

CHAPTER 20 CLASSIFICATION OF LIVING THINGS

Chapter Outline

20.1 Taxonomy

- A. Taxonomy is the branch of biology concerned with identifying and naming organisms.
 - 1. A natural system of classification reflects the evolutionary history of organisms.
 - 2. Naming and identifying organisms began with the Greeks and Romans.
 - 3. In the middle ages, organisms were described using long Latin descriptions.
 - 4. Much later, John Ray, a British naturalist argued that each organism should have a set name.
- B. The Binomial System
 - 1. Number of known organisms expanded greatly in mid-eighteenth century due to European travel.
 - 2. Carolus Linnaeus developed the binomial system to name species.
 - 3. The binomial system of nomenclature names organisms using a two-part Latin name.
 - a. First part is the genus; closely related species are assigned to the same genus.
 - b. Second part is the specific epithet; it usually provides something descriptive about an organism.
 - c. A scientific name consists of both genus and specific epithet (e.g., *Lilium buibiferum* and *Lilium canadense*).
 - d. Both names are italicized or underlined; the first letter of only the genus name is capitalized.
 - e. The genus can be abbreviated when used with a specific epithet if the full name was given before.
 - 4. Common names vary with different languages, lump many species under one name or have various names for the same species, and the same name may refer to different organisms in different regions.
 - 5. The job of naming is far from being finished.
 - a. There are estimated to be between 3 and 30 million species living on earth.
 - b. We have currently named one million species of animals and a half million plant and microorganismic species.
 - c. Some groups, such as birds, are nearly all known; some insect groups are mostly unknown.
- C. Identification of a Species
 - 1. Linnaeus considered each species to have a unique structure that made it distinct.
 - a. Distinguishing species on structure can be a problem because variations occur among members of the same species.
 - b. Males and females may have a different form, as well as juveniles and adults.
 - 2. The biological definition of a species states a species can interbreed and share the same gene pool.
 - a. Distinguishing species on the basis of reproductive isolation can also be a problem.
 - b. Some species do not reproduce sexually.
 - c. Some species hybridize where their ranges overlap.
 - d. Reproductive isolation can be difficult to observe.
 - 3. When a species has a wide geographic range, variant types may tend to interbreed where they overlap; these populations may be named as subspecies.
 - a. The rat snakes *Elaphe obsoleta obsoleta* and *Elaphe obsoleta bairdi* are subspecies of *Elaphe obsoleta*.
 - b. Including the subspecies makes this a trinomial, or three-part, name.
 - 4. In this chapter, a classification approach is taken to the definition of species.
 - a. Classification establishes categories to assign species on the basis of their relationship to other species.
 - b. Here we use the term “species” for a taxonomic category below the rank of genus.
 - c. Species share a more recent common ancestor with species in same genus than with those in other taxa.

- d. A **taxon** is a group of organisms in a classification category; *Rosa* or *Felis* are taxa at the genus level.
 - e. A **common ancestor** is an ancestor held in common by at least two lines of descent.
- D. Classification Categories
- 1. Aristotle classified life into 14 groups (e.g., mammals, birds, etc.), and subdivided them by size.
 - 2. Ray grouped animals and plants according to how he thought they were related.
 - 3. Linnaeus grouped plants by flower parts; his categories were published in *Systema Naturae* in 1735
 - 4. Today, we use a minimum of seven categories of classification: species, genus, family, order, class, phylum (or division for plants), and kingdom.
 - a. A higher category, the domain, has been proposed to be added to these seven categories.
 - b. The higher the category, the more inclusive it is.
 - c. Members of a kingdom share general characters; members of a species share quite specific characters.
 - d. Characters are any structural, chromosomal, or molecular feature that distinguishes groups.
 - e. Additional levels of classification can be added by adding super-, sub-, or infra- (e.g., suborder).

20.2 Phylogenetic Trees

- A. **Systematics** is the study of the diversity of organisms using information from cellular to population levels.
- 1. Classification reflects phylogeny; one goal of systematics is to create phylogenetic trees.
 - 2. Phylogeny is the evolutionary history of a group of organisms.
 - 3. A **phylogenetic tree** indicates common ancestors and lines of descent or lineages.
 - 4. A **primitive character** is a trait that is present in a common ancestor and all members of a group.
 - 5. A **derived character** is present only in a specific line of descent.
 - 6. Different lineages diverging from a common ancestor may have different derived characters.
- B. Fossil Record
- 1. Because fossils can be dated, fossils can establish the age of a species.
 - 2. It can be difficult to associate fossils with currently living groups; a new view of turtle fossils could place them closer to crocodiles.
 - 3. The fossil record is often incomplete because soft-bodied organisms do not fossilize well.
 - 4. Most organisms decay and the chances of becoming a fossil are low.
- C. Homology
- 1. Homology is a character similarity that is due to having a common ancestor.
 - 2. Homologous structures are related to each other through common descent but may differ in structure and function (e.g., the forelimbs of a horse and the wings of a bat).
 - 3. Analogous structures have the same function but are not derived from the same organ in a common ancestor (e.g., the wings of an insect and the wings of a bat).
 - 4. Homology helps indicate when species belong to a related group.
 - 5. **Convergent evolution** may make it difficult to distinguish homologous from analogous structures.
 - 6. Convergent evolution is acquisition of similar traits in distantly related lines of descent as a result of adaptation to similar environmental conditions.
 - a. Both spurge and cacti are adapted to a hot, dry environment and are both similar.
 - b. Details of flower structure indicate these two groups are not closely related.
 - 7. **Parallel evolution** produces similar characters in related lineages without occurring in a common ancestor.
- D. Molecular Data
- 1. Speciation occurs when mutations bring about changes in base pair sequences of DNA.
 - 2. Each distinct lineage accumulates changes in DNA base pair sequences and amino acid sequences in proteins over time.
 - 3. Advances in analyzing nucleotide and amino acid sequences make abundant data available to researchers.
 - 4. Protein Comparisons
 - a. Earlier studies used immunological reactions to antibodies, made by injecting a rabbit with cells of one species, to determine the relatedness of two species.
 - b. We now use amino acid sequences to determine the differences in proteins between two species.
 - c. Cytochrome *c* is a protein found in all aerobic organisms; the amino acid differences in cytochrome *c* between chickens and humans is 13 but between chickens and ducks is only 3.
 - d. Since the number of universal proteins is limited, most new studies use RNA and DNA.

5. RNA and DNA Comparisons
 - a. All cells have ribosomes for protein synthesis; comparing rRNA sequences provides a reliable indicator of similarity.
 - b. DNA–DNA hybridization separates the DNA strands of two species and combines the strands; the more closely related the two species, the more the DNA strands stick together.
 - c. Panda evolution
 - 1) Chinese giant panda resembles a bear, has a false thumb, but bones and teeth resembled a raccoon.
 - 2) The red panda has similar features but lacks the false thumb.
 - 3) Results of DNA hybridization suggest the giant panda diverged from the bear lineage and the red panda diverged from the raccoon lineage.
 - d. Chimpanzees and Humans
 - a) DNA hybridization shows chimpanzees closer to humans than to other apes.
 - b) Yet humans are kept in a separate family and chimpanzees are with the ape family because humans are markedly different in adaptation to the environment.
 - e. Mitochondria DNA (mtDNA) changes ten times faster than nuclear DNA; mtDNA is often used for closely related species; North American songbirds were found to have diverged well before retreating glaciation 250,000–100,000 years ago.
7. Molecular Clocks
 - a. Nucleic acid changes are not tied to adaptation; the fairly constant changes provide a “molecular clock.”
 - b. Comparison of mtDNA sequences equated a 5.1% nucleic acid difference among songbird species to 2.5 million years.
 - c. The fossil record can then be used to calibrate the clock and confirm the hypothesis drawn from molecular data.

20.3 Systematics Today

A. Cladistic Systematics

1. Cladistic systematics is based on work of Willi Hennig.
2. **Cladistics** analyzes primitive and derived characters and constructs cladograms on the basis of **shared derived characters**.
3. **Cladogram** is a diagram showing relationships among species based on shared, derived characters.
4. Constructing a Cladogram
 - a. First step is to construct a table of characters of the taxa being compared.
 - b. Any character found in the outgroup as well is a shared primitive character.
 - c. Homologies shared by certain lineages are shared derived characters.
 - d. A **clade** is an evolutionary branch that includes a common ancestor and all its descendent species.
5. Parsimony
 - a. “Parsimony” means “simple” and the best cladogram is the pattern that has the minimum number of assumptions.
 - b. Cladists are guided by principle of parsimony—the minimum number of assumptions is most logical.
 - c. This approach is vulnerable if convergent evolution produces what appears to be common ancestry.
 - d. Reliability of cladograms is dependent on knowledge and skill of a particular investigator gathering data.

B. Phenetic Systematics

1. Phenetic systematists cluster species on the basis of the number of shared similarities, regardless of whether they might be convergent, parallel, or depend on one another.
2. Systematists of this school do not believe that a classification that actually reflects phylogeny can be constructed; it is better to rely strictly on a method that does away with personal prejudices.
3. Results of their analysis are depicted in a **phenogram**.
4. Phenograms vary for same group of organisms, depending on how the data are collected and handled.

C. Traditional Systematics

1. **Traditional** systematics stresses common ancestry and the degree of structural difference among divergent groups in order to construct phylogenetic trees.
 - a. The traditional school accepts the tenet that mammals and birds evolved from reptilian ancestors, even though the reptile group is monophyletic—it does not include all groups from all ancestors.
 - b. But the reptile group is no longer monophyletic—it does not include all groups from all ancestors.
 - c. To cladists, the traditional method of determining phylogeny is arbitrary.
 - d. In the bird example, birds are more closely related to dinosaurs and crocodiles than they are different.
2. Cladists would not use “reptiles” because it does not include all organisms derived from reptiles.

20.4 Classification Systems

A. Naming the Kingdoms

1. Early biologists recognized two kingdoms: animals (kingdom Animalia) and plants (kingdom Plantae).
2. The microscope revealed unicellular organisms; in the 1880s, Ernst Haeckel proposed the kingdom **Protista**.
3. Haeckel originally placed bacteria and cyanobacteria in **Monera** since they lacked a nucleus.
4. In 1969, R. H. Whittaker suggested a five kingdom system based on cell type, organization, and nutrition:
 - a. Members of **Monera** are prokaryotic bacteria that obtain organic molecules by absorption or photosynthesis.
 - b. Members of **Protista** are mainly unicellular eukaryotes that obtain organic molecules by absorption, ingestion, or photosynthesis; the classification of protists is debated.
 - c. The **Plantae** are multicellular eukaryotes, autotrophic by photosynthesis.
 - d. Members of **Animalia** are multicellular eukaryotes, heterotrophic by ingestion, are generally motile.
 - e. Members of the **Fungi** are multicellular eukaryotes, heterotrophic saprotrophs that form spores, lack flagella and have cell walls containing chitin.
5. Generally, protists are considered to have evolved from monerans, and the fungi, plants, and animals evolved from protists via three separate lineages.

B. Three-Domain System

1. Recent research suggests one group of prokaryotes is so distantly related it should be in separate domain.
2. Sequencing of rRNA suggests all organisms evolved along three distinct lineages: domains **Bacteria**, **Archaea**, and **Eukarya**.
3. Bacteria diverged first; archaea and eukarya are more closely related than either is to bacteria.
4. The archaea live in extreme environments: methanogens in anaerobic swamps, halophiles in salt lakes, and thermoacidophiles in hot acidic environments.
5. The archaea cell wall is diverse but not the same as the bacterial cell wall.
6. The Eukarya contains unicellular to multicellular organisms, always with a membrane-bound nucleus.