chapter 17

Organizing Life's Diversity

section 2 Modern Classification

MAIN Idea

Classification systems have changed over time as information has increased.

What You'll Learn

- species concepts
- methods to reveal phylogeny
- how to construct cladograms

Before You Read

On the lines below, describe your system of organizing your class notes and your method of using the information in your notes to study for tests. In this section, you will learn how scientists have used new information to make adjustments to systems and theories.

Mark the Text

Identify Main Ideas
As you read, underline or highlight the main ideas in each paragraph.

Read to Learn

Determining Species

Organisms that are different species by one definition might be the same species by a different definition. The definition of species is evolving as scientists learn more information about the organisms they study.

What is the typological species concept?

Aristotle and Linnaeus thought of each species as a group of organisms with similar physical characteristics. This definition of a species is called the typological species concept. It is based on the idea that species are unchanging, distinct, natural "types." A type specimen is an individual of the species that best shows the characteristics of that species. When another specimen was found that was different from the type specimen, it was classified as a different species.

Evolution causes species to change. Because there is a lot of variation among members of some species, the typological species concept has been replaced. Some of its traditions such as type specimens remain.

Reading Check

1. Define What is a type specimen?

What is the biological species concept?

In the 1930s and 1940s, the term *species* was redefined as a group of organisms that are able to interbreed and produce fertile offspring in a natural setting. This definition is known as the biological species concept.

There are limitations to the biological species concept. Wolves and dogs are classified as different species, but they are known to interbreed and produce fertile offspring. Many plant species can also interbreed and produce fertile offspring. The biological species concept also does not consider extinct species or species that reproduce asexually. However, the biological species concept works for most classification, so it is often still used.

What is the phylogenetic species concept?

In the 1940s, the evolutionary species concept was proposed to go along with the biological species concept. The evolutionary species concept defines different species as two or more groups that evolve independently from an ancestral population. This concept has developed into the phylogenetic species concept.

Phylogeny (fi LAH juh nee) is the evolutionary history of a species. The phylogenetic species concept defines a species as a group of organisms that is different from other groups of organisms and that has, within the group, a pattern of ancestry and descent. When a phylogenetic species branches, it becomes two different phylogenetic species. For example, you have read that when organisms become isolated, they often develop different adaptations. Over time, these isolated organisms become different from the original group.

Reading Check

2. Describe How is species defined as the biological species concept?

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Picture This

3. Identify Which species concept classifies according to ancestral history?

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Species Concept	Description	Limitation	Benefit
Typological species concept	classification by the comparison of physical characteristics with a type specimen	Alleles produce a wide variety of features within a species.	Descriptions of type specimens provide detailed records of the physical characteristics of many organisms.
Biological species concept	classification by similar characteristics and the ability to interbreed and produce fertile offspring	Some organisms that are different species interbreed occasionally. It does not account for extinct species.	The working definition applies in most cases, so it is still used frequently.
Phylogenetic species concept	classification by evolutionary history	Evolutionary histories are not known for all species.	Accounts for extinct species and considers molecular data.

Has the classification of a species changed?

For more than one hundred years, Asiatic elephants have been classified as one species and African elephants have been classified as a different species. There are two populations of African elephants. One population lives in the savanna, and one population lives in the forest. Until recently, the two African populations had been classified as the same species. Scientists thought that the two African populations interbred at the borders of their habitats. Recent studies have shown that they interbreed rarely. Scientists also found large differences in the DNA and skull measurements of the two African populations. The two populations might be separate species.

Reading Check

4. Summarize Why might African elephants be two species, instead of one?

Characters

To determine the species of an organism, scientists put together pieces of evolutionary history, also called phylogenies, using characters. **Characters** are inherited features that vary among species. Characters can be morphological or biochemical.

How are morphological characters used?

Shared morphological characters suggest that species are closely related and that they evolved from a recent common ancestor. Analogous characters do not indicate a close evolutionary relationship. Recall that analogous characters have the same function but different structure. Homologous characters might perform a different function but show similar structure that was inherited from a common ancestor.

Look at the oviraptor and the sparrow shown below. Some dinosaur fossils such as theropods show that they had feathers and large hollow spaces in their bones. Their hip, leg, wrist, and shoulder structures are similar to those of birds. These morphological characters suggest that birds are related more closely to theropod dinosaurs than to other reptiles.

Picture This

5. Compare What physical characteristics do the oviraptor and the sparrow have in common?

How are biochemical characters used?

Recall that chromosomes are strands of genetic material that become visible during mitosis and meiosis. The number and structure of chromosomes provide information about evolutionary relationships among species. Similarities suggest a common evolutionary history.

DNA and RNA are made up of four nucleotides. The sequence of DNA nucleotides defines the genes that give instructions to RNA for making proteins. Scientists study and understand evolutionary relationships by sequencing DNA of different organisms. They compare the sequences of a variety of organisms. Organisms that are closely related have many similar sequences of nucleotides. Therefore, they have similar proteins.

Broccoli, cabbage, cauliflower, and kale look different, but they have almost the same chromosome structures, which suggest a close evolutionary relationship. Chimpanzees, gorillas, and orangutans also have similar chromosomes.

Different organisms might have many similar sequences in their DNA. However, when all of their DNA sequences are studied, major differences can be found. The more sequences they share, the more likely they are to share a common ancestor.

What are molecular clocks?

Mutations occur randomly in DNA. As time passes, mutations build up in the chromosomes. Some mutations do not affect the function of cells. The rate at which these mutations build up can be viewed as a molecular clock. A **molecular clock** is a model that uses comparisons of DNA sequences to estimate how long species have been evolving.

The rate at which mutations occur does not stay the same. The rate of a mutation is affected by many factors that include the type of mutation, where in the genome the mutation occurs, the type of protein the mutation affects, and the population in which the mutation occurs. In a single organism, genes might mutate at a different rate. This inconsistency makes molecular clocks difficult to read. Scientists are trying to find genes that mutate at a relatively consistent rate throughout a range of organisms.

Even though molecular clocks have limitations, they can be a valuable tool for helping to determine the time when a new species evolved. The molecular clock is often used along with the fossil record to identify the time of divergence.

Reading Check

6. Explain How can DNA sequences be used to determine if organisms are closely related?

Think it Over

7. Discuss Why does the inconsistency in the rate at which genes mutate make molecular clocks difficult to read?

Phylogenetic Reconstruction

Biologists often study evolutionary relationships using cladistics. **Cladistics** (kla DIHS tiks) is a way to study evolutionary relationships that rebuilds phylogenies and hypothesizes evolutionary relationships based on shared characters. The hypothesized relationships formed by cladistics suggest how different groups of organisms might have evolved. To identify possible relationships, the characters of different groups of organisms need to be known.

What are the main character types?

There are two main character types that need to be considered when using cladistics: ancestral characters and derived characters. An ancestral character is found in a variety of groups within the line of descent. A derived character is present in one group within the line of descent, but it is not found in the common ancestor. When comparing two groups of organisms, an ancestral character evolved in a common ancestor of both groups, and a derived character evolved in an ancestor of one group.

Reading Check

8. Compare What is the difference between ancestral and derived characters?

For example, when comparing birds and mammals, a backbone is an ancestral character because both birds and mammals have backbones and both have ancestors with backbones. Feathers are derived characters because only birds have an ancestor with feathers. Hair is also a derived character because only mammals have an ancestor with hair.

What is a cladogram?

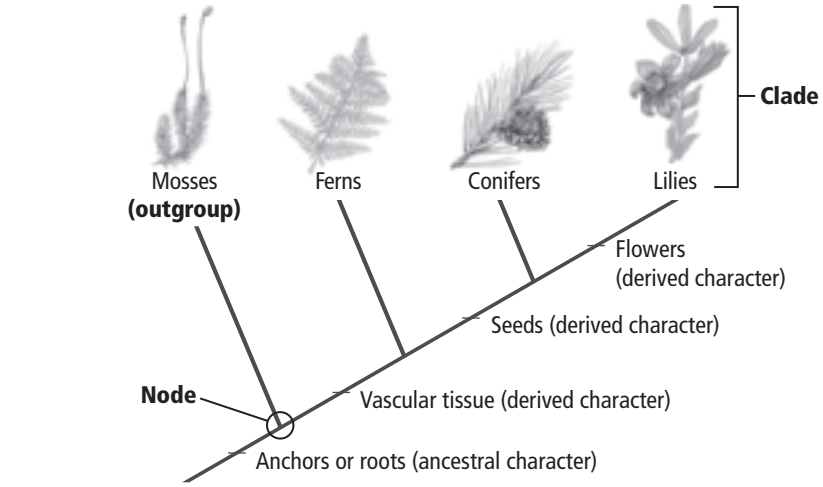
Scientists use ancestral characters and derived characters to make a cladogram. A **cladogram** (KLAD uh gram) is a branching diagram that shows the proposed phylogeny of a species. A cladogram is similar to a pedigree. Both have branches and show the ancestry of an individual or a group. The groups of a cladogram, called clades, have one or more related species. The branches of a cladogram show hypothesized phylogeny. The hypothesized phylogeny shown in a cladogram depends on information from DNA and RNA sequences, bioinformatics, and morphological studies. Places where branching occurs are called nodes. The common ancestor at the nodes is rarely a known organism, species, or fossil. Scientists hypothesize the ancestor's character types based on the traits of its descendants. Scientists think that the more derived characters groups share, the more recent their common ancestor.

Reading Check

9. Define What is a cladogram?

How is a cladogram made?

A cladogram of the lily, a flowering plant, is shown below. First the derived characters—vascular tissue, seeds, and flowers—were identified. Then the ancestry of a variety of species was identified based on whether the species had some or all of the derived characters. The groups that are closer to the lily in the cladogram probably share a more recent ancestor than the groups that are farther away. Flowering plants and conifers share three derived characters and are thought to have a more recent common ancestor than flowering plants and ferns have.



What is a phylogenetic tree?

Phylogenetic trees are used to show the relationships among species and groups of organisms. A phylogenetic tree is a form of cladogram in which each node with descendants represents a common ancestor. The tree of life concept was introduced by scientist Ernest Haeckel. He imagined a tree with a trunk representing ancestral groups. The tree's branches showed species. Similar species were listed on nearby branches. The leaves on the branches represented individual organisms.

A tree that represented all living organisms would be gigantic. Scientists have classified about 1.75 million species. They estimate that millions more have not yet been classified. Although creating a complete tree of life is a large, difficult task, many scientists think it is important. Scientists representing many disciplines are working together to develop a comprehensive tree of life.

Picture This

10. Identify Which traits do flowering plants and conifers share?