Exercise 6 (Modules 15.11–15.13)

Scientists are beginning to understand the biological mechanisms responsible for large-scale evolutionary changes. Review the biological mechanisms underlying macroevolution by matching each of the descriptions on the left with the best evolutionary example on the right.

_____ 1. Changes in body form often result from changes in gene regulation, not in the genes themselves.
_____ 2. Complex structures often evolve step-by-step.
_____ 3. A structure that evolves in one context and takes on a new role is called an exaptation.
_____ 4. Slight changes in the relative rates of growth in different body parts can make big changes in the appearance of adults.
_____ 5. Changes in homeotic genes can radically alter the timing of development and the shape of body parts.
_____ 6. Selection among different species may result in large-scale evolutionary trends or apparent "trends."
_____ 7. Paedomorphosis is a change in timing of development, causing juvenile features to be retained by adults.

A. The horse family
B. Eyes
C. Human and chimp skulls
D. Feathers
E. Fins to legs
F. Salamanders with gills
G. Stickleback spines

Exercise 7 (Modules 15.14–15.19)

Review the principles, methods, and vocabulary of phylogeny and systematics by inserting the correct terms into the following essay.

The evolutionary history of a species or group of species is termed 1_____________. Scientists look to the 2_____________ record to reconstruct phylogeny. Evolutionary history can also be reconstructed by comparing morphological (structural) and molecular features among living species. The teeth and skeletons of lions and bobcats show many 3_____________ that indicate that these animals share a common ancestry. But anatomical comparisons can sometimes be misleading. A process called 4_____________ evolution sometimes causes unrelated organisms to look alike because they have adapted independently to similar environments. The extinct Tasmanian "tiger" (see Chapter 19, Introduction) looks like a cat, but it is actually a marsupial, more closely related to a kangaroo! Such similarity due to convergence is called 5_____________; it can be misleading in reconstructing phylogenies. Often, molecular comparisons allow us to see beyond outward appearance; the DNA of the Tasmanian tiger is very different from the DNA of the two big cats.

6_____________ is the field of biology that focuses on classifying organisms and finding their evolutionary relationships. An important goal of systematics is to name and classify organisms. Biologists called 7_____________ use morphological and molecular comparison to name and group species. Each species is given a two-part name, called a 8_____________. For example, the African lion is *Panthera leo*. The first part of the name is the 9_____________ to which the lion belongs. The second part identifies a particular 10_____________ within that genus.

Naming is only a starting point. The ultimate goal of taxonomy is to place each organism into a hierarchy of taxonomic categories from 11_____________ (the smallest) to 12_____________ (the largest and most inclusive). Ideally, these categories reflect evolutionary history. Biologists depict these relationships in the form of

[13]________________ trees. Species are the twigs of such a tree. The limbs of the tree are larger groupings such as orders, classes, and phyla.

The most widely used method in systematics is called [14]________________. It is a method that that seeks to identify [15]________________—branches that include an ancestral species and all its descendants. Such an inclusive group—a genus, family, or kingdom—is said to be [16]________________. Cladistics makes it possible to construct a classification scheme that reflects the branching of the tree of life.

Cladistics is based on the idea that the evolutionary tree forks when a new heritable trait develops and is passed on to descendants. Groups of organisms that share the new trait are more [17]________________ related than those that have only ancestral traits. For example, the Tasmanian tiger, the lion, and the bobcat all have hair and mammary glands. These are shared [18]________________ characters. But the Tasmanian tiger gives birth to its young very early and nurses them within a pouch. The lion and bobcat retain their young for a much longer period of gestation, nourishing them via a structure called the placenta; this is an added trait, a shared [19]________________ character, that sets the lion and bobcat apart from the Tasmanian tiger. The bobcat and lion are placed in a separate clade, a separate subclass of Class Mammalia, reflecting this evolutionary history. If we are comparing the two cats with the Tasmanian tiger, the cats constitute an ingroup, and the Tasmanian tiger represents an [20]________________, a group known to have diverged before the cat lineage.

The principle of [21]________________, the quest for the simplest explanation, guides cladistics, but this has shaken some branches of the "traditional" evolutionary tree. For example, this approach places [22]________________ within the reptile clade. Several shared [23]________________ characters, such as a four-chambered heart, show that birds and crocodiles are more closely related to each other than crocs are to other reptiles. Similarly, cladistics separates humans and chimps from other apes.

Molecular comparisons can clarify evolutionary relationships. Comparing nucleic acids, proteins, or other molecules to determine relatedness is called molecular [24]________________. Researchers use computers to search through and compare nucleic acid [25]________________ sequences from different species. In general, the more similar the base sequences, the more [26]________________ related the organisms in question. Some nucleic acids, such as the DNA in [27]________________, evolve rather rapidly. Thus, mDNA can be used to trace recent evolutionary events, such as the divergence of various human groups. Other nucleic acids, such as the DNA coding for [28]________________ RNA, change more slowly, so they can track changes occurring over hundreds of millions of years. Because some genes appear to change at a known rate, they allow us to calibrate a molecular [29]________________ that can be used to date evolutionary branch points. Because a good fossil record goes back only about [30]________________ million years, we can use molecular clocks to date divergences thought to have occurred before that time. Returning to the more recent divergence of our cats and the Tasmanian tiger, we would expect that homologous genes of a lion and a bobcat would be more alike than homologous genes of a lion and a Tasmanian tiger. Thus, cladistics and molecular systematics enable us to form testable [31]________________.

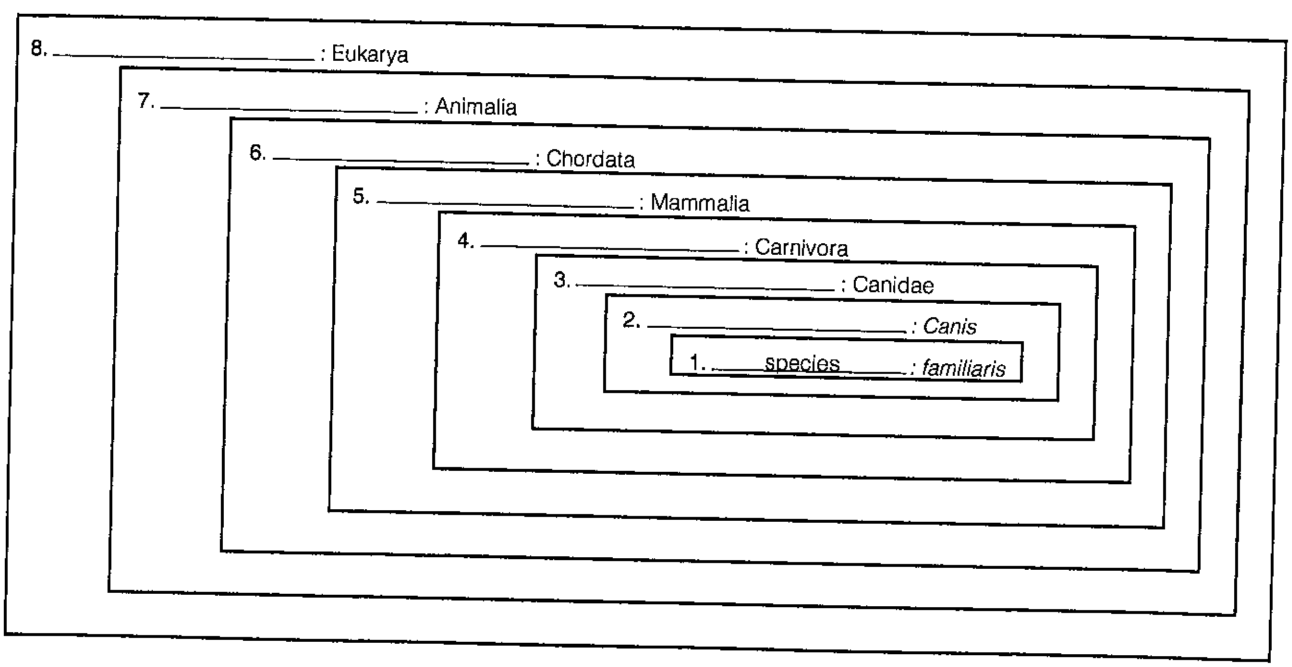
Comparing whole genomes has given us some surprising insights into evolutionary relationships. On a molecular level, the genes of humans and chimps are 96% identical. Amazingly [32]________________ of human genes are homologous with genes in mice, and about half our genes are homologous with genes in [33]________________—single-celled eukaryotes! Genomics has revealed that gene [34]________________ has had an important role in evolution, because it increases the number of genes in the genome and provides "raw material" for evolutionary change.

Looking at the larger picture, molecular systematics has catalyzed rethinking the entire tree of life. Back in the day, all life was divided into two kingdoms— [35]________________ and [36]________________. But where did this leave bacteria or photosynthetic organisms that swim? By the 1960s, it looked like the tree of life had five main branches, but soon enough, molecular comparisons showed that that scheme was flawed too. More recently, biologists have adopted a three-[37]________________ system, with two groups of prokaryotes, called [38]________________ and [39]________________, and one group of eukaryotes, the [40]________________. Plants, [41]________________, fungi, and protists (like those swimming green guys) are [42]________________ within Domain Eukarya.

The most recent discoveries suggest that the tree of life might not be a tree at all! During the early history of life, there appear to have been substantial exchanges of genes among the different domains. This took place via [43]________________ gene transfer, a process carried out by exchange of plasmids, [44]________________ infection, or even fusion of whole organisms. Your mitochondria, for example, were once free-living [45]________________. The tree of life thus becomes a tangled thicket of intertwining vines, or even a ring.

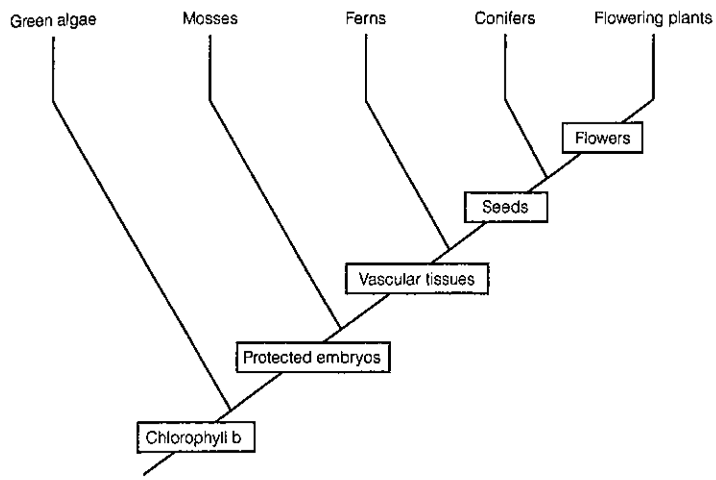
Exercise 8 (Module 15.15)

The system of taxonomic categories used by biologists is like a set of boxes into which organisms are sorted. A cocker spaniel—*Canis familiaris*—for example, is first placed in a small box, the specific name *familiaris* that separates it from all other species. This is placed in a slightly larger box, the genus *Canis*, which also holds *Canis lupus* (the wolf) and *Canis latrans* (the coyote). This genus box is placed in a larger box, along with other genera of doglike animals, and so on, all the way up to the last box that separates eukaryotes from prokaryotes. Imagine that the nested boxes below represent the taxonomic categories, starting with species (omitting subphylum). Label the boxes to show the relationships among the categories.



Exercise 9 (Module 15.16)

Cladistics, the most widely used method of systematics, seeks to clarify evolutionary and taxonomic relationships by grouping organisms into clades. A clade is a group of organisms made up of an ancestor and all its descendants. This simplified phylogenetic tree uses cladistics (based on anatomy, but backed up by molecular data) to reconstruct the relationships among four groups of plants and their closest relatives, the green algae. Read Module 15.16, examine the trees in the module and below, and then answer the following questions. This exercise is rather difficult, so take your time.

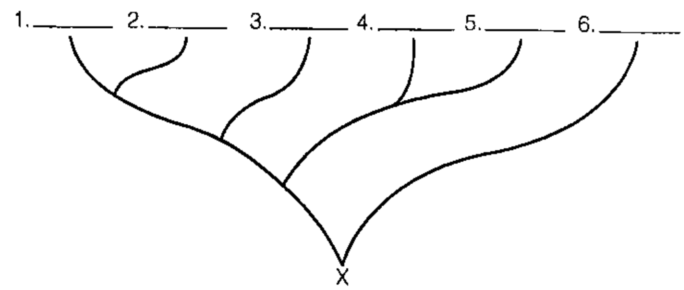


1. Which four groups of organisms above make up the in-group?
2. Which organisms constitute the out-group?
3. Which is more useful in cladistics, analogies or homologies?
4. Which characters are unique to a lineage of organisms, shared derived characters or shared ancestral characters? Which are more useful in differentiating among (separating out) distinct lineages?
5. What is a shared ancestral character common to all plants?
6. What is a shared derived character common to all plants?
7. What is a shared ancestral character common to all plants with seeds?
8. What is a shared derived character common to all plants with seeds?
9. Which characters are most useful in deciding whether an organism is in the out-group or the in-group, shared ancestral characters or shared derived characters?
10. If we are interested in focusing on all plants that have vascular tissues, which groups on the phylogenetic tree constitute the out-group? The in-group?
11. What is the name of a taxonomic group consisting of an ancestor and all its descendants?
12. What other organisms are in the clade that includes the first plants with seeds?
13. Name or describe nine different clades shown on the phylogenetic tree above.

Exercise 10 (Module 15.17)

Homologous structures—similar structures derived from the same structure in a common ancestor—tell us about phylogenetic relationships among organisms. But convergent evolution can make unrelated organisms look alike; their similarities may be analogous, not homologous. Fortunately, we can dig beneath surface similarities and compare biological molecules to measure relatedness between species. For example we can compare protein amino acid sequences, RNA base sequences, or DNA base sequences—even whole genomes. Imagine that you have sequenced mitochondrial DNA (mDNA) for six species of rodents, A through F. All the rodents are thought to have evolved from a common ancestor, X. The number of differences in mDNA sequence are compiled in the table below, which reads like a road map mileage chart. For example, there are four differences between A and C, and nine differences between A and D. Use the differences in sequence to place species A through F on the phylogenetic tree. (Hint: Don't get too mathematical; just "eyeball" overall numbers.)

A						
B	10					
C	4	11				
D	9	5	10			
E	14	16	15	15		
F	10	2	10	6	16	
	A	B	C	D	E	F



Test Your Knowledge

Multiple Choice

1. The science of naming and classifying organisms is called
   a. biology.
   b. polyploidy.
   c. genetics.
   d. taxonomy.
   e. parsimony.

2. Large-scale changes in the history of life, such as mass extinctions, the development of walking legs from fins, and the appearance of new groups of organisms such as birds, are termed:
   a. macroevolution.
   b. adaptation.
   c. exaptation.
   d. microevolution.
   e. paedomorphosis.

3. Which of the following is thought to have been the first step in the origin of life?
   a. cooperation among molecules
   b. formation of protobionts
   c. formation of organic monomers
   d. replication of primitive "genes"
   e. formation of organic polymers

4. Systematics is concerned with
   a. naming organisms.
   b. studying biological diversity.
   c. taxonomy.
   d. tracing phylogeny.
   e. all of the above.