Biology
The Study of Life

Oak Meadow
Teacher Manual

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Introduction

In Oak Meadow Biology, students are encouraged to consider science as a verb, not a noun, as an active exploration rather than a static body of previously-discovered knowledge. Science is questioning, wondering, examining, and imagining: What would happen if. . . ? Why does. . . ? How can. . . ? Science is observing and measuring, guessing what might happen, and then watching and recording what does happen. Science is always attempting to answer questions about our world.

Before the first lesson begins, students are directed to this video, which helps them consider the far reaching implications of biology, the study of life:

> "Introduction to Biology" (Gregorio, YouTube) https://www.youtube.com/watch?v=7L7x0BAqWis

This course puts into practice a major shift in science education. Communication and collaboration is becoming more and more important, as scientific advancement has increasingly global implications. Science is no longer a bunch of facts to learn. Information is widely available. It is more important for students to understand broader concepts and how they are interconnected.

The textbook for this course is *Holt McDougal Biology: Student Edition 2015* (Houghton Mifflin Harcourt) and the Oak Meadow Biology lab kit is required. In addition, other household materials will be needed. You will find a full materials list (sorted according to lesson) and the lab kit list in the appendix of the student coursebook. This will help you and your student plan ahead so that all the necessary materials are on hand when needed.

In this teacher manual, you will find the full text for all assignments and activities, and partial text for the labs (for the full lab text, see the student coursebook). Teacher manual answers are seen in color. If more information is needed about any assignment, you can refer to the textbook or additional reading material in the student's coursebook.

The questions in the coursebook are designed to be answered using information from the textbook readings. No additional research is needed unless otherwise stated. In fact, though students can be tempted to look up answers online, this is strongly discouraged, as it often takes the material out of context and does not contribute to a solid understanding of the material.

Students may choose to find online videos to help explain some of the topics. There are many great videos available, and several are included in these lessons. Watching these is encouraged if it helps a student to visualize a concept.

Note that occasionally student answers may differ from what is in this manual. An example is the modeling labs in lessons 5 and 6. If the student models a different number of chromosomes, the analysis answers may differ slightly. These answers are assuming the student follows the instructions exactly.

If you are homeschooling independently, this teacher manual can serve as your support as you guide and evaluate your student's work. When a student gets a factual answer wrong, you can share the correct answer and address any underlying misconceptions. The focus should always be on the learning process rather than on a sense of judgement. Several incorrect answers related to a particular topic point to an area the student will benefit from revisiting.

For obvious reasons, it is best not to share this teacher manual with your student. Each student is expected to produce original work, and any incidence of plagiarism should be taken very seriously. If you notice a student's answers matching those of the teacher manual word for word, a discussion about plagiarism and the importance of doing original work is necessary. While students in high school are expected to be well aware of academic honesty, some confusion may exist, so any discussion about it should be approached as a learning opportunity. Make sure your student is familiar with when and how to properly attribute sources.

We encourage you and your student to explore the topics introduced this year through dynamic exchanges of ideas, relevant field trips, viewing and discussing films and videos related to course topics, and in other active, experiential ways. We hope this course leads your student into a better appreciation of science and how scientific inquiry can enhance our understanding of the wider world.

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!

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

For this section, your student may want to discuss the topics presented with you, with other adults, or with peers. If you have the opportunity to have a discussion with your student, you might encourage alternative points of view by playing devil's advocate, or you might question your student's ideas, asking him or her to express these ideas with logic and evidence to support them. Be prepared to model giving support to your own argument as well.

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.)

   Species diversity is the variety and number of species in a given area. Genetic diversity refers to the variety of genes present in a population of a species; the higher the genetic diversity, the more stable (less vulnerable to disruption) the population is. Ecosystem diversity is the variety of ecosystems in an area. (Information on this topic is found on page 5 of the textbook. You'll see page numbers after most of the answers that will give you a textbook reference.)

2. If you were to determine if an organism is alive, what characteristics would you look for?

   Students may describe any of the characteristics of life found on pages 5–6: cells, use of energy, responsiveness, and reproduction and development.

3. Homeostasis is an important biological theme. Explain what homeostasis is, and give an example.

   Examples will vary, and may include body temperature, blood sugar, acidity, etc., or a home thermostat or cruise control in a car. Homeostasis is the maintenance of constant internal conditions in an organism. (9)

4. How does natural selection lead to adaptation?

   In natural selection, individuals with favorable traits survive better and are more likely to reproduce, which passes on the favorable genes to the next generation. Gradually, the makeup of the population changes and adaptation has occurred. Adaptation and evolution are constantly occurring. (10)

5. What is the importance of peer review in science?

   Peer review ensures that the methods and data collection have been carried out using good, unbiased science practices, and that the conclusions reached are valid and unbiased. It is an important part of the scientific process. (14–15)

6. Differentiate between an independent variable and a dependent variable, and explain the purpose of a control group in a scientific experiment.

   An independent variable is manipulated; a dependent variable is measured, and changes in response to the independent variable. A control group is important to determine if the independent variable is actually the cause of the results. The control group is not exposed to the independent variable being studied. It is necessary for comparison. (16)

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.

   A TEM (transmission electron microscope) would be best, because it shows the interior of a specimen at high magnification. (20–21)

8. Describe two potential benefits and two potential risks of biotechnology.

   Benefits: prevention and treatment of disease and illness, solving crimes, solving modern problems, improving crop growth and insect resistance. Risks: ethical concerns, potential safety issues or negative environmental effects of genetically modified crops. (26)

Critical Thinking

1. Describe a system that is part of your everyday life. It does not have to be related to biology.

   Answers will vary. Students may describe their family, their household, their body, etc. A system is an organized group of related parts that interact to form a whole.

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?

   The hairs of the polar bear are hollow and thick, which aids insulation. The transparency allows the heat from the sun to get through to the black skin, which absorbs the heat well. This is a perfect example of structure and function working together to keep the bear warm.

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.

   A scientific theory is supported by a wide range of evidence acquired through experimentation. In the everyday sense, a theory is just a guess. Students' examples will vary, but should reflect that understanding. (16)

4. Answer question #2 on the Standards Based Assessment on page 31 of your textbook.

   C—the fertilizer has a greater effect in Soil 2.

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.

Students should be able to list several medical imaging techniques: ultrasound (to view an unborn baby), X-ray imaging (dental X-rays, broken bones, etc.), MRI (other injuries), CT scan (internal injury, abnormalities), PET scan, etc. Even microscopes are used to examine cultures (i.e. throat culture). While an electrocardiogram (EKG or ECG) does not take a picture, the data collected are mapped and graphed, and could be considered medical imaging. This is also true for EEG. The purpose of this is for the student to become aware of the amazing array of imaging technology that is available.

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.

1. The jackals appear to be playing; they look young; they appear healthy.
2. There are five jackals in the group; two jackals are lying down; one jackal is on its back.
3. Answers will vary. Observation of many dolphins (or dolphins captured on photos), recording the number of each color; recording play behavior and how often each behavior is exhibited; skin can be examined more closely, and the skin of many dolphins can be compared.

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.

Answers will vary depending on the experiment the student chooses. All the steps of a scientific investigation should be followed. Variables should be identified.

Lab

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

Walking Crooked!

The Guiding Question

Can a blindfolded person walk in a straight line?

Analyze and Conclude

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

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!

Students are asked to record their data on the data table titled "Measuring Deviations from the Straight Line When Blindfolded." Students will likely notice that nobody walks straight, even if they try. The goal of this activity is for the students to have fun while observing an unexplained phenomenon of the human body, and to come up with questions. Any questions are welcomed, and students will not be penalized for questions that seem silly. Additional questions are listed as a guide to get students thinking. It is not an exhaustive list, by any means.

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

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.

   Homologous chromosomes are chromosomes with a similar structure and genes for the same traits, but the genes might not be identical. Sister chromatids are the two halves of a

duplicated chromosome. They are exact copies, and are attached at the centromere. (159, 163)

2. The Y chromosome has the smallest number of genes. Do you have that chromosome?

   Only males have it, so answers will vary depending on the gender of the student.

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.

      Anaphase II

   b. In what ways are the chromosomes in telophase I of meiosis different from those in telophase of mitosis?

      In telophase I of meiosis, the sister chromatids have not yet separated. In telophase of mitosis, the sister chromatids have separated, forming single chromosomes.

   c. In which division of meiosis do the cells become haploid?

      In the first division, meiosis I (164–165)

4. Who was Gregor Mendel? (Write no more than two sentences.)

   Gregor Mendel was the "father of genetics." He laid the groundwork for genetics, discovering patterns of inheritance. (167)

5. Why were pea plants a good choice for Mendel's experiments?

   Pea plants were good to use because they reproduce quickly, mating was easily controlled, and their traits exist in two clearly distinct forms. (168)

6. Apply the terms ***homozygous***, ***heterozygous***, ***dominant***, or ***recessive*** to describe plants with the genotypes PP and Pp.

   PP is homozygous dominant, and Pp is heterozygous.

7. Identify the phenotypes of rabbits with the genotypes Bb and bb, where B = black fur and b = brown fur.

   The Bb rabbit is black, and the bb rabbit is brown.

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.)

   Students will draw Punnett squares. The phenotypic ratio is 3 freckles:1 no freckles. The genotypic ratio is 1FF:2Ff:1ff. (173)

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.

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.

   Students are encouraged to use Punnett squares because the results are easily visible. The two crosses will be RR x rr and Rr x rr. In a testcross, the parent with the unknown genotype is crossed with a recessive genotype (rr, wrinkled seed plant). If the offspring are all round seeded, the parent is most likely RR. If the parent is Rr, about half of the offspring will have wrinkled seeds. (175)

10. Define the law of independent assortment.

    The law of independent assortment states that different traits are inherited separately. Allele pairs separate independently of each other during meiosis. (176)

Critical Thinking

1. Do you think the Y chromosome contains genes that are critical to an organism's survival? Explain your reasoning.

   No, because females don't have a Y chromosome, and they survive just fine!

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?

   human: 2n = 46, n = 23

   dog: 2n = 78, n = 39

3. Why is it important that gametes are haploid cells?

   Two gametes fuse to form a new organism. Joining haploid gametes results in a new organism with the correct diploid number of chromosomes.

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.

   Mendel observed the inheritance of certain either/or traits and questioned how they were inherited without becoming diluted. He hypothesized that he could learn more by selectively breeding plants and observing the offspring. He tested his hypothesis, crossing large numbers of plants. He analyzed his data carefully, looking for patterns and ratios, and continued to verify it by testing other traits in pea plants. (This is a tricky question, but it encourages the student to notice the scientific process, in one of its variations, at work.)

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?

   Dominance means that an allele is expressed if it is present, and it masks any recessive alleles. A recessive allele will only be expressed if two copies are present. Dominance does not mean that the trait is more common, or that it is better or stronger! This is a common misconception. Polydactyly is a dominant trait, but the allele is rarely found in populations. (171)

6. If crossing over were to happen on sister chromatids during meiosis, would it increase genetic diversity? Explain your response.

   No, sister chromatids are identical to each other, so there would be no change with crossing over.

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.

Students will perform the activity, and fill in the data chart. This is good practice with the repetitive nature of collecting data, as well as calculating probability.

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.

   Answers will vary. It is likely that the results for each individual family will vary from the predictions. For the total, the results may be a little closer, but likely will still show some variation.

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

   Differences are because the results are random. The result of each coin toss is not affected by any other coin toss. The same is true with independent assortment. Also, there is no predicting which sperm will fertilize which egg in nature; this is another source of variation.

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?

   The larger group should more accurately match the predictions. A sample size of 100 will yield results even closer to the predicted pattern.

LAB 6

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.

Students will model meiosis, sketching or photographing each phase of meiosis I and II. There will be 8 phases in total.

Analyze and Conclude

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

   Each of the four daughter cells will have half the original chromosome number (they will each have 2 chromosomes).

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

   No, the gametes will not be identical because of crossing over and independent assortment.

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?

   There will be two copies of each chromosome and each gene in a zygote; the zygote is diploid.

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.)

   If synapsis did not occur, there would be no crossing over, resulting in less recombination and genetic variation. Also, the homologous chromosomes might not separate properly in meiosis I. Synapsis ensures that each new cell will get one member of each pair of homologous chromosomes.

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.)

Students' questions will vary. Hints are given to help the student along. Here are some samples, though there are many more possibilities:

- What would happen if crossing over didn't occur?
- If the homologous chromosomes lined up differently in meiosis I, how would that affect the combination of chromosomes that the gamete receives from the mother and father?
- What would happen if cytokinesis didn't happen properly in one of the nuclei in meiosis II?
- What if crossing over happened two or three times in the same pair of homologous chromosomes?
- What would happen if anaphase I didn't work properly (or any of the other stages)?

Lesson 17 Taxonomy

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

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.

   Answers will vary.

2. Describe the rules used in binomial nomenclature.

   Each species has a two-part scientific name using Latin words. The genus contains physically similar related species. Genus names are capitalized, and species names are not. Both are either italicized or underlined. The species name never appears alone. (487)

3. Choose a species that is not in the textbook, and list the eight levels of classification for that species, using proper nomenclature.

   Answers will vary. Be sure all eight levels are listed, and the genus and species name are italicized and properly written.

4. Describe the contribution of genetic research in reorganizing the classification structure of kingdoms, and the creation of domains.

   Carl Woese researched rRNA in prokaryotes, and found two genetically different groups of prokaryotes. This split the kingdom Monera into the kingdoms Bacteria and Archaea. Since the cell wall chemistry of these two groups was so very different (more so than the differences between the other kingdoms), he proposed a higher level of distinction, and the three domains were created. (501–502)

Optional extra credit question:

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

Cladistics is a method of classifying organisms based on evolutionary relationships and common ancestry. Derived characters are traits that are shared by some species and are not in others. Species are organized by the numbers of derived characters they share. (493)

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?

   Both systems use similarities in organisms to classify them. They differ in that the Linnaean system uses physical similarities, and cladistics analyzes evolutionary relationships. Molecular evidence can be used in cladistics, thus it is the system that is likely to give the most current explanations.

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.

   Mitochondrial DNA would be most useful for determining the evolutionary relationships of closely related species such as this because the mutation rate in mtDNA is very fast. Also, it is not subject to recombination because it is only passed on from the mother, so the lines can be traced very accurately. (500)

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.

   A species is defined as a group of organisms that can interbreed and produce fertile offspring. Bacteria reproduce asexually by binary fission, not by breeding to produce offspring. Also, they often transfer genes among themselves outside of typical reproduction. (140, 503)

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.

   Archaea exist in deep sea vents, hot geysers, Antarctic waters, and salt lakes. Early Earth had extreme environments such as these. (502)

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!)

   Students will investigate and describe the organization system of books in their home. Encourage detail.

   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.

   Answers will vary.

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.

   Answers will vary. Students may group the creatures according to size, presence of wings, fire breathing, etc.

3. Review the biological species concept again. Explain whether this can be used to classify these mythical organisms.

   The biological species concept cannot be used to classify them without knowledge of their breeding compatibility with other groups.

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?

   The morphological species concept uses physical and anatomical features to classify organisms. The ecological species concept defines species as closely related organisms adapted to a single niche. The phylogenetic species concept defines species as organisms that have a shared and unique evolutionary history. The morphological species concept was used, and is the only one possible with the information given.

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.

1. The derived characters are wheels, motor, passengers enclosed, and wings.
2. walking
3. Riding a bike will have an advantage for short distances, since it is not practical to board an airplane for a few miles.

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.

LAB 17

Bioinformatics

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.

Students will likely predict that the Lippizan horse and the Sika deer are most closely related because they are hoofed animals. They might also predict that the dog and hare are more closely related than other pairs.

Data Table: mtDNA Comparisons

mtDNA types compared	Number of differences	Number of base pairs	Percentage
Dog #1 and European brown hare #1	159	904	17.5%
Dog #1 and Sika deer #1	394	1000	39%
Lipizzan horse #1 and European brown hare #1	129	420	31%
Lipizzan horse #1 and Sika deer #1	121	719	17%

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?

   The Lippizan horse and the Sika deer share the most common ancestor, based on these data. The dog and the hare also show a close relationship.

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

   According to the data, the dog and the Sika deer are the most distantly related.

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.

   Scientists may compare rRNA, nuclear DNA, specific genes, and protein sequences.

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.

   Answers may vary. mtDNA evidence should be combined with other types of evidence, such as nuclear DNA, which might be better for studying distant relationships. mtDNA may be more useful for studying relationships within a species.

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.

Students will look at some other pairs of species and comment on their findings. Humans have very few differences in mtDNA.