Lab 2: Introduction to Probability and Statistics

BIOL-8

Name: ______________________ **Date:** ______________________

Objectives

By the end of this lab, you will be able to:

- **Understand the difference** between theoretical (expected) and experimental (observed) probability
- **Formulate testable hypotheses** and make predictions based on probability theory
- **Conduct controlled experiments** using coin flips and dice rolls
- **Record data systematically** using appropriate data tables
- **Calculate probabilities** and compare expected vs. observed results
- **Apply statistical thinking** to interpret biological phenomena

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Introduction

Probability plays a fundamental role in biology. From genetics (inheritance patterns) to ecology (population dynamics) to medicine (disease risk), understanding probability helps us make predictions and interpret data. In this lab, we'll use simple tools—coins and dice—to explore probability concepts that apply directly to biological studies.

Key Terms:

- **Theoretical probability**: What we *expect* to happen based on mathematics
- **Experimental probability**: What we *actually observe* when performing an experiment
- **Sample size**: The number of trials or observations in an experiment
- **Random event**: An outcome that cannot be predicted with certainty

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Part 1: Coin Flipping — Single Coin

> ***Learning Goal:*** *Understand how theoretical probability compares to experimental results, and how sample size affects accuracy.*

Background

A fair coin has two sides (heads and tails). Each flip is an independent event.

Theoretical Probability:

- P(Heads) = 1/2 = 0.50 = 50%
- P(Tails) = 1/2 = 0.50 = 50%

Hypothesis

Based on theoretical probability, write your hypothesis for 20 coin flips:

If I flip a fair coin 20 times, **then** I expect to get approximately __________ heads and __________ tails, **because** __________.

Procedure

1. Obtain one coin from the lab instructor
2. Flip the coin 20 times
3. Record each result immediately in the data table below
4. Calculate your experimental probability

Data Collection

Coin Flip Data — 20 Trials

#	Result (H or T)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	

#	Result (H or T)
17	
18	
19	
20	

Calculations

Count your results:

Outcome	Count	Experimental Probability
Heads		÷ 20 =
Tails		÷ 20 =
Total	20	1.00

Calculating Experimental Probability:

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Experimental Probability = (Number of desired outcomes) ÷ (Total number of trials)

P(Heads) = _____ ÷ 20 = _____
P(Tails) = _____ ÷ 20 = _____
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Show your work:

Analysis

1. Did your experimental results match the theoretical probability (50% heads, 50% tails)?

2. Calculate the difference between your expected and observed results:

Outcome	Expected (out of 20)	Observed	Difference
Heads	10		
Tails	10		

3. Was your hypothesis supported? Explain why or why not:

Part 2: Effect of Sample Size

> ***Learning Goal:*** *Discover how increasing sample size improves the match between experimental and theoretical probability—a crucial concept in statistical analysis.*

Class Data Compilation

Combine your results with the class data:

Class Combined Data

#	Statistic	Value
1		

Comparison

Compare your individual results to the class results:

Measure	Your Data (n=20)	Class Data (n=____)	Theoretical
P(Heads)			0.50
P(Tails)			0.50
Difference from theoretical			0

Why do larger sample sizes typically give results closer to theoretical probability?

In genetics, why do scientists study many offspring rather than just a few?

Part 3: Die Rolling — Single Die

Learning Goal: *Apply probability concepts to a different random event with 6 possible outcomes. Calculate probabilities for more complex events.*

Background

A fair 6-sided die has 6 outcomes, each equally likely.

Theoretical Probability for each number:

- P(1) = P(2) = P(3) = P(4) = P(5) = P(6) = 1/6 ≈ 0.167 ≈ 16.7%

Hypothesis

If I roll a fair die 30 times, **then** I expect each number to appear approximately ______ times, **because** ______.

Calculate the expected number of times each value should appear:

Expected frequency = (Probability) × (Number of trials) = (1/6) × 30 = ______

Procedure

1. Obtain one 6-sided die from the lab instructor
2. Roll the die 30 times
3. Record each result using tally marks
4. Count and calculate probabilities

Data Collection

Die Roll Data — 30 Trials

#	Die Value	Tally (use marks:	)	Count	Experimental Probability
1					
2					
3					
4					
5					
6					

Calculations and Analysis

Calculate probabilities for compound events:

1. P(rolling an even number) — rolling 2, 4, or 6:

Theoretical: P(even) = 3/6 = 0.50 = 50%

Your experimental result:

Count of even rolls (2 + 4 + 6): ______

P(even) = ______ ÷ 30 = ______ = ______%

2. P(rolling greater than 4) — rolling 5 or 6:

Theoretical: P(>4) = 2/6 = 0.333 = 33.3%

Your experimental result:

Count of 5s and 6s: ______

P(>4) = ______ ÷ 30 = ______ = ______%

3. P(rolling 1 or 6):

Theoretical: P(1 or 6) = 2/6 = 0.333 = 33.3%

Your experimental result:

Count of 1s and 6s: ______

P(1 or 6) = ______ ÷ 30 = ______ = ______%

Comparison of Expected vs. Observed:

Die Value	Expected Count (30 × 1/6 = 5)	Observed Count	Difference
1	5		
2	5		
3	5		
4	5		

Die Value	Expected Count (30 × 1/6 = 5)	Observed Count	Difference
5	5		
6	5		

Which value appeared most often? Least often?

Most: | Least:

Does this mean the die was unfair? Explain your reasoning:

Part 4: Two Dice — Combined Probabilities

> ***Learning Goal:*** *Understand how combining independent events creates more complex probability distributions, similar to how traits combine in genetics.*

Background

When rolling two dice, the outcomes combine. While each die is independent, some sums are more likely than others:

Sum	Number of Ways	Theoretical Probability
2	1 (1+1)	1/36 = 2.8%
3	2	2/36 = 5.6%
4	3	3/36 = 8.3%
5	4	4/36 = 11.1%
6	5	5/36 = 13.9%
7	6	6/36 = 16.7%
8	5	5/36 = 13.9%
9	4	4/36 = 11.1%
10	3	3/36 = 8.3%

Sum	Number of Ways	Theoretical Probability
11	2	2/36 = 5.6%
12	1 (6+6)	1/36 = 2.8%

Note: See Dashboard 2 for an interactive visualization of this probability distribution. The key insight is that 7 is the most probable sum because it has the most combinations (6 ways to roll a 7).

Hypothesis

Which sum do you predict will occur most frequently? Why?

Procedure

1. Obtain two dice of different colors
2. Roll both dice together 36 times (to match the number of possible combinations)
3. Record the sum each time

Data Collection

Sum of Two Dice — 36 Trials

#	Sum	Tally	Observed Count	Expected Count (36 × P)	Difference
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					

Analysis

1. Which sum appeared most frequently in your experiment?

2. Did this match the theoretical prediction (7 is most likely)? Explain:

3. Record your observed counts for each sum (2–12) in the data table above.

Use Dashboard 2 to create a bar graph of your results and compare to the theoretical distribution.

4. Why is 7 the most probable sum when rolling two dice?

Part 5: Application to Biology

Learning Goal: *Connect probability concepts to real biological phenomena, particularly genetics.*

1. In genetics, a heterozygous cross (Aa × Aa) has the following offspring probabilities:

Punnett Square (Aa × Aa):

	Parent 1: A	**Parent 1: a**
Parent 2: **A**	AA	Aa
Parent 2: **a**	Aa	aa

Results: 1 AA : 2 Aa : 1 aa

Genotype	Probability	Percentage
AA	1/4	25%
Aa	2/4	50%

Genotype	Probability	Percentage
aa	1/4	25%

How is this similar to rolling dice or flipping coins?

2. A couple plans to have 4 children. If the probability of having a boy or girl is 50% (like a coin flip), complete this prediction:

Outcome	Expected Number in 4 Children
All boys	4 × (1/16) = 0.25
3 boys, 1 girl	4 × (4/16) =
2 boys, 2 girls	4 × (6/16) =
1 boy, 3 girls	4 × (4/16) =
All girls	4 × (1/16) = 0.25

3. Why do real-world genetic outcomes sometimes differ from theoretical expectations?

4. Medical decisions often involve probability. If a screening test is 95% accurate, what does that mean in practical terms? Why is understanding probability important for healthcare?

Summary and Conclusions

1. State the main concept you learned about probability in this lab:

2. Was your coin flip hypothesis supported? Your die roll hypothesis?

3. What is the relationship between sample size and the accuracy of experimental results?

4. Give one example of how probability applies to human biology or medicine:

5. What questions do you still have about probability?

Key Formulas Reference

Formula	Description
P(event) = favorable outcomes / total outcomes	Theoretical probability
P(experimental) = observed count / total trials	Experimental probability
Expected count = P(event) × number of trials	Predicted frequency
Difference = Observed - Expected	Deviation from expected

Connection to Module 02: This lab demonstrates the mathematical foundations underlying biological variation. The same probability rules that govern coin flips and dice also govern inheritance patterns, disease risk, and population genetics. Understanding probability is essential for interpreting scientific data and making informed health decisions.

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