1. Scales of Earth Science—p 9
    a. Extremely small to unimaginably large
    b. Distances, sizes, numbers, time
        i. Atoms in crystalline arrangement
        ii. Formation of mountain ranges
        iii. Stars in the sky
    c. Earth is 4500 million years old, or more (4.5 billion)
        i. Geologic time scale divided into meaningful intervals
        ii. Based on changes in fossil record
        iii. Correlated with numeric dates recently
2. Earth Spheres
    a. Hydrosphere
        i. Water planet—71% of surface covered
        ii. Average depth of ocean is over two miles
        iii. Most water is sea water, small portion is fresh and liquid
    b. Atmosphere
        i. Consider half of the molecules are within 3 ½ miles of surface. Other half are more diffuse with no definite outer boundary
        ii. Gaseous envelope that shields us from cosmic radiation
        iii. Surface layer is homogeneous mixture, outer layers differentiated by density
        iv. Has evolved with life on Earth
    c. Biosphere
        i. All of the organisms—animals, plants, bacteria, fungi
        ii. Interact with hydrosphere and atmosphere, depend on them, alter them
    d. Geosphere
        i. 6400 km radius (the distance from center to surface)
        ii. Dynamic and changing, but on a long time frame
        iii. Acted upon by the other three spheres
3. Mobile Geosphere
    a. Oceanic crust is lower than continental crust, because it is denser. (It has ocean because it is lower.)
        i. Where there are collisions between continental crust and oceanic crust, the continent pushes the oceanic crust down into the mantle to be assimilated (destructive plate margin)
        ii. Consequence is younger oceans, older continents
    b. Continents are higher, and older, because they are less dense
        i. Margin at edge of oceanic crust is below sea level
        ii. Shelf is part of continent, just too much water to let it be above sea level.
    c. Lithosphere moves around, puts continents in different places
    d. Places where crust is torn apart, there is a constructive margin, with mantle material filling in the rip from below. The hotness of this material makes it rise above adjacent ocean floor.

4. Earth System science
    a. Interaction of components, integration of biology, chemistry, physics, meteorology, geology
    b. System subject to feedback mechanisms—parts of the system that increase tendencies, or reduce tendencies
        i. Positive feedback mechanism Global climate change
            1. warmer summers increase melting of ice
            2. less ice, less reflection of heat
            3. more warming, more melting
        ii. Negative feedback mechanism in Global climate change
            1. increase in temperature increases evaporation
            2. more evaporation, more clouds
            3. clouds reflect heat, moderating temperature
    c. Cycles in Earth's system
        i. hydrologic cycle—evaporation, condensation, precipitation, runoff. There are interactions with geosphere, biosphere and atmosphere in this cycle
        ii. rock cycle—come up from mantle as lava, or magma solidifies in upper crust. Hydrosphere dissolves, changes mineral composition, erosion removes material, deposits of sediments become rock, destructive margins may bring material back into crust and upper mantle to be recrystallized or melted.
    d. Energy of Earth's systems comes from two sources
        i. Sun provides energy for biosphere, atmosphere, hydrosphere
        ii. Internal heat, from radioactive decay and gravitational compression fuel the movement of the geosphere.
5. Earth Structure
    a. Composition varies from center to surface: 3 distinct zones
        i. Crust—100 km thick
            1. oxygen, silicon, aluminum, iron, calcium, etc.
            2. about 100 km thick
            3. two types
                a. continental: older, thicker, more silica, less dense
                b. oceanic: younger, thinner, more iron/Mg, more dns
        ii. Mantle—2900 km thick
            1. oxygen, silicon, iron, magnesium…
            2. 2900 km thick
        iii. Core—3600 km radius
            1. iron, nickel…
            2. 3400 km radius

b. Properties change also: 5 zones, only one boundary same as comp.
    i. inner core
        1. solid due to pressure
        2. ~1200 km radius
    ii. outer core
        1. liquid—does not transmit shear waves
        2. over 2200 km thick
    iii. lower mantle
        1. more rigid than asthenosphere
        2. over 2200 km thick
    iv. Asthenosphere
        1. below lithosphere, but part of upper mantle
        2. weak zone, allows lithosphere to move around
        3. about 500 km thick
    v. Lithosphere
        1. rigid crust and uppermost mantle
        2. ~250 km thick

6. Evolution of the Solar System— Nebular hypothesis, p 10—about 5 b.y.
    a. Cloud of atoms, mostly hydrogen and helium
    b. Gravitational collapse contracted it into rotating disc
    c. Heat of conversion of gravitational to thermal energy fired Sun into star in center of nebular cloud
    d. Cooling allowed condensation of rocky particles in inner solar system, that collided to become planets—accretion
        i. Their accretion created gravitational heat of contraction—warm but fairly small
        ii. Unable to attract much lighter elements
    e. Outer nebular cloud stayed cool
        i. Ices of methane, carbon dioxide, ammonia and water
        ii. Cooler at greater distances from Sun,
            1. these solid particles collided to become outer planets.
            2. Large quantities existing there allowed these planets to become enormous, and attract and hold lighter elements
7. Big Bang happened before all of this—14 billion years ago
    a. created the universe, the early galaxies, and the first-generation stars
    b. Remember, Sun is a second or third generation star—the nebular cloud of dust and gases was created by a supernova of a pre-existing star

8. History of Astronomy—ch 21
    a. Most ancient civilizations believed that Earth was at the center of the universe
    b. Age of Reason beginning to recognize Sun is center
    c. Age of Technology exploring wide reaches of the universe
9. Ancient Greeks thought planets rotated around Earth in perfect circles
    a. Anaxagoras, 5th century BC, reasoned that Moon had phases because it is a sphere, and is lighted by Sun
    b. Aristotle, tutor of Alexander BC 382-322,
        i. knew Earth was round from shadow of Earth on Moon during lunar eclipse
        ii. helped cement the Geocentric view of the solar system because
            1. Earth has no apparent movement
            2. Things do not fly off the surface
            3. Looks like the stars and Sun are moving
            4. No stellar parallax could be observed
            5. Earth must be stationary
    c. Aristarchus BC 312-230
        i. Determined relative sizes of Sun and Moon by shadows during eclipse events
        ii. Greater size of Sun lead him to believe Sun was center—Heliocentric
        iii. Believed Earth's axis was tilted to orbit around Sun, and this creates seasons
        iv. Hypothesis discounted due to observations of Aristotle, etc.
    d. Erastosthenes BC 276-194 Librarian in Alexandria
        i. Determined size of Earth
            1. Found notes indicating Sun is directly overhead in Syene on summer solstice
            2. Sun was about 7^{o} south of overhead in Alexandria
            3. this is about 1/50 of a circle, so Earth's circumference must be 50x that distance
        ii. 39,400 km ~ 40,075 km—pretty good for 2200 years ago
    e. Hipparchus
        i. Star catalog: Location, Brightness 1-6
        ii. Length of year within minutes of actual
        iii. Prediction of lunar eclipse events

f. Cladius Ptolemy 85-100 to 165-180 AD
    i. Mathematician, geographer, astronomer
    ii. His “Great Work” (Syntaxis, Amalgest) preserved by Persian scholars through middle ages
    iii. Geographer
        1. Maps were very accurate
        2. first known attempt to project sphere onto a plane
        3. inspired Columbus
    iv. Mathematician—work with circles and chord theorems
    v. Codified Geocentric View—model that planets orbit around Earth
        1. Perfect circle orbits discounted because of ‘retrograde’ motion with respect to Earth
            a. Looks like planet going backward in orbit
            b. Actually different speeds of planets orbiting Sun
        2. devised idea of ‘epicycles’ to explain this
            a. small loops in orbits could explain backward motion
            b. best predictor of location of planets until Kepler (1609)
            c. accepted by Roman Catholic Church
            d. Church punished those who reasoned against it