BGEN 55 - Advanced Genetics II

Guided Calculation Exercise

Recurrent Mutation Modeling Practice

📋 Worksheet Instructions

This worksheet provides guided practice problems for modeling recurrent one-way mutation. For each problem:

- Read the problem carefully
- Use the provided workspace to show your calculations
- Refer to the formula reference sheet if needed
- Check your work against the solution guide
- Spend approximately 10-15 minutes per problem

⏰ Estimated Time: 60 minutes total

Formula Reference Sheet

$p_1 = p_0(1 - \mu)$ $\Delta p = -\mu p_0$ $p_t = p_0(1 - \mu)^t$

Problem 1: Basic Frequency Calculation

Scenario: A population of flowers has a gene for petal color. Allele A (red petals) mutates to allele a (white petals) at a rate of $\mu = 0.0002$ per generation. Initially, the frequency of A is $p_0 = 0.90$.

Calculate: What is the frequency of A after one generation (p_1)?

Step-by-Step Guide:

1. Identify the known values: p_0 = ?, μ = ?
2. Choose the correct formula
3. Substitute the values
4. Calculate the result

Your Work:

Known values: p_0 = _________, μ = _________

Formula: $p_1 = p_0(1 - \mu)$

Calculation: p_1 = _________ × (1 - _________) = _________

Final answer: p_1 = _________

💡 **Hint:** Remember that $(1 - \mu)$ represents the fraction of A alleles that do NOT mutate in one generation.

Solution:
$p_1 = 0.90 \times (1 - 0.0002) = 0.90 \times 0.9998 = 0.89982$

Problem 2: Multiple Generations

Scenario: In a population of bacteria, a gene for antibiotic sensitivity mutates from sensitive (A) to resistant (a) at $\mu = 1 \times 10^{-5}$ per generation. The population starts with only sensitive alleles ($p_0 = 1.0$).

Calculate: What is the frequency of sensitive alleles after 1000 generations?

Step-by-Step Guide:

1. Identify p_0, μ, and t
2. Use the multiple generation formula
3. Calculate $(1 - \mu)^t$
4. Multiply by p_0

Your Work:

Known values: p_0 = ________, μ = ________, t = ________

Formula: $p_t = p_0(1 - \mu)^t$

Calculation: p_{1000} = ________ × (1 - ________)______ = ________

Final answer: p_{1000} = ________

💡 **Hint:** For small μ and large t, you can use the approximation $(1 - \mu)^t \approx e^{-\mu t}$

Solution:
$p_{1000} = 1.0 \times (1 - 0.00001)^{1000} = (0.99999)^{1000} \approx 0.99005$
Using approximation: $e^{-(0.00001 \times 1000)} = e^{-0.01} \approx 0.99005$

Problem 3: Time Calculation

Scenario: A geneticist is studying a neutral mutation in fruit flies. The mutation rate is $\mu = 5 \times 10^{-6}$. The current frequency of the original allele is $p = 0.75$.

Calculate: How many generations will it take for the frequency to drop to $p = 0.50$?

Step-by-Step Guide:

1. Start with $p_t = p_0(1 - \mu)^t$
2. Take natural logarithms of both sides
3. Solve for t
4. Use the formula: $t = \ln(p_t/p_0) / \ln(1 - \mu)$

Your Work:

Known values: p_0 = ________, p_t = ________, μ = ________

Formula: t = ln(________ / ________) / ln(1 - ________)

Calculation: t = ln(________) / ln(________) = ________

Final answer: t = ________ generations

💡 **Hint:** For small μ, $\ln(1 - \mu) \approx -\mu$, so $t \approx -\ln(p_t/p_0) / \mu$

Solution:
t = ln(0.50/0.75) / ln(1 - 0.000005)
t = ln(0.6667) / ln(0.999995)
t ≈ -0.4055 / -0.000005 ≈ 81,100 generations

Using approximation: t ≈ -ln(0.6667) / 0.000005 ≈ 0.4055 / 0.000005 ≈ 81,100 generations

Problem 4: Change in Frequency

Scenario: In a population of 10,000 individuals, allele A has frequency p = 0.60. The mutation rate from A → a is μ = 0.0001.

Calculate: What is Δp, the change in frequency of A after one generation?

Step-by-Step Guide:

1. Use the Δp formula directly
2. Note that population size doesn't affect the calculation
3. The answer should be negative (frequency decreases)

Your Work:

Known values: p_0 = ________, μ = ________

Formula: $\Delta p = -\mu p_0$

Calculation: Δp = -________ × ________ = ________

Final answer: Δp = ________

💡 **Hint:** The negative sign indicates that A is decreasing in frequency due to mutation pressure.

Solution:
$\Delta p = -0.0001 \times 0.60 = -0.00006$

Problem 5: Real-World Application

Scenario: Human chromosome 16 has a region where the mutation rate is estimated at 2×10^{-8} per base pair per generation. A particular SNP starts with frequency $p = 0.95$ in a population.

Calculate: What will be the frequency of this SNP after 100,000 generations? (Assume human generation time ~25 years)

Your Work:

Known values: p_0 = ________, μ = ________, t = ________

Formula: $p_t = p_0(1 - \mu)^t$

Calculation: p_t = ________ × (1 - ________)________ = ________

Final answer: p_t = ________

Time in years: ________ × 25 = ________ years

💡 **Hint:** 100,000 generations at 25 years per generation equals 2.5 million years - enough time for significant evolutionary change!

Solution:
$p_t = 0.95 \times (1 - 0.00000002)^{100000}$
$p_t \approx 0.95 \times e^{-(0.00000002 \times 100000)}$
$p_t \approx 0.95 \times e^{-0.002} \approx 0.95 \times 0.998 \approx 0.9481$

Time: 100,000 × 25 = 2,500,000 years

📈 Learning Reflection

After completing these problems, consider:

- Which concepts were most challenging?
- How does the time scale of mutation compare to other evolutionary forces?
- What real-world factors might make actual mutation dynamics more complex?

- How comfortable are you with the mathematical modeling approach?

Next Steps: Review any problems you found challenging and practice with additional scenarios from the practice problems PDF.
