Biology
The Study of Life

Oak Meadow
Coursebook

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Lesson 1 What Is Biology?

ASSIGNMENT SUMMARY

- ☐ Read chapter 1, Biology in the 21st Century (2–27).
- ☐ Answer eight Comprehension questions.
- ☐ Complete four Critical Thinking questions.
- ☐ Activity: Medical Imaging Technology
- ☐ Activity: Data Analysis Lab
- ☐ Activity: Experiment Design
- ☐ Lesson 1 Lab: Walking Crooked!

Integral to the study of biology or any other scientific discipline is the concept of ***scientific inquiry***. In scientific inquiry, you not only will be observing, inferring, and experimenting, but you will be encouraged to ask questions, form explanations, compare your explanations with current scientific knowledge, and communicate your ideas. We will be focusing on developing critical-thinking and scientific-reasoning skills, and using these skills to advance your understanding of science. Throughout the course, you will be encouraged to question. Please remember: in science, there is no such thing as a stupid question!

When you see a word or term highlighted, such as scientific inquiry, that's a key term you should know. You'll find the word defined in your textbook.

Plan to spend one week on this lesson.

Lesson Objectives

- Define biology and become familiar with the themes of biology and the properties of life
- Review and practice the scientific process and the concept of scientific inquiry
- Explore examples of modern technology and its uses in biology

Lesson 1 Assignments

Reading

Read chapter 1, Biology in the 21st Century (2–27), in your textbook.

Additional Reading Assignment for the Course

For this biology course, you will be reading one additional book. Below you will see a list of four books to choose from. They are all fascinating books so you may have a hard time choosing. Feel free to read them all! Any one of these books will help you see science in a different light.

You have the entire year to complete this additional reading assignment (or the entire semester if you are only taking one semester of biology). You may submit your review of the book (details on this are below) at any point during either semester, and it will be graded with the semester grade. You will see reminders throughout the course about this; try not to leave it until the end. If you are going on a family trip or taking a vacation, that would be a good time to pick up one of these books.

- ***A Planet of Viruses* by Carl Zimmer**

  Viruses are involved in almost every important function on Earth. With the increase in bacterial resistance to antibiotics, viruses might be the future in treating infectious disease. Every liter of seawater is estimated to contain up to one hundred *billion* viruses! Carl Zimmer states, "Viruses are the smallest living things known to science, and yet they hold the entire planet in their sway." Viruses even blur the line between life and nonlife. In describing the intriguing life history of several viruses in short chapters, Zimmer makes science truly fascinating and accessible to anyone.

  Writing assignment: As you read through this book, keep notes for each chapter. Write down at least three facts from each chapter that you find especially interesting or surprising. After you complete the book, write an essay about the effect the book had on you. Was it worth your time, and do you feel it fits well with the biology course? In the textbook, we learn that viruses aren't officially living things, as they are not made of cells. What are your thoughts on that, after reading this book? Submit your essay and the three interesting facts from each chapter to your teacher when you complete the book.

- ***Flight Behavior* by Barbara Kingsolver**

  In this excellent work of fiction, Kingsolver weaves together real life and science as climate change, environmental sustainability, and discoveries made in the natural world reflect and influence what is going on in the life of a young woman. Monarch butterflies migrating through the Appalachian Mountains provide a rich backdrop for the story.

  Writing assignment: After you read the book, write an essay addressing some of the following questions:

  a. How can different people look at one event and see it so very differently? Some felt that the butterflies were a miracle, and others felt their presence was a disastrous result of climate change. What does this say about human behavior and how people decide what to believe?

  b. What do you think about Kingsolver using fiction to spark the conversation about climate change? Is this effective?

  c. Comment on the process of science as it is introduced in this book. What did you learn about how science is done? Consider the sampling methods, data collection, and the concept of causation versus correlation that is addressed in the book. Did you end up with the feeling that science is accessible even to those who don't think they have a scientific mind?

  d. Scientists express things with caution. Rarely are data expressed with certainty, as that would imply 100% certainty, from a scientific perspective. We are accustomed to certainty, and may prefer not to believe an issue if it is only 98% certain. Comment on the idea of certainty and how it relates to the climate change issue.

- ***The Immortal Life of Henrietta Lacks* by Rebecca Skloot**

  Henrietta Lacks was a poor black tobacco farmer who, in 1951, was diagnosed with cervical cancer. Her cells were taken from her tumor, without her knowledge or consent, and became one of the most important tools in medicine. The *HeLa* cell line became very important in the development of the polio vaccine, cloning, gene mapping, cancer research, and more. *HeLa* cells have been, and continue to be, reproduced in labs throughout the world. Henrietta died as a result of her cancer. Meanwhile, her cell line lived on, and all of this happened without her family having any idea of what was going on. This book is like a detective story combined with a heart-wrenching novel. At times it is hard to believe it is all true. *The Immortal Life of Henrietta Lacks* brings the subject of bioethics to the forefront.

Writing assignment: After you read the book, choose **three** of the following topics to discuss in an essay.

a. Review pages 60–62 of your textbook, on the topic of bioethics. How does this book fit into the discussion of bioethics as it is seen today? Do you feel that the discussion should have started many years ago, when Henrietta Lacks's cells were taken?

b. Deborah shares her mother's medical records with the author, Rebecca Skloot, but was adamant that she not copy everything. Deborah says, "Everybody in the world got her cells, only thing we got of our mother is just them records and her Bible." If you were in Deborah's situation, how would you react to someone wanting to look into your mother's medical records?

c. Rebecca Skloot was very careful not to take sides when she reported this story. Since we always bring our own perspectives and experiences into whatever we read, do you feel that Skloot was unbiased, or do you think that she took a side (scientist or family)? Did you take any particular side while reading the book, or are you in the middle? Explain.

d. Review the consent form that Henrietta signed (31). Based on this statement, do you believe TeLinde and Gey had the right to obtain a sample of her cervix to use in research? What information would they have had to give Henrietta for her to give *informed* consent? Do you think she would have agreed for her tissue to be used in research if she'd had all the information?

e. Do you feel the Lacks family should be financially compensated for the *HeLa* cells, all these years later? If so, where do you think the money should come from?

f. Review the case of John Moore (199–201). How does that make you feel? How do you feel about the Supreme Court of California's ruling that states when tissues are removed from your body, with or without consent, any claim you might have had to owning them vanishes?

g. Review chapter 32 (259–267), when Deborah and Zakariyya got to see the *HeLa* cells for the first time. How do you feel about the way Christoph Lengauer handled the situation? Relate this experience to the importance of informed consent. How could simple knowledge about the situation have prevented so much anger and misunderstanding?

- ***Stiff: The Curious Lives of Human Cadavers* by Mary Roach**

  Medical students often practice surgery on cadavers. Before anatomy was understood, "body snatching" (the stealing of bodies from graves) for medical schools was a big business and the money earned from this practice fed many families. Today, criminal forensics is a very important and cutting-edge field, and understanding the process of human decay is necessary. And although it sounds horrible, the use of cadavers is far superior to the use of crash test dummies for auto safety research. While such a book may seem gruesome, Mary Roach is a master at making science, even *this* science, funny. If you are at all interested in medicine or forensics, this is a great read. No matter your interests, this book will open your eyes to fields of study you never knew existed.

  Writing assignment: For this course, you are asked to read only the first six chapters (about 150 pages, half the book). As you read through each chapter of this book, keep notes. Write down at least three facts from each chapter that you find especially interesting or surprising, and any other notes you want to jot down. After you complete the book, write a report and critique of the book. Did it have any particular effect on you? How do you think it relates to the biology course? Do you find forensics to be an interesting biology topic? Submit your essay and the three interesting facts from each chapter when you complete the book.

Think About It

Can all questions be answered by using scientific methods? If you are testing a hypothesis and your results don't support your hypothesis, is your investigation a failure? Take some time to consider these two questions and then discuss your thoughts with a friend, sibling, or parent. Express yourself clearly and check that your discussion partner understands the points you are making. You might have to explain some of the scientific concepts or methods upon which your answers are based. Being able to "talk science" is an important skill, and you'll be practicing this throughout the course.

Comprehension

1. Given the definition of biodiversity found on page 5 of your textbook, how would you define ***species diversity***? How about ***genetic diversity*** and ***ecosystem diversity***? Based on your understanding of the meaning of diversity, explain what you think these terms mean. (We will be exploring each of these concepts later in the course.)
2. If you were to determine if an organism is alive, what characteristics would you look for?
3. Homeostasis is an important biological theme. Explain what homeostasis is, and give an example.
4. How does natural selection lead to adaptation?
5. What is the importance of peer review in science?
6. Differentiate between an independent variable and a dependent variable, and explain the purpose of a control group in a scientific experiment.
7. If you needed detailed images of the internal structure of a bacterium, what type of microscope would you select for the task? Explain your answer.
8. Describe two potential benefits and two potential risks of biotechnology.

Critical Thinking

1. Describe a system that is part of your everyday life. It does not have to be related to biology.
2. Look at the picture of the polar bear hair on page 9 of your textbook, think about its structure, and consider the following additional information: polar bears have black skin. Their hair is transparent, and only appears white because it reflects visible light in the same way snow does. How do the characteristics of the hair and skin contribute to homeostasis in the polar bear?
3. Based on the definitions of theory discussed on page 16 of your textbook, give an example of a theory that you have come up with in your life that would not be considered a scientific theory. Explain why it is not a scientific theory.
4. Answer question #2 on the Standards Based Assessment on page 31 of your textbook.

Activities

Complete all three of the following activities.

A. Medical Imaging Technology

Do some investigation and make a list of the medical imaging technology that you and your family have benefited from or used. Even if you rarely go to the doctor, it is likely that images were taken of you before you were even born! Think broadly, discuss with your family, and come up with as comprehensive a list as you can. This is a general question: respect the privacy of others and please don't share without consent any names or details about the reasons for the imaging.

B. Data Analysis Lab

Complete the Data Analysis Lab on page 12 of your textbook. In addition to the two questions in the lab, please answer the following question, and label it #3: Consider the qualitative data examples about the dolphins as observations that need further investigation. Choose one of these observations and describe how it might be investigated in a quantitative way.

C. Experiment Design

Design a controlled experiment about one of the topics listed below (you will not be carrying out this experiment). As mentioned in lab 1 below, there are variations in the way scientific investigations are carried out. However, section 1.3 in the textbook explains the general format. An *observation* of something usually leads to *questions*, from which a *hypothesis* is generated and tested.

Experiment topics:

- What causes leaves to change color and fall off trees in autumn? Is it temperature, light, or both?
- You have a new drug that has potential for being a cure for the common cold. Design an experiment to test the drug's effectiveness.
- Does hot water freeze faster than cold water? (Feel free to actually carry out this experiment!)
- Is acid rain causing a decline in the population of amphibians (frogs and salamanders)?

Explain the following steps of your experiment:

1. Identify the situation or problem based on your observation.
2. What are the questions that come up about the problem?
3. Consider an explanation for the situation, and put it in the form of a testable hypothesis.
4. Predict what will happen if your hypothesis is correct.
5. Design an experiment to test your hypothesis. Remember to include a control group. Identify the independent and dependent variables. Explain each step clearly.

Lab

Perform Lesson 1 Lab: Walking Crooked! Turn to the lab for detailed instructions (each lab is found directly following the lesson assignments).

FOR ENROLLED STUDENTS

For the discussion assignment in "Think About It," you can connect with a classmate via Skype or Google Hangout to discuss your thoughts, or talk to a friend or parent.

Begin using your Google course doc for all your written work (contact your teacher if you haven't received a link to your course doc yet). If you will be using an alternate submission method for your lessons, please consult with your teacher. Handwritten data tables or other work can be scanned and attached to your course doc or sent to your teacher via email or postal mail. You will send all your work from this lesson to your teacher after you complete lesson 2.

Name _____

Walking Crooked!

This Lab uses your own body to practice scientific inquiry. The step-by-step scientific method that you learned in this chapter is one example of how scientific investigations take place. There are variations. For example, you may simply have a question and you develop a way to test it, or your hypothesis is just something you've heard. Is this still scientific inquiry? Yes! You are controlling the variables, setting up an investigation, and looking for an answer.

The Guiding Question

Can a blindfolded person walk in a straight line?

Materials

- measuring tape or string, 10 meters long
- 5 to 10 markers to imitate "bread crumbs" to mark your path, such as popcorn, small plastic toys such as Legos, dry beans (if they are easy to see), etc.
- blindfold

You will also need a large or outdoor space that is flat, with even terrain, and a partner.

Procedure

1. Using the tape measure or string, mark a straight line 10 meters long. Leave it on the ground.
2. Stand at one end of the string facing in the direction the string goes, and have your partner blindfold you. If there is noise coming from a certain direction, you may need to control for this.
3. When your partner says, "Go," start walking slowly toward what you think is the other end of the marked area. Your partner will quietly walk behind you, dropping the "bread crumbs" to mark your path of travel. When you get toward the end of the 10 meters (or if it becomes unsafe), your partner will say, "Stop." Take off the blindfold and observe the results.
4. Measure how far you've strayed from the far end of the 10-meter path. Record your results in the data table below. Be sure to note whether you have strayed to the right or left. You might also want to note if there was a continuous curve to the path you took.

Biology—Lesson 1 Lab: Walking Crooked!

Data Table: Measuring Deviations from a Straight Line When Blindfolded

Person	Distance strayed	Right or left	Notes

5. Pick up the bread crumbs, switch places with your partner, and repeat the test. If you have more people available, it is fun to do this with as many people as you can. Record all data.

Analyze and Conclude

Describe your results. Answer the guiding question, using your results as evidence to support your conclusion.

Name _____

Biology—Lesson 1 Lab: Walking Crooked!

Extension: Making Connections

A test like this often results in more questions than you started with. Here are a few samples:

- Why don't people walk straight?
- Will one person always go the same direction?
- Is there a pattern if you are left or right handed?
- Would this translate to different activities, such as paddling a kayak?

Now it's your turn to come up with more questions about this experiment that could be tested. Think broadly: you might consider anatomy, gender, terrain, etc. You might have questions about why this happens, or you may want to look for patterns. Write down at least three questions. There are no wrong answers!

Lesson 6

Meiosis and Introduction to Mendelian Genetics

ASSIGNMENT SUMMARY

- ☐ Read chapter 6, Meiosis and Mendel (157–182).
- ☐ Answer ten Comprehension questions.
- ☐ Complete six Critical Thinking questions.
- ☐ Activity: Coin Toss Genetics
- ☐ Lesson 6 Lab: Modeling Meiosis

Stop for a second and think about this question: "How did I become the way I am?" Although some of it has to do with the food you eat, your family and surroundings, and the people you hang out with, a lot of it arrived with you when you were born. You might be thinking, "I'm tall like my mother, but have freckles and blue eyes like my father." Or you might think, "I have no idea why I'm so short when both of my parents are above average height." Or, "My sister and I are both blond, but our parents have dark hair." How do we get these unexpected combinations of physical traits?

In this lesson and the next few, we will focus on those easily observable traits that have a clear genetic basis; in other words, we aren't going to explore why one person is shy and another outgoing. These are more complex, and are likely a combination of nature (genetics) and nurture (environment). We will be exploring the basics of genetics, which is what makes us sort of like, but sort of unlike, our parents.

Before that, though, we need to start at the beginning, learning about the tiny gametes, the sperm and the egg, that create us (or our dog, our spider plant, our resident house flies, etc.). Welcome to meiosis! As you read about meiosis, you will see that it is not a quick process. Human egg cells take years to develop (from birth to fertilization), and human sperm cells take 24 days. The duration of meiosis is highly variable, as different species will go through periods of inactivity. Even in the male reproductive organs of a lily plant, meiosis takes 7 days!

Plan to spend about one and a half weeks on this lesson.

Lesson Objectives

- Differentiate between the processes of mitosis and meiosis, and identify the factors involved in producing genetic variation
- Become familiar with the work of Mendel and the foundations of heredity
- Understand how genes and alleles determine genetic traits
- Investigate and experiment with the role of probability in the inheritance of traits

Lesson 6 Assignments

Reading

Read chapter 6, Meiosis and Mendel (157–182).

Comprehension

When answering comprehension questions, full sentences are not required when you are simply asked to name something, or identify genotypes or phenotypes.

1. Describe the difference between homologous chromosomes and sister chromatids.
2. The Y chromosome has the smallest number of genes. Do you have that chromosome?
3. Examine the steps of meiosis and answer the following questions. You might want to do this assignment *after* you complete the lab.
   a. Name the stage of meiosis during which sister chromatids are separated to opposite poles of the cell.
   b. In what ways are the chromosomes in telophase I of meiosis different from those in telophase of mitosis?
   c. In which division of meiosis do the cells become haploid?
4. Who was Gregor Mendel? (Write no more than two sentences.)
5. Why were pea plants a good choice for Mendel's experiments?
6. Apply the terms ***homozygous***, ***heterozygous***, ***dominant***, or ***recessive*** to describe plants with the genotypes PP and Pp.
7. Identify the phenotypes of rabbits with the genotypes Bb and bb, where B = black fur and b = brown fur.

Think About It

> To learn, read; to know, write; to master, teach.
>
> **Hindu proverb**

In this lesson, you will be learning many terms. In order to succeed with many of the questions here and in subsequent lessons, it is essential that you understand the meaning of these terms. We're leaving it up to you to learn the following terms in the way that works for you. You may be good at writing definitions, drawing pictures, creating flash cards—it's your choice. One of the best ways to learn is by teaching. Use this opportunity to teach family members about the basics of genetics. Formulating good explanations for others is a very useful learning tool, and this topic in particular is something that people may take an interest in if it is explained well.

Asking good questions is also very important, so feel free to ask your teacher or home tutor if you are stumped. However, rather than say, "I don't understand this," try being more specific. Explain what you do understand, and try to refine your question. In other words, be proactive in your learning! The following terms will be important to know:

allele

gene

homozygous

heterozygous

genome

genotype

phenotype

dominant

recessive

probability

genetic linkage

crossing over

You won't be asked the definition of these terms in this lesson, but it will become apparent soon enough if you don't take the time to learn them.

8. Draw a Punnett square to show the offspring of two individuals who are heterozygous for freckles (Ff). Using it, predict both the phenotypic and genotypic ratios of the offspring. Please submit both the Punnett square and your answers to your teacher. (Be sure to review how a ratio is written, as explained on pages 169 and 175 of your textbook, if necessary.)
9. Let's say you have a pea plant with round seeds. Round seeds are dominant, but you don't know if the genotype is RR or Rr. Explain how you would use a testcross to determine what the unknown parent genotype is. Use two Punnett squares to illustrate your results and help demonstrate your answer.
10. Define the law of independent assortment.

Critical Thinking

1. Do you think the Y chromosome contains genes that are critical to an organism's survival? Explain your reasoning.
2. Refer to the analysis questions in the "Modeling and Recognizing the Stages of Mitosis" lab from lesson 5. What is the diploid number of chromosomes in a human? (Express this as $2n$ = ___.) What is the haploid number in human gametes? (n = ___) What is the diploid and haploid number in a dog?
3. Why is it important that gametes are haploid cells?
4. When Mendel performed his experiments, he had no understanding of DNA as genetic material. One thing he excelled at was careful observation. Review the scientific process of observation, forming hypotheses, testing hypotheses, and analyzing data. Use examples from Mendel's work to show how his work fits this pattern.
5. On figure 4.1 (171), you see that polydactyly is a dominant trait. What are the possible genotypes for someone to have this trait? (Use the letters D and d.) Knowing that there are few people who have this trait, what do you think that tells you about the relationship between dominance and commonality of a trait?
6. If crossing over were to happen on sister chromatids during meiosis, would it increase genetic diversity? Explain your response.

Activity

Complete the following activity.

Coin Toss Genetics

In this activity (full instructions are below), you will demonstrate how independent assortment works, and how the probability of a particular outcome of meiosis can be predicted.

The way genes behave during meiosis and fertilization can be simulated using two-sided coins, where heads represent the dominant allele (**A**) that results in normal skin and hair color, and tails represent the recessive allele (**a**) that results in albinism. Suppose a parent is heterozygous (Aa). Then, tossing a coin and checking whether it lands tails up or heads up represents the 50-50 chance that an egg or sperm produced by meiosis will include an **a** allele or an **A** allele.

To simulate reproduction between two heterozygous (**Aa**) parents, you and a friend will each toss a coin and the result of the pair of coin tosses will indicate the pair of alleles contributed to a baby by an egg and a sperm.

Before You Begin

Construct a Punnett square to predict the probability of each outcome. Review page 177, where probability is described, and be sure you understand how probability is expressed (as a fraction or percent), compared with how a ratio is expressed. Enter your predicted probabilities, as both a fraction and a percentage, in the last row of the data table below. Also, put the predicted number in a family of four children. The first column is filled out for you.

Procedure

You can do this with a partner, or by yourself, creating a fictitious person to be your partner. Each person has one coin.

1. Each of you will toss your coin, and this pair of coin tosses will indicate the pair of alleles in the first child produced by a mating of two heterozygous (**Aa**) parents. Make three more pairs of coin tosses to determine the genotypes for the remainder of the children in this family of four children. Record how many of these four children had each of the three possible genotypes (**AA**, **Aa**, or **aa**) in the row labeled "first family of 4 children" in the data table below.
2. Now make four more pairs of coin tosses to indicate the alleles in a second family of 4 children. Record these genotypes in the second row in the table.
3. Do this two more times and record the results in the third and fourth rows of the table.
4. Add up your results to determine the total number of children from your coin tosses who had **AA**, **Aa**, and **aa** genotypes.
5. Using your totals in each column, calculate the percentage of each genotype in your population of 16. Record this in the data table.

6. For each family of 4 children produced by your coin toss matings, compare the results with the predictions from the Punnett square. Do the same for the totals. Next to each row, indicate the following:
    - Put a checkmark for any family that has the expected number of albino (**aa**) children.
    - Mark an arrow for any family that has no albino children.
    - Put an asterisk for any family that has two or more albino children.

DATA TABLE:

Genotypes of "Coin Toss" Children Produced by Two Heterozygous (Aa) Parents

	AA	Aa	aa
first family of 4 children			
second family of 4 children			
third family of 4 children			
fourth family of 4 children			
Totals			
Results (as a percent)			
Predictions based on Punnett square (fraction and percent)	¼ = 25% 1 child		

Analysis

1. For each family of 4 children produced by your coin toss matings, compare the results with the predictions from the Punnett square. Do the same for the totals. Present your answer as a written description.

2. Can you explain any differences between your results and the predictions? How does this lab relate to independent assortment in meiosis?

3. You have two sample sizes here: your samples of 4 children in each family, and your total of 16 children. Which one more accurately matches the predictions based on the Punnett square? How do you think your results would compare to the predictions if you had a group of 100 children?

Lab

Complete Lesson 6 Lab: Modeling Meiosis. This lab expands upon the modeling you did in the previous lesson.

FOR ENROLLED STUDENTS

Notify your teacher when lessons 5 and 6 are ready for review. If you have any questions, please let your teacher know.

Name _____

Modeling Meiosis

In this lab, you will use the same materials that you used for the Mitosis Modeling lab in the previous lesson, but you will increase the number of chromosomes you are working with to represent homologous chromosomes.

The Guiding Question

How can we create a model to demonstrate meiosis?

Materials

- pipe cleaners, 2 each of four different colors
- yarn
- wooden beads

If you used food items in the last lab, you certainly may use them again, but you need to come up with two more pairs of sister chromatids that are distinguished somehow from the others. They can be different sizes, as before.

Before You Begin

Review the stages of meiosis as illustrated on pages 164–165 of your textbook. Note that you will also be modeling crossing over, so review how that works.

Procedure

1. Take each pair of chromatids, and connect them at the centromere as before. You will have four pairs of chromatids, each pair being a different color.
2. Decide which two colors are chromosomes from the father, and which are from the mother. Make a note of this.
3. As you model prophase I and the homologous chromosomes pair up, be sure each pair of homologous chromosomes has one from the father and one from the mother.

4. During prophase I, crossing over happens. You need to model this. There are several ways to do this. Note: Be sure that your sister chromatids are in every way identical before crossing over starts!
    - You can cut a segment of pipe cleaner and exchange with a segment on the homologous chromosome.
    - You can have the end of each sister chromatid marked by wrapping with colored yarn. You then exchange some of the yarn pieces with those on the homologous chromosome.
    - The end of each sister chromatid should be marked with a labeled piece of paper (A, B, etc.). You can then exchange these labels with those on some of the homologous chromosomes.
5. Now continue with your model, demonstrating each phase of meiosis. You have two options for showing each phase in your lab write-up:
    - Draw and label each phase you model.
    - Photograph each phase, being sure to add labels either on the model when you take the pictures, or as captions on the photos.

Analyze and Conclude

1. How does the chromosome number of each of the four daughter cells compare to the original chromosome number?

2. Will all the gametes produced by one parent be identical?

3. When an egg and sperm fuse during sexual reproduction, the resulting cell is called a zygote. How many copies of each chromosome and each gene will be found in a zygote?

4. The pairing of the homologous chromosomes at the start of meiosis I is called ***synapsis***. How would the outcome of meiosis differ if synapsis did not occur? (It might be helpful to model this.)

Extension: Making Connections

Usually, when a scientist finishes a set of observations, many new questions come up. Think about meiosis and all of its phases, and come up with at least two questions that you could ask that could be explored with a model like yours. One way to think about it is with "what if" questions: What if this happened, or this didn't happen, or this happened differently, etc. Consider crossing over, independent assortment, and the infinite possibilities of genetic variation. Or you might consider a change in one of the phases. There are no wrong answers here, as long as it is something that you can test with your model. (A question like "How long does meiosis take?" is not testable with this model.)

Lesson 17 Taxonomy

> "Taxonomy (the science of classification) is often undervalued as a glorified form of filing—with each species in its folder, like a stamp in its prescribed place in an album; but taxonomy is a fundamental and dynamic science, dedicated to exploring the causes of relationships and similarities among organisms. Classifications are theories about the basis of natural order, not dull catalogues compiled only to avoid chaos."
>
> **Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History***

ASSIGNMENT SUMMARY

- ☐ Read chapter 17, The Tree of Life (485–505).
- ☐ Answer four Comprehension questions.
- ☐ Complete four Critical Thinking questions.
- ☐ Choose one:
  - Activity: Library Taxonomy!
  - Activity: Taxonomy of Mythical Creatures
- ☐ Activity: Construct a Cladogram
- ☐ Lesson 17 Lab: Bioinformatics

This quotation says a lot and gives due credit to the sometimes tedious science of classification. It is often perceived as boring and, as mentioned above, dull. But let's look at it in a new light! We are now embarking on a new unit, which will guide us into our study that will take up the rest of the course: all the forms of life that exist on Earth. In order to make sense of the complex diversity of life, scientists have devised a system of classification to categorize it all. This topic builds on our study of evolution, and just as with evolution study, as new discoveries are made, the taxonomic system flexes and changes. Consider it like the fluid mosaic model that you learned about when studying cell membranes (78). There is nothing rigid in taxonomy; it is a fluid model that changes with each new input.

As you will recall, to study the relationships between species, biologists study anatomical and molecular features, among others, and organize them into categories, showing how they evolved through time. If you review the concept map you made about the evidence for evolution in lesson 10, you will see the same features that you will now read about in this chapter—the criteria used to classify organisms.

Plan to spend one week on this lesson.

Lesson Objectives

- Learn the Linnaean system of classification, and how it has been augmented and changed with new evolutionary analysis methods
- Practice using cladistics as a classification tool
- Use an online database to investigate evolutionary relationships using bioinformatics

Lesson 17 Assignments

Reading

Read chapter 17, The Tree of Life (485–505), in your textbook.

Comprehension

1. Come up with a mnemonic device to help you remember the seven levels of Linnaean classification, from kingdom to species. You can find many online, such as "Keeping Precious Creatures Organized For Grumpy Scientists," or "Keep Pond Clean Or Froggy Gets Sick." Check out some of these if you like, but then come up with one of your own that you will remember. If you like, you can include domains as well, for the total of eight modern levels of classification.
2. Describe the rules used in binomial nomenclature.
3. Choose a species that is not in the textbook, and list the eight levels of classification for that species, using proper nomenclature.
4. Describe the contribution of genetic research in reorganizing the classification structure of kingdoms, and the creation of domains.

Optional extra credit question:

What is cladistics? Describe how derived characters are used to determine evolutionary relationships.

Think About It

The father of the system of classification we use today is Carolus Linnaeus. He was so passionate about his work that he even changed his name from Carl to Carolus to make it into a Latin name. He even classified his private letters into groups and subgroups! Linnaeus at first didn't think that we really needed the species descriptor in addition to the genus, but later decided that it was very helpful. He had some groupings that now seem odd, such as placing the rhinoceros among the rodents. He also bravely suggested the relationship between humans and apes. This was a radical move in the 18th century.

Think about Linnaeus's contribution. Consider how such a "mistake" as the rhino/rodent grouping would add to the general understanding of the natural world. Somebody had to come along later, look at it with a skeptical eye, puzzle over it, collect new evidence, and reclassify the rhinoceros. This is science at work, and this is the fluid nature of the system described above. Can you think of anything you classify in your life and how your classification system changes as your knowledge and perspective change? Perhaps you classify people in a certain way, and perhaps you have a friend who sees them another way. What are your reasons for your system? Give this some thought and discuss it with your family, friends, or fellow students.

Critical Thinking

1. How is cladistics similar to the Linnaean system of classification? How are they different? Which system allows more room for revision as we learn more research techniques?
2. Which type of molecular clock would be most useful to examine the relationship between different species of the dog genus, *Canis*? Explain your choice.
3. Given the traditional definition of species according to the biological species concept, explain why it is difficult to classify members of Bacteria and Archaea at the species level. Look up the traditional definition of species in your glossary if you are not perfectly familiar with it, and review section 5.4 (140) before you form your response.
4. List some of the extreme environments that Archaea inhabit. It is thought that Archaea were some of the first life-forms on Earth. Explain how the first part of the question supports this theory.

Activities

Complete both of the activities, A and B.

A. Choose **one** of the following:

1. Library Taxonomy!

Go to the places in your home where you keep books. It is likely they are in some type of order so that a particular book can be found if need be. Look to see how they are categorized. For example, the books in your home might be divided into rooms (yours, your parents' room, the family room, etc.). In each location they might be grouped by subject (which ones are where?) or author. They might be grouped by size, which member of the family owns them, or any other type of classification. Describe the method used to categorize the books. Give an example of a particular book and tell how it came to be classified and placed where it is. (You may even want to use this as an opportunity to create order where there is none!)

2. Taxonomy of Mythical Creatures

For this activity, you will practice classifying organisms based on their characteristics. Use the following list of mythological organisms to complete the analysis (found below).

- **Pegasus** stands six feet tall, has a horse's body, a horse's head, four legs, and two wings.
- **Centaur** stands six feet tall, has a horse's body with a human torso, a male human head, and four legs.
- **Griffin** stands four to six feet tall, has a lion's body, an eagle's head, four legs, two wings, fur on its body, and feathers on its head and wings.
- **Dragon** can grow to several hundred feet, has a snakelike body, from one to three reptilelike heads, fur on its body and head, scales, and has the ability to breathe fire.
- **Chimera** stands six feet tall, has a goat's body, snake's tail, four legs, a lion's head, fur on its body and head, scales on its tail, and has the ability to breathe fire.
- **Hydra** is several hundred feet long, has a long body with four legs and a spiked tail, 100 snake heads, scales, and is poisonous.

Analysis:

1. Identify the characteristics that you think are the most useful for grouping the organisms into separate groups.
2. Classify the organisms into at least three groups based on the characteristics that you think are most important. Each creature should belong to only one group.
3. Review the biological species concept again. Explain whether this can be used to classify these mythical organisms.
4. Look up these other ways of defining species: ecological species concept, morphological species concept, and phylogenetic species concept. Which one did you use in this exercise? Would any of the others be useful with the information you have?

B. Construct a Cladogram

After reviewing figure 2.2 (495), complete the "Construct a Cladogram" quick lab (493). Draw the cladogram, and answer all three "Analyze and Conclude" questions. Include the cladogram with your lesson submission.

Lab

Perform Lesson 17 Lab: Bioinformatics. In this lab, you will be using bioinformatics to analyze the mtDNA of several land mammals, using the online database from the Dolan DNA Learning Center at the Cold Spring Harbor Laboratory in New York.

Name _____

Bioinformatics

In lesson 9, you learned about bioinformatics. Bioinformatics is the use of computer databases to store, organize, and analyze biological data. By comparing DNA sequences of different organisms, we can estimate how closely related they are. The more closely two organisms are related, the more similar their DNA sequences are. As you learned in this lesson, different types of DNA are used in comparisons. Mitochondrial DNA (mtDNA) changes at a faster pace than nuclear DNA, and is used to study relationships between closely related species. Nuclear DNA tends to degrade much faster than mtDNA. For that reason, forensic scientists have used mtDNA from hair, teeth, nails, and bone samples to solve many older cases.

The Guiding Question

How can bioinformatics be used to examine relatedness between species?

Hypothesize/Predict

Look at the data table below. Based on what you know about animal body structure, which was used in the past to determine species' relatedness, predict which pair of species in the data table you think are most closely related.

Procedure

1. Go to the Dolan DNA Learning Center website: http://www.dnalc.org/. Under "Websites" choose "Lab and Bioinformatics Sites," and then click on "BioServers." You can also go directly to the website here http://www.bioservers.org/bioserver/, but taking the roundabout route allows you to see the many other neat features of this resource.
2. Once you are on the BioServer website, click "Enter" under "Sequence server." Click on "Manage groups." This will open another window with some class data on it. Ignore that, go to the drop down menu at the top right, and choose "Non-human mtDNA." From there, select "Land mammal mtDNA" by checking the little box on the left, and click "OK" (not "View").

3. Now you will choose the four species that are in the data table below. You can get them all ready to compare by choosing each species in one of the drop down menus that come up each time you enter a species. Once you have all of them ready, select only two at a time to compare, as indicated by the data table. Once you select two, click "Compare" (not "Open").
4. A new window will open with the two sets of mtDNA sequences aligned for comparison. Change the number so it shows 1,000 per page ("Show ____ per page"). Then, select "Trimmed" and click on "Redraw."
5. You are now ready for counting! Where the mtDNA nucleotides do not match, they will be highlighted in yellow. There are also dashes where a nucleotide is not present in that position. If there is more than one dash in a row, count the entire run of dashes as a single difference. Count all the mismatches in this way, and write the total in the data table. Here is a sample set to make sure you are counting correctly.

C A T C A A C C C T T G C T C G T A A T G T C C C
C A T A – – – – – – T T A T G T A T A A T A – – – – –

T C T T C T C G C T C C G G G C C C A T A C T A A
– – – – – – – – – – – – G T A C A T A A A T T A A

There are 15 differences in these two lines. If you don't get 15 when you count them, reread the instructions and try again. Notice that the second line is a continuation of the first line, so the dashes in the first line continue right into the second, and should not be counted again (there are a total of only two differences due to missing nucleotides—dashes—in this sequence, one in the first line, and one in the first that continues to the second).

6. Record the number of base pairs shown for each comparison in the second column of the data table. This is the number that you see in bold print immediately above the data set: "Showing ___, starting from __ and ending at __."
7. Calculate the percentages of differences for each two species, and record that number in the table.

Percentage difference = (number of differences/number of base pairs) x 100

Name _____

Biology—Lesson 17 Lab: Bioinformatics

Data Table: mtDNA Comparisons

mtDNA types compared	Number of differences	Number of base pairs	Percentage
Dog #1 and European brown hare #1			
Dog #1 and Sika deer #1			
Lipizzan horse #1 and European brown hare #1			
Lipizzan horse #1 and Sika deer #1			

Analyze and Conclude

1. Which two species in the table share the most recent common ancestor, based on these data? Do your data match your prediction?

2. Which two species are the most distantly related, based on these data?

3. Notice that both of the above questions have the caveat "based on these data." Mitochondrial DNA is very useful in determining evolutionary relationships, but it is not the only type of molecular evidence. Describe two other types of molecular evidence that can be used to investigate evolution.

4. If you were to compare the mtDNA of the Lippizan horse and a dog, you would find only a 16% difference. Infer what this means about using mtDNA evidence alone when determining species relationships.

Extension: Making Connections

Choose some other species to compare or different organisms within the same species (there is room in the data table for two more). Human mtDNA is interesting. Spend five to ten minutes looking at a few more comparisons, and summarize what you find.