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 is connected to the ocean.
- The oceans have a long history on Earth.

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

- 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

Comparing Oceans to Continents

- Average ocean depth is 3729 meters (12,234 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 (29,935 feet)

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

Early Exploration of the Oceans

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

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

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

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

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.

The Middle Ages

- **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
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.

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 the Pacific
  - Systematically measured ocean characteristics
  - Marine chronograph (longitude)**

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.
Oceanography Continues

- More high-technology tools available today
  - Sonar
  - Robotics
  - Computers
  - Satellites

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.

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*

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

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
- **Theory**: In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, logical inferences, and tested hypotheses

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

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

Continental vs. Oceanic Crust

<table>
<thead>
<tr>
<th>TABLE 1.1 COMPARING OCEANIC AND CONTINENTAL CRUST</th>
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<tbody>
<tr>
<td>Oceanic crust</td>
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<tr>
<td>----------------</td>
</tr>
<tr>
<td>Main rock type</td>
</tr>
<tr>
<td>Density (grams per cubic centimeter)</td>
</tr>
<tr>
<td>Average thickness</td>
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</tbody>
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Asthenosphere

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

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.

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.

Development of Earth’s Oceans

Stanley Miller’s Experiment

• Organic molecules formed by ultraviolet light, electrical spark (lightning), and a mixture of water, carbon dioxide, hydrogen, methane, and ammonia

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. WHY?
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** (nutrition from organic material or food made by others)
  - Probably the very earliest life
  - Require external food supply
- **Autotrophs** (nutrition from light or chemical energy)
  - 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

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.
• Photosynthetic organisms are responsible for life as we know it today.
• Reduce CO₂, increase O₂ to 21%
• High oxygen = biodiversity increase
• Low oxygen associated with extinction events

Changes to Earth’s Atmosphere

Age of Earth

• Radiometric age dating
  – Spontaneous change/decay of unstable isotopes
  – Half-life = how long it takes half of the parent isotope to decay to daughter isotopes
• Earth is about 4.6 billion years old.

Radioactive Decay

http://www.scotese.com/climate.html
End of CHAPTER 1
Introduction to Planet “Earth”