Introduction to Planet “Earth”

Alan P. Trujillo
Harold V. Thurman
Overview

• The world ocean is the most prominent feature on Earth.
• Oceans cover 70.8% of Earth’s surface.
• The origin and development of life on Earth are connected to the ocean.
• The oceans have a long history on Earth.
Earth’s Oceans

• Earth has one ocean.
• It is divided into four principle oceans and one other.
  – Pacific Ocean
  – Atlantic Ocean
  – Indian Ocean
  – Arctic Ocean
  – Southern, or Antarctic, Ocean
Ocean Size and Depth

(a) Earth’s Surface

- Ocean: 70.8%
- Land: 29.2%

(b) Relative Ocean Size

- Pacific: 50.1%
- Atlantic: 26.0%
- Indian: 20.5%
- Arctic: 3.4%

(c) Average Ocean Depth

- Pacific: 3940 meters (12,927 feet)
- Atlantic: 3844 meters (12,612 feet)
- Indian: 3840 meters (12,596 feet)
- Arctic: 1117 meters (3685 feet)

(d) Comparing Oceans to Land

- Deepest area of ocean: Mariana Trench: 11,022 meters (36,161 feet)
- Average depth of oceans: 3682 meters (12,080 feet)
- Average height of land: 840 meters (2756 feet)
- Tallest mountain = Mt. Everest: 8850 meters (29,035 feet)
Earth’s Oceans

• Pacific Ocean
  – World’s largest ocean
    • Accounts for more than half of Earth’s ocean space
  – World’s deepest ocean
  – Earth’s largest geographic feature
  – Named in 1520 by Ferdinand Magellan
Earth’s Oceans

• Atlantic Ocean
  – Half the size of the Pacific Ocean
  – Shallower than the Pacific Ocean
  – Separates the Old World from the New World

• Indian Ocean
  – Smaller than the Atlantic Ocean
  – Similar depth as the Atlantic Ocean
  – Primarily in the Southern Hemisphere
Earth’s Oceans

- Arctic Ocean
  - Seven percent the size of the Pacific Ocean
  - Shallowest world ocean
  - Permanent layer of sea ice a few meters thick

- Southern Ocean or Antarctic Ocean
  - Circumnavigates Antarctica
  - Is really the parts of the Pacific, Atlantic, and Indian Oceans that lie south of 50° S latitude
The Seven Seas

• Smaller and shallower than oceans
• Salt water
• Usually enclosed by land
  – Sargasso Sea defined by surrounding ocean currents
• Directly connected to the ocean
The Seven Seas

• Before the 15th century, Europeans considered the seven seas to be the following:
  1. Red Sea
  2. Mediterranean Sea
  3. Persian Gulf
  4. Black Sea
  5. Adriatic Sea
  6. Caspian Sea
  7. Indian Ocean
Comparing Oceans to Continents

- Average ocean depth is 3682 meters (12,080 feet)
- Average continental elevation is 840 meters (2756 feet)
- Deepest ocean trench is the Mariana Trench at 11,022 meters (36,161 feet)
- Highest continental mountain is Mt. Everest at 8850 meters (29,035 feet)
Early Exploration of the Oceans

• Early “explorers” used boats to seek new fishing grounds for food.
• The ocean facilitated trade and interaction between cultures.
Pacific Navigators

• The peopling of the Pacific Islands required extensive travel in open boats and exceptional navigation skills.
• It was difficult because islands are widely scattered.
Pacific People

• No written records exist of Pacific human history before the 16th century.
• Archeological evidence suggests island occupation by people from New Guinea as early as 4000–5000 B.C.
• Thor Heyerdahl sailed on a balsa raft – the *Kon Tiki* – to demonstrate migration of South Americans to Pacific Ocean islands.
European Navigators

- **Phoenecians** – first from Western Hemisphere to develop navigation arts
  - Navigated circa 2000 B.C.
  - Explored Mediterranean Sea, Red Sea, and Indian Ocean
  - First circumnavigation of Africa
  - Reached the British Isles
European Navigators

- Greek Pytheas
  - Sailed northward using a simple method to determine latitude in 325 B.C.
  - Navigated using the North Star
- Eratosthenes determined Earth’s circumference fairly accurately.
Europeans

- Herodotus produced inaccurate world map around 450 B.C.
- Claudius Ptolemy produced fairly accurate world map around 150 A.D.
  - Erroneously updated Eratosthenes’ original circumference estimation, later causing Christopher Columbus to believe he had reached Asia
The Middle Ages

• Arabs dominant navigators in the Mediterranean Sea
• Traded extensively with East Africa, India, and Southeast Asia
• Learned to use Indian Ocean monsoon winds for travel
Vikings explored North Atlantic Ocean

- Settled Iceland and Greenland in 9th and 10th centuries A.D.
- Leif Eriksson designated part of eastern Canada Vinland (now Newfoundland) in 995 A.D.
- Greenland, Vinland settlements abandoned by 1450 A.D. due to climatic cooling
Viking Routes and Colonies

- Baffin Island
- Greenland
- Iceland
- Vinland (Newfoundland)
- Scandinavia

- First Viking voyage to Iceland
- Bjarni Herjolfsson
- Leif Eriksson
- Erik the Red
- Viking colonies

© 2014 Pearson Education, Inc.
The Age of Discovery in Europe 1492–1522

• Search for new Eastern trade routes by sea
  – Prince Henry the Navigator of Portugal sought trade routes around Africa.
  – Europeans explore North and South America.
  • Christopher Columbus was financed by the Spanish to find new trade routes to Asia.
• Englishman John Cabot arrived in northeast North America in 1497.
The Age of Discovery in Europe 1492–1522

• Spaniard Ferdinand Magellan circumnavigated the globe.
  – Was killed on a Pacific Island in 1521
• Juan Sebastian del Caño completed the circumnavigation in 1522.
• Voyages paved the way for the Spanish to take gold from the Incas and Mayas.
• Spain’s maritime dominance ended when England defeated the Spanish Armada in 1588.
Voyages of Columbus and Magellan

**Columbus, 1492**
- **Aug. 3, 1492**: Columbus, departure from Spain
- **Oct. 12, 1492**: Landfall on the Bahamas
- **Nov. 19, 1492**: Landing on the shores of Cuba
- **Dec. 6, 1492**: Arrival at Haiti
- **Dec. 25, 1492**: Departure from Guanahani (San Salvador)
- **Jan. 6, 1493**: Arrival at Cuba
- **Mar. 15, 1493**: Departure from Cuba
- **June 25, 1493**: Arrival at Spain

**Magellan, 1519**
- **Sept. 20, 1519**: Departure from Spain
- **Sept. 6, 1522**: Arrival back in Spain

**Magellan was killed, Apr. 27, 1521**
Voyaging for Science

• The English wanted to retain maritime superiority.

• **Captain James Cook** (1728–1779) undertook three scientific voyages.
  – Ships HMS *Endeavour, Resolution, Adventure*
  – Mapped many islands in Pacific
  – Systematically measured ocean characteristics
  – Marine chronograph (longitude)
Cook’s Voyages
Oceanography Continues

• More high-technology tools available today
  – Sonar
  – Robotics
  – Computers
  – Satellites
Nature of Scientific Inquiry

- Natural phenomena governed by physical processes
- Physical processes similar today as in the past
- Scientists discover these processes and make predictions.
- Called the **scientific method**
The Scientific Method

- **Observation**: Collection of scientific facts through observation and measurement.
- **Hypothesis**: A tentative, testable statement about the natural world that can be used to build more complex inferences and explanations.
- **Testing**: Development of observations, experiments, and models to test (and, if necessary, revise) the hypothesis after much testing and experimentation.
- **Theory**: In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, logical inferences, and tested hypotheses.
Theories and Truth

• Science never reaches absolute truth.
• Truth is *probable* and based on available observations.
• New observations yield scientific progress.
• In reality, scientists have no formal method.
Formation of Earth and the Solar System

• Nebular hypothesis
  – all bodies in the solar system formed from nebula
    – Nebula = cloud of gases and space dust
  • Mainly hydrogen and helium
Nebular Hypothesis

- Gravity concentrates material at center of cloud (Sun).
- Protoplanets form from smaller concentrations of matter (eddies).
Protoearth

• Larger than Earth today
• Homogeneous composition
• Bombarded by meteorites
  – Moon formed from collision with large asteroid.
Protoearth

• Radioactive heat
  – Spontaneous disintegration of atoms
  – Fusion reactions
• Heat from contraction (protoplanet shrinks due to gravity)
• Protoearth partially melts
• Density stratification (layered Earth)
Density Stratification

- High density = heavy for its size
- Early Earth experienced gravitational separation.
  - High-density materials (iron and nickel) settled in core.
  - Less dense materials formed concentric spheres around core.
Earth’s Internal Structure

Layers defined by
• Chemical composition
• Physical properties
Layers by Chemical Composition

• Crust
  – Low-density, mainly silicate minerals

• Mantle
  – Mainly iron (Fe) and magnesium (Mg) silicate minerals

• Core
  – High-density, mainly iron (Fe) and nickel (Ni)
Layers by Physical Properties

- Lithosphere
- Asthenosphere
- Mesosphere
- Outer core
- Inner core
Lithosphere

- Cool, rigid shell
- Includes crust and upper mantle
- About 100 km (60 miles) thick
# Continental vs. Oceanic Crust

<table>
<thead>
<tr>
<th></th>
<th>Oceanic crust</th>
<th>Continental crust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main rock type</td>
<td>Basalt (dark-colored igneous rock)</td>
<td>Granite (light-colored igneous rock)</td>
</tr>
<tr>
<td>Density (grams per cubic centimeter)</td>
<td>3.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Average thickness</td>
<td>8 kilometers (5 miles)</td>
<td>35 kilometers (22 miles)</td>
</tr>
</tbody>
</table>
Asthenosphere

- Relatively hot, plastic
- Flows with high viscosity
  - Important for movement of lithospheric plates
- Base of lithosphere to about 700 km (430 miles) deep
Isostatic Adjustment

• Vertical movement of Earth’s crust
• Buoyancy of lithosphere on asthenosphere
  – Less dense continental crust floats higher than denser oceanic crust.
• Isostatic rebound – rising of crust formerly weighed down by glacier ice
Isostatic Adjustment

Container ship empty—rides higher

Container ship loaded with cargo—rides lower

Displaced water
Origin of Earth’s Atmosphere

• Outgassing – occurred during density stratification
  – Water vapor
  – Carbon dioxide
  – Hydrogen
  – Other gases

• Earth’s early atmosphere different from today
Origin of Earth’s Oceans

- Outgassed water vapor fell as rain.
- The first permanent oceans formed 4 billion years ago.
- Salinity developed from dissolved rock elements.
  - Early acidic rain dissolved more crustal minerals than today.
Development of Earth’s Oceans

(a) $H_2O$ vapor and other gases

(b) $H_2O$ vapor and other gases

(c)
Life’s Possible Ocean Origins

• Earth’s earliest known life forms are 3.5-billion-year-old bacteria fossilized in ocean rocks.
• These are the building blocks for life on early Earth.
• There is no direct evidence of early Earth’s environment.
Oxygen

- Humans require $O_2$.
- Ozone ($O_3$) protects from ultraviolet radiation.
- Early Earth had little free oxygen.
- The lack of ozone may have helped originate life.
Stanley Miller’s Experiment

- Organic molecules formed by ultraviolet light, electrical spark (lightning), and a mixture of water, carbon dioxide, hydrogen, methane, and ammonia
Stanley Miller and His Experiment

(a) Laboratory apparatus used by Stanley Miller to simulate the conditions of the early atmosphere and the oceans. The experiment produced various organic molecules and suggests that the basic components of life were created in a “prebiotic soup” in the oceans.

(b) Stanley Miller in 1999, with his famous apparatus in the foreground.
Evolution and Natural Selection

• Organisms adapt and change through time.
• Advantageous traits are naturally selected.
• Traits are passed to the next generation.
• Organisms adapt to environments.
• Organisms can modify environments.
Plants and Animals Evolve

• Heterotrophs
  – Very earliest life
  – Require external food supply
• Autotrophs
  – Evolved later
  – Manufacture own food supply
First Autotrophs

• Probably similar to modern **anaerobic** bacteria
  – Survive without oxygen

• **Chemosynthesis** from chemicals at deep hydrothermal vents

• Supports idea of life’s origins on deep ocean floor in absence of light
Photosynthesis and Respiration

• Complex autotrophs developed chlorophyll.
• This allowed the use of the Sun for photosynthesis.
• Cellular respiration
**Photosynthesis and Respiration**

**Photosynthesis**

- **Light energy input**
- **Water** + **Carbon dioxide** → **Sugar** + **Oxygen**

**Respiration**

- **Heat energy released**
- **Water** + **Carbon dioxide** → **Sugar** + **Oxygen**

**Representative reaction, viewed chemically**

\[ 6\text{H}_2\text{O} + 6\text{CO}_2 + \text{Light energy} \rightarrow \text{Heat} \]

**Photosynthesis**

\[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]
Great Oxidation Event

• 2.45 billion years ago
• Increased oxygen and ozone eliminated the anaerobe food supply.
• Light and oxygen kill anaerobes.
• Cyanobacteria adapted and thrived.
Changes to Earth’s Atmosphere

- Photosynthetic organisms are responsible for life as we know it today.
- Reduce $\text{CO}_2$, increase $\text{O}_2$ to 21%
- High oxygen = biodiversity increase
- Low oxygen associated with extinction events
Plants and Earth’s Environment

- CO₂ removed from atmosphere
- O₂ added to atmosphere
- CO₂ removed from atmosphere

Phytoplankton

Swamp

Oil

Ocean

Land

Coal seam
Age of Earth

• Radiometric age dating
  – Spontaneous change/decay
  – Half-life

• Earth is about 4.6 billion years old.
Radioactive Decay

<table>
<thead>
<tr>
<th>Uranium 235 atoms</th>
<th>1,000,000</th>
<th>500,000</th>
<th>250,000</th>
<th>125,000</th>
<th>62,500</th>
<th>31,250</th>
<th>15,625</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead 207 atoms</td>
<td>0</td>
<td>500,000</td>
<td>750,000</td>
<td>875,000</td>
<td>937,500</td>
<td>968,750</td>
<td>984,375</td>
</tr>
<tr>
<td>Half-life (figures rounded for clarity)</td>
<td>Zero 4.2 billion years ago</td>
<td>One 3.5 billion years ago</td>
<td>Two 2.8 billion years ago</td>
<td>Three 2.1 billion years ago</td>
<td>Four 1.4 billion years ago</td>
<td>Five 700 million years ago</td>
<td>Six Today</td>
</tr>
</tbody>
</table>
Geologic Time Scale

<table>
<thead>
<tr>
<th>Era/Major System</th>
<th>Period</th>
<th>Epoch</th>
<th>Millions of years ago</th>
<th>Significant events in development of life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ediacaran</td>
<td></td>
<td></td>
<td>630</td>
<td>Odd mesh-like creatures of uncertain affinity</td>
</tr>
<tr>
<td>Precambrian/Proterozoic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paleozoic</td>
<td>Devonian</td>
<td>416</td>
<td></td>
<td>First organisms with shells</td>
</tr>
<tr>
<td></td>
<td>Silurian</td>
<td>444</td>
<td></td>
<td>First fish</td>
</tr>
<tr>
<td></td>
<td>Ordovician</td>
<td>488</td>
<td></td>
<td>First land plants</td>
</tr>
<tr>
<td></td>
<td>Cambrian</td>
<td>542</td>
<td></td>
<td>Trilobites dominant</td>
</tr>
<tr>
<td></td>
<td>Carboniferous</td>
<td>Pennsylvanian</td>
<td>318</td>
<td>First insects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mississippian</td>
<td>359</td>
<td>Fishes dominant</td>
</tr>
<tr>
<td>Mesozoic</td>
<td>Triassic</td>
<td>252</td>
<td></td>
<td>Extinction of 90% of marine life</td>
</tr>
<tr>
<td></td>
<td>Jurassic</td>
<td>201.6</td>
<td></td>
<td>First reptiles</td>
</tr>
<tr>
<td></td>
<td>Cretaceous</td>
<td>145.5</td>
<td></td>
<td>First birds</td>
</tr>
<tr>
<td></td>
<td>Neogene</td>
<td>Holocene</td>
<td>Pleistocene</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.6</td>
<td>Extinction of dinosaurs and many other species</td>
</tr>
</tbody>
</table>

Origin of Earth
End of CHAPTER 1
Introduction to Planet “Earth”