oak meadow
INDEPENDENT LEARNING SINCE 1975

Biology with Lab

This comprehensive full year lab course introduces students to modern biology. Students will be actively engaged through textbook readings, exploring current research and events, conducting research projects, analyzing and interpreting data, developing creative projects, and conducting lab experiments. Scientific reasoning and critical thinking skills will be developed throughout, with an expanded focus on scientific inquiry, requiring students to ask questions and construct explanations. The course also emphasizes communicating ideas both verbally and in writing, and practicing scientific argumentation among peers and adults.

Course topics include:

- cell structure and growth
- genetics
- biotechnology
- evolution
- ecology
- ·classification
- plant life cycles
- animal biology
- plant biology
- human biological systems

In addition to the coursebook, the following materials are included in this course:

Holt Biology (2012)

Oak Meadow Biology Lab Kit

There is no teacher manual available for this course at this time.

Biology

Oak Meadow
Coursebook

Oak Meadow, Inc.
Post Office Box 1346
Brattleboro, Vermont 05302-1346
oakmeadow.com

Item #09181

Contents

Lesson 6 Meiosis and Introduction to Mendelian Genetics

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 both of my 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!

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

Lesson 6

(continued)

- 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. What is the smallest chromosome in human cells? Do you have that chromosome?
3. Examine the steps of meiosis and name the stage of meiosis during which sister chromatids are separated to opposite poles of the cell. In what ways are the chromosomes in telophase I of meiosis different from those in telophase of mitosis? 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 coat and b = brown coat.

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 in 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.

Lesson 6

(continued)

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, 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 you 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 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 the 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. Explain how the trait of polydactyly can be a dominant trait. Look at the figure 4.1 (171) and use your understanding of dominance and recessivity in your explanation.
6. If crossing over were to happen on sister chromatids during mitosis, would it increase genetic diversity? Explain your response.

Activities

Complete the following activity.

1. Coin Toss Genetics

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

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.

Lesson 6

(continued)

Activity: Coin Toss Genetics

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 a mating 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 either find someone to "mate" with, or you can do this 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 four 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 probability of each genotype in your population of 16. Record this in the data table as a percent.
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			
Probability (as a percent)			
Predictions based on Punnett square (fraction and percent)	¼–25% 1 child		

Lesson 6

(continued)

Analysis

For each family of four 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.

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

You have two samples sizes here: your samples of four 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?

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.

Problem

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.
    - You can have the end of each sister chromatid marked with a labeled piece of paper (A, B, etc.). You 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 the four daughter cells compare to the original chromosome number?

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

Biology—Lesson 6 Lab
Modeling Meiosis

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.)

Biology—Lesson 6 Lab
Modeling Meiosis

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*

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.

ASSIGNMENT SUMMARY

- ☐ Read chapter 17, The Tree of Life (485–505).
- ☐ Begin your semester review in preparation for the exam in lesson 18.
- ☐ Answer five comprehension questions.
- ☐ Complete four critical-thinking questions.
- ☐ Activity: Library Taxonomy! or,
- ☐ Activity: Taxonomy of Mythical Creatures; or
- ☐ Activity: Construct a Cladogram
- ☐ Lesson 17 Lab: Bioinformatics

Lesson 17

(continued)

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

Assignments

Reading

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

Begin your semester review in preparation for the exam in lesson 18. In lesson 18, you will be taking a test on the material covered so far in the course. Begin reviewing the material this week. More guidelines for this are found in lesson 18, so you may want to read ahead.

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. What is cladistics? Describe how derived characters are used to determine evolutionary relationships.
5. Describe the contribution of genetic research in reorganizing the classification structure of kingdoms, and the creation of domains.

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 has 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

Lesson 17

(continued)

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 the second.

Activities

Choose **one** of the following activities to complete.

A. 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!)

B. 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 snake-like body, from one to three reptile-like 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 only belong to 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?

C. 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.

Lesson 17

(continued)

FOR ENROLLED STUDENTS

If you have any specific material that you'd like help with before you take your semester test, please communicate with your teacher. Use your teacher's lesson feedback to help you focus on areas that you may need to study with care in your semester review.

Name _____

LAB 17

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?

Hypothesis/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/ Click on "Websites" in the menu bar, and then choose "Bioservers." From there, click on the *bioservers.org* website. 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 1000 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-second).

6. Record the number of base pairs shown for each comparison in the second column of the data table.
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 Sitka deer #1			
Lipizzan horse #1 and European brown hare #1			
Lipizzan horse #1 and Sitka deer #1			

Analyze and Conclude

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

_____

_____

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

_____

_____

3. Notice that both of the above questions have the caveat "based on this 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.