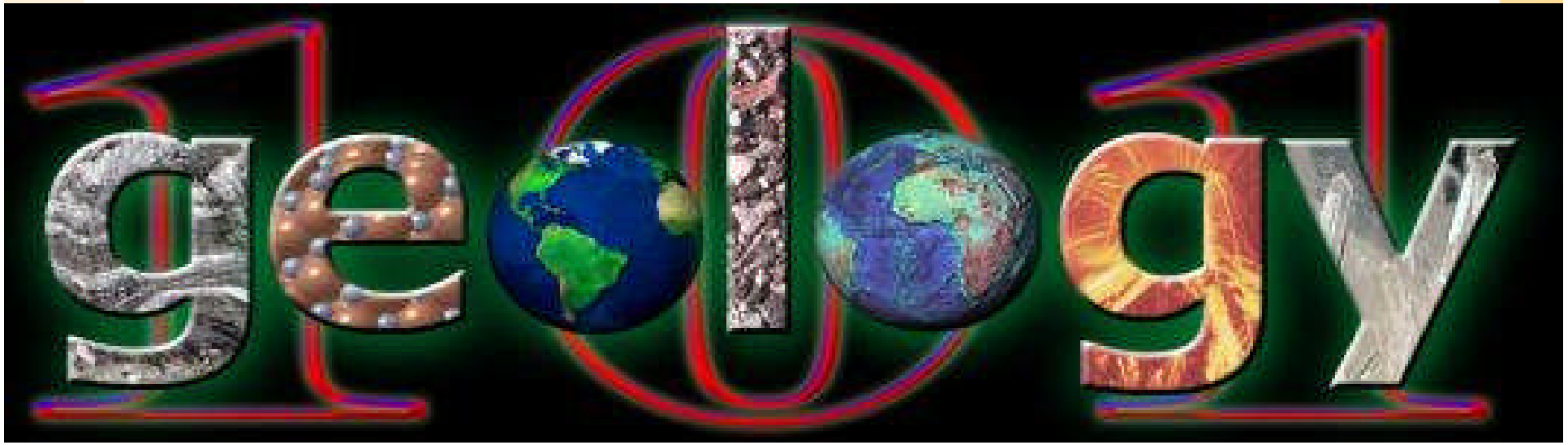
Chapter 1

Introduction to Earth Science

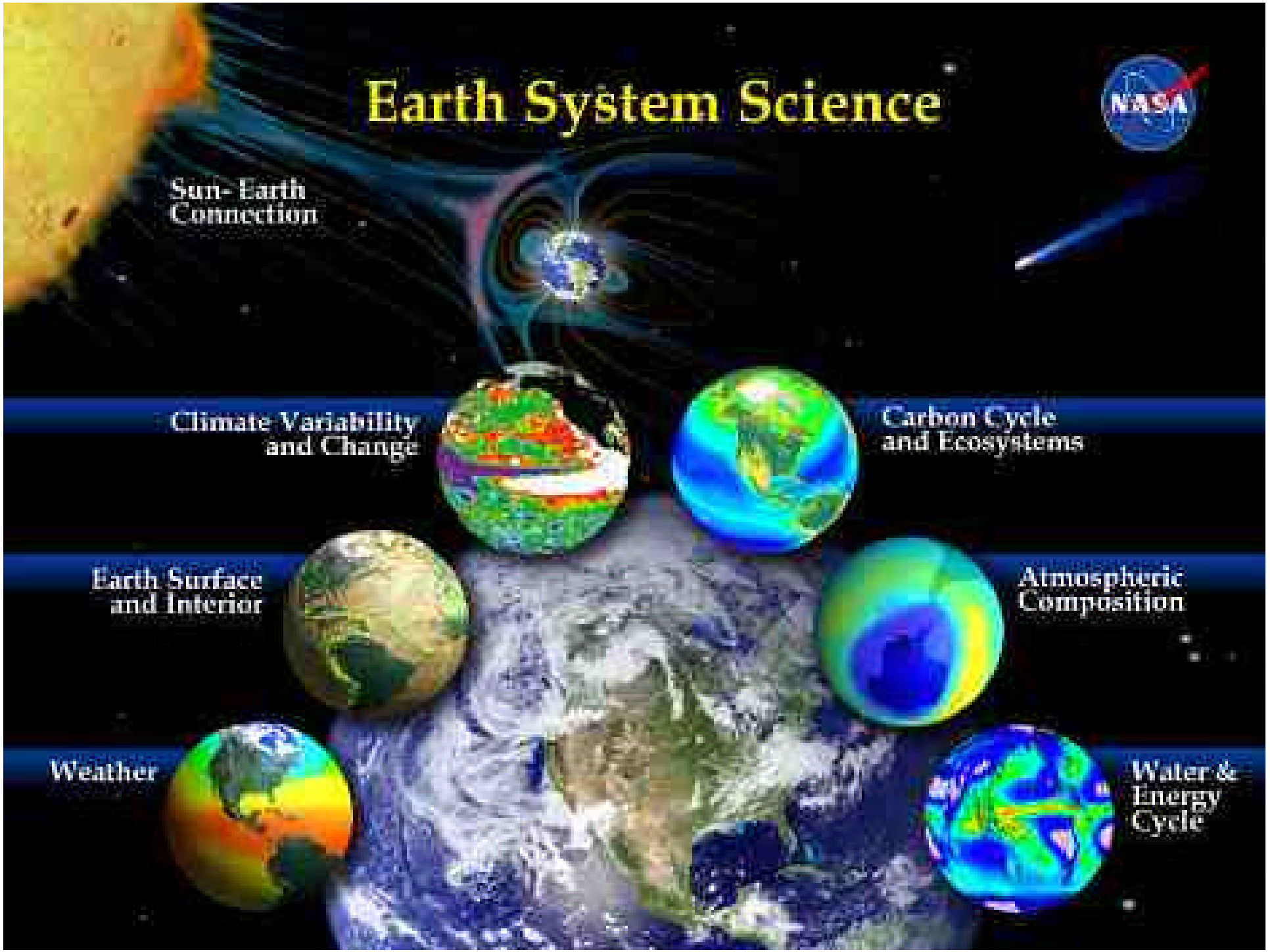
1.1 What Is Earth Science?
Overview of Earth Science

- **Encompasses all sciences that seek to understand**
  - **Earth**
  - **Earth's neighbors in space**



EARTH IS THE THIRD PLANET FROM THE SUN IN OUR SYSTEM.


Magnetosphere
Crust
Core
Atmosphere
Mantle
Biosphere
Hydrosphere
Humansphere
Cryosphere
Earth & Planetary SystemScience
UNIVERSITY OF TOKYO


Earth System Science
NASA
Sun- Earth Connection
Climate Variability and Change
Carbon Cycle and Ecosystems
Earth Surface and Interior
Atmospheric Composition
Weather
Water & Energy Cycle

1.1 What Is Earth Science?

- **Earth science includes**

1. geology, the study of Earth

a. physical geology - examination of the materials that make up Earth and possible explanations for the many processes that shape our planet

1.1 What Is Earth Science?

- **Earth science includes**

1. geology, the study of Earth

b. historical geology - aim is to understand Earth's long history by establishing a timeline of the vast number of physical and biological changes that have occurred in the past

1.1 What Is Earth Science?

- **Earth science includes**

2. **oceanography, the study of the ocean**
3. **meteorology, the study of the atmosphere and the processes that produce weather**
4. **astronomy, the study of the universe**

1.1 What Is Earth Science?

Formation of Earth

- **Most researchers conclude that Earth and the other planets formed at essentially the same time.**
- **Nebular Hypothesis**
  - **The solar system evolved from an enormous rotating cloud called the solar nebula.**

1.1 What Is Earth Science?

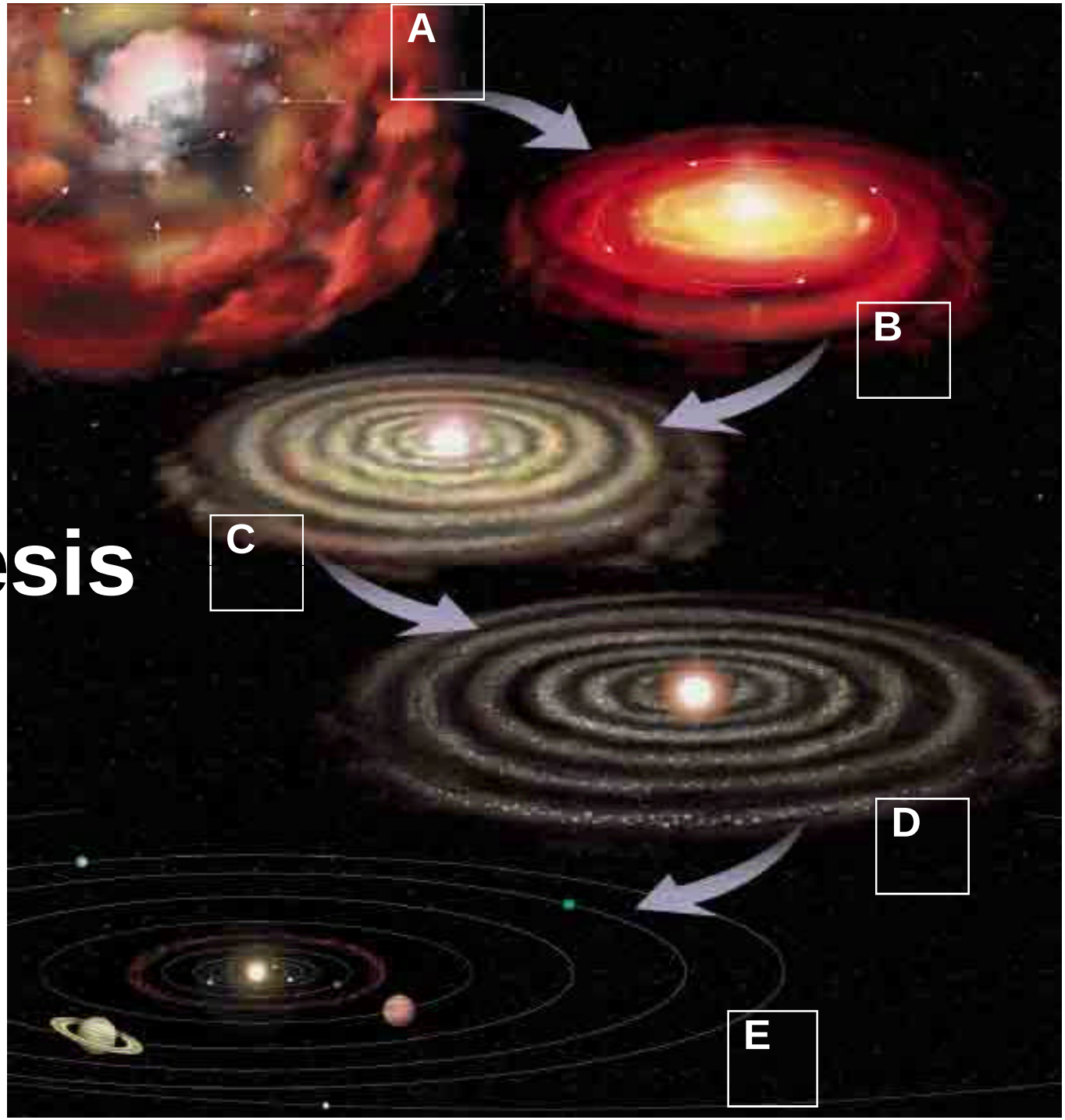
- **Nebular Hypothesis**
  - The nebula was composed mostly of hydrogen and helium.
  - About 5 billion years ago, the nebula began to contract.
  - It assumed a flat, disk shape with the protosun (pre-Sun) at the center.

1.1 What Is Earth Science?

Nebular Hypothesis cont.

- Inner planets begin to form from metallic and rocky clumps.
- Larger outer planets began forming from fragments with a high percentage of ices.

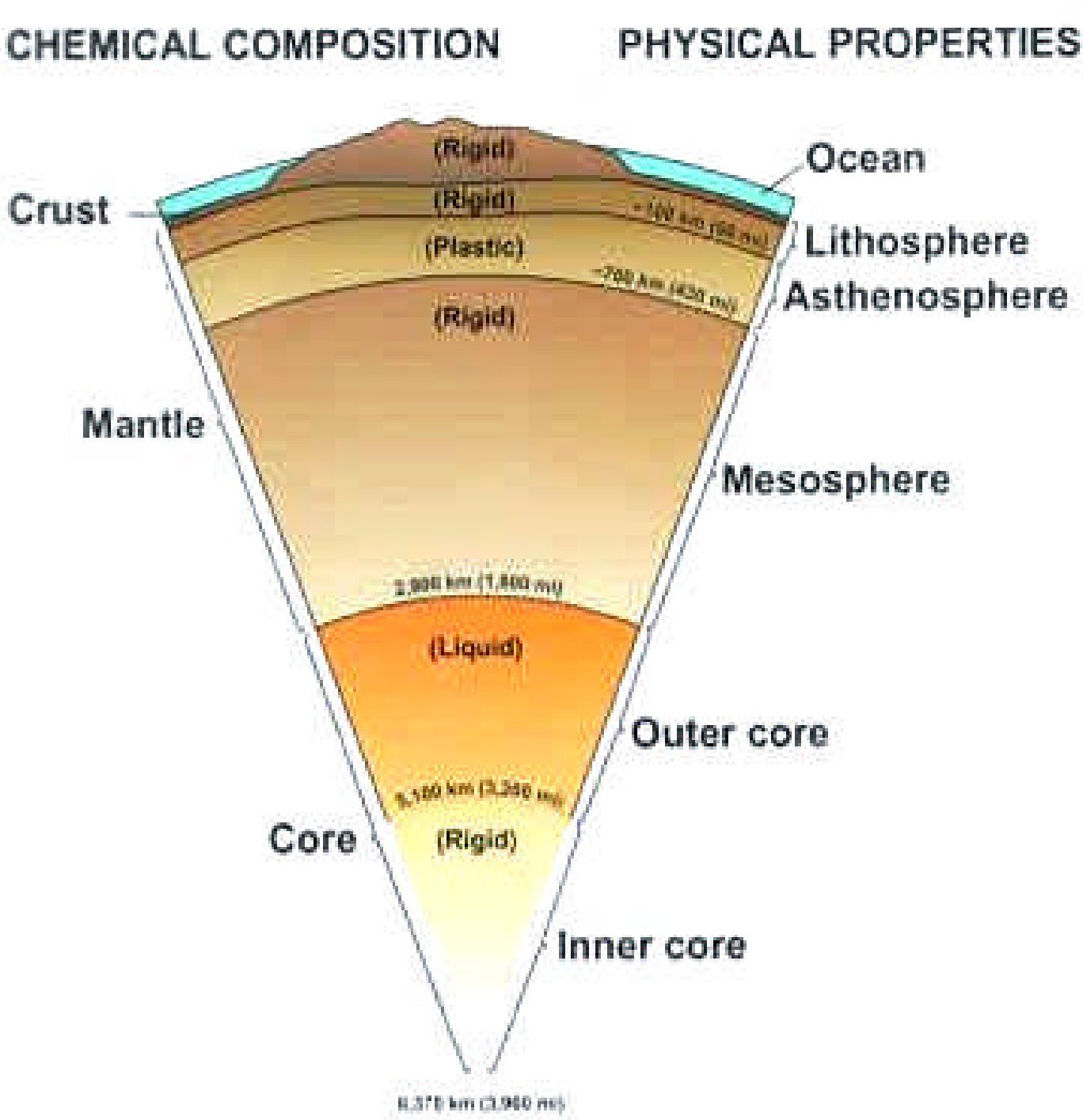
The Nebular Hypothesis



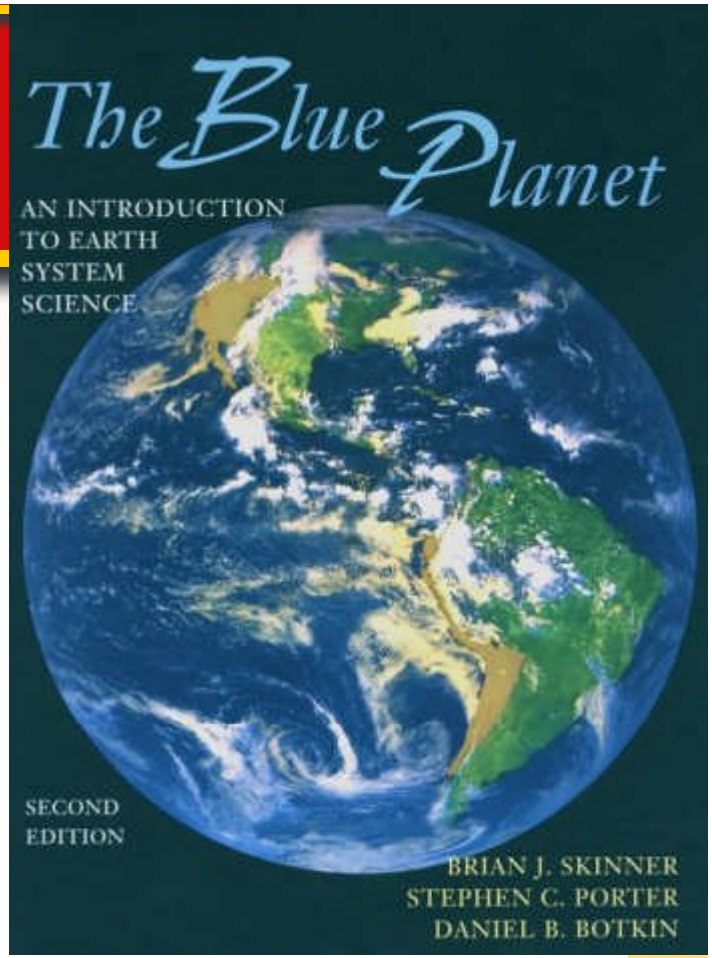
1.1 What Is Earth Science?

Layers Form on Earth

- As Earth formed, the decay of radioactive elements and heat from high-velocity impacts caused the temperature to increase.
- Lighter rocky components floated outward, toward the surface.
- Gaseous material escaped from Earth's interior to produce the primitive atmosphere.


CHEMICAL COMPOSITION
PHYSICAL PROPERTIES
Crust
Mantle
Core
(Rigid)
(Rigid)
(Plastic)
(Rigid)
(Liquid)
(Rigid)
Ocean
Lithosphere
Asthenosphere
Mesosphere
Outer core
Inner core

1.2 A View of Earth



Earth's Major Spheres

1. Hydrosphere

- Ocean is the most prominent feature of the hydrosphere.

- Is nearly 71% of Earth's surface
- Holds about 97% of Earth's water

1.2 A View of Earth

Earth's Major Spheres

1. Hydrosphere cont.

- Also includes fresh water found in streams, lakes, glaciers, and groundwater

1.2 A View of Earth

Earth's Major Spheres

2. Atmosphere

- Thin, tenuous blanket of air
- 90% lies within 16 km (abt 10 miles) of the earth’s surface

1.2 A View of Earth

Earth's Major Spheres

3. Biosphere

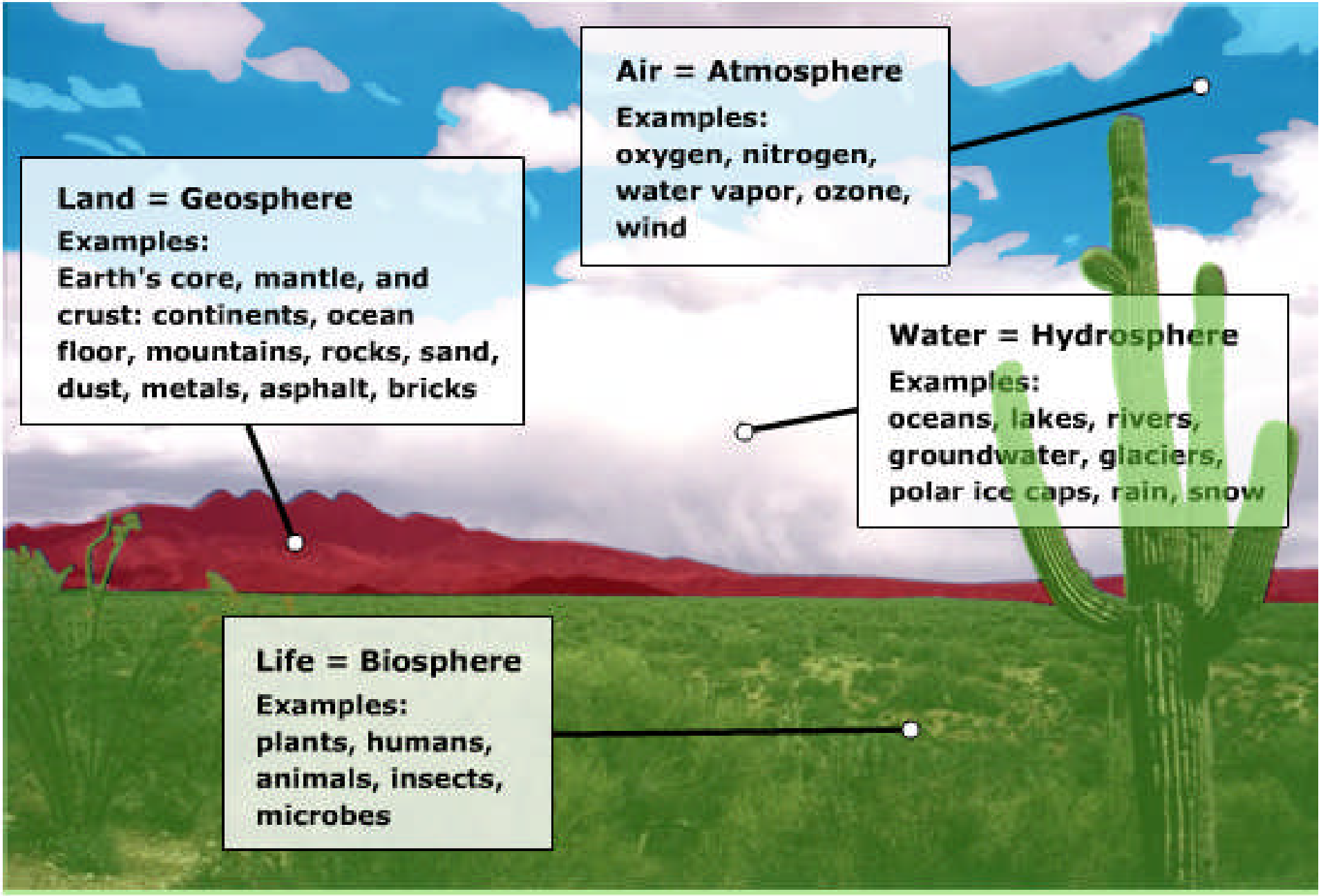
- Includes all life
- Concentrated in a zone that extends from the ocean floor upward for several kilometers into the atmosphere

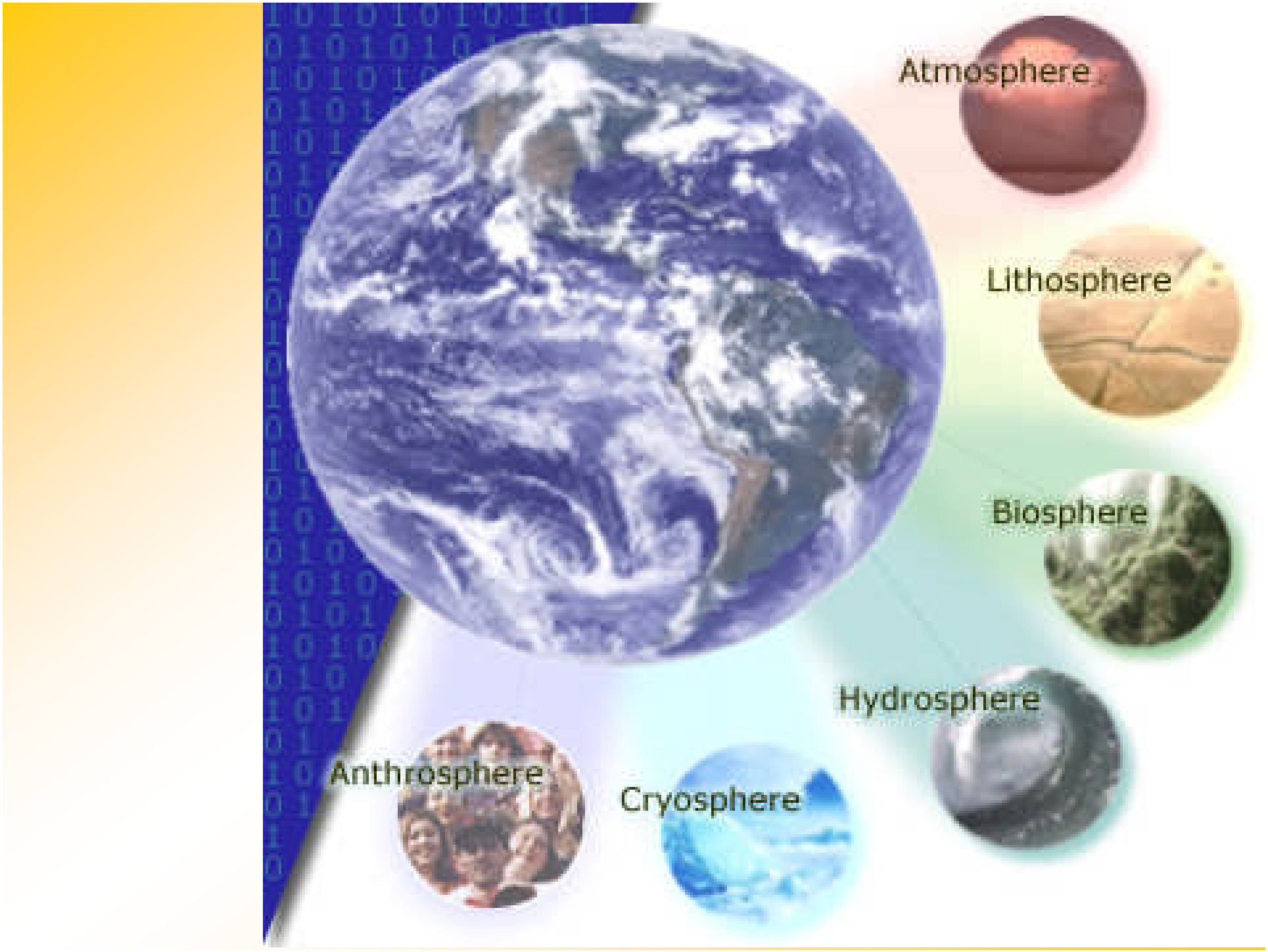
1.2 A View of Earth

4. Geosphere

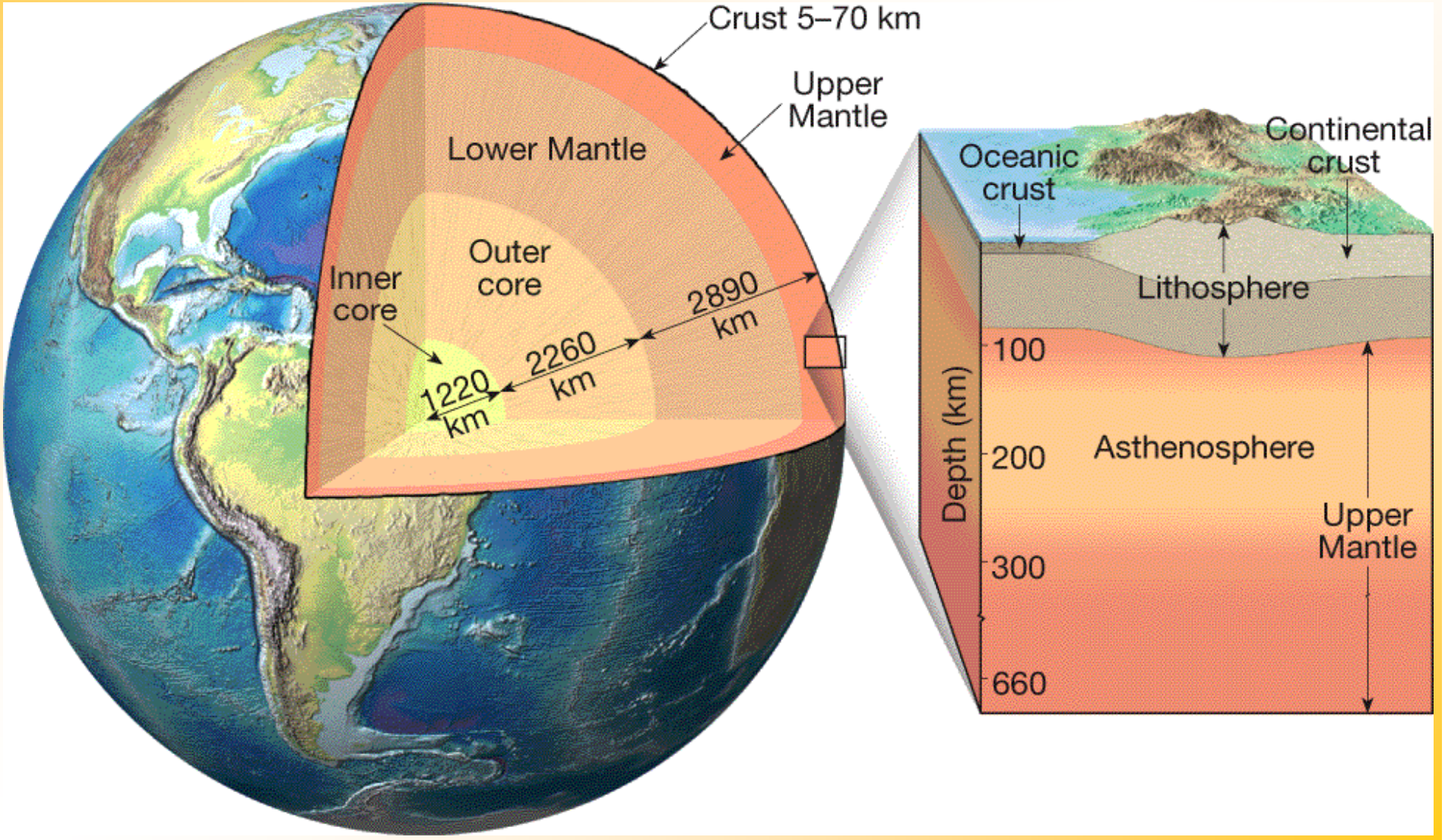
- Based on compositional differences, it consists of the crust, mantle, and core.

- Crust—the thin, rocky outer layer of Earth.
- Mantle—the 2890-kilometer-thick layer of Earth located below the crust.
- Core—the innermost layer of Earth, located beneath the mantle.

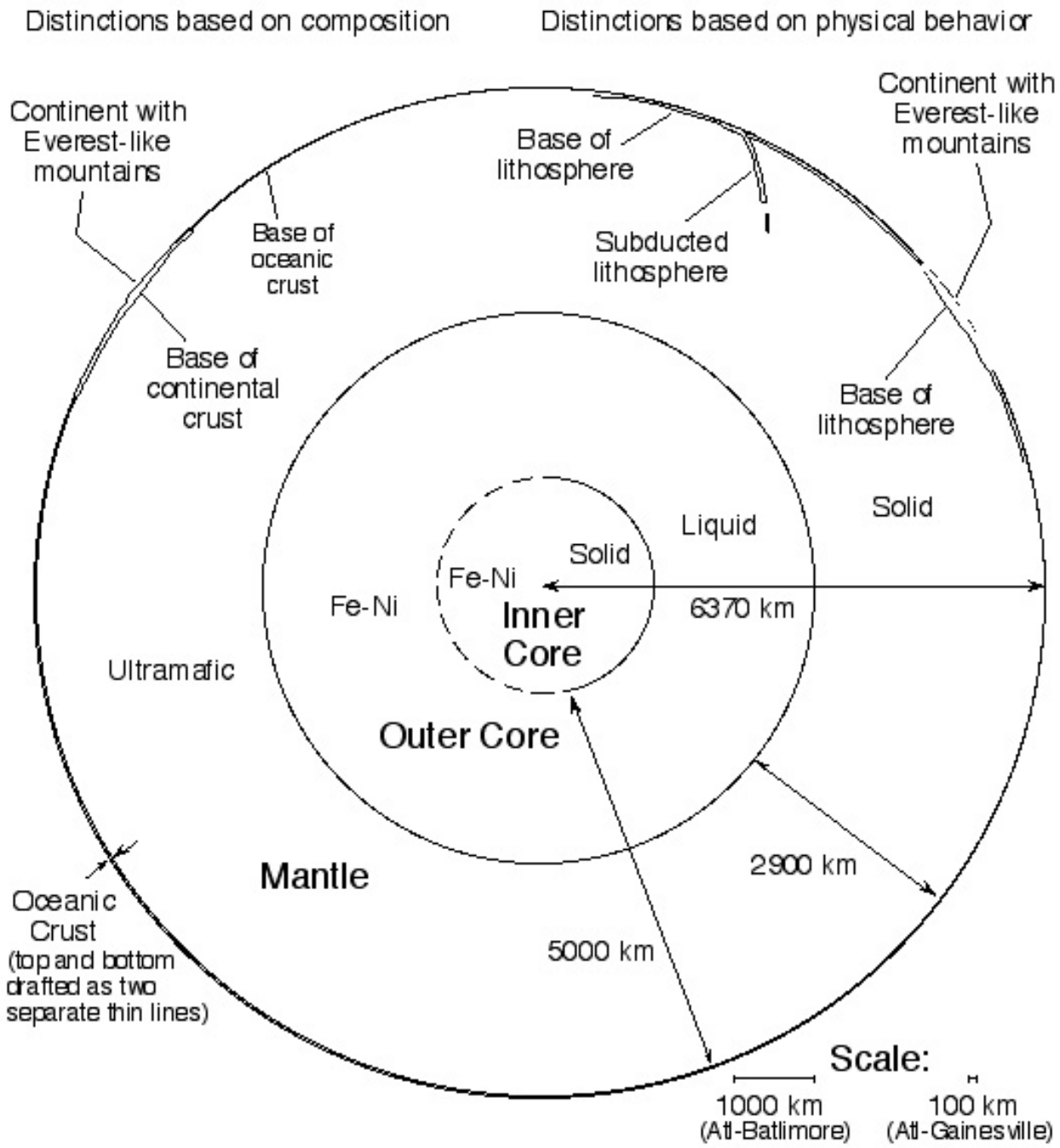

Air = Atmosphere
Examples:
oxygen, nitrogen, water vapor, ozone, wind
Land = Geosphere
Examples:
Earth's core, mantle, and crust: continents, ocean floor, mountains, rocks, sand, dust, metals, asphalt, bricks
Water = Hydrosphere
Examples:
oceans, lakes, rivers, groundwater, glaciers, polar ice caps, rain, snow
Life = Biosphere
Examples:
plants, humans, animals, insects, microbes

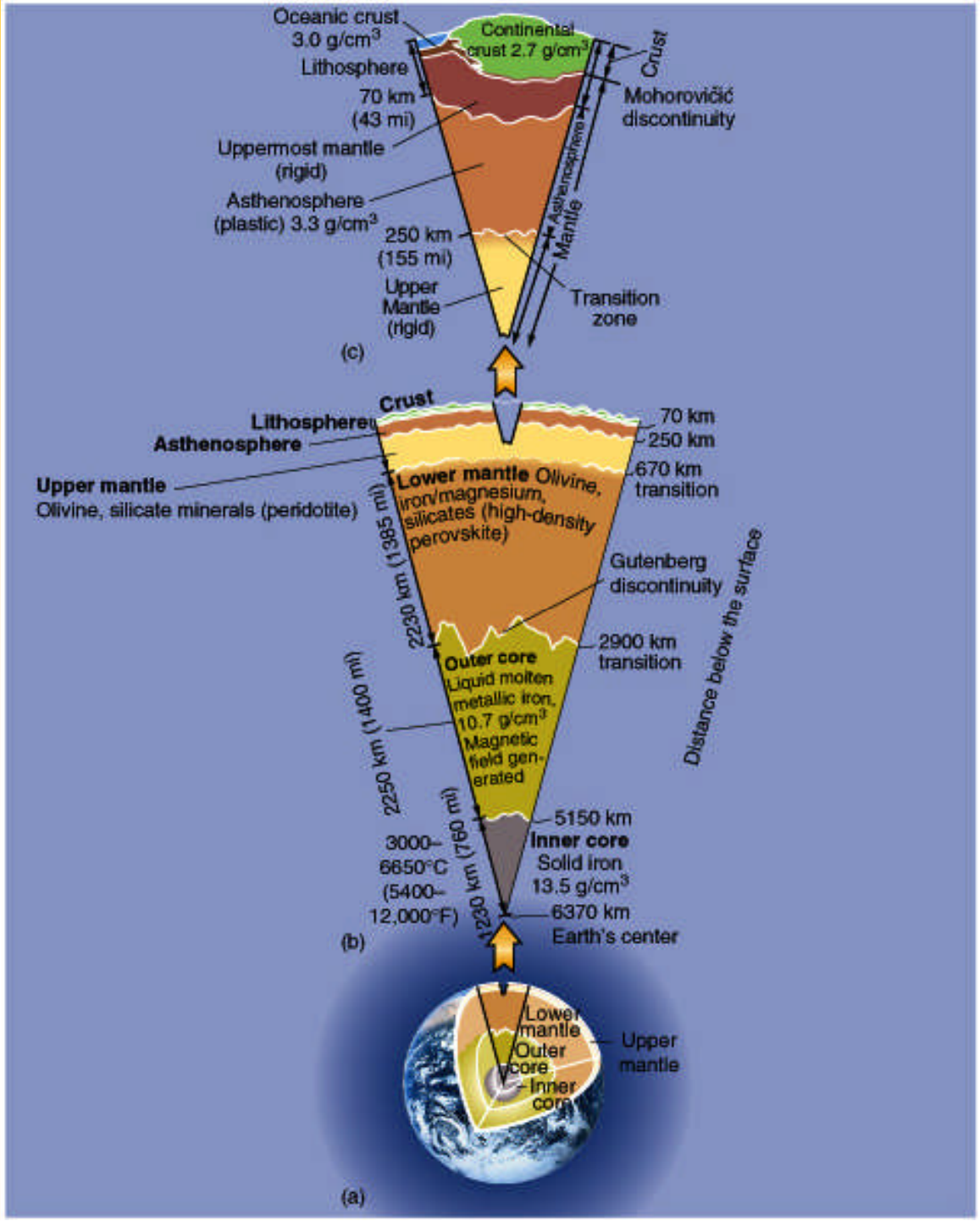

Atmosphere
Lithosphere
Biosphere
Hydrosphere
Anthrosphere
Cryosphere

Earth's Layered Structure



The Earth to Scale




Oceanic crust
3.0 g/cm3
Lithosphere
70 km
(43 mi)
Uppermost mantle
(rigid)
Asthenosphere
(plastic) 3.3 g/cm3
250 km
(155 mi)
Upper
Mantle
(rigid)
(c)
Continental
crust 2.7 g/cm3
Crust
Mohorovičić
discontinuity
Asthenosphere
Mantle
Transition
zone
Crust
Lithosphere
Asthenosphere
Upper mantle
Olivine, silicate minerals (peridotite)
70 km
250 km
670 km
transition
Lower mantle Olivine, iron/magnesium, silicates (high-density perovskite)
2230 km (1385 mi)
Gutenberg
discontinuity
2900 km
transition
Outer core
Liquid molten metallic iron, 10.7 g/cm3
Magnetic field generated
2250 km (1400 mi)
1230 km (760 mi)
5150 km
Inner core
Solid iron
13.5 g/cm3
3000–6650°C
(5400–12,000°F)
6370 km
Earth's center
(b)
Distance below the surface
Lower mantle
Outer core
Inner core
Upper mantle
(a)

Water and Ice

Wind

Volcanism

Impact Cratering

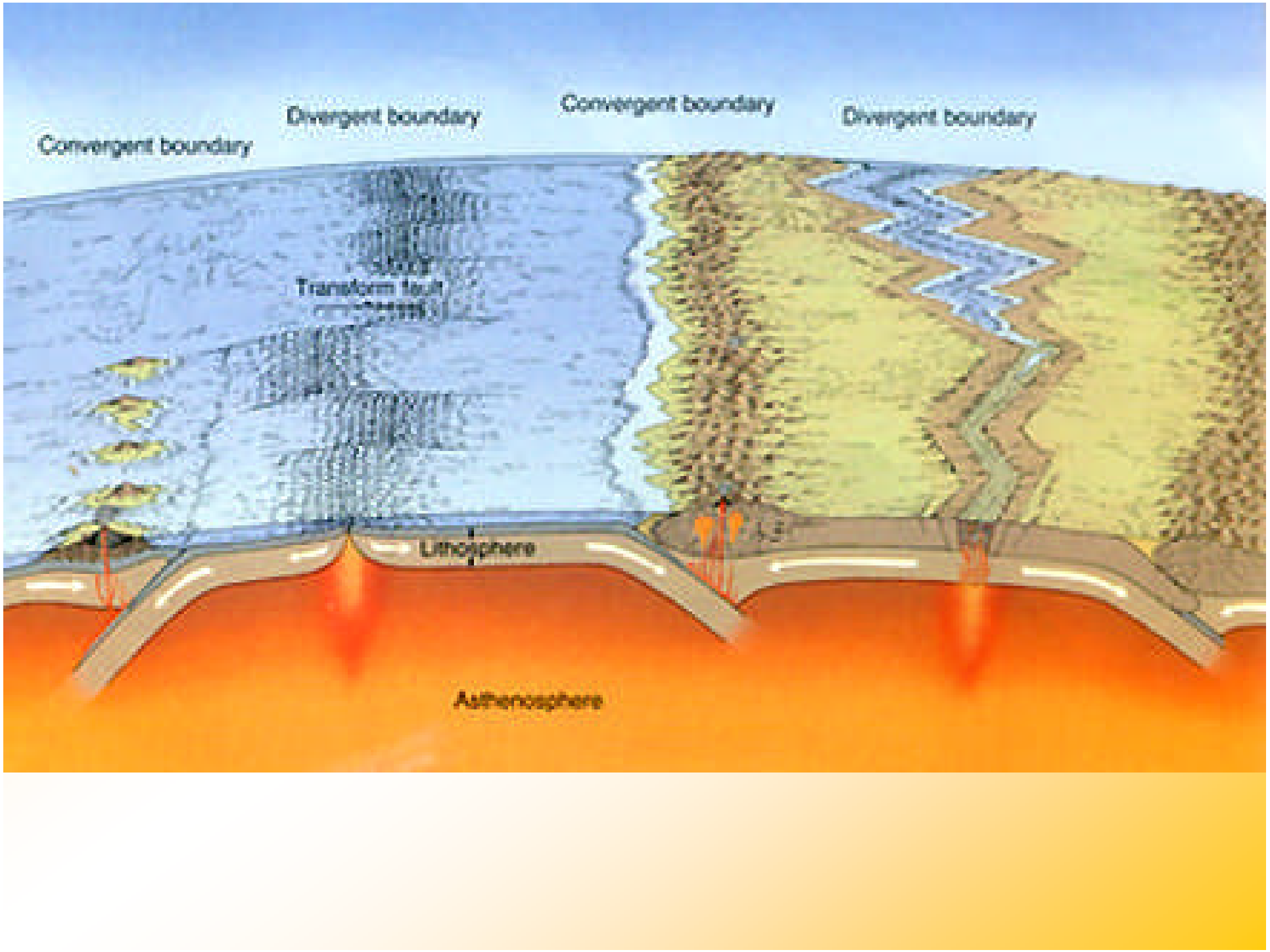
Tectonics

Living Things

1.2 A View of Earth

Plate Tectonics

- **Plate tectonics is the theory that proposes that Earth's outer shell consists of individual plates that interact in various ways and thereby produce earthquakes, volcanoes, mountains, and Earth's crust itself.**
  - **Plate movement is driven by unequal distribution of heat within the Earth**

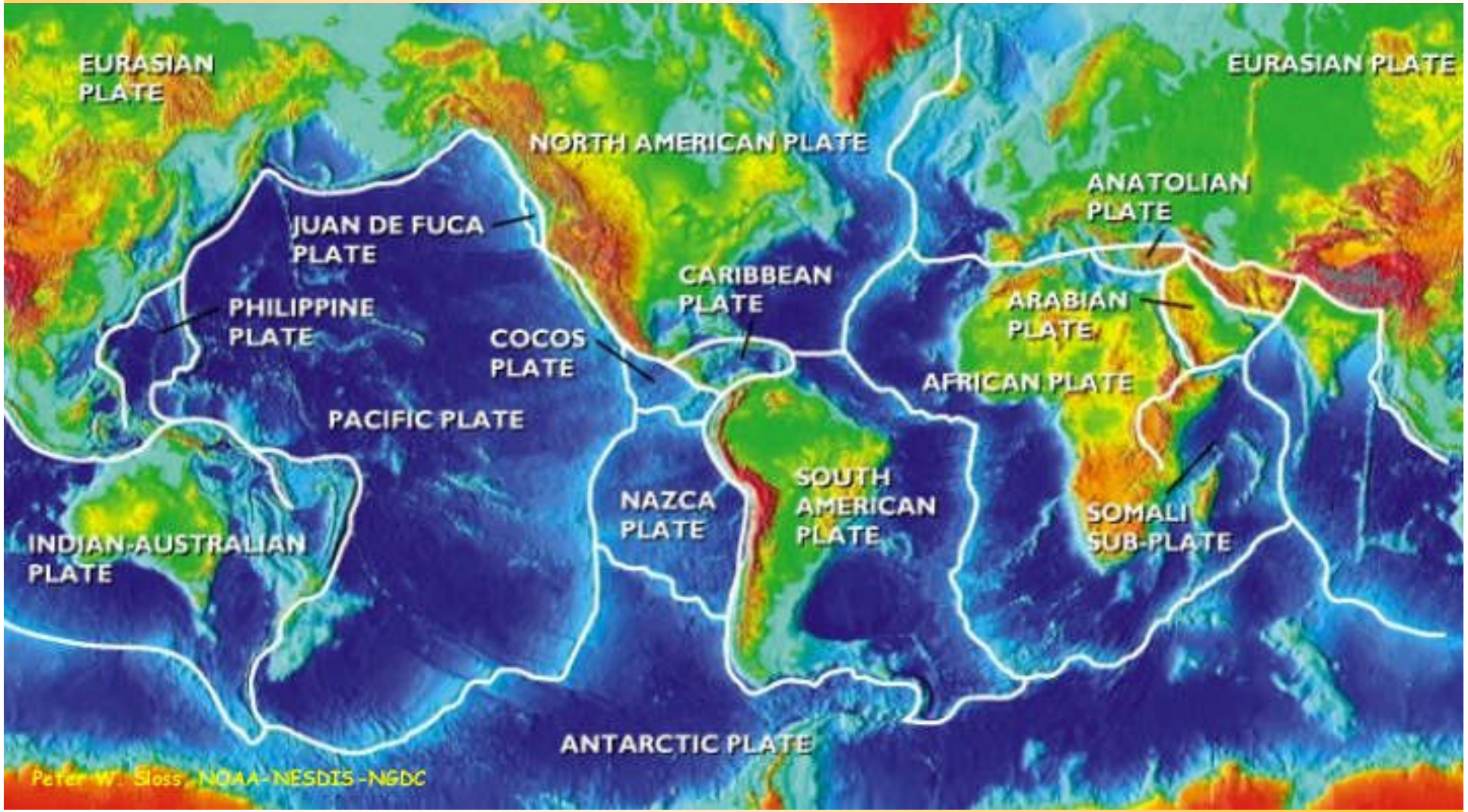

Convergent boundary
Divergent boundary
Convergent boundary
Divergent boundary
Transform fault
Lithosphere
Asthenosphere

1.2 A View of Earth

Plate Tectonics

- Two types of forces affecting the Earth's surface
  - *destructive* - weathering and erosion flatten the Earth
  - *constructive* - mountain building and volcanism build up the surface

1.2 A View of Earth



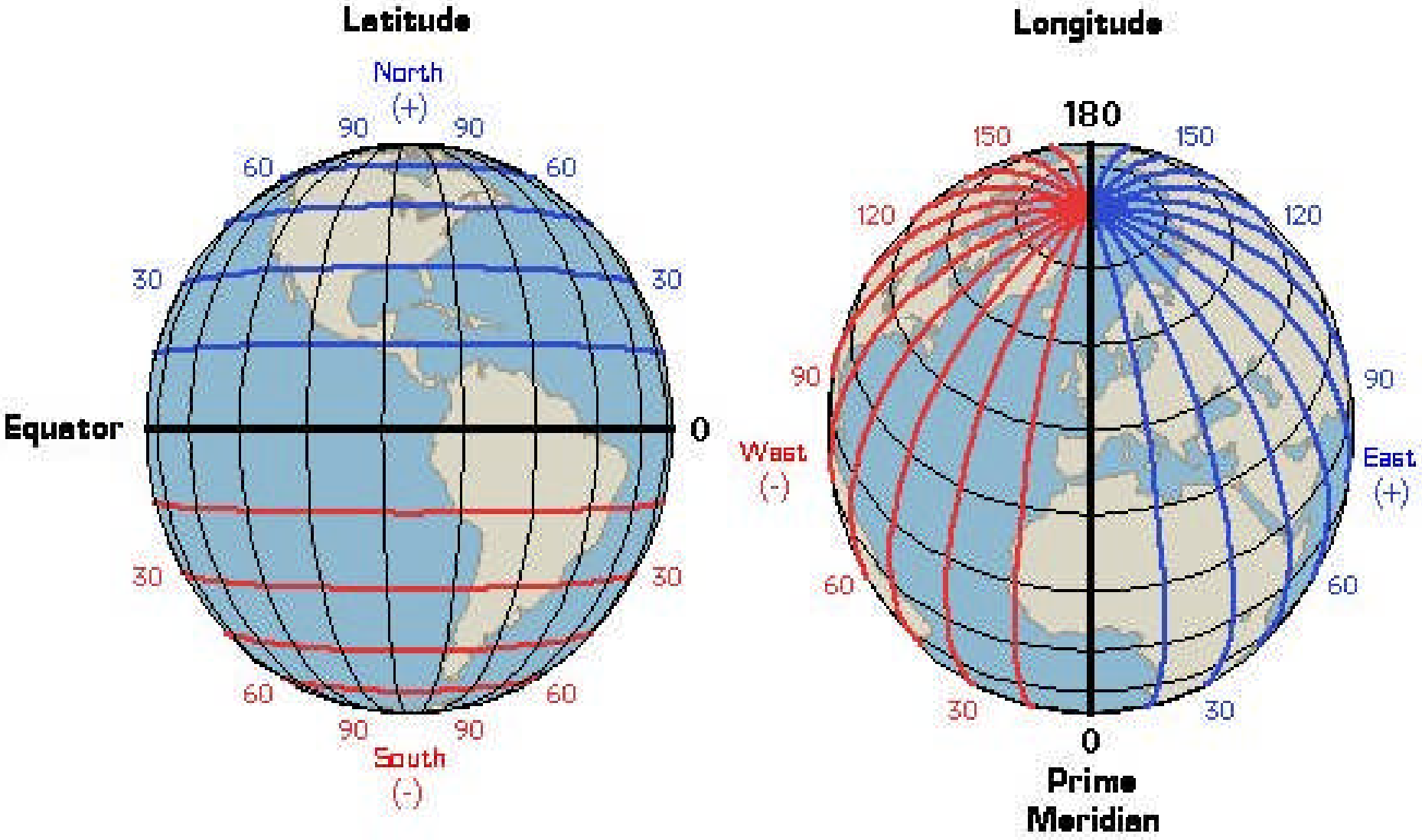
How to represent this as a flat surface?

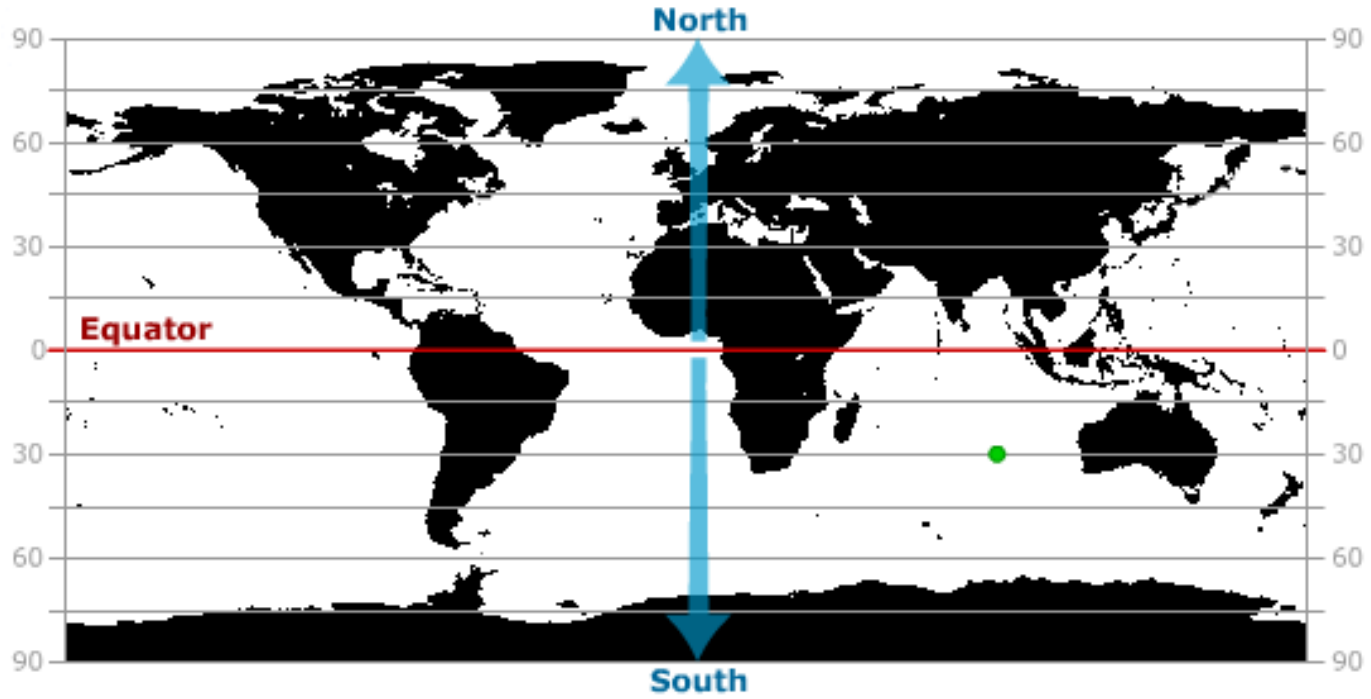
1.3 Representing Earth's Surface

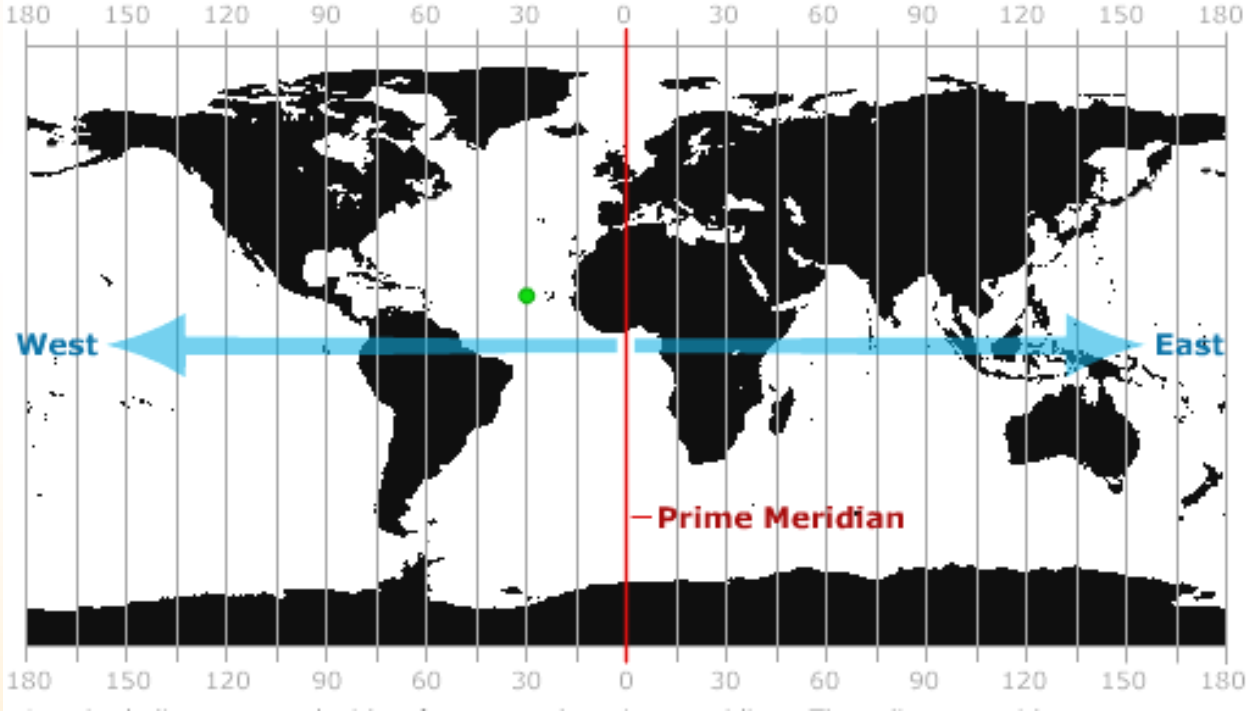
Determining Location

- **Latitude and longitude are lines on the globe that are used to determine location.**
- **Latitude is distance north or south of the equator, measured in degrees.**
- **Longitude is distance east or west of the prime meridian, measured in degrees.**

1.3 Representing Earth's Surface




North
90
60
30
Equator
0
30
60
90
South


180
150
120
90
60
30
0
West
East
Prime Meridian

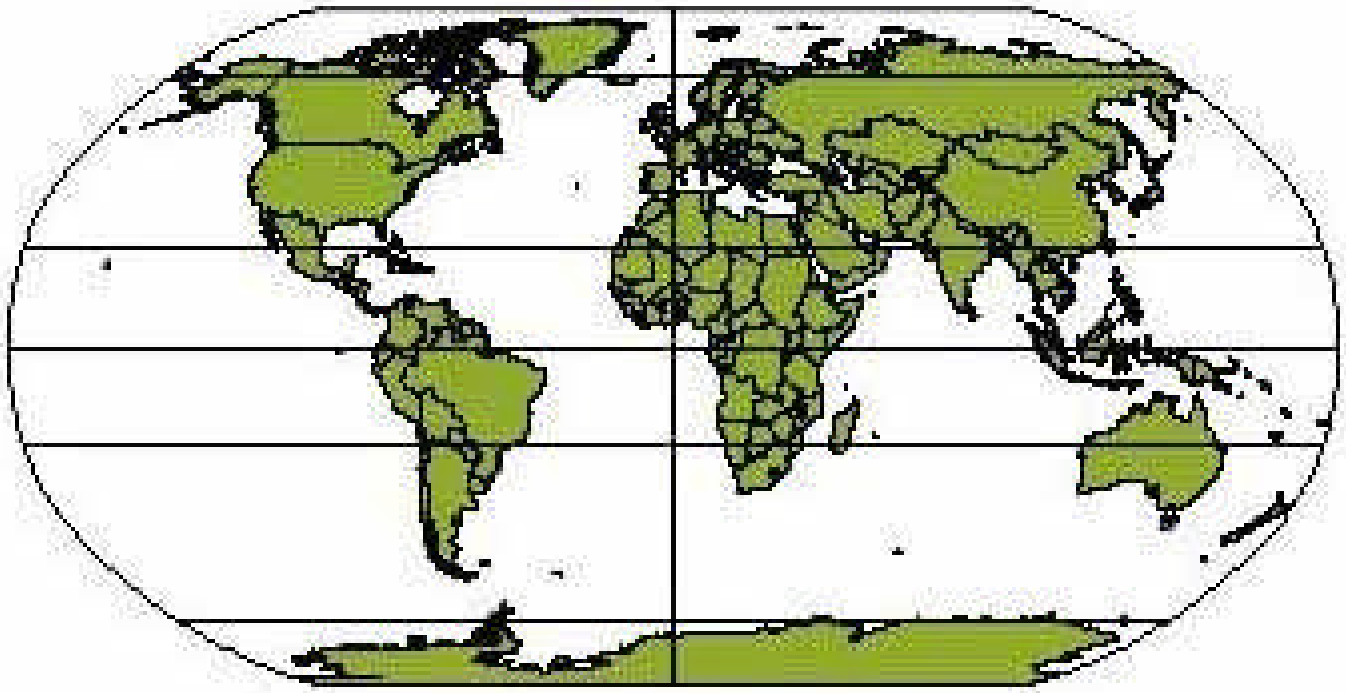
1.3 Representing Earth's Surface

Maps and Mapping

- **No matter what kind of map is made, some portion of the surface will always look either too small, too big, or out of place. Mapmakers have, however, found ways to limit the distortion of shape, size, distance and direction.**

1.3 Representing Earth's Surface

- **Robinson projection map**
  - show most distances, sizes, and shapes accurately with distortions in areas around the edges of the map

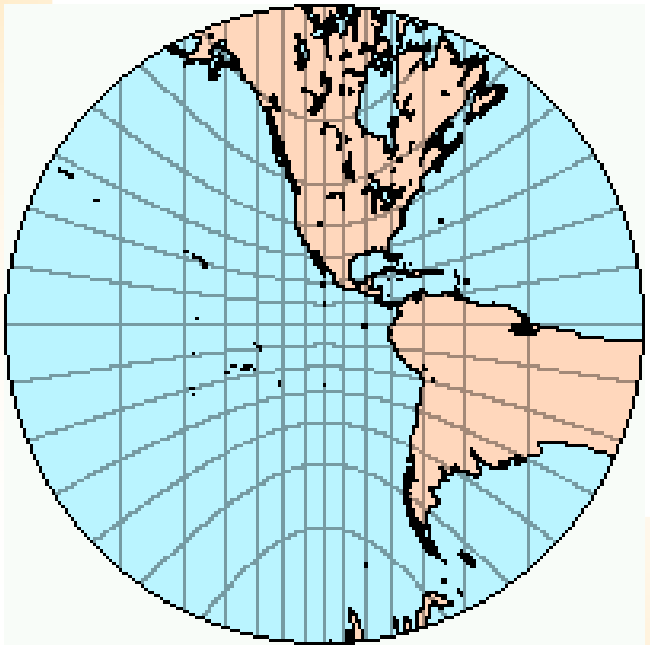


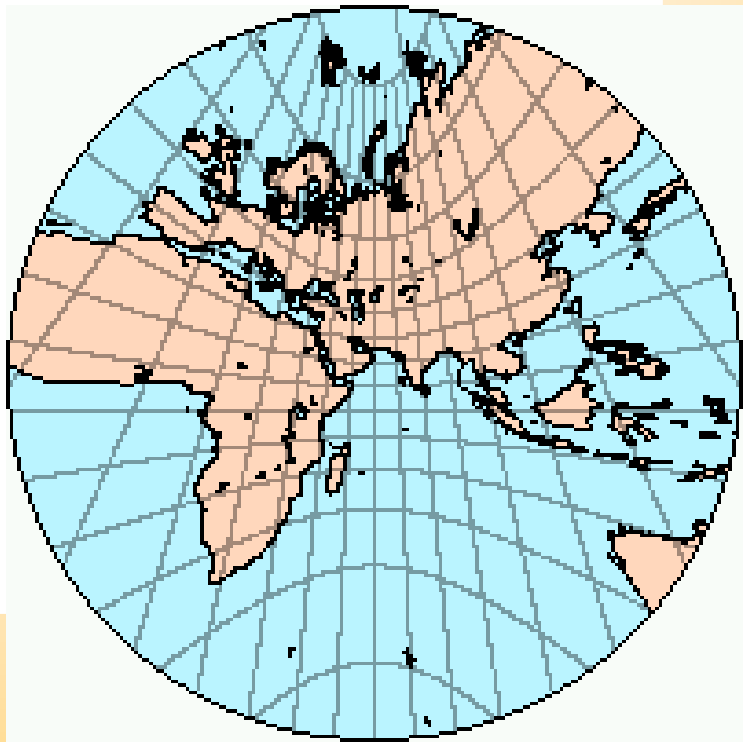
1.3 Representing Earth's Surface

- **Conic projection map**
  - accuracy is great over a small area so are good for making road and weather maps

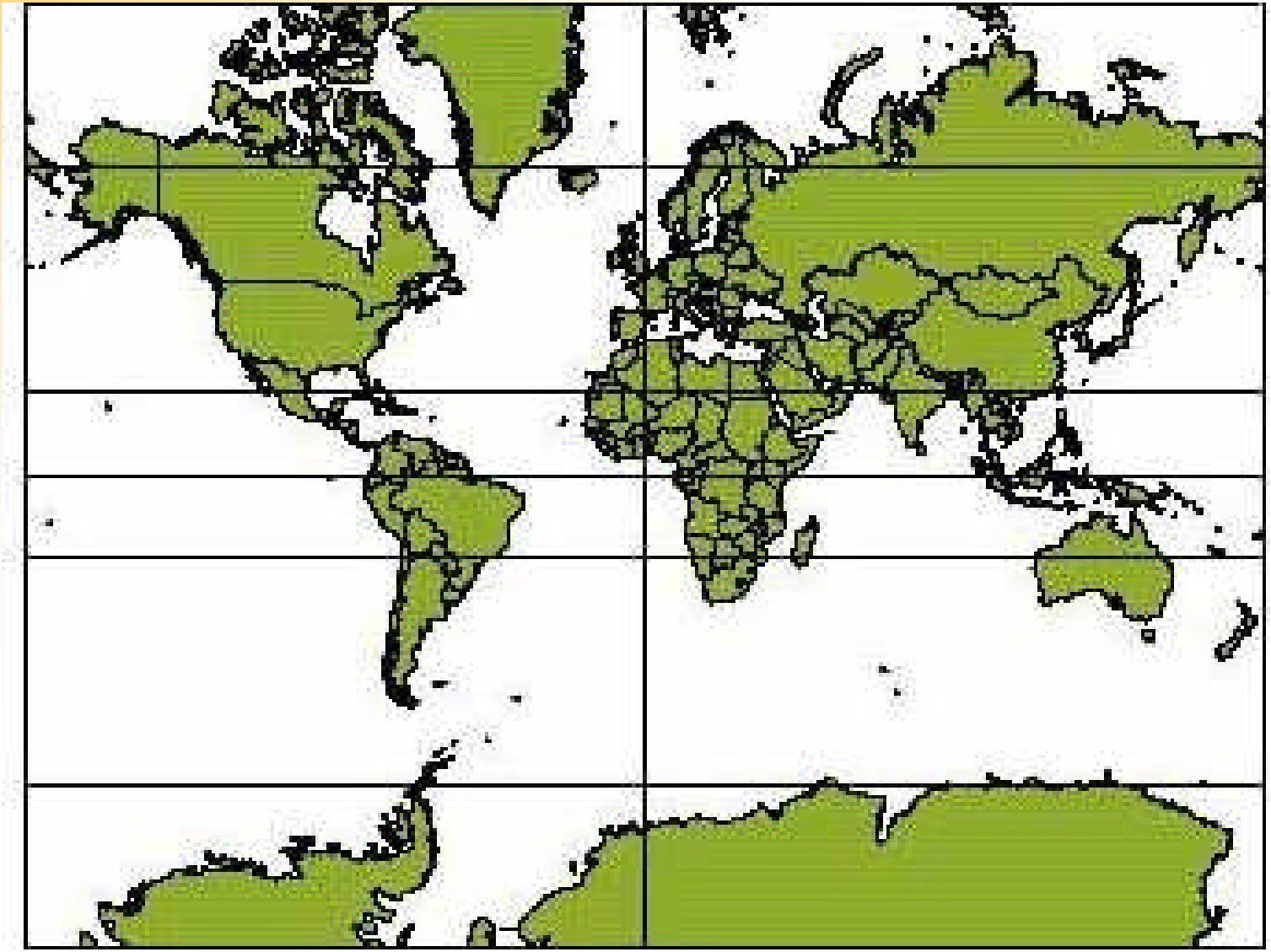
1.3 Representing Earth's Surface

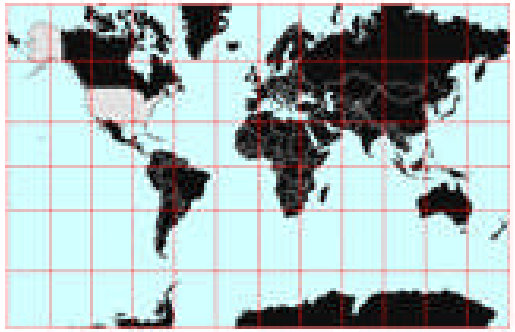
- **Gnonomic projection map**
  - distances and directions are distorted but they show with great accuracy the shortest distance between two points





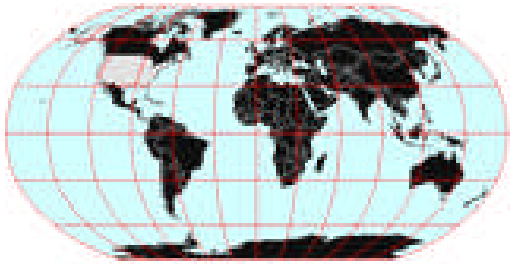
Mercator Projection



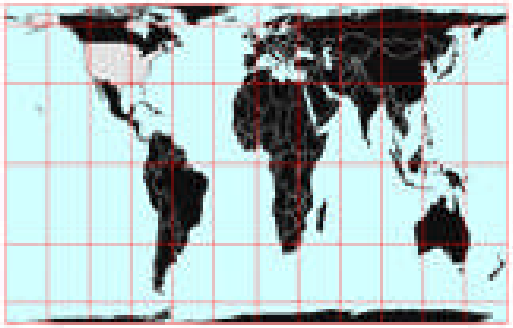


Mercator

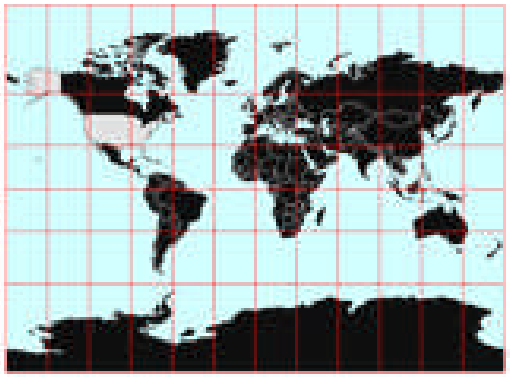
Sinusoidal



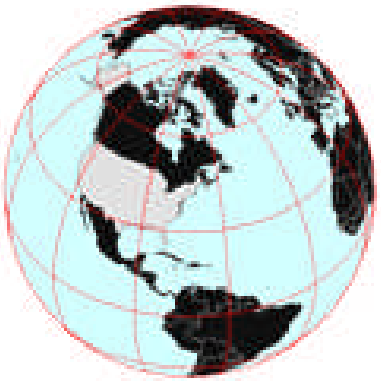
Robinson



Peters



Miller



Orthographic

1.3 Representing Earth's Surface

Topographic Maps

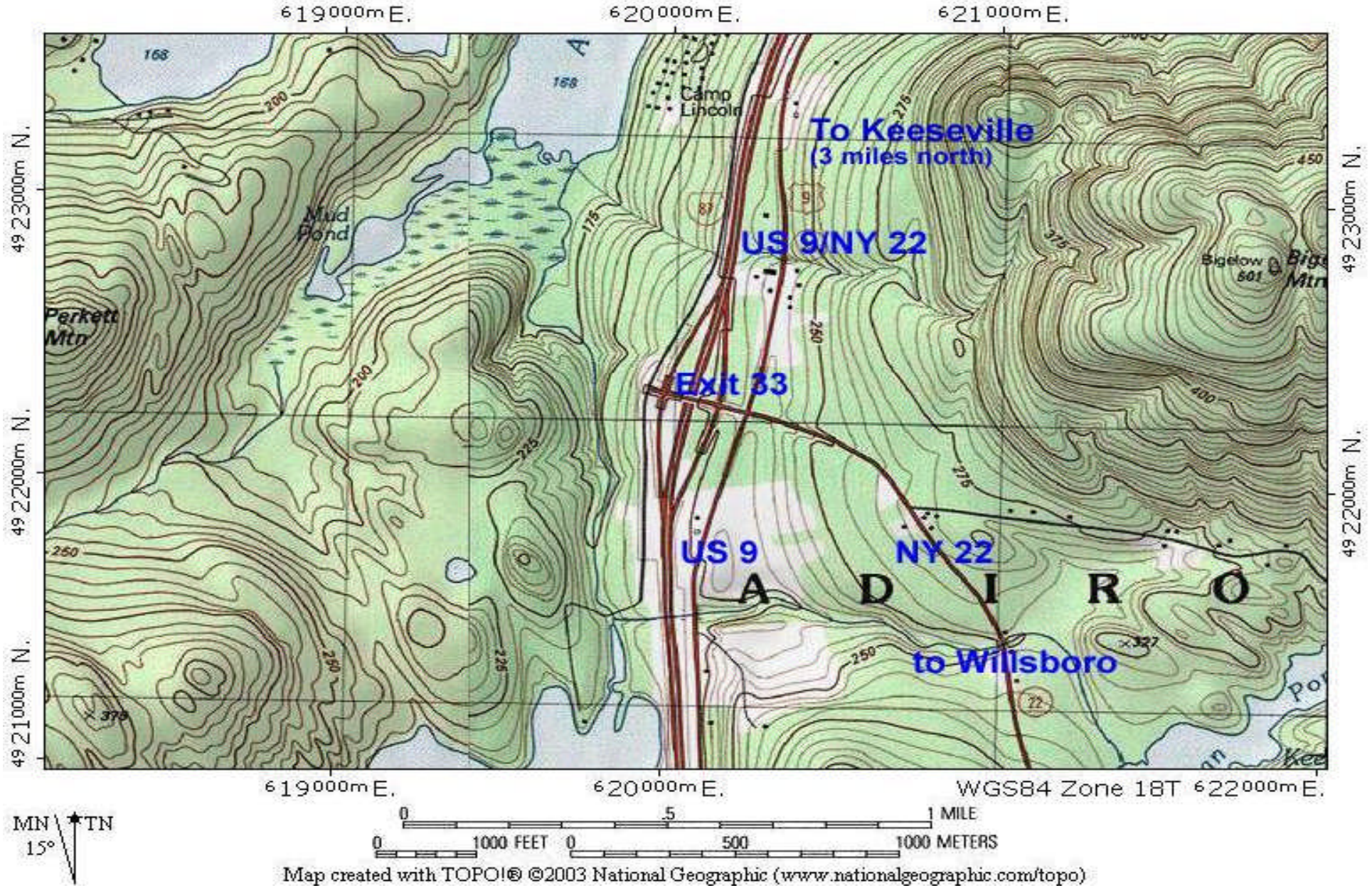
- Topographic maps represent Earth's surface in three dimensions; they show elevation, distance directions, and slope angles.
- Contour lines are lines on a topographic map that indicate an elevation.

1.3 Representing Earth's Surface

Topographic Maps

- **Contour interval is the distance in elevation between adjacent contour lines.**
- **Lines close together indicate a steeper slope.**

1.3 Representing Earth's Surface



1.3 Representing Earth's Surface

Topographic Maps

- **Scale - maps are drawn to scale where a certain distance on the map is equal to a certain distance on the surface**
- **bar scales - allow you to determine the distance represented**
- **Geologic Maps - show the type and age of the exposed rocks**

1.3 Representing Earth's Surface

Advanced Technology

- Use of satellites and computers to send and receive data
- The process of collecting data from a distance is called remote sensing
- GPS - Global Positioning Systems - receives signals to compute the user's latitude and longitude as well as speed, direction, and elevation

1.4 Earth System Science

What is Earth System Science?

- Earth is a dynamic planet with many separate but interactive parts or spheres.
- Earth scientists study how these spheres are interconnected

1.4 Earth System Science

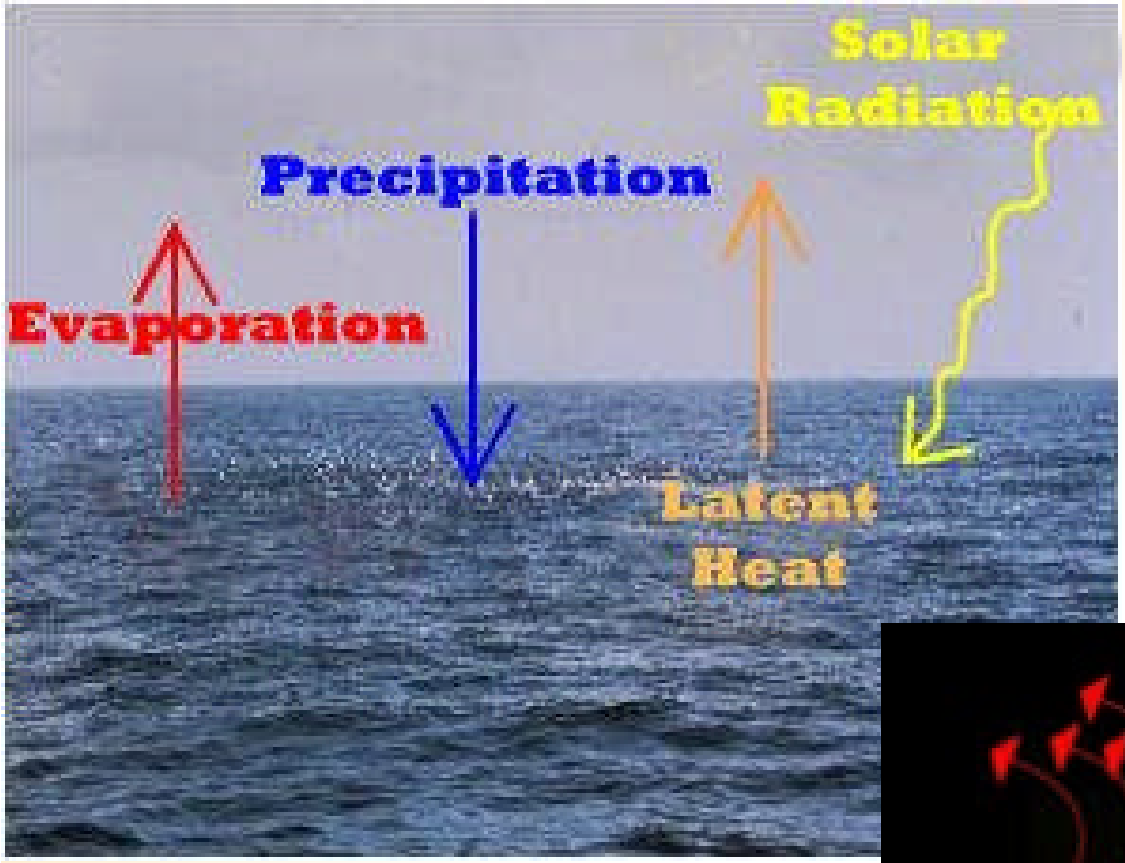
What is Earth System Science?

- **This way of looking at Earth is Earth system science - its aim is to understand earth as a system made up of numerous interacting parts, or subsystems.**

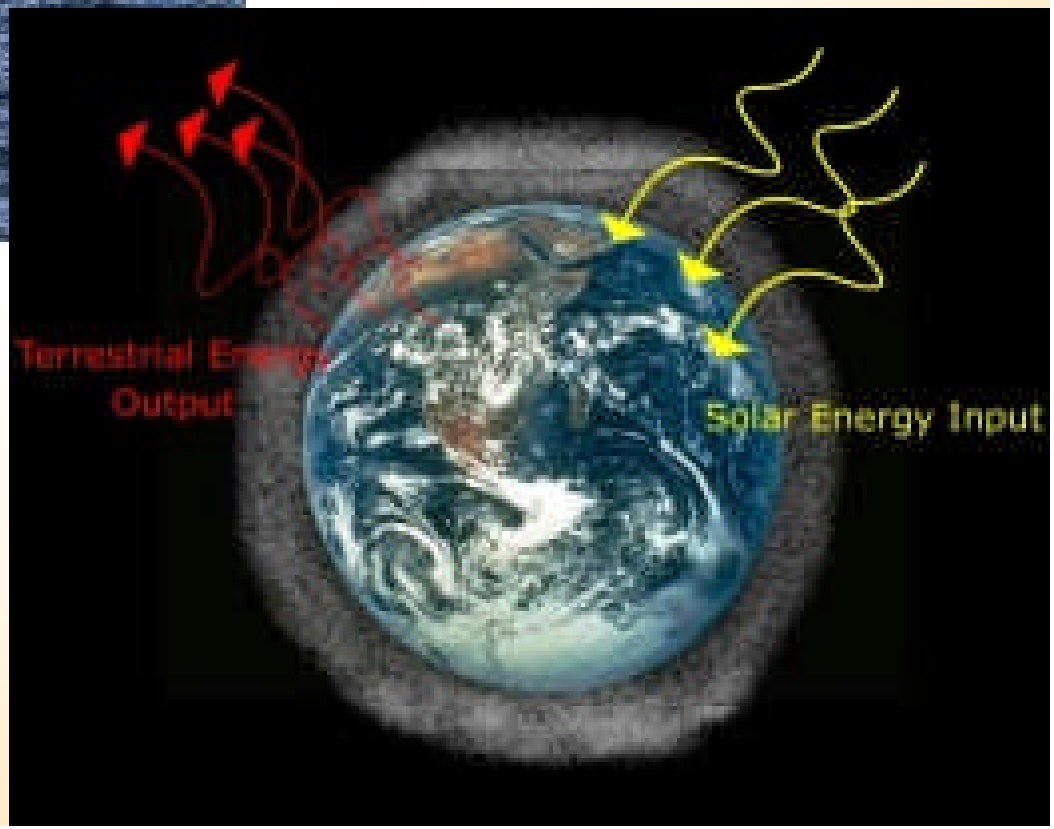
1.4 Earth System Science

What Is a System?

- A system is any size group of interacting parts that form a complex whole.
- Closed systems are self contained (e.g., an automobile cooling system).
- Open systems allow both energy and matter to flow in and out of the system (e.g., a river system).



Open system



Closed system

1.4 Earth System Science

Earth as a System

Sources of Energy

- Sun—drives external processes such as weather, ocean circulation and erosional processes
- Earth's interior—drives internal processes including volcanoes, earthquakes and mountain building

1.4 Earth System Science

Earth as a System

- Consists of a nearly endless array of subsystems (e.g., hydrologic cycle)
- Humans are part of the Earth system.
  - Our actions produce changes in all of the other parts of the Earth system

1.4 Earth System Science

People and the Environment

- **Environment**
  - **Surrounds and influences organisms**
- **Physical environment encompasses water, air, soil, and rock**
- **The term *environmental* is usually reserved for those aspects that focus on the relationships between people and the natural environment.**

1.4 Earth System Science

Resources

- Include water, soil, minerals, and energy
- Two broad categories

1. Renewable—can be replenished (e.g., plants, energy from water and wind)
2. Nonrenewable—cannot be replenished in the near future (e.g., metals, fuels)

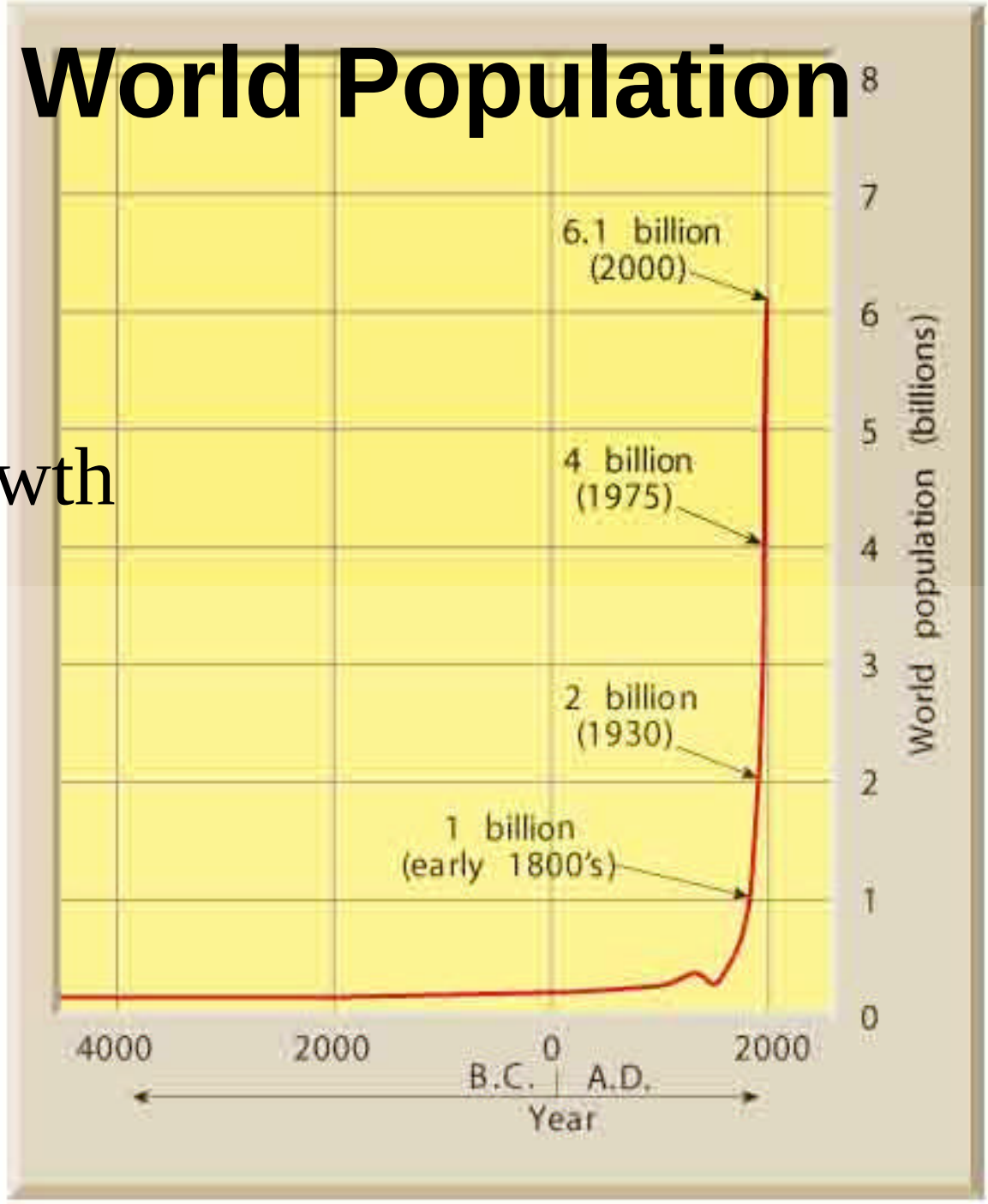
1.4 Earth System Science

Population

- Population of the planet is growing rapidly
- Use of minerals/energy has climbed more rapidly than the overall growth of population

Growth of World Population

Exponential Growth



1.4 Earth System Science

Environmental Problems

- Local, regional, and global
- Caused by people and societies
  - Urban air pollution • Acid rain
  - Ozone depletion • Global warming
- Caused by natural hazards
  - Earthquakes • Landslides

1.5 What Is Scientific Inquiry?

Science

- **Science assumes the natural world is**
  - **consistent**
  - **predictable**

1.5 What Is Scientific Inquiry?

Science

- **Goals of science are**

- **to through careful, systematic study, we can understand and explain the natural world's behavior**

- **to use the knowledge to make predictions about what should or should not be expected**

1.5 What Is Scientific Inquiry?

Hypothesis and Theory

- An idea can become a
- hypothesis—tentative or untested explanation
- theory—tested, confirmed, supported hypothesis

1.5 What Is Scientific Inquiry?

Hypothesis and Theory

- **Scientific Method**
  - **Gather facts through observation**
  - **Formulate hypotheses**
  - **Test hypotheses to formulate theories**

1.5 What Is Scientific Inquiry?

Science Methods

- Scientific knowledge is gained through following systematic steps

1. Collecting facts through observation and measurement
2. Developing a hypothesis
3. Conducting experiments to test the hypothesis
4. Reexamining the hypothesis and accepting, modifying, or rejecting it

Stanley gathered few trophies racing slow rabbits.

SCIENTIFIC METHOD

The basic steps in the scientific method are:

State the problem.

Gather information.

Form a hypothesis.

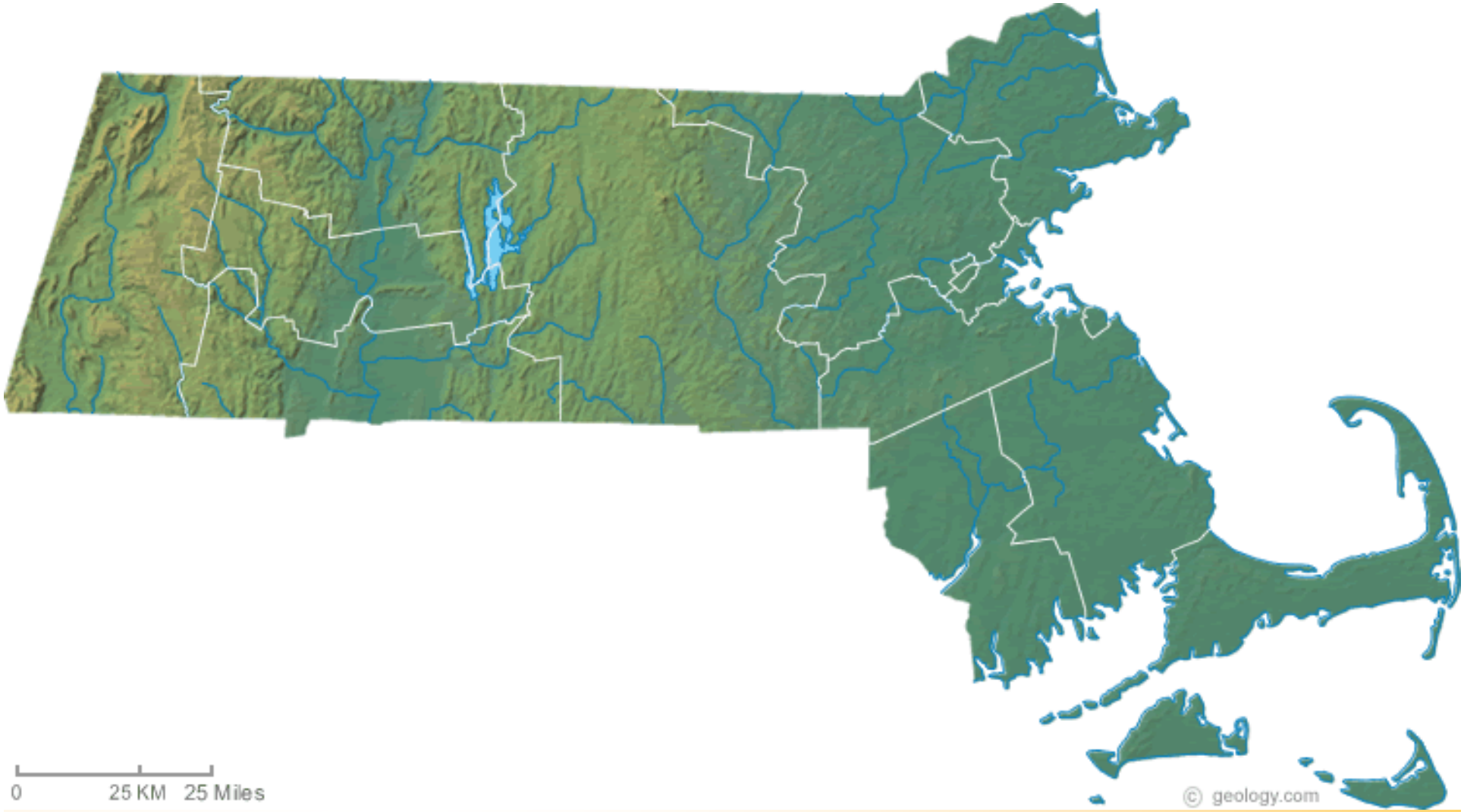
Test the hypothesis.

Record and analyze data.

State the conclusion.

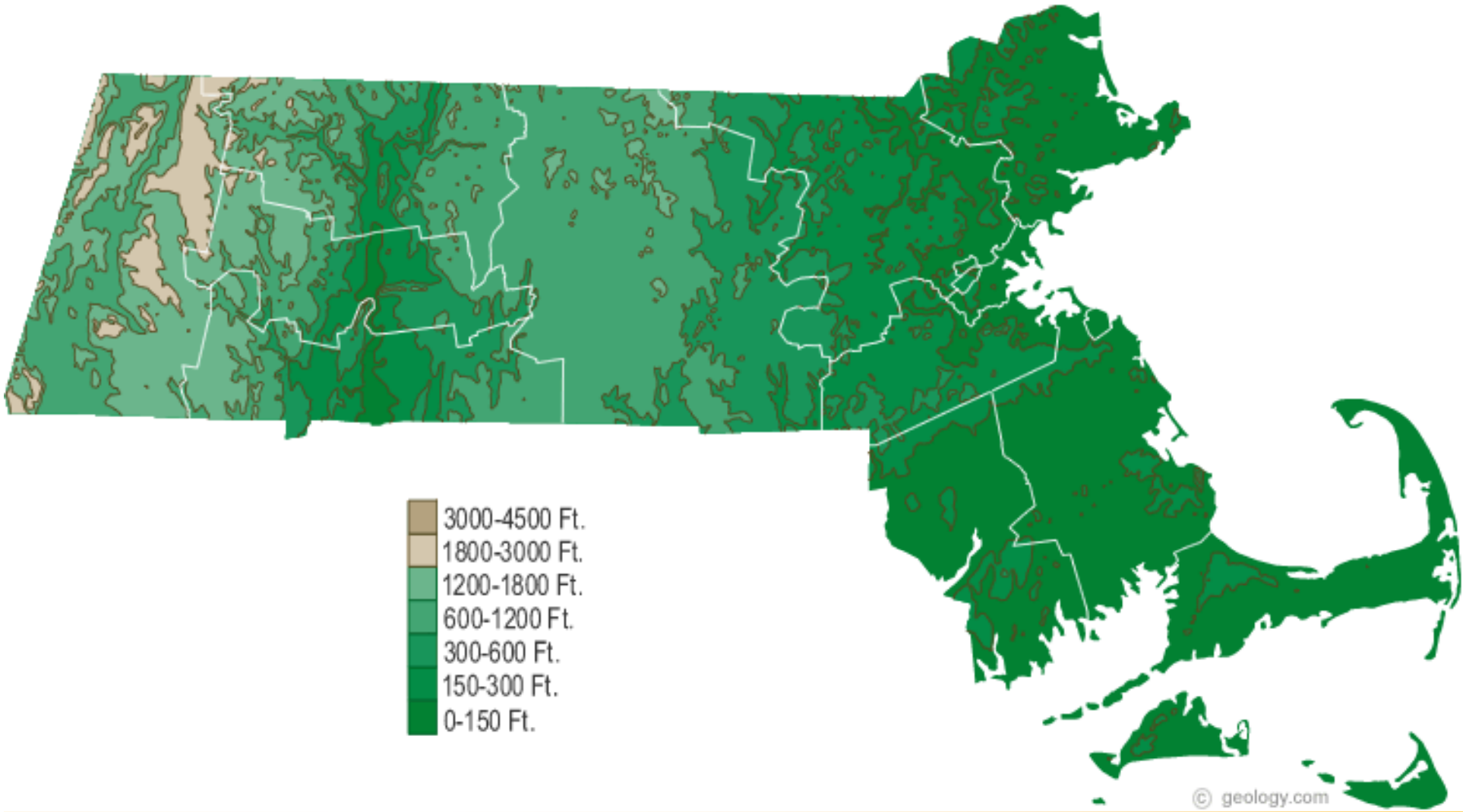
Repeat the work.

Explore the World of Earth Science...



Massachusetts Physical Map - Massachusetts Relief Map

:This Massachusetts shaded relief map shows the major physical features of the state.

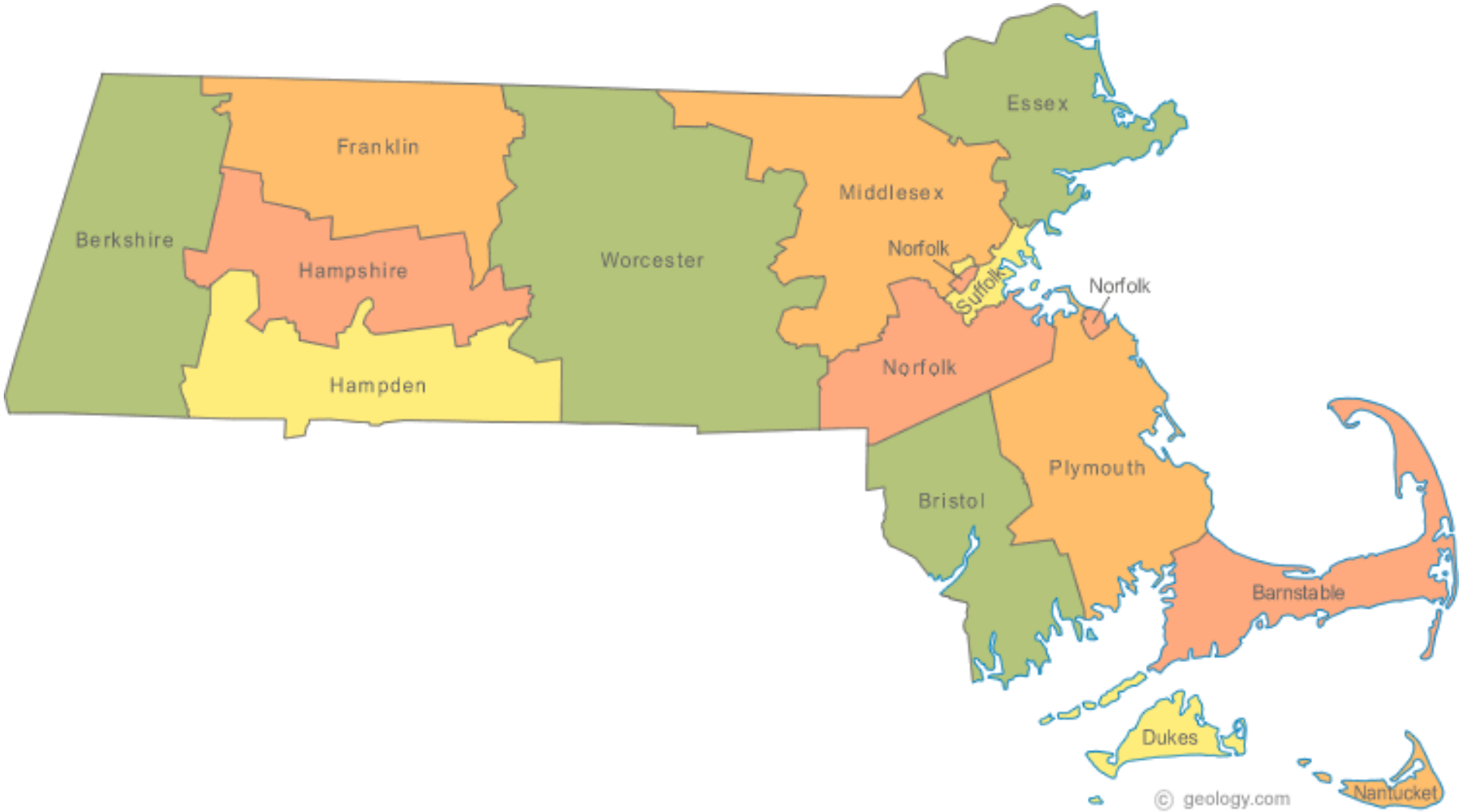


Massachusetts Elevation Map

:This is a generalized topographic map of Massachusetts. It shows elevation trends across the state.

Massachusetts Rivers Map - Massachusetts Lake Map

:This map shows the major streams and rivers of Massachusetts and some of the larger lakes. The state is within the Atlantic Ocean Watershed.

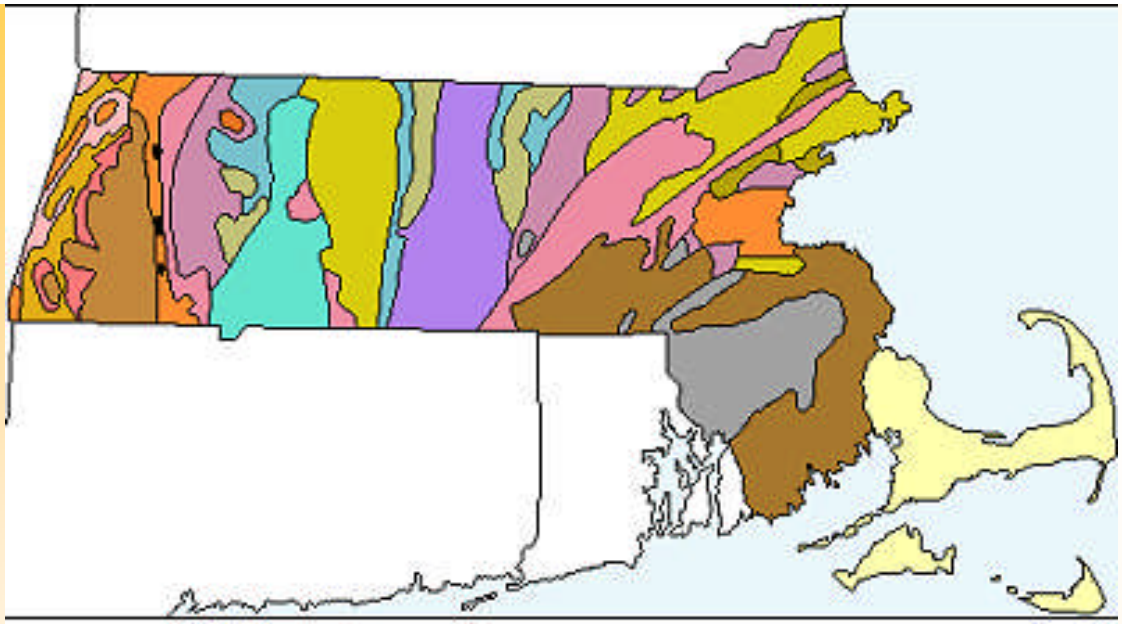


Massachusetts County Map - Massachusetts Political Map

:This map shows Massachusetts's 7 counties and 7 census areas.

Map of Massachusetts Cities - Massachusetts Road Map

:This map shows many of Massachusetts's important cities and most important roads. Important north - south routes include: Interstate 91, Interstate 93, Interstate 95, Interstate 195, Interstate 395 and Interstate 495. Important east - west routes include: Interstate 90 and Interstate 290.



Explanation

SEDIMENTARY ROCKS

- Pleistocene and Holocene sediments
- Ordovician sedimentary rocks
- Cambrian and Ordovician carbonates
- Cambrian clastics

IGNEOUS ROCKS

- Triassic volcanics
- Paleozoic mafic intrusives
- Middle Paleozoic granites
- Ordovician volcanics & metasediments
- Lower Paleozoic granites
- Precambrian granites
- ultramafic rocks

METAMORPHIC ROCKS

- Pennsylvanian metasediments
- Devonian metasediments
- Silurian and Devonian metasediments
- Silurian metasediments
- Cambrian metasediments
- Precambrian gneiss and schist