THE CaSE BOOK

Companion to "Cells, Heredity & Classification"

Student Resources

The 21st Century Center for Research and Development in Cognition and Science Instruction

ies NATIONAL CENTER FOR EDUCATIONAL RESEARCH

THE 21ST CENTURY CENTER FOR RESEARCH & DEVELOPMENT IN COGNITION & SCIENCE INSTRUCTION

The CaSEbook Companion: Student Resource Book

Produced by
The 21st Century Center for Research and Development in Cognition and Science Education

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APPENDIX

7 Classification

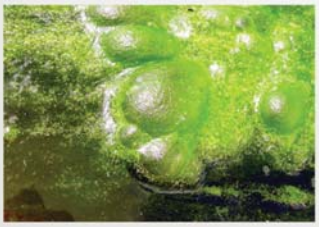
Protist

Euglena

- Made up of one cell that has a nucleus
- Found in freshwater and marine environments
- Moves by using a flagellum, a whiplike tail that propels it forward
- Makes its own food by photosynthesis and engulfs food particles found in its environment
- Reproduces asexually

Protist

Algae



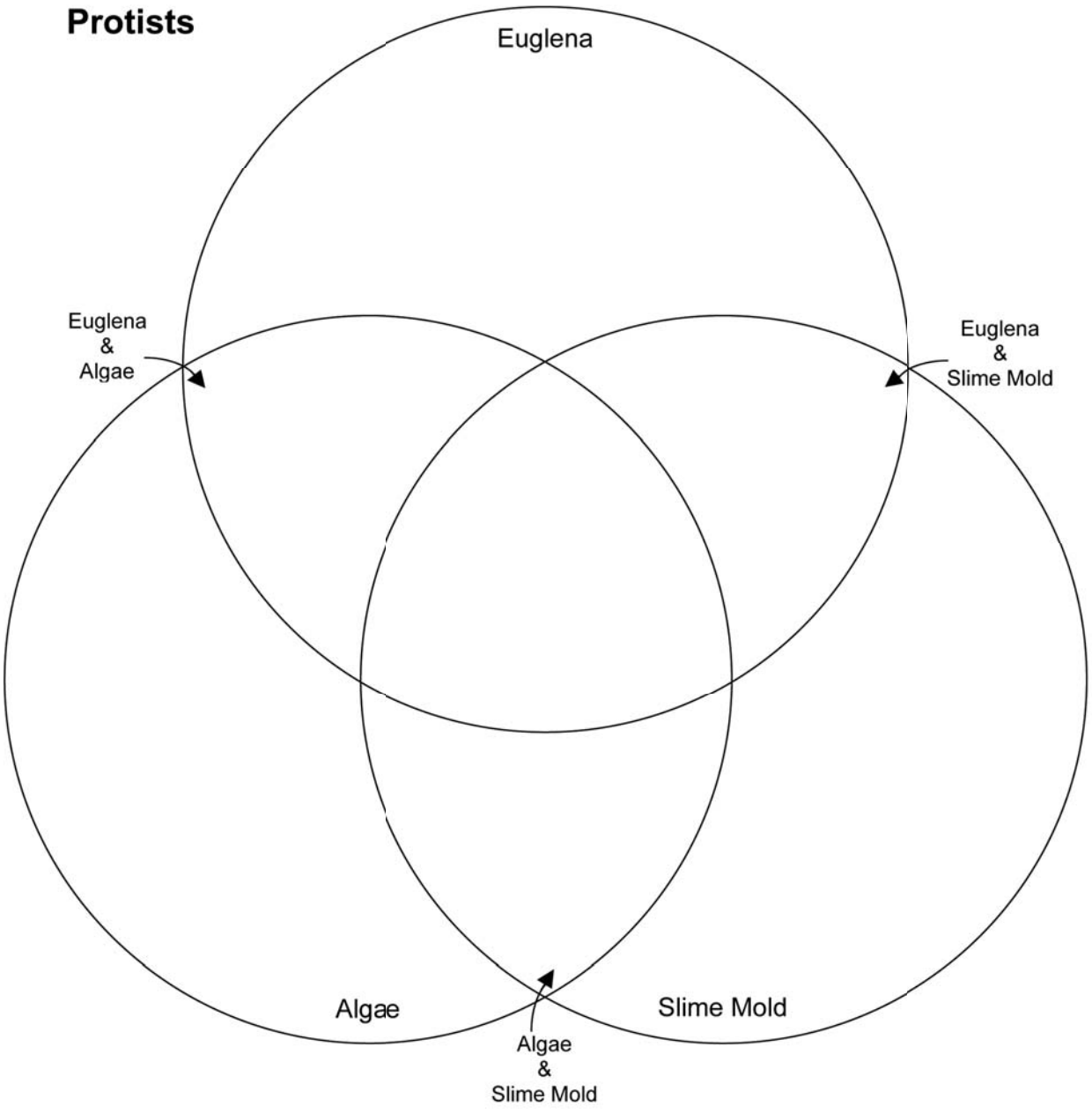
- Made up of one or more cells; each cell has a nucleus
- Found in freshwater and marine environments
- Some are mobile and have flagella
- Makes its own food by photosynthesis and absorbs nutrients from its environment
- Reproduces asexually and sexually

Protist

Slime Molds

- Made up of one or more cells; each cell has a nucleus
- Found on land, usually on plants
- Immobile
- Engulfs food particles found in its environment
- Reproduces asexually and sexually

Holt: Cells, Heredity, and Classification
Chapter 7
Part 1 -- Compare Kingdoms



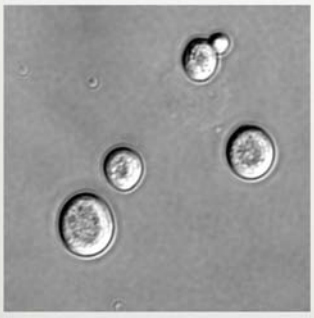
Fungus

Destroying angel

- Made up of many cells; each cell has at least one nucleus
- Found on land, usually near trees or shrubs
- Immobile
- Absorbs nutrients from its environment
- Reproduces asexually and sexually
- Extremely poisonous

Fungus

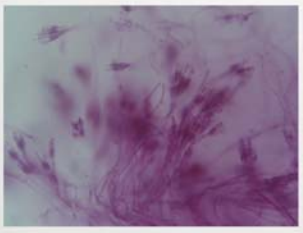
Yeast



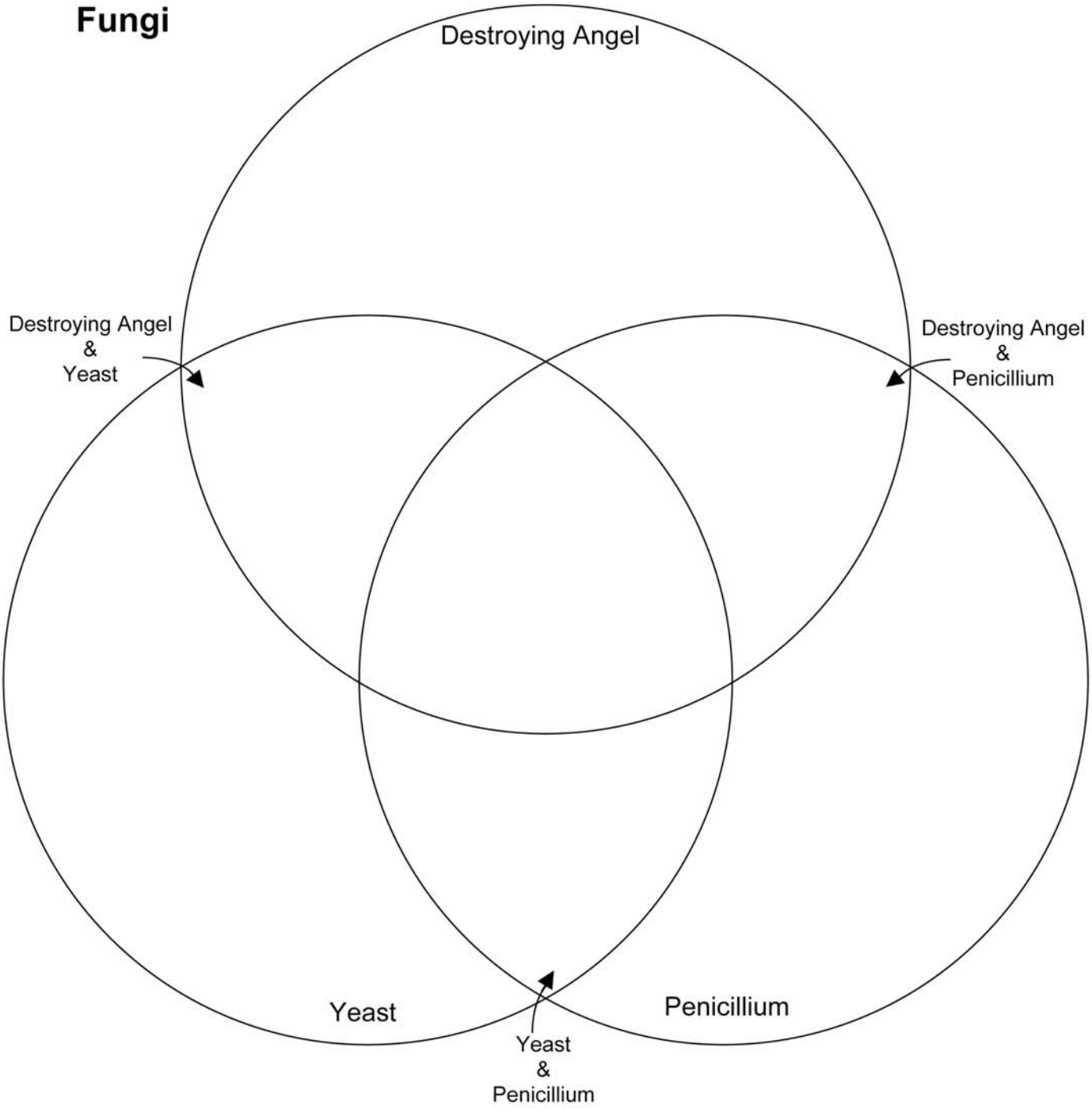
- Made up of one cell that has a nucleus
- Found on land and in freshwater and marine environments
- Immobile
- Absorbs nutrients from its environment
- Reproduces asexually or sexually
- Used in baking bread and brewing beer

Fungus

Penicillium



- Made up of many cells; each cell has a nucleus
- Found on land; often on foods and in indoor environments
- Immobile
- Absorbs nutrients from its environment
- Reproduces asexually
- Source of antibiotic penicillin


Fungi
Destroying Angel
Destroying Angel & Yeast
Destroying Angel & Penicillium
Yeast
Penicillium
Yeast & Penicillium

Animal

Tyrannosaurus rex

- Made up of many different kinds of cells; each cell had a nucleus.
- Found on land, 65 to 68 million years ago
- Moved by walking upright
- Fed on animals found in its environment
- Reproduced sexually

Animal

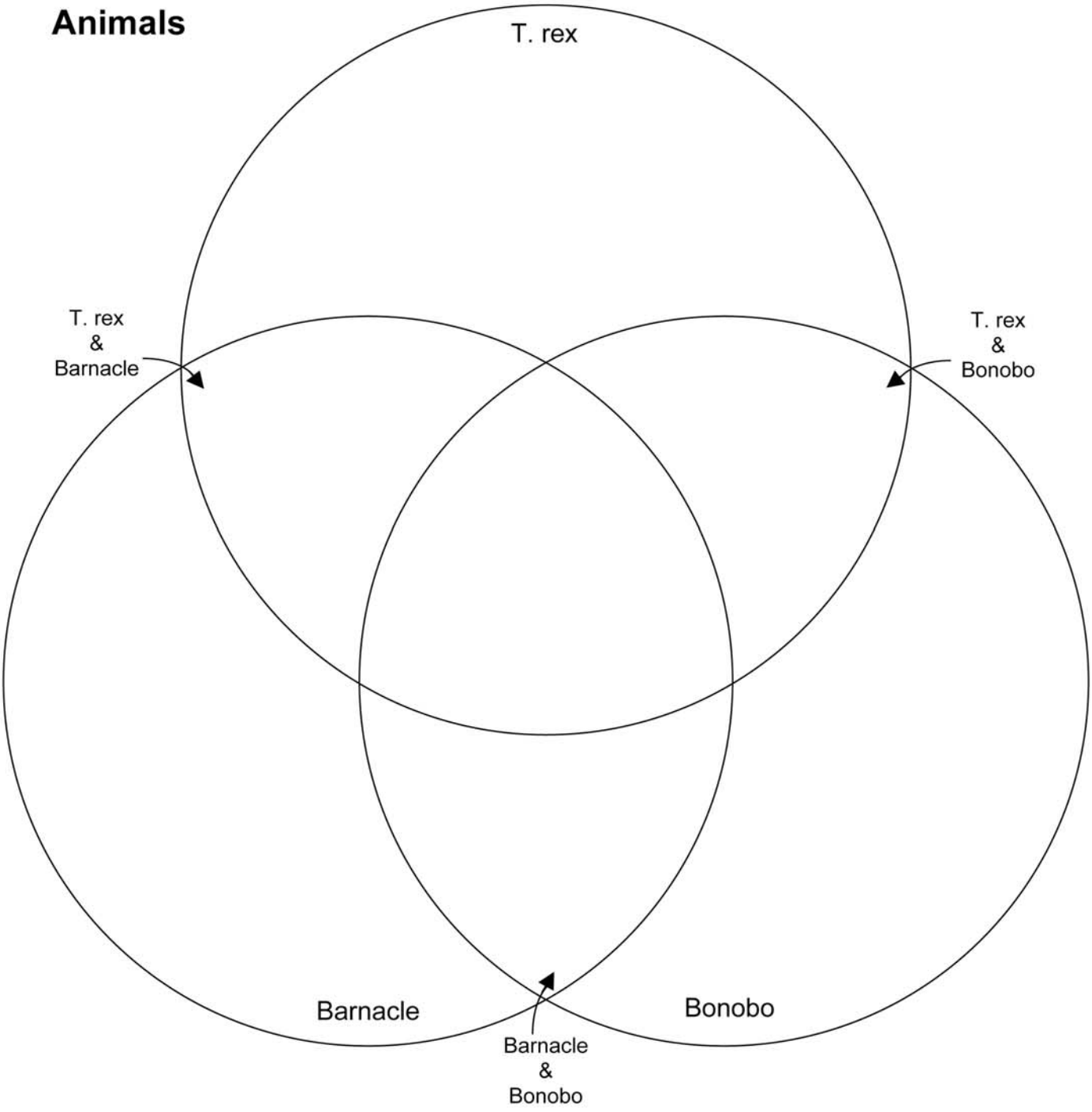
Barnacle

- Made up of many different kinds of cells; each cell has a nucleus
- Found in marine environments; attached to hard substances
- Moves by swimming when young; adults are immobile
- Feeds on plankton found in its environment
- Reproduces sexually

Animal

Bonobo

- Made up of many different kinds of cells; each cell has a nucleus.
- Found on land, in rainforests in Africa
- Moves by walking upright and on all fours
- Eats fruits, leaves, and small animals found in its environment
- Reproduces sexually


Animals
T. rex
T. rex
&
Barnacle
T. rex
&
Bonobo
Barnacle
Bonobo
Barnacle
&
Bonobo

Plant

Cactus

- Made up of many different kinds of cells; each cell has a nucleus and a cell wall
- Found on land, in desert environments
- Immobile
- Makes its own food by photosynthesis
- Reproduces sexually

Plant

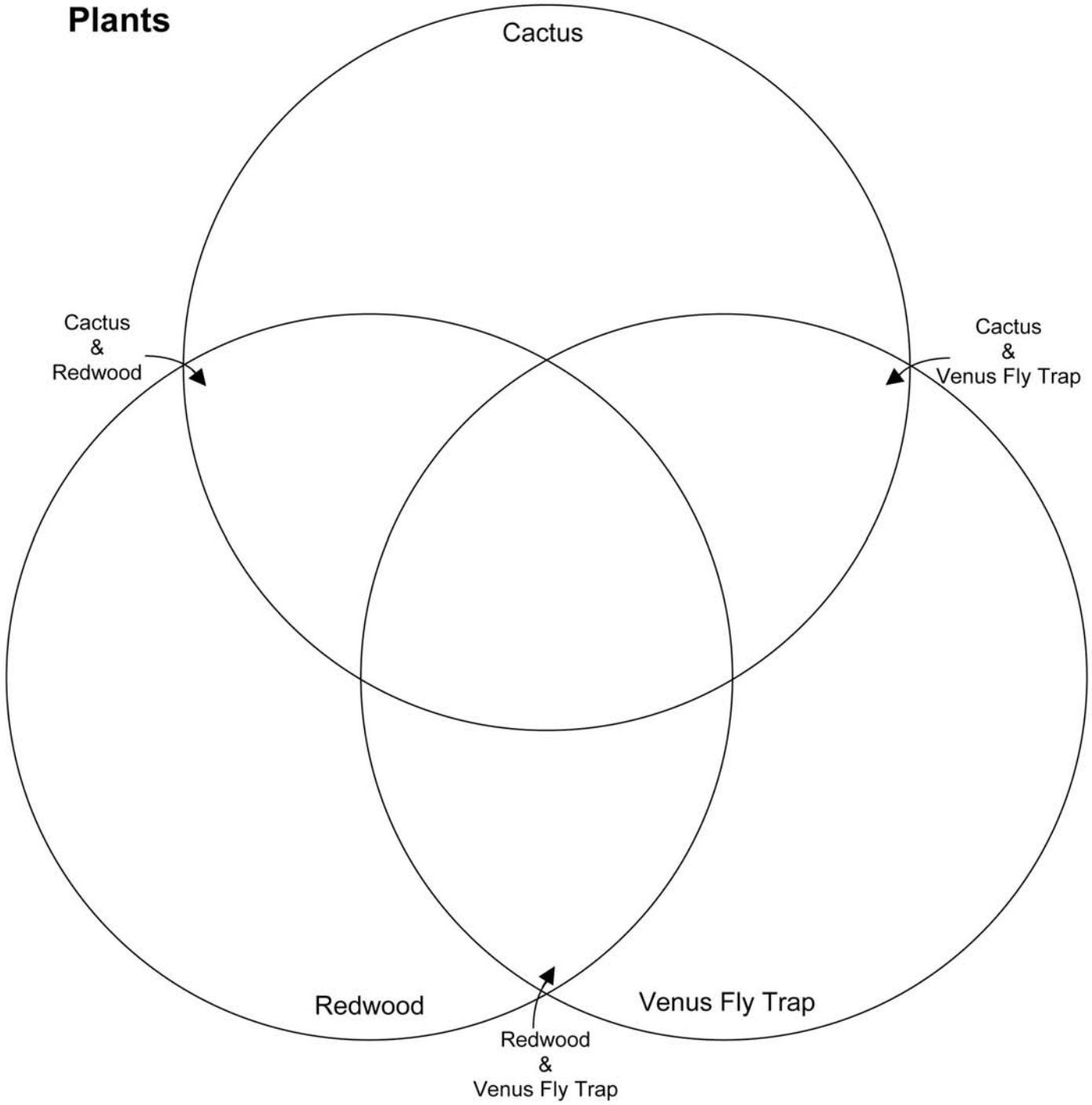
Redwood

- Made up of many different kinds of cells; each cell has a nucelus and a cell wall.
- Found on land, in forests and parks in California and Oregon
- Immobile
- Makes its own food by photosynthesis
- Reproduces sexually

Plant

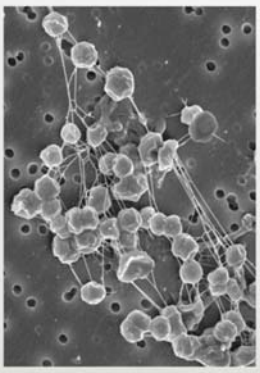
Venus fly trap

- Made up of many different kinds of cells; each cell has a nucelus and a cell wall
- Found on land, in wet sandy soils
- Immobile
- Makes its own food by photosynthesis and feeds on insects found in its environment
- Reproduces sexually


Plants
Cactus
Cactus
&
Redwood
Cactus
&
Venus Fly Trap
Redwood
Venus Fly Trap
Redwood
&
Venus Fly Trap

Archaea

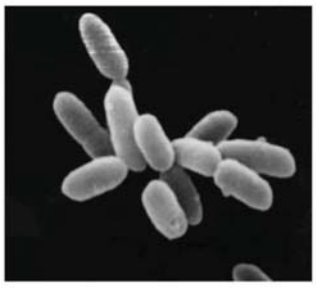
Methanogen



- Made up of one cell that has a cell wall but not a nucleus
- Found in many different environments; common in wetlands and in human and animal intestines
- Moves by using a flagellum
- Metabolizes carbon dioxide and hydrogen found in its environment
- Reproduces asexually

Archaea

Halobacteria



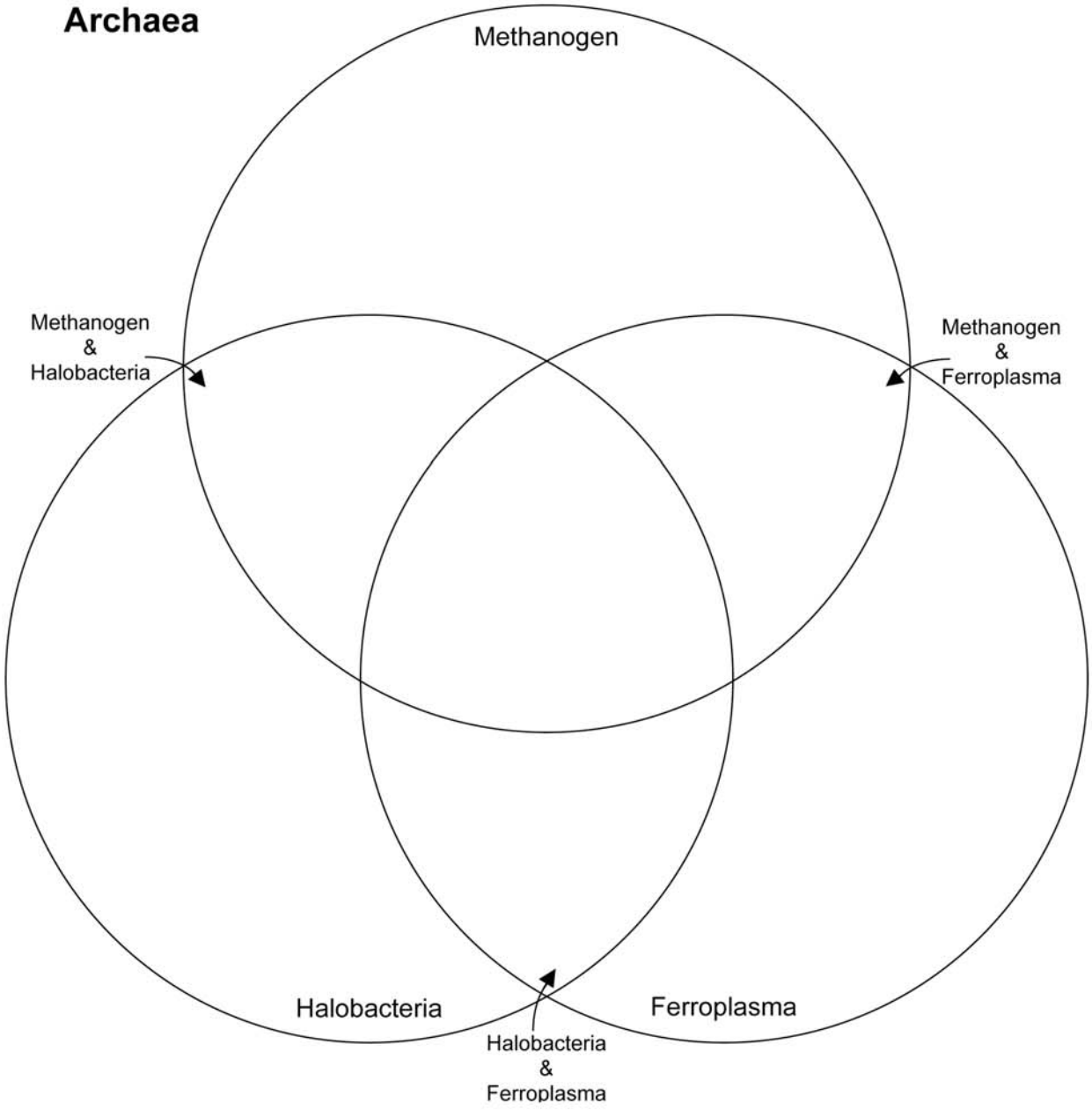
- Made up of one cell that has a cell wall but not a nucleus
- Found in extremely salty environments
- Moves by using a flagellum
- Metabolizes amino acids found in its environment and makes its own food by photosynthesis
- Reproduces asexually

Archaea

Ferroplasma

- Made up of one cell that has a cell wall but not a nucleus
- Found in extremely acidic environments; common in mine drainage sites
- Moves by using a flagellum
- Metabolizes iron found in its environment
- Reproduces asexually

Holt: Cells, Heredity, and Classification
Chapter 7
Part 2 -- Compare Domains



Bacteria

Streptococcus

- Made up of one cell that has a cell wall but not a nucleus
- Found in acidic environments; common in human and animal mouths and throats
- Moves by using a flagellum
- Metabolizes sugars found in its environment
- Reproduces asexually

Bacteria

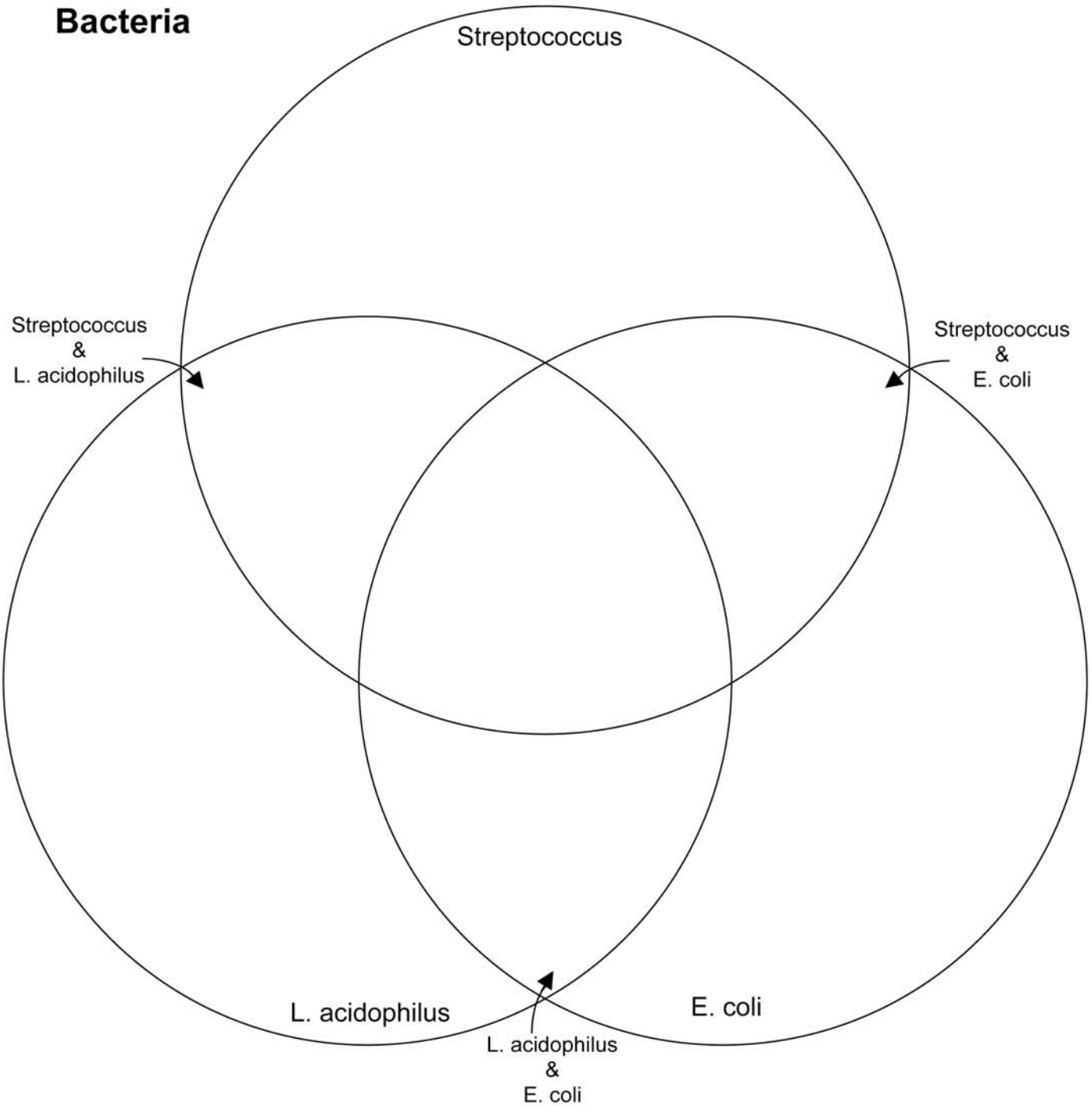
L. acidophilus

- Made up of one cell that has a cell wall but not a nucleus
- Found in warm, acidic environments, common in human and animal intestines
- Moves by using a flagellum
- Metabolizes sugars found in its environment
- Reproduces asexually

Bacteria

E. coli

- Made up of one cell that has a cell wall but not a nucleus
- Found in many different environments; common in human and animal intestines
- Moves by using a flagellum
- Metabolizes sugars found in its environment
- Reproduces asexually


Bacteria
Streptococcus
Streptococcus
&
L. acidophilus
Streptococcus
&
E. coli
L. acidophilus
E. coli
L. acidophilus
&
E. coli

Eukarya

Slime molds

- Made up of one or more cells; each cell has a nucleus
- Found on land, usually on plants
- Immobile
- Engulfs food particles found in its environment
- Reproduces asexually and sexually

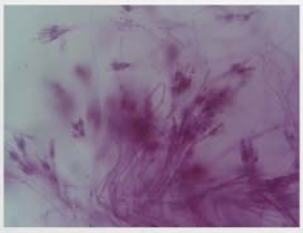
Eukarya

Bonobo

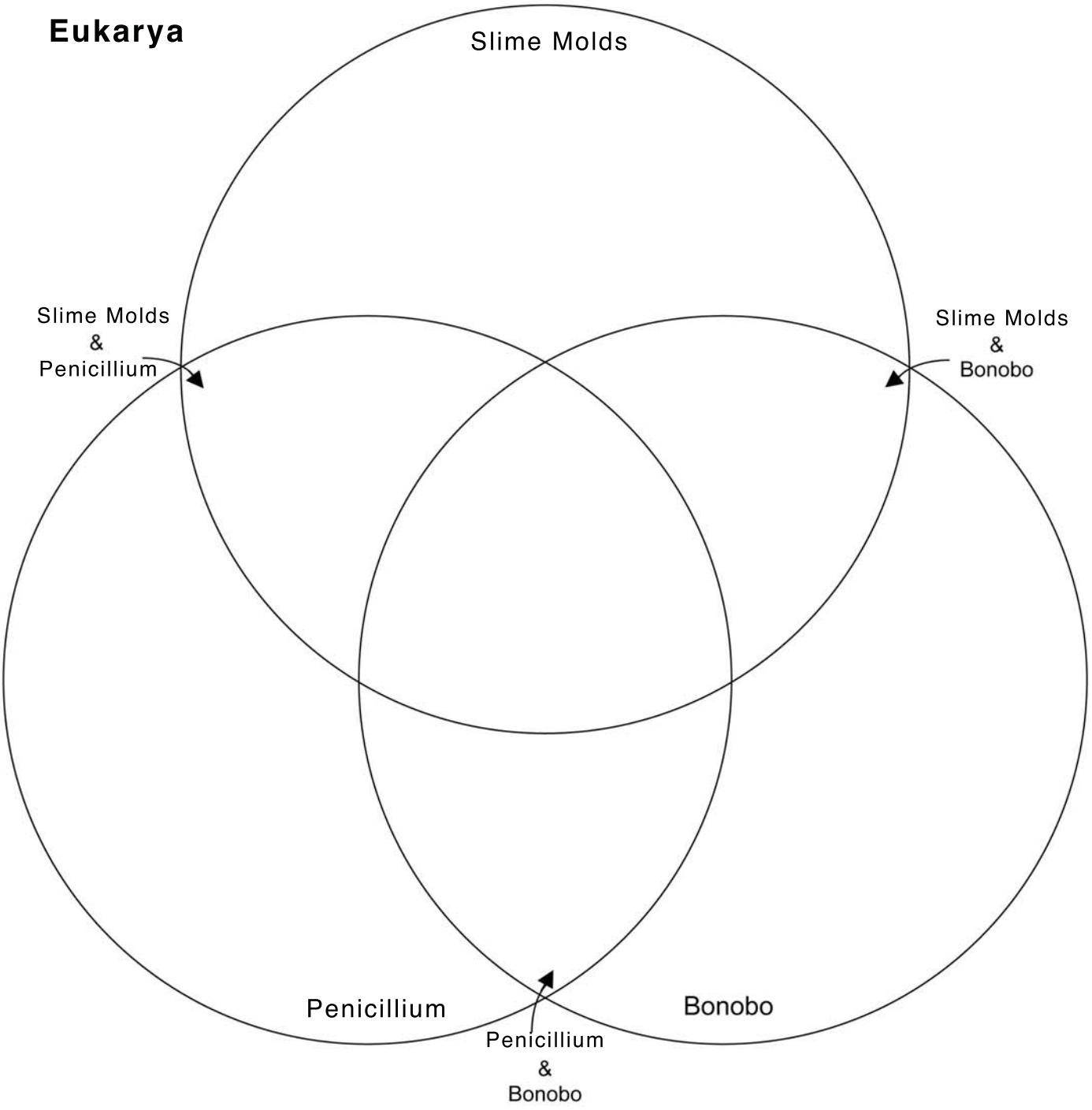
- Made up of many different kinds of cells; each cell has a nucleus.
- Found on land, in rainforests in Africa
- Moves by walking upright and on all fours
- Eats fruits, leaves, and small animals found in its environment
- Reproduces sexually

Eukarya

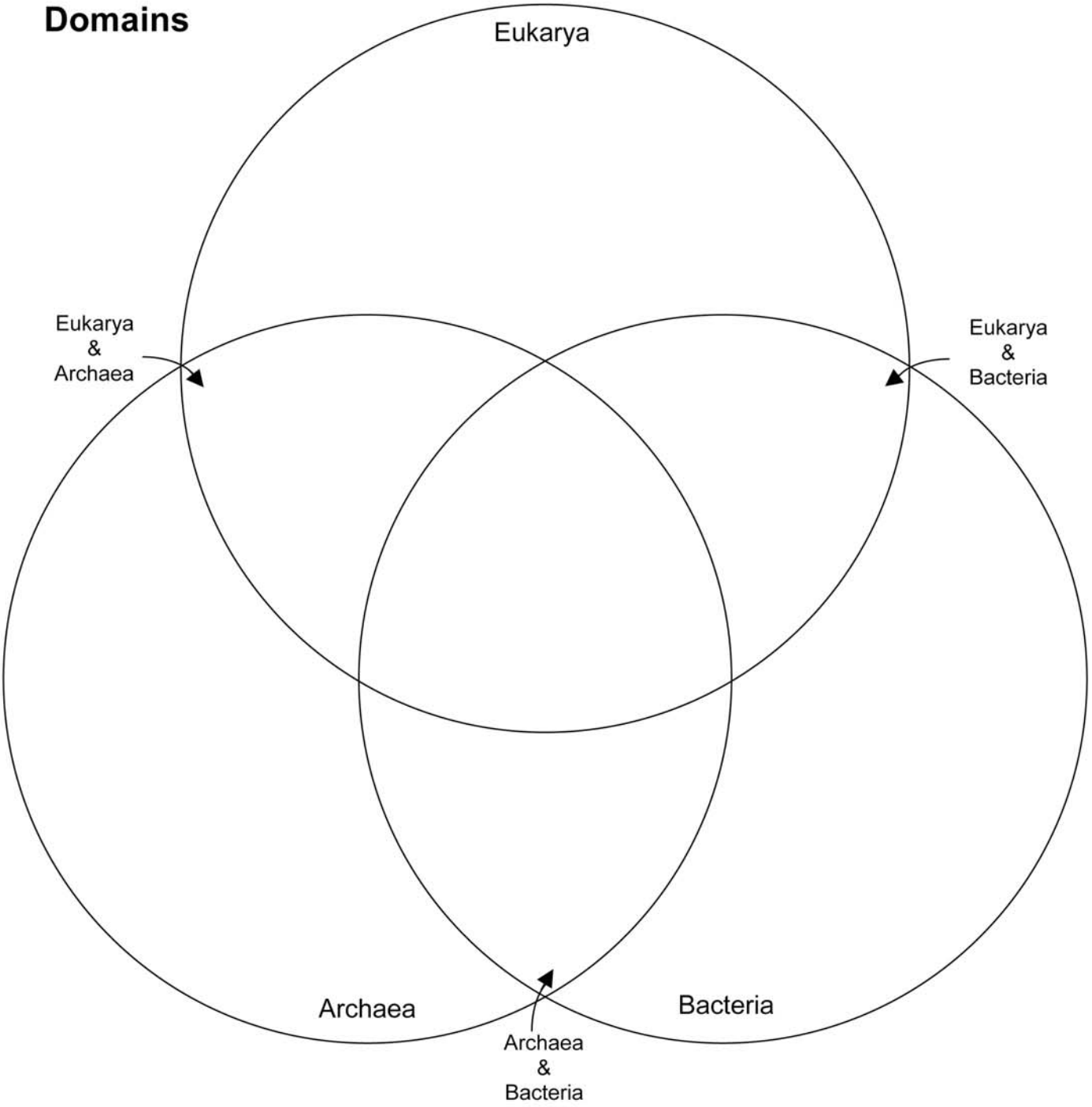
Penicillium



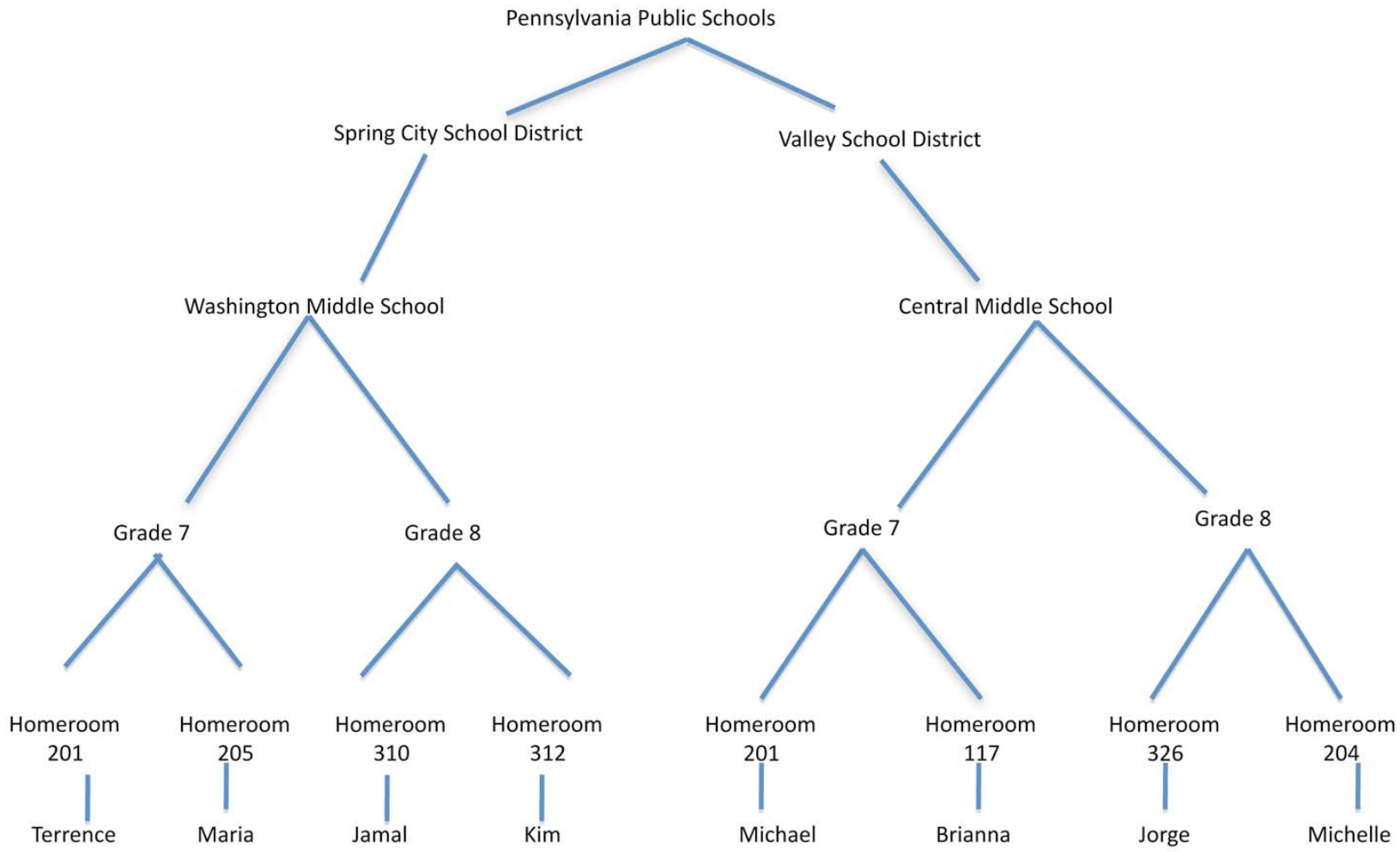
- Made up of many cells; each cell has a nucleus
- Found on land, often on foods and in indoor environments
- Immobile
- Absorbs nutrients from its environment
- Reproduces asexually
- Source of antibiotic penicillin


Eukarya
Slime Molds
Slime Molds & Penicillium
Slime Molds & Bonobo
Penicillium
Bonobo
Penicillium & Bonobo

Domains


Eukarya
Eukarya
&
Archaea
Eukarya
&
Bacteria
Archaea
Bacteria
Archaea
&
Bacteria

Working with Class-inclusion Classification Systems



	What do you know for sure?	What might be true?
What can you figure out about Brianna?		
If you know that another student (who belongs in this chart) attends Washington Middle School, what else can you figure out about him or her?		
If you know that a student is in Grade 7 on this chart, what else can you figure out about him or her?		
A new 8th grader comes to Central Middle School. What other students might be in their homeroom?		

Could you move Michael to the same spot as Terrence on the chart, since they are both in Homeroom 201? Why or why not?

Living Things

Domains

Kingdoms

Categories to be placed in the chart: **Protista, Bacteria, Fungi, Archaea, Animalia, Eukarya, Plantae**

Review Questions

1. If you know something is a protist, what else can you say about it?

2. If something is a member of the domain Eukarya, could it be a plant?

3. If something is an animal, could it be a member of the domain Archaea?

4. If something is a member of the domain Bacteria, could it be a protist?

5. If something is a living thing, does it have to be an animal?

5 The Evolution of Living Things

Selective Breeding – Case 1

All dogs (Canis familiaris) come from a single ancestor, the grey wolf (Canis lupus). Over the past 15,000 years humans have selectively bred dogs to have particular characteristics and traits (height, size, weight, color, type of ear, herding or hunting behaviors, etc.). We now have over 200 breeds of dogs. Dog breeders select dogs to mate based on some set of desired characteristics or traits. For example, huskies were bred for certain traits including: medium size, thick fur coat, and high energy because they were needed for pulling sleds over long distances in extremely cold climates. The huskies with the desired characteristics were *bred* and passed their genes on to their offspring. The pups were born with combinations of the parents' genes. The huskies that showed the desired traits were then selected for the next round of breeding. Pups that were born with undesired traits such as small size or low energy were not selected for breeding. With each new generation, the dog breeders continued to select for the desired traits - medium sizes, thick fur coat, and high energy.

Why are there so many different breeds of dogs today?

Case comparison handout 1

1. What changed in terms of the dogs reproducing**?**

2. What changed in the characteristics of the dogs over time**?**

3. What features did breeders select for?

4. Which organisms get to reproduce?

Selective Breeding – Case 2

Several kinds of vegetables (broccoli, cauliflower, cabbage, Brussels sprouts, kale, kohlrabi) come from a single ancestor, one species of plant called wild mustard. Over the past several thousand years humans have selectively bred the wild mustard plant for different characteristics or traits to create other types of vegetables. Farmers select plants to reproduce based on some desired set of characteristics. For example, broccoli was bred for large flower clusters and a short stalk. The plants showed the desired characteristics were *bred* and passed their genes on to their offspring. The offspring (seedlings) inherited combinations of the parents' genes. The plants that showed the desired traits (large flower clusters and a short stalk) were then selected for the next round of breeding. Plants with undesired traits (small flower clusters or long stalks) were not selected for reproduction. With each new generation the farmers continue to select for increases in the desired characteristics - larger flower clusters and shorter stalks.

Why do we have broccoli plants today?

Case comparison handout 2

1. What changed in terms of the broccoli reproducing?

2. What changed in the characteristics of the broccoli over time?

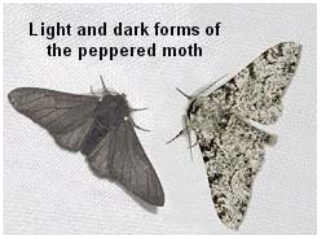
3. What features did breeders select for?

4. Which organisms get to reproduce?

Across the cases:

Question	Case 1: Dogs	Case 2: Broccoli
How did the patterns of reproduction within each species change?		
What changed in the characteristics of the dogs and the broccoli plants over time?		
Why did those changes occur?		
What (who) determines which organisms reproduce?		

Natural Selection – Case 1



The peppered moth evolution is an example of natural selection. The peppered moth varies in wing color from light to dark. In the early 1800's the peppered moth population had mostly light colored wings. The wing color served as a type of camouflage that protected them from bird predators because they were similar in color to the light-colored birch trees that they rested on and therefore were hard to see. In contrast, moths with darker wings were easier to see on the light colored trees (see above) and therefore less likely to survive The birds could see and eat them. The moths with light colored wings were better able to survive and were thus more likely to reproduce, passing their genes to their offspring who were then also likely to have light colored wings. The moths with darkly colored wings were not as likely to survive and thus were less likely to pass their genes on to the next generation. After several generations, the light winged moths outnumbered the dark winged moths.

However, things changed during the Industrial Revolution (late 1800's) because the pollution from the factories changed the environment. Many of the light colored trees became dark with soot (black smoke) from the pollution. Therefore, the dark colored moths now became better camouflaged than the light colored moths. The dark colored moths were now better able to survive, reproduce and pass on their genes to their offspring. The light colored moths now were easier to see on the darkened trees and be eaten by the birds. After several generations, the dark winged moths outnumbered the light winged moths.

What caused the number of light colored moths as compared to the number of dark colored moths to change over several generations?

_____

_____

_____

In the 1900's, pollution laws were made and factories had to install cleaner smokestacks. This decreased the amount of soot being put into the air. What do you think happened?

_____

_____

_____

Case comparison handout 1

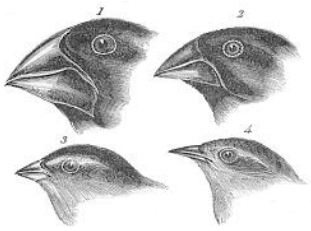
1. What moth characteristics (traits) varied?

2. What characteristics (traits) were selected for?

3. How does the selection process work?

4. What (who) determines which organisms reproduce?

Natural Selection – Case 2



Finches from Galapagos Archipelago

The finch evolution on the Galapagos Islands is another example of natural selection. When Darwin visited the islands in the mid 1800's he found a wide variety of different types of finches. He hypothesized that the different kinds of finches were a result of natural selection and evolution. Although many of the finches shared similar coloring and body size they differed in their beak type (see the picture above).

Darwin hypothesized that some finches from the mainland of South America flew over to the islands, and those that were able to survive in the new environment reproduced and passed their genes to the next generation. Initially the birds varied in the size and shape of their beaks. The birds that were most able to survive were the ones who could live off the food found on the island. For example, islands that had nut trees supported finch populations that had blunt beaks that were strong enough to crack the nuts. Therefore, those finches with the strong, blunt beaks were better able to survive and reproduced, passing their genes to their offspring. Finches in the next generation who had those traits continued to survive and were more likely to reproduce. Finches in that environment who did not have the strong, blunt beaks did not survive as well as the others and therefore were less likely to reproduce and pass their genes to offspring in the next generation.

Other islands had different environments in which finches with different beak types were better able to survive. For example, one island did not have nut trees but instead had lots of berries, and finches with beaks that were better fit for picking berries survived and reproduced, passing their genes to the next generation. On each island the finches that were able to survive and reproduce were the ones that passed their genes on to the next generation. Eventually after many generations of natural selection most individuals in the population had a beak type that helped them survive in that particular environment.

How did the finches on different Galapagos Islands come to have different types of beaks?

_____

_____

_____

_____

Case comparison handout 2

1. What finch characteristics (traits) varied?

2. What characteristics (traits) were selected for?

3. How does the selection process work?

4. What (who) determines which organisms reproduce?

Across the cases:

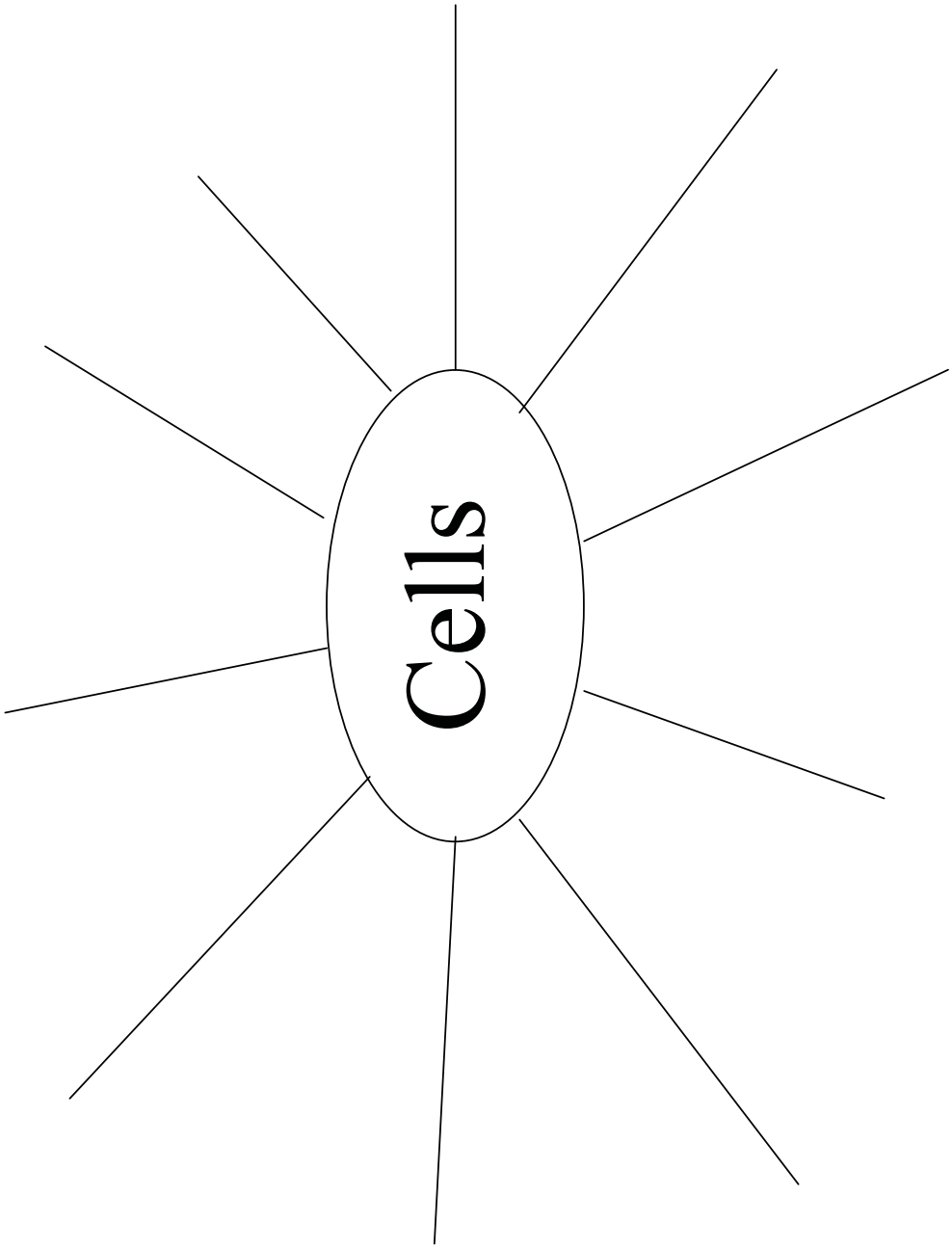
Question	Moths	Finches
What characteristics affected the survival of the organisms?		
Why were those characteristics important? (selected for)		
How does the selection process work?		
What (who) determines which organisms reproduce?		

Comparing Selective Breeding to Natural Selection

What is similar?

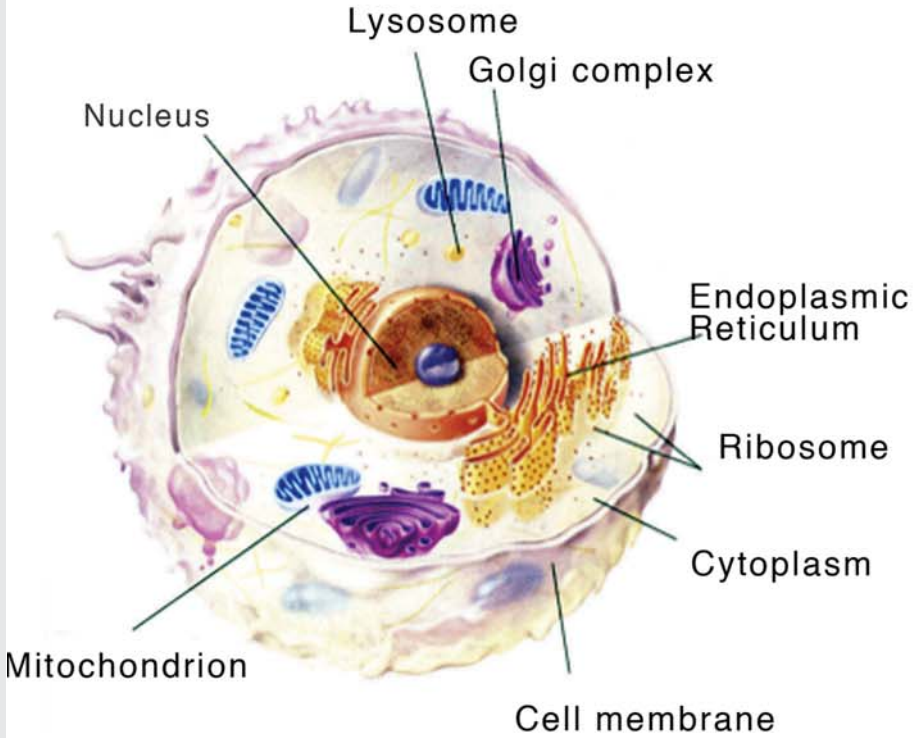
What is different?

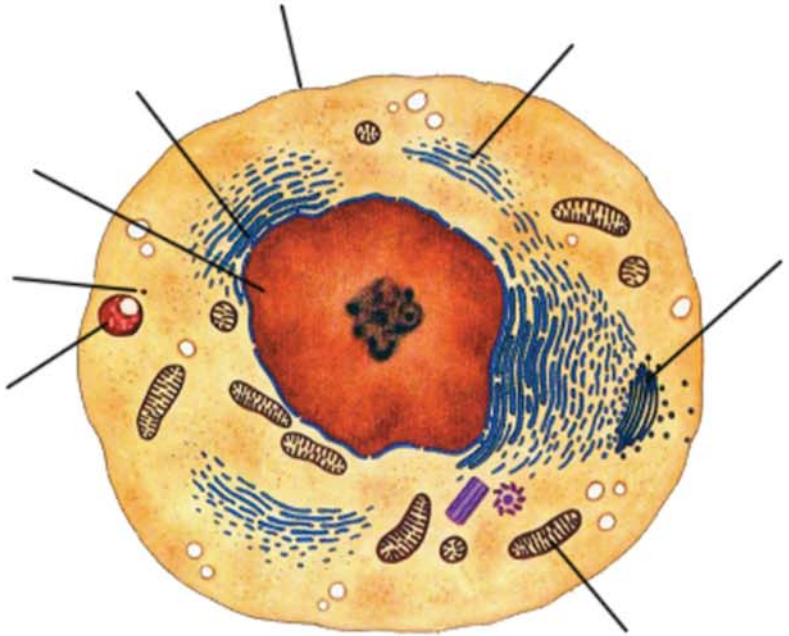
1 Cells: The Basic Units of Life


Cells

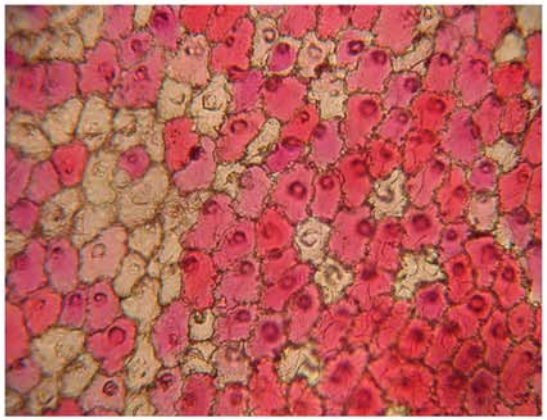
Animal Cells

The picture to the left is of a human neuron (brain cell). Below it, on the bottom left, is a drawing of an animal cell with its organelles labeled. Can you find and label the corresponding organelles on the animal cell on the right side below?

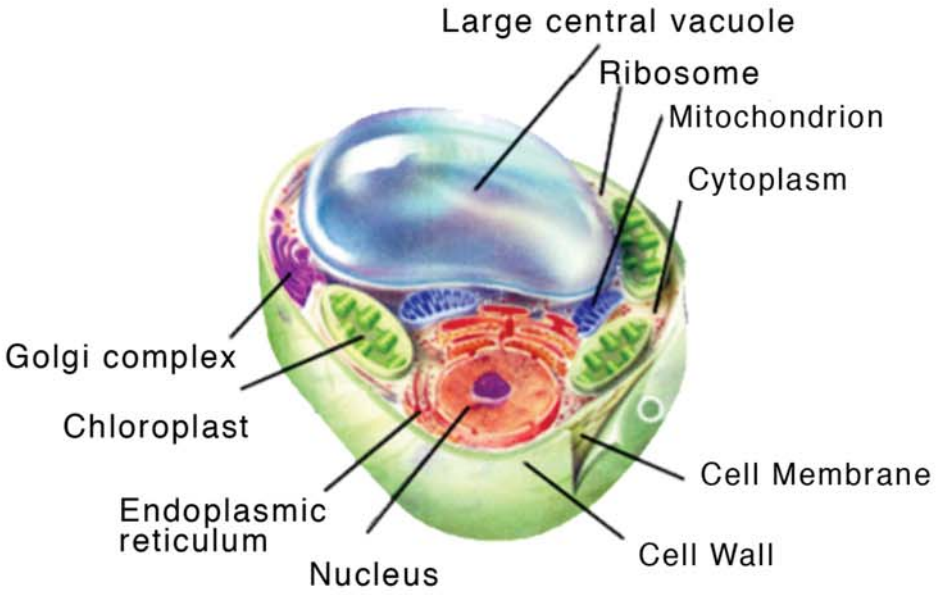


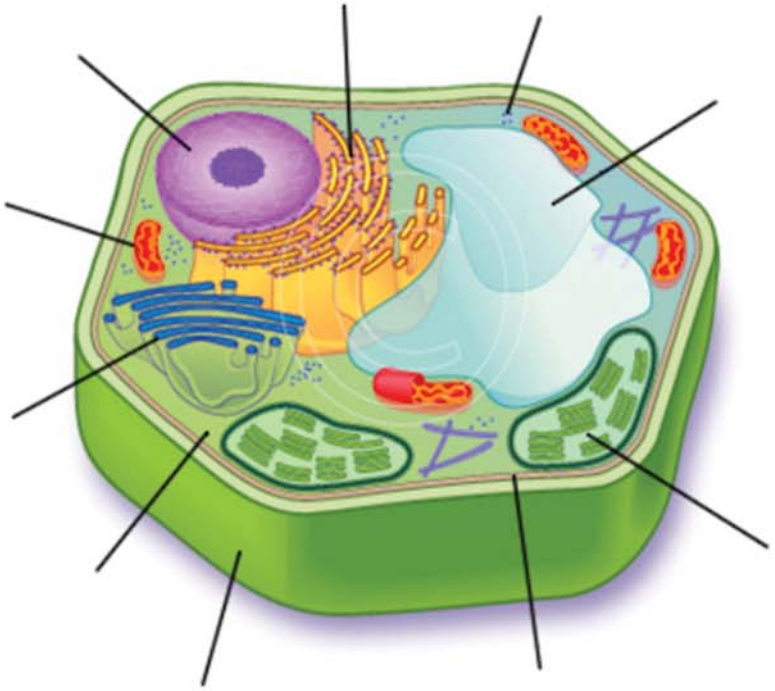


Plant Cells



To the left are pictures of cells from rose petals, taken from under a microscope. Real cells are much smaller, and cannot be seen with the naked eye. Underneath the rose cells is a drawing of a plant cell with its organelles labeled. Can you find and label the corresponding organelles on the plant cell on the right below?





With your partner, please fill in the appropriate organelles in each column, and draw an asterisk (*) next to the ones that are same across both plant and animal cells.

Plant cell	Animal Cell

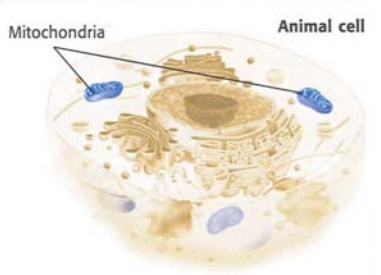
2 The Cell in Action

Cellular Respiration – Case 1

The following data comes from a biology research laboratory investigating cells from the Siberian Tiger. Your job is to figure out which inputs into the cell are required for an output from the cell.

Sample	Input into the cell	Output from the cell
1	Light + Glucose + Oxygen	Carbon Dioxide + Water + Energy
2	Glucose	Nothing New
3	Light + Glucose	Nothing New
4	Glucose + Oxygen	Carbon Dioxide + Water + Energy

These cell activities took place in the Mitochondrion.



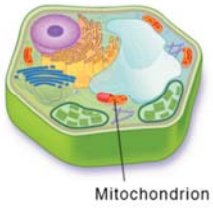
What variables are necessary for output? Why?

Cellular Respiration – Case 2

The following data comes from a biology research laboratory investigating cells from rye grass. Your job is to figure out which inputs into the cell are required for an output from the cell.

Sample	Input into the cell	Output from the cell
1	Glucose + Oxygen	Carbon Dioxide + Water + Energy
2	Glucose + Water	Nothing New
3	Glucose	Nothing New
4	Light + Glucose + Oxygen	Carbon Dioxide + Water + Energy

These cell activities took place in the Mitochondrion.



What variables are necessary for output? Why?

Across the cases

What does cellular respiration look like?

What is the input?

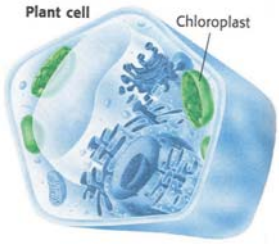
What is the output?

Photosynthesis – Case 1

The following data comes from a biology research laboratory investigating cells from the Ginkgo Tree. Your job is to figure out which inputs into the cell are required for an output from the cell.

Sample	Input into the cell	Output from the cell
1	Water	Nothing New
2	Glucose	Nothing New
3	Carbon Dioxide + Water	Nothing New
4	Water + Energy (Sunlight) + Carbon Dioxide	Oxygen + Glucose

These cell activities took place in the Chloroplast.



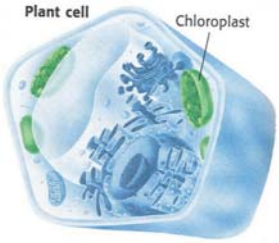
What variables are necessary for output? Why?

Photosynthesis – Case 2

The following data comes from a biology research laboratory investigating cells from the Sage Flower. Your job is to figure out which inputs into the cell are required for an output from the cell.

Sample	Input into the cell	Output from the cell
1	Carbon Dioxide	Nothing New
2	Water + Energy (Sunlight)	Nothing New
3	Dirt + Water + Energy (Sunlight) + Carbon Dioxide	Oxygen + Glucose
4	Water + Energy (Sunlight) + Carbon Dioxide	Oxygen + Glucose

These cell activities took place in the Chloroplast.



What variables are necessary for output? Why?

Across the cases

What does photosynthesis look like?

What is the input?

What is the output?

Respiration vs. Photosynthesis

Process	Input	Output
Cellular Respiration		
Photosynthesis		

Where does cellular respiration occur?

Where does photosynthesis occur?

What is the same between cellular respiration and photosynthesis?

What is different between cellular respiration and photosynthesis?

Review Questions

Compare	Respiration	Photosynthesis
Which living things use this process?		
Where does the process take place in the cell?		
Is glucose (food) made or broken down?		
Is Carbon Dioxide a product or raw material?		
Is Oxygen a product or a raw material?		
Is light needed for the process to occur?		
What does the process produce?		

3 Heredity

Name _____ Team # _____

If each set of parent Labrador retrievers has 16 puppies, how many will have black coats? How many will have yellow coats? Fill in your predictions, and then the actual numbers.

		Predicted # (out of 16)		Actual # (out of 16)	
Family	**Parents**	Black	Yellow	Black	Yellow
A	Black-Yellow				
B	Black-Black				
C	Black-Black				
D	Yellow-Yellow				
E	Yellow-Black				

What do you think "dominant" means? _____

_____

What do you think "recessive" means? _____

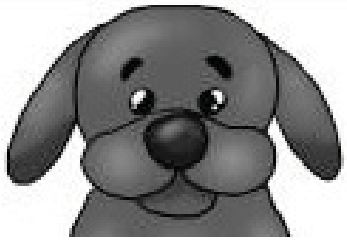
_____

Which color coat is dominant? _____

How do you know?_____

Which color coat is recessive? _____

How do you know? _____



If each set of pea blossom flowers are crossed to product 16 offspring flowers, how many will be purple? How many will be white? Fill in your predictions, and then the actual numbers.

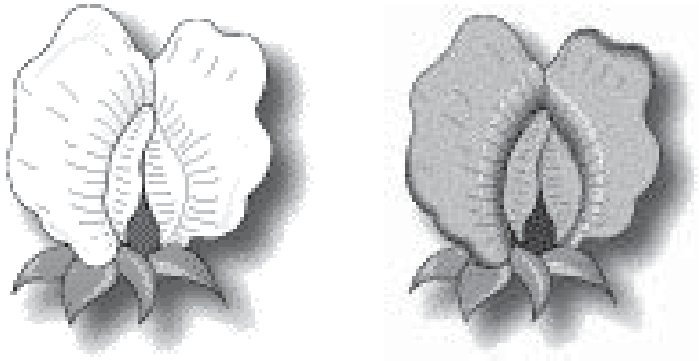
		Predicted # (out of 16)		Actual # (out of 16)	
Cross	**Parent Generation**	Purple	White	Purple	White
A	Purple-White				
B	Purple-Purple				
C	Purple-Purple				
D	White-White				
E	White-Purple				

Which flower color is dominant? _____

How do you know? _____

Which flower color is recessive?

How do you know? _____



Student Worksheet

Thinking about Genotypes & Phenotypes

Parents' Phenotypes	Puppy's Genotype	Puppy's Phenotype	Which alleles could this puppy pass on to its off spring?
	Black from Father/Black from Mother (homozygous)	 Max	
	Yellow from Father/Yellow from Mother (homozygous)	 Cody	
	Black from Father/Yellow from Mother (heterozygous)	 Nikki	
	Yellow from Father/Black from Mother (heterozygous)	 Daisy	
	Yellow from Father/Yellow from Mother (homozygous)	 Lady	

Part 1: Fill in the right-hand column in the chart above.

Part 2: Use the chart above to think about the following questions.

1. Give an example of how two puppies could have the same phenotype but different genotypes.

2. Can a puppy with a yellow phenotype have a black allele as part of its genotype? Why or why not?

3. Can a puppy with a black phenotype have a yellow allele as part of its genotype? Why or why not?

4. Use what you know about genotypes and phenotypes to explain how two parents who both have black coats could have a puppy with a yellow coat.

5. How come two black parents could have a puppy with a yellow phenotype but two yellow parents could not have a puppy with a black phenotype?

AP Appendix

Appendix for users of 2004-2005 version of Holt "Cells, Classification and Heredity"

Changes in Biological Classification Systems

Some people think that science is collection of facts that never change. The truth is that science is a body of knowledge that is constantly changing as scientists continue to question and to learn more about our world.

In biology the classification system has changed a couple of times. Classification systems do not exist in nature, they are systems created by people to describe and show the relationships between the great diversity of living things in our world. Over the years, as we gained new knowledge, we revised the classification system to reflect our current understandings. However, the place of some organisms in the current system is still unclear and scientists are currently debating to which group they belong.

Before 1969 all organisms were grouped into two or three kingdoms, plants, animals and sometimes fungi. With advances in cell and evolutionary biology, scientists discovered that some organisms did not fit into those two or three kingdoms so a five kingdom system was created. Now that scientists can study the organelles and the genetic material of cells even more differences have been discovered. Within the original kingdom of Bacteria, it was found that there are two very different groups which were called eubacteria and archaebacteria. Because the organisms in the domain Archaea are very different from those in Bacteria, the word bacteria was eliminated from the name archaebacteria and those organisms are simply called archaea. The terms archaebacteria and eubacteria are no longer used in modern biology having been simplified and replaced by archaea and bacteria.

Scientists now believe that the first forms of life on earth split into three branches so they have created three domains to represent that split – Bacteria, Archaea, and Eukarya. Eukarya then is divided into four kingdoms – Plants, Animals, Protists and Fungi. Along with differences, scientists have also discovered similarities in the cells of living things that help us trace the evolution of the organisms we have today. Scientists believe that the new system of three domains and four kingdoms is a better representation of the relationship between the organisms we have today and their ancestors.

In this appendix, we have included the text pages from the updated 2007 version of your book which describes the new classification system. These pages will replace Section 1 of Chapter 1 (pages 4-10) and Section 2 of Chapter 7 (pages 170-175). The new section review for Section 2 is also included (pages 178-179).

SECTION 1

The Diversity of Cells

Most cells are so small they can't be seen by the naked eye. So how did scientists find cells? By accident, that's how! The first person to see cells wasn't even looking for them.

What You Will Learn

- State the parts of the cell theory.
- Explain why cells are so small.
- Describe the parts of a cell.
- Describe how bacteria are different from archaea.
- Explain the difference between prokaryotic cells and eukaryotic cells.

Vocabulary

cell	nucleus
cell membrane	prokaryote
organelle	eukaryote

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

All living things are made of tiny structures called cells. A **cell** is the smallest unit that can perform all the processes necessary for life. Because of their size, cells weren't discovered until microscopes were invented in the mid-1600s.

Cells and the Cell Theory

Robert Hooke was the first person to describe cells. In 1665, he built a microscope to look at tiny objects. One day, he looked at a thin slice of cork. Cork is found in the bark of cork trees. The cork looked like it was made of little boxes. Hooke named these boxes *cells,* which means "little rooms" in Latin. Hooke's cells were really the outer layers of dead cork cells. Hooke's microscope and his drawing of the cork cells are shown in **Figure 1.**

Hooke also looked at thin slices of living plants. He saw that they too were made of cells. Some cells were even filled with "juice." The "juicy" cells were living cells.

Hooke also looked at feathers, fish scales, and the eyes of houseflies. But he spent most of his time looking at plants and fungi. The cells of plants and fungi have cell walls. This makes them easy to see. Animal cells do not have cell walls. This absence of cell walls makes it harder to see the outline of animal cells. Because Hooke couldn't see their cells, he thought that animals weren't made of cells.

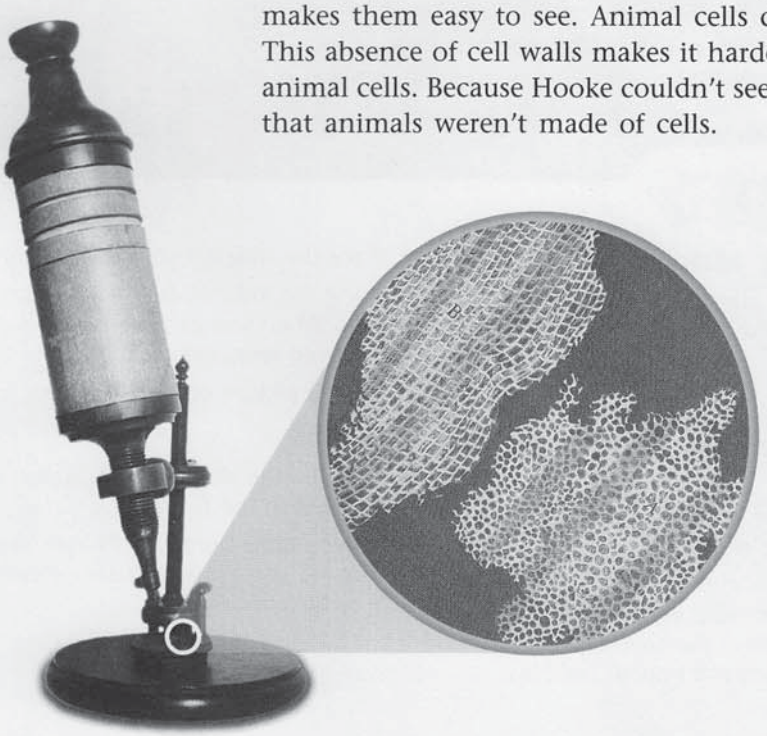


Figure 1 *Hooke discovered cells using this microscope. Hooke's drawing of cork cells is shown to the right of his microscope.*

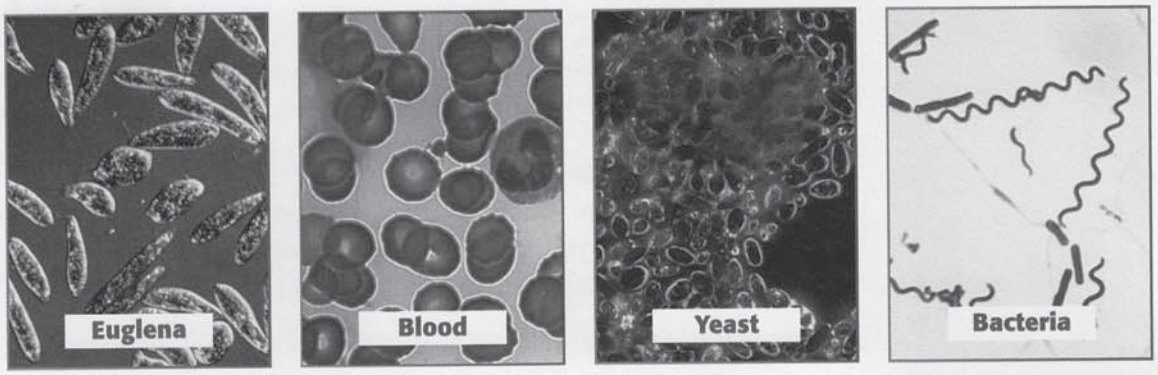


Figure 2 *Leeuwenhoek examined many types of cells, including protists such as* Euglena *and the other types of cells shown above. The bacteria cells in the photo have been enlarged more than the other cells. Bacterial cells are usually much smaller than most other types of cells.*

cell in biology, the smallest unit that can perform all life processes; cells are covered by a membrane and have DNA and cytoplasm

Finding Cells in Other Organisms

In 1673, Anton van Leeuwenhoek (LAY vuhn HOOK), a Dutch merchant, made his own microscopes. Leeuwenhoek used one of his microscopes to look at pond scum. Leeuwenhoek saw small organisms in the water. He named these organisms *animalcules,* which means "little animals." Today, we call these single-celled organisms protists (PROH tists).

Leeuwenhoek also looked at animal blood. He saw differences in blood cells from different kinds of animals. For example, blood cells in fish, birds, and frogs are oval. Blood cells in humans and dogs are round and flat. Leeuwenhoek was also the first person to see bacteria. And he discovered that yeasts that make bread dough rise are single-celled organisms. Examples of the types of cells Leeuwenhoek examined are shown in **Figure 2.**

The Cell Theory

Almost 200 years passed before scientists concluded that cells are present in all living things. Scientist Matthias Schleiden (mah THEE uhs SHLIE duhn) studied plants. In 1838, he concluded that all plant parts were made of cells. Theodor Schwann (TAY oh dohr SHVAHN) studied animals. In 1839, Schwann concluded that all animal tissues were made of cells. Soon after that, Schwann wrote the first two parts of what is now known as the *cell theory*.

- All organisms are made of one or more cells.
- The cell is the basic unit of all living things.

Later, in 1858, Rudolf Virchow (ROO dawlf FIR koh), a doctor, stated that all cells could form only from other cells. Virchow then added the third part of the cell theory.

- All cells come from existing cells.

Reading Check **What are the three parts of the cell theory?**
(*See the Appendix for answers to Reading Checks.*)

CONNECTION TO Physics

Microscopes The microscope Hooke used to study cells was much different from microscopes today. Research different kinds of microscopes, such as light microscopes, scanning electron microscopes (SEMs), and transmission electron microscopes (TEMs). Select one type of microscope. Make a poster or other presentation to show to the class. Describe how the microscope works and how it is used. Be sure to include images.

ACTIVITY

Cell Size

Most cells are too small to be seen without a microscope. It would take 50 human cells to cover the dot on this letter *i*.

A Few Large Cells

Most cells are small. A few, however, are big. The yolk of a chicken egg, shown in **Figure 3,** is one big cell. The egg can be this large because it does not have to take in more nutrients.

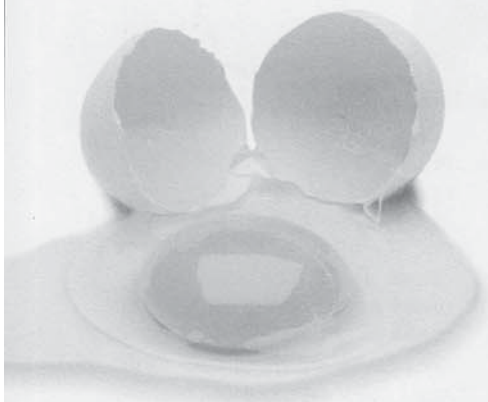


Figure 3 *The white and yolk of this chicken egg provide nutrients for the development of a chick.*

Many Small Cells

There is a physical reason why most cells are so small. Cells take in food and get rid of wastes through their outer surface. As a cell gets larger, it needs more food and produces more waste. Therefore, more materials pass through its outer surface.

As the cell's volume increases, its surface area grows too. But the cell's volume grows faster than its surface area. If a cell gets too large, the cell's surface area will not be large enough to take in enough nutrients or pump out enough wastes. So, the area of a cell's surface—compared with the cell's volume—limits the cell's size. The ratio of the cell's outer surface area to the cell's volume is called the *surface area–to-volume ratio,* which can be calculated by using the following equation:

$$\textit{surface area–to-volume ratio} = \frac{\textit{surface area}}{\textit{volume}}$$

Reading Check **Why are most cells small?**

MATH FOCUS

Surface Area–to-Volume Ratio Calculate the surface area–to-volume ratio of a cube whose sides measure 2 cm.

Step 1: Calculate the surface area.

surface area of cube = *number of sides* × *area of side*

surface area of cube = 6 × (2 cm × 2 cm)

surface area of cube = 24 cm^2

Step 2: Calculate the volume.

volume of cube = *side* × *side* × *side*

volume of cube = 2 cm × 2 cm × 2 cm

volume of cube = 8 cm^3

Step 3: Calculate the surface area–to-volume ratio.

$$\textit{surface area–to-volume ratio} = \frac{\textit{surface area}}{\textit{volume}} = \frac{24}{8} = \frac{3}{1}$$

Now It's Your Turn

1. Calculate the surface area–to-volume ratio of a cube whose sides are 3 cm long.
2. Calculate the surface area–to-volume ratio of a cube whose sides are 4 cm long.
3. Of the cubes from questions 1 and 2, which has the greater surface area–to-volume ratio?
4. What is the relationship between the length of a side and the surface area–to-volume ratio of a cell?

Parts of a Cell

Cells come in many shapes and sizes. Cells have many different functions. But all cells have the following parts in common.

The Cell Membrane and Cytoplasm

All cells are surrounded by a cell membrane. The **cell membrane** is a protective layer that covers the cell's surface and acts as a barrier. It separates the cell's contents from its environment. The cell membrane also controls materials going into and out of the cell. Inside the cell is a fluid. This fluid and almost all of its contents are called the *cytoplasm* (SIET oh PLAZ uhm).

Organelles

Cells have organelles that carry out various life processes. **Organelles** are structures that perform specific functions within the cell. Different types of cells have different organelles. Most organelles are surrounded by membranes. For example, the algal cell in **Figure 4** has membrane-bound organelles. Some organelles float in the cytoplasm. Other organelles are attached to membranes or other organelles.

Reading Check **What are organelles?**

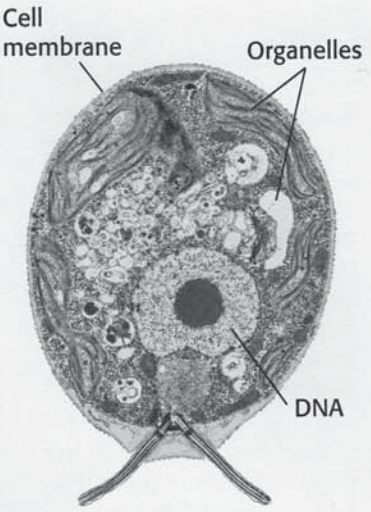


Figure 4 *This green alga has organelles. The organelles and the fluid surrounding them make up the cytoplasm.*

Genetic Material

All cells contain DNA (deoxyribonucleic acid) at some point in their life. *DNA* is the genetic material that carries information needed to make new cells and new organisms. DNA is passed on from parent cells to new cells and controls the activities of a cell. **Figure 5** shows the DNA of a bacterium.

In some cells, the DNA is enclosed inside an organelle called the **nucleus.** For example, your cells have a nucleus. In contrast, bacterial cells do not have a nucleus.

In humans, mature red blood cells lose their DNA. Red blood cells are made inside bones. When red blood cells are first made, they have a nucleus with DNA. But before they enter the bloodstream, red blood cells lose their nucleus and DNA. They survive with no new instructions from their DNA.

cell membrane a phospholipid layer that covers a cell's surface; acts as a barrier between the inside of a cell and the cell's environment

organelle one of the small bodies in a cell's cytoplasm that are specialized to perform a specific function

nucleus in a eukaryotic cell, a membrane-bound organelle that contains the cell's DNA and that has a role in processes such as growth, metabolism, and reproduction

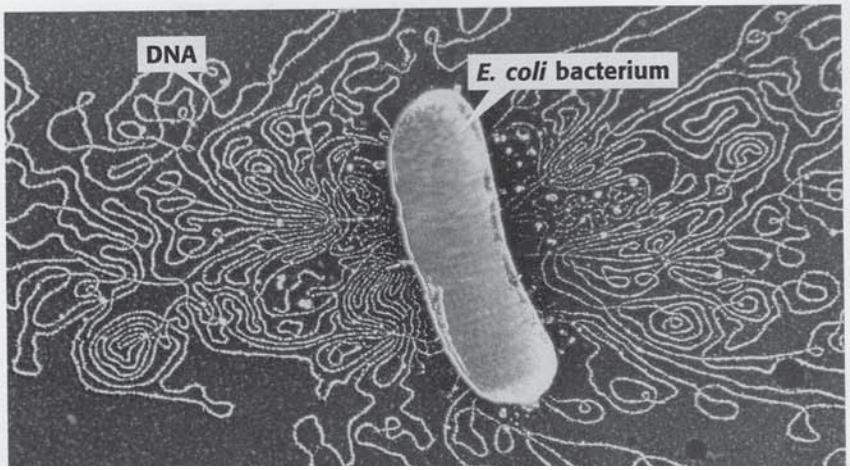


Figure 5 *This photo shows an* Escherichia coli *bacterium. The bacterium's cell membrane has been treated so that the cell's DNA is released.*

Two Kinds of Cells

All cells have cell membranes, organelles, cytoplasm, and DNA. But there are two basic types of cells—cells without a nucleus and cells with a nucleus. Cells with no nucleus are *prokaryotic* (proh KAR ee AHT ik) *cells*. Cells that have a nucleus are *eukaryotic* (yoo KAR ee AHT ik) *cells*. Prokaryotic cells are further classified into two groups: *bacteria* (bak TIR ee uh) and *archaea* (AHR kee uh).

Prokaryotes: Bacteria and Archaea

Bacteria and archaea are prokaryotes (pro KAR ee OHTS). **Prokaryotes** are single-celled organisms that do not have a nucleus or membrane-bound organelles.

Bacteria

The most common prokaryotes are bacteria (singular, *bacterium*). Bacteria are the smallest cells known. These tiny organisms live almost everywhere. Bacteria do not have a nucleus, but they do have DNA. A bacteria's DNA is a long, circular molecule, shaped like a twisted rubber band. Bacteria have no membrane-covered organelles. But they do have ribosomes. *Ribosomes* are tiny, round organelles made of protein and other material.

Bacteria also have a strong, weblike exterior cell wall. This wall helps the cell retain its shape. A bacterium's cell membrane is just inside the cell wall. Together, the cell wall and cell membrane allow materials into and out of the cell.

Some bacteria live in the soil and water. Others live in, or on, other organisms. For example, you have bacteria living on your skin and teeth. You also have bacteria living in your digestive system. These bacteria help the process of digestion. A typical bacterial cell is shown in **Figure 6.**

prokaryote an organism that consists of a single cell that does not have a nucleus

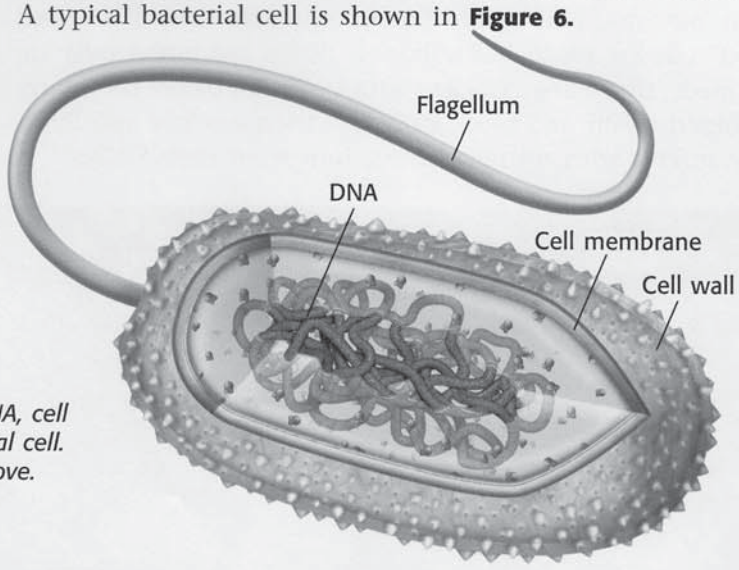


Figure 6 *This diagram shows the DNA, cell membrane, and cell wall of a bacterial cell. The flagellum helps the bacterium move.*

Quick Lab

Bacteria in Your Lunch?

Most of the time, you don't want bacteria in your food. Many bacteria make toxins that will make you sick. However, some foods—such as yogurt—are supposed to have bacteria in them! The bacteria in these foods are not dangerous.

In yogurt, masses of rod-shaped bacteria feed on the sugar (lactose) in milk. The bacteria convert the sugar into lactic acid. Lactic acid causes milk to thicken. This thickened milk makes yogurt.

1. Using a **cotton swab,** put a **small dot of yogurt** on a **microscope slide.**
2. Add a **drop of water.** Use the cotton swab to stir.
3. Add a **coverslip**.
4. Use a **microscope** to examine the slide. Draw what you observe.

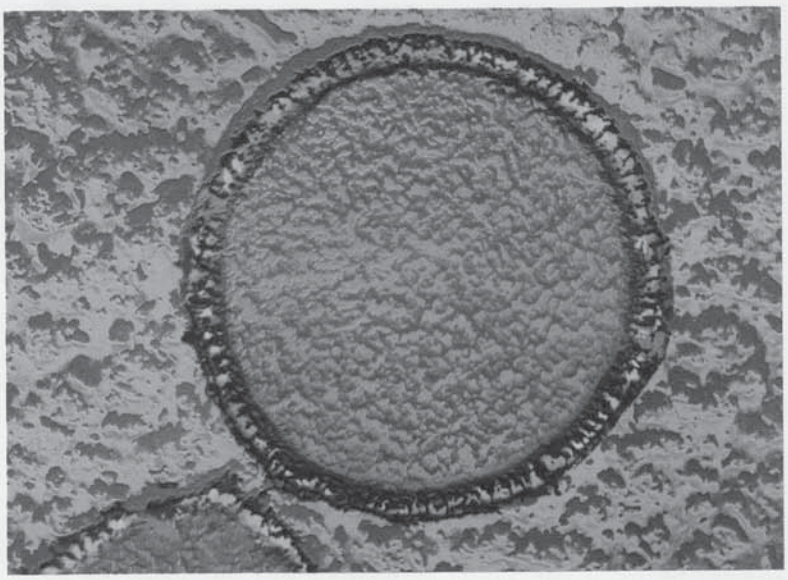


Figure 7 *This photograph, taken with an electron microscope, is of an archaeon that lives in the very high temperatures of deep-sea volcanic vents. The photograph has been colored so that the cell wall is green and the cell contents are pink.*

Archaea

The second kind of prokaryote are the archaea (singular, *archaeon*). Archaea are similar to bacteria in some ways. For example, both are single-celled organisms. Both have ribosomes, a cell membrane, and circular DNA. And both lack a nucleus and membrane-bound organelles. But archaea differ from bacteria in some way, too. For example, archaeal ribosomes are different from bacterial ribosomes.

Archaea are similar to eukaryotic cells in some ways, too. For example, archaeal ribosomes are more like the ribosomes of eukaryotic cells. But archaea also have some features that no other cells have. For example, the cell wall and cell membranes of archaea are different from the cell walls of other organisms. And some archaea live in places where no other organisms could live.

Three types of archaea are *heat-loving, salt-loving,* and *methane-making*. Methane is a kind of gas frequently found in swamps. Heat-loving and salt-loving archaea are sometimes called extremophiles. *Extremophiles* live in places where conditions are extreme. They live in very hot water, such as in hot springs, or where the water is extremely salty. **Figure 7** shows one kind of methane-making archaea that lives deep in the ocean near volcanic vents. The temperature of the water from those vents is extreme: it is above the boiling point of water at sea level.

Reading Check **What is one difference between bacteria and archaea?**

CONNECTION TO Social Studies

Where Do They Live? While most archaea live in extreme environments, scientists have found that archaea live almost everywhere. Do research about archaea. Select one kind of archaea. Create a poster showing the geographical location where the organism lives, describing its physical environment, and explaining how it survives in its environment.

ACTIVITY

Eukaryotic Cells and Eukaryotes

eukaryote an organism made up of cells that have a nucleus enclosed by a membrane; eukaryotes include animals, plants, and fungi, but not archaea or bacteria

Eukaryotic cells are the largest cells. Most eukaryotic cells are still microscopic, but they are about 10 times larger than most bacterial cells. A typical eukaryotic cell is shown in **Figure 8.**

Unlike bacteria and archaea, eukaryotic cells have a nucleus. The nucleus is one kind of membrane-bound organelle. A cell's nucleus holds the cell's DNA. Eukaryotic cells have other membrane-bound organelles as well. Organelles are like the different organs in your body. Each kind of organelle has a specific job in the cell. Together, organelles, such as the ones shown in **Figure 8,** perform all the processes necessary for life.

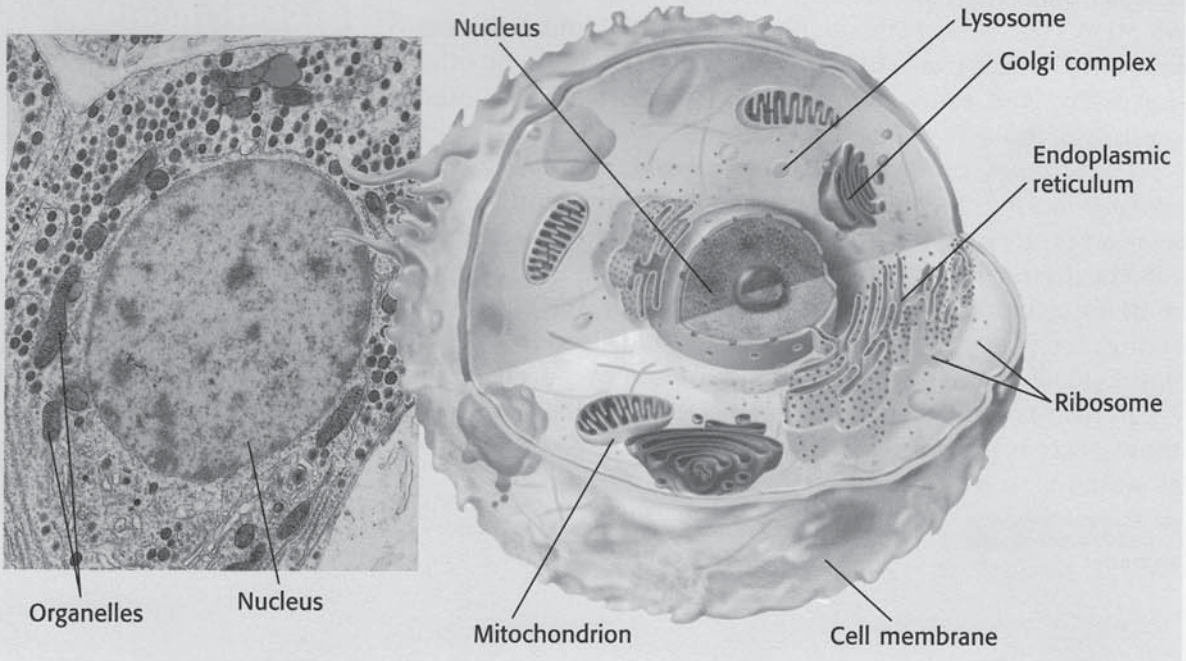
INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5CELW.**

All living things that are not bacteria or archaea are made of one or more eukaryotic cells. Organisms made of eukaryotic cells are called **eukaryotes.** Many eukaryotes are multicellular. *Multicellular* means "many cells." Multicellular organisms are usually larger than single-cell organisms. So, most organisms you see with your naked eye are eukaryotes. There are many types of eukaryotes. Animals, including humans, are eukaryotes. So are plants. Some protists, such as amoebas, are single-celled eukaryotes. Other protists, including some types of green algae, are multicellular eukaryotes. Fungi are organisms such as mushrooms or yeasts. Mushrooms are multicellular eukaryotes. Yeasts are single-celled eukaryotes.

Reading Check **How are eukaryotes different from prokaryotes?**

Figure 8 **Organelles in a Typical Eukaryotic Cell**



SECTION 2

Domains and Kingdoms

What do you call an organism that is green, makes its own food, lives in pond water, and moves? Is it a plant, an animal, or something in between?

For hundreds of years, all living things were classified as either plants or animals. But over time, scientists discovered species that did not fit easily into these two kingdoms. For example, an organism of the genus *Euglena,* such as the one shown in **Figure 1,** has characteristics of both plants and animals. How would you classify such an organism?

What You Will Learn

- Explain how classification developed as greater numbers of organisms became known.
- Describe the three domains.
- Describe four kingdoms in the domain Eukarya.

Vocabulary

Archaea
Bacteria
Eukarya
Protista
Fungi
Plantae
Animalia

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

What Is It?

Organisms are classified by their characteristics. For example, euglenoids, which include members of the genus *Euglena,* have the following characteristics:

- Euglenoids are single celled and live in pond water.
- Euglenoids are green and make their own food by photosynthesis.

These characteristics might lead you to conclude that euglenoids are plants. However, you should consider the following characteristics of euglenoids:

- Euglenoids move by whipping their "tails," which are called *flagella.*
- Euglenoids can feed on other organisms.

Plants do not move around and usually do not eat other organisms. So, are euglenoids animals? As you can see, euglenoids do not fit into plant or animal categories. Scientists solved this classification problem by adding another kingdom —kingdom Protista—to classify organisms such as euglenoids.

As scientists learned more about living things, they changed the classification system. Today, there are three domains in the classification system. Domains represent the largest differences between organisms. These domains are divided into several kingdoms.

Figure 1 *How would you classify this organism? This member of the genus* Euglena, *which is shown here highly magnified, has characteristics of both plants and animals.*

Figure 2 *The Grand Prismatic Spring in Yellowstone National Park contains water that is about 90°C (194°F). The spring is home to archaea that thrive in its hot water.*

Domain Archaea

The domain **Archaea** (ahr KEE uh) is made up entirely of archaea. Archaea are one of two kinds of prokaryotes (proh KAR ee OHTS). *Prokaryotes* are single-celled organisms that do not have a nucleus. Archaea were first discovered living in extreme environments, where other organisms could not survive. **Figure 2** shows a hot spring in Yellowstone National Park. The yellow and orange rings around the edge of the hot spring are made up of billions of archaea. Some archaea can also be found in moderate environments, such as the open ocean.

Reading Check **Describe one characteristic of an organism in the domain Archaea.**

Archaea in a modern taxonomic system, a domain made up of prokaryotes (most of which are known to live in extreme environments) that are distinguished from other prokaryotes by differences in their genetics and in the makeup of their cell wall; this domain aligns with the traditional kingdom Archaebacteria

Bacteria in a modern taxonomic system, a domain made up of prokaryotes that usually have a cell wall and that usually reproduce by cell division; this domain aligns with the traditional kingdom Eubacteria

Domain Bacteria

All bacteria (bak TEER ee uh) belong to the domain **Bacteria.** Bacteria are another kind of prokaryote. Bacteria can be found in soil, water, and even on and inside the human body! For example, *Escherichia coli* (ESH uh RIK ee uh KOH LIE), shown in **Figure 3,** is present in large numbers in human intestines, where it produces vitamin K. One kind of bacterium converts milk into yogurt. Some bacteria cause diseases, such as pneumonia. Other bacteria make chemicals that help humans fight disease-causing bacteria.

Figure 3 *Specimens of* E. coli *are shown on the point of a pin under a scanning electron microscope. These bacteria live in the intestines of animals and decompose undigested food.*

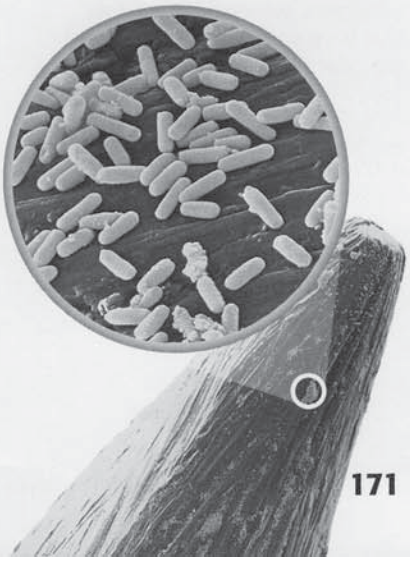


Figure 4 *This slime mold is a protist.*

Domain Eukarya

All organisms whose cells have a nucleus and membrane-bound organelles are called *eukaryotes*. Eukaryotes belong to the domain **Eukarya.** Four kingdoms currently make up the domain Eukarya: Protista, Fungi, Plantae, and Animalia.

Kingdom Protista

Today, members of the kingdom **Protista** (proh TIST uh), commonly called *protists,* are single-celled or simple multicellular organisms. Scientists think that the first protists evolved from ancient bacteria about 2 billion years ago. Eventually, ancient protists gave rise to fungi, plants, and animals. The kingdom Protista contains many kinds of organisms. Some animal-like protists are called *protozoans*. Some plantlike protists are called *algae*. Protists also include slime molds, such as the one shown in **Figure 4,** and euglenoids.

Kingdom Fungi

Molds and mushrooms are examples of the complex, multicellular members of the kingdom **Fungi** (FUHN JIE). Unlike plants, fungi do not perform photosynthesis. Unlike animals, fungi do not eat food. Instead, fungi absorb nutrients from substances in their surroundings. They use digestive juices to break down the substances. **Figure 5** shows a very poisonous fungus. Never eat wild fungi.

Eukarya in a modern taxonomic system, a domain made up of all eukaryotes; this domain aligns with the traditional kingdoms Protista, Fungi, Plantae, and Animalia

Protista a kingdom of mostly one-celled eukaryotic organisms that are different from plants, animals, bacteria, and fungi

Fungi a kingdom made up of nongreen, eukaryotic organisms that have no means of movement, reproduce by using spores, and get food by breaking down substances in their surroundings and absorbing the nutrients

Figure 5 *This beautiful fungus of the genus* Amanita *is poisonous.*

Figure 6 *Giant sequoias can measure 30 m around at the base and can grow to more than 91.5 m tall.*

Figure 7 *Plants such as these are common in the Tropics.*

Kingdom Plantae

Although plants vary remarkably in size and form, most people easily recognize the members of the kingdom Plantae. **Plantae** consists of organisms that are eukaryotic, have cell walls, and make food through photosynthesis. For photosynthesis to occur, plants must be exposed to sunlight. Plants can therefore be found on land and in water that light can penetrate.

The food that plants make is important not only for the plants but also for all of the organisms that get nutrients from plants. Most life on Earth is dependent on plants. For example, some fungi, protists, and bacteria consume plants. When these organisms digest the plant material, they get energy and nutrients made by the plants.

Plants also provide habitat for other organisms. The giant sequoias in **Figure 6** and the flowering plants in **Figure 7** provide birds, insects, and other animals with a place to live.

Reading Check **How do plants provide energy and nutrients to other organisms?**

Plantae a kingdom made up of complex, multicellular organisms that are usually green, have cell walls made of cellulose, cannot move around, and use the sun's energy to make sugar by photosynthesis

MATH PRACTICE

Ring-Around-the-Sequoia

How many students would have to join hands to form a human chain around a giant sequoia that is 30 m in circumference? Assume for this calculation that the average student can extend his or her arms about 1.3 m.

Animalia a kingdom made up of complex, multicellular organisms that lack cell walls, can usually move around, and quickly respond to their environment

Kingdom Animalia

The kingdom **Animalia** contains complex, multicellular organisms that don't have cell walls, are usually able to move around, and have specialized sense organs. These sense organs help most animals quickly respond to their environment. Organisms in the kingdom Animalia are commonly called *animals*. You probably recognize many of the organisms in the kingdom Animalia. All of the organisms in **Figure 8** are animals.

Animals depend on the organisms from other kingdoms. For example, animals depend on plants for food. Animals also depend on bacteria and fungi to recycle the nutrients found in dead organisms.

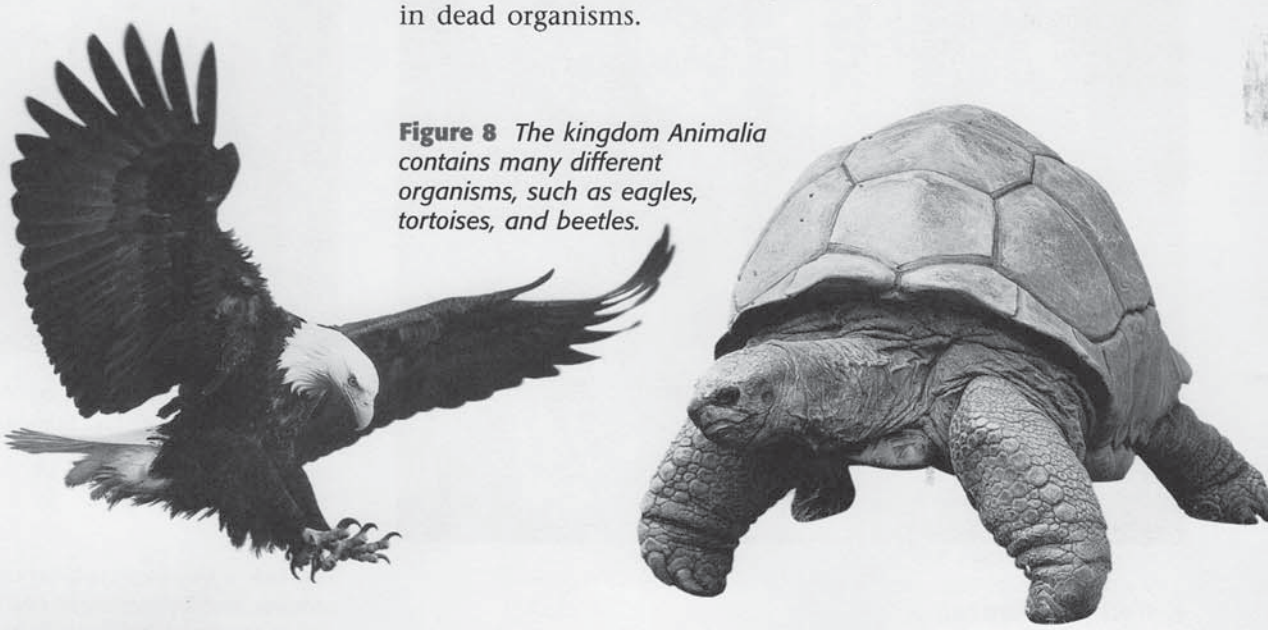


Figure 8 *The kingdom Animalia contains many different organisms, such as eagles, tortoises, and beetles.*

CONNECTION TO Social Studies

WRITING SKILL **Animals That Help** Humans have depended on animals for thousands of years. Many people around the world still use oxen to farm. Camels, horses, donkeys, goats, and llamas are all still used as pack animals. Dogs still help herd sheep, protect property, and help people hunt. Scientists are even discovering new ways that animals can help us. For example, scientists are training bees to help find buried land mines. Using the library or the Internet, research an animal that helps people. Make a poster describing the animal and the animal's scientific name. The poster should show who uses the animal, how the animal is used, and how long people have depended on the animal. Find or draw pictures to put on your poster.

ACTIVITY

Strange Organisms

Classifying organisms is often not easy. Like animals, some plants can eat other organisms to obtain nutrients. Some protists can use photosynthesis as plants do and can move around as animals do. The kingdom Animalia also includes members that might surprise you, such as worms, insects, and corals.

The red cup sponge in **Figure 9** is also an animal. Sponges are usually considered the simplest animals. They lack sense organs, and most of them cannot move. Scientists used to classify sponges as plants. But sponges cannot make their own food. They must eat other organisms to get nutrients, which is one reason that sponges are classified as animals.

Reading Check **Why were sponges once thought to be plants?**

Figure 9 *This red cup sponge is a simple animal.*

SECTION Review

Summary

- In the past, organisms were classified as plants or animals. As scientists discovered more species, they found that organisms did not always fit into one of these two categories, so they changed the classification system.
- Today, domains are the largest groups of related organisms. The three domains are Archaea and Bacteria, both of which consist of prokaryotes, and Eukarya, which consists of eukaryotes.
- The kingdoms of the domain Eukarya are Protista, Fungi, Plantae, and Animalia.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *Archaea* and *Bacteria*
2. *Plantae* and *Fungi*

Understanding Key Ideas

3. Biological classification schemes change
   - **a.** as new evidence and more kinds of organisms are discovered.
   - **b.** every 100 years.
   - **c.** when scientists disagree.
   - **d.** only once.
4. Describe the characteristics of each of the three domains.
5. Describe the four kingdoms of domain Eukarya.

Math Skills

6. A certain bacterium can divide every 30 min. If you begin with 1 bacterium, when will you have more than 1,000 bacteria?

Critical Thinking

7. **Identifying Relationships** How are bacteria similar to fungi? How are fungi similar to animals?
8. **Analyzing Methods** Why do you think Linnaeus did not include classification kingdoms for categories of archaea and bacteria?
9. **Applying Concepts** The Venus' flytrap does not move around. It can make its own food by using photosynthesis. It can also trap insects and digest the insects to get nutrients. The flytrap also has a cell wall. Into which kingdom would you place the Venus' flytrap? What makes this organism unusual in the kingdom you chose?

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Topic: Kingdoms
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Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

Animalia	Protista
Bacteria	Plantae
Archaea	classification
taxonomy	

1. Linnaeus founded the science of ___.
2. Prokaryotes that live in extreme environments are in the domain ___.
3. Complex multicellular organisms that can usually move around and respond to their environment are in the kingdom ___.
4. A system of ___ can help group animals into categories.
5. Prokaryotes that can cause diseases are in the domain ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Scientists classify organisms by
   - **a.** arranging the organisms in orderly groups.
   - **b.** giving the organisms many common names.
   - **c.** deciding whether the organisms are useful.
   - **d.** using only existing categories of classification.

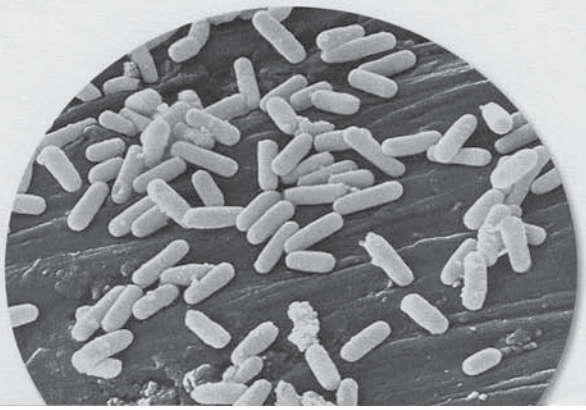
7. When the eight levels of classification are listed from broadest to narrowest, which level is sixth in the list?
   - **a.** class
   - **b.** order
   - **c.** genus
   - **d.** family

8. The scientific name for the European white waterlily is *Nymphaea alba*. To which genus does this plant belong?
   - **a.** *Nymphaea*
   - **b.** *alba*
   - **c.** water lily
   - **d.** alba lily

9. *Animalia, Protista, Fungi,* and *Plantae* are the
   - **a.** scientific names of different organisms.
   - **b.** names of kingdoms.
   - **c.** levels of classification.
   - **d.** scientists who organized taxonomy.

10. The simple, single-celled organisms that live in your intestines are classified in the domain
    - **a.** Protista.
    - **b.** Bacteria.
    - **c.** Archaea.
    - **d.** Eukarya.

11. What kind of organism thrives in hot springs and other extreme environments?
    - **a.** fungus
    - **b.** bacterium
    - **c.** archaean
    - **d.** protist



Short Answer

12. Why is the use of scientific names important in biology?

13. What kind of evidence is used by modern taxonomists to classify organisms based on evolutionary relationships?

14. Is a bacterium a type of eukaryote? Explain your answer

15. Scientists used to classify organisms as either plants or animals. Why doesn't that classification system work?

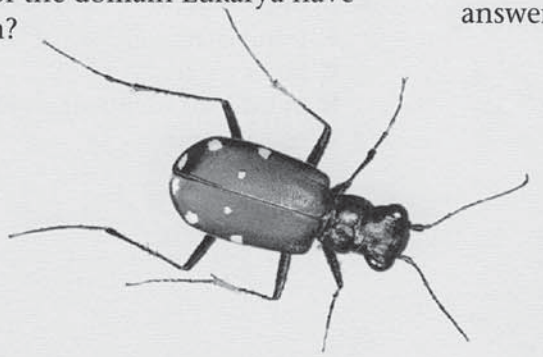
CRITICAL THINKING

16. **Concept Mapping** Use the following terms to create a concept map: *kingdom, fern, lizard, Animalia, Fungi, algae, Protista, Plantae,* and *mushroom*.

17. **Analyzing Methods** Explain how the levels of classification depend on the similarities and differences between organisms.

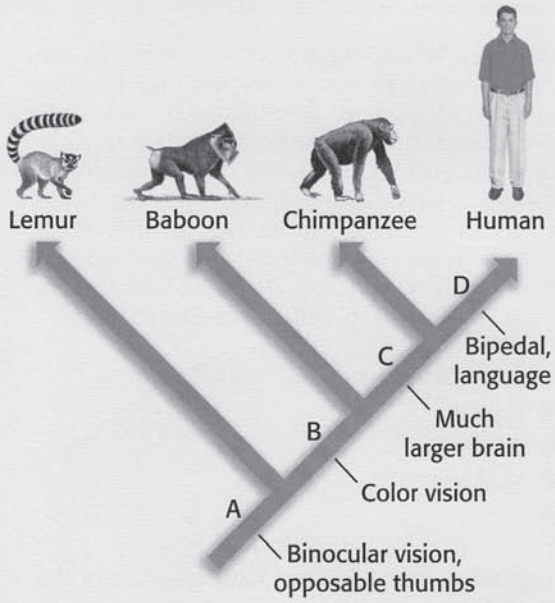
18. **Making Inferences** Explain why two species that belong to the same genus, such as white oak (*Quercus alba*) and cork oak (*Quercus suber*), also belong to the same family.

19. **Identifying Relationships** What characteristics do the members of the four kingdoms of the domain Eukarya have in common?



INTERPRETING GRAPHICS

Use the branching diagram of selected primates below to answer the questions that follow.



20. Which primate is the closest relative to the common ancestor of all primates?

21. Which primate shares the most traits with humans?

22. Do both lemurs and humans have the characteristics listed at point D? Explain your answer.

23. What characteristic do baboons have that lemurs do not have? Explain your answer.