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?
The Earth’s atmosphere, oceans, and surface are extraordinarily active.

All activity in the Earth’s atmosphere, oceans, and surface is powered by three sources of energy.

<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>

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

The internal heat of the Earth is the energy source for geologic activity

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

...warms, and rises again.

Studies of earthquakes reveal the Earth's layered interior structure

(a) During differentiation, iron sank to the center and less dense material floated upward
(b) As a result of differentiation, the Earth has the layered structure that we see today
Seismologists deduce the Earth's interior structure by studying how longitudinal P waves and transverse S waves travel through the Earth's interior.

The Earth's Internal Structure

- The Earth’s inner and outer cores are composed of almost pure iron with some nickel 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 core (km)</th>
<th>Average Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crust (solid)</td>
<td>0-4 (under ocean)</td>
<td>0-55 (under continents)</td>
<td>3.40-4.00</td>
</tr>
<tr>
<td>Melted (solid)</td>
<td>4 km from bottom of crust</td>
<td>3100-5100</td>
<td>1.00-1.30</td>
</tr>
<tr>
<td>Outer core (solid)</td>
<td>2000-4500</td>
<td>7-1300</td>
<td>13,000</td>
</tr>
<tr>
<td>Inner core (solid)</td>
<td>5100-6600</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Plate movement produces earthquakes, mountain ranges, and volcanoes that shape the Earth’s surface.

- 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.

(a) 237 million years ago: the supercontinent Pangaea
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.
Plate tectonics is responsible for most of the major features of the Earth's surface, including mountain ranges, volcanoes, and the shapes of the continents and oceans.

Plate tectonics is involved in the formation of the three major categories of rocks:

- **Igneous rocks**
  - cooled from molten material
- **Sedimentary rocks**
  - formed by the action of wind, water, and ice
- **Metamorphic rocks**
  - altered in the solid state by extreme heat and pressure

**Igneous rock (basalt)**
The Earth's magnetic field produces a magnetosphere that traps particles from the solar wind:

- Electric currents in the liquid outer core generate a magnetic field.
- This magnetic field produces a magnetosphere that surrounds the Earth and blocks the solar wind from hitting the atmosphere.
- 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.

The Earth’s atmosphere has changed substantially over our planet’s history:
- 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 evolved 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 9.4 Chemical Compositions of Three Planetary Atmospheres

<table>
<thead>
<tr>
<th></th>
<th>Venus</th>
<th>Earth</th>
<th>Mars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N₂)</td>
<td>3.5%</td>
<td>78.01%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>almost zero</td>
<td>20.93%</td>
<td>almost zero</td>
</tr>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>96.5%</td>
<td>0.03%</td>
<td>95.7%</td>
</tr>
<tr>
<td>Water vapor (H₂O)</td>
<td>0.003%</td>
<td>almost 1%</td>
<td>0.03%</td>
</tr>
<tr>
<td>Other gases</td>
<td>almost zero</td>
<td>almost zero</td>
<td>2%</td>
</tr>
</tbody>
</table>
The appearance of photosynthetic living organisms led to our present atmospheric composition, about four-fifths nitrogen and one-fifth oxygen.

- The Earth’s atmosphere is divided into layers called the troposphere, stratosphere, mesosphere, and thermosphere.
- Ozone molecules in the stratosphere absorb ultraviolet light.

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.
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?

A burgeoning human population is profoundly altering the Earth's biosphere.

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
Deforestation and the burning of fossil fuels are increasing the greenhouse effect in our atmosphere and warming the planet.

(a) Changes in the Earth's average temperature

(b) Breakup of the Larsen B ice shelf, Antarctica, 2002
Industrial chemicals released into the atmosphere have damaged the ozone layer in the stratosphere.