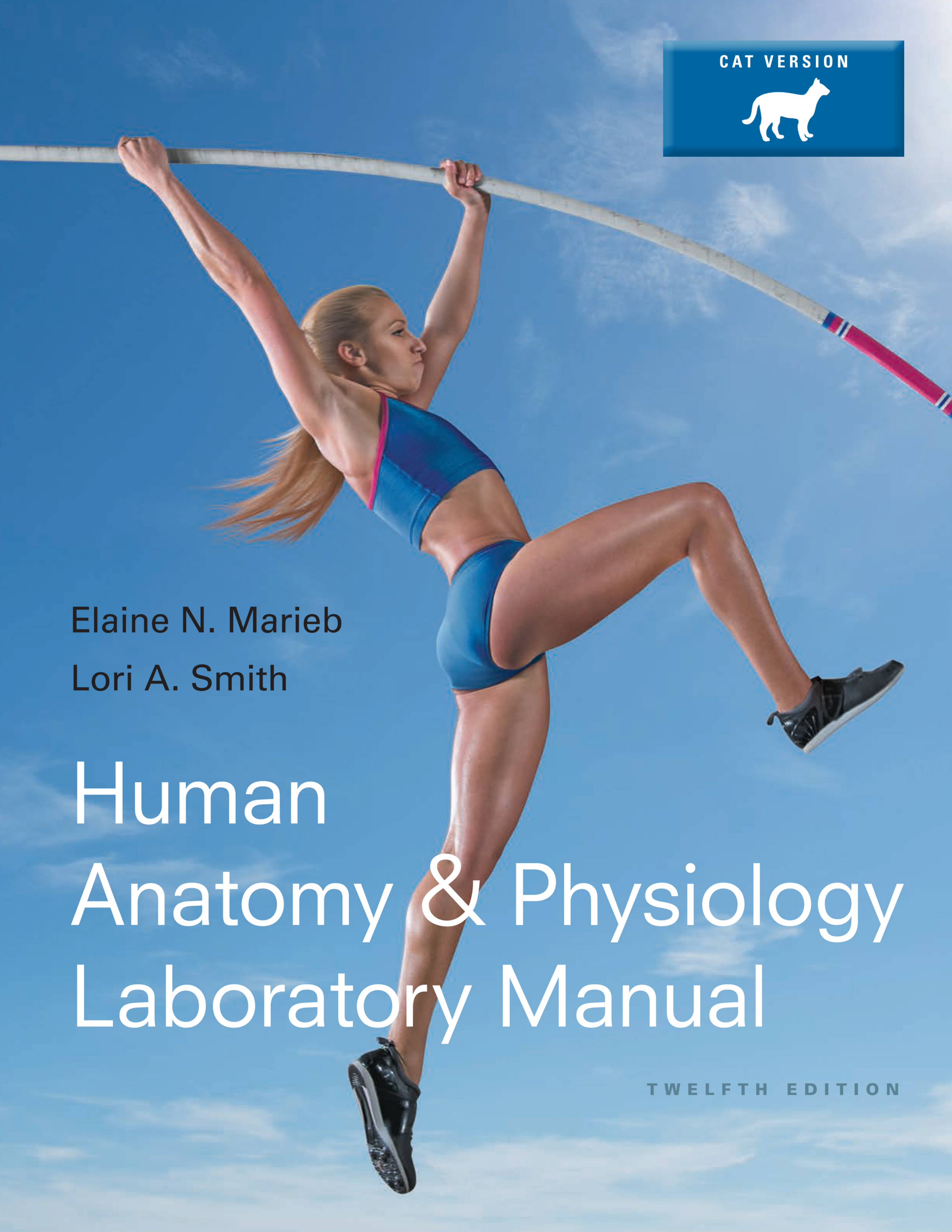


CAT VERSION

Elaine N. Marieb

Lori A. Smith

Human Anatomy & Physiology Laboratory Manual

TWELFTH EDITION

Getting Started—What to Expect, The Scientific Method, and Metrics

Two hundred years ago, science was largely a plaything of wealthy patrons, but today's world is dominated by science and its technology. Whether or not we believe that such domination is desirable, we all have a responsibility to try to understand the goals and methods of science that have seeded this knowledge and technological explosion.

The biosciences are very special and exciting because they open the doors to an understanding of all the wondrous workings of living things. A course in human anatomy and physiology (a subdivision of bioscience) provides such insights in relation to your own body. Although some experience in scientific studies is helpful when beginning a study of anatomy and physiology, perhaps the single most important prerequisite is curiosity.

Gaining an understanding of science is a little like becoming acquainted with another person. Even though a written description can provide a good deal of information about the person, you can never really know another unless there is personal contact. And so it is with science—if you are to know it well, you must deal with it intimately.

The laboratory is the setting for "intimate contact" with science. It is where scientists test their ideas (do research), the essential purpose of which is to provide a basis from which predictions about scientific phenomena can be made. Likewise, it will be the site of your "intimate contact" with the subject of human anatomy and physiology as you are introduced to the methods and instruments used in biological research.

For many students, human anatomy and physiology is an introductory-level course; and their scientific background exists, at best, as a dim memory. If this is your predicament, this prologue may be just what you need to fill in a few gaps and to get you started on the right track before your actual laboratory experiences begin. So—let's get to it!

The Scientific Method

Science would quickly stagnate if new knowledge were not continually derived from and added to it. The approach scientists commonly use when they investigate various aspects of their respective disciplines is called the **scientific method.** This method is *not* a single rigorous technique that must be followed in a lockstep manner. It is nothing more or less than a logical, practical, and reliable way of approaching and solving problems of every kind—scientific or otherwise—to gain knowledge. It includes five major steps.

Step 1: Observation of Phenomena

The crucial first step involves observation of some phenomenon of interest. In other words, before a scientist can investigate anything, he or she must decide on a *problem* or focus for the investigation. In most college laboratory experiments, the problem or focus has been decided for you. However, to illustrate this important step, we will assume that you want to investigate the true nature of apples, particularly green apples. In such a case you would begin your studies by making a number of different observations concerning apples.

Step 2: Statement of the Hypothesis

Once you have decided on a focus of concern, the next step is to design a significant question to be answered. Such a question is usually posed in the form of a **hypothesis,** an unproven conclusion that attempts to explain some phenomenon. (At its crudest level, a hypothesis can be considered to be a "guess" or an intuitive hunch that tentatively explains some observation.) Generally, scientists do not restrict themselves to a single hypothesis; instead, they usually pose several and then test each one systematically.

We will assume that to accomplish step 1, you go to the supermarket and randomly select apples from several bins. When you later eat the apples, you find that the green apples are sour but that the red and yellow apples are sweet. From this observation, you might conclude *(hypothesize)* that "green apples are sour." This statement would represent your current understanding of green apples. You might also reasonably predict that if you were to buy more apples, any green ones you buy will be sour. Thus, you would have gone beyond your initial observation that "these" green apples are sour to the prediction that "all" green apples are sour.

Any good hypothesis must meet several criteria. First, *it must be testable.* This characteristic is far more important than its being correct. The test data may or may not support the hypothesis, or new information may require that the hypothesis be modified. Clearly the accuracy of a prediction in any scientific study depends on the accuracy of the initial information on which it is based.

In our example, no great harm will come from an inaccurate prediction—that is, were we to find that some green apples are sweet. However, in some cases human life may depend on the accuracy of the prediction. For that and other reasons: (1) Repeated testing of scientific ideas is important, particularly because scientists working on the same problem do not always agree in their conclusions. (2) Careful observation is essential, even at the very outset of a study, because conclusions drawn from scientific tests are only as accurate as the information on which they are based.

A second criterion is that, even though hypotheses are guesses of a sort, *they must be based on measurable, describable facts. No mysticism can be theorized.* We cannot conjure up, to support our hypothesis, forces that have not been shown to exist. For example, as scientists, we cannot say that the tooth fairy took Johnny's tooth unless we can prove that the tooth fairy exists!

Third, a hypothesis *must not be anthropomorphic.* Human beings tend to anthropomorphize—that is, to relate all experiences to human experience. Whereas we could state that bears instinctively protect their young, it would be anthropomorphic to say that bears love their young, because love is a human emotional response. Thus, the initial hypothesis must be stated without interpretation.

Step 3: Data Collection

Once the initial hypothesis has been stated, scientists plan experiments that will provide data (or evidence) to support or disprove their hypotheses—that is, they *test* their hypotheses. They accumulate data by making qualitative or quantitative observations of some sort. The observations are often aided by the use of various types of equipment such as cameras, microscopes, stimulators, or various electronic devices that allow chemical and physiological measurements to be taken.

Observations referred to as **qualitative** are those we can make with our senses—that is, by using our vision, hearing, or sense of taste, smell, or touch. For some quick practice in qualitative observation, compare and contrast an orange and an apple. (*Compare* means to emphasize the similarities between two things, whereas *contrast* means to emphasize the differences.)

Whereas the differences between an apple and an orange are obvious, this is not always the case in biological observations. Quite often a scientist tries to detect very subtle differences that cannot be determined by qualitative observations; data must be derived from measurements. Such observations based on precise measurements of one type or another are **quantitative observations**. Examples of quantitative observations include careful measurements of body or organ dimensions such as mass, size, and volume; measurement of volumes of oxygen consumed during metabolic studies; determination of the concentration of glucose in urine; and determination of the differences in blood pressure and pulse under conditions of rest and exercise. An apple and an orange could be compared quantitatively by analyzing the relative amounts of sugar and water in a given volume of fruit flesh, the pigments and vitamins present in the apple skin and orange peel, and so on.

A valuable part of data gathering is the use of experiments to support or disprove a hypothesis. An **experiment** is a procedure designed to describe the factors in a given situation that affect one another (that is, to discover cause and effect) under certain conditions.

Two general rules govern experimentation. The first of these rules is that the experiment(s) should be conducted in such a manner that every **variable** (any factor that might affect the outcome of the experiment) is under the control of the experimenter. The **independent variables** are manipulated by the experimenter. For example, if the goal is to determine the effect of body temperature on breathing rate, the independent variable is body temperature. The effect observed or value measured (in this case breathing rate) is called the **dependent** or **response variable**. Its value "depends" on the value chosen for the independent variable. The ideal way to perform such an experiment is to set up and run a series of tests that are all identical, except for one specific factor that is varied.

One specimen (or group of specimens) is used as the **control** against which all other experimental samples are compared. The importance of the control sample cannot be overemphasized. The control group provides the "normal standard" against which all other samples are compared relative to the dependent variable. Taking our example one step further, if we wanted to investigate the effects of body temperature (the independent variable) on breathing rate (the dependent variable), we could collect data on the breathing rate of individuals with "normal" body temperature (the implicit control group), and compare these data to breathing-rate measurements obtained from groups of individuals with higher and lower body temperatures.

The second rule governing experimentation is that valid results require that testing be done on large numbers of subjects. It is essential to understand that it is nearly impossible to control all possible variables in biological tests. Indeed, there is a bit of scientific wisdom that mirrors this truth—that is, that laboratory animals, even in the most rigidly controlled and carefully designed experiments, "will do as they damn well please." Thus, stating that the testing of a drug for its painkilling effects was successful after having tested it on only one postoperative patient would be scientific suicide. Large numbers of patients would have to receive the drug and be monitored for a decrease in postoperative pain before such a statement could have any scientific validity. Then, other researchers would have to be able to uphold those conclusions by running similar experiments. *Repeatability* is an important part of the scientific method and is the primary basis for support or rejection of many hypotheses.

During experimentation and observation, data must be carefully recorded. Usually, such initial, or raw, data are recorded in table form. The table should be labeled to show the variables investigated and the results for each sample. At this point, *accurate recording* of observations is the primary concern. Later, these raw data will be reorganized and manipulated to show more explicitly the outcome of the experimentation.

Some of the observations that you will be asked to make in the anatomy and physiology laboratory will require that a drawing be made. Don't panic! The purpose of making drawings (in addition to providing a record) is to force you to observe things very closely. You need not be an artist (most biological drawings are simple outline drawings), but you do need to be neat and as accurate as possible. It is advisable to use a 4H pencil to do your drawings because it is easily erased and doesn't smudge. Before beginning to draw, you should examine your specimen closely, studying it as though you were going to have to draw it from memory. For example, when looking at cells you should ask yourself questions such as "What is their shape—the relationship of length and width? How are they joined together?" Then decide precisely what you are going to show and how large the drawing must be to show the necessary detail. After making the drawing, add labels in the margins and connect them by straight lines (leader lines) to the structures being named.

Step 4: Manipulation and Analysis of Data

The form of the final data varies, depending on the nature of the data collected. Usually, the final data represent information converted from the original measured values (raw data) to some other form. This may mean that averaging or some other statistical treatment must be applied, or it may require conversions from one kind of units to another. In other cases, graphs may be needed to display the data.

Elementary Treatment of Data

Only very elementary statistical treatment of data is required in this manual. For example, you will be expected to understand and/or compute an average (mean), percentages, and a range.

Two of these statistics, the mean and the range, are useful in describing the *typical* case among a large number of samples evaluated. Let us use a simple example. We will assume that the following heart rates (in beats/min) were recorded during an experiment: 64, 70, 82, 94, 85, 75, 72, 78. If you put these numbers in numerical order, the **range** is easily computed, because the range is the difference between the highest and lowest numbers obtained (highest number minus lowest number). The **mean** is obtained by summing the items and dividing the sum by the number of items. What is the range and the mean for the set of numbers just provided?

1. ____*

The word *percent* comes from the Latin meaning "for 100"; thus *percent,* indicated by the percent sign, %, means parts per 100 parts. Thus, if we say that 45% of Americans have type O blood, what we are really saying is that among each group of 100 Americans, 45 (45/100) can be expected to have type O blood. Any ratio can be converted to a percent by multiplying by 100 and adding the percent sign.

$$.25 \times 100 = 25\% \qquad 5 \times 100 = 500\%$$

It is very easy to convert any number (including decimals) to a percent. The rule is to move the decimal point two places to the right and add the percent sign. If no decimal point appears, it is *assumed* to be at the end of the number; and zeros are added to fill any empty spaces. Two examples follow:

$$0.25 = 0.25 = 25\%$$
$$5 = 5 \quad = 500\%$$

Change the following to percents:

2. 38 = ___________ **4.** 1.6 = ___________

3. .75 = ___________

Note that although you are being asked here to convert numbers to percents, percents by themselves are meaningless. We always speak in terms of a percentage *of* something.

To change a percent to decimal form, remove the percent sign, and divide by 100. Change the following percents to whole numbers or decimals:

5. 800% = ___________ **6.** 0.05% = ___________

Making and Reading Line Graphs

For some laboratory experiments you will be required to show your data (or part of them) graphically. Simple line graphs allow relationships within the data to be shown interestingly and allow trends (or patterns) in the data to be demonstrated. An advantage of properly drawn graphs is that they save the reader's time because the essential meaning of a large amount of statistical data can be seen at a glance.

To aid in making accurate graphs, graph paper (or a printed grid in the manual) is used. Line graphs have both horizontal (X) and vertical (Y) axes with scales. Each scale should have uniform intervals—that is, each unit measured on the scale should require the same distance along the scale as any other. Variations from this rule may be misleading and result in false interpretations of the data. By convention, the condition that is manipulated (the independent variable) in the experimental series is plotted on the X-axis (the horizontal axis); and the value that we then measure (the dependent variable) is plotted on the Y-axis (the vertical axis). To plot the data, a dot or a small x is placed at the precise point where the two variables (measured for each sample) meet; and then a line (this is called the **curve**) is drawn to connect the plotted points.

Sometimes, you will see the curve on a line graph extended beyond the last plotted point. This is (supposedly) done to predict "what comes next." When you see this done, be skeptical. The information provided by such a technique is only slightly more accurate than that provided by a crystal ball! When constructing a graph, be sure to label the X-axis and Y-axis and give the graph a legend **(Figure 1)**.

To read a line graph, pick any point on the line, and match it with the information directly below on the X-axis and with that directly to the left of it on the Y-axis. The figure below (Figure 1) is a graph that illustrates the relationship between breaths per minute (respiratory rate) and body temperature. Answer the following questions about this graph:

7. What was the respiratory rate at a body temperature of 96°F? _________________

8. Between which two body temperature readings was the increase in breaths per minute greatest? _________________

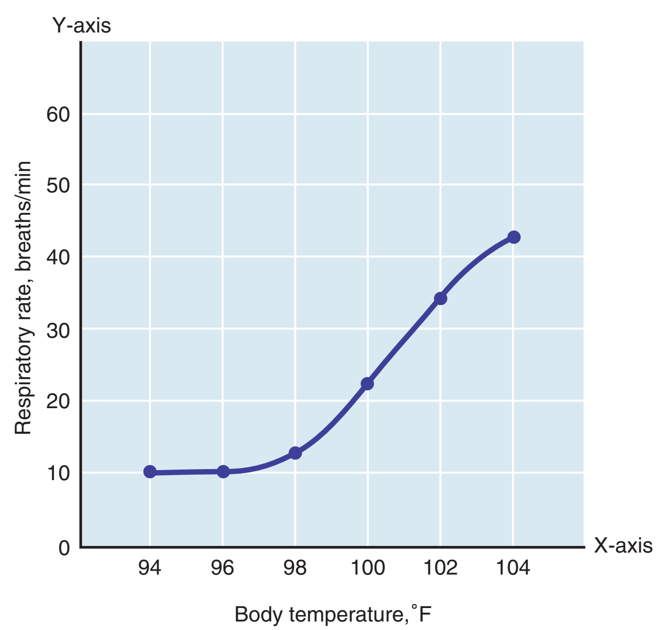


Figure 1 Example of graphically presented data. Respiratory rate as a function of body temperature.

*Answers are given at the end of this section (page xx).

Step 5: Reporting Conclusions of the Study

Drawings, tables, and graphs alone do not suffice as the final presentation of scientific results. The final step requires that you provide a straightforward description of the conclusions drawn from your results. If possible, your findings should be compared to those of other investigators working on the same problem. For laboratory investigations conducted by students, these comparative figures are provided by classmates.

It is important to realize that scientific investigations do not always yield the anticipated results. If there are discrepancies between your results and those of others, or what you expected to find based on your class notes or textbook readings, this is the place to try to explain those discrepancies.

Results are often only as good as the observation techniques used. Depending on the type of experiment conducted, you may need to answer several questions. Did you weigh the specimen carefully enough? Did you balance the scale first? Was the subject's blood pressure actually as high as you recorded it, or did you record it inaccurately? If you did record it accurately, is it possible that the subject was emotionally upset about something, which might have given falsely high data for the variable being investigated? Attempting to explain an unexpected result will often teach you more than you would have learned from anticipated results.

When the experiment produces results that are consistent with the hypothesis, then the hypothesis can be said to have reached a higher level of certainty. The probability that the hypothesis is correct is greater.

A hypothesis that has been validated by many different investigators is called a **theory.** Theories are useful in two important ways. First, they link sets of data; and second, they make predictions that may lead to additional avenues of investigation. (OK, we know this with a high degree of certainty; what's next?)

When a theory has been repeatedly verified and appears to have wide applicability in biology, it may assume the status of a **biological principle.** A principle is a statement that applies with a high degree of probability to a range of events. For example, "Living matter is made of cells or cell products" is a principle stated in many biology texts. It is a sound and useful principle, and will continue to be used as such—unless new findings prove it wrong.

We have been through quite a bit of background concerning the scientific method and what its use entails. Because it is important that you remember the phases of the scientific method, they are summarized here:

1. Observation of some phenomenon

2. Statement of a hypothesis (based on the observations)

3. Collection of data (testing the hypothesis with controlled experiments)

4. Manipulation and analysis of the data

5. Reporting of the conclusions of the study (routinely done by preparing a lab report—see page xvii)

Lab Report

Cover Page

- Title of Experiment
- Author's Name
- Course
- Instructor
- Date

Introduction

- Provide background information.
- Describe any relevant observations.
- State hypotheses clearly.

Materials and Methods

- List equipment or supplies needed.
- Provide step-by-step directions for conducting the experiment.

Results

- Present data using a drawing (figure), table, or graph.
- Analyze data.
- Summarize findings briefly.

Discussion and Conclusions

- Conclude whether data gathered support or do not support hypotheses.
- Include relevant information from other sources.
- Explain any uncontrolled variables or unexpected difficulties.
- Make suggestions for further experimentation.

Reference List

- Cite the source of any material used to support this report.

Writing a Lab Report Based on The Scientific Method

A laboratory report is not the same as a scientific paper, but it has some of the same elements and is a formal way to report the results of a scientific experiment. The report should have a cover page that includes the title of the experiment, the author's name, the name of the course, the instructor, and the date. The report should include five separate, clearly marked sections: Introduction, Materials and Methods, Results, Discussion and Conclusions, and References. Use the previous template to guide you through writing a lab report.

Metrics

No matter how highly developed our ability to observe, observations have scientific value only if we can communicate them to others. Without measurement, we would be limited to qualitative description. For precise and repeatable communication of information, the agreed-upon system of measurement used by scientists is the **metric system.**

A major advantage of the metric system is that it is based on units of 10. This allows rapid conversion to workable numbers so that neither very large nor very small figures need be used in calculations. Fractions or multiples of the standard units of length, volume, mass, time, and temperature have been assigned specific names. The metric system **(Table 1)** shows the commonly used units of the metric system, along with the prefixes used to designate fractions and multiples thereof.

To change from smaller units to larger units, you must *divide* by the appropriate factor of 10 (because there are fewer of the larger units). For example, a milliunit (*milli* = one-thousandth), such as a millimeter, is one step smaller than a centiunit (*centi* = one-hundredth), such as a centimeter. Thus to change milliunits to centiunits, you must divide by 10. On the other hand, when converting from larger units to smaller ones, you must *multiply* by the appropriate factor of 10. A partial scheme for conversions between the metric units is shown on the next page.

The objectives of the sections that follow are to provide a brief overview of the most-used measurements in science or health professions and to help you gain some measure of confidence in dealing with them. A listing of the most frequently used conversion factors, for conversions between British and metric system units, is provided on the inside back cover.

Length Measurements

The metric unit of length is the **meter (m).** Smaller objects are measured in centimeters or millimeters. Subcellular structures are measured in micrometers.

To help you picture these units of length, some equivalents follow:

One meter (m) is slightly longer than one yard (1 m = 39.37 in.).

One centimeter (cm) is approximately the width of a piece of chalk. (Note: There are 2.54 cm in 1 in.)

One millimeter (mm) is approximately the thickness of the wire of a paper clip or of a mark made by a No. 2 pencil lead.

One micrometer (μm) is extremely tiny and can be measured only microscopically.

Make the following conversions between metric units of length:

9. 12 cm = ___________ mm

10. 2000 μm = ___________ mm

Now, circle the answer that would make the most sense in each of the following statements:

11. A match (in a matchbook) is (0.3, 3, 30) cm long.

12. A standard-size American car is about 4 (mm, cm, m, km) long.

Table 1 **Metric System**

A. Commonly used units		B. Fractions and their multiples		
Measurement	**Unit**	**Fraction or multiple**	**Prefix**	**Symbol**
Length	Meter (m)	10^6 one million	mega	M
Volume	Liter (L; l with prefix)	10^3 one thousand	kilo	k
Mass	Gram (g)	10^{-1} one-tenth	deci	d
Time*	Second (s)	10^{-2} one-hundredth	centi	c
Temperature	Degree Celsius (°C)	10^{-3} one-thousandth	milli	m
		10^{-6} one-millionth	micro	μ
		10^{-9} one-billionth	nano	n

* The accepted standard for time is the second; and thus hours and minutes are used in scientific, as well as everyday, measurement of time. The only prefixes generally used are those indicating *fractional portions* of seconds—for example, millisecond and microsecond.

$$\text{microunit} \underset{\times 1000}{\overset{\div 1000}{\rightleftharpoons}} \text{milliunit} \underset{\times 10}{\overset{\div 10}{\rightleftharpoons}} \text{centiunit} \underset{\times 100}{\overset{\div 100}{\rightleftharpoons}} \text{unit} \underset{\times 1000}{\overset{\div 1000}{\rightleftharpoons}} \text{kilounit}$$

$$\text{smallest} \rightleftharpoons \text{largest}$$

Volume Measurements

The metric unit of volume is the liter. A **liter** (l, or sometimes L, especially without a prefix) is slightly more than a quart (1 L = 1.057 quarts). Liquid volumes measured out for lab experiments are usually measured in milliliters (ml). (The terms *ml* and *cc,* cubic centimeter, are used interchangeably in laboratory and medical settings.)

To help you visualize metric volumes, the equivalents of some common substances follow:

A 12-oz can of soda is a little less than 360 ml.

A fluid ounce is about 30 (it's 29.57) ml (cc).

A teaspoon of vanilla is about 5 ml (cc).

Compute the following:

13. How many 5-ml injections can be prepared from 1 liter of a medicine? ______________

14. A 450-ml volume of alcohol is ______________ L.

Mass Measurements

Although many people use the terms *mass* and *weight* interchangeably, this usage is inaccurate. **Mass** is the amount of matter in an object; and an object has a constant mass, regardless of where it is—that is, on earth, or in outer space. However, weight varies with gravitational pull; the greater the gravitational pull, the greater the weight. Thus, our astronauts are said to be weightless when in outer space, but they still have the same mass as they do on earth. (Astronauts are not *really* weightless. It is just that they and their surroundings are being pulled toward the earth at the same speed; and so, in reference to their environment, they appear to float.)

The metric unit of mass is the **gram (g).** Medical dosages are usually prescribed in milligrams (mg) or micrograms (μg); and in the clinical agency, body weight (particularly of infants) is typically specified in kilograms (kg; 1 kg = 2.2 lb).

The following examples are provided to help you become familiar with the masses of some common objects:

Two aspirin tablets have a mass of approximately 1 g.

A nickel has a mass of 5 g.

The mass of an average woman (132 lb) is 60 kg.

Make the following conversions:

15. 300 g = __________ mg = __________ μg

16. 4000 μg = __________ mg = __________ g

17. A nurse must administer to her patient, Mrs. Smith, 5 mg of a drug per kg of body mass. Mrs. Smith weighs 140 lb. How many grams of the drug should the nurse administer to her patient?

__________ g

Temperature Measurements

In the laboratory and in the clinical agency, temperature is measured both in metric units (degrees Celsius, °C) and in British units (degrees Fahrenheit, °F). Thus it helps to be familiar with both temperature scales.

The temperatures of boiling and freezing water can be used to compare the two scales:

The freezing point of water is 0°C and 32°F.

The boiling point of water is 100°C and 212°F.

As you can see, the range from the freezing point to the boiling point of water on the Celsius scale is 100 degrees, whereas the comparable range on the Fahrenheit scale is 180 degrees. Hence, one degree on the Celsius scale represents a greater change in temperature. Normal body temperature is approximately 98.6°F or 37°C.

To convert from the Celsius scale to the Fahrenheit scale, the following equation is used:

$$°\text{C} = \frac{5\,(°\text{F} - 32)}{9}$$

To convert from the Fahrenheit scale to the Celsius scale, the following equation is used:

$$°\text{F} = (9/5\ °\text{C}) + 32$$

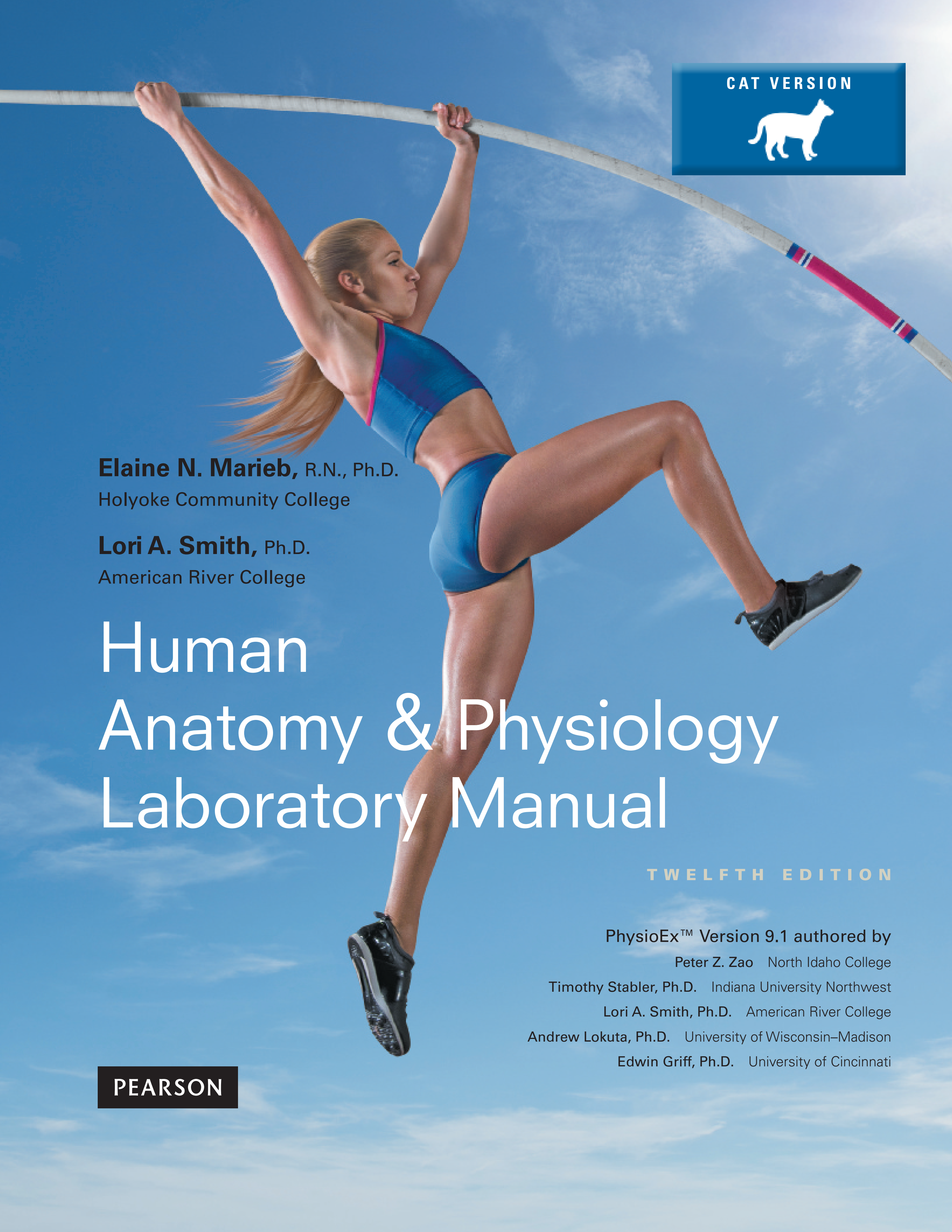
Perform the following temperature conversions:

18. Convert 38°C to °F: ______________

19. Convert 158°F to °C: ______________

Answers

1. range of 94–64 or 30 beats/min; mean 77.5 **2.** 3800% **3.** 75% **4.** 160% **5.** 8 **6.** 0.0005 **7.** 10 breaths/min
8. interval between 100–102° (went from 22 to 36 breaths/min) **9.** 12 cm = 120 mm **10.** 2000 μm = 2 mm **11.** 3 cm long
12. 4 m long **13.** 200 **14.** 0.45 L **15.** 300 g = $\underline{3 \times 10^5}$ mg = $\underline{3 \times 10^8}$ μg **16.** 4000 μg = $\underline{4}$ mg = $\underline{4 \times 10^{-3}}$ g (0.004 g)
17. 0.32 g **18.** 100.4°F **19.** 70°C



CAT VERSION

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Human Anatomy & Physiology Laboratory Manual

TWELFTH EDITION

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6

Activity 1

Examining Epithelial Tissue Under the Microscope

Obtain slides of simple squamous, simple cuboidal, simple columnar, stratified squamous (nonkeratinized), pseudostratified ciliated columnar, stratified cuboidal, stratified columnar, and transitional epithelia. Examine each carefully, and notice how the epithelial cells fit closely together to form intact sheets of cells, a necessity for a tissue that forms linings or the coverings of membranes. Scan each epithelial type for modifications for specific functions, such as cilia (motile cell projections that help to move substances along the cell surface), and microvilli, which increase the surface area for absorption. Also be alert for goblet cells, which secrete lubricating mucus. Compare your observations with the descriptions and photomicrographs in Figure 6.3.

While working, check the questions in the Review Sheet at the end of this exercise. A number of the questions there refer to some of the observations you are asked to make during your microscopic study.

WHY THIS MATTERS | **Buccal Swabs**

A buccal, or cheek, swab is a method used to collect stratified squamous cells from the oral cavity. The cells contain DNA that can be used for DNA fingerprinting or tissue typing. DNA fingerprinting can be used in criminal investigations, and tissue typing can be used to match a recipient with a donor for organ transplant, especially a bone marrow transplant. The buccal swab procedure involves using a cotton-tipped applicator to scrape the inside of the mouth in the buccal region and remove cells at the surface. This noninvasive procedure provides an easy way to obtain the DNA profile of an individual, a unique molecular "signature." ■

Group Challenge 1

Identifying Epithelial Tissues

Following your observations of epithelial tissues under the microscope, obtain an envelope for each group that contains images of various epithelial tissues. With your lab manual closed, remove one image at a time and identify the epithelium. One member of the group will function as the verifier, whose job is to make sure that the identification is correct.

After you have correctly identified all of the images, sort them into groups to help you remember them. (*Hint:* You could sort them according to cell shape or number of layers of epithelial cells.)

Now, carefully go through each group and try to list one place in the body where the tissue is found and one function for it. After you have correctly listed the locations, take your lists and draw some general conclusions about where epithelial tissues are found in the body. Then compare and contrast the functions of the various epithelia. Finally, identify the tissues described in the **Group Challenge 1** chart, and list several locations in the body.

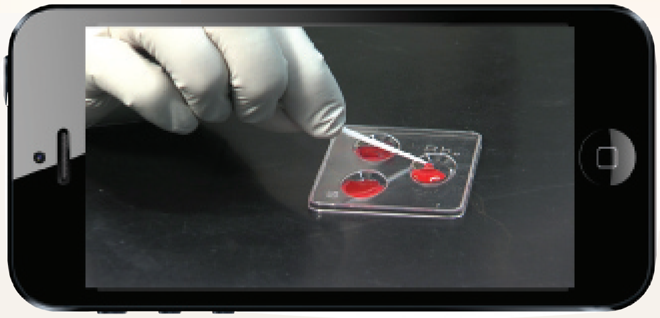
Group Challenge 1: Epithelial Tissue IDs

Magnified appearance	Tissue type	Locations in the body
• Apical surface has dome-shaped cells (flattened cells may also be mixed in) • Multiple layers of cells are present		
• Cells are mostly columnar • Not all cells reach the apical surface • Nuclei are located at different levels • Cilia are located at the apical surface		
• Apical surface has flattened cells with very little cytoplasm • Cells are not layered		
• Apical surface has square cells with a round nucleus • Cells are not layered		

Succeed in the Lab

NEW!

Prepare for lab by watching pre-lab videos on your smartphone, tablet, or computer. Short pre-lab videos will give you some background information on the lab, explain what materials you will be using, help you see the connections between the content you learn in the classroom and the experiment, and give you the opportunity to check your understanding—all before you even step foot in the lab.



Prepare for lab: Watch the Pre-lab Video
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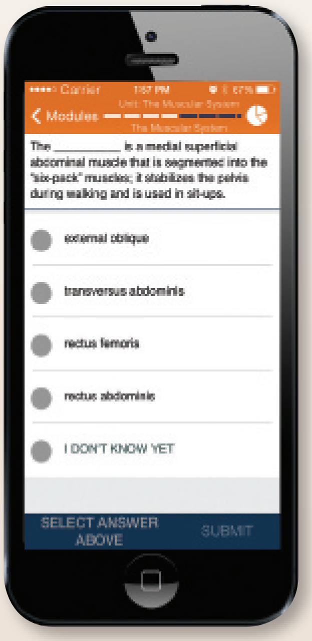

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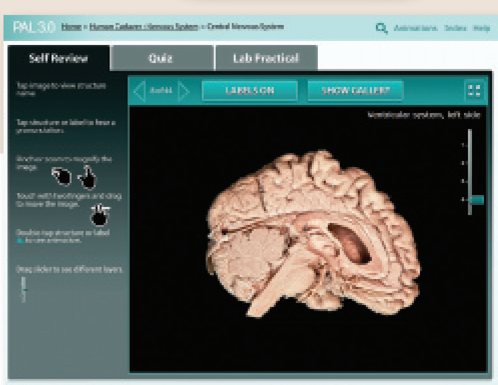

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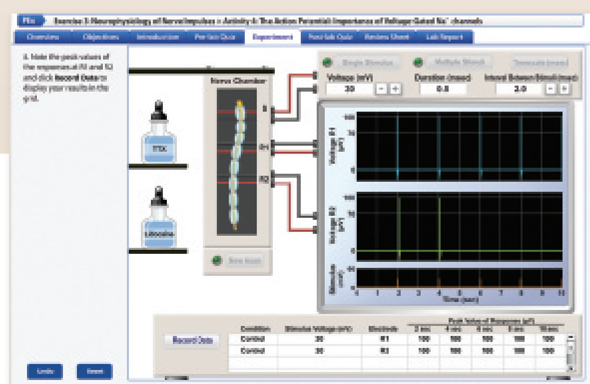

PhysioEx™ 9.1 is an easy-to-use lab simulation program that allows you to repeat labs as often as you like, perform experiments without animals, and conduct experiments that are difficult to perform in a wet lab environment because of time, cost, or safety concerns. The online format with easy step-by-step instructions includes everything you need in one convenient place.

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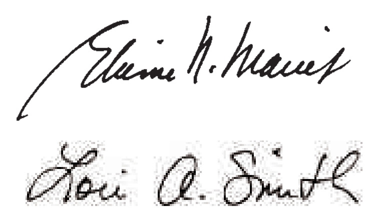

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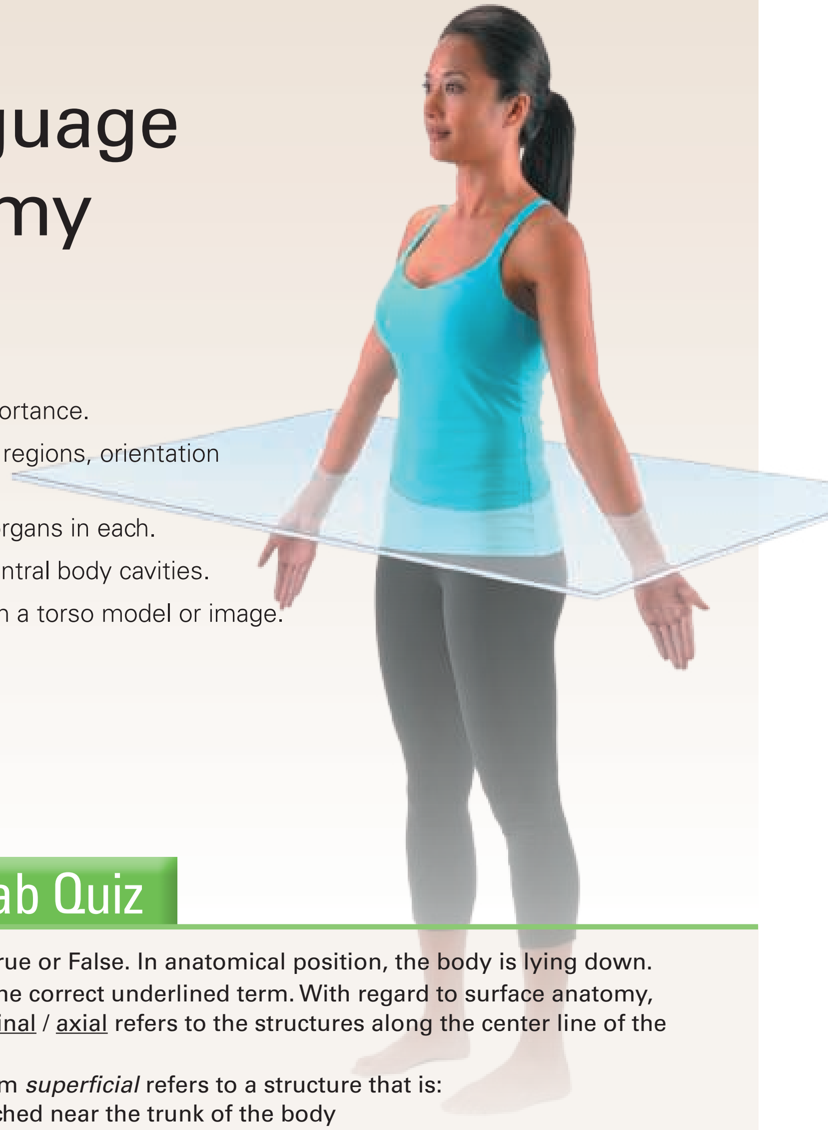
EXERCISE

1 The Language of Anatomy



Objectives

- ☐ Describe the anatomical position, and explain its importance.
- ☐ Use proper anatomical terminology to describe body regions, orientation and direction, and body planes.
- ☐ Name the body cavities, and indicate the important organs in each.
- ☐ Name and describe the serous membranes of the ventral body cavities.
- ☐ Identify the abdominopelvic quadrants and regions on a torso model or image.

Materials

- Human torso model (dissectible)
- Human skeleton
- Demonstration: sectioned and labeled kidneys (three separate kidneys uncut or cut so that [a] entire, [b] transverse sectional, and [c] longitudinal sectional views are visible)
- Gelatin-spaghetti molds
- Scalpel
- Post-it® Notes

Pre-Lab Quiz

1. Circle True or False. In anatomical position, the body is lying down.
2. Circle the correct underlined term. With regard to surface anatomy, abdominal / axial refers to the structures along the center line of the body.
3. The term *superficial* refers to a structure that is:
   a. attached near the trunk of the body
   b. toward or at the body surface
   c. toward the head
   d. toward the midline
4. The ________ plane runs longitudinally and divides the body into right and left sides.
   a. frontal **c.** transverse
   b. sagittal **d.** ventral
5. Circle the correct underlined terms. The dorsal body cavity can be divided into the cranial / thoracic cavity, which contains the brain, and the sural / vertebral cavity, which contains the spinal cord.

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Most of us are naturally curious about our bodies. This curiosity is apparent even in infants, who are fascinated with their own waving hands or their mother's nose. Unlike an infant, however, an anatomy student must learn to observe and identify the dissectible body structures formally.

A student new to any science is often overwhelmed at first by the terminology used in that subject. The study of anatomy is no exception. But without this specialized terminology, confusion is inevitable. For example, what do *over, on top of, above,* and *behind* mean in reference to the human body? Anatomists have an accepted set of reference terms that are universally understood. These allow body structures to be located and identified precisely with a minimum of words.

This exercise presents some of the most important anatomical terminology used to describe the body and introduces you to basic concepts of **gross anatomy,** the study of body structures visible to the naked eye.

1

Anatomical Position

When anatomists or doctors refer to specific areas of the human body, the picture they keep in mind is a universally accepted standard position called the **anatomical position.** It is essential to understand this position because much of the directional terminology used in this book refers to the body in this position, regardless of the position the body happens to be in. In the anatomical position, the human body is erect, with the feet only slightly apart, head and toes pointed forward, and arms hanging at the sides with palms facing forward (**Figure 1.1a**).

☐ Assume the anatomical position, and notice that it is not particularly comfortable. The hands are held unnaturally forward rather than hanging with palms toward the thighs.

Check the box when you have completed this task.

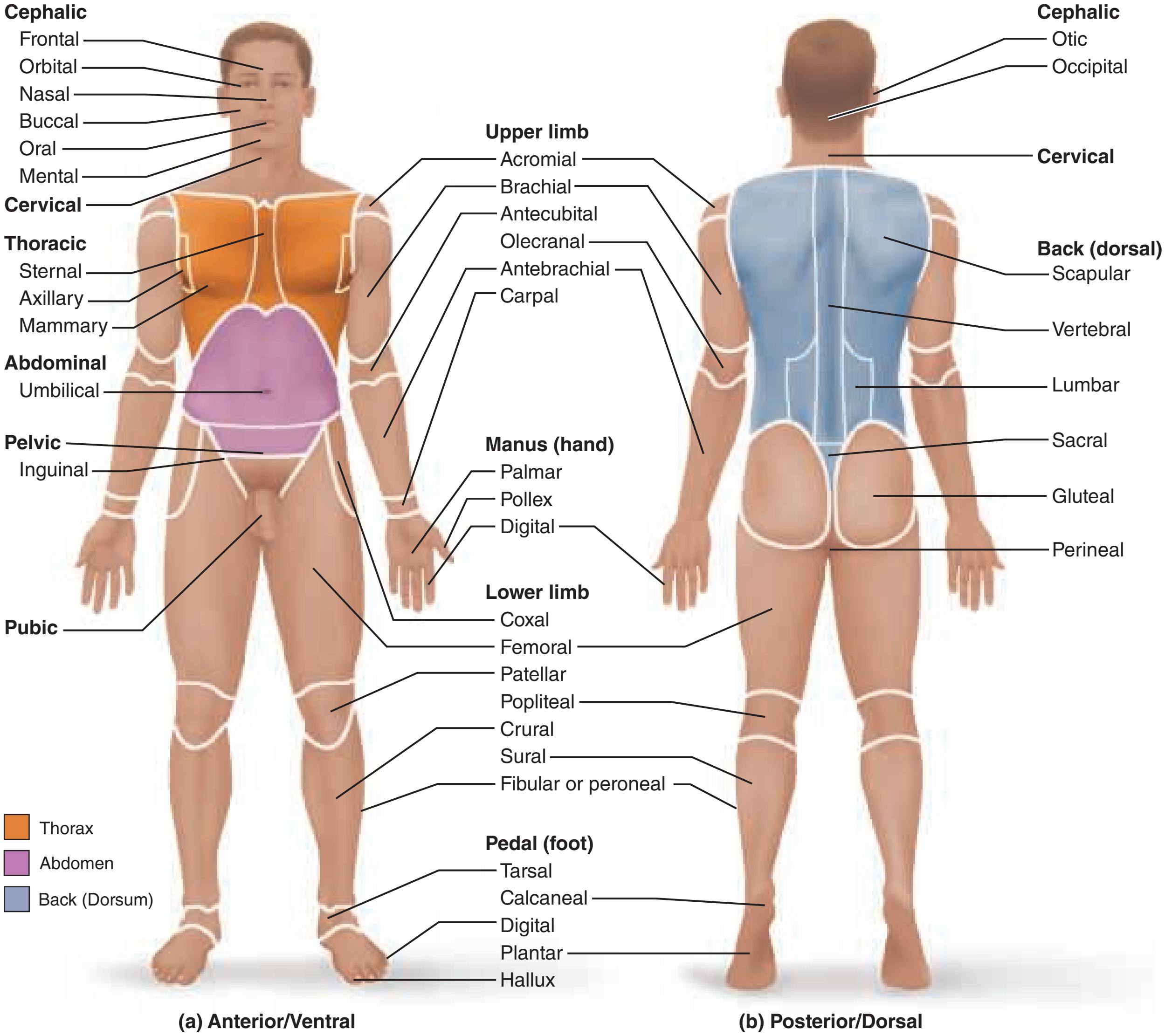

Figure 1.1 Surface anatomy. (a) Anatomical position. **(b)** Heels are raised to illustrate the plantar surface of the foot.

Surface Anatomy

Body surfaces provide a wealth of visible landmarks for study. There are two major divisions of the body:

Axial: Relating to head, neck, and trunk, the axis of the body

Appendicular: Relating to limbs and their attachments to the axis

Anterior Body Landmarks

Note the following regions in Figure 1.1a:

Abdominal: Anterior body trunk region inferior to the ribs

Acromial: Point of the shoulder

Antebrachial: Forearm

Antecubital: Anterior surface of the elbow

Axillary: Armpit

Brachial: Arm

Buccal: Cheek

Carpal: Wrist

Cephalic: Head

Cervical: Neck region

Coxal: Hip

Crural: Leg

Digital: Fingers or toes

Femoral: Thigh

Fibular (peroneal): Side of the leg

Frontal: Forehead

Hallux: Great toe

Inguinal: Groin area

Mammary: Breast region

Manus: Hand

Mental: Chin

Nasal: Nose

Oral: Mouth

Orbital: Bony eye socket (orbit)

Palmar: Palm of the hand

Patellar: Anterior knee (kneecap) region

Pedal: Foot

Pelvic: Pelvis region

Pollex: Thumb

Pubic: Genital region

Sternal: Region of the breastbone

Tarsal: Ankle

Thoracic: Chest

Umbilical: Navel

Posterior Body Landmarks

Note the following body surface regions in Figure 1.1b:

Acromial: Point of the shoulder

Brachial: Arm

Calcaneal: Heel of the foot

Cephalic: Head

Dorsum: Back

Femoral: Thigh

Gluteal: Buttocks or rump

Lumbar: Area of the back between the ribs and hips; the loin

Manus: Hand

Occipital: Posterior aspect of the head or base of the skull

Olecranal: Posterior aspect of the elbow

Otic: Ear

Pedal: Foot

Perineal: Region between the anus and external genitalia

Plantar: Sole of the foot

Popliteal: Back of the knee

Sacral: Region between the hips (overlying the sacrum)

Scapular: Scapula or shoulder blade area

Sural: Calf or posterior surface of the leg

Vertebral: Area of the spinal column

Activity 1

Locating Body Regions

Locate the anterior and posterior body landmarks on yourself, your lab partner, and a human torso model.

Body Orientation and Direction

Study the terms below, referring to **Figure 1.2** on p. 4 for a visual aid. Notice that certain terms have different meanings, depending on whether they refer to a four-legged animal (quadruped) or to a human (biped).

Superior/inferior *(above/below):* These terms refer to placement of a structure along the long axis of the body. For example, the nose is superior to the mouth, and the abdomen is inferior to the chest.

Anterior/posterior *(front/back):* In humans, the most anterior structures are those that are most forward—the face, chest, and abdomen. Posterior structures are those toward the backside of the body. For instance, the spine is posterior to the heart.

Medial/lateral *(toward the midline/away from the midline or median plane):* The sternum (breastbone) is medial to the ribs; the ear is lateral to the nose.

The terms of position just described assume the person is in the anatomical position. The next four term pairs are more absolute. They apply in any body position, and they consistently have the same meaning in all vertebrate animals.

Cephalad (cranial)/caudal *(toward the head/toward the tail):* In humans, these terms are used interchangeably with *superior* and *inferior,* but in four-legged animals they are synonymous with *anterior* and *posterior,* respectively.

Ventral/dorsal *(belly side/backside):* These terms are used chiefly in discussing the comparative anatomy of animals, assuming the animal is standing. In humans, the terms *ventral* and *dorsal* are used interchangeably with the terms *anterior* and *posterior,* but in four-legged animals, *ventral* and *dorsal* are synonymous with *inferior* and *superior,* respectively.

Proximal/distal *(nearer the trunk or attached end/farther from the trunk or point of attachment):* These terms are used primarily to locate various areas of the body limbs. For example, the fingers are distal to the elbow; the knee is proximal to the toes. However, these terms may also be used to indicate regions (closer to or farther from the head) of internal tubular organs.

Superficial (external)/deep (internal) *(toward or at the body surface/away from the body surface):* For example, the skin is superficial to the skeletal muscles, and the lungs are deep to the rib cage.

Activity 2

Practicing Using Correct Anatomical Terminology

Use a human torso model, a human skeleton, or your own body to specify the relationship between the following structures when the body is in the anatomical position.

1. The wrist is ______________ to the hand.
2. The trachea (windpipe) is ______________ to the spine.
3. The brain is ______________ to the spinal cord.
4. The kidneys are ______________ to the liver.
5. The nose is ______________ to the cheekbones.
6. The thumb is ______________ to the ring finger.
7. The thorax is ______________ to the abdomen.
8. The skin is ______________ to the skeleton.

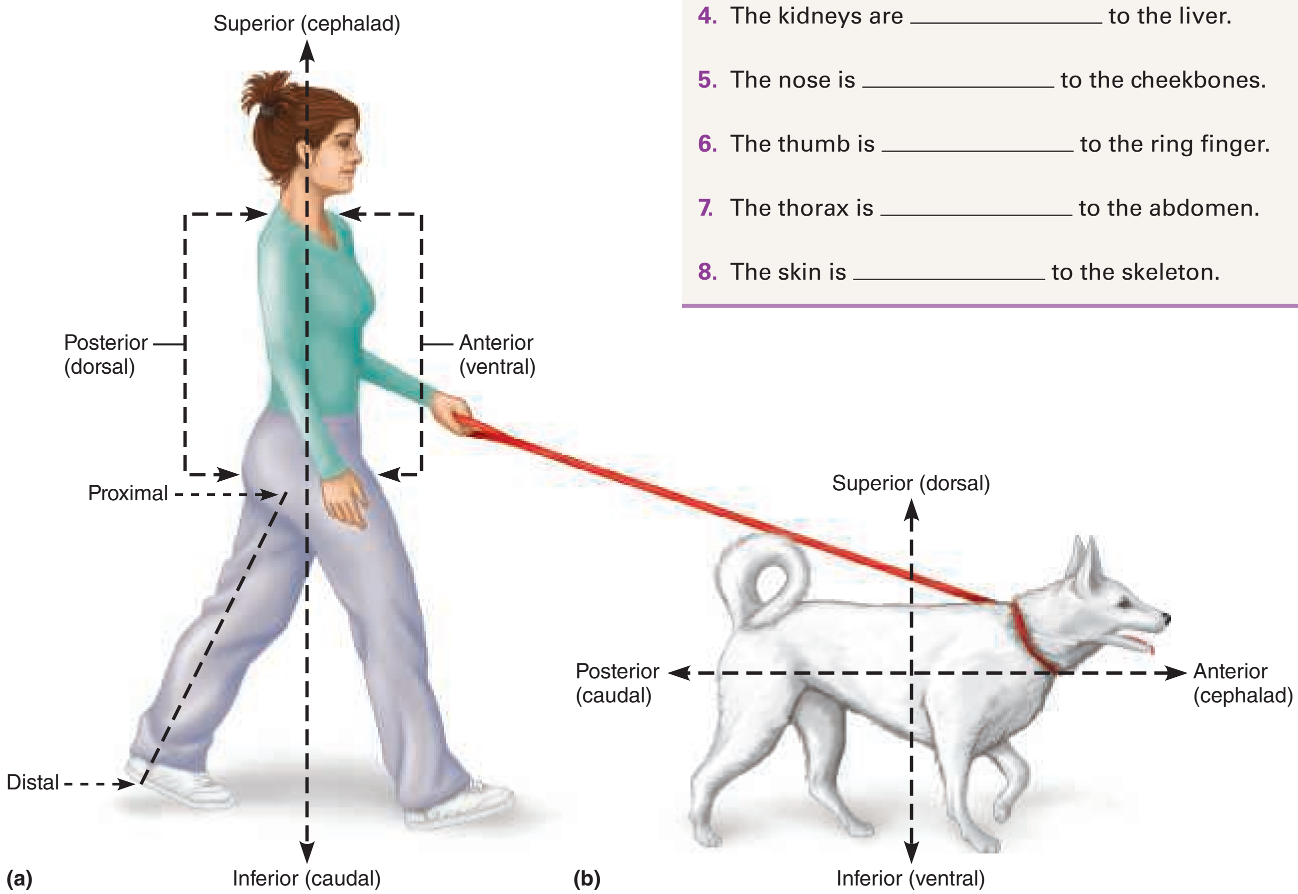

Figure 1.2 Anatomical terminology describing body orientation and direction. **(a)** With reference to a human. **(b)** With reference to a four-legged animal.

Body Planes and Sections

The body is three-dimensional, and in order to observe its internal structures, it is often necessary to make a **section,** or cut. When the section is made through the body wall or through an organ, it is made along an imaginary surface or line called a **plane.** Anatomists commonly refer to three planes (**Figure 1.3**), or sections, that lie at right angles to one another.

Sagittal plane: A sagittal plane runs longitudinally and divides the body into right and left parts. If it divides the body into equal parts, right down the midline of the body, it is called a **median,** or **midsagittal, plane.**

Frontal plane: Sometimes called a **coronal plane,** the frontal plane is a longitudinal plane that divides the body (or an organ) into anterior and posterior parts.

Transverse plane: A transverse plane runs horizontally, dividing the body into superior and inferior parts. When organs are sectioned along the transverse plane, the sections are commonly called **cross sections.**

On microscope slides, the abbreviation for a longitudinal section (sagittal or frontal) is l.s. Cross sections are abbreviated x.s. or c.s.

A median or frontal plane section of any nonspherical object, be it a banana or a body organ, provides quite a different view from a cross section (**Figure 1.4**, p. 6).

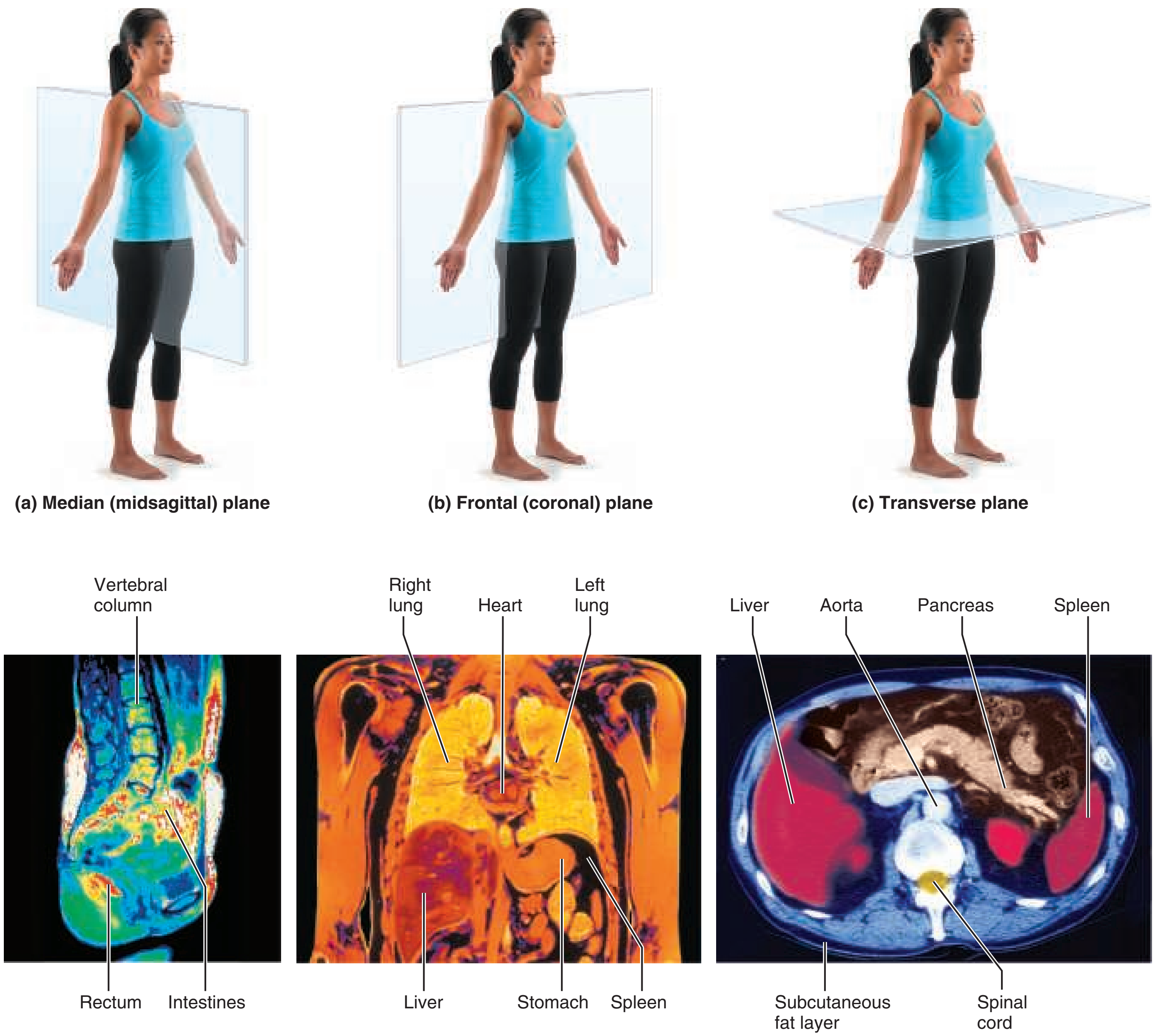

Figure 1.3 Planes of the body with corresponding magnetic resonance imaging (MRI) scans. Note the transverse section is an inferior view.

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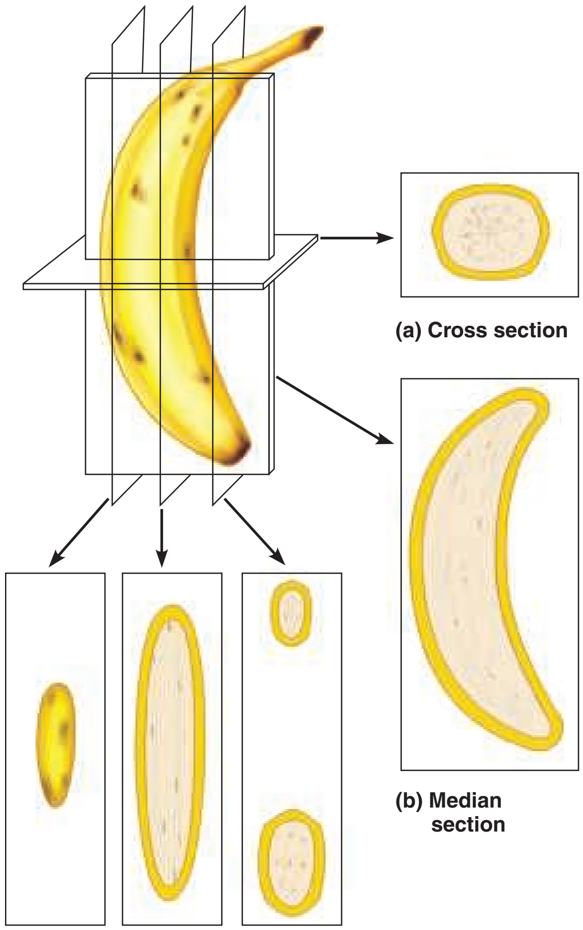


Figure 1.4 Objects can look odd when viewed in section. This banana has been sectioned in three different planes **(a–c)**, and only in one of these planes **(b)** is it easily recognized as a banana. If one cannot recognize a sectioned organ, it is possible to reconstruct its shape from a series of successive cuts, as from the three serial sections in **(c)**.

Activity 3

Observing Sectioned Specimens

1. Go to the demonstration area and observe the transversely and longitudinally cut organ specimens (kidneys). Pay close attention to the different structural details in the samples; you will need to draw these views in the Review Sheet at the end of this exercise.
2. After completing instruction 1, obtain a gelatin-spaghetti mold and a scalpel, and take them to your laboratory bench. (Essentially, this is just cooked spaghetti added to warm gelatin, which is then allowed to gel.)
3. Cut through the gelatin-spaghetti mold along any plane, and examine the cut surfaces. You should see spaghetti strands that have been cut transversely (x.s.) and some cut longitudinally.
4. Draw the appearance of each of these spaghetti sections below, and verify the accuracy of your section identifications with your instructor.

Transverse cut	Longitudinal cut

Body Cavities

The axial portion of the body has two large cavities that provide different degrees of protection to the organs within them (**Figure 1.5**).

Dorsal Body Cavity

The dorsal body cavity can be subdivided into the **cranial cavity,** which lies within the rigid skull and encases the brain, and the **vertebral** (or **spinal**) **cavity,** which runs through the bony vertebral column to enclose the delicate spinal cord. Because the spinal cord is a continuation of the brain, these cavities are continuous with each other.

Ventral Body Cavity

Like the dorsal cavity, the ventral body cavity is subdivided. The superior **thoracic cavity** is separated from the rest of the ventral cavity by the dome-shaped diaphragm. The heart and lungs, located in the thoracic cavity, are protected by the bony rib cage. The cavity inferior to the diaphragm is often referred to as the **abdominopelvic cavity.** Although there is no further physical separation of the ventral cavity, some describe the abdominopelvic cavity as two areas: a superior **abdominal cavity,** the area that houses the stomach, intestines, liver, and other organs, and an inferior **pelvic cavity,** the region that is partially enclosed by the bony pelvis and contains the reproductive organs, bladder, and rectum. Notice in Figure 1.5a that the abdominal and pelvic cavities are not aligned with each other in a plane because the pelvic cavity is tipped forward.

Serous Membranes of the Ventral Body Cavity

The walls of the ventral body cavity and the outer surfaces of the organs it contains are covered with an exceedingly thin, double-layered membrane called the **serosa,** or **serous membrane.** The part of the membrane lining the cavity walls is referred to as the **parietal serosa,** and it is continuous with a

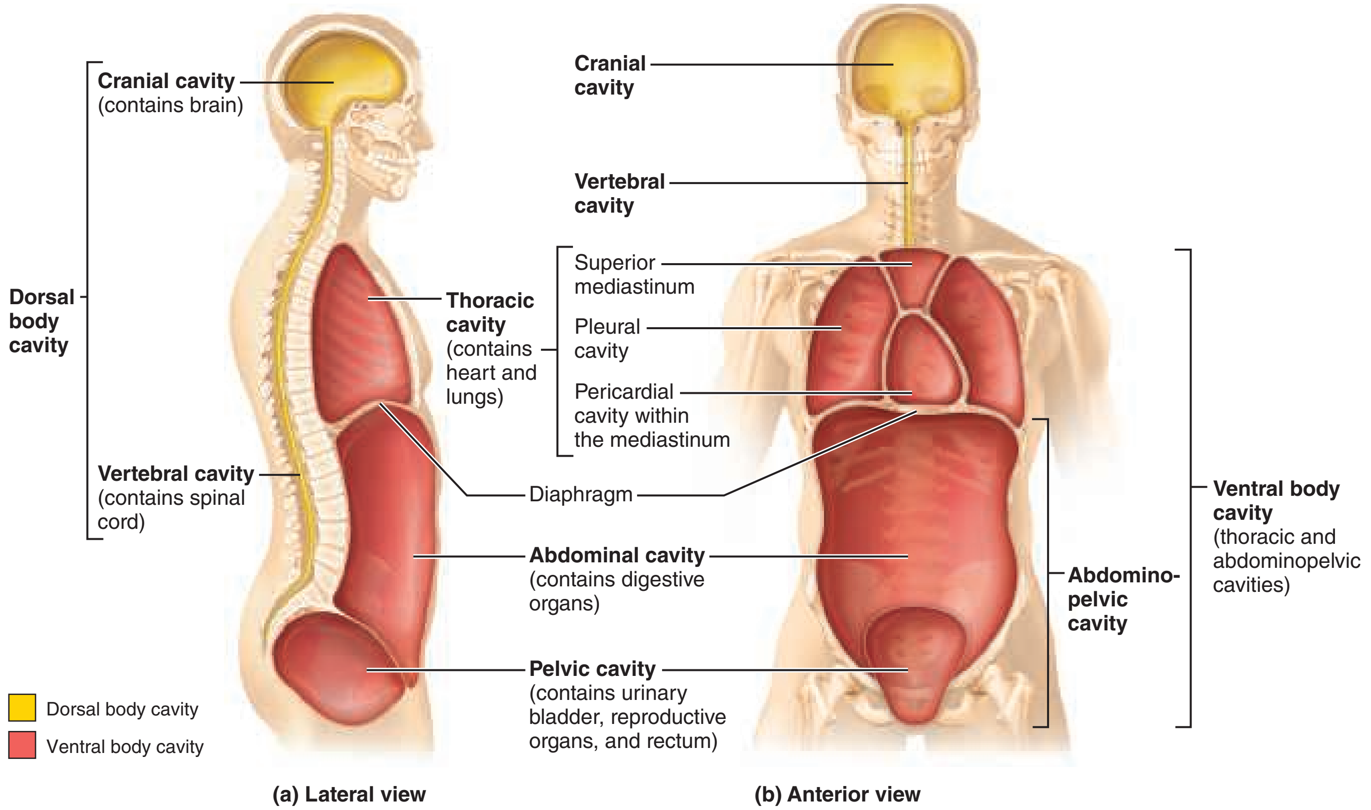
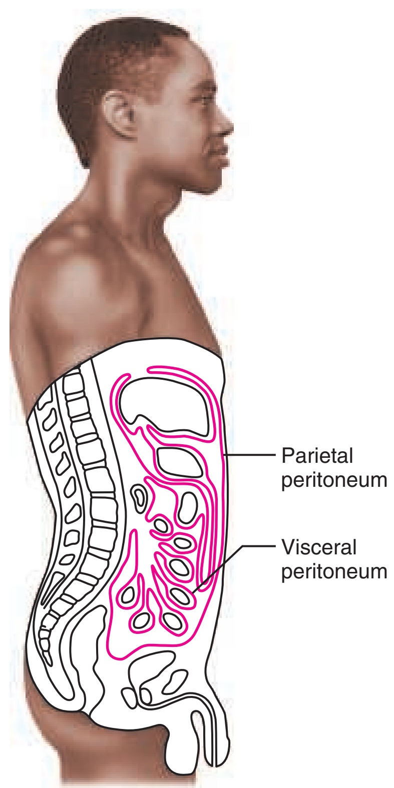


Figure 1.5 **Dorsal and ventral body cavities and their subdivisions.**

similar membrane, the **visceral serosa,** covering the external surface of the organs within the cavity. These membranes produce a thin lubricating fluid that allows the visceral organs to slide over one another or to rub against the body wall with minimal friction. Serous membranes also compartmentalize the various organs to prevent infection in one organ from spreading to others.

The specific names of the serous membranes depend on the structures they surround. The serosa lining the abdominal cavity and covering its organs is the **peritoneum,** the serosa enclosing the lungs is the **pleura,** and the serosa around the heart is the **pericardium** (**Figure 1.6**).



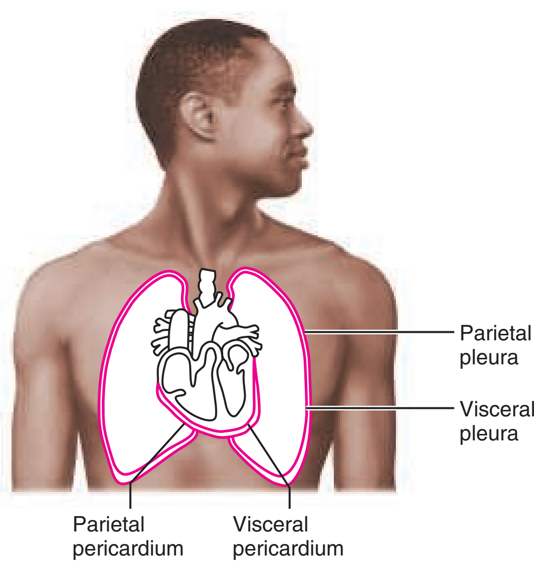


Figure 1.6 **Serous membranes of the ventral body cavities.**

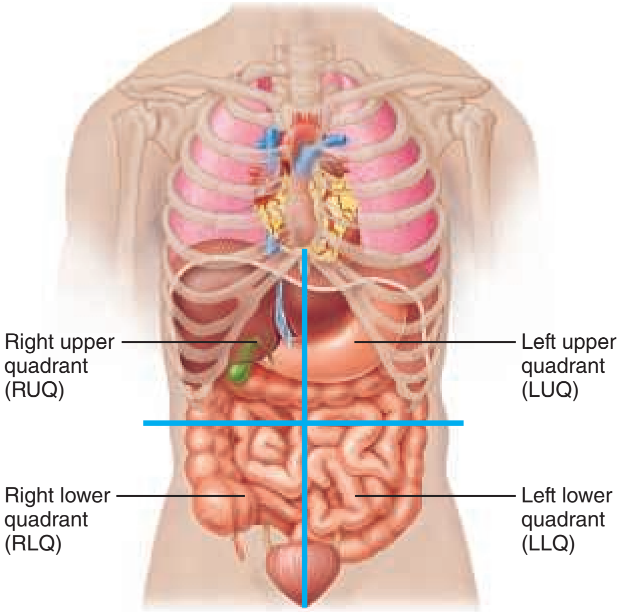


Figure 1.7 Abdominopelvic quadrants. Superficial organs all shown in each quadrant.

Abdominopelvic Quadrants and Regions

Because the abdominopelvic cavity is quite large and contains many organs, it is helpful to divide it up into smaller areas for discussion or study.

Most physicians and nurses use a scheme that divides the abdominal surface and the abdominopelvic cavity into four approximately equal regions called **quadrants.** These quadrants are named according to their relative position—that is, *right upper quadrant, right lower quadrant, left upper quadrant,* and *left lower quadrant* (**Figure 1.7**). Note that the terms *left* and *right* refer to the left and right side of the body in the figure, not the left and right side of the art on the page.

Activity 4

Identifying Organs in the Abdominopelvic Cavity

Examine the human torso model to respond to the following questions.

Name two organs found in the left upper quadrant.

________________ and ________________

Name two organs found in the right lower quadrant.

________________ and ________________

What organ (Figure 1.7) is divided into identical halves by the median plane? ________________

A different scheme commonly used by anatomists divides the abdominal surface and abdominopelvic cavity into nine separate regions by four planes (**Figure 1.8**). As you read through the descriptions of these nine regions, locate them in Figure 1.8, and note the organs contained in each region.

Umbilical region: The centermost region, which includes the umbilicus (navel)

Epigastric region: Immediately superior to the umbilical region; overlies most of the stomach

Hypogastric (pubic) region: Immediately inferior to the umbilical region; encompasses the pubic area

Iliac, or inguinal, regions: Lateral to the hypogastric region and overlying the superior parts of the hip bones

Lumbar regions: Between the ribs and the flaring portions of the hip bones; lateral to the umbilical region

Hypochondriac regions: Flanking the epigastric region laterally and overlying the lower ribs

Activity 5

Locating Abdominal Surface Regions

Locate the regions of the abdominal surface on a human torso model and on yourself.

Other Body Cavities

Besides the large, closed body cavities, there are several types of smaller body cavities (**Figure 1.9**). Many of these are in the head, and most open to the body exterior.

Oral cavity: The oral cavity, commonly called the *mouth*, contains the tongue and teeth. It is continuous with the rest of the digestive tube, which opens to the exterior at the anus.

Nasal cavity: Located within and posterior to the nose, the nasal cavity is part of the passages of the respiratory system.

Orbital cavities: The orbital cavities (orbits) in the skull house the eyes and present them in an anterior position.

Middle ear cavities: Each middle ear cavity lies just medial to an eardrum and is carved into the bony skull. These cavities contain tiny bones that transmit sound vibrations to the hearing receptors in the inner ears.

Synovial cavities: Synovial cavities are joint cavities—they are enclosed within fibrous capsules that surround the freely movable joints of the body, such as those between the vertebrae and the knee and hip joints. Like the serous membranes of the ventral body cavity, membranes lining the synovial cavities secrete a lubricating fluid that reduces friction as the enclosed structures move across one another.

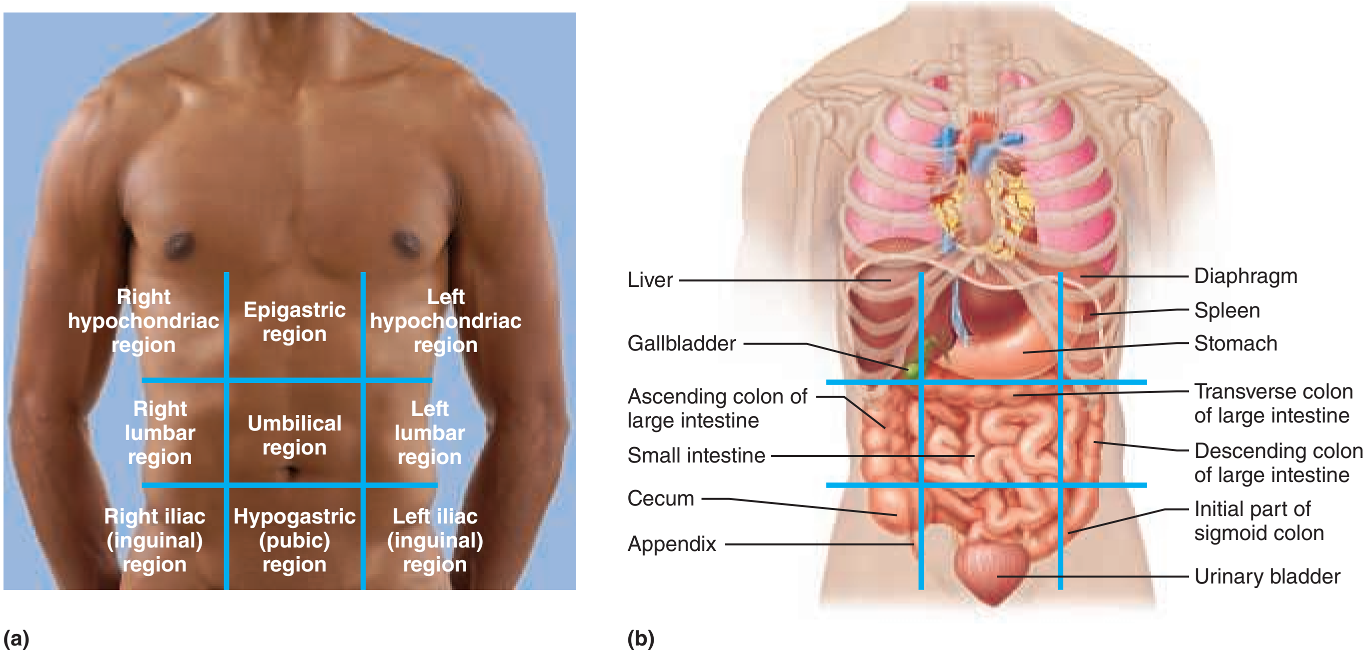


Figure 1.8 Abdominopelvic regions. Nine regions delineated by four planes. (a) The superior horizontal plane is just inferior to the ribs; the inferior horizontal plane is at the superior aspect of the hip bones. The vertical planes are just medial to the nipples. (b) Superficial organs are shown in each region.

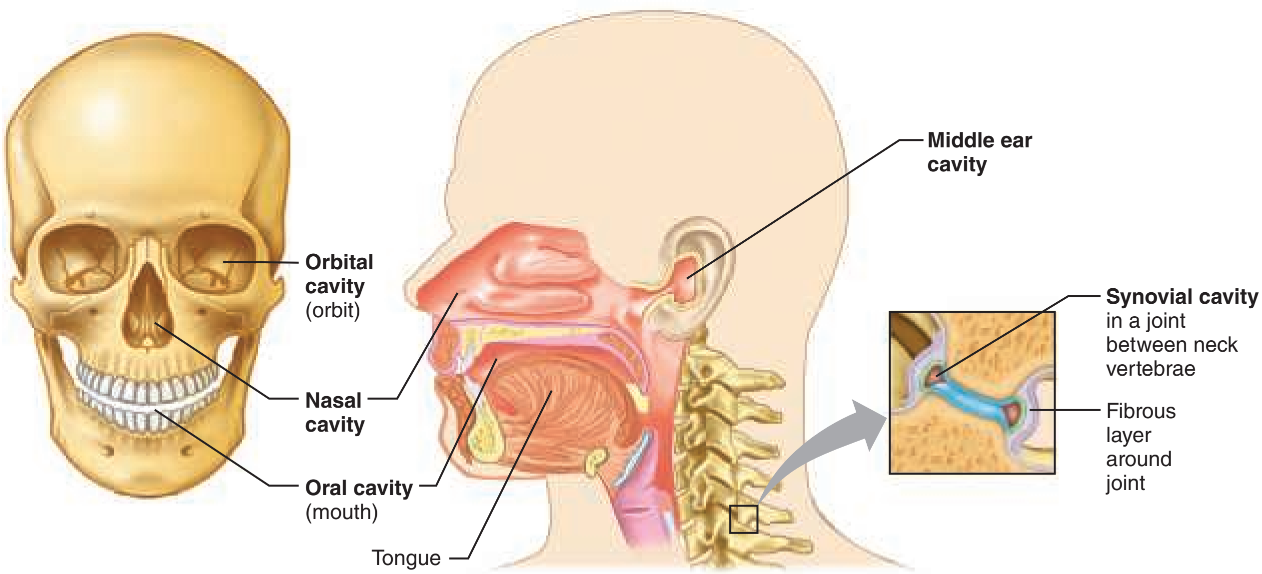


Figure 1.9 Other body cavities. The oral, nasal, orbital, and middle ear cavities are located in the head and open to the body exterior. Synovial cavities are found in joints between many bones, such as the vertebrae of the spine, and at the knee, shoulder, and hip.

1

Group Challenge

The Language of Anatomy

Working in groups of three, complete the tasks described below.

For questions 1–4, each student within a group will assume a different role: facilitator, subject, or recorder. (Remind the subject to stand in the anatomical position.) The facilitator will write each term on a separate Post-it Note. For each term, discuss within your group where on the subject to place the Post-it. Once your group members have come to consensus, the facilitator will stick the Post-it on the subject on the appropriate body landmark. After all of the Post-it Notes have been placed, the group will discuss the order in which the terms should be recorded. Then the recorder will write down the terms in the appropriate order.

1. Arrange the following terms from superior to inferior: cervical, coxal, crural, femoral, lumbar, mental, nasal, plantar, sternal, and tarsal. ______________________________

____

____

____

2. Arrange the following terms from proximal to distal: antebrachial, antecubital, brachial, carpal, digital, and palmar. ______________________________________

____

3. Arrange the following terms from medial to lateral: acromial, axillary, buccal, otic, pollex, and umbilical.

____

____

4. Arrange the following terms from distal to proximal: calcaneal, femoral, hallux, plantar, popliteal, and sural.

____

____

5. Name a plane that you could use to section a four-legged chair and still be able to sit in the chair without falling over. ______________________________________

____

6. Name the abdominopelvic region that is both medial and inferior to the right lumbar region.

____

7. Name the type of inflammation (think "-itis") that is typically accompanied by pain in the lower right quadrant.

____

EXERCISE 1

REVIEW SHEET
The Language of Anatomy

Name ______________________________ Lab Time/Date ______________________

Surface Anatomy

1. Match each of the numbered descriptions with the related term in the key, and record the key letter or term in front of the description.

Key: a. buccal c. cephalic e. patellar
b. calcaneal d. digital f. scapular

__________ 1. cheek __________ 4. anterior aspect of knee

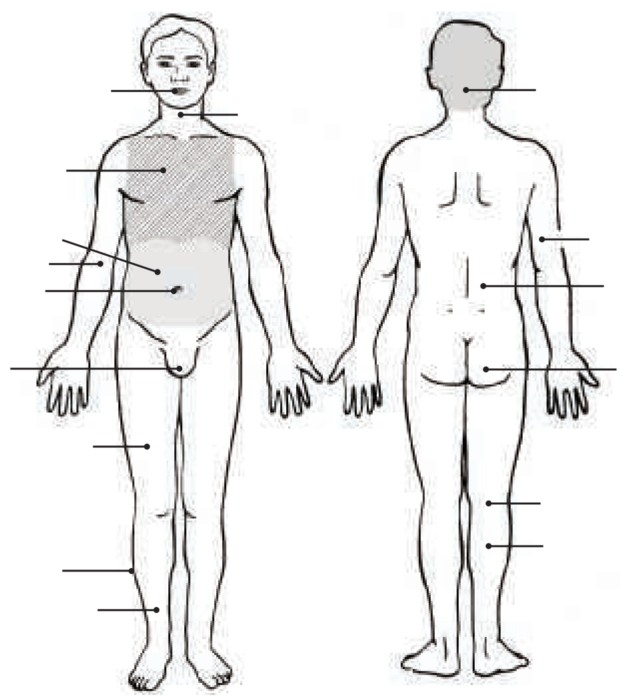
__________ 2. fingers __________ 5. heel of foot

__________ 3. shoulder blade region __________ 6. head

2. Indicate the following body areas on the accompanying diagram by placing the correct key letter at the end of each line.

Key:

a. abdominal
b. antecubital
c. brachial
d. cervical
e. crural
f. femoral
g. fibular
h. gluteal
i. lumbar
j. occipital
k. oral
l. popliteal
m. pubic
n. sural
o. thoracic
p. umbilical



3. For each term in the key of question 2 above, determine which of the two major body divisions it belongs to. Insert the appropriate key letters on the answer blanks.

______________ 1. appendicular ______________ 2. axial

Body Orientation, Direction, Planes, and Sections

4. Describe completely the standard human anatomical position. ______________________________

____

5. Define *section.* ____

6. Several incomplete statements appear below. Correctly complete each statement by choosing the appropriate anatomical term from the key. Record the key letters and/or terms on the correspondingly numbered blanks below. Some terms are used more than once.

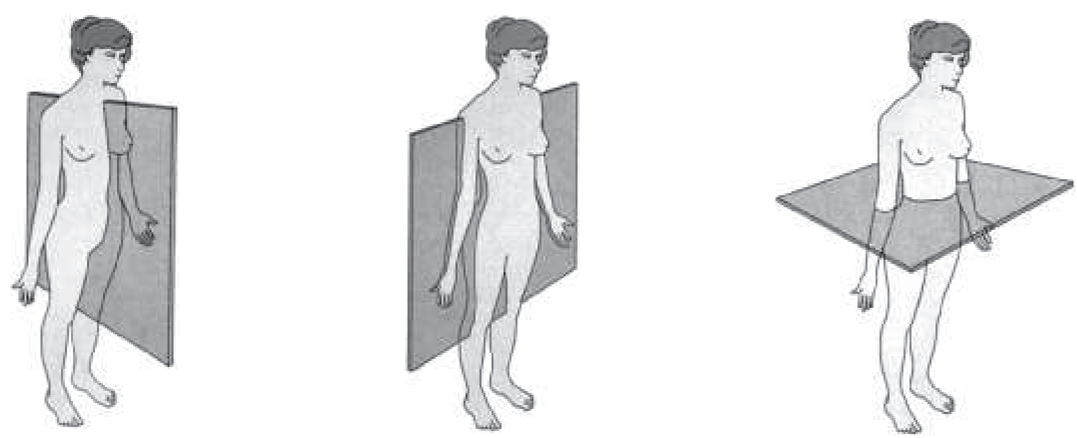
Key:			
a. anterior	d. inferior	g. posterior	j. superior
b. distal	e. lateral	h. proximal	k. transverse
c. frontal	f. medial	i. sagittal	

In the anatomical position, the face and palms are on the ___1___ body surface; the buttocks and shoulder blades are on the ___2___ body surface; and the top of the head is the most ___3___ part of the body. The ears are ___4___ and ___5___ to the shoulders and ___6___ to the nose. The heart is ___7___ to the vertebral column (spine) and ___8___ to the lungs. The elbow is ___9___ to the fingers but ___10___ to the shoulder. The abdominopelvic cavity is ___11___ to the thoracic cavity and ___12___ to the spinal cavity. In humans, the dorsal surface can also be called the ___13___ surface; however, in quadruped animals, the dorsal surface is the ___14___ surface.

If an incision cuts the heart into right and left parts, the section is a ___15___ section; but if the heart is cut so that superior and inferior portions result, the section is a ___16___ section. You are told to cut a dissection animal along two planes so that both kidneys are observable in each section. The two sections that can meet this requirement are the ___17___ and ___18___ sections. A section that demonstrates the continuity between the spinal and cranial cavities is a ___19___ section.

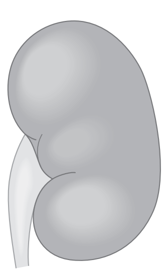
1. ____________	8. ____________	14. ____________
2. ____________	9. ____________	15. ____________
3. ____________	10. ____________	16. ____________
4. ____________	11. ____________	17. ____________
5. ____________	12. ____________	18. ____________
6. ____________	13. ____________	19. ____________
7. ____________		

7. Correctly identify each of the body planes by inserting the appropriate term on the answer line below the drawing.



(a) ____________ **(b)** ____________ **(c)** ____________

8. Draw a kidney as it appears when sectioned in each of the three different planes.



Transverse section	Sagittal section	Frontal section

9. Correctly identify each of the nine regions of the abdominopelvic cavity by inserting the appropriate term for each letter indicated in the drawing.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

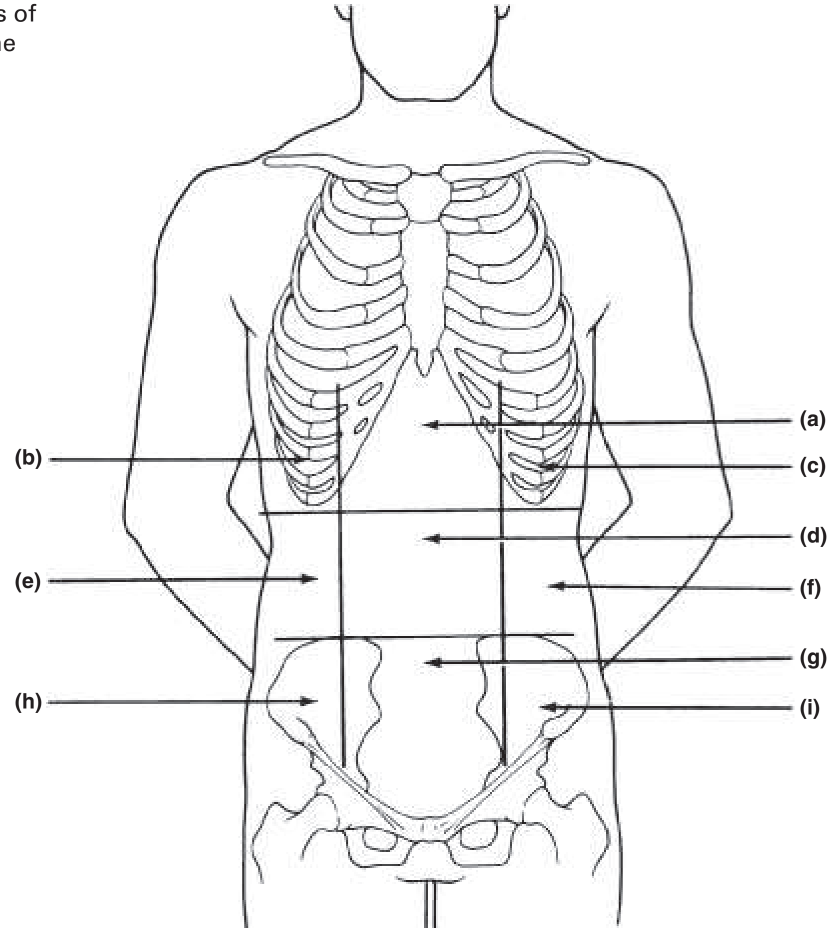
e. ______________________

f. ______________________

g. ______________________

h. ______________________

i. ______________________



Body Cavities

10. Which body cavities would have to be opened for the following types of surgery or procedures? (Insert the letter of key choice in the same-numbered blank. More than one choice applies.)

Key:			
a. abdominopelvic	c. dorsal	e. thoracic
b. cranial	d. spinal	f. ventral

__________ 1. surgery to remove a cancerous lung lobe

__________ 2. removal of the uterus, or womb

__________ 3. removal of a brain tumor

__________ 4. appendectomy

__________ 5. stomach ulcer operation

__________ 6. delivery of pre-operative "saddle" anesthesia

11. Name the muscle that subdivides the ventral body cavity. ______________________

12. What are the bony landmarks of the abdominopelvic cavity? ______________________

____

13. Which body cavity provides the least protection to its internal structures? ______________________

14. What is the function of the serous membranes of the body? ______________________

____

15. Using the key choices, identify the small body cavities described below.

Key: a. middle ear cavity c. oral cavity e. synovial cavity
b. nasal cavity d. orbital cavity

__________ 1. holds the eyes in an anterior-facing position

__________ 2. houses three tiny bones involved in hearing

__________ 3. contained within the nose

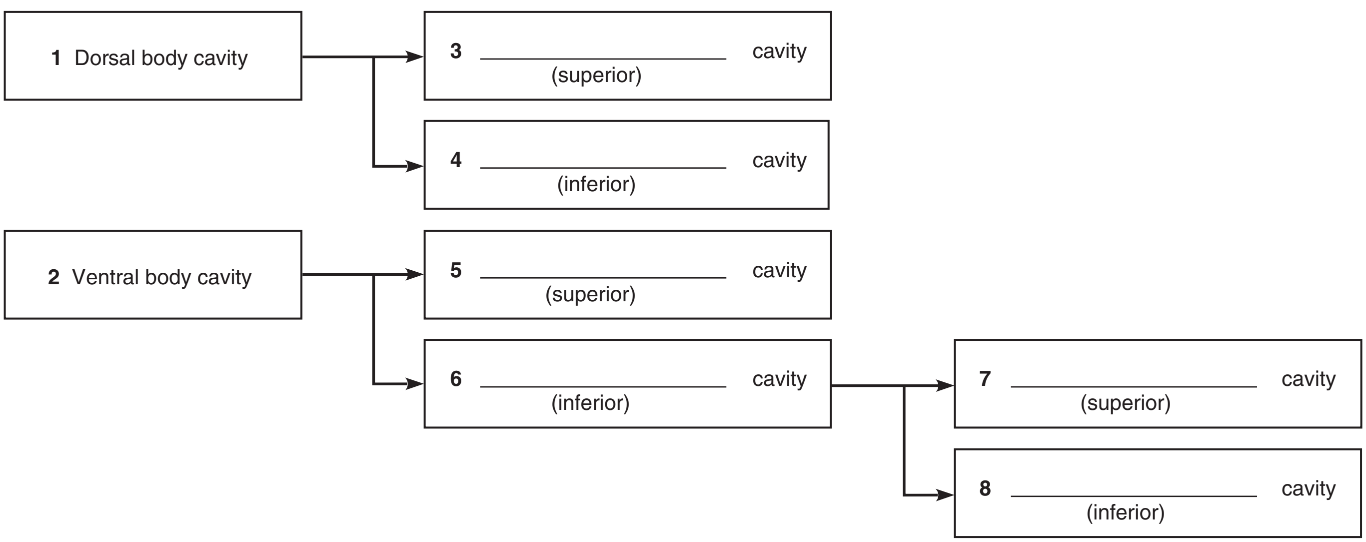
__________ 4. contains the tongue

__________ 5. surrounds a joint

16. On the incomplete flowchart provided below:

- Fill in the cavity names that belong in boxes 3–8.
- Then, using either the name of the cavity or the box numbers, identify the descriptions in the list that follows.

Body cavities



__________ a. contained within the skull and vertebral column

__________ b. houses female reproductive organs

__________ c. the most protective body cavity

__________ d. its name means “belly”

__________ e. contains the heart

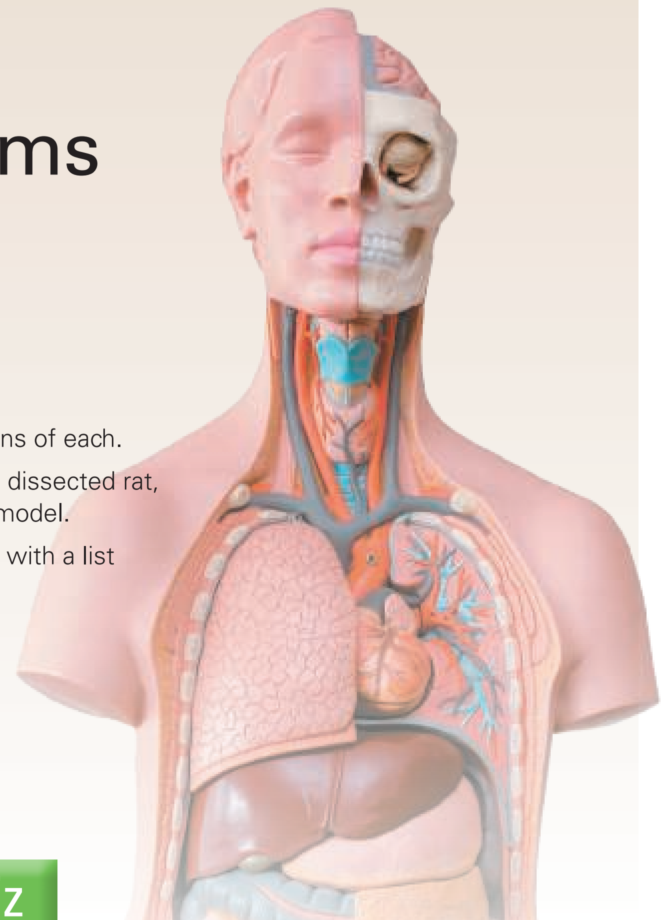
__________ f. contains the small intestine

__________ g. bounded by the ribs

__________ h. its walls are muscular

EXERCISE 2

Organ Systems Overview



Objectives

- ☐ Name the human organ systems, and indicate the major functions of each.
- ☐ List several major organs of each system, and identify them in a dissected rat, human cadaver or cadaver image, or a dissectible human torso model.
- ☐ Name the correct organ system for each organ when presented with a list of organs studied in the laboratory.

Materials

- Freshly killed or preserved rat (predissected by instructor as a demonstration or for student dissection [one rat for every two to four students]) or predissected human cadaver
- Dissection trays
- Twine or large dissecting pins
- Scissors
- Probes
- Forceps
- Disposable gloves
- Human torso model (dissectible)

Pre-Lab Quiz

1. Name the structural and functional unit of all living things. _________
2. The small intestine is an example of a(n) _________, because it is composed of two or more tissue types that perform a particular function for the body.
   a. epithelial tissue b. muscular tissue
   c. organ d. organ system
3. The ________________ system is responsible for maintaining homeostasis of the body via rapid transmission of electrical signals.
4. The kidneys are part of the ________________ system.
5. The thin muscle that separates the thoracic and abdominal cavities is the ________________.

The basic unit or building block of all living things is the **cell.** Cells fall into four different categories according to their structures and functions. These categories correspond to the four tissue types: epithelial, muscular, nervous, and connective. A **tissue** is a group of cells that are similar in structure and function. An **organ** is a structure composed of two or more tissue types that performs a specific function for the body. For example, the small intestine, which digests and absorbs nutrients, is made up of all four tissue types.

An **organ system** is a group of organs that act together to perform a particular body function. For example, the organs of the digestive system work together to break down foods and absorb the end products into the bloodstream in order to provide nutrients and fuel for all the body's cells. In all, there are 11 organ systems, described in **Table 2.1** on p. 16. The lymphatic system also encompasses a *functional system* called the immune system, which is composed of an army of mobile *cells* that protect the body from foreign substances.

Read through this summary of the body's organ systems (Table 2.1) before beginning your rat dissection or examination of the predissected human cadaver. If a human cadaver is not available, Figures 2.3–2.6 will serve as a partial replacement.

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2

Table 2.1 Overview of Organ Systems of the Body

Organ system	Major component organs	Function
Integumentary (Skin)	Epidermal and dermal regions; cutaneous sense organs and glands	• Protects deeper organs from mechanical, chemical, and bacterial injury, and from drying out • Excretes salts and urea • Aids in regulation of body temperature • Produces vitamin D
Skeletal	Bones, cartilages, tendons, ligaments, and joints	• Body support and protection of internal organs • Provides levers for muscular action • Cavities provide a site for blood cell formation
Muscular	Muscles attached to the skeleton	• Primary function is to contract or shorten; in doing so, skeletal muscles allow locomotion (running, walking, etc.), grasping and manipulation of the environment, and facial expression • Generates heat
Nervous	Brain, spinal cord, nerves, and sensory receptors	• Allows body to detect changes in its internal and external environment and to respond to such information by activating appropriate muscles or glands • Helps maintain homeostasis of the body via rapid transmission of electrical signals
Endocrine	Pituitary, thymus, thyroid, parathyroid, adrenal, and pineal glands; ovaries, testes, and pancreas	• Helps maintain body homeostasis, promotes growth and development; produces chemical messengers called hormones that travel in the blood to exert their effect(s) on various target organs of the body
Cardiovascular	Heart, blood vessels, and blood	• Primarily a transport system that carries blood containing oxygen, carbon dioxide, nutrients, wastes, ions, hormones, and other substances to and from the tissue cells where exchanges are made; blood is propelled through the blood vessels by the pumping action of the heart • Antibodies and other protein molecules in the blood protect the body
Lymphatic/ Immunity	Lymphatic vessels, lymph nodes, spleen, thymus, tonsils, and scattered collections of lymphoid tissue	• Picks up fluid leaked from the blood vessels and returns it to the blood • Cleanses blood of pathogens and other debris • Houses lymphocytes that act via the immune response to protect the body from foreign substances
Respiratory	Nasal passages, pharynx, larynx, trachea, bronchi, and lungs	• Keeps the blood continuously supplied with oxygen while removing carbon dioxide • Contributes to the acid-base balance of the blood via its carbonic acid–bicarbonate buffer system
Digestive	Oral cavity, esophagus, stomach, small and large intestines, and accessory structures including teeth, salivary glands, liver, and pancreas	• Breaks down ingested foods to smaller particles, which can be absorbed into the blood for delivery to the body cells • Undigested residue removed from the body as feces
Urinary	Kidneys, ureters, bladder, and urethra	• Rids the body of nitrogen-containing wastes including urea, uric acid, and ammonia, which result from the breakdown of proteins and nucleic acids • Maintains water, electrolyte, and acid-base balance of blood
Reproductive	Male: testes, prostate gland, scrotum, penis, and duct system, which carries sperm to the body exterior	• Provides germ cells called sperm for perpetuation of the species
	Female: ovaries, uterine tubes, uterus, mammary glands, and vagina	• Provides germ cells called eggs; the female uterus houses the developing fetus until birth; mammary glands provide nutrition for the infant

DISSECTION AND IDENTIFICATION

The Organ Systems of the Rat

Many of the external and internal structures of the rat are quite similar in structure and function to those of the human. So, a study of the gross anatomy of the rat should help you understand our own physical structure. The following instructions include directions for dissecting and observing a rat. In addition, the descriptions of the organs (Activity 4, Examining the Ventral Body Cavity, which begins on p. 18) also apply to superficial observations of a previously dissected human cadaver. The general instructions for observing external structures also apply to human cadaver observations. The photographs in Figures 2.3 to 2.6 will provide visual aids.

Note that four organ systems (integumentary, skeletal, muscular, and nervous) will not be studied at this time, because they require microscopic study or more detailed dissection.

Activity 1

Observing External Structures

1. If your instructor has provided a predissected rat, go to the demonstration area to make your observations. Alternatively, if you and/or members of your group will be dissecting the specimen, obtain a preserved or freshly killed rat, a dissecting tray, dissecting pins or twine, scissors, probe, forceps, and disposable gloves, and bring them to your laboratory bench.

If a predissected human cadaver is available, obtain a probe, forceps, and disposable gloves before going to the demonstration area.

2. Don the gloves before beginning your observations. This precaution is particularly important when handling freshly killed animals, which may harbor pathogens.

3. Observe the major divisions of the body—head, trunk, and extremities. If you are examining a rat, compare these divisions to those of humans.

Activity 2

Examining the Oral Cavity

Examine the structures of the oral cavity. Identify the teeth and tongue. Observe the extent of the hard palate (the portion underlain by bone) and the soft palate (immediately posterior to the hard palate, with no bony support). Notice that the posterior end of the oral cavity leads into the throat, or pharynx, a passageway used by both the digestive and respiratory systems.

Activity 3

Opening the Ventral Body Cavity

1. Pin the animal to the wax of the dissecting tray by placing its dorsal side down and securing its extremities to the wax with large dissecting pins as shown in **Figure 2.1a**.

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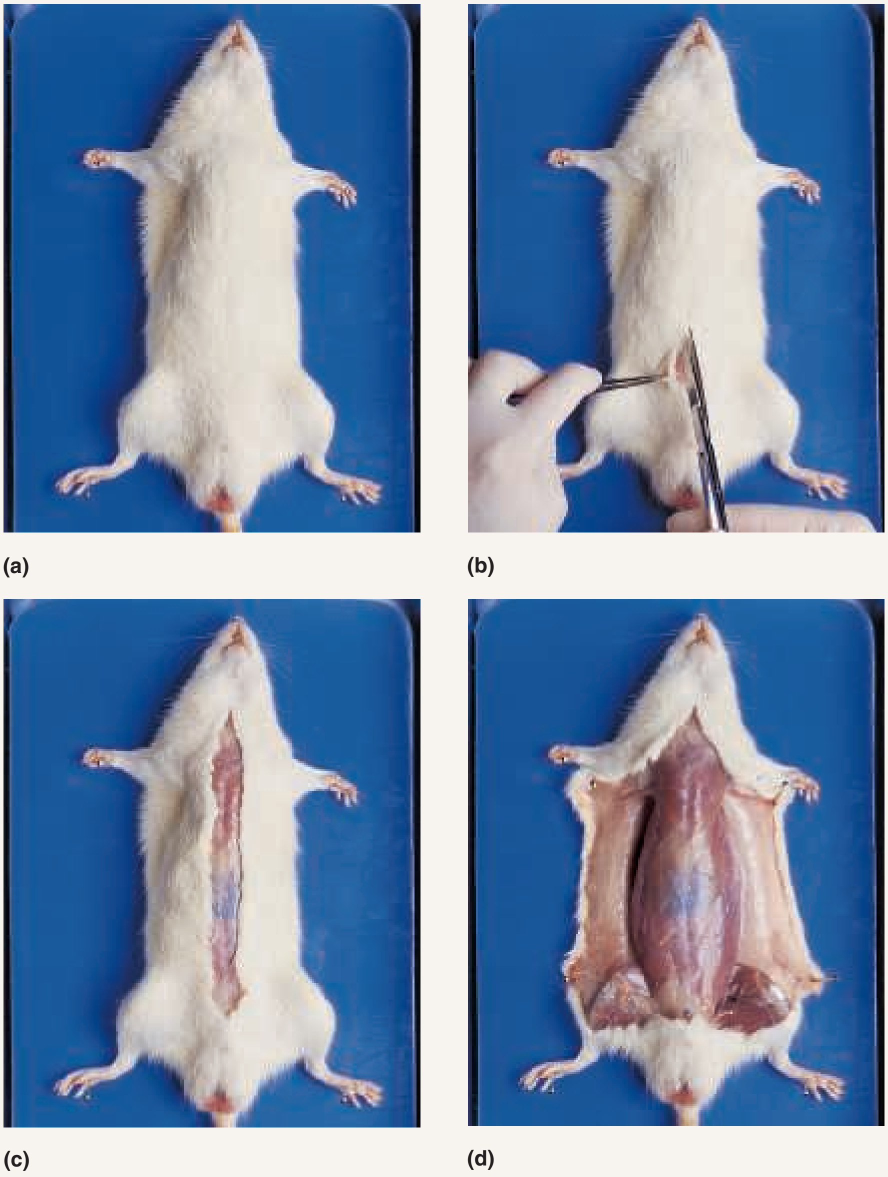

Figure 2.1 Rat dissection: Securing for dissection and the initial incision. **(a)** Securing the rat to the dissection tray with dissecting pins. **(b)** Using scissors to make the incision on the median line of the abdominal region. **(c)** Completed incision from the pelvic region to the lower jaw. **(d)** Reflection (folding back) of the skin to expose the underlying muscles.

2

If the dissecting tray is not waxed, you will need to secure the animal with twine as follows. (Your instructor may prefer this method in any case.) Obtain the roll of twine. Make a loop knot around one upper limb, pass the twine under the tray, and secure the opposing limb. Repeat for the lower extremities.

2. Lift the abdominal skin with a forceps, and cut through it with the scissors (Figure 2.1b). Close the scissor blades, and insert them flat under the cut skin. Moving in a cephalad direction, open and close the blades to loosen the skin from the underlying connective tissue and muscle. Now, cut the skin along the body midline, from the pubic region to the lower jaw (Figure 2.1c). Finally, make a lateral cut about halfway down the ventral surface of each limb. Complete the job of freeing the skin with the scissor tips, and pin the flaps to the tray (Figure 2.1d). The underlying tissue that is now exposed is the skeletal musculature of the body wall and limbs. Notice that the muscles are packaged in sheets of pearly white connective tissue (fascia), which protect the muscles and bind them together.

3. Carefully cut through the muscles of the abdominal wall in the pubic region, avoiding the underlying organs. Remember, to *dissect* means "to separate"—not mutilate! Now, hold and lift the muscle layer with a forceps and cut through the muscle layer from the pubic region to the bottom of the rib cage. Make two lateral cuts at the base of the rib cage (**Figure 2.2**). A thin membrane attached to the inferior boundary of the rib cage should be obvious; this is the **diaphragm,** which separates the thoracic and abdominal cavities. Cut the diaphragm where it attaches to the ventral ribs to loosen the rib cage. Cut through the rib cage on either side. You can now lift the ribs to view the contents of the thoracic cavity. Cut across the flap, at the level of the neck, and remove the rib cage.

Figure 2.2 Rat dissection. Making lateral cuts at the base of the rib cage.

Activity 4

Examining the Ventral Body Cavity

1. Starting with the most superficial structures and working deeper, examine the structures of the thoracic cavity. Refer to **Figure 2.3**, which shows the superficial organs, as you work. Choose the appropriate view depending on whether you are examining a rat (a) or a human cadaver (b).

Thymus: An irregular mass of glandular tissue overlying the heart (not illustrated in the human cadaver photograph).

With the probe, push the thymus to the side to view the heart.

Heart: Medial oval structure enclosed within the pericardium (serous membrane sac).

Lungs: Lateral to the heart on either side.

Now observe the throat region to identify the trachea.

Trachea: Tubelike "windpipe" running medially down the throat; part of the respiratory system.

Follow the trachea into the thoracic cavity; notice where it divides into two branches. These are the bronchi.

Bronchi: Two passageways that plunge laterally into the tissue of the two lungs.

To expose the esophagus, push the trachea to one side.

Esophagus: A food chute; the part of the digestive system that transports food from the pharynx (throat) to the stomach.

Diaphragm: A thin muscle attached to the inferior boundary of the rib cage; separates the thoracic and abdominopelvic cavities.

Follow the esophagus through the diaphragm to its junction with the stomach.

Stomach: A curved organ important in food digestion and temporary food storage.

2. Examine the superficial structures of the abdominopelvic cavity. Lift the **greater omentum,** an extension of the peritoneum (serous membrane) that covers the abdominal viscera. Continuing from the stomach, trace the rest of the digestive tract (**Figure 2.4**, p. 20).

Small intestine: Connected to the stomach and ending just before the saclike cecum.

Large intestine: A large muscular tube connected to the small intestine and ending at the anus.

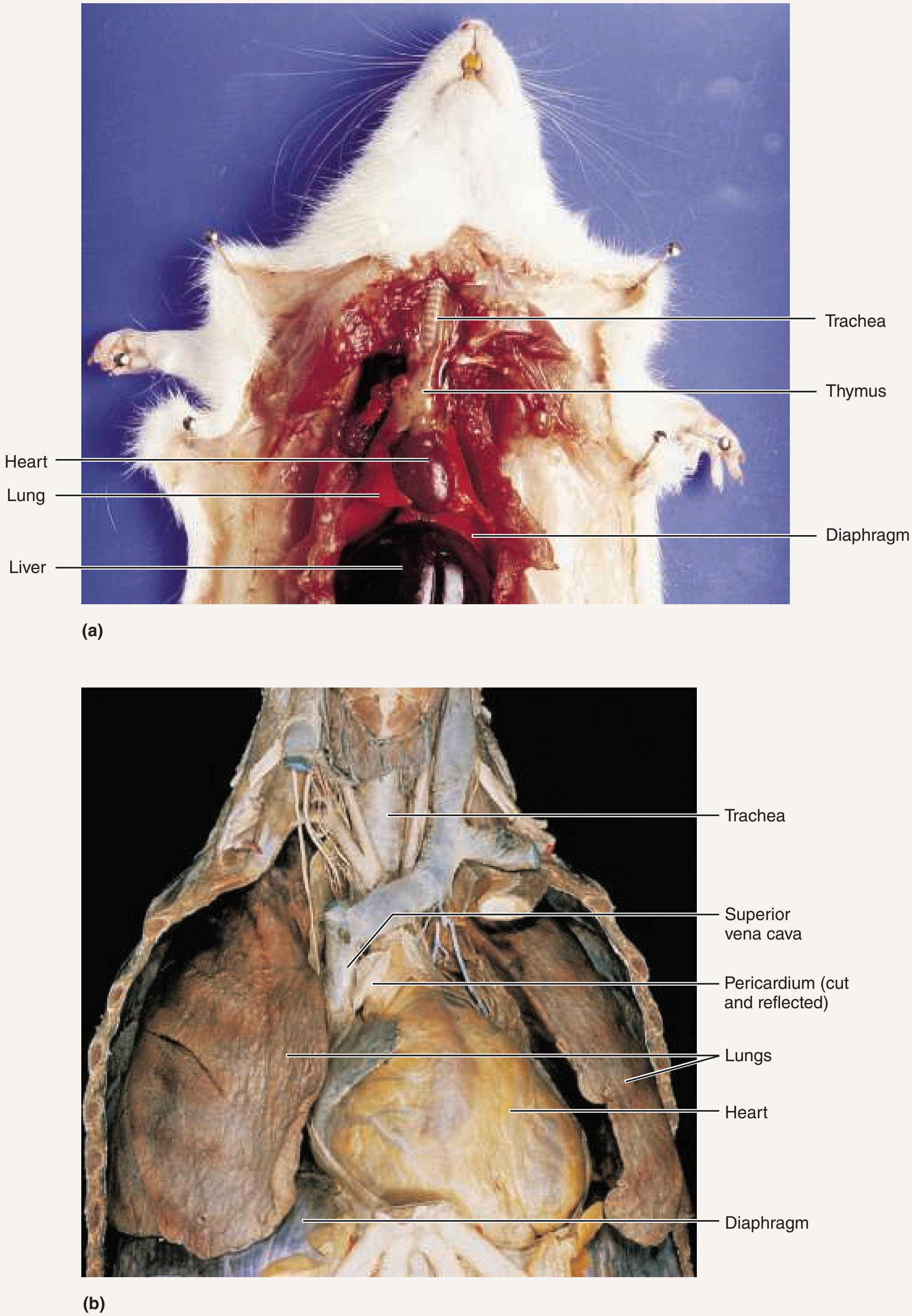

Figure 2.3 Superficial organs of the thoracic cavity. (a) Dissected rat. **(b)** Human cadaver.

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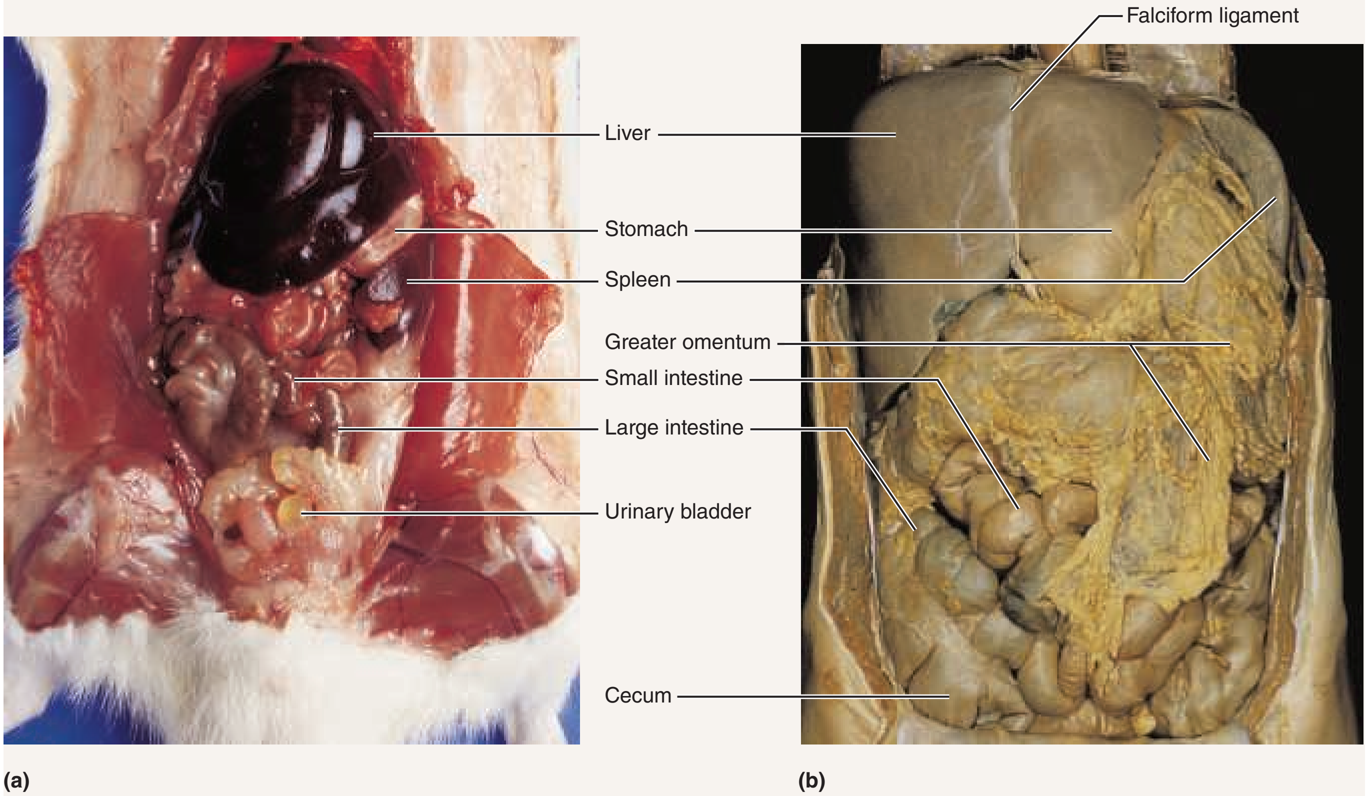

Figure 2.4 Abdominal organs. (a) Dissected rat, superficial view. **(b)** Human cadaver, superficial view.

Cecum: The initial portion of the large intestine.

Follow the course of the large intestine to the rectum, which is partially covered by the urinary bladder (**Figure 2.5**).

Rectum: Terminal part of the large intestine; continuous with the anal canal.

Anus: The opening of the digestive tract (through the anal canal) to the exterior.

Now lift the small intestine with the forceps to view the mesentery.

Mesentery: An apronlike serous membrane; suspends many of the digestive organs in the abdominal cavity. Notice that it is heavily invested with blood vessels and, more likely than not, riddled with large fat deposits.

Locate the remaining abdominal structures.

Pancreas: A diffuse gland; rests dorsal to and in the mesentery between the first portion of the small intestine and the stomach. You will need to lift the stomach to view the pancreas.

Spleen: A dark red organ curving around the left lateral side of the stomach; considered part of the lymphatic system and often called the red blood cell graveyard.

Liver: Large and brownish red; the most superior organ in the abdominal cavity, directly beneath the diaphragm.

3. To locate the deeper structures of the abdominopelvic cavity, move the stomach and the intestines to one side with the probe.

Examine the posterior wall of the abdominal cavity to locate the two kidneys (Figure 2.5).

Kidneys: Bean-shaped organs; retroperitoneal (behind the peritoneum).

Adrenal glands: Large endocrine glands that sit on top of each kidney; considered part of the endocrine system.

Carefully strip away part of the peritoneum with forceps and attempt to follow the course of one of the ureters to the bladder.

Ureter: Tube running from the indented region of a kidney to the urinary bladder.

Urinary bladder: The sac that serves as a reservoir for urine.

4. In the midline of the body cavity lying between the kidneys are the two principal abdominal blood vessels. Identify each.

Inferior vena cava: The large vein that returns blood to the heart from the lower body regions.

Descending aorta: Deep to the inferior vena cava; the largest artery of the body; carries blood away from the heart down the midline of the body.

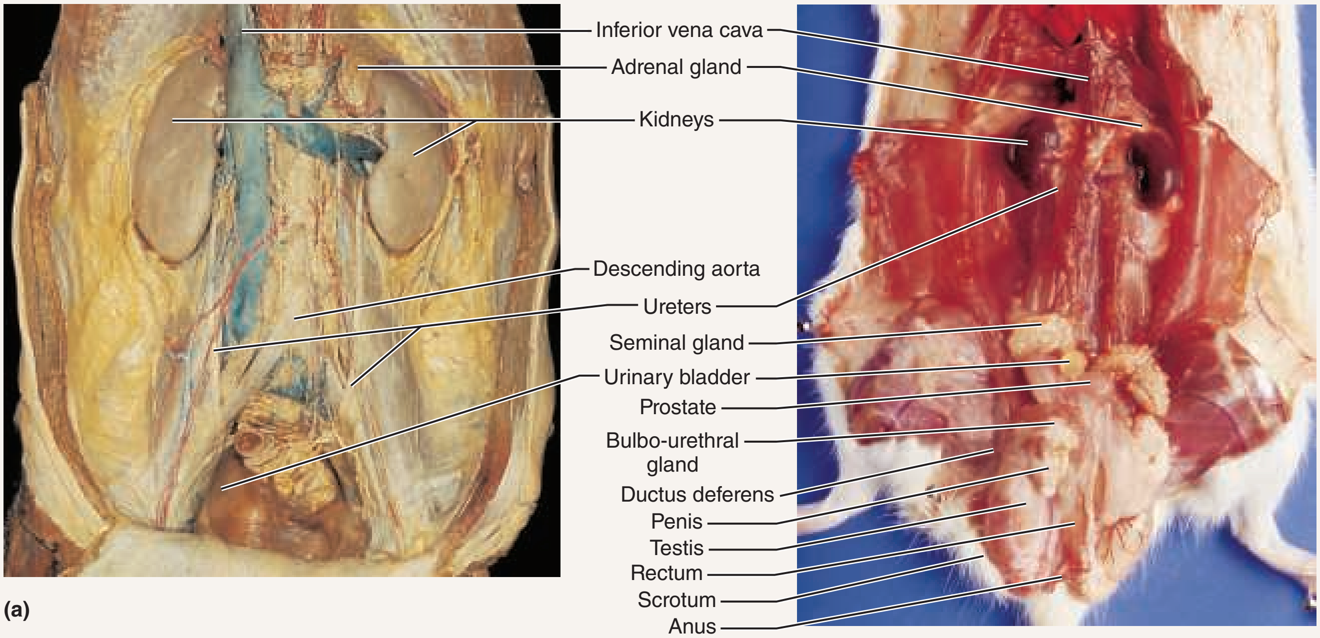

Figure 2.5 Deep structures of the abdominopelvic cavity. (a) Human cadaver. **(b)** Dissected male rat. (Some reproductive structures also shown.) **(c)** Dissected female rat. (Some reproductive structures also shown.)

5. You will perform only a brief examination of reproductive organs. If you are working with a rat, first determine if the animal is a male or female. Observe the ventral body surface beneath the tail. If a saclike scrotum and an opening for the anus are visible, the animal is a male. If three body openings—urethral, vaginal, and anal—are present, it is a female.

Male Rat

Make a shallow incision into the **scrotum.** Loosen and lift out one oval **testis.** Exert a gentle pull on the testis to identify the slender **ductus deferens,** or **vas deferens,** which carries sperm from the testis superiorly into the abdominal cavity and joins with the urethra. The urethra runs through the penis and carries both urine and sperm out of the body. Identify the **penis,** extending from the bladder to the ventral body wall. Figure 2.5b indicates other glands of the male rat's reproductive system, but they need not be identified at this time.

Female Rat

Inspect the pelvic cavity to identify the Y-shaped **uterus** lying against the dorsal body wall and superior to the

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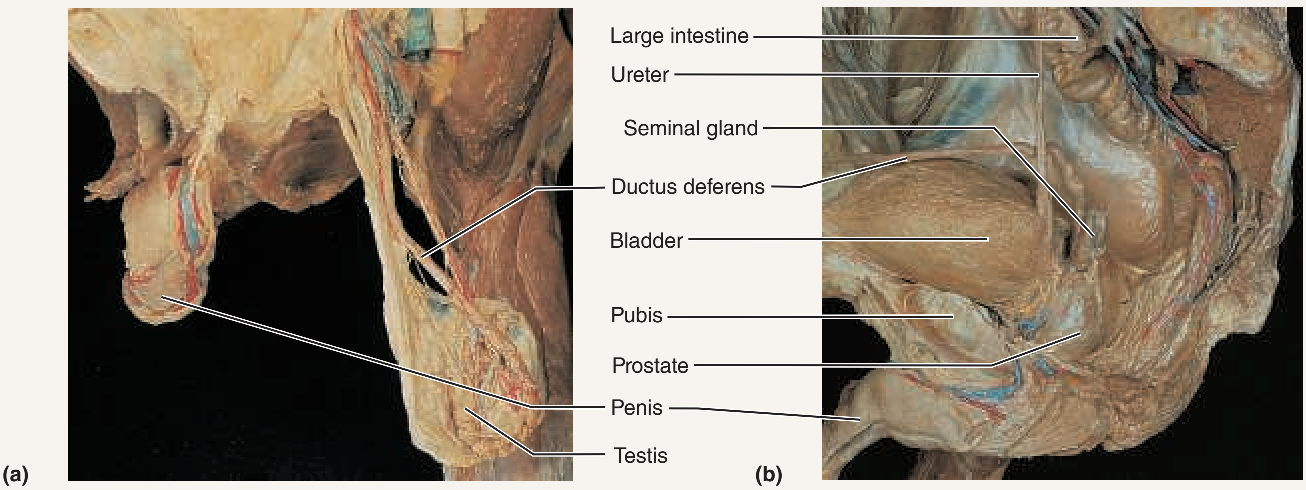


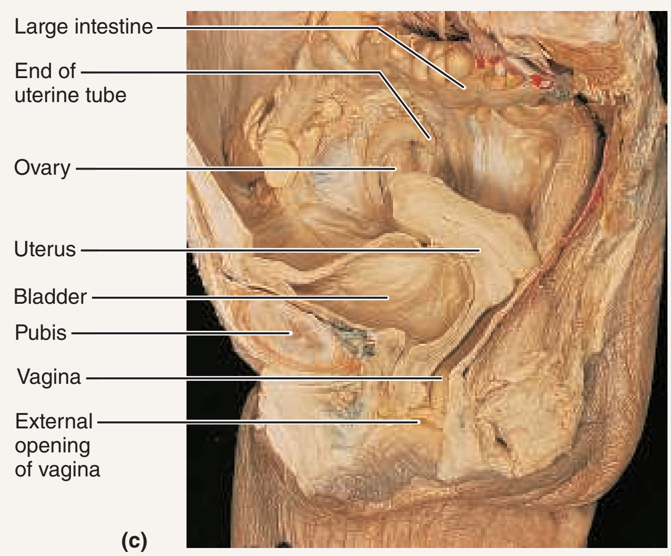


Figure 2.6 Human reproductive organs. (a) Male external genitalia. **(b)** Sagittal section of the male pelvis. **(c)** Sagittal section of the female pelvis.

bladder (Figure 2.5c). Follow one of the uterine horns superiorly to identify an **ovary,** a small oval structure at the end of the uterine horn. (The rat uterus is quite different from the uterus of a human female, which is a single-chambered organ about the size and shape of a pear.) The inferior undivided part of the rat uterus is continuous with the **vagina,** which leads to the body exterior. Identify the **vaginal orifice** (external vaginal opening).

If you are working with a human cadaver, proceed as indicated next.

Male Cadaver

Make a shallow incision into the **scrotum** (**Figure 2.6a**). Loosen and lift out the oval **testis.** Exert a gentle pull on the testis to identify the slender **ductus (vas) deferens,** which carries sperm from the testis superiorly into the abdominopelvic cavity and joins with the urethra (Figure 2.6b). The urethra runs through the penis and carries both urine and sperm out of the body. Identify the **penis,** extending from the bladder to the ventral body wall.

Female Cadaver

Inspect the pelvic cavity to identify the pear-shaped **uterus** lying against the dorsal body wall and superior to the bladder. Follow one of the **uterine tubes** superiorly to identify an **ovary,** a small oval structure at the end of the uterine tube (Figure 2.6c). The inferior part of the uterus is continuous with the **vagina,** which leads to the body exterior. Identify the **vaginal orifice** (external vaginal opening).

6. When you have finished your observations, rewrap or store the dissection animal or cadaver according to your instructor's directions. Wash the dissecting tools and equipment with laboratory detergent. Dispose of the gloves as instructed. Then wash and dry your hands before continuing with the examination of the human torso model.

2

Activity 5

Examining the Human Torso Model

1. Examine a human torso model to identify the organs listed. Some model organs will have to be removed to see the deeper organs. If a torso model is not available, the photograph of the human torso model (**Figure 2.7**) may be used for this part of the exercise.

2. Using the terms at the right of Figure 2.7, label each organ on the supplied leader line.

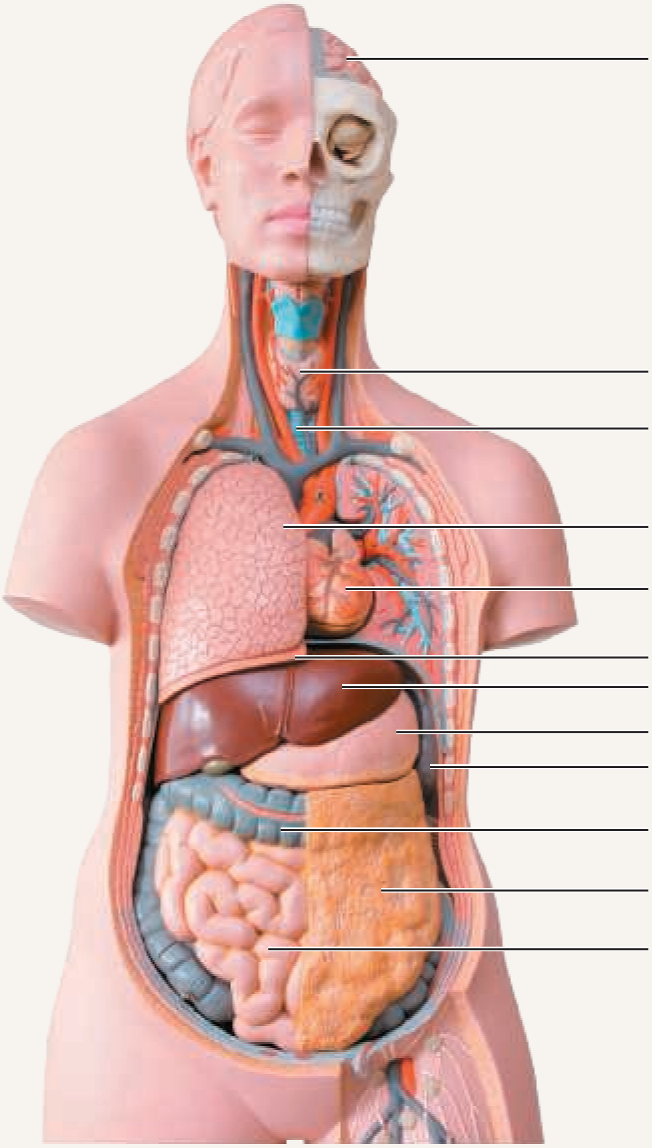


Figure 2.7 Human torso model.

3. List each organ in the correct body cavity or cavities.

Dorsal body cavity ______________________________

Thoracic cavity ______________________________

____

____

Abdominopelvic cavity ______________________________

____

____

Adrenal gland	Lungs
Aortic arch	Mesentery
Brain	Pancreas
Bronchi	Rectum
Descending aorta	Small intestine
Diaphragm	Spinal cord
Esophagus	Spleen
Greater omentum	Stomach
Heart	Thyroid gland
Inferior vena cava	Trachea
Kidneys	Ureters
Large intestine	Urinary bladder
Liver	

Text continues on next page. →

2

4. Now, assign each of the organs to one of the organ systems listed below.

Digestive: ____

____

Urinary: ____

Cardiovascular: ____

____

Endocrine: ____

Reproductive: ____

Respiratory: ____

Lymphatic/Immunity: ____

Nervous: ____

Group Challenge

Odd Organ Out

Each of the following sets contains four organs. One of the listed organs in each case does not share a characteristic that the other three do. Work in groups of three, and discuss the characteristics of the four organs in each set. On a separate piece of paper, one student will record the characteristics of each organ in the set. For each set of four organs, discuss the possible candidates for the "odd organ" and which characteristic it lacks, based on your recorded notes. Once you have come to a consensus among your group, circle the organ that doesn't belong with the others, and explain why it is singled out. Include as many reasons as you can think of, but make sure the "odd organ" does not have the key characteristic. Use the overview of organ systems (Table 2.1) and the pictures in your lab manual to help you select and justify your answer.

1. Which is the "odd organ"?	**Why is it the odd one out?**
Stomach Teeth Small intestine Oral cavity	
2. Which is the "odd organ"?	**Why is it the odd one out?**
Thyroid gland Thymus Spleen Lymph nodes	
3. Which is the "odd organ"?	**Why is it the odd one out?**
Ovaries Prostate gland Uterus Uterine tubes	
4. Which is the "odd organ"?	**Why is it the odd one out?**
Stomach Small intestine Esophagus Large intestine	

EXERCISE 2

REVIEW SHEET
Organ Systems Overview

Name ______________________________ Lab Time/Date ______________________________

1. Use the key below to indicate the body systems that perform the following functions for the body; note that some responses are used more than once. Then, circle the organ systems (in the key) that are present in all subdivisions of the ventral body cavity.

Key: a. cardiovascular
b. digestive
c. endocrine
d. integumentary
e. lymphatic/immunity
f. muscular
g. nervous
h. reproductive
i. respiratory
j. skeletal
k. urinary

__________ 1. rids the body of nitrogen-containing wastes

__________ 2. is affected by removal of the thyroid gland

__________ 3. provides support and the levers on which the muscular system acts

__________ 4. includes the heart

__________ 5. has a menstrual cycle in females

__________ 6. protects underlying organs from drying out and from mechanical damage

__________ 7. protects the body; destroys bacteria and tumor cells

__________ 8. breaks down ingested food into its building blocks

__________ 9. removes carbon dioxide from the blood

__________ 10. delivers oxygen and nutrients to the tissues

__________ 11. moves the limbs; facilitates facial expression

__________ 12. conserves body water or eliminates excesses

__________ and __________ 13. facilitate conception and childbearing

__________ 14. controls the body by means of chemical molecules called hormones

__________ 15. is damaged when you cut your finger or get a severe sunburn

2. Using the above key, choose the *organ system* to which each of the following sets of organs or body structures belongs.

__________ 1. thymus, spleen, lymphatic vessels

__________ 2. bones, cartilages, tendons

__________ 3. pancreas, pituitary, adrenals

__________ 4. trachea, bronchi, lungs

__________ 5. epidermis, dermis, and cutaneous sense organs

__________ 6. testis, ductus deferens, urethra

__________ 7. esophagus, large intestine, rectum

__________ 8. muscles of the thigh, postural muscles

3. Using the key, place the following organs in their proper body cavity. Some responses may be used more than once.

Key: a. abdominopelvic b. cranial c. spinal d. thoracic

______ 1. stomach	______ 4. liver	______ 7. heart
______ 2. esophagus	______ 5. spinal cord	______ 8. trachea
______ 3. large intestine	______ 6. urinary bladder	______ 9. rectum

4. Using the organs listed in question 3 above, record, by number, which would be found in the abdominopelvic regions listed below.

______ 1. hypogastric region	______ 4. epigastric region
______ 2. right lumbar region	______ 5. left iliac region
______ 3. umbilical region	______ 6. left hypochondriac region

5. The levels of organization of a living body include ______________, ______________,

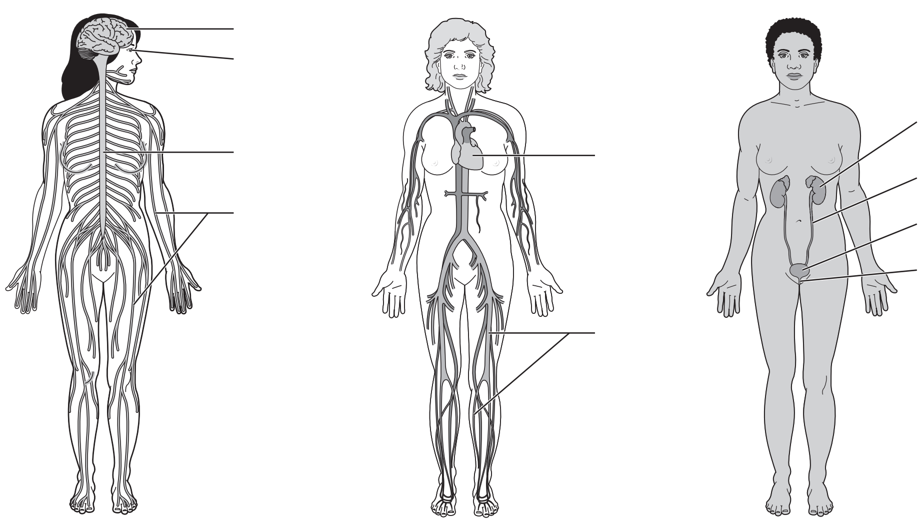
______________, ______________, and organism.

6. Define *organ*. ____

____

7. Using the terms provided, correctly identify all of the body organs provided with leader lines in the drawings shown below. Then name the organ systems by entering the name of each on the answer blank below each drawing.

Key:				
blood vessels	heart	nerves	spinal cord	urethra
brain	kidney	sensory receptor	ureter	urinary bladder



a. ______________ b. ______________ c. ______________

8. Why is it helpful to study the external and internal structures of the rat? ______________________________

____

EXERCISE

3 The Microscope

Objectives

- ☐ Identify the parts of the microscope, and list the function of each.
- ☐ Describe and demonstrate the proper techniques for care of the microscope.
- ☐ Demonstrate proper focusing technique.
- ☐ Define *total magnification, resolution, parfocal, field, depth of field,* and *working distance*.
- ☐ Measure the field diameter for one objective lens, calculate it for all the other objective lenses, and estimate the size of objects in each field.
- ☐ Discuss the general relationships between magnification, working distance, and field diameter.

Materials*

- Compound microscope
- Millimeter ruler
- Prepared slides of the letter ***e*** or newsprint
- Immersion oil
- Lens paper
- Prepared slide of grid ruled in millimeters
- Prepared slide of three crossed colored threads
- Clean microscope slide and coverslip
- Toothpicks (flat-tipped)
- Physiological saline in a dropper bottle
- Iodine or dilute methylene blue stain in a dropper bottle
- Filter paper or paper towels
- Beaker containing fresh 10% household bleach solution for wet mount disposal
- Disposable autoclave bag
- Prepared slide of cheek epithelial cells

Pre-Lab Quiz

1. The microscope slide rests on the ______________ while being viewed.
   a. base **c.** iris
   b. condenser **d.** stage
2. Your lab microscope is *parfocal*. What does this mean?
   a. The specimen is clearly in focus at this depth.
   b. The slide should be almost in focus when changing to higher magnifications.
   c. You can easily discriminate two close objects as separate.
3. If the ocular lens magnifies a specimen 10×, and the objective lens used magnifies the specimen 35×, what is the total magnification being used to observe the specimen? ______________
4. How do you clean the lenses of your microscope?
   a. with a paper towel
   b. with soap and water
   c. with special lens paper and cleaner
5. Circle True or False. You should always begin observation of specimens with the oil immersion lens.

With the invention of the microscope, biologists gained a valuable tool to observe and study structures, such as cells, that are too small to be seen by the unaided eye. The knowledge they acquired helped establish many of the theories basic to the biological sciences. This exercise will familiarize you with the workhorse of microscopes—the compound microscope—and provide you with the necessary instructions for its proper use.

*****Note to the Instructor:*** *The slides and coverslips used for viewing cheek cells are to be soaked for 2 hours (or longer) in 10% bleach solution and then drained. The slides and disposable autoclave bag containing coverslips, lens paper, and used toothpicks are to be autoclaved for 15 min at 121°C and 15 pounds pressure to ensure sterility. After autoclaving, the disposable autoclave bag may be discarded in any disposal facility, and the slides and glassware washed with laboratory detergent and prepared for use. These instructions apply as well to any bloodstained glassware or disposable items used in other experimental procedures.*

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3

Care and Structure of the Compound Microscope

The **compound microscope** is a precision instrument and should always be handled with care. *At all times you must observe the following rules for its transport, cleaning, use, and storage:*

- When transporting the microscope, hold it in an upright position, with one hand on its arm and the other supporting its base. Do not swing the instrument during its transport or jar the instrument when setting it down.
- Use only special grit-free lens paper to clean the lenses. Use a circular motion to wipe the lenses, and clean all lenses before and after use.
- Always begin the focusing process with the lowest-power objective lens in position, changing to the higher-power lenses as necessary.
- Use the coarse adjustment knob only with the lowest-power objective lens.
- Always use a coverslip with wet mount preparations.
- Before putting the microscope in the storage cabinet, remove the slide from the stage, rotate the lowest-power objective lens into position, wrap the cord neatly around the base, and replace the dust cover or return the microscope to the appropriate storage area.
- Never remove any parts from the microscope; inform your instructor of any mechanical problems that arise.

Activity 1

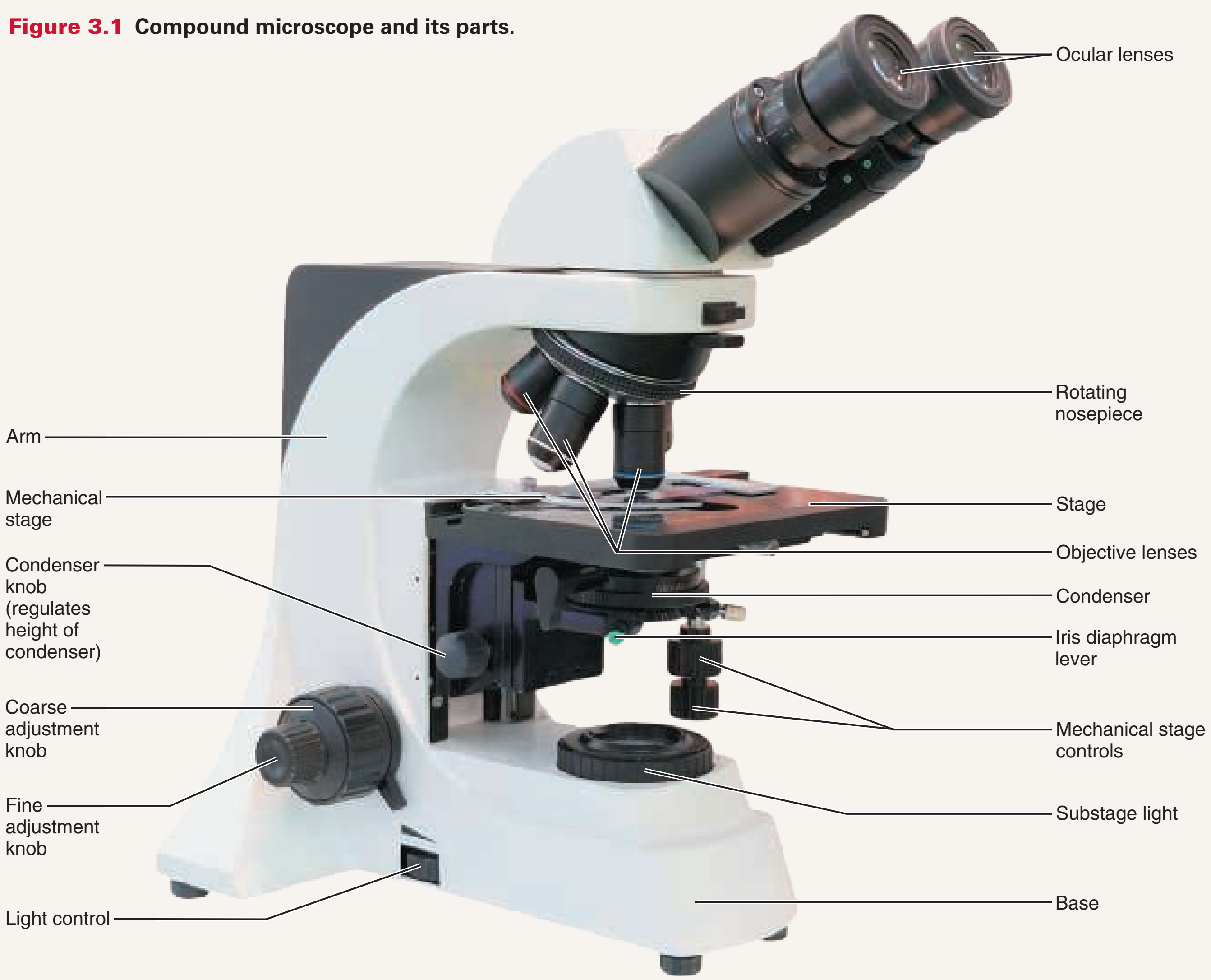
Identifying the Parts of a Microscope

1. Using the proper transport technique, obtain a microscope and bring it to the laboratory bench.

☐ Record the number of your microscope in the **Summary chart** (p. 31).

Compare your microscope with **Figure 3.1**, and identify the microscope parts described in **Table 3.1** on p. 30.

Figure 3.1 **Compound microscope and its parts.**



2. Examine the objective lenses carefully; note their relative lengths and the numbers inscribed on their sides. On many microscopes, the scanning lens, with a magnification between 4× and 5×, is the shortest lens. The low-power objective lens typically has a magnification of 10×. The high-power objective lens is of intermediate length and has a magnification range from 40× to 50×, depending on the microscope. The oil immersion objective lens is usually the longest of the objective lenses and has a magnifying power of 95× to 100×. Some microscopes lack the oil immersion lens.

☐ Record the magnification of each objective lens of your microscope in the first row of the Summary chart (p. 31). Also, cross out any column relating to a lens that your microscope does not have. Plan on using the same microscope for all microscopic studies.

3. Rotate the lowest-power objective lens until it clicks into position, and turn the coarse adjustment knob about 180 degrees. Notice how far the stage (or objective lens) travels during this adjustment. Move the fine adjustment knob 180 degrees, noting again the distance that the stage (or the objective lens) moves.

Magnification and Resolution

The microscope is an instrument of magnification. With the compound microscope, magnification is achieved through the interplay of two lenses—the ocular lens and the objective lens. The objective lens magnifies the specimen to produce a **real image** that is projected to the ocular. This real image is magnified by the ocular lens to produce the **virtual image** that your eye sees (**Figure 3.2**).

The **total magnification** (TM) of any specimen being viewed is equal to the power of the ocular lens multiplied by the power of the objective lens used. For example, if the ocular lens magnifies 10× and the objective lens being used magnifies 45×, the total magnification is 450× (or 10 × 45).

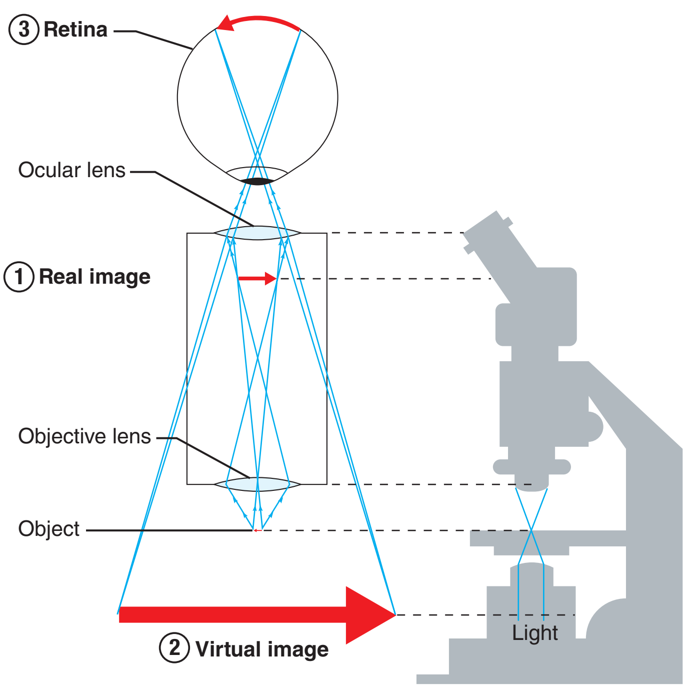


Figure 3.2 Image formation in light microscopy. **Step** ① The objective lens magnifies the object, forming the real image. **Step** ② The ocular lens magnifies the real image, forming the virtual image. **Step** ③ The virtual image passes through the lens of the eye and is focused on the retina.

- Determine the total magnification you may achieve with each of the objectives on your microscope, and record the figures on the third row of the Summary chart.

The compound light microscope has certain limitations. Although the level of magnification is almost limitless, the **resolution** (or resolving power), that is, the ability to discriminate two close objects as separate, is not. The human eye can resolve objects about 100 µm apart, but the compound microscope has a resolution of 0.2 µm under ideal conditions. Objects closer than 0.2 µm are seen as a single fused image.

Resolving power is determined by the amount and physical properties of the visible light that enters the microscope. In general, the more light delivered to the objective lens, the greater the resolution. The size of the objective lens aperture (opening) decreases with increasing magnification, allowing less light to enter the objective. Thus, you will probably find it necessary to increase the light intensity at the higher magnifications.

Prepare for lab: Watch the Pre-Lab Video
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Activity 2

Viewing Objects Through the Microscope

1. Obtain a millimeter ruler, a prepared slide of the letter *e* or newsprint, a dropper bottle of immersion oil, and some lens paper. Adjust the condenser to its highest position, and switch on the light source of your microscope.

2. Secure the slide on the stage so that you can read the slide label and the letter *e* is centered over the light beam passing through the stage. On the mechanical stage of your microscope, open the jaws of its slide holder by using the control lever, typically located at the rear left corner of the mechanical stage. Insert the slide squarely within the confines of the slide holder.

3. With your lowest-power (scanning or low-power) objective lens in position over the stage, use the coarse adjustment knob to bring the objective lens and stage as close together as possible.

Text continues on next page. →

3

Table 3.1 Parts of the Microscope

Microscope part	Description and function
Base	The bottom of the microscope. Provides a sturdy flat surface to support and steady the microscope.
Substage light	Located in the base. The light from the lamp passes directly upward through the microscope.
Light control knob	Located on the base or arm. This dial allows you to adjust the intensity of the light passing through the specimen.
Stage	The platform that the slide rests on while being viewed. The stage has a hole in it to allow light to pass through the stage and through the specimen.
Mechanical stage	Holds the slide in position for viewing and has two adjustable knobs that control the precise movement of the slide.
Condenser	Small nonmagnifying lens located beneath the stage that concentrates the light on the specimen. The condenser may have a knob that raises and lowers the condenser to vary the light delivery. Generally, the best position is close to the inferior surface of the stage.
Iris diaphragm lever	The iris diaphragm is a shutter within the condenser that can be controlled by a lever to adjust the amount of light passing through the condenser. The lever can be moved to close the diaphragm and improve contrast. If your field of view is too dark, you can open the diaphragm to let in more light.
Coarse adjustment knob	This knob allows you to make large adjustments to the height of the stage to initially focus your specimen.
Fine adjustment knob	This knob is used for precise focusing once the initial coarse focusing has been completed.
Head	Attaches to the nosepiece to support the objective lens system. It also provides for attachment of the eyepieces which house the ocular lenses.
Arm	Vertical portion of the microscope that connects the base and the head.
Nosepiece	Rotating mechanism connected to the head. Generally, it carries three or four objective lenses and permits positioning of these lenses over the hole in the stage.
Objective lenses	These lenses are attached to the nosepiece. Usually, a compound microscope has four objective lenses: scanning (4×), low-power (10×), high-power (40×), and oil immersion (100×) lenses. Typical magnifying powers for the objectives are listed in parentheses.
Ocular lens(es)	Binocular microscopes will have two lenses located in the eyepieces at the superior end of the head. Most ocular lenses have a magnification power of 10×. Some microscopes will have a pointer and/or reticle (micrometer), which can be positioned by rotating the ocular lens.

4. Look through the ocular lens and adjust the light for comfort using the iris diaphragm lever. Now use the coarse adjustment knob to focus slowly away from the *e* until it is as clearly focused as possible. Complete the focusing with the fine adjustment knob.

5. Sketch the letter *e* in the circle on the Summary chart (p. 31) just as it appears in the **field**—the area you see through the microscope.

How far is the bottom of the objective lens from the surface of the slide? In other words, what is the **working distance**? (See Figure 3.3.) Use a millimeter ruler to make this measurement.

Record the working distance in the Summary chart.

How has the apparent orientation of the *e* changed top to bottom, right to left, and so on?

____

____

6. Move the slide slowly away from you on the stage as you view it through the ocular lens. In what direction does the image move?

____

Move the slide to the left. In what direction does the image move?

____

7. Today, most good laboratory microscopes are **parfocal;** that is, the slide should be in focus (or nearly so) at the higher magnifications once you have properly focused at the lower magnification. *Without touching the focusing knobs,* increase the magnification by rotating the next higher magnification lens into position over the stage. Make sure it clicks into position. Using the fine adjustment only, sharpen the focus. If you are unable to focus with a new lens, your microscope is not parfocal. Do not try to force the lens into position. Consult your instructor. Note the decrease in working distance. As you can see, focusing with the coarse adjustment knob could drive the objective lens through the slide, breaking the slide and possibly damaging the lens. Sketch the letter *e* in the Summary chart. What new details become clear?

____

____

As best you can, measure the distance between the objective and the slide.

Record the working distance in the Summary chart.

Is the image larger or smaller? ______________________

Approximately how much of the letter *e* is visible now?

____

Is the field larger or smaller? ______________________

Why is it necessary to center your object (or the portion of the slide you wish to view) before changing to a higher power?

____

Move the iris diaphragm lever while observing the field. What happens?

____

Is it better to increase *or* to decrease the light when changing to a higher magnification?

______________ Why? ______________________

____

8. If you have just been using the low-power objective, repeat the steps given in direction 7 using the high-power objective lens. What new details become clear?

____

____

Record the working distance in the Summary chart.

9. Without touching the focusing knob, rotate the high-power lens out of position so that the area of the slide over the opening in the stage is unobstructed. Place a drop of immersion oil over the *e* on the slide and rotate the oil immersion lens into position. Set the condenser at its highest point (closest to the stage), and open the diaphragm fully. Adjust the fine focus and fine-tune the light for the best possible resolution.

Note: *If for some reason the specimen does not come into view after adjusting the fine focus, do not go back to the 40× lens to recenter. You do not want oil from the oil immersion lens to cloud the 40× lens. Turn the revolving nosepiece in the other direction to the low-power lens, and recenter and refocus the object. Then move the immersion lens back into position, again avoiding the 40× lens. Sketch the letter* e *in the Summary chart. What new details become clear?*

____

____

Is the field again decreased in size? ________________

As best you can, estimate the working distance, and record it in the Summary chart. Is the working distance less *or* greater than it was when the high-power lens was focused?

____

Compare your observations on the relative working distances of the objective lenses with the illustration in

3

Summary Chart for Microscope #____

	Scanning	Low power	High power	Oil immersion
Magnification of objective lens	________ ×	________ ×	________ ×	________ ×
Magnification of ocular lens	10 ×	10 ×	10 ×	10 ×
Total magnification	________ ×	________ ×	________ ×	________ ×
Working distance	________ mm	________ mm	________ mm	________ mm
Detail observed letter *e*	◯	◯	◯	◯
Field diameter	_____ mm _____ μm	_____ mm _____ μm	_____ mm _____ μm	_____ mm _____ μm

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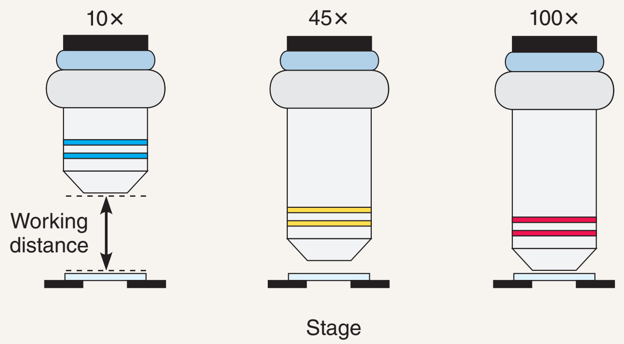


Figure 3.3 **Relative working distances of the 10×, 45×, and 100× objectives.**

Figure 3.3. Explain why it is desirable to begin the focusing process at the lowest power.

____

____

____

10. Rotate the oil immersion lens slightly to the side, and remove the slide. Clean the oil immersion lens carefully with lens paper, and then clean the slide in the same manner with a fresh piece of lens paper.

The Microscope Field

The microscope field decreases with increasing magnification. Measuring the diameter of each of the microscope fields will allow you to estimate the size of the objects you view in any field. For example, if you have calculated the field diameter to be 4 mm and the object being observed extends across half this diameter, you can estimate that the length of the object is approximately 2 mm.

Microscopic specimens are usually measured in micrometers and millimeters, both units of the metric system. You can get an idea of the relationship and meaning of these units from **Table 3.2**. A more detailed treatment appears in the appendix.

Table 3.2 **Comparison of Metric Units of Length**

Metric unit	Abbreviation	Equivalent
Meter	m	(about 39.37 in.)
Centimeter	cm	10^{-2} m
Millimeter	mm	10^{-3} m
Micrometer (or micron)	µm (µ)	10^{-6} m
Nanometer	nm (mµ)	10^{-9} m

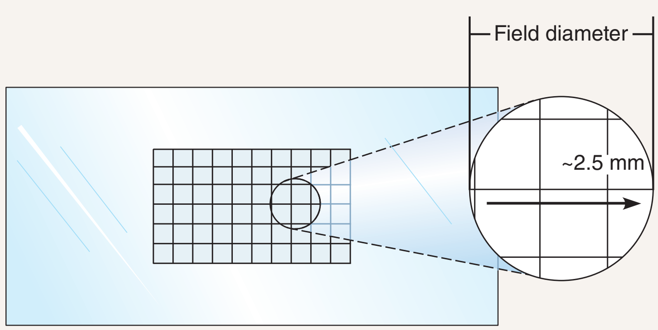
(Refer to the Getting Started exercise on MasteringA&P for tips on metric conversions.)

Activity 3

Estimating the Diameter of the Microscope Field

1. Obtain a grid slide, which is a slide prepared with graph paper ruled in millimeters. Each of the squares in the grid is 1 mm on each side. Use your lowest-power objective to bring the grid lines into focus.

2. Move the slide so that one grid line touches the edge of the field on one side, and then count the number of squares you can see across the diameter of the field. If you can see only part of a square, as in the accompanying diagram, estimate the part of a millimeter that the partial square represents.



Record this figure in the appropriate space marked "field diameter" on the Summary chart (p. 31). (If you have been using the scanning lens, repeat the procedure with the low-power objective lens.)

Complete the chart by computing the approximate diameter of the high-power and oil immersion fields. The general formula for calculating the unknown field diameter is:

$$\text{Diameter of field } A \times \text{total magnification of field } A = \text{diameter of field } B \times \text{total magnification of field } B$$

where *A* represents the known or measured field and *B* represents the unknown field. This can be simplified to

$$\text{Diameter of field } B = \frac{\text{diameter of field } A \times \text{total magnification of field } A}{\text{total magnification of field } B}$$

For example, if the diameter of the low-power field (field *A*) is 2 mm and the total magnification is 50×, you would compute the diameter of the high-power field (field *B*) with a total magnification of 100× as follows:

$$\text{Field diameter } B = (2 \text{ mm} \times 50)/100$$

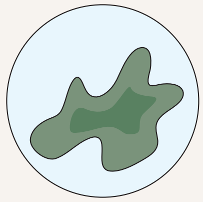
$$\text{Field diameter } B = 1 \text{ mm}$$

3. Estimate the length (longest dimension) of the following drawings of microscopic objects. *Base your calculations on the field sizes you have determined for your microscope and the approximate percentage of the diameter that the object occupies.*

Object seen in low-power field:

approximate length:

_________ mm

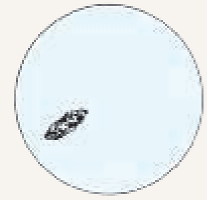


Object seen in high-power field:

approximate length:

_________ mm

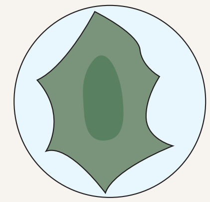
or _________ μm



Object seen in oil immersion field:

approximate length:

_________ μm



Perceiving Depth

Any microscopic specimen has depth as well as length and width; it is rare indeed to view a tissue slide with just one layer of cells. Normally you can see two or three cell thicknesses. Therefore, it is important to learn how to determine relative depth with your microscope. In microscope work, the **depth of field** (the thickness of the plane that is clearly in focus) is greater at lower magnifications. As magnification increases, depth of field decreases.

Activity 4

Perceiving Depth

1. Obtain a slide with colored crossed threads. Focusing at low magnification, locate the point where the three threads cross each other.

2. Use the iris diaphragm lever to greatly reduce the light, thus increasing the contrast. Focus down with the coarse adjustment until the threads are out of focus, then slowly focus upward again, noting which thread comes into clear focus first. Observe: As you rotate the adjustment knob forward (away from you), does the stage rise or fall? If the stage rises, then the first clearly focused thread is the top one; the last clearly focused thread is the bottom one.

If the stage descends, how is the order affected?________

____

Record your observations, relative to which color of thread is uppermost, middle, or lowest:

Top thread ______________________________

Middle thread ____________________________

Bottom thread ____________________________

Viewing Cells Under the Microscope

There are various ways to prepare cells for viewing under a microscope. One method is to mix the cells in physiological saline (called a *wet mount*) and stain them.

If you are not instructed to prepare your own wet mount, obtain a prepared slide of epithelial cells to make the observations in step 10 of Activity 5.

Activity 5

Preparing and Observing a Wet Mount

1. Obtain the following: a clean microscope slide and coverslip, two flat-tipped toothpicks, a dropper bottle of physiological saline, a dropper bottle of iodine or methylene blue stain, and filter paper (or paper towels). Handle only your own slides throughout the procedure.

2. Place a drop of physiological saline in the center of the slide. Using the flat end of the toothpick, *gently* scrape the inner lining of your cheek. Transfer your cheek scrapings to the slide by agitating the end of the toothpick in the drop of saline (**Figure 3.4a** on p. 34).

! *Immediately* discard the used toothpick in the disposable autoclave bag provided.

3. Add a tiny drop of the iodine or methylene blue stain to the preparation. (These epithelial cells are nearly transparent and thus difficult to see without the stain, which

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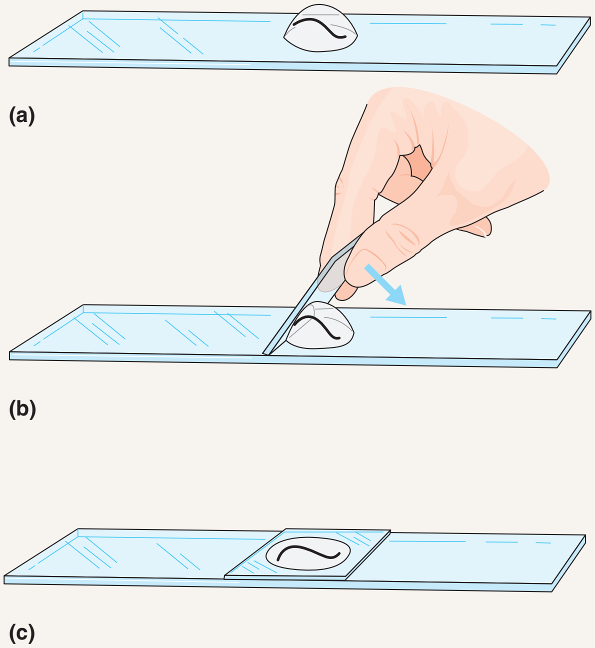


Figure 3.4 Procedure for preparation of a wet mount. **(a)** Place the object in a drop of water (or saline) on a clean slide; **(b)** hold a coverslip at a 45° angle with the fingertips; and **(c)** lower the coverslip slowly.

colors the nuclei of the cells.) Stir again, using a second toothpick.

! *Immediately* discard the used toothpicks in the disposable autoclave bag provided.

4. Hold the coverslip with your fingertips so that its bottom edge touches one side of the drop (Figure 3.4b), then *slowly* lower the coverslip onto the preparation (Figure 3.4c). *Do not just drop the coverslip,* or you will trap large air bubbles under it, which will obscure the cells. *Always use a coverslip with a wet mount* to protect the lens.

5. Examine your preparation carefully. The coverslip should be tight against the slide. If there is excess fluid around its edges, you will need to remove it. Obtain a piece of filter paper, fold it in half, and use the folded edge to absorb the excess fluid.

! Before continuing, discard the filter paper or paper towel in the disposable autoclave bag.

6. Place the slide on the stage, and locate the cells at the lowest power. You will probably want to dim the light to provide more contrast for viewing the lightly stained cells.

7. Cheek epithelial cells are very thin, flat cells. In the cheek, they provide a smooth, tilelike lining (**Figure 3.5**). Move to high power to examine the cells more closely.

8. Make a sketch of the epithelial cells that you observe.

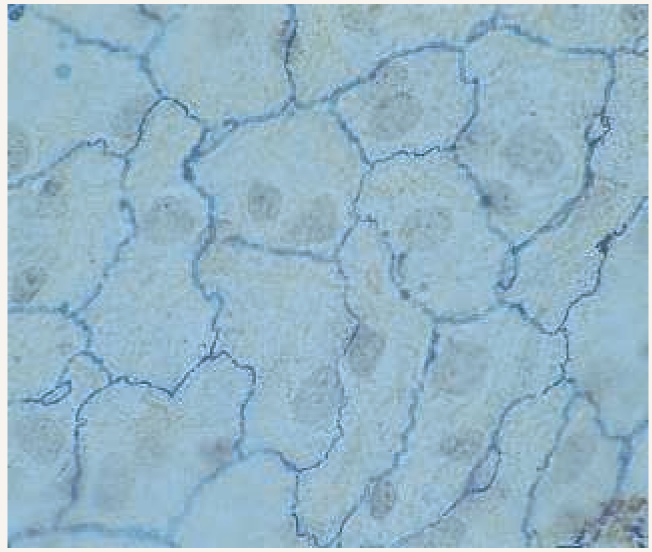


Figure 3.5 Epithelial cells of the cheek cavity (surface view, 600×).

Use information on your Summary chart (p. 31) to estimate the diameter of cheek epithelial cells. Record the total magnification (TM) used.

______________ μm ______________ × (TM)

Why do *your* cheek cells look different than those in Figure 3.5? (Hint: What did you have to *do* to your cheek to obtain them?)

____

____

! 9. When you complete your observations of the wet mount, dispose of your wet mount preparation in the beaker of bleach solution, and put the coverslips in an autoclave bag.

10. Obtain a prepared slide of cheek epithelial cells, and view them under the microscope.

Estimate the diameter of one of these cheek epithelial cells using information from the Summary chart (p. 31).

______________ μm ______________ × (TM)

Why are these cells more similar to those in Figure 3.5 and easier to measure than those of the wet mount?

____

____

____

11. Before leaving the laboratory, make sure all other materials are properly discarded or returned to the appropriate laboratory station. Clean the microscope lenses, and return the microscope to the storage cabinet.

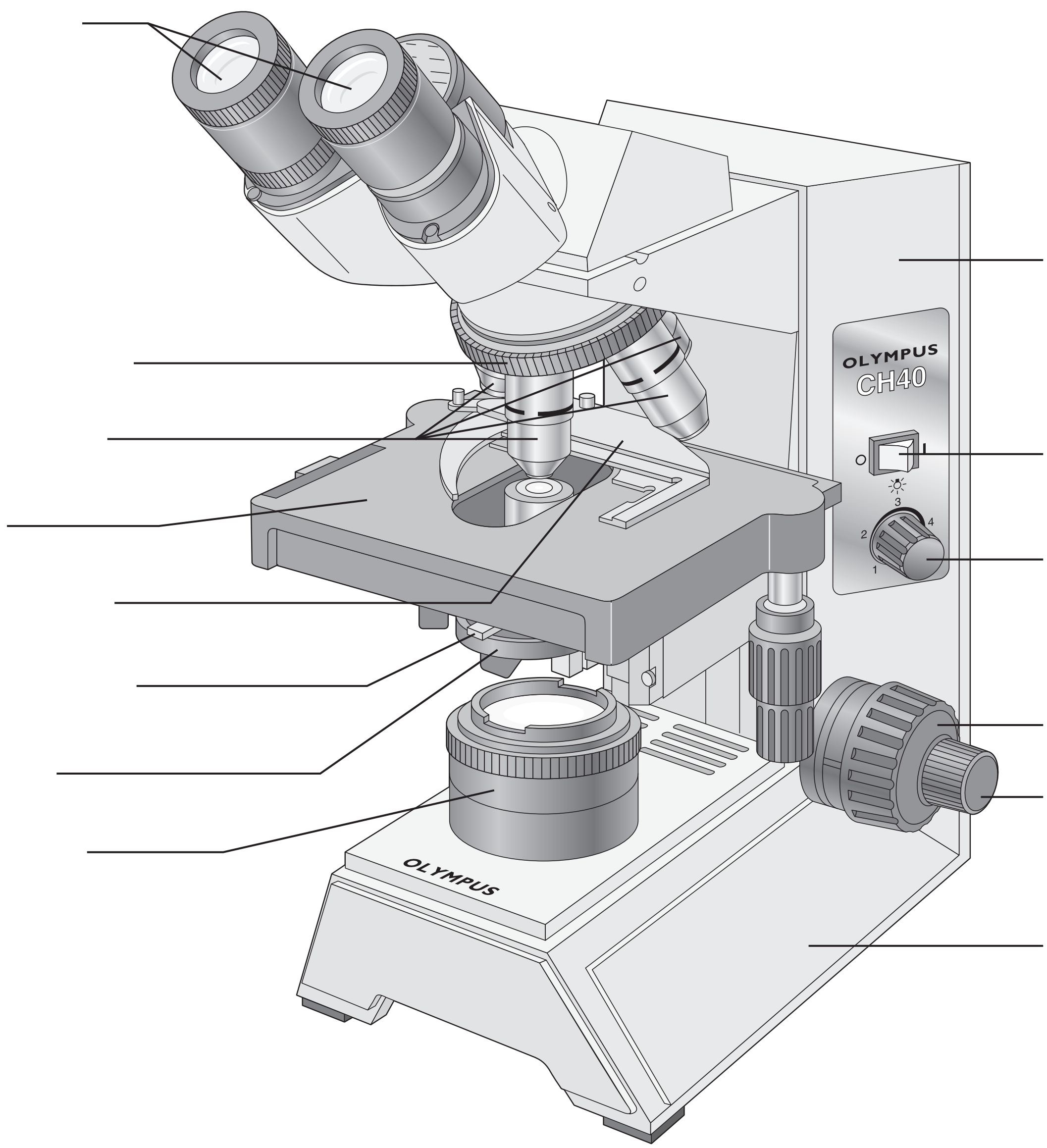
EXERCISE 3

REVIEW SHEET
The Microscope

Name ______________________ Lab Time/Date ______________________

Care and Structure of the Compound Microscope

1. Label all indicated parts of the microscope.



2. Explain the proper technique for transporting the microscope.

3. The following statements are true or false. If true, write *T* on the answer blank. If false, correct the statement by writing on the blank the proper word or phrase to replace the one that is underlined.

_______________ 1. The microscope lens may be cleaned <u>with any soft tissue</u>.

_______________ 2. The microscope should be stored with the <u>oil immersion</u> lens in position over the stage.

_______________ 3. When beginning to focus, use the <u>lowest-power</u> lens.

_______________ 4. When focusing on high power, always use the <u>coarse</u> adjustment knob to focus.

_______________ 5. A coverslip should always be used <u>with wet mounts</u>.

4. Match the microscope structures in column B with the statements in column A that identify or describe them.

Column A

_______ 1. platform on which the slide rests for viewing

_______ 2. used to adjust the amount of light passing through the specimen

_______ 3. controls the movement of the slide on the stage

_______ 4. delivers a concentrated beam of light to the specimen

_______ 5. used for precise focusing once initial focusing has been done

_______ 6. carries the objective lenses; rotates so that the different objective lenses can be brought into position over the specimen

Column B

a. coarse adjustment knob
b. condenser
c. fine adjustment knob
d. iris diaphragm lever
e. mechanical stage
f. nosepiece
g. objective lenses
h. ocular lens
i. stage

5. Define the following terms.

virtual image: ____

____

resolution: ____

Viewing Objects Through the Microscope

6. Complete, or respond to, the following statements:

_______________ 1. The distance from the bottom of the objective lens to the surface of the slide is called the _______.

_______________ 2. Assume there is an object on the left side of the field that you want to bring to the center (that is, toward the apparent right). In what direction would you move your slide? _______.

_______________ 3. The area of the slide seen when looking through the microscope is the _______.

_______________ 4. If a microscope has a 10× ocular lens and the total magnification at a particular time is 950×, the objective lens in use at that time is _______ ×.