# THE CLASSIFICATION OF LIVING THINGS

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# INTRODUCTION

What makes a fish be a fish? Why is a sunflower a sunflower and not a rose? Bats and birds and dragonflies all take to the air, but they are in very different classification groups. Why?

Biological classification is a complex but fundamental part of the study of living things—and it can be exciting. It reveals the history of life on Earth by acknowledging the evolutionary relationships between different species. It is a story that continues to be written as new evidence makes our account more accurate. Building a meaningful biological classification system requires a lot of knowledge of biology and its basic concepts. Using a classification system can be an effective way to teach many of those concepts.

What ideas does the word "classification" conjure for you and your students? All too often, people connect classification with a task of memorizing a list of names, but this is misleading. The science of biological classification is an active area of research, and the names are much more than just an arbitrary list. Instead, they are labels that tell us about the unique characteristics of an organism. The labels also show how an organism is related to other species, and its path of descent from ancient ancestors. That is one reason that classification assignments continue to change. As we know more, we can do a better job of grouping organisms in a meaningful way.

New technologies continue to expand and modify our classification system. For example, DNA technology has provided valuable data for testing and correlating assumptions about relationships that are built on structural or physiological data. The changes in biological classification help to make the scheme become a more accurate description of evolutionary relationships. The classification scheme is a human-based system to organize what we know about a set of real relationships. As species continue to evolve, even the relationships change—but at a very slow rate.

Students need to understand classification more than to memorize dozens of labels and names. No one can hold all this knowledge in their head—indeed, it is even difficult to record it in print or online for all organisms. Students must start by understanding the significance of classification, learning a few examples so that they have something to work with, and being aware of the ongoing process of research in classification and taxonomy.

How can you make this topic appealing for students? The video program ***The Classification of Living Things*** brings to life the topic of classification for your students. Colorful images catch their attention. The narrative line opens the idea of classification as a meaningful scientific investigation. Students begin to see the structure of the system overall. They begin to see that scientific names tell them something about the organism in question. With the help of the video and teaching guide exercises, students will come to understand the meaning behind the biological classification system. You can use this program to wake up student interest in the topic and to provide a lively but solid foundation of understanding.

# LEARNING OBJECTIVES

After viewing the video program ***The Classification of Living Things*** and using the student worksheets and exercises in this Teacher's Resource Book, your students should be able to:

- describe the significance of biological classification
- be aware that taxonomic distinctions reflect evolution
- explain the criteria on which classifications are based
- recognize genus and species names
- report on the five biological kingdoms
- diagram the relationship between the five kingdoms and the larger taxa known as domains
- provide examples of taxonomic groups
- understand how new technologies and discoveries change our view of classification
- carry out a classification exercise

A fast-paced visual collage of living things provides an enticing entry into the program ***The Classification of Living Things***. This rich array of biological images reflects the enormously diverse world of living things and the enormous task of identifying and organizing them for study. Students immediately see the challenge of meaningful organization in an opening story that takes place in a grocery store. In this particular store, items have been arranged at random. Right away, students have a familiar example that connects to their own experience: they can easily relate to how difficult a shopping task would be if grocery stock were not arranged in a logical way.

From this familiar starting point, the video goes on to show how much greater the problem is of arranging biological information about species. The numbers are daunting, although only a small fraction of all species that ever lived are alive today. The diversity of life on Earth is so great that it is hard to organize according to fundamental biological principles (such as evolution). But the result is worth the effort: classification makes the collected body of biological information usable.

An interview with taxonomist Kathy Hodge of Cornell University explains that the label for each level of the classification hierarchy tells you a great deal about the organism. For example, if you know something is a mammal, you already know that it is an animal with a backbone, with hair or fur and that it probably feeds its young with milk.

Dr. Hodge goes on to illuminate how our ways to classify the living world have changed over the course of human history. Increased knowledge and understanding have brought about many changes. New tools and technologies also have brought about new versions of classification. For example, the microscope revealed a world of tiny organisms previously unknown. These had to be fit into the classification scheme—or more accurately, the classification scheme had to be altered to account for this discovery of new data. Other tools, such as DNA analysis technologies, continue to improve and adjust biological classification.

The largest change in classification came with an understanding of evolution. All living things are descended from common ancestors, and biological classification reflects that relationship. Other changes include the distinction between organisms based on their cell structure. Prokaryotes such as bacteria have simple cells that lack an internal compartment known as a nucleus. More complex cells with a nucleus are called eukaryotic cells. Even some microscopic or single-celled organisms are eukaryotes. This large division among living things is one of the most fundamental aspects of classification.

Another step in the history of classification came in the 1950s as scientists recognized that fungi are fundamentally different from plants. The main differences have to do with how organisms in each group get food. While plants carry out photosynthesis, fungi get food from the remains of other organisms.

The program moves forward with the introduction of the five kingdoms. Students begin to see how each level of the classification system together form a hierarchy of groups known as taxa. Students learn to follow through the levels from most general (kingdom) through phylum, class, order, family, genus and on to the species. The video explains that these differences, even at the species level, generally are represented by a barrier to breeding. A specific example of the common house cat (*Felis domesticus*) is used to show the levels of classification. Students also discover that extinct organisms are part of the classification scheme. They provide clues to modern relationships.

Students begin to see that species with similar evolutionary histories belong together in a classification group or taxon. Darwin's impact on meaningful classification is enormous. Students see that change is a strength in the process of scientific investigations. Discoveries, such as finding archaebacteria in extreme habitats, improve the quality of classification assignments. As more data are found, the classification system changes and thus becomes more accurate.

One modern change is the consideration of a large-scale division above that of the five kingdoms. This large-scale division would be three domains. Two of the three (bacteria and archaea) would comprise prokaryotes, while the third contains all eukaryotes. Showing this example helps students appreciate that classification is an active and ever-changing investigation rather than a static list of names. The changes are not whimsical: they are adjustments to fine-tune the system to better reflect the meaningful connections between species.

# NATIONAL SCIENCE EDUCATION CONTENT STANDARDS

The topic of biological classification is one of the concepts recommended by the National Science Education Content Standards for biology. ***The Classification of Living Things*** can be used effectively to bring these concepts to life for your students. For details, you may want to consult a print copy of the standards or look online at:

http://www.nap.edu/readingroom/books/nses/html/6e.html
Life Sciences Content Standard C

Some examples of the concepts supported by the video are summarized here:

**Biological Evolution**
The great diversity of organisms covers the Earth and is the result of more than 3.5 billion years of change as modern organisms evolved from common ancestors. Natural selection is part of the mechanism that has led to diversity. Biological classification not only provides an orderly way to organize and think about the many species that live or have lived on Earth, but it also reflects the evolutionary relationships among species. The biological taxa are arranged in a hierarchy that shows these relationships.

How does ***The Classification of Living Things*** fit into your course syllabus?

You can use the video and student exercises effectively in several different points in your biology course. Classification can fit with a study of evolution, as an introduction to the study of the different kingdoms, or as an application of scientific methods of observation, careful organization of data, and consistent thinking. Classification also is a topic that goes hand-in-hand with the study of diversity, of differences in the food web or with the ancient history of life on Earth.

Preview Questions

We suggest that you establish a foundation for thinking by using these preview questions or by letting students look over some of the worksheets prior to viewing the video. In either case, the purpose is to focus your students' thinking, not to look for complete or correct answers at this point.

Suggested preview questions:

- What is the difference between a common name such as "cat," and a scientific name such as *Felis domesticus*?
- What is the connection between classification and evolution?
- How many organisms need to be classified?

Use these questions to arouse curiosity prior to showing the video and to get students thinking along specific lines. The questions let you find out what pre-conceptions students may have. Use them in this way rather than to insist on getting a complete answer before students have viewed the video or worked the exercises. You may want to re-visit the questions after students complete work on the program.

The ideas behind the preview questions are to help students think about the uncertainty of a common name as compared with the precise relationships revealed by the scientific name. Evolution is a major concept of biology and an underlying principle in biological taxonomy. Groupings reflect relative degrees of evolutionary relatedness. The number of organisms to be classified is staggering. Estimates vary from a few to about eight or nine million more. Around 1.5 million organisms have been identified.

**Activity 1: Key Concepts**

*Briefly define these terms:*

taxa (plural of taxon): Organisms grouped together at one classification level.
classification: Organization of things into a system.
evolution: Long-term change in a biological system such as species that is inherited.
extinction: Disappearance of a species.

**Activity 2: Invent Your Own Classification Scheme**

*Name three ways you could arrange items in a grocery store. Make a chart with two columns labeled "Advantage" and "Disadvantage." For each classification system you have invented, describe the advantages and disadvantages. Which system do you think customers would prefer?*

Student responses will vary. They might write something like "by color," "by alphabetical listing of name," or "by nutritional group." Example of Disadvantage: color might be hard if people are color blind; people might find it difficult to select things for a dinner; items that are used for similar purpose have different colors. Advantage: color is a simple distinction; most people can see different colors; color has a strong emotional connection for some people.

The process of choosing criteria, thinking about them critically and assessing the system in a logical and consistent manner are the things being tested here.

**Activity 3: Biological Classification**

*Name two ways in addition to the current scientific system that organisms on Earth could be classified. For all three ways (the two you invented and the actual system), make a chart to list advantages and disadvantages.*

Student responses will vary. They might include "alphabetically" or "by geographical region." Again, the process of assessing a system is more important than the particular system itself. For actual biological classification system, disadvantages might include difficulty with determining actual evolutionary relationships. Advantages could include the current naming system which tells us much about the organisms and the fact that the classification scheme has a biologically meaningful basis.

**Activity 4: Technology and Classification**

*Name two technologies mentioned in the video that have expanded and changed our views of biological classification. Explain how each one has enhanced our understanding of biological classification.*

Students should answer (1) microscope and (2) DNA technologies, and provide their own explanations of how these technologies have enhanced the current view of classification.

**Activity 5: Evolution and Classification**

*How is evolution tied to biological classification?*

Modern biological classification is based on characteristics shared organisms descended from a relatively recent common ancestor. In other words, current schemes reflect the relative degree of evolutionary relatedness.

**Activity 6: Cell Structure**

*Into what two groups can all organisms be divided based on their cell structure? Draw a diagram of each type of cell. Label key features.*

Prokaryotes and eukaryotes. Diagrams should show that students understand that cells are membrane bound compartments. Diagram of prokaryote should show a DNA molecule as the genetic material (could be just a dark coil). Some students might show special features such as a flagellum. Eukaryote diagram should show the internal compartment known as a nucleus. Some students may also include mitochondria, chloroplasts or other features.

**Activity 7: The Five Kingdoms**

*Name the five kingdoms. How many of the kingdoms are prokaryotes? Explain.*

Animals (Animalia), Plants (Plantae), Fungi, Protista and Monera. All but the Monera are eukaryotes. The Monera are prokaryotes.

**Activity 8: Fungi**

*To what kingdom did fungi originally belong? Why are they now considered to be a separate kingdom?*

Fungi were originally included with plants. The video points out that their different way to obtain food (from organic material from living or dead organisms) sets them apart from photosynthetic plants.

**Activity 9: Hierarchy**

*What is meant by the term "hierarchy?" How does this term apply to biological classification?*

Hierarchy refers to organization system in which groups are nested in each level. Higher levels are the most general and contain a collection of groups and so on down each level to the most specific. Biological classification is a hierarchy from general groups (such as domains) down to specific groups (genus and species).

**Activity 10: Genus and Species**

*Which statement shows a closer relationship: (1) Organism A and Organism B belong to the same genus. (2) Organism A and Organism C belong to the same species.*

Two members of the same species are more closely related than two members of the same genus. A species is a lower level taxon.

*Does Organism C belong to the same genus as Organism B or to a different one? Explain.*

Organism C does belong to the same genus as Organism B, because species is the next level below genus. So all members of one species belong to the same genus. A branched line or overlapping circle diagram might help students express this idea.

**Activity 11: Dinosaurs**

*Are dinosaurs considered as part of the system of biological classification even though they are extinct? Explain your answer, giving specific examples. You may want to expand what you learned in the video to include outside material.*

Extinct organisms are part of the evolutionary history of life on Earth and thus are included in the classification scheme. Understanding the relationships among ancestors of modern species helps students understand relationships of organisms living today. Specific examples from students will vary. Remind them to name their sources of information.

An excellent *Scientific American* article called "Rulers of the Jurassic Seas" by Ryosuke Motani (December 2000, p. 52) has a very good, simple diagram on page 54 that might help students see the connection between prehistoric and extinct creatures including dinosaurs and modern organisms.

**Activity 12: What's in a Name?**

*What does a scientific name tell you about an organism? For example, if you know that a particular animal is a mammal, what characteristics would you predict it would have?*

Answers will vary. Students might include some of these comments: The animal would likely feed their young with milk, give live birth, have hair or fur, have a spinal cord and vertebrae, have a relatively well developed brain. The animal would have eukaryotic cells, like all animals and mammals.

*What taxonomic groups could you exclude?*

Answers will vary. The organism is not any species of plant, fungus, nor a protist. The organism is not any prokaryote. The organism is not an invertebrate animal, nor is it a bird, or insect.

**Activity 13: Building the Hierarchy from the Top Down**

*Here is a list of taxonomic labels given to you in alphabetical order. Put these taxonomic labels in the order they occur in a biological hierarchy from the most general to the most specific. Then add the correct word for the plural in each case.*

Correct sequence is: Kingdom, Phylum, Class, Order, Family, Genus, Species. Plurals are Kingdoms, Phyla, Classes, Orders, Families, Genus, Species.

**Activity 14: Building the Taxonomy for Humans**

*Using the list you made in sequence in Activity 13, fill in the information at each level for your own species, humans. You will need to consult outside resources.*

Kingdom: Animals (Animalia); Phylum: Chordates (Chordata); Class: Mammals (Mammalia); Order: Primates; Family: Hominids (Hominidae); Genus: Homo; Species: *Homo sapiens*.

**Activity 15: Hyrax and Elephant**

*An ongoing area of research in classification is to figure out what species are the closest living relatives of the elephants. There are two species of elephant, African and Asian. African elephants are classified as* ***Loxodonta Africana****. For many years, many scientists have concluded that the nearest living relatives to African elephants are the six species of hyrax, such as the rock hyrax or* ***Procavia capensis****.*

*An elephant is a mammal. What characteristics would you expect a hyrax to share with the elephant as another mammal?*

Among the shared characteristics would be to have hair or fur, a vertebral backbone and spinal cord, give birth to live young, nurture young with milk, be warm blooded.

*What prehistoric and now extinct species is also a close relative of an elephant?* Mastodon

**Activity 16: Scientific versus Common Names**

*A day lily, a mariposa tulip, and an Easter lily all have some connection to the word "lily." Do these names tell you how closely related these plants are? Explain.*

The two sound especially close because of the word "lily" but because these are common names, they are not reliable.

*What is the value of a scientific name?*

A scientific name, such as the two-part name system worked out by Linnaeus with genus and species, is a consistent tag that tells you if you are referring to the same species as someone else. In addition, the genus name tells you a lot about the characteristics and near relatives.

*Use outside sources (including online sources) to find more information about these plants that share a common name of "lily." If possible, look at images of each one, making a sketch for comparison. Explain why they may have similar names.*

Flower shapes are similar for day lilies and Easter lilies. All are monocots.

*Locate the scientific name of each one.*

Day lilies are a variety of species in the genus Hemerocallis. Mariposa tulip refers to a variety of species in the genus Calochortus, such as *Calochortus splendens.* Easter lily is a "true" lily called *Lilium longiflorum.*

*Describe how closely related they are.*

All three are in the Lily Family, Liliaceae, as are tulips, garlics, and onions. There are 250 genera in the Lily Family.

*What is the connection to the word "lily?"*

Scientifically the connection is that all are in the Lily Family. But not all are "true lilies" or Lilium genus.

*Do you think "lily" is an appropriate name?*

This question asks for an opinion; answers will vary. Lily is somewhat appropriate because all are in the Lily Family. But the name lily also is misleading, making it sound like these flowers are more closely related than is true. All three are in different genera. Note also that the Mariposa tulip is sometimes is called a Mariposa lily.

**Activity 17: Endospores**

*Bacteria are single-celled organisms that on first glance may seem to all be alike. How can they be classified? List some features or behaviors that could be used to distinguish different species of bacteria. (You will need to extend what you learned in the video and apply it to this new example.)*

Answers will vary. Students may suggest that bacteria are distinguished by cell shape (rod, sphere or spiral), by metabolism (photosynthetic; heterotrophic) whether or not they live in presence of oxygen (aerobic or anaerobic) and what special structures they have or produce (flagella; toxins; endospores). The living conditions in which they thrive also offer a hint to how related different species are.

*Some bacteria produce endospores for survival. These include **Bacillus anthracis** that cause the disease known as anthrax, **Clostridium tetanii** that cause tetanus, and **Clostridium botulinum** that can result in a potentially fatal kind of food poisoning known as botulism. (The botox treatment to relax wrinkles in facial muscles uses a toxin produced by **Clostridium botulinum**.)*

*Research the characteristics that are shared by these three species of bacteria. How are they grouped taxonomically? How do they compare to* ***Streptococcus****, the bacteria that causes serious sore throats?*

The *Bacillus* and *Clostridium* species are more closely related than any is to the *Streptococcus* bacteria. The latter is a spherical shape and is Gram negative. The others are Gram positive rods. The *Bacillus* and *Clostridium* species grow in soil, become endospores when conditions are too harsh, and they produce a dangerous toxin. However they are in different genera. The *Bacillus anthracis* can grow in the presence of oxygen, while *Clostridium* species are anaerobic.

**Activity 18: Domains**

*The video described new information about a group of prokaryotes known as archaebacteria (archaea). What unusual characteristics do they have?*

They are very ancient; they are found in extreme environments with great heat or salt.

*There is a trend to organize biological taxa into three high level groups called Domains. What three domains did the video mention? Indicate for each if they are eukaryotes or prokaryotes.*

Archaea, True Bacteria (Eubacteria) and Eukarya. Only the Eukarya are eukaryotes. The others are prokaryotes.

*What is the connection between the five Kingdoms and the three Domains? Draw a diagram below to show the relationships.*

The five Kingdoms is an older classification system. The three domains system recognizes that prokaryotes vary a lot, so it divides this group (once considered to be a single kingdom) into two large domains and groups all the eukaryotic kingdoms into a single domain.

**Activity 20: Extinction**

*How do classification systems build a bridge between current organisms and extinct species?*

They show how extinct species were related to existing species, and thus provide a history for life on Earth.

*What types of things could cause modern species to become extinct?*

Severe changes in climate; overuse or distribution of water by humans; loss of habitat; invasion by new predators or, more likely, new parasites.

**Activity 21: Connections: Evolution of Immunity**

*You may also find the following article interesting: "Sharks and the Origins of Vertebrate Immunity" by Gary W. Litman in* ***Scientific American*** *Vol. 275 (5) November 1996, p. 67. From the title, what connection is there to the human immune system?*

Ancient species show a connection to aspects of the human immune system.

*A quote from that article on p. 67 reads, "Although the placoderms and their ancestors are long gone, we do have the next best thing: several of their phylogenetic relations, including sharks, skates, rays and ratfishes." Why might it be an advantage to know about modern organisms that are close relatives to an extinct species of interest?*

This connection provides clues about how organisms have evolved, about the selective pressures that were at work, and about how organisms interacted.

**Activity 22: Virtual Field Trip**

*Visit the Monterey Aquarium website and investigate these three species: (1) Penguins, (2) Whales, (3) Sea Otters. All three live in salt water for all or much of their lives. They all are streamlined for moving easily through water. How closely related are they?*

Despite living in similar environments, these organisms have some large evolutionary differences. The otter is a mammal, the penguin is a bird (although also an animal and a vertebrate and the whale is a mammal although it looks like a fish). So the bird is the least closely related.

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# STUDENT ACTIVITIES

Name: _____

ACTIVITY 1

## KEY CONCEPTS

Briefly define these terms:

taxa:

classification:

evolution:

extinction:

Name: _____

ACTIVITY 2

# INVENT YOUR OWN CLASSIFICATION SCHEME

Name three ways you could arrange items in a grocery store. Use the chart below, with its columns labeled "Advantages" and "Disadvantages" or make your own chart on a separate sheet of paper. For each classification system you have invented, describe the advantages and disadvantages. Which system do you think customers would prefer?

Classification System #1:

_____

_____

| ADVANTAGES | DISADVANTAGES |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |

Classification System #2:

_____

_____

| ADVANTAGES | DISADVANTAGES |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |

Classification System #3:

_____

_____

| ADVANTAGES | DISADVANTAGES |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |

Name: _____

## Activity 3

## Biological Classification

Name two ways in addition to the current scientific system that organisms on Earth could be classified. For all three ways (the two you invented and the actual system), make a chart to list advantages and disadvantages.

Name: _____

## ACTIVITY 4

## TECHNOLOGY AND CLASSIFICATION

Name two technologies mentioned in the video that have expanded and changed our views of biological classification. Explain how each one has enhanced our understanding of biological classification.

TECHNOLOGY 1:

TECHNOLOGY 2:

Name: _____

## Activity 5

## Evolution and Classification

How is evolution tied to biological classification?

Name: _____

## ACTIVITY 6

## CELL STRUCTURE

Into what two groups can all organisms be divided based on their cell structure? Draw a diagram of each type of cell. Label key features.

Draw your diagram here:

Name: _____

## ACTIVITY 7

## THE FIVE KINGDOMS

Name the five kingdoms.

1. _____

2. _____

3. _____

4. _____

5. _____

How many of the kingdoms are prokaryotes? Explain.

Name: _____

## ACTIVITY 8

## FUNGI

To what kingdom did fungi originally belong? Why are they now considered to be a separate kingdom?

Name: _____

## ACTIVITY 9

## HIERARCHY

What is meant by the term "hierarchy?" How does this term apply to biological classification?

Name: _____

ACTIVITY 10

GENUS AND SPECIES

Which statement shows a closer relationship:

- Organism A and Organism B belong to the same genus.
- Organism A and Organism C belong to the same species.

Does Organism C belong to the same genus as Organism B or to a different one? Explain.

Name: _____

ACTIVITY 11

# DINOSAURS

Are dinosaurs considered as part of the system of biological classification even though they are extinct? Explain your answer, giving specific examples. You may want to expand what you learned in the video to include outside material.

Name: _____

ACTIVITY 12

## WHAT'S IN A NAME?

What does a scientific name tell you about an organism? For example, if you know that a particular animal is a mammal, what characteristics would you predict it would have?

What taxonomic groups could you exclude?

Name: _____

## ACTIVITY 13

## BUILDING THE HIERARCHY FROM THE TOP DOWN

Below is a list of taxonomic labels in alphabetical order. Put these taxonomic labels in the order they occur in a biological hierarchy from the most general to the most specific. Then add the correct word for the plural in each case.

Class

Family

Genus

Kingdom

Order

Phylum

Species

| **Biological Hierarchy** | **Plural** |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |

Name: _____

ACTIVITY 14

# BUILDING THE TAXONOMY FOR HUMANS

Using the biological hierarchy list you made in sequence in Activity 13, fill in the information at each level for your own species, humans. You will need to consult outside resources.

| Biological Hierarchy | Human Taxonomy |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |

Name: _____

ACTIVITY 15

HYRAX AND ELEPHANT

**PART 1:**

An ongoing area of research in classification is to figure out what species are the closest living relatives of the elephants. There are two species of elephant, African and Asian. African elephants are classified as *Loxodonta Africana.* For many years, many scientists have concluded that the nearest living relatives to African elephants are the six species of hyrax, such as the rock hyrax or *Procavia capensis.*

An elephant is a mammal. What characteristics would you expect a hyrax to share with the elephant as another mammal?

**PART 2:**

Consult outside sources to find the evidence that these species may be part of the same Superorder, known as "Paenungulates." Be certain to give references for your sources of information. Include the following in your report:

- description of African elephants
- description of Asian elephants
- description of at least one species of hyrax
- what order each belongs to
- their relationship to the taxon known as Eutheria
- what types of evidence suggest that hyrax is the nearest relative.

What prehistoric and now extinct species is also a close relative of an elephant?

Name: _____

ACTIVITY 16

# SCIENTIFIC VERSUS COMMON NAMES

**PART 1:**

A day lily, a mariposa tulip, and an Easter lily all have some connection to the word "lily." Do these names tell you how closely related these plants are? Explain.

What is the value of a scientific name?

**PART 2:**

Extension: Use outside sources (including online sources) to find more information about these plants that share a common name of "lily."

- If possible, look at images of each one, making a sketch for comparison. Explain why they may have similar names.
- Locate the scientific name of each one.
- Describe how closely related they are.

What is the connection to the word "lily?"

Do you think "lily" is an appropriate name?

Name: _____

## ACTIVITY 17

## ENDOSPORES

Bacteria are single-celled organisms that on first glance may seem to all be alike. How can they be classified? List some features or behaviors that could be used to distinguish different species of bacteria. (You will need to extend what you learned in the video and apply it to this new example.)

Some bacteria produce endospores for survival. These include *Bacillus anthracis* that cause the disease known as anthrax, *Clostridium tetanii* that cause tetanus, and *Clostridium botulinum* that can result in a potentially fatal kind of food poisoning known as botulism. (The botox treatment to relax wrinkles in facial muscles uses a toxin produced by *Clostridium botulinum.*)

Research the characteristics that are shared by these three species of bacteria. How are they grouped taxonomically? How do they compare to the bacteria that cause serious sore throat, *Streptococcus*?

Name: _____

ACTIVITY 18

DOMAINS

**PART 1:**

The video described new information about a group of prokaryotes known as archaebacteria (archaea). What unusual characteristics do they have?

_____
_____
_____
_____
_____
_____

There is a trend to organize biological taxa into three high level groups called Domains. What three domains did the video mention? Indicate for each if they are eukaryotes or prokaryotes.

1. _____

2. _____

3. _____

**PART 2:**

What is the connection between the five Kingdoms and the three Domains? Draw a diagram below to show the relationships.

Name: _____

ACTIVITY 19

# COMPARISONS OF BIOLOGICAL RELATIONSHIPS

The class will be divided into teams.

**Step 1:**

With your team, select three organisms. They can be of different domains, kingdoms or even closely related species—the choice is yours. Write the scientific names of these organisms on separate index cards. Add the common name if you know it. Add one comment to describe the organism from common knowledge or indicate why you selected it.

**Step 2:**

With your team, do some research to find out how these organisms are related. Draw a schematic chart or diagram to show their relationship. For example, you could draw circles to indicate which taxa they share: two might be in the same Kingdom but in different orders. Support your diagram with the information you have obtained about these organisms.

**Step 3:**

Now combine all the class cards. Your teacher will mix them up and re-distribute them to the teams.

**Step 4:**

Repeat step 2, adding in the new organisms you have received from other teams into your chart. The important idea is to show how certain characteristics group some species together at one level of the classification scheme and separate them at other levels.

Name: _____

ACTIVITY 20

# EXTINCTION

How do classification systems build a bridge between current organisms and extinct species?

What types of things could cause modern species to become extinct?

Name: _____

ACTIVITY 21

# CONNECTIONS: EVOLUTION OF IMMUNITY

Biological classification reflects the evolutionary history of organisms on Earth. Read the article about the evolution of the immune system written by Gregory Beck and Gail Habicht. "Immunity and the Invertebrates" in *Scientific American* Vol. 275 (5) November 1996, p. 60.

Explain how the chart on p. 62 shows the connection between classification and evolutionary history.

You may also find the following article interesting: "Sharks and the Origins of Vertebrate Immunity" by Gary W. Litman in *Scientific American* Vol. 275 (5) November 1996, p. 67. From the title, what connection is there to the human immune system?

A quote from that article on p. 67 reads, "Although the placoderms and their ancestors are long gone, we do have the next best thing: several of their phylogenetic relations, including sharks, skates, rays and ratfishes." Why might it be useful to know about modern organisms that are close relatives to an extinct species?

Name: _____

ACTIVITY 22

# VIRTUAL FIELD TRIP

Check out this website for the Monterey Aquarium in California:

http://www.mbayaq.org/

Visit the site and investigate these three species:

penguins

whales

sea otters

All three live in salt water for all or much of their lives. They all are streamlined for moving easily through water. How closely related are they?

# FACT SHEETS

Name: _____

FACT SHEET 1A

# GLOSSARY OF TERMS

**Animal:** One of the five biological Kingdoms. Animals are eukaryotes. They rely on other organisms for food.

**Archaea:** One of three domains, a high level taxon. The Archaea include some very ancient prokaryotes and modern prokaryotic single-celled organisms that live in extreme environments.

**Cell:** Unit of organization of an organism. A cell is a membrane bound compartment. Some organisms consist of a single cell (such as amoeba or bacterium). Others are multicellular, with different types of cells.

**Class:** Biological classification group or taxon that falls between a Phylum and an Order.

**Classification:** Organization of things into a uniform and consistent system.

**Darwin, Charles:** A British naturalist who in the mid-1800s presented data to support an explanation of long term heritable biological change in groups of organisms (species). This long-term change is called evolution.

**DNA:** Deoxyribonucleic acid, a genetic material.

**Domain:** High-level biological taxon. There are thought to be three domains, two of which (Archaea and Eubacteria) are prokaryotic. The domain called Eukarya includes eukaryotic organisms.

**Eukarya:** One of three domains, a high level taxon. The Eukarya include the eukaryotic kingdoms of Animals, Plants, Protists and Fungi.

**Evolution:** Long term, gradual heritable change in a species.

**Extinction:** The complete disappearance of a species.

**Family:** Biological classification group or taxon that falls between an Order and a Genus.

**Fungi:** One of the five biological Kingdoms. Fungi are eukaryotes that include mushrooms and mold. They live on biological material from living or dead organisms.

**Genus (**plural **genera):** Biological taxon that falls between Family and Species.

**Hierarchy:** Scheme of organization with nested higher levels (lower levels grouped together into higher levels).

Name: _____

FACT SHEET 1B

# GLOSSARY OF TERMS

**Kingdom:** Large-scale biological classification group or taxon. There generally are thought to be five distinct Kingdoms (Animals, Plants, Protists, Monera and Fungi).

**Linnaeus, Carolus:** Swedish scientist of the 1750s who devised a biologically meaningful classification system for organisms.

**Mass extinction:** Abrupt decrease in the number and variety of species living on Earth.

**Monera:** One of the five biological Kingdoms. The Monera are prokaryotes. They obtain nutrients in a variety of ways.

**Nucleus:** Internal, membrane bound compartment in eukaryotic cells that houses the genetic material.

**Phylum (**plural **phyla):** Biological classification group or taxon that falls between a Kingdom and a Class.

**Plants:** One of the five biological Kingdoms. The Plants are eukaryotes that can produce their own food through photosynthesis.

**Prokaryotes:** One of two large-scale divisions of organisms. The prokaryotes have simple cells that lack a nucleus. Bacteria are prokaryotes. The five-Kingdom system collects all prokaryotes in the Kingdom Monera. The three-Domain system has two prokaryotic domains, the Archaea and the Eubacteria (sometimes called True Bacteria).

**Protista:** One of the five biological Kingdoms. Protists often are single-celled and microscopic, but they are eukaryotes. Amoebas and Paramecia are Protists.

**Taxon (**plural **taxa):** Group in a classification scheme.

**Taxonomy:** The science or technique of identifying, naming and classifying organisms.

Name: _____

FACT SHEET 2

SUGGESTED READING

## Books of Interest


Dando, Marc, and Hull, Richard, primary contributors. Waller, Geoffrey, editor. *Sea Life: A Complete Guide to the Marine Environment*. Smithsonian Press: Washington D.C. 1996.

Heywood, V.H., editor. *Flowering Plants of the World.* Mayflower Books, Inc.: New York, 1978.

MacDonald, David, editor. *The Encyclopedia of Mammals.* Barnes and Noble Books/Oxford Andromeda: New York, 2001.

Norell, Mark, Gaffney, Eugene, and Dingus, Lowell. *Discovering Dinosaurs in the American Museum of Natural History.* Alfred A. Knopf: New York, 1995.

Norman, David. *The Illustrated Encyclopedia of Dinosaurs*. Barnes and Noble Books: New York, 1998.

Sibley, David Allen. *The Sibley Guide to Bird Life and Behavior*. National Audubon Society. Alfred A. Knopf: New York, 2001.

Sibley, David Allen. *The Sibley Guide to Birds*. National Audubon Society. Alfred A. Knopf: New York, 2000.


## Articles of Interest


Beck, Gregory and Habicht, Gail. "Immunity and the Invertebrates" in *Scientific American* Vol. 275 (5) November 1996, p. 60.

Brocks, J.J., G.A. Logan, R. Buick, and R.E. Summons. "Archean molecular fossils and the early rise of eukaryotes" in *Science* 285:1033-1036, 1999.

Brown, J.R. and W.F. Doolittle. "Archaea and the prokaryote-to-eukaryote transition" in *Microbiology and Molecular Biology Reviews* 61:456-502, 1997.

Litman, Gary W. "Sharks and the Origins of Vertebrate Immunity" in *Scientific American* Vol. 275 (5) November 1996, p. 67.

Motani, Ryosuke. "Rulers of the Jurassic Seas" in *Scientific American* Vol. 283 (6) December 2000, p. 52.

Name: _____

## FACT SHEET 3

## INTERNET RESOURCES

Some websites useful for studying classification are given in the following URLs. Please keep in mind that Web addresses change from time to time. You may also find it helpful to do a search with keywords such as "classification," "extinction," or enter the name of a particular kingdom.

Monterey Bay Aquarium: Go for a virtual field trip here: http://www.mbayaq.org/

Image library of plants in California: Visit the Calflora website associated with the University of California at Berkeley. You can search the site for specific plant names or genera here: http://www.calflora.org/

An excellent general reference online for biological classification is the Tree of Life project: http://tolweb.org/tree/phylogeny.html

# OTHER BIOLOGY PRODUCTS FOR GRADES 8-12 FROM HUMAN RELATIONS MEDIA

| | |
|---|---|
| ***Biodiversity: The Web of Life*** | video/print or DVD/print |
| ***Cellular Respiration: Energy for Life*** | video/print |
| ***Homeostasis: The Body in Balance*** | video/print |
| ***Introduction to Cells*** | video/print |
| ***Meiosis: The Key to Genetic Diversity*** | video/print |
| ***Mitosis: Sending the Genetic Message*** | video/print |
| ***Organic Compounds in Action*** | video/print |
| ***Patterns of Inheritance: Understanding Genetics*** | video/print |
| ***Photosynthesis: Light into Life*** | video/print |
| ***The Theory of Evolution*** | folding display |
| ***The Rising Threat of Infectious Diseases*** | video/print |
| ***Translating the Code: Protein Synthesis*** | video/print |
| ***Understanding Evolution: Change and Inheritance*** | video/print |
| ***Viruses: The Deadly Enemy*** | video/print |

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