1 ***Earth's Interior***

Earth 9th edition, Chapter 12

2 ***Probing Earth's Interior***

- Most of our knowledge of Earth's interior comes from the study of earthquake waves
  - Travel times of P (compressional) and S (shear) waves through the Earth vary depending on the properties of the materials
  - Variations in the travel times correspond to changes in the materials encountered

3 ***Probing Earth's Interior***

- The nature of seismic waves
  - Velocity depends on the density and elasticity of the intervening material
  - Within a given layer the speed generally increases with depth due to pressure forming a more compact elastic material
  - Compressional waves (P waves) are able to propagate through liquids as well as solids

4 ***Probing Earth's Interior***

- The nature of seismic waves
  - Shear waves (S waves) cannot travel through liquids
  - In all materials, P waves travel faster than do S waves
  - When seismic waves pass from one material to another, the path of the wave is refracted (bent) provided that the ray is not traveling perpendicular to the boundary

5 ***Seismic waves and Earth's structure***

- The rather abrupt changes in seismic-wave velocities that occur at particular depths helped seismologists conclude that Earth must be composed of distinct shells
  - Layers are defined by composition
    - Because of density sorting during an early period of partial melting, Earth's interior is not homogeneous

6 ***Seismic waves and Earth's structure***

- Layers are defined by composition
  - Three principal compositional layers
    - Crust
      - the comparatively thin outer skin that ranges from 3 kilometers (2 miles) at the oceanic ridges to 70 kilometers (40 miles in some mountain belts)
    - Mantle
      - a solid rocky (silica-rich) shell that extends to a depth of about 2900 kilometers (1800 miles)
    - Core
      - an iron-rich sphere having a radius of 3486 kilometers (2161 miles)

7 ***Velocity vs. Depth***

8 ***Seismic waves and Earth's structure***

- Layers defined by physical properties
  - With increasing depth, Earth's interior is characterized by gradual increases in temperature, pressure, and density
  - Depending on the temperature and depth, a particular Earth material may behave like a brittle solid, deform in a plastic–like manner, or melt and become liquid
  - Main layers of Earth's interior are based on physical properties and hence mechanical strength

9 ***Seismic waves and Earth's structure***

- Layers defined by physical properties
  - Lithosphere (sphere of rock)
    - Earth's outermost layer
    - Consists of the crust and uppermost mantle
    - Relatively cool, rigid shell

- Averages about 100 kilometers in thickness, but may be 250 kilometers or more thick beneath the older portions of the continents

10 ***Seismic waves and Earth's structure***

- Layers defined by physical properties
  - Asthenosphere (weak sphere)
    - Beneath the lithosphere, in the upper mantle to a depth of about 600 kilometers
    - Small amount of melting in the upper portion mechanically detaches the lithosphere from the layer below allowing the lithosphere to move independently of the asthenosphere

11 ***Seismic waves and Earth's structure***

- Layers defined by physical properties
  - Mesosphere or lower mantle
    - Rigid layer between the depths of 660 kilometers and 2900 kilometers
    - Rocks are very hot and capable of very gradual flow

12 ***Seismic waves and Earth's structure***

- Layers defined by physical properties
  - Outer core
    - Composed mostly of an iron-nickel alloy
    - Liquid layer
    - 2270 kilometers (1410 miles) thick
    - Convective flow within generates Earth's magnetic field

13 ***Seismic waves and Earth's structure***

- Layers defined by physical properties
  - Inner core
    - Sphere with a radius of 3486 kilometers (2161 miles)
    - Material is stronger than the outer core
    - Behaves like a solid

14 ***The composition and mechanical layers of Earth***

15 ***Discovering Earth's major boundaries***

- The Moho (Mohorovicic discontinuity)
  - Discovered in 1909 by Andriaja Mohorovicic
  - Separates crustal materials from underlying mantle
  - Identified by a change in the velocity of P waves

16 ***Discovering Earth's major boundaries***

- The core-mantle boundary
  - Discovered in 1914 by Beno Gutenberg
  - Based on the observation that P waves die out at 105 degrees from the earthquake and reappear at about 140 degrees - this 35 degree wide belt is named the P-wave shadow zone
  -

17 ***Wave Reflection and Refraction***

18 ***The P-wave shadow zone***

19 ***Discovering Earth's major boundaries***

- The core-mantle boundary
  - Characterized by bending (refracting) of the P waves
  - The fact that S waves do not travel through the core provides evidence for the existence of a liquid layer beneath the rocky mantle

20 ***Discovering Earth's major boundaries***

- Discovery of the inner core
  - Predicted by Inge Lehmann in 1936
  - P waves passing through the inner core show increased velocity suggesting that the inner core is solid

21 ***Crust***

- Thinnest of Earth's divisions
  - Varies in thickness (exceeds 70 km under some mountainous regions while oceanic crust ranges from 3 to 15 km thick)
- Two parts:
  - Continental crust
    - Average rock density about 2.7 g/cm^3
    - Composition comparable to the felsic igneous rock granodiorite

22 ***Crust***

- Two parts:
  - Oceanic crust
    - Density about 3.0 g/cm3
    - Composed mainly of the igneous rock basalt

23 ***Mantle***

- Contains 82 percent of Earth's volume
- Solid, rocky layer
- Upper portion has the composition of the ultramafic rock peridotite
- Two parts
  - Mesosphere (lower mantle)
  - Asthenosphere or upper mantle

24 ***Core***

- Larger than the planet Mars
- Earth's dense central sphere
- Two parts
  - Outer core
    - liquid outer layer about 2270 kilometers thick
  - Inner core
    - solid inner sphere with a radius of 1216 kilometers

25 ***Using travel times to measure the depth of the inner core***

26 ***Core***

- Density and composition
  - Average density is nearly 11 g/cm3 and at Earth's center approaches 14 times the average density of water
  - Mostly iron, with 5 to 10 percent nickel and lesser amounts of lighter elements

27 ***Core***

- Origin
  - Most accepted explanation is that the core formed early in Earth's history
  - As Earth began to cool, iron in the core began to crystallize and the inner core began to form

28 ***Core***

- Earth's magnetic field
  - The requirements for the core to produce Earth's magnetic field are met in that it is made of material that conducts electricity and it is mobile
  - Inner core rotates faster than the Earth's surface and the axis of rotation is offset about 10 degrees from the Earth's poles

29 ***Possible origin of Earth's magnetic field***

30 ***Earth's internal heat engine***

- Earth's temperature gradually increases with an increase in depth at a rate known as the geothermal gradient
  - Varies considerably from place to place
  - Averages between about 20°C and 30°C per kilometer in the crust (rate of increase is much less in the mantle and core)

31 ***The geothermal gradient***

32 ***Earth's internal heat engine***

- Major processes that have contributed to Earth's internal heat
  1. Heat emitted by radioactive decay of isotopes of uranium (U), thorium (Th), and potassium (K)
  2. Heat released as iron crystallized to form the solid inner core
  3. Heat released by colliding particles during the formation of Earth

33 ***Earth's internal heat engine***

- Heat flow in the crust
  - Process called conduction
  - Rates of heat flow in the crust varies
- Mantle convection
  - There is not a large change in temperature with depth in the mantle
  - Mantle must have an effective method of transmitting heat from the core outward

34 ***Transfer of heat in the Earth by mantle convection***

35 ***Earth's internal heat engine***

- Mantle convection
  - This is an important process in Earth's interior
  - This provides the force that propels the rigid lithospheric plates across the globe
  - Because the mantle transmits S waves and at the same time flows, it is referred to as exhibiting plastic behavior – solid under certain conditions and fluid under other conditions

36 ***End of Chapter 12***