EvolutionHQ Activity: Mendelian Genetics and Mathematical Analysis

Names: ________________________________

Date: ____________

Period: _____

AP Biology Connection: This activity addresses Learning Objective 3.14 (Apply mathematical routines to determine Mendelian patterns of inheritance) and Science Practice 2.2 (Apply mathematical routines to quantities that describe natural phenomena).

Learning Objectives

- Apply the law of segregation and law of independent assortment to predict offspring ratios
- Calculate and interpret genotypic and phenotypic ratios from genetic crosses
- Use probability to predict outcomes of monohybrid and dihybrid crosses
- Analyze simplified ratio representations of genetic crosses
- Connect mathematical patterns to underlying biological mechanisms

🔗 **Required Tools:** Keep these tabs open throughout the activity

EvolutionHQ.org - Explore Punnett Squares

EvolutionHQ.org - Learn Evolution (Mendelian Genetics section)

Part 1: Foundations of Mendelian Inheritance

📖 Reading: Review the Mendelian Genetics Section

Navigate to the **Learn Evolution** page on EvolutionHQ.org and read through the **Mendelian Genetics** section. Pay particular attention to the definitions and explanations provided.

Model 1: Core Principles of Inheritance

Gregor Mendel's experiments with pea plants revealed fundamental patterns of inheritance that can be expressed mathematically. His work led to two major principles:

Principle	Description	Mathematical Implication
Law of Segregation	The two alleles for a gene separate during gamete formation, and each gamete receives one allele	Each parent contributes one allele with equal probability (50% each)
Law of Independent Assortment	Alleles of different genes assort independently during gamete formation	Inheritance of one trait does not affect inheritance of another; probabilities multiply

Critical Thinking Questions

1. Based on the EvolutionHQ.org reading and Model 1, explain why each gamete from a heterozygous individual (Aa) has a 50% chance of carrying the dominant allele and a 50% chance of carrying the recessive allele.

2. A heterozygous organism (Aa) produces gametes. What is the probability that two consecutive gametes both carry the recessive allele? Show your calculation.

3. According to the law of independent assortment, if an organism is AaBb, what is the probability of producing a gamete that is ab? Explain your reasoning.

Part 2: Monohybrid Crosses and Ratio Analysis

🌐 **Use the Monohybrid Cross section** on the Explore Punnett Squares page

Model 2: The Classic 3:1 Ratio

When two heterozygous individuals are crossed (Aa × Aa), a predictable pattern emerges:

Cross: Aa × Aa

Genotype	Number	Fraction	Percentage	Phenotype
AA	1	1/4	25%	Dominant
Aa	2	2/4 = 1/2	50%	Dominant

aa	1	1/4	25%	Recessive

Genotypic Ratio: 1 AA : 2 Aa : 1 aa (or simplified: 1:2:1)

Phenotypic Ratio: 3 dominant : 1 recessive (or simplified: 3:1)

Critical Thinking Questions

4. Using the EvolutionHQ.org Punnett Square tool, verify the cross shown in Model 2. Does the interactive tool show both the detailed genotypic counts and the simplified ratios? Describe what you observe.

5. Why is the genotypic ratio 1:2:1 but the phenotypic ratio 3:1? What biological principle explains this difference?

6. If you performed this cross and obtained 80 offspring, how many would you expect to show the recessive phenotype? Show your calculation.

7. Using probability theory, explain why the heterozygous genotype (Aa) appears twice as often as either homozygous genotype. (Hint: Consider all possible combinations of alleles from each parent.)

Key Question: How does the mathematical outcome of a Punnett square reflect the random nature of gamete fusion during fertilization?

Part 3: Alternative Monohybrid Cross Scenarios

Exploring Other Ratio Patterns

Not all crosses produce a 3:1 ratio. Complete the following crosses using the EvolutionHQ.org tool and record both the detailed counts and simplified ratios.

Cross A: AA × aa

Offspring genotypes and counts: ____________________________________

Simplified genotypic ratio: ____________________________________

Simplified phenotypic ratio: ____________________________________

Cross B: Aa × aa

Offspring genotypes and counts: ____________________________________

Simplified genotypic ratio: ____________________________________

Simplified phenotypic ratio: ____________________________________

8. Compare the three monohybrid crosses (Aa × Aa, AA × aa, and Aa × aa). Which cross(es) could produce offspring with the recessive phenotype? Why?

9. For Cross A, explain why the phenotypic ratio is 1:0 (or 100% dominant). How does this relate to the genotypes of the parents?

10. A test cross involves crossing an organism with an unknown genotype with a homozygous recessive organism. If the offspring show a 1:1 phenotypic ratio, what was the genotype of the unknown parent? Justify your answer mathematically.

Part 4: Dihybrid Crosses and Independent Assortment

🌐 **Navigate to the Dihybrid Cross section** on Explore Punnett Squares

Model 3: The Classic 9:3:3:1 Ratio

When two traits are considered simultaneously in a cross between two double heterozygotes, a characteristic pattern emerges.

Cross: AaBb × AaBb (where A and B are on different chromosomes)

Use the EvolutionHQ.org dihybrid tool to set up this cross and examine the results carefully.

Critical Thinking Questions

11. Using the interactive tool, perform the AaBb × AaBb cross. Record the number of offspring for each phenotypic class:

Dominant for both traits (A_B_): ________
Dominant for A, recessive for B (A_bb): ________
Recessive for A, dominant for B (aaB_): ________
Recessive for both traits (aabb): ________

12. Express your results from question 11 as a simplified phenotypic ratio:

13. Does the EvolutionHQ.org tool display this simplified ratio automatically? What is the advantage of seeing both the raw counts and the simplified ratio?

14. Explain how the 9:3:3:1 ratio can be derived from two independent 3:1 ratios. (Hint: Consider each trait separately, then combine using probability rules.)

Key Question: How does the 9:3:3:1 ratio provide evidence for the law of independent assortment? What would the ratio look like if the two genes were linked on the same chromosome?

Part 5: Probability and Chi-Square Analysis

Model 4: Using Probability to Predict Outcomes

The multiplication rule states that the probability of two independent events both occurring is the product of their individual probabilities.

Example: What is the probability that an offspring from an AaBb × AaBb cross will be aabb?

- Probability of aa = 1/4 (from Aa × Aa)
- Probability of bb = 1/4 (from Bb × Bb)
- Probability of aabb = 1/4 × 1/4 = 1/16

Application: Calculating Probabilities

15. What is the probability that an offspring from AaBb × AaBb will show the dominant phenotype for trait A but the recessive phenotype for trait B (A_bb)? Show your work.

16. Verify your answer to question 15 using the EvolutionHQ.org dihybrid tool. Count the number of A_bb offspring out of 16 total. Does this match your calculated probability?

17. A trihybrid cross (AaBbCc × AaBbCc) would produce offspring with how many different phenotypic classes? (Hint: Each trait has 2 phenotypes.) If the genes assort independently, what would be the expected phenotypic ratio?

18. In the trihybrid cross described in question 17, what is the probability of obtaining an offspring that is recessive for all three traits (aabbcc)?

Part 6: Recognizing and Interpreting Ratio Patterns

Model 5: Common Genetic Ratios

Cross Type	Parent Genotypes	Phenotypic Ratio	What It Reveals
Monohybrid	Aa × Aa	3:1	Both parents heterozygous
Monohybrid test cross	Aa × aa	1:1	Unknown parent is heterozygous
Dihybrid	AaBb × AaBb	9:3:3:1	Both parents double heterozygous; genes assort independently
Dihybrid test cross	AaBb × aabb	1:1:1:1	Unknown parent is double heterozygous; genes assort independently

Critical Thinking Questions

19. A scientist crosses two organisms and observes 48 offspring with the dominant phenotype and 15 with the recessive phenotype. Is this consistent with a 3:1 ratio? Calculate the expected numbers if 63 total offspring should follow a 3:1 ratio and compare.

20. Another cross produces offspring in the following numbers: 28 with phenotype A_B_, 11 with A_bb, 9 with aaB_, and 4 with aabb. Is this consistent with a 9:3:3:1 ratio? What might explain small deviations from expected ratios?

21. If a cross produces a 1:1:1:1 phenotypic ratio for two traits, what can you conclude about the genotypes of the parents? Verify your answer using the EvolutionHQ.org tool.

Key Question: Why are genetic ratios expressed as whole numbers (like 3:1) even though they represent probabilities? Under what conditions might observed ratios deviate significantly from expected ratios?

Part 7: Synthesis and Review

📖 Complete the Review Questions

Return to the **Mendelian Genetics section** on the Learn Evolution page at EvolutionHQ.org. Scroll to the bottom and complete the review questions provided there. Record your answers below:

EvolutionHQ Review Questions

Complete the review questions from the Mendelian Genetics section on EvolutionHQ.org. Write your answers in the space provided for each question.

Review Question 1:

Review Question 2:

Review Question 3:

Review Question 4:

Part 8: Application to Real Genetic Scenarios

Complex Problem Solving

22. In humans, the ability to taste PTC (phenylthiocarbamide) is dominant (T) over non-tasting (t). If two tasters who are heterozygous have four children, what is the probability that:

a) All four children will be tasters? Show your calculation.

b) Exactly three children will be tasters and one will be a non-taster?

c) At least one child will be a non-taster?

23. In fruit flies, gray body (G) is dominant to black body (g), and long wings (L) are dominant to vestigial wings (l). A cross between two flies produces 90 gray-bodied, long-winged flies; 30 gray-bodied, vestigial-winged flies; 32 black-bodied, long-winged flies; and 10 black-bodied, vestigial-winged flies.

a) What ratio do these numbers approximate?

b) What were the most likely genotypes of the parent flies?

c) Verify your answer by setting up this cross on the EvolutionHQ.org tool.

24. A woman who is a carrier for color blindness (X-linked recessive) marries a man with normal vision. They are also both heterozygous for widow's peak (autosomal dominant). What is the probability they will have a son with both color blindness and a straight hairline (no widow's peak)? Show your work.

Reflection and Connection to AP Biology

Final Synthesis Question: How do the mathematical patterns revealed by Punnett squares and genetic ratios reflect the cellular mechanisms of meiosis? Connect the law of segregation and law of independent assortment to specific events during meiosis I.

25. Evaluate the usefulness of the EvolutionHQ.org tools for understanding Mendelian genetics. How did the visual representation of Punnett squares and the automatic calculation of ratios enhance your understanding of probability in genetics?

26. Based on what you learned from the Mendelian Genetics section on EvolutionHQ.org, explain why Mendel's choice of pea plants and the specific traits he studied was crucial to discovering these patterns of inheritance.

AP Exam Connection: Be prepared to:

- Calculate probabilities for genetic crosses using multiplication and addition rules
- Interpret data from genetic crosses and determine parent genotypes
- Use chi-square analysis to evaluate goodness of fit to expected ratios
- Connect mathematical patterns to mechanisms of meiosis and fertilization
- Predict outcomes of multi-generational crosses