

THINKING ABOUT BIOLOGY

AN INTRODUCTORY LABORATORY MANUAL SIXTH EDITION

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PRINCE GEORGE'S COMMUNITY COLLEGE



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On the cover: A baby orangutan native to the island of Borneo. The image was taken in Tanjung Puting National Park, on the south coast of Borneo, in the Indonesian province of Central Kalimantan. Orangutans are under severe threat from deforestation, mining, and forest fires. Their population and habitat has decreased by more than 50% since 1960. The national park, established in 1982, protects more than 1,500 square miles of tropical and lowland rainforests, mangroves, and many more disappearing habitats. It's one of the most amazing ecotourism destinations on the planet.

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Preface

Thinking About Biology is designed for a one-semester, general biology course for nonmajors. The topics and exercises are general enough to be compatible with any introductory level human and general biology text. The activities demonstrate that basic biological concepts can be applied to a wide variety of plants, animals, and microorganisms.

The basis of scientific work is asking questions and answering them by making observations and conducting experiments. Therefore, we strongly believe that the most important goal of an introductory course in the life sciences is to achieve some understanding of the processes of investigation that are basic to science and how scientists work to solve problems.

However, in today's society, we get information from a variety of sources. This can lead to some confusion about how to determine whether information you hear or read is trustworthy as opposed to "fake news." Critical thinking is a key skill for making that determination. But as with any skill, expertise comes with practice.

Thinking About Biology has many activities that will help you develop your critical thinking skills. You'll find them marked with this icon \bigcirc in both the Table of Contents and within the exercises themselves.

This book is unique not because of the specific topics covered, but because of the approach to these topics. The laboratory exercises are planned to help you

- gain practical experience that will help you understand lecture concepts
- acquire the basic knowledge needed to make informed decisions about biological questions that arise in everyday life
- develop the problem-solving skills that will lead to success in college and in a competitive job market
- learn to work effectively and productively as a member of a team

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We hope that working through these laboratory exercises will be an exciting experience for both students and instructors, and one that will leave you better prepared to meet the demands of our increasingly scientific society.

Wishing you an enjoyable and successful semester.



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NEW FOR THE SIXTH EDITION

New and revised activities are based on feedback from students and faculty. Among the key features, you'll find

- a new exercise: biodiversity and conservation
- more than 50 activities that that emphasize the development of critical thinking and problem solving skills (identified by icons in the Table of Contents and within the exercises themselves)
- emphasis in the Self Tests of each chapter on questions that require higher order thinking skills
- new activities on stem cells and ecology
- expanded and updated evolution activities
- added photos and diagrams
- exercises are broken into activities that are related to a particular topic—you can break up each exercise into blocks that fit your specific lab period

SPECIAL FEATURES FOR STUDENTS

Informal Style

• The text is written simply with easy-to-understand language. Key terms and important definitions are highlighted with bold print for easy recognition. Large spaces are provided throughout the manual for you to record and fully explain your answers. Preface

Active Learning Experience

Every exercise gives you an opportunity to be an investigator using the scientific method. You'll form hypotheses, set up experiments, collect data, record your data in graphs and charts, and draw conclusions from your experimental results.

Team-Building Opportunities

• Most laboratory activities emphasize a team approach. Group work is encouraged and often required. In the real-world job market, you'll be expected to interact with others to solve problems and complete projects. This approach provides opportunities for you to work together, share ideas, and function effectively in groups to accomplish tasks.

Real-Life Connections

Lab activities are designed to stimulate interest in topics that can help you make
decisions regarding your own health and nutrition, understand current topics
in the news, and become informed about how your personal actions affect the
environment.

Tools for Success

The following components of each exercise will help you succeed.

- **Instructional Objectives.** The objectives are listed first in each exercise so that you'll be able to focus your attention on the main concepts of each activity.
- Content Focus. Each exercise includes a brief discussion of the background information that you'll need to understand the subject of the exercise and to prepare you to complete the activities that follow.
- Notes, Hints, and Cautions. Note boxes provide helpful hints for solving problems and accomplishing laboratory tasks. Pay special attention to caution boxes that provide important safety information.
- Comprehension Checks. Stop and complete the Comprehension Check questions to get immediate feedback on your understanding of the basic principles covered in each activity. These questions also provide a chance for you to apply what you've learned to situations outside the classroom.
- Check-off Boxes. These boxes allow your instructor to check your progress and make sure you've understood the important concepts in each activity. This will help you focus your study time and be more successful in the course.
- Self Tests. Answer these questions after completing the laboratory exercise. The Self Test questions allow you to assess your comprehension and apply your knowledge. You can find the answers to the Self Test questions in Appendix 2 at the back of the book.

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We wish to express special thanks to the dedicated reviewers who shared their time and expertise to help make this edition the best it could be.



Introduction to the Scientific Method

Objectives

After completing this exercise, you should be able to:

- use the scientific method to solve problems
- organize information to facilitate analysis of your data
- draw graphs that present data clearly and accurately
- interpret data in tables, charts, and graphs
- draw conclusions that are supported by experimental data
- analyze data using common statistical measures
- apply your knowledge of the scientific method to real-life situations

CONTENT FOCUS

What is science? What do scientists *do* all day? For most of you, these aren't easy questions to answer. The widespread picture of a middle-aged man in a white lab coat doesn't apply to most scientists. So, what are scientists really like? They all have the "four Cs" in common.

Just like you, scientists are **curious** about the world around them. They ask questions about everything. Can my diet cause heart disease? Why does the river look brown instead of blue? How can squirrels remember where they bury their nuts? Why do some cars get better mileage than others? Science is a method for answering these and many other questions.

Scientists don't accept things without **collecting information.** All the facts relating to a problem or question have to be carefully explored and checked for accuracy. The most common way to collect information is through controlled experiments. Answering the complicated questions asked by today's scientists may require many different experiments performed over months or even years.

When scientists complete a series of experiments, they **communicate the results** of their research to their peers and the scientific community by publishing papers in print or Internet journals.

When the research results are made public, subject matter experts from around the world will do similar experiments to duplicate and verify the published results. Extensive verification is needed before experimental results are accepted as fact by the scientific community.

Scientists are **comfortable with new concepts.** If a better explanation can be found, scientists aren't afraid to give up old ideas for new ones.

To make the four Cs happen, scientists have developed a series of steps in investigation called **the scientific method**. Through trial and error, the scientific method has proved to be an efficient and effective way of attacking a problem. You've probably used some version of the scientific method many times in your life—without being aware of the steps you were following.

Note:

All the information, concepts, and relationships you'll read about in your textbook and laboratory manual were discovered and verified by the same scientific process you'll use in this exercise.

During this course, we'll be summarizing hundreds of years of study and experimentation. Information presented on television, in newspapers, and on the Internet often hasn't been confirmed by this same careful process and may not be correct.

ACTIVITY 1

FORMING HYPOTHESES TO SOLVE PROBLEMS

There are several ways that a problem can come to your attention. Someone may **assign** you the problem (this happens often in a school or a work situation), the problem may **thrust itself** upon you (your car won't start), or you may discover the problem by simply being **curious** about something you've seen. An easy way to attack the problem is to make an **educated guess** about the possible solution to the problem. It's an "educated" guess because you use all the background information that's available when making your guess. In scientific terms, an educated guess is called a **hypothesis**.

Let's begin with a simple situation that you might face in your college education.

The Problem

You were absent from chemistry class the day your professor gave out instructions to mix the chemicals needed for your laboratory experiment. Your roommate was in class and copied the instructions for you. You rush off to chemistry lab and mix the chemicals, but when you use them in your experiment, they don't perform as expected.

In **Table 1-1, list three hypotheses** about why the formula didn't work. Don't forget—hypotheses must be **testable!**

T A B L E 1-1
CHEMISTRY EXPERIMENT HYPOTHESES
A:
_
B:
C:



Check your hypotheses with your instructor before you continue.

Some hypotheses can be tested by observation only, but, more often, you'll need a **combination of observation and experimentation** to be sure about the accuracy of your results. To understand how scientists work, you must follow the steps of the scientific method as they are used in actual **experiments**. In Activities 2 and 3, you'll **see how scientific method skills** are used to **set up experiments** and analyze the **information (data)** that's collected.



TESTING HYPOTHESES

The Problem

Investigate the effects of fertilizer on plant growth.

STEP 1:

You form a hypothesis about what you think will happen.

Hypothesis: Adding fertilizer will make plants grow taller.

STEP 2:

You design an experiment that compares the growth (in height) of plants that receive fertilizer with those grown without fertilizer. Your design might be similar to the following:

Begin with 20 plants of the same type and approximately the same size.

• An experiment is designed to isolate the factor (variable) you're interested in testing. Variables can change over time or under different experimental conditions. In a well-designed experiment, you should be able to easily measure the changes in your variables. For example, in this experiment, the changes in variable "plant height" will be measured.

All other conditions must be held constant. In this way, you're sure that your observed results were caused by the only variable that was tested.

• Because you're investigating the effect of fertilizer, you'll want to hold all other factors constant (plant type, plant size, pot size, amount of water, amount of light, etc.) to avoid confusion. This way you can be sure that any differences in height are due to the presence of fertilizer and not to some other factor.

It's helpful to plan an experiment with a **group** of plants (or animals). There are **two good reasons** to use groups:

- If unexpected factors (such as death, disease, or accidents) affect a few experimental subjects, it won't ruin the experiment.
- Natural genetic differences among individuals of the same species will cause some plants to grow taller than others (just as some people grow taller than others). You can separate this effect from that of the fertilizer by measuring the height in a group of plants for each treatment (fertilizer and no fertilizer). Because there's so much variation among individuals, you can increase the validity and reliability of your results by testing as large a group as possible.

STEP 3:

You decide that **10 plants will receive identical, measured amounts of fertilizer** each week. These are the **experimental** plants. They are receiving the treatment (fertilizer) that will help you test your original hypothesis (fertilizer will make plants grow taller).

Ten other plants will receive no fertilizer. These are the control plants. They don't receive the experimental treatment. You'll use these for comparison with the experimental group to help you interpret your results and to show that any observed differences in height between the two groups are due to the only difference between them—the application of fertilizer.

In this example, there are 10 replications of the experimental treatment and 10 replications of the control treatment.

You plan to measure the growth of your plants (height in centimeters) **once a week for a month.** You'll keep detailed **records** of your **observations.**

✓ Comprehension Check

1. Why is it necessary to divide the plants into two groups (a control group and an experimental group)?

2. Why is it important to keep conditions exactly the same in the control and experimental groups, **except** for the application of fertilizer?

3. If you were designing this experiment for a fertilizer manufacturer, what changes would you make in the experimental design to be confident that your results would be accepted as fact by the scientific community? Explain your answer.



Check your answers with your instructor before you continue.



INTERPRETING DATA

The month is up. You're ready to draw conclusions from your **data** (the information you have recorded). You'll be thinking about what your results mean and whether your hypothesis is **supported**. The information you collected during your experiment is presented in **Tables 1-2 and 1-3**.

T A B L E 1 - 2 HEIGHT GAIN (cm) OVER FOUR WEEKS—CONTROL PLANTS							
PLANT NUMBER	INITIAL HEIGHT (cm)	Week 1	Week 2	Week 3	Week 4	GROWTH OVER FOUR WEEKS (cm)	
1	10.0	1.6	2.0	3.0	2.5	9.1	
2	11.5	2.2	1.5	1.5	2.0	7.2	
3	9.6	1.5	2.3	2.6	2.0	8.4	
4	9.2	2.0	3.0	2.8	1.5	9.3	
5	10.2	2.3	1.2	1.6	2.0	7.1	
6	11.0	3.2	1.7	2.0	3.2	10.1	
7	10.0	2.6	3.0	3.0	1.4	10.0	
8	9.7	4.0	2.6	4.0	2.3	12.9	
9	10.4	DIED	_	_	_	_	
10	10.4	2.3	2.3	2.7	2.7	10.0	
TOTAL H	TOTAL HEIGHT GAIN—84.1 cm						
AVERAGI	AVERAGE HEIGHT GAIN—9.3 cm						

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TABLE 1-3 HEIGHT GAIN (cm) OVER FOUR WEEKS—EXPERIMENTAL PLANTS

Plant Number	INITIAL HEIGHT (cm)	Week 1	Week 2	Week 3	Week 4	GROWTH OVER FOUR WEEKS (cm)
1	9.6	4.2	5.0	3.0	4.7	16.9
2	9.8	6.0	4.0	5.5	5.0	20.5
3	10.3	5.3	5.5	3.6	4.2	18.6
4	11.0	2.1	3.2	6.2	3.8	15.3
5	10.1	3.4	4.0	4.4	4.0	15.8
6	9.2	4.7	3.1	3.1	4.0	14.9
7	9.5	4.2	5.2	3.9	3.6	16.9
8	10.0	3.3	6.0	5.6	4.2	19.1
9	9.7	5.8	6.1	6.5	5.0	23.4
10	10.4	5.1	3.4	5.8	5.3	19.6
TOTAL HE	IGHT GAIN—1	181.0 cm				
AVERAGE HEIGHT GAIN—18.1 cm						

✓ Comprehension Check

1. Were there differences in growth between the control and experimental plants?

If so, which group grew taller?

2. Do the results support the original hypothesis? Explain your answer.

3. Why is it more accurate to compare the **average** height gain of the control and experimental groups (instead of comparing individual plants)?



Check your answers with your instructor before you continue.

ACTIVITY 4

PERFORMING AN EXPERIMENT AND COLLECTING DATA

Regardless of where you live, you've probably heard a lot of news stories lately about the increasing spread of HIV (which causes AIDS) and other sexually transmitted infections throughout the United States. In this activity, you'll simulate how multiple sexual encounters by an infected person can lead to the spread of a disease through a population.

1. On your laboratory table, you'll find a dropper bottle of distilled water and a dropper bottle of phenolphthalein solution (a chemical indicator).

From the supply area, get four clean sampling cups, a marker pen, and a container that holds an unidentified liquid.

Note:

The unidentified liquid in your container represents the body fluids that may be exchanged during sexual encounters. Your container holds either distilled water or a solution that changes color when exposed to phenolphthalein. A color change simulates body fluids that are infected with HIV. Only one container in the class is "infected."

2. Using a marker pen, label the first small sampling cup with the number 2 as shown in **Figure 1-1.** Label the others 4, 6, and D (which stands for distilled water).



FIGURE 1-1. Labeled Sampling Cups

3. Read through the following instructions on how to perform "body fluid" exchanges. WHEN YOUR INSTRUCTOR TELLS YOU TO START, follow the steps listed and complete Exchange #1.

To "exchange" body fluids, follow these steps:

- Randomly select **one partner** for the exchange.
- Pour **all** of the solution in your container into your partner's container.
- Your partner will pour **all** of the solution in his/her container back into your container.
- Pour only half of the solution back into your partner's empty container.
- Return to your seat. Exchange #1 has been completed.
- 4. WAIT until all the students in the class have completed Exchange #1.

WHEN YOUR INSTRUCTOR TELLS YOU TO START, perform Exchange #2 using the same procedures as you did for Exchange #1.

Don't select the same partner you had before.

5. Pour a small amount of liquid from your container of "body fluids" into the sampling cup labeled with the number 2 (just enough liquid to cover the bottom of your sampling cup).

Set the sampling cup aside and wait for your instructor's signal to continue with the simulation.

6. WHEN YOUR INSTRUCTOR TELLS YOU TO START, perform Exchange #3.

Don't select any partner you've had before.

7. WHEN YOUR INSTRUCTOR TELLS YOU TO START, perform Exchange #4.

Don't select any partner you've had before.

8. Pour a small amount of liquid from your container of "body fluids" into the sampling cup labeled with the number 4 (just enough liquid to **cover the bottom** of your sampling cup).

Set the sampling cup aside and wait for your instructor's signal to continue with the simulation.

9. WHEN YOUR INSTRUCTOR TELLS YOU TO START, perform Exchange #5.

Don't select any partner you've had before.

10. WHEN YOUR INSTRUCTOR TELLS YOU TO START, perform Exchange #6.

Don't select any partner you've had before.

- 11. Pour a small amount of liquid from your container of "body fluids" into the sampling cup labeled with the number 6 (just enough liquid to cover the bottom of your sampling cup).
- 12. Using the dropper bottle of distilled water, drop a small amount of **distilled water** into the sampling cup labeled with the letter D (just enough to cover the bottom of your sampling cup).
- 13. Place **one drop of phenolphthalein** indicator solution into each of the four sampling cups (cups 2, 4, 6, and D).

If the liquid in any of the sampling cups **turns bright pink**, you've been **infected with HIV**.

Based on the results of your indicator tests, check the appropriate box in **Table 1-4** (infected or not infected) for **Exchanges #2**, **#4**, **#6**, and the **distilled water**.

TABLE 1-4 RESULTS OF INDICATOR TESTS FOR BODY FLUID EXCHANGES					
INFECTED NOT INFECTED					
Exchange #2					
Exchange #4	Exchange #4				
Exchange #6					
Distilled Water					

14. When everyone has recorded his/her results, your instructor will survey the class to determine the total number of infected students after Exchanges #2, #4, and #6. Record the results of the survey in Table 1-5.

TABLE 1-5 SIMULATION RESULTS—SPREAD OF HIV				
EXPERIMENTAL TRIALS	Number of Infected Class Members			
Start of experiment	1			
Exchange #2				
Exchange #4				
Exchange #6				

15. What was the reason for performing the phenolphthalein indicator test on the distilled water? Explain your answer.

16. In scientific terminology, what name is given to the part of the simulation in which you performed the indicator test on the distilled water?

ACTIVITY 5

GRAPHING YOUR RESULTS

- 1. Graphs provide a good visual representation of the relationships between the factors investigated in an experiment.
- 2. Look at the graph structure in **Figure 1-2** and note the following **key points**:
 - The **horizontal** axis is referred to as the **X-axis**. The **vertical** axis is called the **Y-axis**.
 - Numbers on the X- and Y-axes must have an **equal interval** between them (for example, 5, 10, 15, but **not** 5, 10, 20, 50).

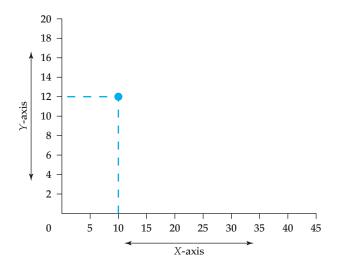
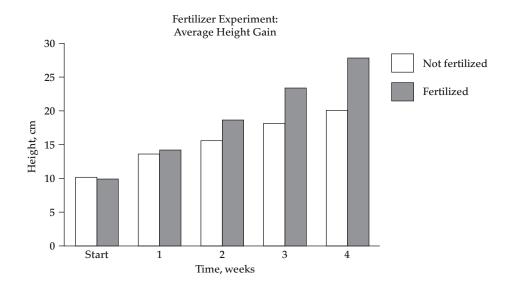


FIGURE 1-2. Graph Structure

- When deciding which factors to plot on the X- and Y-axes, here's a good rule of thumb: if one data set consists of words (months of the year, car models, country names) and the other is numbers (number of cars sold, average income), plot the words on the X-axis and the numbers on the Y-axis. If both sets of data are numbers, plot the factor being measured on the Y-axis.
- Numbers on the X- and Y-axes are chosen carefully to make the **best use** of the space available. It's not necessary to always begin numbering with zero. It's also not necessary to use the same number scale on both the X- and Y-axes. As shown in **Figure 1-2**, each axis should have a number scale tailored specifically to the data being presented.
- It's not permissible to extend lines or bars outside the margins of the graph.
 Adjust the graph scale to make the data fit comfortably.
- 3. The data point shown in Figure 1-2 is at the intersection of 10 on the X-axis and 12 on the Y-axis.
- 4. **Bar graphs** and **line graphs** are examples of types of graphs that are used frequently to present scientific data. **Figure 1-3** illustrates two different ways to present the same information. Note that in both versions of the graphed data:
 - Lines or bars are large and easy to read.
 - Each graph has a **title** that describes the subject matter being graphed. The title can be placed either above or below the graph.
 - Each axis has a title that clearly explains the information being plotted (including units, if appropriate).
 - If the graph contains more than one set of bars or lines (as is the case in **Figure 1-3**), each must be identified with a **key**.



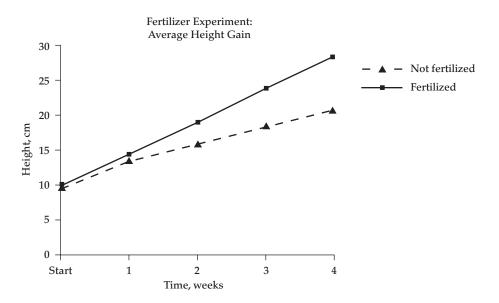


FIGURE 1-3. Comparison of Bar and Line Graphs

✓ Comprehension Check

1. On the graph paper in **Figure 1-4**, plot a graph of your experimental results from Activity 4.

Choose an appropriate number scale for the **Y-axis** and label it **Number of Infections**. Choose an appropriate number scale for the **X-axis** and label it **Number of Exchanges**.

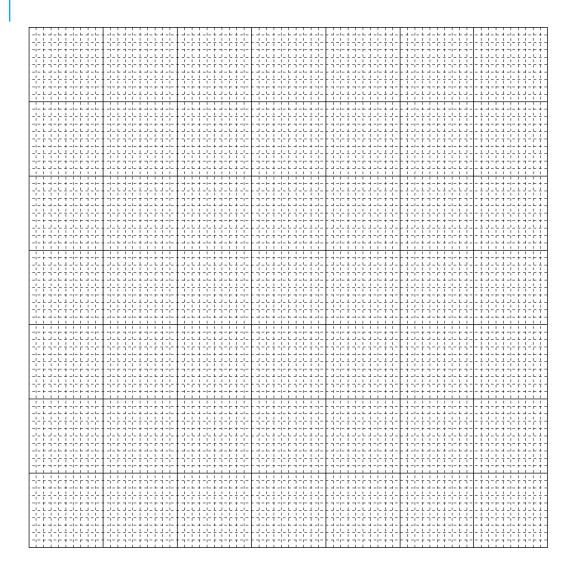


FIGURE 1-4. Results of HIV Simulation

2.	In a few sentences, summarize the results of the experiment. In your summary include data from your summary chart and graph. Statements of results should include only facts—no interpretation.
3.	In real life, infections don't spread as rapidly as they did in our simulation. Why not?
4.	Suggest some methods to slow the rate of infection in the general population.
	Check your graph and answers with your instructor before you continue.



INTERPRETING DATA USING SIMPLE STATISTICS

Often, the data collected in an experiment is in a form that isn't easily understandable. Measurements have been established to make it easier to interpret and draw conclusions from large collections of information. We're all familiar with the U.S. Census, which collects huge amounts of information on family size, income, housing conditions, population distributions, and so on.

Simple statistical analysis can reduce the data and convert it to a usable form. A similar approach is used when analyzing the results of large experiments (such as evaluating the effectiveness of new medications or airbags in automobiles). The most commonly used statistical measures are the mean, the mode, the median, the range, and the standard deviation.

The **mean** is the **average** of a set of numbers. The mean is equal to the **sum of all the numbers in the set divided by the sample size.** For example, to find the average pulse rate of a group of 10 students, you would add the pulse values for all of the students together and then divide the answer by the number of students (10).

The mean of a group of numbers often doesn't give you the information you need to correctly interpret the data. For example, the following two sets of numbers have exactly the same mean, but the spread (dispersion) of numbers is quite different.

```
Set 1: 39, 38, 38, 40, 40 mean = 39
```

The **mode** is the **most frequently occurring number** in a set. The mode represents the most common response and, therefore, can be used as a predictor to determine market response (for example, which car model will sell the best in a specific area of the United States).

The **median** is the **middle** number of a set when they're arranged in either **ascending or descending order.** If your income level is above the median, for example, your salary is in the upper 50% of salaries being compared. If a set of numbers has **no middle value**, you can find the median by **averaging the middle two numbers** in the set.

The range is the difference between the largest and smallest values in a set, for example, the difference between the number of yards gained by the best and worst running backs in the National Football League.

To demonstrate how applying different statistical measures changes the meaning of results, consider the set of 20 biology exam scores in **Table 1-6**.

T A B L E 1 - 6						
BIOLOGY EXAM SCORES						
STUDENT NUMBER	Score: Exam 1	STUDENT NUMBER	Score: Exam 1			
1	90	11	88			
2	94	12	54			
3	80	13	32			
4	82	14	47			
5	91	15	25			
6	46	16	56			
7	97	17	59			
8	96	18	60			
9	87	19	87			
10	84	20	86			
Mean = 72.05						
Mode = 87						
Median = 83						

- 1. What's the range of exam scores in Table 1-6?
- 2. If your **exam score was 80,** was your score in the top 50% of the class? Explain your answer.
- 3. In this situation, is the **mean** a good representation of the class scores? **Why or why not?**

4. While watching television last night, you saw an advertisement for Lose-Fast Weight Control Pills. The 12 women shown lost an **average** of 30 pounds while taking the pills. What additional **statistical measures** (as discussed in **Activity 6**) should be reported for you to make an informed decision whether or not to purchase this product?



Check your answers with your instructor before you continue.

SELF TEST

A national hospital chain performed a study to determine whether a new drug was effective in lowering blood pressure in patients suffering from hypertension (high blood pressure):

Group A (1000 patients) received a daily pill containing the new drug. Group B (1000 patients) received an identical-looking pill, but no medication was included. All the participants in the study had previously been identified as having higher blood pressure than normal (above 140/95 mm Hg). Blood pressure was checked twice daily for a month in all 2000 participants in the study. At the end of the study, the results were published in the *New England Journal of Medicine*.

Fill in the blanks with the choice that is most appropriate. The questions relate to the study of the new blood pressure medication that was described above. **Answers can be used only once.**

a. b. c. d. e. f.	variable control experime hypothes verify X-axis	h ental i.	•	Y-axis data point mode average median	
1.		In this experiment, Group A was the group.			
2.		Group B represents the group.			
3.		When the results of the study are published, other experts will want to duplicate the experiment in order to the results.			
4.		If you were graphing the results of this study, on which axis of the graph would it be best to plot blood pressure changes?			
5.		To calculate the decrease in blood pressure in Group A, you should add up all the numbers in the data set and divide by the number of data points.			
6.		Each time a patient's blood pressure is measured, it adds one to the study results.			
7.		The being tested in this students' blood pressure.	ly '	was that the new drug would decrease	

Identify the graphing mistakes in Figures 1-5 and 1-6:

8.

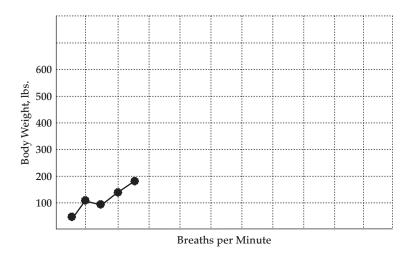


FIGURE 1-5. Sample Graph One

9.

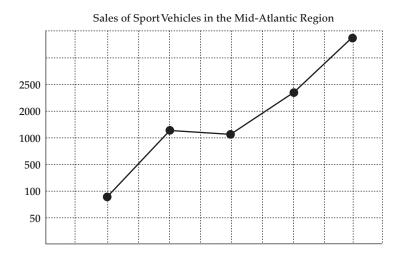


FIGURE 1-6. Sample Graph Two

Answer the following questions in reference to the graph in **Figure 1-7**.

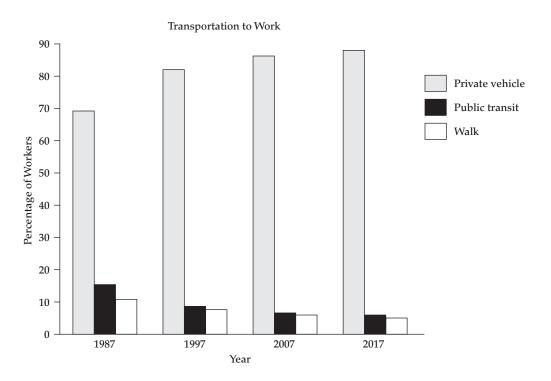


FIGURE 1-7. Percentage of Workers Using Various Modes of Transportation

- 10. **(Circle one answer.)** Between 1987 and 2017, the percentage of workers who walked to work **increased / decreased / remained the same.**
- 11. Between 1987 and 2017, the number of people who drove cars to work increased by ______ %.
- 12. In 2017, what percentage of workers drove cars to work? ____
- 13. The number of workers who used public transportation dropped by 7% between 1987 and _____.

14. On the graph grid in **Figure 1-8**, graph the following data on energy usage in the home (www.energystar.gov). Graph the data in order from the **lowest percentage** of energy consumed to the **highest**.

HOME ENERGY CONSUMPTION	PERCENTAGE OF TOTAL (%)	
hot water heating	14	
lighting	12	
electronics	4	
space cooling	17	
space heating	29	
appliances	13	
other	11	

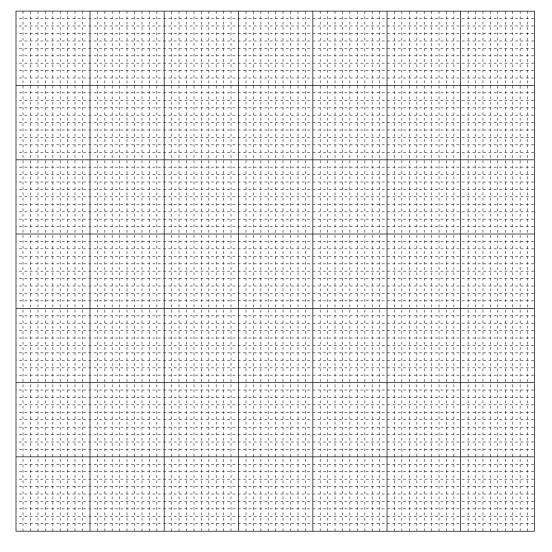


FIGURE 1-8.



Windows to a Microscopic World

Objectives

After completing this exercise, you should be able to:

- identify the parts of the compound and dissecting microscopes and explain their functions
- choose the correct type of microscope for viewing different specimens
- focus the compound microscope using the scanning, low-, and high-power lenses
- prepare a wet mount slide
- correct viewing problems that commonly occur when using the compound microscope
- accurately describe specimens viewed through the dissecting and compound microscopes
- use the microscope to test a hypothesis

CONTENT FOCUS

All organisms, large and small, make valuable contributions to the functioning of the ecosystem. Many plants and animals are large and easy to see, but many important organisms are too small to be seen without the assistance of magnifying lenses.

You'll have an opportunity to get a close look at the anatomy and behavior of some interesting organisms that live around you unnoticed. Microscopes work like magnifying glasses to give you a closer look at these small organisms.

Different types of microscopes can be used for different purposes. During this exercise, you'll be learning to use a **dissecting microscope** to examine larger objects and a **compound microscope** to view smaller specimens. However, other types of specialized microscopes allow us to see even smaller details.

An **electron microscope** focuses a beam of high-energy electrons onto a specimen to create a detailed image. Depending on the type of electron microscope, you can examine objects on a very fine scale, viewing both the internal structures and details of external appearance (see the example in **Figure 2-1**).

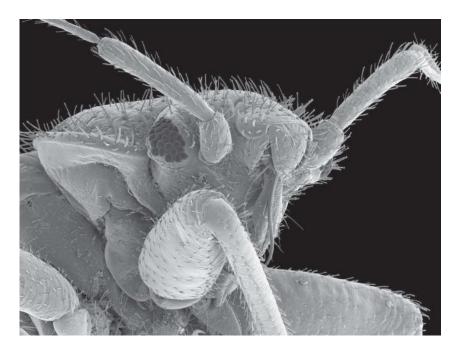


FIGURE 2-1. A Scanning Electron Micrograph of a Bedbug

ACTIVITY 1

LEARNING TO USE THE DISSECTING MICROSCOPE



Caution!

Always carry a microscope upright with one hand under the base and the other hand on the arm.

- 1. Work in groups of **two students**. Get the following supplies: **a dissecting microscope** and **a penny**.
- 2. Place the penny on the microscope **stage.** Locate the stage by referring to the photo in **Figure 2-2.** Position the penny so that the side showing a shield and scroll with the inscription "one cent" is facing up. **Adjust the light** until the penny is brightly illuminated.

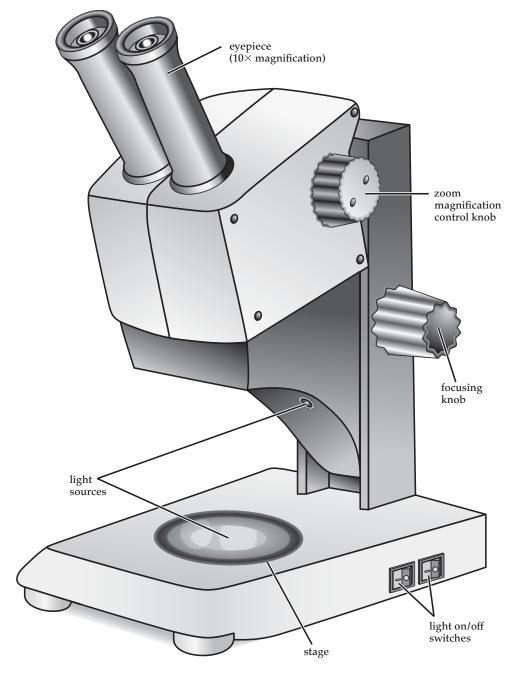


FIGURE 2-2. Parts of the Dissecting Microscope

- 3. Set the **magnification control knob**, located on the top or the side of the **head**, to the **lowest setting**.
- 4. Turn the **focusing knob**, located on the microscope arm, until you can't lower the lens any further. Look through the **ocular lens (eyepiece)** at the penny. **Turn the focusing knob** until the image on the penny is sharp and clear.
- 5. While looking through the eyepiece, gradually turn the **magnification control knob**. The change in image size will be similar to the zoom action of a camera. Zoom up until you can see the tiny letters written on the left and right sides **beneath the scroll**.

The letters written on the left side are	_•
The letters written on the right side are	

ACTIVITY 2

MAKING OBSERVATIONS WITH THE DISSECTING MICROSCOPE

- 1. Work in groups. Get the following supplies: a small glass bowl, a pipette, and a blunt metal probe.
- 2. Use the pipette to remove a **planaria** from the culture container and place it in your bowl. Locate the worm of your choice and draw it into the tip of the pipette (as shown in **Figure 2-3**). When the planaria feels the water current, it will probably form itself into a small protective ball, and it will be easy to draw it into the pipette.

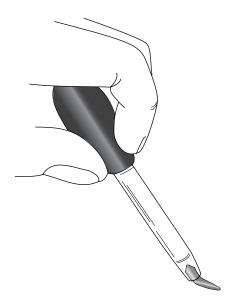


FIGURE 2-3. Drawing a Planaria into the Pipette

Caution!

Don't suck the planaria too far into the pipette. It will attach to the inside of the pipette and you won't be able to get it out.

If additional water is needed in your glass dish, add pond water. Don't use tap water or distilled water.

3.	Observe your worm under the dissecting microscope. Use a medium or low light level.
	Observe carefully through the microscope for at least two minutes.
	Does the worm swim or crawl?
	Describe the movement of the worm's muscles as it moves forward.
4.	Draw a picture of your worm. Increase the magnification in order to see the details of the head. When drawing the head, pay particular attention to the position of the eyes in relation to each other. Make your drawing large and clear. Label the head and the eyes .
	DRAWING OF PLANARIA

5. Hold the **blunt probe motionless** directly in the path of a moving worm. How does the worm respond?

- 6. Touch the head end **gently** with the blunt probe. How does the worm respond?
- 7. Touch the planaria **gently** on several other body parts. Record your observations.
- 8. In what way was the **touch response** on other body parts **similar** to or **different** from the response you observed when the worm was touched on the head end?



Check your answers with your instructor before you continue.

ACTIVITY 3

GETTING FAMILIAR WITH THE COMPOUND MICROSCOPE

1. Work in groups. Get a compound microscope.



Caution!

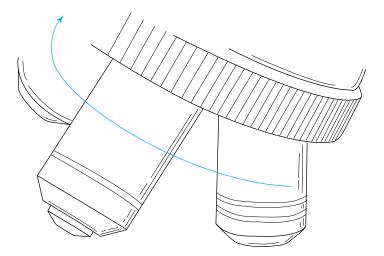
Always carry the microscope upright with one hand under the base and the other hand on the arm.

- 2. Plug the microscope into an electrical outlet and **turn the light on.** The light switch is located on the **base** of the microscope.
- 3. The compound microscope consists of a system of **optics** (lenses and mirrors) and focusing controls. The base and the arm support a **body tube** that **houses the lenses** that magnify the image.
- 4. At the top of the scope is the **ocular lens (eyepiece).** The ocular lens is only one of a series of lenses that magnify the image. The ocular lens makes the image **10 times** larger than life size (abbreviated **10**×).

Look through the ocular lens. You'll see a black pointer. Rotate the eyepiece while looking through the lens. One of the objective lenses must be "clicked" into position for you to see the pointer.

What happens to the pointer?

5. At the bottom of the body tube is a revolving **nosepiece**. The lenses that screw into the nosepiece are called **objective lenses**.



Turn the nosepiece until you hear or feel one of the objective lenses quietly click into position (see Figure 2-4). When an objective lens clicks into position, it's in the proper alignment for light to pass from the light source, through the objective lens, through the ocular lens, and into the viewer's eye. Turn the nosepiece again to bring a different objective lens into position.

FIGURE 2-4. Revolving Nosepiece and Objective Lenses

6. **How will you know** when you've placed the objective lens in the proper position?

7. Note that each objective lens is of a different length. Each of the lenses has a different magnifying power. The **shortest lens** has the **lowest magnifying power** and the **longest lens** has the **highest magnifying power**.

Because light from the specimen passes through **both** an objective lens **and** the ocular lens, the **total magnification** of the image is the result of the objective lens magnification **multiplied** by the ocular lens magnification.

8. Using the information provided in step #4, complete the magnification table.

Length of Objective Lens	Magnification of Objective Lens	Magnification of Ocular Lens (Eyepiece)	Total Magnification of Specimen
Short	4×		
Medium	10×		
Long	40×		

9. On both sides of the arm, you'll see the **focus knobs**. The larger ring is the **coarse focus knob** and the smaller ring is the **fine focus knob**.

The coarse focus moves the stage in fairly large increments to bring the object on the slide into approximate focus. The small adjustments possible with the fine focus knob are then used to make the image sharp and clear.

10. The **mechanical stage** is a movable platform designed to hold a microscope slide. Notice that one side of the metal stage clip makes a 90° angle. When you place a slide on the stage, **make sure** that one corner of the slide **fits exactly into that angle.** If not, you won't be able to move the slide or focus properly.

Two control knobs move the mechanical stage. One moves the stage left and right; the other moves the stage forward and back. Always move the stage using the control knobs. Don't attempt to move the slide using your fingers.

- 11. In the center of the stage, you'll see the glass of the **condenser lens**, which focuses the light on the specimen.
- 12. **Looking at the condenser lens,** move your hand to the **iris diaphragm lever** (just under the stage). Push the lever all the way to the left and then all the way to the right. What happens to the amount of light passing through the condenser lens as you move the iris diaphragm lever?

ACTIVITY 4 PARTS OF THE COMPOUND MICROSCOPE

Now that you have some experience with the parts of the microscope and their functions, **label the parts** of the microscope on **Figure 2-5**.



FIGURE 2-5. Parts of the Compound Microscope

ACTIVITY 5

LEARNING TO USE THE COMPOUND MICROSCOPE

- 1. Work in groups. Get the following supplies: a prepared slide labeled letter "e" and a piece of lens paper.
- 2. Complete the following steps to view the letter "e" (or another specimen) with the compound microscope:
 - Plug in the microscope and turn on the light. Open the iris diaphragm so that you can see the light shining through the condenser lens.
 - Using the coarse focus knob, lower the stage as low as it can go.
 - Clean the slide with lens paper and carefully position the slide so that it fits precisely into the 90° angle of the metal clip on the stage. Position the slide on the stage so that the letter "e" is facing you **right-side up**, in its **normal reading position**.
 - Rotate the **lowest power** objective lens into position.
 - Using the control knobs on the mechanical stage, position the slide so that light is shining on the letter "e."
 - While looking through the eyepiece, use the **coarse focus knob** to raise the stage slowly. Continue until the letter "e" **pops into focus.**
 - Once again, use the **control knobs** on the mechanical stage to **center** the letter "e" in your field of view.
 - Using the fine focus knob, adjust the focus until the letter "e" is sharp and clear.

Comprehension Check

- 1. If the letter "e" isn't lighted brightly enough or is too bright, what part of the microscope would it be best to adjust?
- 2. What is the **total magnification** of the image of the letter "e"? **Show** your work.



Check your answers with your instructor before you continue.

3. Draw the letter "e" exactly as it appears under low power. Make it large and clear.

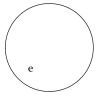
LETTER "e"

- 4. How is the **orientation** of the letter "e" as seen through the microscope **different** from the way an "e" **normally** appears? List **two** differences.
- 5. **While looking through the eyepiece,** move the stage to the **left.**

In what direction does the image appear to move? _____

While looking through the eyepiece, move the stage away from you.

In what direction does the image appear to move? _____



If you wanted to **center** the letter "e" in this drawing, in which **two directions** would you have to move the stage?

_____and _____

- 6. Follow these steps to view a specimen at a higher magnification:
 - Center the letter "e" (or other specimen) in your field of view.
 - Rotate the 10× objective lens into position. DON'T adjust the stage at this point!
 - DON'T use the coarse focus knob! Using the fine focus knob, adjust the focus slowly until the letter "e" is sharp and clear.
 - Repeat the previous steps to change to other objective lenses.

7. Centering the specimen is absolutely necessary before you can change to a higher-power objective! Do you know why? The reason is simple. The more powerful the magnifying lens, the smaller the area you see, but you see that small area in greater detail. The area you can see at one time is called the field of view. So you could say that the higher the power of the objective, the smaller the field of view.

If the specimen you're trying to view isn't centered before you switch to a higher-power lens, it may no longer be within the field of view, and you'll think your specimen has disappeared!

8.	Looking through the eyepiece, can you still see the letter "e"?
	Is the letter "e" exactly in the center of the field of view?
	If not, move the slide slightly to center the image.
	Is the letter "e" sharp and clear?
	If not, gradually adjust the fine focus knob until the problem is corrected.
	Do you have enough light?
	If not, gradually adjust the iris diaphragm.
	How has the image of the letter "e" changed from the way it looked using the 4 × objective lens?
9.	Repeat the instructions in step #6, this time changing from 10× to the high-power objective.
	Looking through the eyepiece, can you see the entire letter "e"?
10.	(Circle one answer.) Your field of view on high power is larger / smaller than the field of view on 10×.

neid of view on 10×.

How does the size of the field of view determine how much of the letter "e" you can see?

11. When using the **high-power objective**, what is the **total magnification** of the image of the letter "e"? ______ **Show your work.**



Check your answers with your instructor before you continue.

ACTIVITY 6

PREPARING TEMPORARY SLIDES— WET MOUNTS

A wet mount is a method of preparing a slide that will be used only for a short time. Unlike the letter "e," which was permanently attached to the slide, a wet mount is made by placing the specimen into a drop of liquid on a slide. The specimen and water droplet are held in place by a coverslip.

Human Epithelial Cells (Cells from the Inside of Your Cheek)

- 1. Work in groups. Your group will make **two different wet mounts** of cheek cells.
 - One will be made with a drop of **stain.** The second will be made by substituting a drop of **physiological saline** for the stain.
- 2. Get the following supplies: a dropper bottle of iodine stain or physiological saline, a slide, a coverslip, lens paper, and a clean toothpick.
- 3. Place a drop of iodine stain or a drop of saline near the center of a clean slide.
- 4. **Gently** scrape the inside of your cheek with the **end of a toothpick**.

Caution!

If you scrape too hard, you'll be examining blood cells instead of epithelial cells!

You've removed some of the cells that form a **protective covering** for the inside of the mouth. Like other epithelial cells, these are constantly being worn off and replaced by new cells of the same type.

5. **Spread the material from the toothpick** into the drop of iodine stain or saline. Add a coverslip.

Put two microscopes together (yours and your partner's) on the laboratory table so that you can view and compare the stained and unstained slides.

Hint:

Unstained cells are clear. They're visible only with very low light levels. If you think there are no cells on your slide, adjust the iris diaphragm.

- 6. **View both slides. Begin with the 4**× **objective.** Continue until you've located the cells using **all three objective lenses.**
- 7. Draw a picture of one cheek cell, viewed on high power. Make it large and clear.

HUMAN CHEEK CELL

8. **Label** the following cell structures (referred to as **organelles**) in your drawing of the cheek cells:

Organelles to Label	Function
nucleus	directs all cell activities
cell membrane	controls movement of materials in and out of the cell
cytoplasm	jelly-like fluid found between the nucleus and cell membrane

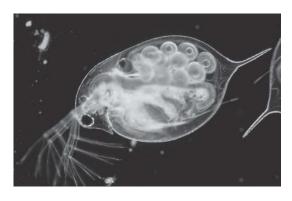
9.	Give an example of a medical procedure in which epithelial cells are scraped from another area of the body and examined microscopically .
10.	Is there an advantage in using a stain to view cells microscopically? If so, how is the stain helpful?

Daphnia—An Aquatic Organism

The water flea, daphnia, is a microscopic organism commonly found in ponds, lakes, and streams. Because they are small and transparent, living daphnia can be studied easily in the laboratory. Daphnia feed on microscopic food particles. Their five pairs of legs are modified into strainers that filter the food particles from the water. Daphnia, in turn, are an important part of the food chain. Many fishes and even larger aquatic animals feed on daphnia.

- 1. Work in groups. Get the following supplies: a depression slide and a bottle of methyl cellulose (the bottle may also be labeled Protoslo®).
- 2. Put a **small** drop of the methyl cellulose into the depression on your slide.
 - Use the pipette in the culture jar to remove a daphnia from the container and place it in the depression on the slide. **You don't need a coverslip.**
- 3. Make your observations using the scanning lens of the microscope (4×). Add the following details to the daphnia outline in Figure 2-6: eye, heart, brain, and intestine.

Label the details you're adding to the drawing. Also, label the head and legs.



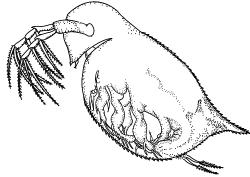


FIGURE 2-6. Daphnia



Check your answers with your instructor before you continue.



USING THE MICROSCOPE TO ANSWER A QUESTION: WHAT DO AQUARIUM SNAILS EAT?

- 1. Work in groups. Go to your **classroom aquarium** and **observe the feeding activity** of the snails.
- Write a hypothesis: What are the snails eating?Hypothesis:

Hint:

Don't forget to make sure your hypothesis is testable!

3. Develop and carry out an observation plan. Refer to **Figure 2-7** to help you identify organisms you observe. **Record** the results of your observations.

Comprehension Check

- 1. **Discuss** the results with your other group members. **(Circle one answer.)** My hypothesis **was / was not** supported.
- 2. Write a conclusion based on your hypothesis and collected data. Support your conclusion by mentioning facts collected during your experiment.



Check your answers with your instructor before you continue.

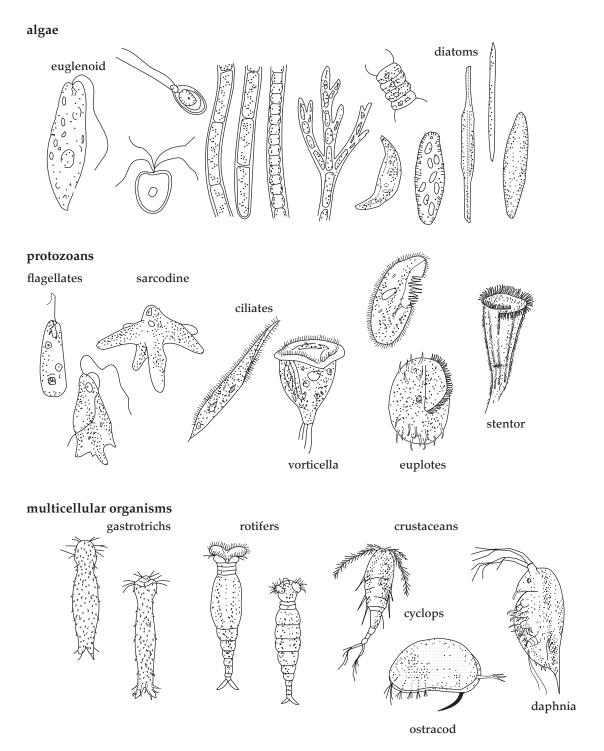


FIGURE 2-7. Organisms Commonly Found in Pond Water

SELF TEST

1. Complete the table by entering the appropriate part of the compound microscope or the correct function for the part of the microscope listed.

PARTS OF THE COMPOUND MICROSCOPE	Function
Ocular lens (eyepiece)	
Stage	
	Focuses light on the specimen
Nosepiece	
	Objective lens used to first locate a specimen
	Regulates the amount of light that passes through the specimen
Fine focus knob	
	Objective lens with the lowest magnifying power
	Objective lens with the highest magnifying power
Coarse focus knob	

2. What is the **total magnification** if the ocular lens is $15 \times$ and the objective lens is $20 \times$? **Show your work.**

3.	List three differences between the dissecting microscope and the compound microscope:
	a.
	b.
	c.
4.	Which type of microscope (compound or dissecting) would you use to observe the following:
	Cells from the lining of your stomach
	A seashell you found on the beach
	A cockroach you found in the kitchen
	Mold from your shower curtain
5.	Suppose you were watching a daphnia under the compound microscope and noticed that it moved toward you and then to your right.
	Which direction(s) did the daphnia actually move?
	Explain your answer.

•	Explain how you would correct the following problems experienced when using a microscope:
	a. When changing magnification from $10\times$ to $40\times$, the specimen disappears.
	b. The field of view is too dark.
	c. Your field of view is partially obscured by a dark area.
	d. There's a fingerprint in your field of view.
	e. There are many hollow, dark circles in your field of view.

Fill in the blank with the most appropriate answer.

7	First focus knob you would use when viewing
	a specimen.
8	Power of lens you would use first when viewing
	a specimen.

Circle one choice for each question.

- 9. You should use a **dissecting / compound / electron** microscope to observe human muscle cells in the lab.
- 10. When you switch from low power to high power, the **field of view** becomes **larger / smaller**.
- 11. When using a dissecting microscope, you **do / don't** need to prepare a slide.
- 12. Planaria are phytoplankton / zooplankton / worms.