Chapter 13
Prospecting for Biological Gold Biodiversity and Classification

13.1 Biological Classification- How Many Species Exist?

- **Biodiversity** is the variety within and among living species
  - Number of species known to science is between 1.4 and 1.8 million
  - Uncertainty due to differences in methods of storing and describing specimens
  - Total number of species – estimates range from 3 – 100 million
  - Average estimate is ~10 million species on Earth

13.1 Biological Classification - Kingdoms and Domains

- Modern species are divided into three large groups, or domains.
  - Bacteria
  - Archaea
  - Eukarya

- Within Eukarya, four kingdoms are also recognized
  - Plantae
  - Animalia
  - Fungi
  - Protista

13.1 Biological Classification - A Closer Look: Kingdoms and Domains

- Recently, some scientists have begun to suggest that organisms should be classified based on evolutionary relationships.
  - Major groups under this system correspond to divergences early in life's history.
  - Determining evolutionary relationships requires comparing DNA.
  - DNA of closely related organisms should be more similar than DNA of distantly related organisms.

- Using rRNA to determine relationships among distantly related organisms

13.2 The Diversity of Life - Bacteria and Archaea

- Life on earth arose at least 3.6 million years ago, according to the fossil record
  - Most ancient fossilized cells are very similar to modern bacteria and archaea
  - **Prokaryotic** – bacteria and archaea don't have a nucleus, and also lack mitochondria and chloroplasts
  - Most are unicellular
  - Incredibly numerous and diverse. Found on every square centimeter of the earth's surface, even inside deep sea vents, far underground, and in clouds.

- Domain Bacteria
- Most bacteria are probably harmless to humans.
  - We are most familiar with the ones that cause disease

- Many known bacteria obtain nutrients by decomposing dead organisms
- Competition between bacteria has produced compounds that humans make use of.
  - Antibiotics – ~50% of antibiotics are derived from bacterial sources
  - Restriction enzymes – proteins that chop DNA at specific sequences; useful in biotechnology

- Domain Archaea
- Superficially similar to bacteria
  - Differ in structure of cell membranes
  - Archaeans typically found in extreme environments (high temperature, high pressure, high salt concentration)
  - *Taq* polymerase comes from an archaean, *Thermophilus aquaticus*
  - Archaeans are likely to be source of other interesting biomolecules

13.2 The Diversity of Life - Protista

- Evolution of the Eukaryotes
  - Protists are the simplest of the eukaryotes
  - Oldest eukaryotic fossils are ~2 billion years old, 1.5 billion years later than the first prokaryotic cells
  - **Endosymbiotic** theory explains the evolution of eukaryotes and their specialized structures

- Modern protists contain members that resemble animals, plants, and fungi
  - Most members of the kingdom are not known
  - No agreement among scientists on number of groups below kingdom
    - Number of proposed groups ranges from 8 to 80

- Bioprospectors have examined the plant-like protists most closely for useful compounds
  - Natural selection has driven the evolution of defensive compounds in these organisms
  - Extracts from red algae might be used in anti-viral medication
  - Carageenan, stabilizer and thickener, also comes from protists

13.2 The Diversity of Life - Animalia

- Animals comprise a wide range of organisms, but all share a common set of characteristics
  - Multicellular
  - Heterotrophic (must eat to get energy)
  - Mobile during at least one stage of life

- By 530 million years ago, all modern animal groups were present
  - Most appeared quickly in fossil record
  - Multicellular organisms quickly proliferated
  - Known as **Cambrian explosion**

- Most bioprospecting work focuses on invertebrates
  - Vertebrates only account for ~4% of animals

- Invertebrates are far more numerous and diverse
- Many invertebrates produce compounds found nowhere else in nature

13.2 The Diversity of Life - Fungi

- Fungi characteristics
  - Immobile
  - Heterotrophic
    - Feed by means of hyphae
- DNA analysis indicates fungi is more closely related to animals than to plants

- The hyphae of fungi can extend over a very large area

- Fungi are grouped on the basis of spore formation

- Fungi produce a number of important drugs
  - Antibiotics
  - Cyclosporin
  - Statins

13.2 The Diversity of Life - Plantae

- Characteristics of Plantae
  - Multicellular
  - Eukaryotic
  - Autotrophic (manufacture own food) via photosynthesis

- Plants have been present on land for ~400 million years
  - First plants were low to ground, lacked **vascular tissue**
  - Evolution of vascular tissue for water and nutrient transport
    - Allowed growth to tree size
    - Allowed growth in drier areas
  - Most modern plants in group only ~140 million years old
    - Flowering plants

- Over 90% of modern plants are flowering plants and many specializations
  - Rapid increase of flower plant species is called **adaptive radiation**
  - Flowering plants employ double fertilization method or reproduction
  - Also often involve animals in reproductive process (pollination)
  - Also synthesize many **secondary compounds** that deter predators

- Double fertilization

- Kingdom Plantae is the source of many drugs and compounds
  - Source of most naturally derived drugs

- Aspirin
- Digitalis
- Morphine
- Caffeine

- Pharmaceutical manufacturers reproduce hundreds of compounds first found in plants

13.2 The Diversity of Life - Viruses

- A virus consists of a strand of DNA or RNA
  - Viruses hijack transcription machinery of cells to reproduce
  - Once hijacked cell cannot perform own functions
  - HIV, smallpox, polio, influenza are all caused by viruses

13.3 Learning About Species - Fishing For Useful Species

- The National Cancer Institute has employed a brute-force approach to looking for anti-cancer compounds
  - Receive specimens from around the world, extract materials and screen against cancer cell lines
  - One major compound, Taxol, has been identified using this technique

13.3 Learning About Species - Understanding Ecology

- Understanding an organism's ecology—how it lives in its environment—can be helpful in evaluating potentially beneficial compounds
  - Survival in extreme environments
  - High levels of competition with bacteria and fungi
  - Susceptibility to predation
  - Ability to live on or in other organisms
  - Survival in high population densities

13.3 Learning About Species - Reconstructing Evolutionary History

- A classification system reflecting evolutionary relationships is more useful to scientists
  - An organism's chemical traits will probably be similar to those of its closest relative
  - If looking for new compounds, could begin by screening close relatives of organisms already known to produce compounds

- The challenge in making an evolutionary classification is that organisms do not always resemble their closest living relatives
- New World vultures are more closely related to storks than they are to Old World vultures

13.3 Learning About Species - Developing Evolutionary Classifications

- Reconstructing evolutionary history not always as easy as the sparrow example
  - Can be confounded by loss of traits, and convergence
  - DNA provides a means of testing evolutionary hypotheses

13.3 Learning About Species - Testing Evolutionary Classifications

- Scientists can test evolutionary hypotheses with data from fossils and from living organisms
  - Fossils provide information about the genealogy of different living groups
  - Comparison of DNA from living organisms can also validate or refute proposed classifications
  - DNA supports vulture classification, but does not support sparrow classification
  - DNA can give clues to near relatives, but lab process can take time

13.3 Learning About Species - Learning From the Shamans

- Often local people in biologically diverse areas make extensive use of naturally occurring products.
  - Shamans often have much knowledge of locally useful compounds.
  - **Biopiracy** is when local knowledge is used without benefiting local people.
  - UN Convention on Biodiversity is supposed to address this.
  - Our biodiversity represents an enormous potential, but only if we recognize its value.