Guiding Questions

1. What is the greenhouse effect? How does it affect the average temperature of the Earth?
2. Is the Earth completely solid inside? How can scientists tell?
3. How is it possible for entire continents to move across the face of the Earth?
4. How does our planet’s magnetic field protect life on Earth?
5. Why is Earth the only planet with an oxygen-rich atmosphere?
6. Why are prevailing winds generally from the west over most of North America but generally from the east in Hawaii?
7. What are global warming and the “ozone hole”? Why should they concern us?
Telling Rocks Apart

• How geologists tell apart different minerals and rocks
  – color, luster, texture
  – hardness test
    • scratching one against another
      – diamond is hardest
  – acid test
    • using weak hydrochloric acid to test for carbonates
  – streak test
    • form a streak across a ceramic tile

• Plate tectonics is involved in the formation of the three major categories of rocks
  – Igneous Rock
    • cooled from molten material
  – Sedimentary Rock
    • Layered eroded material formed by the action of wind, water, or ice
  – Metamorphic Rock
    • Rock that has been altered in the solid state by extreme heat and pressure

Minerals
• Characteristics
  – naturally occurring
  – inorganic
  – definite crystalline structure
• Uses
  – The natural resources of industry
Classification of Rocks

- **Igneous**
  - Rocks formed from hot molten mass of melted rock material
- **Sedimentary**
  - Rocks formed from particles or dissolved materials
- **Metamorphic**
  - Previously existing rocks that have been changed by heat, pressure, or hot solutions into a distinctly different rock

The Rock Cycle

Surface Building Processes

- **Stress**
  - “stress is a force that tends to compress, pull apart, or deform”
  - different types of stress
    - compressive stress
    - tensile stress
    - shear stress
- **Strain**
  - “the adjustment to stress”
Stress and Strain

Surface Building Processes
- Folds
  - bends in layered bedrock
- Anticline
- Syncline

Surface Building Processes
- Faulting
  - formation of a crack caused by relative movement of rock on either side of a fracture
  - different types - normal, reverse, thrust
Mountains

- "elevated parts of the Earth's crust that rise abruptly above the surrounding surface"
- Causes
  - folding, faulting, volcanic activity

Volcanoes

- "hill or mountain formed by the extrusion of lava or rock fragments from magma below"
- Different types
  - shield, cinder cone, composite (composite shown)

Earthquakes

- Defined as "quaking, shaking, vibrating, or upheaval of the ground"
- Earthquake causes
  - elastic rebound theory
- Intensity measure
  - Richter Magnitude
    - not linear scale
Earthquakes Galore

Earth's Inside Story

Energy Transfer in the Earth – Like a Pot of Boiling Water

Convection moves hot water...where it cools, moves from the bottom to the top...laterally, sinks....

...warms, and rises again.
Modeling The Earth’s Interior

Seismologists deduce the Earth’s interior structure by studying longitudinal P waves and transverse S waves during earthquakes.
Earth's Interior and How We Know It

- The Earth’s inner and outer cores are composed of iron with some nickel and other metals mixed in.
- The mantle is composed of iron-rich minerals.
- Both temperature and pressure steadily increase with depth inside the Earth.

<table>
<thead>
<tr>
<th>Region</th>
<th>Depth below surface (km)</th>
<th>Distance from center (km)</th>
<th>Average density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core (solid)</td>
<td>0-5 (under oceans)</td>
<td>6343-4378</td>
<td>3000</td>
</tr>
<tr>
<td>Mantle (solid)</td>
<td>from bottom of crust to 2900</td>
<td>2500-6343</td>
<td>3000-5500</td>
</tr>
<tr>
<td>Outer core (liquid)</td>
<td>2900-3100</td>
<td>1200-1300</td>
<td>10,000-12,000</td>
</tr>
<tr>
<td>Inner core (solid)</td>
<td>3100-6600</td>
<td>0-1,300</td>
<td>13,000</td>
</tr>
</tbody>
</table>

What We Learn from Seismometers

- The Earth’s inner and outer cores are composed of iron with some nickel and other metals mixed in.
- The mantle is composed of iron-rich minerals.
- Both temperature and pressure steadily increase with depth inside the Earth.

(c) The continents today
Crustal Rumblings

Boundaries Galore

The continents appear to fit together like a jigsaw puzzle
Plate Tectonics

- “The theory that the Earth’s crust is made of rigid plates that float on the asthenosphere.”
- Consider the scientific evidence for plate tectonics and what forced scientists to accept the theory as fact

Plate tectonics, or movement of the plates, is driven by convection within the asthenosphere

- Molten material wells up at oceanic rifts, producing seafloor spreading, and is returned to the asthenosphere in subduction zones
- As one end of a plate is subducted back into the asthenosphere, it helps to pull the rest of the plate along

Plates are smashing
Plate Tectonics

- The Earth's crust and a small part of its upper mantle form a rigid layer called the lithosphere.
- The lithosphere is divided into huge plates that move about over the plastic layer called the asthenosphere in the upper mantle.

Fossils across an ocean

(b) 152 million years ago: the breakup of Pangaea
Development of Geologic Time

• Fossilization
• “Reading the Rocks”
  – principle of uniformity
  – principle of original horizontality
  – principle of superposition
  – principle of crosscutting relationships
  – principle of faunal succession
  – radiometric dating
• Geologic Time Scale
Tear-Down Processes

- Weathering
  - mechanical weathering
  - chemical weathering
- Erosion
  - mass movement (mass wasting)
  - running water (floodplain, delta)
  - glacier
  - wind (deflation and abrasion)
  - impact cratering

The Earth’s Atmosphere and Surface

Atmosphere

- Composition
  - Nitrogen (78%), Oxygen (21%), Argon, Water Vapor, CO₂, Methane, other
- Atmospheric Pressure
  - pressure exerted by atmosphere
- Warming
  - Sun - solar constant is not really constant
  - greenhouse effect
The Earth’s atmosphere has changed substantially over time

- The Earth’s atmosphere differs from those of the other terrestrial planets in its chemical composition, circulation pattern, and temperature profile
- The Earth’s atmosphere changed from being mostly water vapor to being rich in carbon dioxide
- A strong greenhouse effect kept the Earth warm enough for water to remain liquid and to permit the evolution of life

<table>
<thead>
<tr>
<th>Chemical Compositions of Three Planetary Atmospheres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venus</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
</tr>
<tr>
<td>Carbon dioxide (CO₂)</td>
</tr>
<tr>
<td>Water vapor (H₂O)</td>
</tr>
<tr>
<td>Other gases</td>
</tr>
</tbody>
</table>

Structure of the Atmosphere

Circulation in our atmosphere results from convection and the Earth’s rotation

Because of the Earth’s rapid rotation, the circulation in its atmosphere is complex, with three circulation cells in each hemisphere.
Winds

- Local winds
  - wind chill factor
- Global wind patterns

Hydrosphere

- Evaporation
- Humidity
- Condensation Process
  - Clouds, fog
  - Precipitation

Size of condensation nuclei and droplet
Figure 16.15  
Weather Producers  
- Air Masses  
- Fronts  
- Waves and cyclones  
- Storms  
  - thunderstorms, tornadoes, hurricanes  

An idealized cold front
An idealized warm front

A thunderstorm cell develops

Weather Forecasting

- Predictions based upon
  - “characteristics, location, and rate of movement of air masses and associated fronts and pressure systems”
  - Complex computer models
- Led to science of “chaos”
  - Chaotic dynamic systems
Climate

- "general pattern of the weather that occurs for a region over a number of years"
- Major climate regions
  - tropical
  - temperate
  - polar

The principal climate zones

General rainfall patterns
Ocean currents influence temperatures

Tidal forces from the Moon and Sun help power the motion of the oceans

Distribution of the Water

[Diagram showing distribution of the water with labels and percentages]
The hydrologic cycle

Watersheds of three rivers

The path of groundwater
Oceanography

- Waves and tides
  - changes coastal structure
  - transport of material
  - long term and short term changes
- A Climate control mechanism
  - ocean conveyor belt
    - major control of climate

A wave passing in the open ocean

A wave becoming breaking onshore
The Earth’s Magnetic Field

- Electric currents in the liquid outer core generate a dipole magnetic field
  - Similar to a coil of wire around an iron nail
- This magnetic field produces a magnetosphere that surrounds the Earth and blocks the solar wind from hitting the atmosphere
- Traps particles from the solar wind in regions – Producing Van Allen Belts
- Most of the particles of the solar wind are deflected around the Earth by the magnetosphere.

A bow-shaped shock wave, where the supersonic solar wind is abruptly slowed to subsonic speeds, marks the outer boundary of the magnetosphere.
An increased flow of charged particles from the Sun can overload the Van Allen belts and cascade toward the Earth, producing aurorae.

Some charged particles from the solar wind are trapped in two huge, doughnut-shaped rings called the Van Allen belts.

Energy Sources and the Earth’s atmosphere, oceans, and surface

<table>
<thead>
<tr>
<th>Activity</th>
<th>Energy Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion of water in oceans, lakes, rivers</td>
<td>Solar energy, tidal forces</td>
</tr>
<tr>
<td>Motion of the atmosphere</td>
<td>Solar energy</td>
</tr>
<tr>
<td>Reshaping of surface</td>
<td>Earth’s internal heat</td>
</tr>
<tr>
<td>Life</td>
<td>Solar energy (a few species that live on the ocean floor make use of the Earth’s internal heat)</td>
</tr>
</tbody>
</table>

The appearance of photosynthetic living organisms led to our present atmospheric composition, about four-fifths nitrogen and one-fifth oxygen.
What does the color of the white layer, due to the lack of iron oxide, tell us about the history of the Earth's atmosphere?

The Distribution of Plant Life

- Land colors designate vegetation: dark green for the rain forests, light green and gold for savannas and farmland, and yellow for the deserts
- Ocean colors show that phytoplankton are most abundant in the red and orange areas and least abundant in the dark blue areas

The Greenhouse Effect

- Solar energy is the energy source for the atmosphere
- In the greenhouse effect, some of this energy is trapped by infrared absorbing gases in the atmosphere, raising the Earth's surface temperature above what it would be if there was no greenhouse effect
(a) Changes in the Earth’s average temperature

(b) Breakup of the Larsen B ice shelf, Antarctica, 2002

(c) CO₂ concentration (ppm)
Deforestation and the burning of fossil fuels are increasing the greenhouse effect in our atmosphere and warming the planet.

A burgeoning human population may be altering the Earth’s biosphere.

Industrial chemicals released into the atmosphere have damaged the ozone layer in the stratosphere.
Key Words

- albedo
- asthenosphere
- atmosphere (atm)
- atmospheric pressure
- aura (plural auras)
- aurora
- convection
- convection cell
- convection current
crake
- core
- core-mass ejection
crust (of Earth)
crystal
earthquake
epicenter
global warming
- greenhouse effect
- greenhouse gas
- igneous rock
- Inner and outer core (of Earth)
- lava
- lithosphere
- magma
- magnetopause
- metamorphic rock
- mineral
- northern and southern lights
- ozone layer
- ozone hole
- ozonosphere
- photosynthesis
- plume
- plate (lithospheric)
- plate tectonics
- respiration
- rift
- seafloor spreading
- seismic wave
- seismograph
- shock wave
- stratosphere
- subduction zone
- surface wave
- thermosphere
- Van Allen belts
- mesosphere