Modeling Mendel: Genetic Crosses

Lesson Overview

In this lesson, students will develop and use Punnett squares to predict patterns of inheritance by using toothpicks to model chromosomes. Students will write a description of the genotypes and phenotypes of the possible offspring of a monohybrid cross that they have modeled. Also, students will dialogue as a class the patterns that they are seeing and any surprises that they have discovered.

Alignment

Standard 7.L.4 The student will demonstrate an understanding of how genetic information is transferred from parent to offspring and how environmental factors and the use of technologies influence the transfer of genetic information.

7.L.4A.3 Develop and use models (Punnett squares) to describe and predict patterns of the inheritance of single genetic traits from parent to offspring (including dominant and recessive traits, incomplete dominance, and codominance). (**NEW**)

Science and Engineering Practices (as appropriate)

7. S.1A.2 Develop, use, and refine models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.

Students should also ask questions and define problems; analyze and interpret data; construct explanations and design solutions; plan and carry out investigations; use mathematical and computational thinking; engage in scientific argument from evidence; and obtain, evaluate and communicate information.

Crosscutting Concepts: Patterns, Cause and effect, Systems and system models, Stability and change

Standard/Indicator Addressed

SCCCR Math 7.RP.2 — Identify and model proportional relationships given multiple representations, including tables, graphs, equations, diagrams, verbal descriptions, and real-world situations.

a. Determine when two quantities are in a proportional relationship.

d. Use equations to model proportional relationships.

SCCCR Math 7.RP.3 — Solve real-world and mathematical problems involving ratios and percentages using proportional reasoning (e.g., multi-step dimensional analysis, percent increase/decrease/ tax).

SCCCR Math 7.DSP.6 — Investigate the relationship between theoretical and experimental probabilities for simple events.
  a. Determine approximate outcomes using theoretical probability.

SCCCR Math 7.DSP.8 — Extend the concepts of simple events to investigate compound events.
  a. Understand that the probability of a compound event is between 0 and 1.
  b. Identify the outcomes in a sample space using organized lists, tables, and tree diagrams.
  c. Determine the probabilities of compound events using organized lists, tables, and tree diagrams.
  d. Design and use simulations to collect data and determine probabilities.
  e. Compare theoretical and experimental probabilities for compound events.

Standards for Mathematical Practice (as appropriate)

Standard 1: Make sense of problems and persevere in solving them.
  a. Relate a problem to prior knowledge.

Standard 2: Reason both contextually and abstractly.
  a. Make sense of quantities and their relationships in mathematical and real-world situations.

Standard 3: Use critical thinking skills to justify mathematical reasoning and critique the reasoning of others.
  a. Construct and justify a solution to a problem.
  b. Compare and discuss the validity of various reasoning strategies.
  c. Make conjectures and explore their validity.
  d. Reflect on and provide thoughtful responses to the reasoning of others.

Standard 6: Communicate mathematically and approach mathematical situations with precision.
  a. Express numerical answers with the degree of precision appropriate for the context of a situation.
  b. Represent numbers in an appropriate form according to the context of the situation.
  c. Use appropriate and precise mathematical language

Standard 7: Identify and utilize structure and patterns.
  c. Look for structures to interpret meaning and develop solution strategies.

Connections

Active Learning Strategies

- Partner Dialogue
- Graphic Organizer (Genetic cross diagram and Punnett square)
- Pairs Squared
- 3-2-1 as an Exit Slip

Computational Thinking:

- Formulating problems in a way that enables us to use a computer and other tools to help solve them.
- Logically organizing and analyzing data
- Representing data through abstractions such as models and simulations
- Tolerance for ambiguity & the ability to deal with open ended problems
- The ability to communicate and work with others to achieve a common goal or solution

Content Connections

- Science
- Computational Thinking
- Mathematics

Lesson Plan

Time Required – Two 60 minute class periods
Disciplinary Vocabulary – Punnett square, Mendel, dominant trait, recessive trait, heterozygous, homozygous, carrier, genotype, phenotype, incomplete dominance, codominance, monohybrid cross

Materials Needed:

- Video "*The Mysteries of Life: Heredity*" (2:49)
  https://www.brainpop.com/health/geneticsgrowthanddevelopment/heredity/
- Ziploc bags (snack size will be fine)
- Flat toothpicks
- Fine point permanent marker (purple)
- White-out pen or bottle **(*Liquid Whiteout* is not permitted for use by students)**
- For each pair of students:
  - 1 set of 32 (16 purple dotted, 16 white dotted) toothpicks prepared by the teacher (see note about *White Out*) placed in bags
  - 1 Genetic Cross Diagram handout (attached)-can be laminated
  - 1 Punnett Square for Modeling handout (attached)-can be laminated

NOTE TO TEACHER- Using fine point markers (and liquid white-out for the white spots), prepare enough toothpick chromosomes to provide 16 of each color or kind shown in the picture (e.g., 16 purple-spotted, 16 white-spotted) for every pair of students in your largest class. Flat toothpicks are preferred because they stay put where students place them. Try to make your spots the same size and place them in the same location on each toothpick. You may wish to prepare a laminated copy of the genetics cross diagram and the Punnett square for modeling toothpick chromosomes for each pair of students. Place a complete set of 32 toothpicks for each pair of students in a plastic bag and distribute the bags at beginning of class and collect at the end of class. Have students check the contents of the bag and replace any missing or damaged toothpicks as needed.

Formative Assessment Strategies: Students will be assessed by genetic cross diagrams, modeling Punnett squares, partner dialogue, and written and oral responses to questioning.

Computational Thinking: This lesson addresses computational thinking by allowing students to interact with authentic data to organize and analyze data about single genetic traits, represent the data in a Punnett square, use evidence, apply logic, and construct arguments for their proposed explanations, and evaluate and communicate the information scientifically.

Misconceptions:
According to Benchmarks, when asked to explain how physical traits are passed from parents to offspring, elementary-, middle-, and some high-school students express various misconceptions. For example, some students believe that traits are inherited from only one of the parents (e.g., the traits are inherited from the mother, because she gives birth or has most contact as children grow up; or the same-sex parent will be the determiner). Other students believe that certain characteristics are always inherited from the mother and others come from the father. Additionally, some students believe in a "blending of characteristics."

Early middle-school students explain inheritance only in observable features, but upper middle-school and high-school students have some understanding that characteristics are determined by a particular genetic entity that carries information to be translated by the cell. (*Benchmarks for Science Literacy,* p. 341)

Some students may also think that because they look similar to an aunt or uncle that they received those traits from them.

Another misconception is that a dominant trait is the trait most likely found in the population However, a dominant trait does not mean "more potent," and recessive does not mean "weaker." The terms simply refer to the visible trait, the phenotype.

Students may believe that one set of alleles is responsible for determining each trait, and there are only 2 different alleles (dominant and recessive) for each gene.

Engage

Focus Question**:** What is the purpose of a Punnett square and how is it used?

- Show the video "The Mysteries of Life: Heredity" (2:49) https://www.brainpop.com/health/geneticsgrowthanddevelopment/heredity/
- Tell students that today they will be using a diagram/model called a Punnett Square.
    - The **Punnett square** is a diagram that is used to predict an outcome of a particular cross or breeding experiment. It is named after Reginald C. Punnett, who devised the model, and is used by biologists to determine the probability of an offspring having a particular genotype. The Punnett square is a summary of every possible combination of one maternal allele with one paternal allele for each gene being studied in the cross.
- Ask students where they have heard the prefix *mono* before? *(i.e. monarch – government ruled by one person; monologue – speech delivered by one person; monopoly – business or service controlled by one person or group; monorail – a train with a single track).*The prefix *mono* means one. Tell students that when using one trait only, that is called a ***monohybrid*** crossing or breeding.
- Review terminology by using sentence strips and Frayer Models from the previous lesson.

Explore

- Tell students they will now work in pairs to simulate a trait Gregor Mendel studied, flower color in garden pea plants. They will be using toothpicks to model a monohybrid cross.
- Distribute the *teacher* prepared bags of toothpick chromosomes to pairs of students and have them place all the purple-spotted and white-spotted toothpicks on their desk.
- Explain to the class that some garden pea plants have purple flowers and some have white flowers and the **gene** for flower color is carried on one of the pea plant's seven pairs of **chromosomes**.
- Hold up a purple-spotted toothpick and a white-spotted toothpick and tell students that the **toothpick** represents the **chromosomes** and the **spots** represent the **genes** for flower color.

- Ask students the question, "Why are there two colors of spots?" Students should say that the purple spot is the form of gene for purple flowers and the white spot is the form of gene for white flowers.
- Introduce the term **allele** and distinguish it from a gene by saying that two alleles are different forms of the same gene.
- Give each pair of students a copy of the **genetic cross diagram.** *Students may have used a similar diagram in math class called a tree diagram* with the correlating lesson for this unit called *Exploring the Genetics of Albinism*. Students will use this diagram and their toothpick chromosomes to model pea plant reproduction to see how genes are passed down from parents to offspring.

- Have students model a simple cross in which both parents have two alleles for purple flowers. Have students place two purple- spotted toothpicks in each of the parent boxes. Then they add a single purple-spotted toothpick to each of the gamete boxes, because in this cross the parents can only produce gametes containing the allele for purple flowers. Finally, students add two purple-spotted toothpicks to each of the offspring boxes as they show all possible combinations of gametes. The students will find that the offspring resulting from this cross all have the same combination of alleles (genotype) as the parents, two purple flower alleles, and can correctly predict that the offspring will all have purple flowers.
- Repeat the process with both parents having two alleles for white flowers. Students should see that all the offspring will have the same **genotype** as the parents, two white flower alleles, and therefore all offspring will have white flowers(**phenotype**).You may wish to tell the students that Gregor Mendel called these plants true-breeding (purebred) because the offspring were always identical to the parents.

  NOTE TO TEACHERS-*In our current support documents, the term purebred has been replaced with the term homozygous and the term hybrid has been replaced with term heterozygous.*

- Provide students with the **Punnett square for modeling** handout (and have the students cross a true-breeding plant with white flowers (2 white toothpicks) with a true-breeding plant with purple flowers (2 purple toothpicks). Students who accurately model the processes of gamete formation and fertilization for this cross will see that all the offspring will all have one allele for white flowers and one for purple flowers.
- Ask students "What color flowers would the offspring have and why?" Student predictions may include the idea that some offspring will have white flowers and some purple flowers or that all offspring with have both white and purple flowers.
- Tell students that Gregor Mendel actually did this experiment and found that all the offspring had purple flowers. He proposed that the purple flower allele overpowers the white flower allele, and so is referred to as the ***dominant*** allele. The white allele is said to be ***recessive*.**
- Capital letters are used to represent a dominant allele and lowercase letters are used to represent a recessive allele. Purple is the dominant allele so you would use a capital letter P. For the recessive trait you would use a lower case p. It's important to use the same letter for monohybrid crosses.
- The prefix "homo" means the same, therefore, when you have 2 copies of the same allele (i.e., 2 capital or 2 lowercase) it is called homozygous. The prefix "hetero" in the term heterozygous means different or other so this would be an offspring that has one copy of the dominant allele (trait) and one copy of the recessive allele (trait).
- List the following on the board: PP, Pp and pp
- Have students indicate the phenotypes for each genotype and whether each is heterozygous or homozygous.
- Review the procedure on the attached lab sheet.
- Now that students know that the purple allele is the dominant allele and the white is the recessive allele, have students perform a final cross using the offspring of the

previous cross. Both parents should be heterozygous for flower color. (Each parent should have one purple and one white toothpick)

- Ask for any questions and then have students complete the final cross.
- Each pair of students should write a description of the genotypes and phenotypes of the possible offspring of this monohybrid cross. (Students should draw and complete the Punnett square and predict the genotypes and phenotypes and their answer should indicate the 3 possible genotypes and both phenotypes possibilities.)
- Use the **Pairs Squared** Strategy to have students relate their answers to the questions on the lab sheet.
- Dialogue as a class the answers to the following questions: What patterns are you seeing? What surprises? What questions do you have?

Explain

- Tell students you will now model a ***monohybrid*** crossing using a Punnett Square and another trait from Mendel's research on pea plant
- Draw a Punnett Square on the board. Explain where each allele from the genotype is placed. Have students provide 2 offspring from Mendel's work with pea plants. Ask students what trait they would like to use? *(NOTE: This example uses plant height.)*

Female pea plant, phenotype Tall, genotype Tt

	T	**t**
T	1 **TT**	2 **Tt**
t	3 **Tt**	4 **tt**

Male pea plant, phenotype Tall, genotype Tt

Height:
TT=Tall
Tt= Tall
tt = Short

- Show students how to match alleles on a Punnett Square. Column 1 matches with Row 1, Column 2 matches with Row 1. Column 1 matches with Row 2, Column 2 matches with Row 2.

- Ask the following questions:
  - What are the phenotypes of the offspring? Each square represents a possible allele combination. *(Offspring 1 is Tall with both dominant alleles, Offspring 2 is Tall with one dominant and one recessive allele (short), Offspring 3 is Tall with one dominant and one recessive allele (short), Offspring 4 is short with two recessive alleles for short)*

- Which two Tall Offspring could possibly have Short Offspring? *(2 and 3)*
- Could Offspring 4 ever have a Tall Offspring? *(yes, by mating with a Tall phenotype either with both dominant alleles or dominant and recessive Tall alleles)*
- Could Offspring 1 ever have Short Offspring? *(No, but possibly the "grandchild" of one of its Offspring with a recessive allele for Short.)*
- Can a Punnett square accurately predict the true outcomes of a cross? *(No. It shows possibilities for 4 offspring, but the combination of alleles is random during meiosis.)*

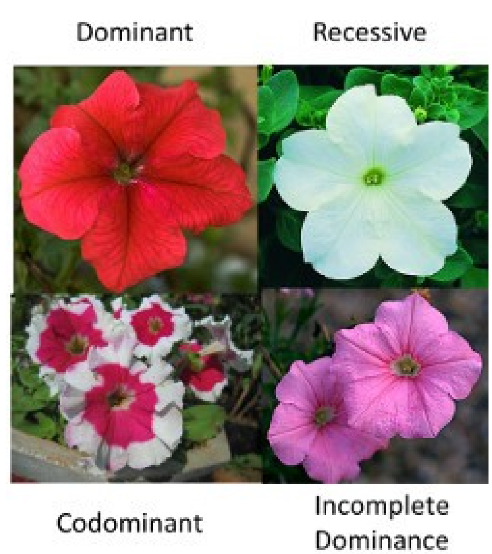
NOTE TO TEACHER:
From the 7TH grade Instructional Unit Resource SCDE | Office of Standards and Learning

http://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Units/7-Life-Science-- Heredity--Inheritance-and-Variation-of-Traits.pdf

Punnett Squares Steps
Steps for Completing a Punnett Square:
1. Identify the genotype of each parent.
2. Draw a Punnett square.
3. Write the genotype of one parent across the top.
4. Write the genotype of the other parent down the side.
5. One allele is given from each parent and copied in the boxes beginning with the columns.
6. Complete distributing alleles by moving across the rows.
7. Upon completion, there should be 2 letters in all 4 boxes representing all of the possible genotypes for the offspring.

- "We have looked at inherited traits that were dominant or recessive, but there are two additional types of inheritance we that need to discuss"

- **Incomplete dominance** is a condition in which the dominant allele does not completely mask the recessive allele. So some of the recessive trait will be observed in the phenotype. For example, some flowers even though red is dominant over white, the red is not completely dominant so therefore the red and white blend to make pink.
- **Codominance** is a condition when there is more than one dominant allele. As a result, **both (prefix co-)** both alleles are expressed in the phenotype. If both red and white alleles are dominant, both traits will be expressed in the flower. (Other examples, speckled chickens, spotted cows, and AB blood type in humans)



- **Exit Slip**: Students complete a 3-2-1 before leaving class. Students list 3 things they learned, 2 things they found interesting, and 1 thing that is confusing where additional help is needed.

Extend

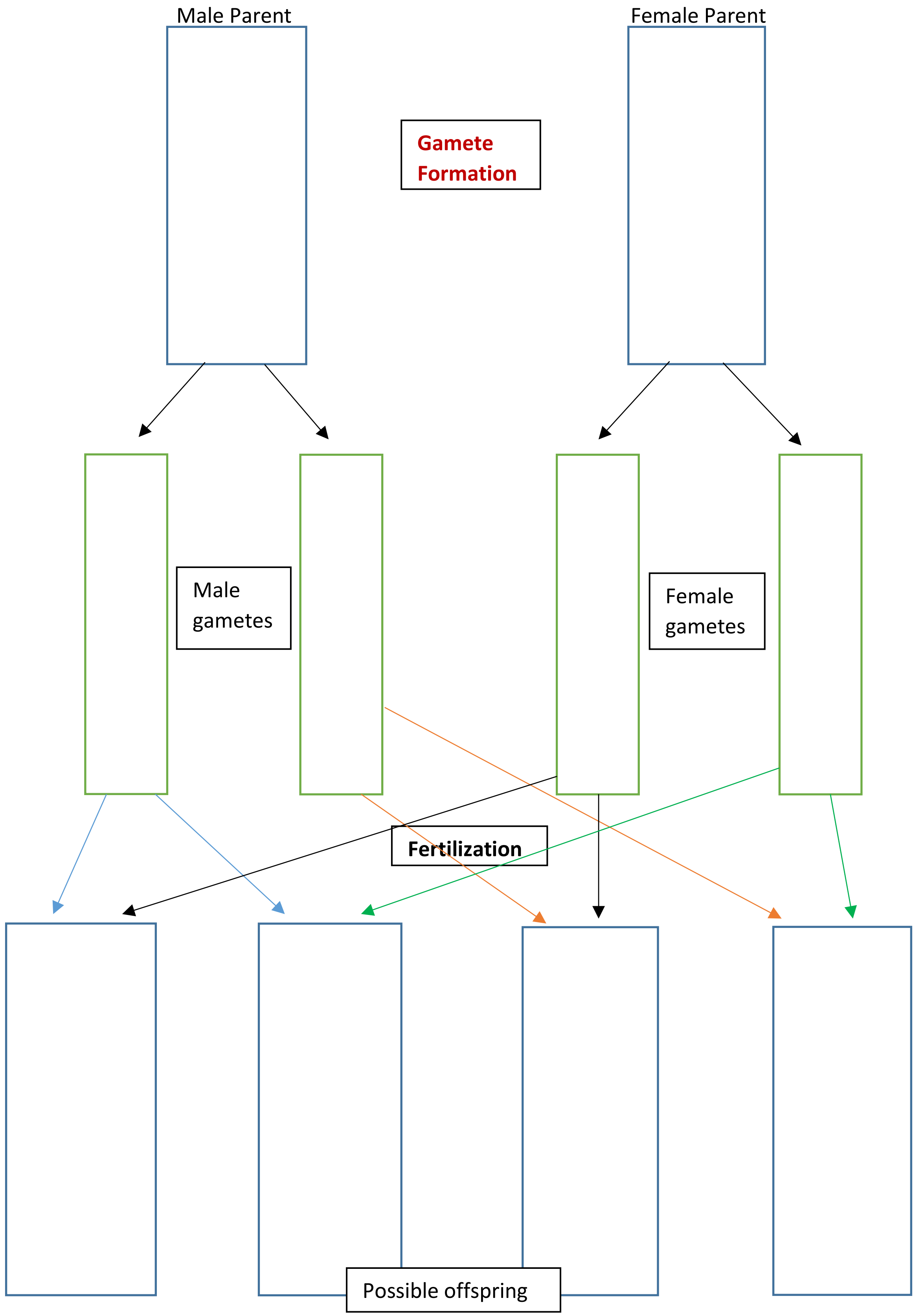
- Students may wish to continue investigating the reliability of Punnett Squares with additional trials.
- Have students conduct research on polygenic inheritance (i.e. skin color, eye color, etc.)
- Math Celebrity Punnett Square Calculator is a website where students can practice problems using Punnett Squares http://www.mathcelebrity.com/punnett_square.php?p1=A&p2=a&q1=A&q2=a&pl=Show+Punnett+Square
- Punnett Square on Google Play is an app that students can use to practice problems Punnett Squares: https://play.google.com/store/apps/details?id=net.piestudios.app.punnettsquare&hl=e%20n
- Compare the number of pairs of chromosomes for humans and pea plants and other organisms. Is there a connection between the number of chromosomes and the complexity of the organism?
- https://www2.edc.org/weblabs/Mendel/MendelMenu.html Online lab for pea plant genetics (requires a plug in)

Lesson adapted from

- Toothpick Chromosomes: Simple Manipulatives to Help Students Understand Genetics, Richard J. Bryant, Science Scope, April 2003.
- K-8 Science Lessons. (2010, August). Retrieved April 25, 2017, from http://www.s2temsc.org/k-8-science-lessons.html (Science S3 Seventh Grade 7-2.6 Lessons A)

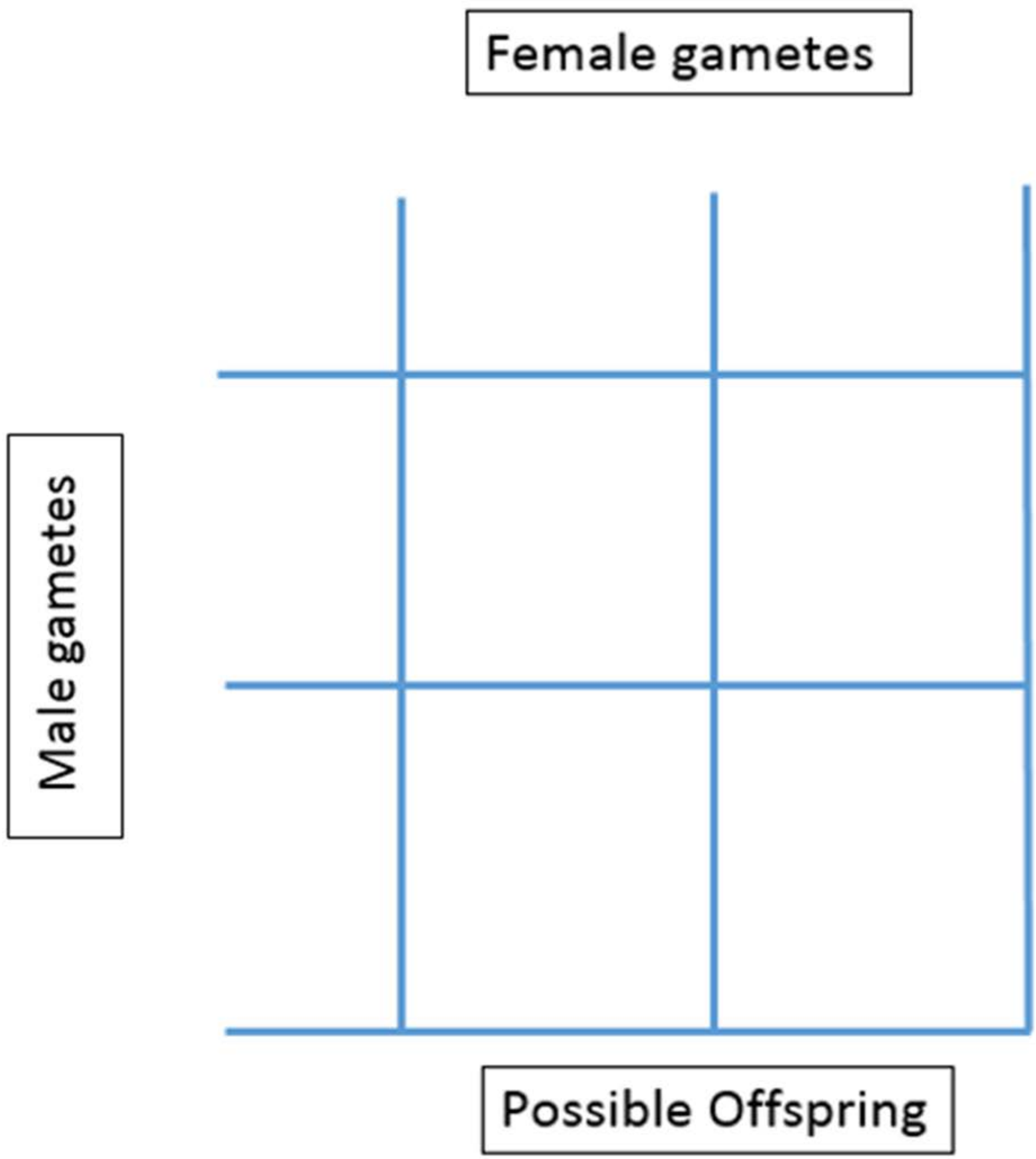
Lesson 3 Toothpick Chromosomes Handout 1

Genetic Cross/Tree Diagram



Adapted from *Toothpick Chromosomes: Simple Manipulatives to Help Students Understand Genetics, Richard J. Bryant, Science Scope, April 2003.*

PUNNETT SQUARE MODEL



Adapted from *Toothpick Chromosomes: Simple Manipulatives to Help Students Understand Genetics, Richard J. Bryant, Science Scope, April 2003.*

Genetics definitions

From *Toothpick Chromosomes: Simple Manipulatives to Help Students Understand Genetics, Richard J. Bryant, Science Scope, April 2003.*

Gene—A small region of a chromosome that contains information about a specific trait

Chromosome—A long DNA molecule that carries hundreds, even thousands, of genes

Trait—An observable characteristic of an individual; may be structural, biochemical, or behavioral

Allele—One of two or more different forms of a gene

Co-dominance—Condition in which two non-identical alleles are both expressed, even though they specify two different phenotypes. Ex. Blood types, chickens

Punnett square—A simple modeling device for predicting the genotypes of all possible offspring when the genotypes

of both parents are known

Dominant allele—An allele that masks the expression of its partner on the homologous chromosome

Recessive allele—An allele whose expression is masked by the expression of its partner on the homologous chromosome

Homozygous—Describing a genotype in which the individual has two identical alleles of a particular gene (e.g., PP or pp)

Heterozygous—Describing a genotype in which the individual has two different alleles of a particular gene (e.g., Pp)

Genotype—A description of an individual's genetic make-up that specifies which alleles are present

Phenotype—A description of an individual in terms of its observable traits

Gamete—A sexual reproductive cell that contains half a set of chromosomes, one of each homologous pair

Incomplete Dominance—Condition when the dominant allele does not completely mask the recessive. Ex. Color of flowers in plants-red and white blend to make pink flowers.