CHAPTER 4 STUDY GUIDE : CLASSIFICATION AND PHYLOGENY OF ANIMALS

4.1 Order in Diversity

A. History

1. All cultures classify or group animals according to patterns in animal diversity.
2. Systematic zoologists have three goals:
   a. to discover all species of animals,
   b. to reconstruct their evolutionary relationships, and
   c. to classify animals according to their evolutionary relationships.
3. Taxonomy is the formal system for naming and classifying species.
4. Systematics is the broader science of classifying organisms based on similarity, biogeography, … to understand evolutionary relationships.
5. Adjusting taxonomy to accommodate evolution has produced several methods of classification.

B. Linnaeus and the Development of Classification

1. The Greek philosopher Aristotle first classified organisms.
2. The English naturalist John Ray produced a more comprehensive system and a concept of species.
3. **Carolus Linnaeus** (Figure 4.1) invented the current system of classification.
   a. Linnaeus was a Swedish botanist with extensive experience classifying flowers.
   b. He used morphology to develop a classification of animals and plants in his *Systema Naturae*.
4. A **hierarchy of taxa** is one major concept Linnaeus introduced (Table 4-1).
   a. His hierarchy contains seven major ranks: kingdom, phylum, class, order, family, genus and species.
   b. All animals are classified in kingdom Animalia, each species has its own name; the names of animal groups at each rank in the hierarchy are called taxa (singular: *taxon*).
   c. Each rank can be subdivided into additional levels of taxa, as in superclass and suborder, etc.
   d. For large and complex groups, such as fishes and insects, up to 30 ranks may be used.
5. Linnaeus introduced **binomial nomenclature**.
   a. A scientific name of an animal consists of two words (binomial) as in *Turdus migratorius*.
   b. The first word is the genus and is capitalized; the second is the specific epithet and is in lower case.
   c. To separate a scientific name from common text, it is always in *italics* or underlined if handwritten.
   d. The specific epithet is never used; the genus must be used to form the scientific name.
   e. A specific epithet may be used in many names; names of animal genera must always be different.
   f. Ranks above species are single names written with a capital initial letter (e.g., Reptilia and Cnidaria).
   g. Geographic subspecies are trinomials; all three terms are in italics and the subspecies is lower case.

4.4 Species

A. Criteria for Recognition of Species

1. Huxley was among the first to ask, “What is a species?”
2. “Species” is easy to use but the term “species” has been hard to define.
3. Criteria For Species Recognition
   a. Common descent.
   b. A species is the smallest distinct groupings of organisms sharing patterns of ancestry and descent.
   c. A reproductive community that excludes other species.
   d. Asexual organisms occupy a particular ecological niche in a particular place and respond as a unit to evolutionary processes.
   e. A species has a distribution in space, its **geographic range**.
   f. A species has a distribution through time, its **evolutionary duration**.
   g. Seemingly identical populations that are isolated for thousands of years pose a species question.

B. Concept of Species

1. Typological Species Concept
   a. Before Darwin, species were considered fixed and with essential and immutable features.
2. Biological Species Concept
   a. Theodosius Dobzhansky and Ernst Mayr formulated this during the evolutionary synthesis.

b. A species is a reproductive community of populations (reproductively isolated from others) that occupies a specific niche in nature.
c. The ability to successfully interbreed is central to the concept.
d. The criteria of "niche" tie in ecological properties.
e. However, controlled breeding experiments can be difficult to conduct.

3. Criticism
   a. It refers to contemporary populations, not ancestral populations
   b. Systematist disagree on the amount of reproductive divergence needed for speciation.
   c. Interbreeding is not an operational definition in asexual organisms.
4. Evolutionary Species Concept (Figure 4.2)
   a. Where do we set the species boundary in a lineage leading back to a fossil form?
   b. Simpson provided the evolutionary species concept in the 1940s; it persists with modification.
   c. An evolutionary species is a single lineage of ancestor-descendant populations that maintains its identity from other such lineages and that has its own evolutionary tendencies and historical fate.
   d. This definition accommodates both sexual and asexual forms as well as fossils.
5. Phylogenetic Species Concept
   a. The phylogenetic species is an irreducible (basal) grouping of organisms diagnosably distinct from other such groupings and within which there is a parental pattern of ancestry and descent.
   b. This is a monophyletic unit that recognizes the smallest groupings that undergo evolutionary change.
   c. It discerns the greatest number of species but may be impractical.
   d. This system disregards details of evolutionary process.
6. Dynamism of Species Concepts
   a. Disagreement is a sign of dynamic research and argument.
   6. b. No one concept is comprehensive or final; all need to be understood to understand future

4.2 Taxonomic Characters and Phylogenetic Recognition

A. Phylogeny, characters, and homology

1. A **phylogeny,** or evolutionary trees, is based on the study of characters that vary among species.
2. Character similarity that results from common ancestry is called homology.
3. Different lineages may develop similar features independently; this is convergent evolution.
4. Characters that are similar but misrepresent common descent are nonhomologous or homoplastic.

B. Using Character Variation to Reconstruct Phylogeny

1. Reconstructing phylogeny requires determining ancestors and descendants.
2. The form that was present in the common ancestor is **ancestral**.
3. Characters that arose later are **derived** character states.
4. polarity of a character refers to ancestral/descendent relationships among its different states.
5. An **outgroup** shows if a character occurred both within and outside the common ancestor.
6. A series of species that share derived characters form a subset called a **clade** (Figure 4.2).
7. The derived character shared by members of a clade is called a synapomorphy of that clade.
8. By identifying the nested hierarchy of clades or branches, we can form patterns of **common descent.**
9. Identifying the level at which a character state is a synapomorphy may identify a clade.
10. A **cladogram** is a nested hierarchy of clades (Figure 4.3).
11. To obtain a phylogenetic tree, we must add important information on ancestors, duration of lineages, and amount of change (Figure 4.4)

C. Sources of Phylogenetic Information

1. Comparative morphology examines shapes, sizes and development of organisms.
   a. Skull bones, limb bones, scales, hairs and feathers are important morphological characteristics.
   b. Both living specimens and fossils are used as phylogenetic information.
2. Comparative biochemistry analyzes sequences of amino acids in proteins and nucleotides in nucleic acids.
   a. Direct sequencing of DNA and indirect comparisons of protein sequences are comparative methods.
   b. Some recent studies use biochemical techniques to analyze fossils.
3. Comparative cytology examines variation in number, shape and size of chromosomes in living organisms.
4. Fossils can provide information on the relative time of evolution; radioactive dating can confirm age.

4.3 Theories of Taxonomy

A. Phyletic Relationships

1. A relationship between a taxonomic group and a phylogenetic tree or cladogram can be one of three forms.
    a. A **monophyletic** taxon includes the most recent common ancestor and all descendants of that ancestor.
    b. A taxon is **paraphyletic** if it includes the most recent common ancestor of all members of a group but not all descendants of that ancestor.
    c. A taxon is **polyphyletic** if it does not include the most recent common ancestor of members of that group; the group has at least two separate evolutionary origins (Figure 4.5).
2. Both evolutionary and cladistic taxonomy accepts monophyletic and rejects polyphyletic groups; they differ on accepting paraphyletic groups.

B. Traditional Evolutionary Taxonomy

1. The two main principles are common descent and amount of adaptive evolutionary change.
2. A branch on a family tree represents a distinct **adaptive zone**; a distinct "way of life."
3. A taxon that represents an adaptive zone is a **grade**; modifications of the penguin branch to swimming are an example (George Gaylord Simpson, Figure 4.6).
4. Evolutionary taxa may be either monophyletic or paraphyletic; chimpanzees and gorillas share a more recent ancestor with man than with orangutans, but are in a family separate from humans.
5. By accommodating adaptive zones, nomenclature reflecting common descent is not as clear.
7. **Phenetic taxonomy** was another school of classification that abandoned producing phylogenetic trees in favor of measuring overall similarity; but at this point has had only minor impact on classification today.
    7. Adaptive zone concepts used to separate penguins and diving petrels (Figure 4.6).

C. Phylogenetic Systematics/Cladistics (Figure 4.7)

1. **Willi Hennig** (Figure 4.8) first proposed cladistics or phylogenetic systematics in 1950.
2. It emphasizes common descent and cladograms.
3. In the above example, chimpanzees, gorillas and orangutans are included in *Hominidae* with humans.
4. Cladists do not assert that amphibians evolved from fish or birds from reptiles; they contend that a monophyletic group descending from a paraphyletic group contains no useful information.
5. Likewise, extinct ancestral groups are always paraphyletic since they exclude a descendant that shares their most recent common ancestor.
6. Some cladists indicate that primitive and advanced are relic ideas derived from a pre-Darwinian times because all groups of animals contain combinations of primitive, advanced, specialized, and generalized features.
8. Cladists avoid paraphyletic groups by defining a long list of **sister groups** to each more inclusive taxon.

D. Phylogenies from DNA Sequences (BOX)

1. Cladistic analysis of DNA sequence data can be used to examine phylogenetic relationships.
2. Analysis of two Madagascaran chameleons to determine degree of relationship using characters that share a derived state (**synapomorphy**).
3. Parsimony: used to resolve conflicts among taxonomic characters, requiring the smallest total amount of character change in the phylogram.
4. unlike evolutionary classification, cladistic taxonomy places pongo, gorilla, pan, and homo into a single monphyletic family hominidae.

E. Current State of Animal Taxonomy

1. Modern animal taxonomy was established using evolutionary systematics and recent cladistic revisions.
2. Total use of cladistic principles would require abandonment of Linnaean ranks.
3. **Sister groups** relationships are clear descriptions that will replace "mammals evolved from reptiles" paraphyletic statements that are problematic.
4. The terms "primitive," "advanced," "specialized" and "generalized" are used for specific characteristics and not for groups as a whole.
5. Cladistics causes confusion by using "bony fishes" to also include amphibians and amniotes, reptiles to include birds, but not some fossil forms.

4.5 Major Divisions of Life (Figure 4.9)

1. Aristotle's two-kingdom system included plants and animals; one-celled organisms became a problem.
2. Haeckel proposed Protista for single-celled organisms in 1866.
3. In 1969, R.H. Whittaker proposed a five-kingdom system to distinguish prokaryotes and fungi.

4. Woese, Kandler and Wheelis proposed three monophyletic domains above kingdom level—Eucarya, Bacteria and Archaea—based on ribosomal RNA sequences. Evolutionary relationships among major groups from comparisons of ribosomal RNA sequences are illustrated in Figure 4.9.
5. Retaining Whittaker's five kingdoms, the Eucarya are paraphyletic unless Protists are broken up into Ciliata, Flagellata and Microsporidia, etc. (Figure 4.10).
6. More revisions are necessary to clarify taxonomic kingdoms based on monophyly.
7. "Protozoa" are neither animals nor a valid monophyletic taxon.
5. "Protista" is not a monophyletic kingdom but is most likely composed of seven or more phyla.

4.6 Major Subdivisions of the Animal Kingdom

A. Classification

1. Animal phyla have been informally grouped based on embryological and anatomical traits.
2. Protozoa constitute many phyla and none of them belong within the animal kingdom.
3. Metazoa is therefore synonymous with the animal kingdom proper.
4. In the classical outline, bilateral animals are divided into deuterostomes and protostomes; however some phyla have mixed traits.
5. Molecular studies call into question the classification of Bilateria; protostome phyla groupings by acoelomate, pseudocoelomate and eucoelomate may not be monophyletic.
6. Basis for distinction between Protostomes and Deuterostomes (Figure 4.11).
7. Recent molecular phylogenetic studies have challenged traditional classification of Bilateria
    a. Branch A is the phyla Mesozoa.
    b. Branch B (Parazoa) includes the phyla Porifera and Placozoa.
    c. Branch C (Eumetozoa) are all other phyla.
    d. In Grade II Bilateria, Division A includes Protostomia and Division B includes Deuterostomia.