Lab 3: Basic Measurement Techniques

BIOL-8

Name: ______________________ **Date:** ______________________

Name: [ ] **Date:** [ ]

Objectives

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

- **Measure mass accurately** using analytical and triple-beam balances
- **Measure pH** using pH paper and/or digital pH meters
- **Measure temperature** using thermometers and temperature probes
- **Measure length** using metric rulers with proper precision
- **Record measurements** with appropriate significant figures and units
- **Compare measurement methods** and understand sources of error

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Introduction

Accurate measurement is the foundation of all scientific investigation. In biology and medicine, precise measurements of mass, pH, temperature, and dimensions are essential for everything from drug dosing to diagnosing disease. In this lab, you'll practice using common laboratory instruments and learn to record data with proper precision and units.

Key Concepts:

- **Precision**: How close repeated measurements are to each other
- **Accuracy**: How close a measurement is to the true value
- **Significant figures**: Digits that convey meaningful information about precision
- **Metric system**: The international standard for scientific measurement (SI units)

Part 1: Mass Measurement

> ***Learning Goal:*** *Learn to use balances correctly and understand the relationship between mass, weight, and volume.*

Background

Mass measures the amount of matter in an object. In the lab, we measure mass using balances. Common units include:

- Kilograms (kg) - 1 kg = 1,000 g
- Grams (g) - basic unit
- Milligrams (mg) - 1 g = 1,000 mg

Why is mass important in biology?

- Drug dosing (mg/kg body weight)
- Nutritional content
- Growth measurements
- Chemical reactions

Procedure

1. **Zero the balance** before each measurement
2. Place object on balance pan
3. Wait for reading to stabilize
4. Record the measurement with units

Data Collection

Station A: Measuring Common Objects

Mass Measurements — Common Objects

#	Object	Predicted Mass (g)	Measured Mass (g)	Difference
1				
2				
3				
4				
5				
6				

Standard coin masses (for reference):

- Penny: 2.5 g
- Nickel: 5.0 g
- Quarter: 5.67 g

How accurate were your predictions? What surprised you?

Were your measured values close to the standard values? Calculate the percent error for the penny:

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Percent Error = |Measured - Actual| ÷ Actual × 100%
Percent Error = |_____ - 2.5| ÷ 2.5 × 100% = _____%
```

Station B: Measuring Liquids (Density)

Use a graduated cylinder and balance to measure water mass.

Water Mass Measurements

#	Volume of Water (mL)	Cylinder + Water Mass (g)	Empty Cylinder Mass (g)	Water Mass (g)	Calculated Density (g/mL)
1					
2					
3					

Calculate density:

```
Density = Mass ÷ Volume

Example: If 25 mL of water has mass of 25.1 g
Density = 25.1 g ÷ 25 mL = 1.004 g/mL
```

The actual density of water is 1.00 g/mL at room temperature. How close were your measurements?

Why is density important in biology and medicine?

Part 2: pH Measurement

> ***Learning Goal:*** *Understand the pH scale and learn to measure acidity/basicity using different methods.*

Background

pH measures how acidic or basic (alkaline) a solution is:

- pH < 7 = Acidic (more H^+ ions)
- pH = 7 = Neutral
- pH > 7 = Basic/Alkaline (more OH^- ions)

The pH Scale (0-14):

```
 ACIDIC                       NEUTRAL                        BASIC
←─────────────────────────────────┼─────────────────────────────────→
 0   1   2   3   4   5   6   7   8   9   10  11  12  13  14
 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
 ▼   ▼   ▼   ▼   ▼   ▼   ▼   ▼   ▼   ▼   ▼   ▼   ▼   ▼   ▼
Battery Lemon  Vinegar   Coffee Milk  Pure Baking Blood Bleach Drain
 Acid Juice   (2.5)    (5)  (6.5) Water Soda (7.4) (12.5) Cleaner
(0.5) (2)                          (7)   (8.5)             (14)
```

pH in the Human Body:

Body System	Normal pH Range
Stomach acid	1.5 - 3.5
Blood	7.35 - 7.45
Saliva	6.2 - 7.4
Urine	4.5 - 8.0

Procedure — Using pH Paper

1. Tear off a small strip of pH paper
2. Dip briefly into the solution (or place drop on paper)
3. Compare color to the pH scale chart
4. Record the pH value

Data Collection

Station A: Measuring Common Solutions

pH Measurements — Common Solutions

#	Solution	Predicted pH	Color Observed	Measured pH	Acidic/Neutral/ Basic?
1					
2					
3					
4					
5					
6					
7					
8					

Station B: pH Range Comparison

Arrange your measured solutions from most acidic to most basic:

Ranked by pH (most acidic to most basic):

1. ________ (pH = ____) — Most acidic
2. ________ (pH = ____)
3. ________ (pH = ____)
4. ________ (pH = ____)

5. ______ (pH = ______)
6. ______ (pH = ______)
7. ______ (pH = ______)
8. ______ (pH = ______) — Most basic

Analysis

1. Which solution was most acidic? Most basic?

Most acidic: ______

Most basic: ______

2. Why is blood pH tightly regulated? What happens if blood becomes too acidic or too basic?

3. What would happen to stomach function if the pH were not acidic?

4. If you used both pH paper and a digital pH meter, which was more precise? Why?

Part 3: Temperature Measurement

> ***Learning Goal:*** *Practice reading thermometers accurately and understand temperature's role in biological systems.*

Background

Temperature measures the kinetic energy of molecules. We commonly use:

- Celsius (°C) - scientific standard
- Fahrenheit (°F) - common in US daily life
- Kelvin (K) - absolute temperature scale

Conversion formulas:

- $°F = (°C \times 9/5) + 32$
- $°C = (°F - 32) \times 5/9$
- $K = °C + 273$

Temperature in Biology:

Condition	Temperature
Normal body temp	37°C (98.6°F)
Fever	>38°C (>100.4°F)
Hypothermia	<35°C (<95°F)
Room temperature	~20-25°C
Water freezing	0°C (32°F)
Water boiling	100°C (212°F)

Procedure

1. Hold thermometer vertically in the liquid
2. Wait for temperature reading to stabilize (30-60 seconds)
3. Read at eye level
4. Record temperature with units

Data Collection

Station A: Various Water Temperatures

Temperature Measurements — Water Samples

#	Water Sample	Temperature (°C)	Convert to (°F)	Convert to (K)
1				
2				
3				
4				

Show your conversion calculations:

Example: Convert room temperature water from °C to °F and K

Measured temperature: ______ °C

To Fahrenheit: (_ × **9/5) + 32** = ____ °F

To Kelvin: _ **+ 273** = ____ K

Station B: Environmental Temperatures

Environmental Temperature Measurements

#	Location/Item	Predicted Temp (°C)	Measured Temp (°C)	Difference
1				
2				
3				
4				
5				

Analysis

1. Why is it important for the human body to maintain a constant internal temperature (~37°C)?

2. Was your skin temperature the same at different body locations? Why or why not?

3. Enzymes work best at specific temperatures. What happens to enzymes if temperature is too high or too low?

Part 4: Length Measurement

> ***Learning Goal:*** *Use metric units correctly and measure objects with appropriate precision using rulers.*

Background

The metric system is based on powers of 10:

- 1 meter (m) = 100 centimeters (cm) = 1,000 millimeters (mm)
- 1 cm = 10 mm
- 1 mm = 1,000 micrometers (μm)

Precision in measurement:

- Always estimate one digit beyond the smallest division
- If smallest division is 1 mm, estimate to 0.1 mm

Procedure

1. Place ruler firmly against object
2. Align the zero mark with one end
3. Read the measurement at the other end
4. Estimate to one decimal place

Data Collection

Station A: Measuring Common Objects

Length Measurements — Common Objects

#	Object	Measurement (mm)	Measurement (cm)	Measurement (m)
1				
2				
3				
4				
5				
6				

Conversion practice:

Convert 85 mm to cm: 85 mm ÷ 10 = ______ cm

Convert 15.3 cm to mm: 15.3 cm × 10 = ______ mm

Convert 23 cm to m: 23 cm ÷ 100 = ______ m

Convert 0.076 m to cm: 0.076 m × 100 = ______ cm

Station B: Calculating Perimeter and Area

Choose one rectangular object and measure its dimensions:

Rectangle Measurements

#	Object	Length (cm)	Width (cm)	Perimeter (cm)	Area (cm^2)
1					

Show your calculations:

Perimeter = 2(Length) + 2(Width)
Perimeter = 2(**) + 2(****) = _______ cm

Area = Length × Width
Area = __ × _ = ____ cm^2

Analysis

1. Why is it important to use the metric system in science rather than inches/feet?

2. When would you use mm vs. cm vs. m in biological measurements?

3. What is the relationship between the width of your thumb and 1 cm? Can your thumb be used as a rough measuring tool?

Part 5: Measurement Summary and Error Analysis

Learning Goal: *Synthesize your understanding of measurement techniques and identify sources of error.*

Summary Table

Measurement Tools Summary

#	Property Measured	Tool Used	SI Unit	Precision Available	One Biological Application
1					
2					
3					
4					

Sources of Error

For each measurement type, identify at least one source of possible error:

Measurement	Possible Source of Error	How to Minimize It
Mass		
pH		
Temperature		
Length		

What is the difference between systematic error and random error?

Conclusions

1. Which measurement technique did you find easiest to perform accurately? Most difficult?

2. Why is accurate measurement critical in fields like medicine and pharmacology?

3. Give an example of how incorrect measurements could have serious consequences in healthcare:

4. What new skill did you develop today that you will use in future labs?

Quick Reference

Measurement	Common Units	Conversions
Mass	g, mg, kg	1 kg = 1000 g, 1 g = 1000 mg

Measurement	Common Units	Conversions
Length	m, cm, mm	1 m = 100 cm, 1 cm = 10 mm
Volume	L, mL	1 L = 1000 mL
Temperature	°C, °F, K	°F = (°C × 9/5) + 32; K = °C + 273
pH	pH units	Scale 0-14; 7 = neutral

Connection to Module 03: Accurate measurement of mass, pH, temperature, and size is essential for understanding biomolecules and their functions. Enzymes, for example, are affected by pH and temperature. Drug dosing depends on mass. Cell size is measured in micrometers. The skills you practiced today form the foundation for all biological research.

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