively narrow ocean and is the shallower than the Pacific or Indian.

- The land area that drains into the Atlantic is four times greater than that of either the Pacific or Indian.
- There are a number of gulfs and seas around the Atlantic including the Caribbean Sea, Gulf of Mexico, Mediterranean Sea, Black Sea, and Baltic Sea.
- The Indian Ocean is entirely in the Southern Hemisphere.
- The Indian Ocean has a long history of strategic importance as a trade route between Asia and Africa.
- The Arctic Ocean is the smallest of the four.
- The Arctic connects to the Pacific through the Bering Strait and to the Atlantic through the Greenland Sea.
- The floor of the Arctic Ocean is divided into two deep basins by a submarine mountain range.
- The major flow of water into and out of the Arctic Ocean is through the North Atlantic.
- Each ocean is bounded roughly by continents, has its own distinct water masses, and well defined surface currents.

Major Concept (XIII) *Location at sea is determined by a number of different methods depending on distance from land and position on the globe. Most methods rely on some sort of electronic navigational equipment as opposed to the astronomical methods used in the past.*

Related or supporting concepts:

- There are three principal systems used in modern navigation:
 - a. radar : "**radio detecting and ranging**"
 - b. loran : "**long-range navigation**"
 - c. satellite navigation
- Radar systems emit bursts of energy that travel outward and then return after reflecting off distant objects. By carefully measuring the travel time of the reflected energy, you can determine distance quite accurately. Radar is only useful when you are close enough to land for signals to be reflected back to the vessel.
- Loran systems utilize fixed stations that transmit radio waves at specific frequencies. A loran receiver on board a ship can detect these transmissions. The difference in arrival time of the signals from pairs of stations is a measure of distance from the stations. Unlike radar, loran can be used far from land as long as the vessel is within receiving distance of loran stations. In addition, loran units can be interfaced with computers to automatically calculate latitude and longitude and to determine the ship's course to some pre-determined location.
- The most accurate technique is satellite navigation. By monitoring signals from orbiting satellites, it is possible to obtain a location with an accuracy as great as 30 meters (or about 100 feet).

- Modern electronic navigation methods permit the determination of location in any kind of weather and at any time of day. Small Global Positioning System (GPS) receivers are now routinely used by hikers, hunters, boaters, and others who need to know their location in the outdoors.
- The GPS system consists of 24 navigational satellites and 5 ground-based monitoring stations

Key Terms and Related Major Concepts

At the back of the chapter in your book there are a number of key terms. You should be able to find the following terms referenced in the major concept indicated in parentheses.

radiometric dating(II)	Tropic of Capricorn(VIII)	temperate(VIII)
isotope(II)	Tropic of Cancer(VIII)	reservoir(IX)
half-life(II)	winter solstice(VIII)	hydrologic cycle(IX)
latitude(V)	vernal equinox(VIII)	hypsographic curve(XI)
longitude(V)	autumnal equinox(VIII)	universal time(VI)
prime meridian(V)	summer solstice(VIII)	radar(XIII)
international date line(VI)	Arctic Circle(VIII)	loran(XIII)
Greenwich Mean Time(VI)	Antarctic Circle(VIII)	satellite navigation(XIII)
		Global Positioning System(XIII)

Test Your Understanding With The Following Questions:

FILL IN THE BLANK

1. The core of the earth is rich in two metals, _____ and _____.
2. The greatest depth in the oceans is about _____ kilometers.
3. The time over which one-half of the atoms of an isotope will decay is called its _____.
4. In geologic time, _____ are divided into periods.
5. Lines of _____ are circles that are all parallel to one another.
6. The line of longitude passing through Greenwich, England is called the _____.
7. The farthest south the sun can be seen directly overhead is on the Tropic of _____.
8. Water is stored in many different places on Earth called _____.
9. A graph of elevation or depth versus surface area of the planet is called the _____.

- _____.
10. The navigational method that relies on differences in arrival time of radio signals from pairs of stations is called _____.

TRUE - FALSE

1. Earth's first atmosphere probably had little, if any, oxygen.
2. On a scale model of Earth the size of a basketball, the differences in elevation between the tops of mountains and the ocean deeps would be about half an inch.
3. The half-life of any specific isotope is constant as it decays.
4. The number of nautical miles per degree of longitude decreases away from the equator.
5. The Tropic of Cancer is farther away from the equator than the Tropic of Capricorn.
6. The prime meridian is located on the international date line.
7. Earth's axis of rotation is tilted by $23\frac{1}{2}^\circ$ with respect to its plane of orbit around the sun.
8. There is more water in the oceans than in any other reservoir.
9. Water moves from one reservoir to another in a process called the hydrologic cycle.
10. The oceans cover about 64 percent of the surface of Earth.

MULTIPLE CHOICE

1. Our sun is but one of billions of stars in the _____ galaxy.
 - a. Andromeda
 - b. Milky Way
 - c. Almond Joy
 - d. Nebular
 - e. Ursa Major
2. Earth is approximately how many years old?
 - a. 10 billion
 - b. 120 million
 - c. 2500
 - d. 4.6 billion
 - e. 8.4 billion
3. The average radius of Earth is about:
 - a. 6371 km
 - b. 8950 km
 - c. 10,000 km
 - d. 2745 km
 - e. 5500 km
4. The deepest point in the oceans is found in the _____ Trench.
 - a. Middle America
 - b. Java
 - c. Mariana
 - d. Kuril

- e. Aleutian
5. The determination of the age of rocks by studying the decay of isotopes is called:
 - a. atomic dating
 - b. nuclear dating
 - c. relative dating
 - d. absolute dating
 - e. radiometric dating
 6. The boundaries of geologic time units were first set by noting:
 - a. which rock units were found on top of others
 - b. the appearance and disappearance of fossils
 - c. changes in the predominant color of the rocks
 - d. the location of major faults
 - e. the variable location of the water table
 7. There are _____ nautical miles in each degree of latitude.
 - a. 100
 - b. 50
 - c. 10
 - d. 60
 - e. 12
 8. This is another term for Greenwich Mean Time.
 - a. ZULU time
 - b. standard time
 - c. Universal Time
 - d. all of the above
 - e. a and c above
 9. Earth rotates _____ degrees of longitude each hour.
 - a. 12
 - b. 60
 - c. 15
 - d. 10
 - e. 30
 10. The sun is directly above the equator on the:
 - a. summer solstice
 - b. vernal equinox
 - c. autumnal equinox
 - d. winter solstice
 - e. b and c above

Answer Key for 'Key Terms' and 'Test Your Understanding'

FILL IN THE BLANK

1. iron, nickel
2. 11
3. half-life
4. eras
5. latitude

6. prime meridian
7. Capricorn
8. reservoirs
9. hypsographic curve
10. loran

TRUE - FALSE

- 1.T 2.F 3.T 4.T 5.F 6.F 7.T 8.T 9.T 10.F

MULTIPLE CHOICE

- 1.b 2.d 3.a 4.c 5.e 6.b 7.d 8.e 9.c 10.e