

Investigate cladograms

How might we group organisms to demonstrate evolutionary relationships?

How can we use genetics to build evolutionary relationships?

Standards

- **B.H.1:** Cellular genetics: Genes code for proteins
- **B.E.2:** Speciation: Biological classification expanded to molecular evidence

Introduction

On the surface, many organisms may not appear to have much in common. However, at the genetic level, they may have more in common than you might guess. Genes are made of DNA which is inherited from a parent by its offspring. Some DNA sequences code for mRNA which, in turn, codes for the amino acid sequence of proteins. Genes and proteins that code for basic survival functions tend to be shared by many organisms. Cytochrome c (cyt c) is a protein involved in energy use within the cell. Cyt c is found in all eukaryotes as well as some prokaryotes. As a result, cyt c is an ideal tool to help scientists learn more about the relationships between organisms.

Student prior knowledge

Students should understand that genes in DNA code for proteins that perform cellular functions. Over time, random mutations in the DNA sequence can occur. As a result, the amino acid sequence changes. Scientists can use the changes in the amino acid sequence of cytochrome c to detect evolutionary relationships between organisms. Students should also be familiar with cladograms, branching diagrams that show evolutionary relationships between organisms.

Suggested timeline

1–2 class period(s) (50–100 minutes)

Materials

- Student worksheets: Compare and group, Research and genetic relationships
- Cytochrome c amino acid protein table

Teacher preparation

Print the student worksheet and cytochrome c amino acid protein table

Procedure

1. Brainstorm characteristics for the 10 organisms in each group of cards. What are some of the criteria scientists might use to determine how closely related two organisms are? Discuss with your group and share your ideas with the class.
2. As a group, place the organism cards in order based upon their evolutionary age, from which organism evolved first to the last (left to right). Create a claim with evidence and reasoning (CER) to support your conclusions. Present your CER to the class and compare your claim to that of other class groups.
3. Pass out the cytochrome c amino acid protein table and compare the cyt c sequences between the organisms. Count the number of differences between humans and the other organisms and place that number in the Data table 2. For each organism, circle each amino acid that differs from the human sequence. *Note that a blank cell indicates an amino acid that is missing in some species. In places*

where one species has a blank cell and another has a letter, count that as a difference.

4. Reflect with students how it is possible for all of the organisms to have the same functioning protein, cytochrome c, when there are one or more amino acid sequence differences between organisms.
5. Create a cladogram using the number of amino acid differences between organisms by starting with the greatest number of differences and going to the least number of differences.
6. Make a cladogram using the data in table 2.
 - a. Place the two most closely-related species on the two shortest branches. The two most closely-related species have the fewest number of differences in the amino acid sequence.
 - b. Place the next two closest related species on the next two shortest branches.
 - c. Place the species which is the next closest on the next longest branch. Continue until all the species have been placed.

Suggested wrap-up activity

The students will compare their cytochrome c cladogram to their previous CER construction and determine how similar their evolutionary predictions are to the amino acid sequences.

Differentiation

- Create heterogeneous groups of students (of varying knowledge and ability levels) to complete the CER and cladogram activities together.
- Display the vocabulary at the end of the document ahead of time for the students.

More challenges

- Have the students explore more eukaryotic organism cytochrome c amino acid sequences to add additional information into their cladogram.
- Have students research and report on scientists that have contributed to our understanding of evolution theory over time.
- Compare cladograms: Gather several cladograms and practice reading and interpreting them. If there are differences between them, compare the points of difference. Why are they different and similar? What does this communicate about the evolutionary relationships scientists have formed about each cladogram?
- **Home connection:** Start a conversation about how genetics are used to better understand evolutionary relationships between organisms. Discuss how previous morphological similarities may not demonstrate the same ancestral link as the amino acid, cytochrome c.

Support information

- **Cladogram:** a branching diagram that shows the ancestral relationships among species.
- **Evolution:** the change in the heritable characteristics of biological populations over successive generations.
- **Morphology:** a branch of biology that studies the external and internal structures of living things.
- **Eukaryote:** an organism consisting of a cell or cells in which the genetic material is DNA in the form of chromosomes contained within a distinct nucleus.
- **DNA (deoxyribonucleic acid):** the molecule that carries genetic information for the development and functioning of an organism.
- **Gene:** the basic unit of heredity passed from parent to child. Genes are made up of sequences of DNA and are arranged, one after another, at specific locations on chromosomes in the nucleus of cells.
- **mRNA (messenger ribonucleic acid):** a single-stranded molecule of RNA that corresponds to the genetic sequence of a gene and is read by a ribosome in the process of synthesizing a protein.
- **Amino acids:** molecules that combine to form proteins.
- **Protein:** a molecule made up of amino acids. Proteins are needed for the body to function properly.

- **Cytochrome c:** a protein found in the mitochondria where it functions to transfer electrons in ATP synthesis.
- According to evolutionary theory, species that recently shared a common ancestor have more similarities in their DNA than ones that last shared a common ancestor long ago. By comparing the order of amino acids that make up the protein cytochrome c and noting the differences in the arrangement, scientists can infer relationships among species. In general, the more amino acids two species share, the more closely related they are in evolutionary time.
- Cladistics is a method of placing species with similar characteristics into groups called **clades**. Clades can be grouped according to branching diagrams (*cladograms*) to show evolutionary relationships. Key features of cladograms are:
 - **Root:** the initial ancestor common to all organisms within the cladogram
 - **Nodes:** a hypothetical or last common ancestor
 - **Outgroup:** the most distantly related species (ancestor) in the cladogram
 - **Ingroups/clades:** a common ancestor and all of its descendants
 - **Derived characters/traits:** evolutionary traits that only appear in some members of an evolutionary group
- Amoeba Sisters Protein Synthesis video: youtu.be/oefAI2x2CQM
- Bozeman Science cladogram tutorial: youtu.be/ouZ9zEkx6Wg

Teaching suggestions

Have the students tape their CER organisms together in order from oldest to youngest, left to right, to share with the class as they discuss their claims.

Career connections

Have you ever wondered what type of scientists may be working in the evolutionary field to improve poultry genetics? Let's take a look!

- **Animal geneticists** analyze the genetic makeup of organisms to discover which genes cause them to behave in certain ways. Geneticists may also study animal health to determine what causes animals to be immune to specific diseases or fail to thrive in certain environments.
- **Evolutionary biologists** study the evolutionary processes that have led to the genetic biodiversity of life on earth.
- **Veterinarians** care for the health of the poultry flock and work to protect public health. They diagnose, treat, and research medical conditions and diseases of pets, livestock, and other animals.