Biological Molecules

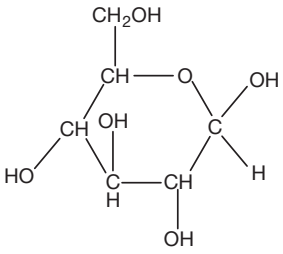
What are the building blocks of life?

Why?

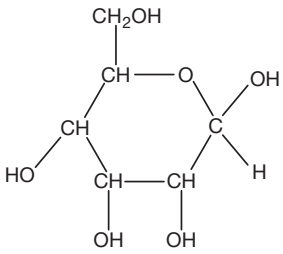
From the smallest single-celled organism to the tallest tree, all life depends on the properties and reactions of four classes of **organic** (carbon-based) compounds—**carbohydrates**, **lipids**, **proteins**, and **nucleic acids**. These organic molecules are the building blocks of all living things, and are responsible for most of the structure and functions of the body, including energy storage, insulation, growth, repair, communication, and transfer of hereditary information. Simple organic molecules can be joined together to form all the essential biological molecules needed for life.

Model 1 – Molecules of Life

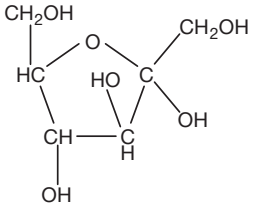
Carbohydrates (monosaccharides)



Glucose

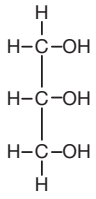


Galactose

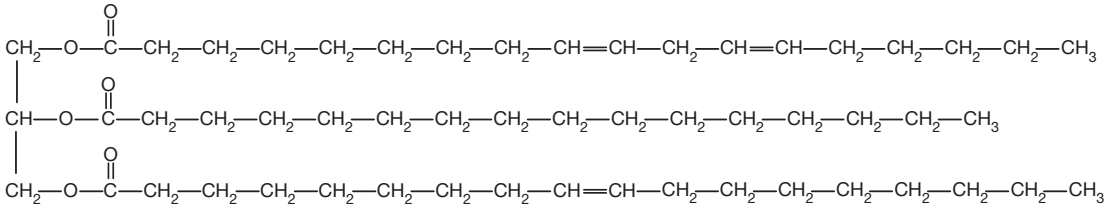


Fructose

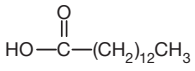
Lipids

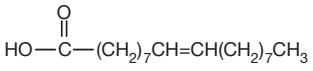


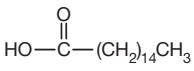
Glycerol



Triglyceride (fat or oil)

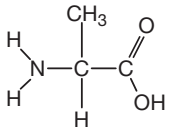




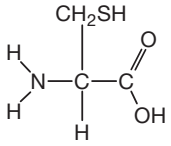


Fatty acids

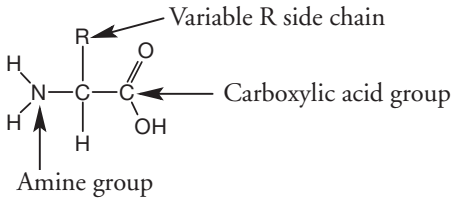
Proteins (amino acids)



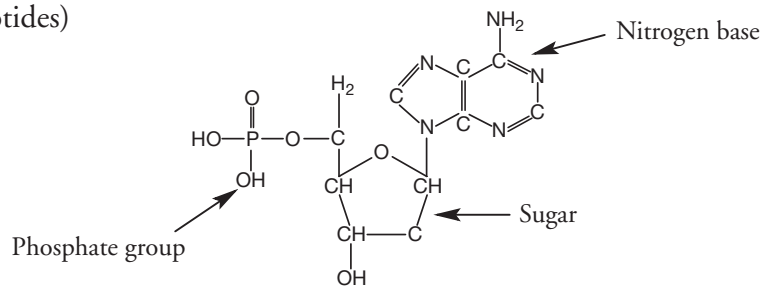
Alanine



Cysteine



Nucleic acids (nucleotides)



1. Use Model 1 to show which atoms are present in each type of molecule by listing the symbol for each atom included. Carbohydrate has been done for you.

   a. Carbohydrate— C, H, O

   b. Lipid—

   c. Amino acid—

   d. Nucleic acid—

2. Which type of molecule includes an example with a long-chain carbon backbone?

3. In the molecule referred to in the previous question, what is the dominant element attached to the carbon backbone?

4. The fatty acid chain of the lipids is often referred to as a hydrocarbon chain. Discuss with your group why the chain is given this name and write a one-sentence definition for a hydrocarbon.

5. Which molecule has a central carbon atom with four different components around it?

6. Which molecule has a sugar, nitrogenous base, and phosphate group?

7. Discuss with your group members some similarities among all four types of molecules. List as many as you can.

8. What is the chemical formula of the first carbohydrate molecule shown?

9. What three structural groups shown do all amino acids have in common?

10. There are 20 naturally-occurring amino acids, and each one only varies in the structure of the R side chain. Two amino acids are shown in Model 1. What are the R side chains in each?

Read This!

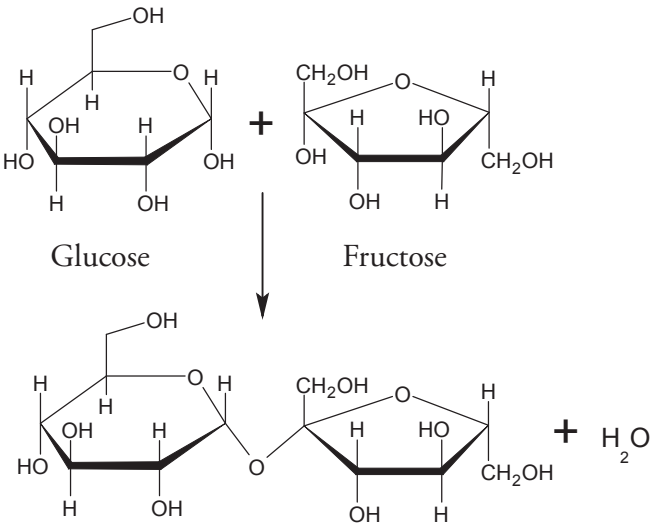
During chemical reactions, the bonds in molecules are continually broken and reformed. To break a bond, energy must be absorbed. When bonds are formed, energy is released. If more energy is released than absorbed during a chemical change, the process can be used as a source of energy. A general rule for processes such as respiration is the more carbon atoms there are in a molecule, the more energy that molecule can provide to the organism when it is used as food.

11. Using the information from above, is a carbohydrate or a lipid more likely to be a good source of energy for an organism?

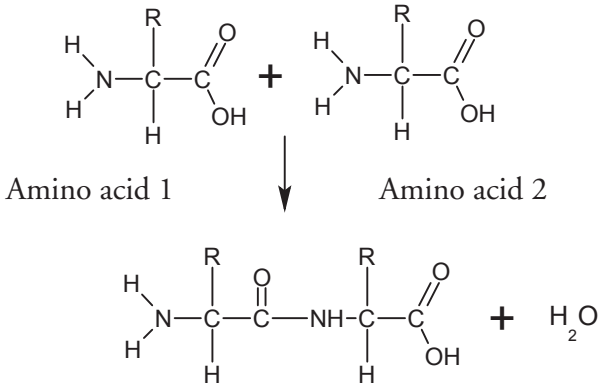
STOP

Model 2 – Biochemical Reactions

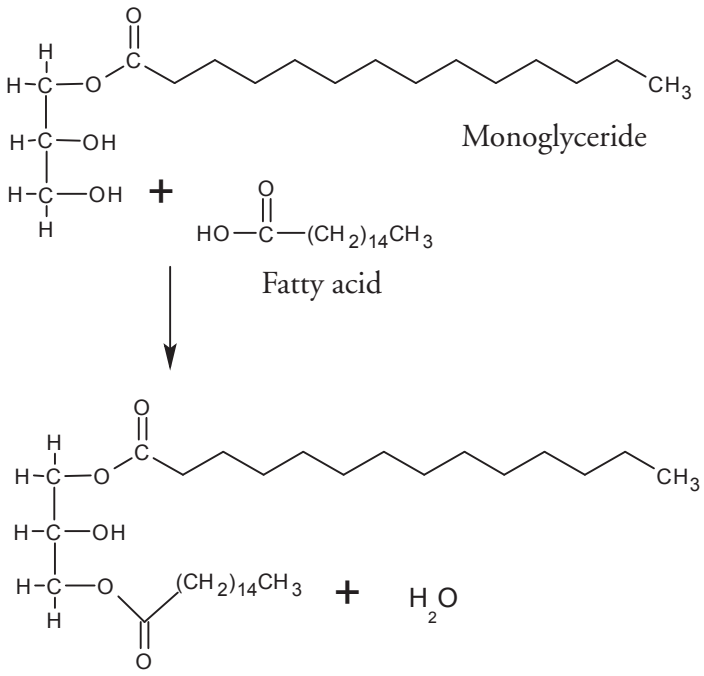
A.



B.



C.



12. What are the reactants of reaction A?

13. What are the products of reaction A?

14. Each of the reactants in reaction A is a single sugar molecule, also called a monosaccharide. What prefix before saccharide would you use to describe sucrose?

15. What are the reactants of reaction B?

16. When the two molecules in reaction B are joined together, what other two molecules are produced?

17. What product do all three reactions in Model 2 have in common?

Read This!

When sugars are joined together the new bond that forms is a **glycosidic** bond. When amino acids are joined the new bond that forms is a **peptide** bond. When fatty acids are joined to a glycerol the bond that holds them is an **ester** bond.

18. On the diagrams in Model 2, circle and label the glycosidic, peptide, and ester bonds.

19. These reactions are all referred to as **dehydration synthesis** or condensation reactions. With your group develop an explanation for why these terms are used to describe these reactions.

20. These reactions can also be reversed, breaking the large molecule into its individual molecules. What substance would need to be added in order to reverse the reaction?

21. *Lysis* means to split or separate. What prefix would you add to lysis to mean separate or split using water?

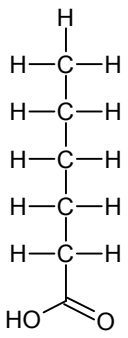
22. Using your answers to the previous two questions, what word is used to describe the reaction that uses water to break apart a large molecule?

Extension Questions

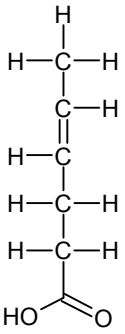
23. Metabolism is the collective term used to describe all the chemical reactions taking place inside living organisms. Why is water so important for metabolic reactions?

24. We store excess food in our body either in the form of carbohydrates (in muscles and the liver) or as fat (adipose tissue). When our body needs additional energy it uses the carbohydrate source first as a source of "quick" energy, then the fat. Why do you think carbohydrates are used as a source of quick energy rather than fat? Use complete sentences and scientific terminology in your response.

25. Look at the two types of fatty acids below, saturated and unsaturated. What is the difference between the two?



Saturated Fatty Acid



Unsaturated Fatty Acid

26. Saturated fats are solid fats, like the animal fats lard and butter, whereas unsaturated fats are more fluid and form oils, such as vegetable oil. Trans fats are plant oils that are artificially solidified to make them suitable for baking purposes. In recent years trans fats have been associated with negative health issues and are not as widely used. Explain in simple molecular terms what would have to be done to a plant oil to transform it to a trans fat.

BIO FAX!

FLINN SCIENTIFIC
"Your Safer Source for Science"

P.O. Box 219 • Batavia, IL 60510
(800) 452-1261 • Fax (866) 452-1436
www.flinnsci.com • E-mail: flinn@flinnsci.com

Catalog No. FB2199

Publication No. 11339

Sno-ball Sillies—Genetics Simulation

Student Laboratory Kit

Introduction

As a *naturalist*, a student of natural history, you are studying organisms of the Amazon Rainforest. On an expedition, you discovered a colony of a new species—dubbed the "sno-ball sillies" due to their snow ball-shaped bodies—which has yet to be identified. Wanting to know as much as you can about this new species, you bring a male and female back to your research lab to breed them and learn about their traits.

Concepts

- Alleles
- Chromosomes
- Genotype vs. phenotype
- Meiosis
- Dominant and recessive

Background

The discovery of a new species is a time of excitement and questions. For example, *Microhyla laterite*, a new species of frog discovered in Manipal, India, in 2016 led researchers on an exhilarating adventure to determine whether this tiny frog, which can sit on the tip of your thumb, was in fact, a new species. Finally, through genetic analysis it was confirmed to be an unknown species. The frog's scientific name came from its narrow mouth (*Microhyla*) and the habitat where it was found, *laterite*—a rocky terrain of iron-rich, weathered soil.

Examining an organism at the cellular level shows that almost all cells have the same number and type of chromosomes. For example, a human body cell has 46 chromosomes. Each chromosome matches up to make a pair that is similar in shape and size. These are called *homologous chromosomes* (see Figure 1) and are inherited from the parents. One is inherited from the mother and one is inherited from the father. Each homologous chromosome in a pair carries the same sequence of genes which encode for traits. However, the version of the gene, called an *allele*, found on one homologous chromosome does not always match the other. Alleles generally are either *dominant* or *recessive*. A *genotype* represents the alleles contained in the gene of a homologous pair and can only be determined through laboratory testing, whereas a *phenotype* is the observable characteristic. A dominant phenotype only requires the presence of one allele in order for the trait to be observable, regardless of the other allele present. Recessive phenotypes require the presence of two copies of the same allele. For example, the gene for freckles is on chromosome 16 (see Figure 1a). The alleles present determine whether or not a person has freckles (dominant) or no freckles (recessive). Looking at Figure 1, one chromosome carries the dominant allele (F) for freckles and the other carries the recessive allele (f) for no freckles. In this person, freckles will be seen in the phenotype because the dominant allele hides or masks the recessive allele.

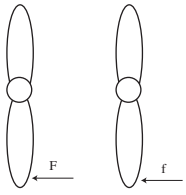


Figure 1a. Chromosomes

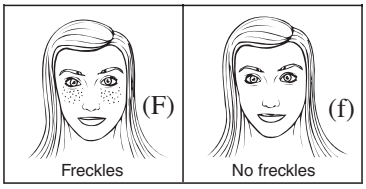
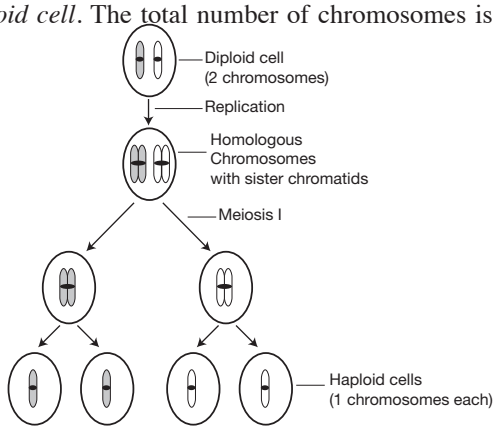


Figure 1b. Phenotype

Humans have 23 homologous pairs of chromosomes. In females, all 23 match in size and shape. In males, however, one pair does not match. The two chromosomes that do not match are the X and Y, or *sex chromosomes*. Not all species follow this pattern. For example, in birds, snakes and some insects, females carry the mismatched chromosome pair while males carry the identical pair.

IN11339
120916

A cell that contains two homologous sets of chromosomes is knows as a *diploid cell*. The total number of chromosomes is known as the *diploid number*. In humans, a diploid cell has 46 chromosomes. Sex cells, or *gametes*, are not diploid cells. Sperm cells and egg cells each have a single set of chromosomes, one from each homologous pair. They are known as *haploid cells* and are produced through the process of *meiosis*.



Meiosis is the type of cell division that occurs in reproductive tissues. During meiosis two cellular divisions occur. In the first division, homologous chromosomes with two sister chromatids are separated, reducing the number of chromosomes. In the second division, sister chromatids are separated, just as they are in mitosis. During meiosis, the cells reduce their normal diploid chromosome number by half to create four haploid cells. By reducing the number to half, when *fertilization* (fusion of nuclei and cytoplasm from gametes resulting in a *zygote*) occurs, the number of chromosomes in the offspring return to the diploid number. Each offspring would have two homologous sets of chromosomes, one from each parent. Having haploid cells fuse rather than diploid cells prevents the doubling of chromosomes between generations, which would be detrimental.

Experiment Overview

Use your knowledge of meiosis and heredity to create an offspring from a mating pair of the new, unknown species. From the offspring created, determine the parents' genotypes.

Pre-Lab Questions

1. Each diploid cell of the new species contains 16 homologous chromosomes. How many chromosomes are present in each haploid cell?
2. Upon fertilization, how many chromosomes will the offspring possess?
3. Use a diagram to explain how the process of meiosis produces four haploid cells.

Materials

Plastic bag labeled DAD
Plastic bag labeled MOM
Chenille wire
Corks
Pop beads
Push pins, clear and colored
Screws, black and silver
Styrofoam balls
Toothpicks, plastic
Toothpicks, wooden

Safety Precautions

Pins are sharp; handle with care. Please follow all laboratory safety guidelines.

Procedure

Part A. Chromosome Sorting

1. Take the pink chromosomes out of the plastic bag labeled "MOM."
2. Put the chromosomes on the lab table with the letters face down.
3. Match the chromosomes as homologous pairs (matching size).
4. Randomly take one chromosome from each homologous pair. Place chromosomes NOT chosen back in the plastic bag.
5. Repeat steps 1-4 with the blue chromosomes in the plastic bag labeled "DAD."
6. Match the "MOM" chromosomes to the homologous "DAD" chromosomes (match size).

7. Flip the chromosomes over and fill in the table on the *Sno-ball Sillies Genetics Simulation* worksheet.
8. Return all the chromosomes to the correct plastic bags.
9. Obtain a Sno-ball Sillies Genetics Simualtion Decoder sheet from the instructor and determine the phenotype of the offspring. Fill in the correct phenotype on the worksheet.

Part B. Offspring Building

1. Using the materials provided, assemble the offspring according to the genotype selected in *Part A*.
2. Use wooden toothpicks to hold the body segments together and attach the humps. The toothpicks may be broken in half if needed.
3. After the offspring is assembled, draw the offspring on the worksheet. Used colored pencils or label the appropriate color when necessary.
4. Record the phenotype of each trait for the offspring on the class data worksheet on the board.
5. Fill in the Class Data table on the worksheet in your packet. This will be needed for the *Post-Lab Questions*.

Disposal

Consult your instructor for appropriate disposal procedures.

Name: _____

Sno-ball Sillies—Genetics Simulation Worksheet

Data Table – Offspring

Allele Letter	Trait	Allele from Mom	Allele from Dad	Offspring Genotype	Offspring Phenotype
A	Antenna				
H	Humps				
N	Nose Color				
T	Tail				
E	Eyes				
B	Body Segments				
L	Leg Color				
X or Y	Gender				

Offspring Sketch

Post-Lab Questions

1. How many unique offspring phenotypes were created in the class?
2. If any two looked exactly alike, did their genotypes match also?
3. Compare the offspring to the parents.

   a. Do any of the offspring look exactly like either of the parents?

   b. What would happen if it were possible for an offspring to inherit all of its chromosomes from one parent?

4. Choose another team's offspring to be a mate for your model. Select two of the traits and complete a Punnett square for each.

Trait:_____

Genetic Cross: _____ X _____

Offspring Genotypic Ratio:

Offspring Phenotypic Ratio:

Trait:_____

Genetic Cross: _____ X _____

Offspring Genotypic Ratio:

Offspring Phenotypic Ratio:

Name: _____

5. The following table includes the phenotypes of each parent. Using the class data of offspring, determine the genotypes for each parent's traits.

Trait	MOM Phenotype	MOM Genotype	DAD Phenotype	DAD Genotype
Number of Antenna	1		2	
Number of Humps	3		3	
Nose color	silver		black	
Tail shape	curly		straight	
Number of eyes	2		3	
Number of body segments	3		2	
Leg color	clear		colored	
Gender	female		male	

6. Is it possible for a mating pair of two-eyed Sno-ball Sillies to have offspring with three eyes? Explain your reasoning.

7. By random selection of one of two alleles for each of the eight traits, how many different varieties of offspring can be created? (*Hint:* If two forms for a trait exist, the possibilities are $2 \times 2 = 4$; if three traits exist, the possibilities are $2 \times 2 \times 2 = 8$).

8. If none of the offspring had three body segments, what might be inferred about the DAD's genotype for body segments? Can you be certain?

Phenotypes of Sno-ball Sillies Offspring

Trait	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8	Team 9	Team 10	Team 11	Team 12	Team 13	Team 14	Team 15
Number of Antenna															
Number of Humps															
Nose color															
Tail shape															
Number of Eyes															
Number of Body Segments															
Number of Leg Segments															
Feet Color															
Gender															

IN11339

Teacher's Notes

Sno-ball Sillies—Genetics Simulation

Materials Included in Kit (for 15 groups of students)

Chenille wires, 10
Corks, Size 00, 45
Dad chromosomes, blue, 16 sets
Mom chromosomes, pink, 16 sets
Plastic bags, 30
Pop beads, 100
Push pins, clear, 1 box
Push pins, colored, 1 box
Screws, black, 16
Screws, silver, 16
Styrofoam balls, 1-½″, 60
Toothpicks, plastic, 50
Toothpicks, wooden, 75

Additional Materials Needed *(for Pre-Lab Preparation)*

Scissors

Pre-Lab Preparation

1. Cut out enough sets of the pink (MOM) chromosomes for each student group and place into separate reclosable plastic bags. Label each bag "MOM."
2. Cut out enough sets of the blue (DAD) chromosomes for each student group and place into separate reclosable plastic bags. Label each bag "DAD."
3. Cut each chenille wire (tail) in half. There will be a total of 20 tails available for use.
4. Photocopy enough Sno-ball Sillies—Genetics Simulation Decoder worksheets for each student group to use after they have determined the offsprings' genotypes.

Safety Precautions

Remind students to use caution when handling sharp pins. Please follow all laboratory safety guidelines.

Disposal

Offspring can be dismantled and all items may be saved for future use or disposed of in the regular trash.

Lab Hints

- Enough materials are provided in this kit for 30 students working in pairs, or for 15 groups of students. Both parts of this laboratory activity can reasonably be completed in one 50-minute class period. The pre-laboratory assignment may be completed before coming to lab, and the data compilation may be completed the day after the lab.
- Copying and cutting out extra chromosomes is a good idea in case students lose or misplace chromosomes. This will prevent delay in future class periods. One extra set is provided.
- There are enough materials to build a "MOM" and "DAD" Sno-ball Silly to have on display in the classroom.

Teacher's Notes *continued*

Teaching Tips

- This activity is ideal as a review of heredity, meiosis, dominant and recessive traits, alleles, chromosomes and Punnett squares.
- A test cross is a breeding experiment with an organism of an unknown genotype associated with the dominant phenotype. This organism is mated to an organism that possesses the homozygous recessive phenotype. Based on the offspring, the unknown genotype can be inferred.

Answers to Pre-Lab Questions *(Student answers will vary.)*

1. Each diploid cell of the new species contains 16 homologous chromosomes. How many chromosomes are present in each haploid cell?

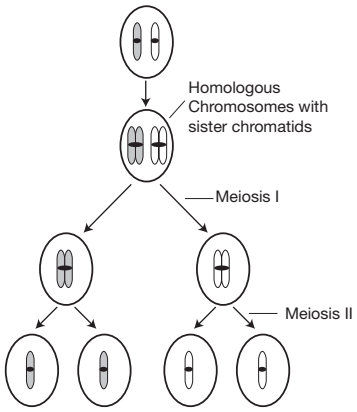
   Each haploid cell of the new species would have 8 chromosomes.

2. Upon fertilization, how many chromosomes will the offspring possess?

   After fertilization, the number of chromosomes would return to the diploid number of 16.

3. Use a diagram to explain how the process of meiosis produces four haploid cells.

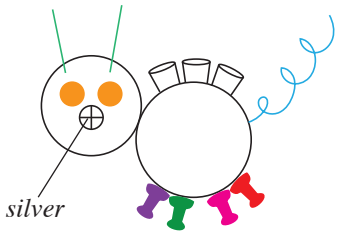
   The process of meiosis has two cellular divisions. In the first division, homologous chromosomes with two sister chromatids are separated reducing the number of chromosomes. In the second division, sister chromatids are separated just as they are in mitosis.



Sample Data Table *(Student data will vary.)*

Allele Letter	Trait	Allele from Mom	Allele from Dad	Offspring Genotype	Offspring Phenotype
A	Antenna	*a*	*a*	*aa*	*2 antenna*
H	Humps	*h*	*H*	*Hh*	*3 humps*
N	Nose Color	*n*	*n*	*nn*	*silver nose*
T	Tail	*T*	*t*	*Tt*	*curly tail*
E	Eyes	*E*	*e*	*Ee*	*2 eyes*
B	Body Segments	*b*	*B*	*Bb*	*2 body segments*
L	Leg Color	*l*	*l*	*ll*	*colored legs*
X or Y	Gender	*X*	*Y*	*XY*	*male*

Offspring Sketch



Answers to Post-Lab Questions *(Student answers will vary)*

1. How many unique offspring were created in the class?

   Data will vary. It is probable that there will be 15 unique offspring.

2. If any two were exactly alike, did their genotypes match also?

   Data will vary. It is unlikely that genotypes and gender will be identical.

3. Compare the offspring to the parents.

   a. Do any of the offspring look exactly like either of the parents?

   Student answers will vary, however, it is unlikely that an offspring will be identical to one parent.

   b. What would happen if it were possible for an offspring to inherit all of its chromosomes from one parent?

   If an offspring inherited all of the chromosomes from one parent, it would be an identical copy or a clone.

4. Choose another team's offspring to be a mate for your model. Select two of the traits and complete a Punnett square for each. *Student answers will vary. Example:*

   Trait: *Tail Shape*

   Genetic Cross: *Tt* X *Tt*

	T	t
T	TT	Tt
t	Tt	tt

   Offspring Genotypic Ratio: *1 TT: 2 Tt: 1 tt*

   Offspring Phenotypic Ratio: *3 curly: 1 straight*

   Trait: *Body Segments*

   Genetic Cross: *bb* X *Bb*

	B	b
b	Bb	bb
b	Bb	bb

   Offspring Genotypic Ratio: *0 BB: 2 Bb: 2 bb*

   Offspring Phenotypic Ratio: *2 two body segments: 2 three body segments or 1:1*

5. The following table includes the phenotypes of each parent. Using the class data of offspring, determine the genotypes for each parent's traits.

Trait	MOM Phenotype	MOM Genotype	DAD Phenotype	DAD Genotype
Number of Antenna	1	*AA or Aa**	2	*aa*
Number of Humps	3	*HH or Hh**	3	*HH or Hh**
Nose color	silver	*nn*	black	*NN or Nn**
Tail shape	curly	*TT or Tt**	straight	*tt*
Number of eyes	2	*EE or Ee**	3	*ee*
Number of body segments	3	*bb*	2	*BB or Bb**
Leg color	clear	*LL or Ll**	colored	*ll*
Gender	female	*XX*	male	*XY*

*Correct genotype based on chromosomes.

Teacher's Notes *continued*

6. Is it possible for a mating pair of two-eyed Sno-ball Sillies to have offspring with three eyes? Explain your reasoning.

   It is possible. If the two-eyed Sno-ball Sillies are both heterozygous for number of eyes, then even though they both have two eyes, they possess the allele for three eyes; it is just hidden by the dominant allele. If the offspring received the recessive allele from each parent, the offspring would have three eyes.

7. By random selection of one of two alleles for each of the eight traits, how many different varieties of offspring can be created? (*Hint:* If two forms for a trait exist, the possibilites are $2 \times 2 = 4$; if three traits exist, the possibilities are $2 \times 2 \times 2 = 8$).

   $2^8 = 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 256$ different varieties could be created.

8. If none of the offspring had three body segments, what might be inferred about the DAD's genotype for body segments? Can you be certain?

   It could be inferred that the DAD's genotype is homozygous dominant (BB); however, it cannot be certain. It is possible the DAD's genotype is Bb and the dominant allele was randomly selected for all the offspring.

The *Sno-ball Sillies—Genetics Simulation Student Laboratory Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
FB2199	*Sno-ball Sillies—Genetics Simulation Student Laboratory Kit*

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Sno-ball Sillies—Genetics Simulation Decoder

Trait	Body Part Material	Genotype/Phenotype
Antenna	Plastic toothpick	AA – 1 antenna Aa – 1antenna aa – 2 antenna
Humps	Cork stopper	HH – 3 hump Hh – 3 humps hh – 1 hump
Nose color	Screws, appropriate color	NN – black nose Nn – black nose nn – silver nose
Tail	Chenille wire	TT – curly tail Tt – curly tail tt – straight tail
Eyes	Pop beads	EE – 2 eyes Ee – 2 eyes ee – 3 eyes
Body Segments	Styrofoam balls	BB – 2 body segments Bb – 2 body segments bb – 3 body segments
Leg Color	Push pins, clear or colored	LL – clear Ll – clear ll – colored
Gender/Sex		XX – female XY - male

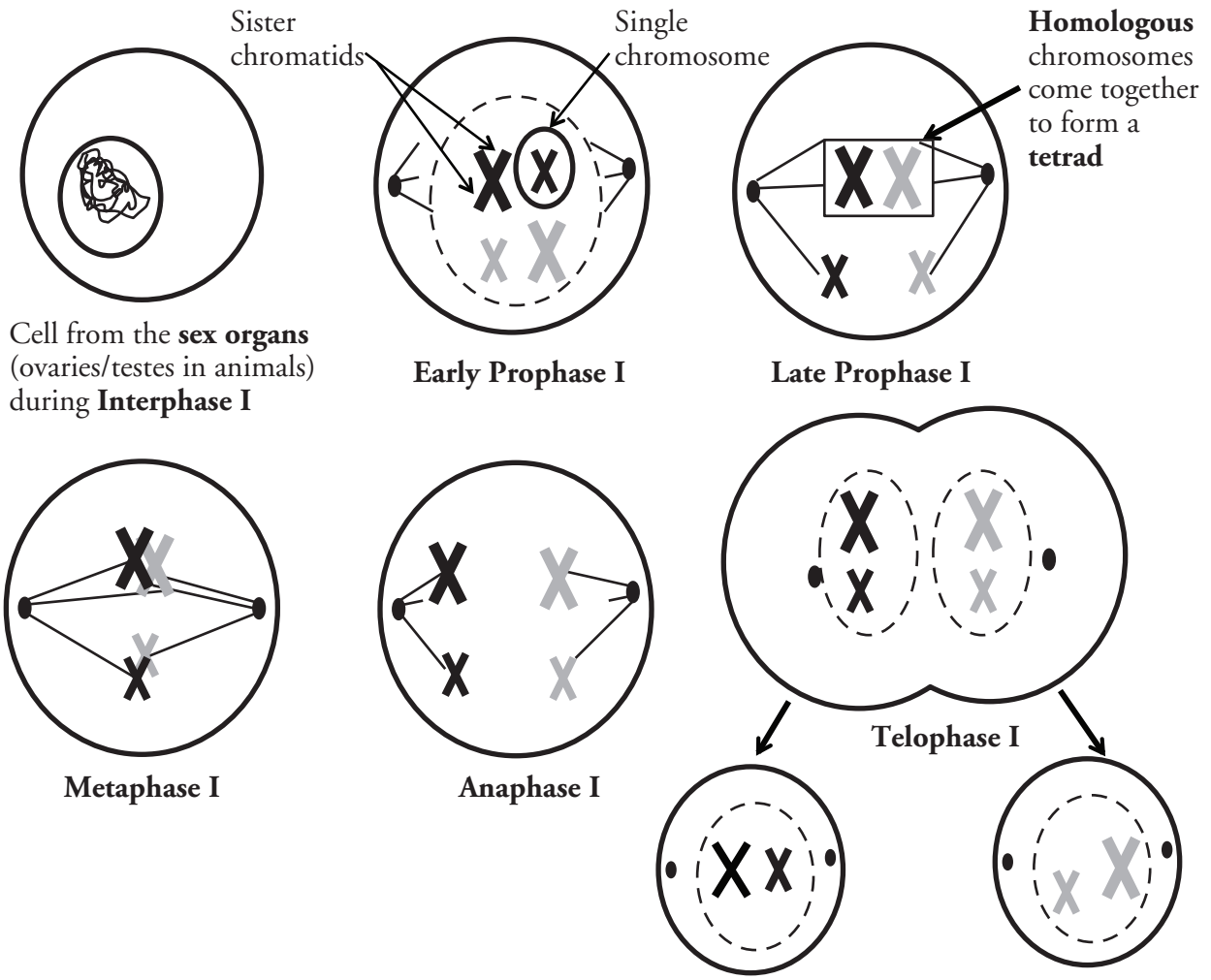
Meiosis

How does sexual reproduction lead to genetic variation?

Why?

Cells reproduce through mitosis to make exact copies of the original cell. This is done for growth and repair. Sexually-reproducing organisms have a second form of cell division that produces reproductive cells with half the number of chromosomes. This process is called **meiosis**, and without it, humans, oak trees, beetles, and all other sexually-reproducing organisms would be vastly different than they are today.

Model 1 – Meiosis I



1. According to Model 1, in what type of organs are the cells that enter meiosis I found?

   Sex organs (ovaries and testes).

2. Considering what you already know about mitosis in cells, what event must take place during interphase before a cell proceeds to division?

   DNA replication.

3. What two structures make up a single replicated chromosome?

   Sister chromatids.

4. In Model 1, how many replicated chromosomes does the cell contain during prophase?

   Four.

Read This!

Alleles are alternative forms of the same gene. For example, gene A may contain the information for fur color. One allele "A" may result in white fur, while the alternative allele "a" may result in black fur. **Homologous chromosomes** are chromosomes that contain the same genes, although each chromosome in the homologous pair may have different alleles.

5. At which stage in meiosis I do the pairs of homologous chromosomes come together?

   Late prophase I.

6. Once the chromosomes have formed a pair, what are they called?

   Tetrads.

7. At the end of meiosis I, two cells have been produced. How many replicated chromosomes are in each of these cells?

   Two.

8. Cells with a full set of chromosomes are referred to as **diploid** or **2n**, whereas cells with half the chromosomes are **haploid** or **n**. At which stage(s) of meiosis I are the cells diploid and at which stage(s) are they haploid?

   Diploid = prophase, metaphase, and anaphase

   Haploid = telophase after the cell has split.

9. Which of the statements below correctly describes the relationship between the cells at the end of telophase I and the original cell?

   a. The new cells have one copy of all of the genetic information in the original cell.

   b. The new cells have two copies of all of the genetic information in the original cell.

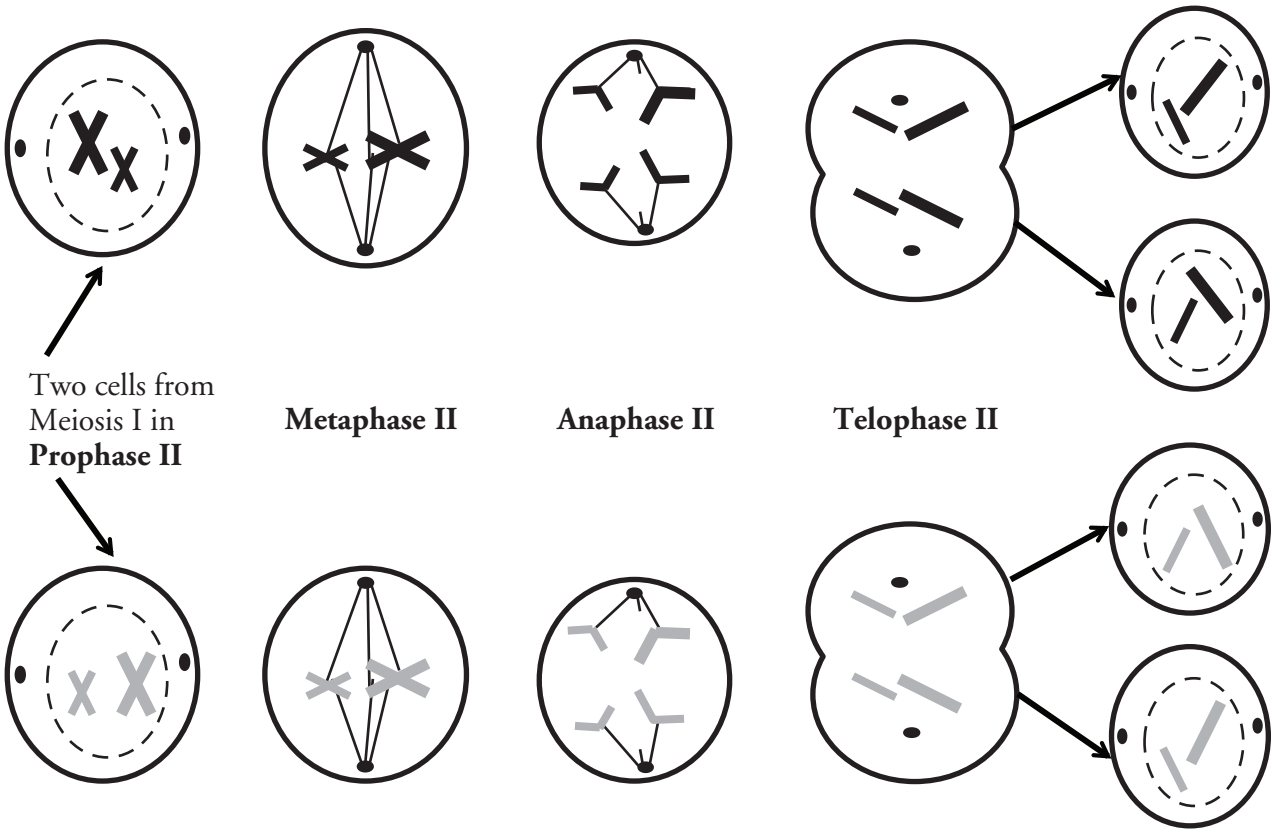
   c. The new cells have one copy of half of the genetic information in the original cell.

   (*d.*) The new cells have two copies of half of the genetic information in the original cell.

10. Considering the genetic makeup of the homologous pairs, will the cells at the end of telophase I be genetically identical to each other?

    No, they will not be genetically identical to each other because the homologous pairs separated and the alleles on each homologous pair are not necessarily identical.

Model 2 – Meiosis II



11. According to Model 2, where did each of the cells come from that started meiosis II?

    Meiosis I.

12. In meiosis I, during anaphase I, which structures separated—homologous chromosomes or sister chromatids?

    Homologous chromosomes separated.

13. In meiosis II, during anaphase II, which structures separated—homologous chromosomes or sister chromatids?

    Sister chromatids.

14. At the end of the meiosis II are four daughter cells. Are they haploid or diploid? Explain your answer in a complete sentence.

    The cells are still haploid. They each contain one chromosome (sister chromatid) from each homologous pair. Each chromosome contains a complete set of genes.

15. Which of the statements below correctly describes the relationship between the cells at the end of meiosis II and the original cell?

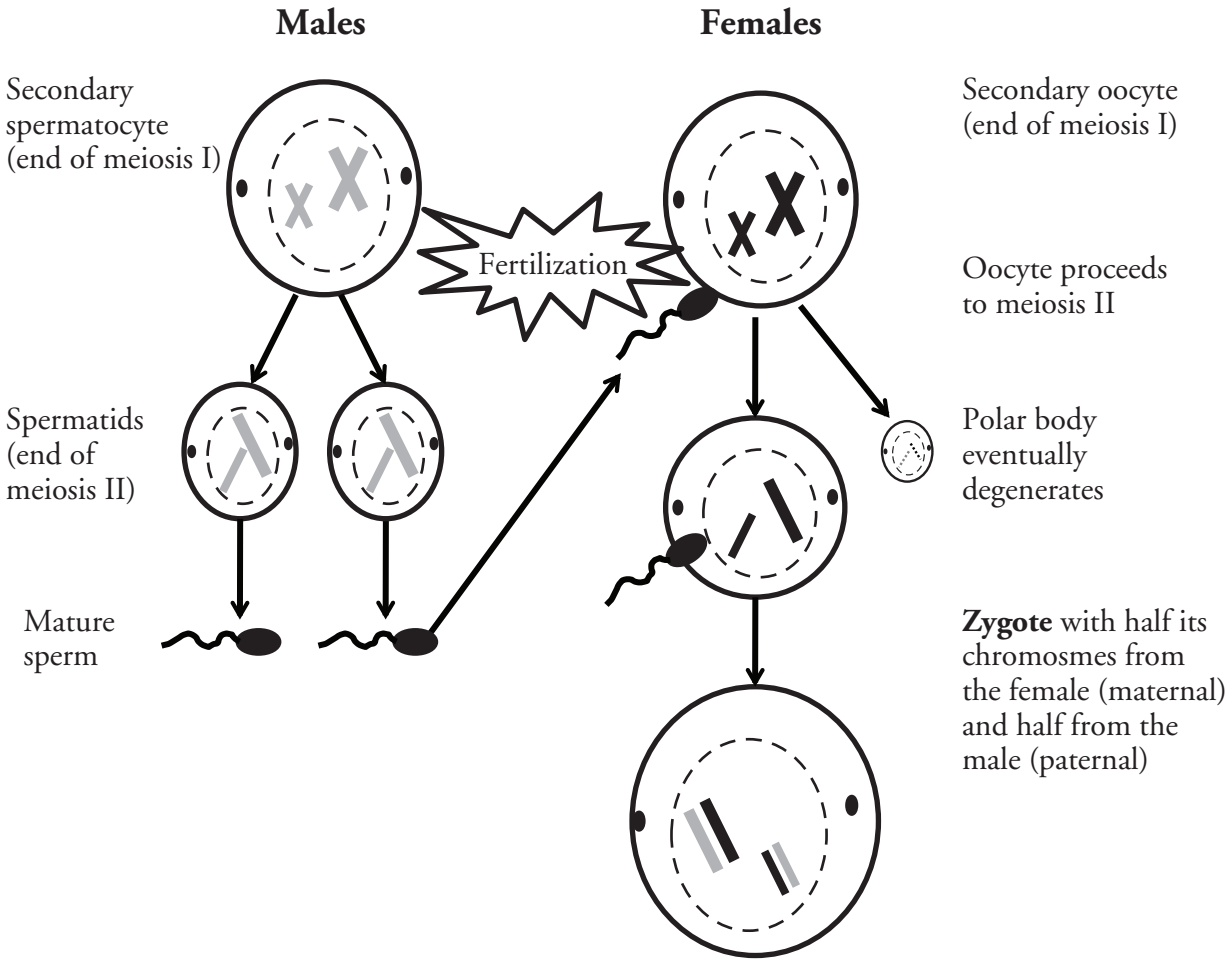
    a. The new cells have one copy of all of the genetic information in the original cell.

    b. The new cells have two copies of all of the genetic information in the original cell.

    (*c.*) The new cells have one copy of half of the genetic information in the original cell.

    d. The new cells have two copies of half of the genetic information in the original cell.

Model 3 – Gametogenesis and Fertilization (Human)



16. According to Model 3, what is the name given to the cells produced at the end of meiosis I in males?

    Secondary spermatocyte.

17. What is the name given to the cells produced at the end of meiosis I in females?

    Secondary oocyte.

18. Refer to Model 3.

    a. At the end of meiosis II in males, what cells are produced?

    Spematids.

    b. What do these cells (from the previous question) eventually become?

    Mature sperm.

19. Before fertilization, what happens to the secondary oocyte?

    Proceeds to meiosis II.

20. During fertilization which two cells come together? Be specific in your answer.

    Mature sperm and secondary oocyte.

21. During meiosis II, the secondary oocyte divides unevenly, with one cell (the ovum) receiving half of the chromosomes and nearly all the cytoplasm and organelles, while the other cell, the polar body, is much smaller and eventually degenerates. With your group, propose an explanation to explain why the secondary oocyte divides in this way.

    The ovum will receive more organelles, such as mitochondria for making energy, which will provide the zygote with all of its cytoplasm and organelles (note that the sperm contains only scant cytoplasm, a few mitochondria and haploid chromosomes), but nuclear division is necessary to produce the correct number of chromosomes in the oocyte.

22. What is the **ploidy** of the zygote produced by fertilization—haploid or diploid?

    Diploid.

23. What would the ploidy of the zygote be if egg and sperm were produced by mitosis rather than meiosis? How would this affect the ploidy of each successive generation?

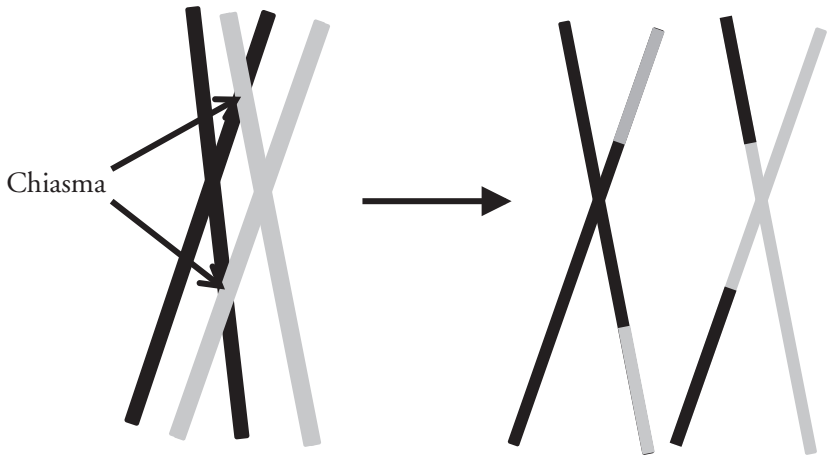
    If the egg and sperm were produced by mitosis, each would be diploid, so the zygote would be tetraploid (four sets of chromosomes). If this tetraploid organism produced tetraploid egg and sperm, the next generation would be octoploid (eight sets of chromosomes), and this doubling would continue with each generation.

24. With your group write a statement to explain the origin of the chromosomes found in the zygote. Your statement must include the term *homologous pair*.

    The homologous pairs of chromosomes found in the zygote have come from each parent. One half of each pair is maternal and the other half is paternal.

Extension Questions

Model 4 – Crossover of DNA in Chromosomes



Homologous pair of chromosomes (tetrad) during Prophase I

Recombinant chromatids

25. At which stage of meiosis are the chromosomes in Model 4?

    Prophase I.

26. When the chromosomes come together as homologous pairs, the arms of the sister chromatids may cross over.

    a. What are these crossover points called?

    The crossover points are chiasma.

    b. Describe what happens to the chromatids during crossover.

    Sections of the homologous pair switch places on the chromatids.

27. What phrase is used to describe the chromatids after crossing over takes place and the homologous chromosomes separate?

    Recombinant chromatids.

28. Compare the recombinant chromatids with the original pair.

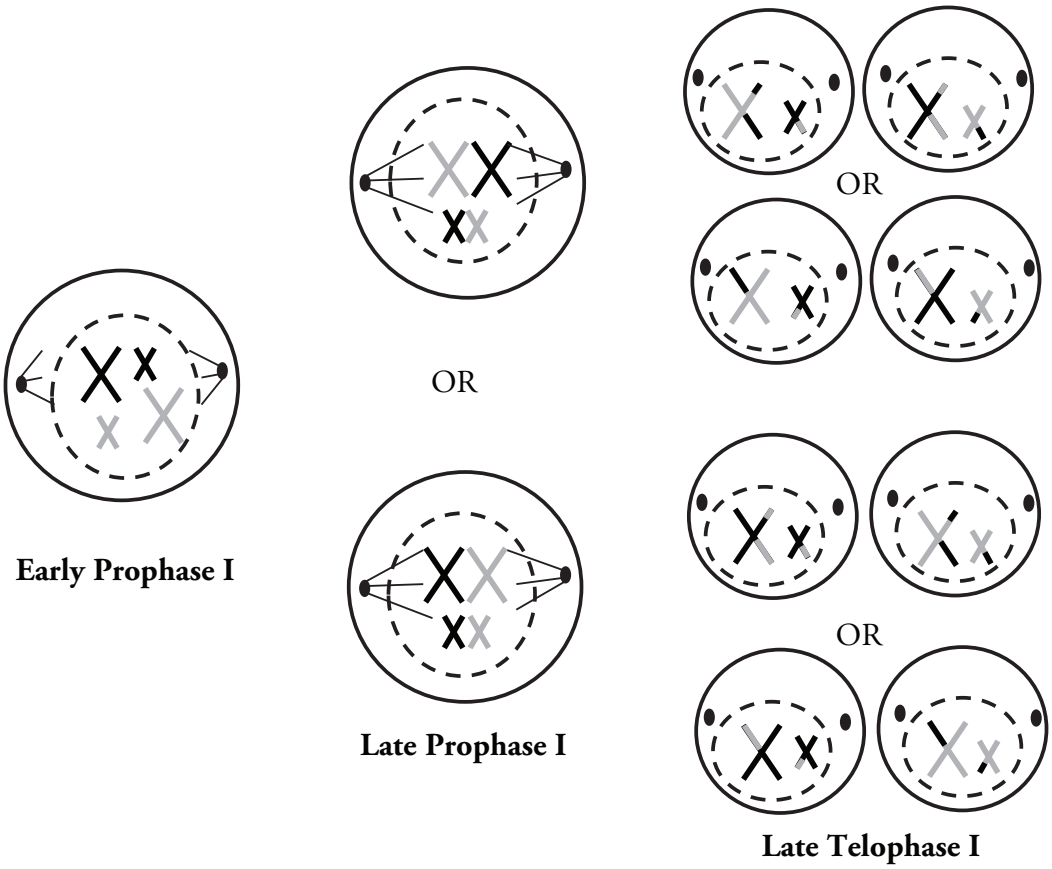
    a. Are the genes on a recombinant chromatid the same as the original chromatid?

    Yes, each chromosome in the homologous pair contains the same genes in the same place on the chromosome, so a switch between chromosomes would not affect the genes present.

    b. Are the alleles on a recombinant chromatid the same as the original chromatid?

    No, the chromosomes in the homologous pair can have different alleles for each gene, so a switch in a portion of the chromosome would affect the information in that chromatid.

Model 5 – Genetic Variation



Early Prophase I

Late Prophase I

Late Telophase I

29. Model 5 is a condensed version of meiosis I. Notice the two possible arrangements of chromosomes in late prophase I. Considering what you know about DNA replication and meiosis, is either arrangement equally likely during the formation of tetrads in late prophase I? Explain.

    DNA replication occurs randomly within the nucleus of a cell. When the homologous chromosomes come together as tetrads, they are just as likely to line up on one side of the cell as another.

30. If there were three sets of homologous chromosomes in the cell in Model 5, how many possible arrangements would there be for the tetrads in late prophase I?

    2 x 2 x 2 = 8 possible arrangements.

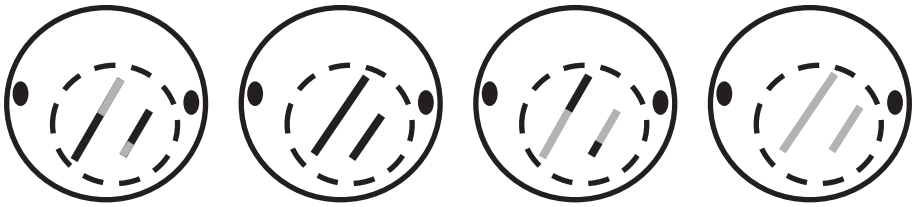
Read This!

When homologous chromosome pairs align on the spindle during metaphase I the orientation of one pair is independent of the orientation of any other pair. This is known as **independent assortment**. Humans have 46 chromosomes, arranged as 23 pairs. During metaphase I each pair lines up independently, which results in 2^{23} **possible combinations.**

31. With your group, calculate the number of possible genetic combinations due to independent assortment.

    2^{23} = 8,388,608

32. As a group, choose one set of daughter cells in late telophase I from Model 5. Imagine that those cells now undergo meiosis II. Draw at least four resulting haploid cells that could result.



33. Meiosis and sexual reproduction each lead to variation in the genetic make-up of every person. With your group, explain how meiotic events, as well as the random fertilization of eggs and sperm, together lead to this genetic variation.

Independent assortment leads to multiple different maternal and paternal gene combinations being produced in the cells at the end of meiosis I. Chiasma formation between homologous pairs of chromosomes leads to blocks of genes being swapped between nonsister chromatids during separation at anaphase I. This leads to allele combinations on the chromosomes being shuffled, and further varies the chromosomes that end up in egg and sperm after meiosis II. Random fertilization of eggs and sperm means that when zygotes are formed, the gene combination will be different each time, even if they come from the same two parents.

Teacher Resources – Meiosis

Learning Objectives

1. Explain the stages of meiosis and how haploid cells are produced for reproduction.
2. Explain how fertilization restores the diploid number and how meiosis maintains the diploid number across generations.

Prerequisites

1. Students should be familiar with all the events that occur at each stage of mitosis and interphase.
2. Students should have an understanding of vocabulary from mitosis and genetics, such as chromosome, chromatid, genes, and alleles.

Assessment Questions

1. If an organism contains 10 chromosomes in its body cells, how many chromosomes will be in the spermatid cells?

   a. 5 *b.* 10 *c.* 20

2. If an organism contains 10 chromosomes in its body cells, how many chromosomes will be in the zygote?

   a. 5 *b.* 10 *c.* 20

3. How many daughter cells are produced from one parent cell during the process of meiosis?

Assessment Target Responses

1. *a.*
2. *b.*
3. *Four cells.*

Teacher Tips

- It will be important to emphasize that no further DNA replication takes place between meiosis I and II but nuclear division occurs twice. Similarly, in this activity the process of oogenesis is abbreviated and the production of the three polar bodies and one ovum is not emphasized.
- Many concepts in this activity can be named by various terms. For example, the term "tetrad" is sometimes interchanged with "bivalent." If the text for your course uses different vocabulary, this should be made clear to the students before starting this activity.
- The Flinn Scientific laboratory kit, *Allele's Crossing Over to the Other Side,* Catalog No. FB1792, is a hands-on simulation using beads (alleles) and chenille wires (chromosomes) to create a unique gene sequence that students then crossover to complete the phases of meiosis.

Notes