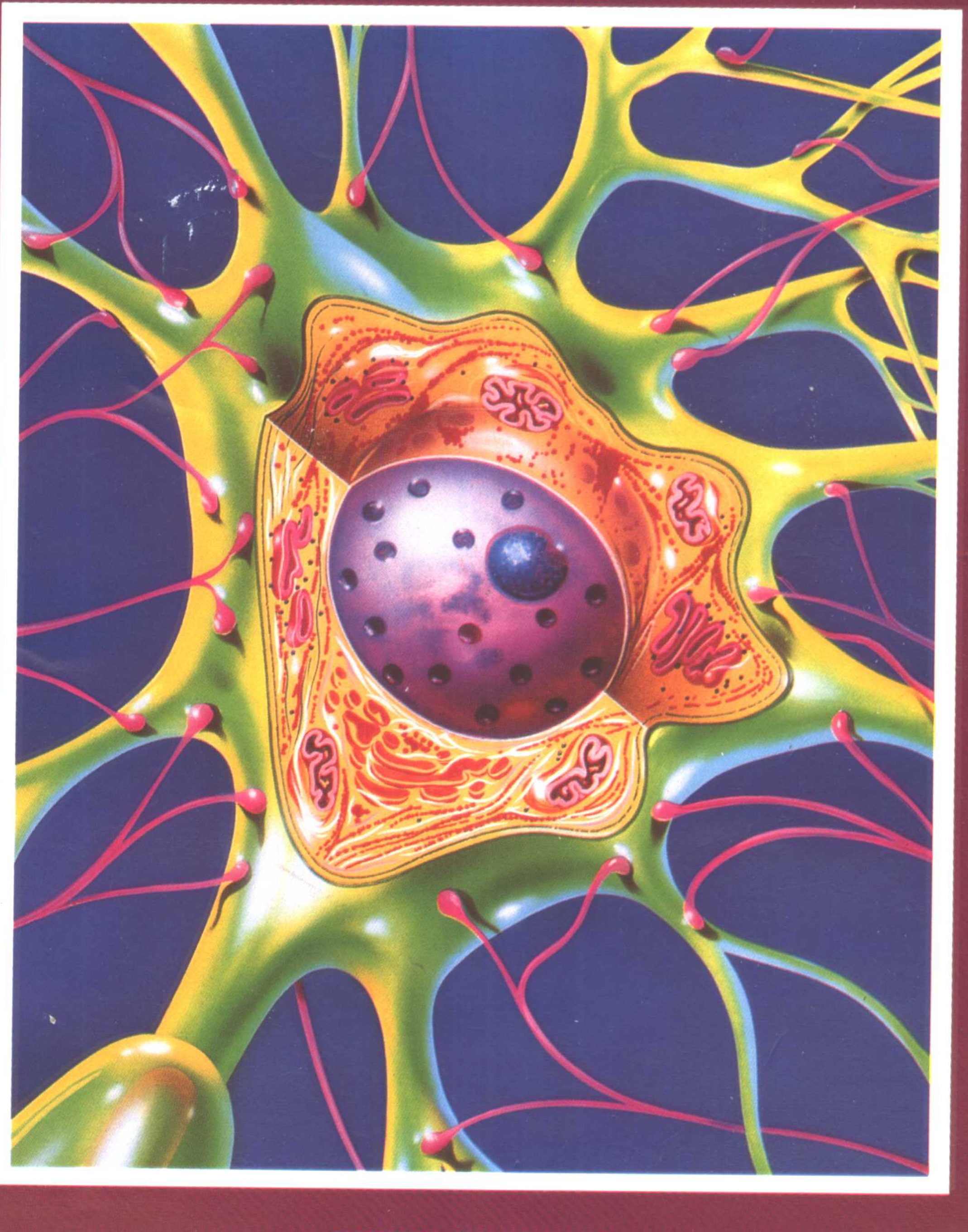
Experimental and Applied Physiology

RICHARD G. PFLANZER



FIFTH EDITION

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PREFACE

The purpose of this text is to introduce the student to the basic principles of human physiology through laboratory experimentation. The major intent of instruction is to (1) reinforce basic principles of human physiology; (2) improve the student's ability to reason scientifically and to strengthen the student's habit of thinking in this manner; (3) develop a sense of inquiry, understanding, and appreciation of the functional aspects of the human organism as they relate to health and general well-being; and (4) allow the student to gain, from actual laboratory experimentation, an appreciation of laboratory science and its role in advancing knowledge of the human body.

This text is intended for a one-semester (or a one- or two-quarter) course in human physiology at the undergraduate level. It has not been designed to accompany any particular textbook of physiology or textbook of anatomy/physiology; rather, it has been developed to allow for laboratory reinforcement of basic physiological principles that are covered in most of the undergraduate textbooks of recent years.

The nature of physiology is to investigate and understand how living systems function. A few of the experiments in this book require the use of a live animal such as a frog or turtle. Such use is essential if certain concepts of physiology are to be demonstrated and mastered. However, most of the laboratory experiments in this text make use of students as experimental subjects rather than nonhuman animals. It has been my experience in teaching physiology to undergraduate, graduate, medical, and dental students that experiments which relate concepts of physiology directly to the functions of the student's own body are far more likely to be successful in terms of illustration and reinforcement.

All of the experiments presented have been performed many times by students and are safe, provided that ordinary precautions and normal laboratory safety procedures are observed.

Each experiment has been designed to be performed within a two-hour laboratory period, which includes time for the presentation of introductory material by the instructor. The introduction to each chapter provides a review of concepts pertinent to the experimentation. The objectives stated at the beginning of experimentation indicate to the student the reasons for performing the laboratory exercise and the expected gains from the experience. Most of the experiments require a minimum of equipment and are easily performed by inexperienced students. Many chapters have a *Quick Access* section at the beginning which indicates the page numbers for specific equipment setups. Some experiments (e.g., electrocardiography) require sophisticated equipment and adequate preparation on behalf of the student and instructor. In general, the experiments have been designed not just because they are inexpensive or easy to perform, but rather because they illustrate and reinforce some fundamental principles of human physiology.

Nearly all of the experiments that require physiological recording systems are easily adaptable for any standard physiological recording system. The experiments in this edition have been written for use with the Harvard modular recording system, the Lafayette Datagraph and Minigraph systems, and the Narco Bio-Systems Physiograph. Most of the experiments that require standard physiological recorders are easily adapted for use with updated versions of the previously listed recorders or other recording systems such as the Beckman or Grass recorders.

New experiments that utilize computer hardware and software are being developed and tested for inclusion in the next edition of this book. These experiments will utilize students as experimental subjects and provide alternatives to some of the experiments requiring animals. The computer-based experiments also will introduce to the undergraduate physiology student a more sophisticated technology with increased capabilities for data acquisition, display, storage, and analysis. Experiments using computer technologies developed by Lafayette Instrument Co. and Intellitool, Inc. are being prepared and will be available as separates from Wm. C. Brown Publishers.

Previous editions also contained directions for using the kymograph. Sections of the book dealing with the kymograph have been removed to make room for the addition of new material such as chapter 12, Cranial Nerves: Assessment of Functions. The kymograph experiments will continue to be available as separates from Wm. C. Brown Publishers.

ACKNOWLEDGMENTS

The author gratefully acknowledges the help of his wife, Diane Kelly Pflanzer, who typed this manuscript and provided the necessary secretarial assistance. I would like to thank the many professors who took the time to fill out a questionnaire on how to improve this edition. Your comments were greatly appreciated and have been implemented into this fifth edition; and the editorial and production staff of Wm. C. Brown Publishers.

TO THE STUDENT

▶ REQUIRED SUPPLIES

1. One high-quality dissecting kit containing a metric rule, dropper, forceps, blunt and needle point probes, large and small surgical scissors, and a fixed blade scalpel.
2. One plastic or rubber chemical laboratory apron or one long white laboratory coat.
3. Four felt-tip marking pens (black, red, green, blue).
4. One wax glass-marking pencil.
5. Safety goggles or safety glasses.

▶ LABORATORY SAFETY

1. Infants and children are not permitted in the laboratory under any circumstances. Please make proper arrangements for child care prior to attending class.
2. Become familiar with the location of exits, chemical hood, emergency shower, fire extinguishers, and first-aid supplies associated with your laboratory room.
3. Upon the sounding of the fire alarm, immediately evacuate the building in an orderly and safe manner.
4. Eating, drinking, smoking, and chewing tobacco are not permitted in the laboratory except when dictated by experimental protocol.
5. Follow the directions of the laboratory book and your laboratory instructor regarding experimental precautions and procedures. Do not deviate without permission. If uncertain or unclear, ask for clarification.
6. Eye protection is required for all labs that use chemicals, biologicals, or physically hazardous materials. Safety goggles are preferred, safety glasses are acceptable, but standard glasses containing corrective lenses are not. Students are responsible for purchasing and using acceptable eye protection. Compliance will be monitored by the laboratory instructor.
7. In experiments dealing with body fluid (blood, saliva, urine) handle only your own to avoid contamination and/or transmission of disease.
8. Disposable mouthpieces, blood lancets, microhematocrit tubes, and other clean disposable supplies are to be used only once and discarded into appropriately marked containers for disposal. If an experimental procedure must be repeated, use new clean or sterile supplies.
9. Nondisposable supplies (test tubes, hemacytometers, etc.) that come in contact with body fluids must be thoroughly cleaned and sterilized after use. Follow the directions of your laboratory instructor.
10. Animal remains (e.g., frog skin, muscles, organs, etc.) must be discarded into appropriately marked containers for proper disposal. Wastebaskets and sinks are not appropriate containers for animal remains.
11. At the conclusion of a laboratory period, restore your laboratory table to a clean, orderly condition. Wipe the table clean by using napkins and disinfectant solution, clean and return equipment and supplies to their proper place, ensure that the sink is clean and free of debris, and place your chair beneath the laboratory bench.
12. Violation of laboratory rules and regulations may result in your being asked to leave the laboratory for your own benefit and safety as well as the benefit and safety of your classmates. Repeat violators will be dismissed from the class and awarded a failing grade for the semester.

▶ HUMAN LABORATORY EXPERIMENTS

Many of the laboratory experiments require humans as subjects. All of the experiments, if performed properly according to instructions, are safe. If, for any reason, you feel that you should not perform as the subject of an experiment, simply inform your laboratory instructor and you will be excused from being the subject without penalty. You are responsible for notifying your laboratory instructor of any disease or physiological disorder which you have or have had that would preclude your being used as a subject. If you are in doubt, please ask. For example, if you have, or have had

1. hemophilia or other abnormalities of blood coagulation or are currently taking anticoagulant therapy: do not act as a donor for experiments that require blood (e.g., hematocrit, blood typing, etc.).
2. chronic or acute respiratory infections: do not breathe into spirometers unless they can be sterilized or disinfected before another student's use.
3. diabetes mellitus (sugar diabetes) or hypoglycemia (low blood sugar): do not act as a subject in the oral glucose tolerance test.
4. epilepsy: do not hyperventilate or rebreathe CO_2 in respiratory experiments.
5. cardiovascular disease (high blood pressure, angina, etc.): do not perform stressful exercise.

▶ LABORATORY ORGANIZATION

Each experimental laboratory period will be organized and conducted as follows.

Review and Evaluation of Previous Experimentation

The first part of the laboratory period will be devoted to a discussion of prior experimentation. On occasion your laboratory instructor may also administer short unannounced quizzes.

Introduction and Directions For Current Experimentation

Your laboratory instructor will explain the techniques and precautions to take in performing each experiment. In some cases, introductory review material may also be supplied by the instructor.

Setting up Experimental Apparatus

The laboratory equipment provided for your use in the laboratory is some of the finest available for undergraduate laboratory instruction. It is also very expensive. Handle it with care at all times, following instructions as to its proper care and use. Report any damage or malfunction immediately. Do not attempt to repair it. All equipment used in the laboratory will be assigned by your laboratory instructor. Each person will be held responsible for the proper use and care of the equipment.

Experimentation

Never begin an experiment until you read, hear, and clearly understand all instructions. It is wise to read the experimental protocol prior to attending the laboratory so that you are familiar with the experimental procedure you will be asked to follow. Do not be reluctant to ask questions if you are unclear about any procedure.

Never prepare a living animal, organ, or tissue until all experimental apparatus has been set up. In any procedure involving pain, the nervous system of the animal must be destroyed by pithing or inhibited by an anesthetic. This rule must not be violated. If there is any doubt about an animal's inability to perceive pain, contact your laboratory instructor immediately before continuing any further experimentation.

Always record all observations immediately, either on the experimental recording or in your report for future reference. Experimental recordings should include the name of the experiment, the date it was performed, your name along with the names of other students in the group who performed the experiment, the laboratory section, and the instructor's name.

Your laboratory instructor may require you to complete in full and in ink the laboratory reports associated with each experiment and to turn them in for evaluation. Questions in the report are to be answered using complete and grammatically correct statements. Be as clear and concise as possible. Neatness is assumed. Most of the questions can be answered directly on the basis of the results that have been obtained from experimentation. Some require outside reading and thought; that is, an analysis of the facts in the light of previous experience. Many of the questions are designed to stimulate, improve, and strengthen your ability to think scientifically. Be as independent as possible in this phase of the work in order to derive maximum benefits.

Most of the laboratory experimentation will involve working in harmony with one or more students in a group. Nevertheless, strive to be independent both in observation and thought. Failing to make independent observations and copying a fellow student's data and answers is unethical, dishonest, and will not be tolerated.

Cleanup

Following the completion of experimentation, the laboratory bench is to be returned to the condition in which it was found. Dirty glassware is to be properly disposed of according to instructions. Paper and other disposable materials are to be placed in the appropriate containers. Animal, tissue, and organ remains are to be placed in a special container for proper disposal. All electrical equipment is to be unplugged from the electrical outlets at the end of the laboratory period. The equipment is to be wiped clean and returned to its original position. Laboratory benches are to be wiped clean with a disinfectant and the laboratory chair returned to its proper position.

CONTENTS

CHAPTER 1

Metrics, Measurements, and Computations

▶ INTRODUCTION

Crude measurements of length, capacity, and weight have existed since prehistoric times. Later, units of measurement were based on body size, such as the length of a king's arm or foot, and upon plant seeds. As civilization became more complex, technological and commercial requirements led to an increased standardization of measurements. But for a long time standards varied greatly between one locale and another, because units were usually fixed by edict of local or national rulers. As late as the eighteenth century, for example, one of the earliest units, the foot, possibly had as many as 280 variants in Europe. Today there are two principal systems of measurement—the **American-British system** (commonly called the *English system*) and the **metric system.**

In 1866 the United States government permitted the use of the metric system and established a conversion table based upon the yard and the pound. Because the federal government did not require the country to convert to the metric system, it was not widely adopted by commerce and industry in the United States. In scientific work, however, the metric system has been used for well over a century in the United States and for much longer in Europe.

The metric system utilizes units that are based on the decimal system and related to one another by some power of 10. The term denoting a metric unit of measurement usually contains a prefix indicating the power of 10. The prefix *centi,* for example, means "one-hundredth," or 10^{-2}; the prefix *milli* means "one-thousandth," or 10^{-3}. Table 1.1 indicates prefixes used in the metric system.

▶ UNITS OF LENGTH

The English system of linear measurement is based upon the *yard,* which is the equivalent of 3 feet, or 36 inches. The metric system of linear measurement is based on the *meter,* which is equivalent to 39.37 inches. The meter is defined as 1,650,763.73 wavelengths of the spectral orange-red line of krypton-86, or one-millionth part of the distance measured on a meridian from the equator of the earth to a pole. Table 1.2 indicates metric units of linear measure.

▶ UNITS OF WEIGHT

In the English system, two sets of weight are employed: *avoirdupois weights,* based on the 16-ounce pound, are used in general commerce; and *troy weights,* based on the 12-ounce pound, are used for precious metals. Troy units form the basis of apothecary weights. By contrast, metric units of weight are based on the *gram*—defined as the weight of pure water at 4° C and 760 mm Hg pressure contained in a cube whose edge is one-hundredth of a meter (a cubic centimeter). Table 1.3 indicates metric units of weight.

▶ UNITS OF VOLUME

The American (U.S.) system of liquid measure is based on the 16-ounce pint, and the British (Imperial) system is based on the 20-ounce pint. Metric units of liquid measure are based on the *liter,* which is defined as the volume of a kilogram of pure water at 4° C, equal to exactly 0.001 cubic meters. Table 1.4 indicates metric units of volume.

Although arithmetical conversion between English and metric systems is simple, many students have difficulty in visualizing a distance of 10 meters or sensing the weight of a 2-kilogram object. Figure 1.1 illustrates some common conversions and measurements between English and metric systems.

TABLE 1.1 Metric prefixes

Prefix	*Abbreviation*	*Meaning*	*Factor*	*Decimal*
tera	T	one trillion	10^{12}	1,000,000,000,000
giga	G	one billion	10^{9}	1,000,000,000
mega	M	one million	10^{6}	1,000,000
myria	my	ten thousand	10^{4}	10,000
kilo	k	one thousand	10^{3}	1,000
hecto	h	one hundred	10^{2}	100
deka	da	ten	10^{1}	10
uni	—	one	10^{0}	1.0
deci	d	one-tenth	10^{-1}	0.1
centi	c	one-hundredth	10^{-2}	0.01
milli	m	one-thousandth	10^{-3}	0.001
micro	μ	one-millionth	10^{-6}	0.000001
nano	n	one-billionth	10^{-9}	0.000000001
pico	p	one-trillionth	10^{-12}	0.000000000001
femto	f	one-quadrillionth	10^{-15}	0.000000000000001

TABLE 1.2 Metric units of linear measure

Metric unit	*Definition*	*English equivalent*
megameter (Mm)	10^{6} meters	621.37 miles
myriameter (mym)	10^{4} meters	6.2137 miles
kilometer (km)	10^{3} meters	0.62137 miles
hectometer (hm)	10^{2} meters	328.0833 feet
dekameter (dam)	10 meters	32.80833 feet
meter (m)	basic unit of reference	39.37 inches
decimeter (dm)	10^{-1} meter	3.937 inches
centimeter (cm)	10^{-2} meter	0.3937 inch
millimeter (mm)	10^{-3} meter	0.03937 inch
micrometer (μ)	10^{-6} meter	0.00003937 inch
nanometer (nm)	10^{-9} meter	0.00000003937 inch
angstrom (Å)	10^{-10} meter	0.000000003937 inch
picometer (pm)	10^{-12} meter	0.00000000003937 inch
femtometer (fm)	10^{-15} meter	0.00000000000003937 inch

▶ TEMPERATURES: FAHRENHEIT, CELSIUS (CENTIGRADE), KELVIN (ABSOLUTE)

In the average U.S. household, as well as in general U.S. commerce and industry, changes in thermal energy are measured on the **Fahrenheit scale** rather than the **Celsius (centigrade) scale** used nearly everywhere else. In scientific work, the Celsius scale and/or the **Kelvin (absolute) scale** are always used. Comparisons and conversions of one scale to another conveniently use the freezing and boiling points of pure water.

On the Fahrenheit scale, the freezing point of water is 32° and the boiling point is 212°. On the Celsius scale, water freezes at 0° and boils at 100°. Therefore, one degree on the Fahrenheit scale indicates a smaller change in thermal energy than does one degree on the Celsius scale. Using the Kelvin, or absolute, scale, water freezes at 272° and boils at 373°. Thus, one degree on the Kelvin scale measures the same thermal change as one degree on the Celsius scale. The Kelvin scale is primarily used in chemistry and physics and we will not consider it further. To convert between Celsius and Fahrenheit scales the following formulas are used:

$$°C = 0.56\,(°F - 32°)$$
$$°F = (1.8 \times °C) + 32°$$

▶ MEASUREMENT AND COMPUTATION

Scientific Notation

The biological and physical sciences frequently deal with very large numbers and very small numbers when an observation is to be described quantitatively. For example, the hydrogen ion concentration (H^+) of human urine may be close to 0.000001 gram per liter. Very small numbers such as the latter and very large numbers are cumbersome to manipulate if written or expressed verbally in the form of a decimal. **Scientific notation** simplifies the expression and manipulation of such numbers and is widely used within and without the scientific community.

Scientific notation is a floating-point system of numerical expression in which numbers are expressed as products consisting of a number between *1 and 10 multiplied* by an appropriate power of 10. Consider the

TABLE 1.3 Metric units of weight

Metric unit	*Definition*	*English equivalent (avoirdupois)*
metric ton	10^6 grams	2204.62 pounds
kilogram (kg)	10^3 grams	2.20462 pounds
hectogram (hg)	10^2 grams	0.220462 pound
dekagram (dag)	10 grams	0.35274 ounce
gram (g)	basic unit of reference	0.035274 ounce
decigram (dg)	10^{-1} gram	0.0035274 ounce
centigram (cg)	10^{-2} gram	0.00035274 ounce
milligram (mg)	10^{-3} gram	0.000035274 ounce
microgram (μg)	10^{-6} gram	0.000000035274 ounce
nanogram (ng)	10^{-9} gram	0.000000000035274 ounce
picogram (pg)	10^{-12} gram	0.000000000000035274

TABLE 1.4 Metric units of volume

Metric unit	*Definition*	*English equivalent (U.S.)*
myrialiter (myl)	10^4 liters	2641.7 gallons
kiloliter (kl)	10^3 liters	264.17 gallons
hectoliter (hl)	10^2 liters	26.417 gallons
dekaliter (dal)	10 liters	10.567 quarts
liter (l)	basic unit of reference	1.0567 quarts
deciliter (dl)	10^{-1} liter	0.10567 quart
centiliter (cl)	10^{-2} liter	0.010567 quart
milliliter (ml)	10^{-3} liter	0.0010567 quart
microliter (μl)	10^{-6} liter	0.0000010567 quart
nanoliter (nl)	10^{-9} liter	0.0000000010567 quart
picoliter (pl)	10^{-12} liter	0.0000000000010567 quart
femtoliter (fl)	10^{-15} liter	0.0000000000000010567 quart

number 186,740,000. Using scientific notation, this number would be expressed as 1.8674×10^8. Essentially, scientific notation removes the need to write out all of the zeros in this number by using a power of 10 to represent the zeros. Numbers without zeros can also be represented by scientific notation—e.g., $247,632 = 2.47632 \times 10^5$, $78,323 = 7.8323 \times 10^4$. When any number greater than 10 is expressed by scientific notation, the decimal point is moved to the left until the number has a value between 1 and 10, and that number is multiplied by some positive power of 10. The positive power of 10 is equal to the number of places the decimal point was moved to the left; for example,

10,263
1.0263 (decimal moved 4 places to left)
$1.0263 \times 10^4 = 10,263$.

Very small numbers may also be expressed using scientific notation. For example, $0.00008 = 8 \times 10^{-5}$. When any number less than 1 is expressed by scientific notation, the decimal point is moved to the right until the number has a value between 1 and 10, and that number is multiplied by some negative power of 10. The negative power of 10 is equal to the number of places the decimal point was moved to the right; for example,

0.01467
01.467 (decimal moved 2 places to right)
$1.467 \times 10^{-2} = 0.01467$.

To convert a number expressed by scientific notation into a single decimal number, simply move the decimal point the appropriate number of spaces to the right or to the left and omit the power of 10 multiplier. The power of 10 indicates the number of spaces to move the decimal point, and the sign of the power indicates the direction of movement.

With positive power, the decimal point is moved to the right; for example,

1.3×10^3
1,300 (decimal moved 3 places to right, power of 10 omitted)
$1,300 = 1.3 \times 10^3$.

With negative powers, the decimal point is moved to the left; for example,

1.76×10^{-4}
0.000176 (decimal moved 4 places to left, power of 10 omitted)
$0.000176 = 1.76 \times 10^{-4}$.

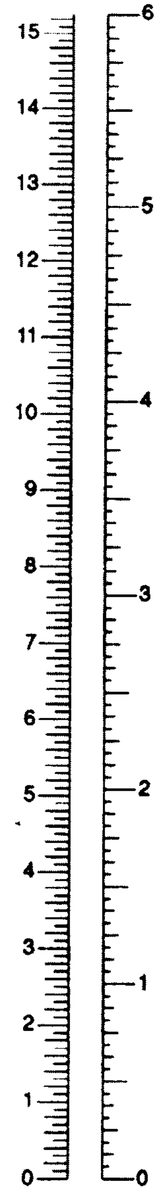
Ratios and Proportions

A **ratio** is an expression that compares two numbers or quantities by division. For example, if 400 students were enrolled in a class at the beginning of a semester and 40 students had withdrawn from class by the end of the semester, the ratio of students withdrawn to students enrolled is 40/400 or 1/10. That is, one student out of ten elected to withdraw from class.

Ratios can be expressed several ways. Each method of expression, however, means the same thing:

1. 1:250 means 1 part of 250 parts,
2. 1/5 means 1 part out of 5 parts, and
3. 2 females to 6 males means a ratio of 1 female to 3 males.

Whenever two quantities are expressed as a ratio, they must have the same units. For example, if the first of two compared animals weighed 300 grams and the second



LENGTH

A speed limit of 85 kph is about 55 mph

A kilometer is about 0.6 miles

A meter is a little more than a yard (39 inches)

A centimeter is about the width of your index fingernail

Length Conversion

1 in	= 2.54 cm	1 mm	= 0.04 in
1 ft	= 30.5 cm	1 cm	= 0.39 in
1 yd	= 0.91 m	1 m	= 39.4 in
1 mi	= 1.61 km	1 m	= 1.1 yd
		1 km	= 0.62 mi

WEIGHT

A large man weighs 90 kilograms

A small woman weighs 50 kilograms

This book weighs about 0.8 kg

A pound of cheese weighs about half a kilogram

A teaspoon of sugar weighs about 4 grams

A grain of salt weighs about 1 milligram

Weight Conversion

1 oz	= 28 g	1 g	= 0.035 oz
1 lb	= 0.45 kg	1 kg	= 2.2 lb

VOLUME

A large auto gas tank holds about 100 liters

One liter is a standard "quart" bottle of soda, milk, or wine

A cup of coffee is about 150 ml

5 milliliters is a standard teaspoon of medicine

A drop of water is about 50 microliters

Volume Conversion

1 tsp	= 5 ml	1 ml	= 0.03 fl. oz
1 tbsp	= 15 ml	1 l	= 2.1 pt
1 fl oz	= 30 ml	1 l	= 1.06 qt
1 cup	= 0.24 l	1 l	= 0.26 gal
1 pt	= 0.47 l		
1 qt	= 0.95 l		
1 gal	= 3.8 l		

FIGURE **1.1** Comparison of metric and English units of measurement

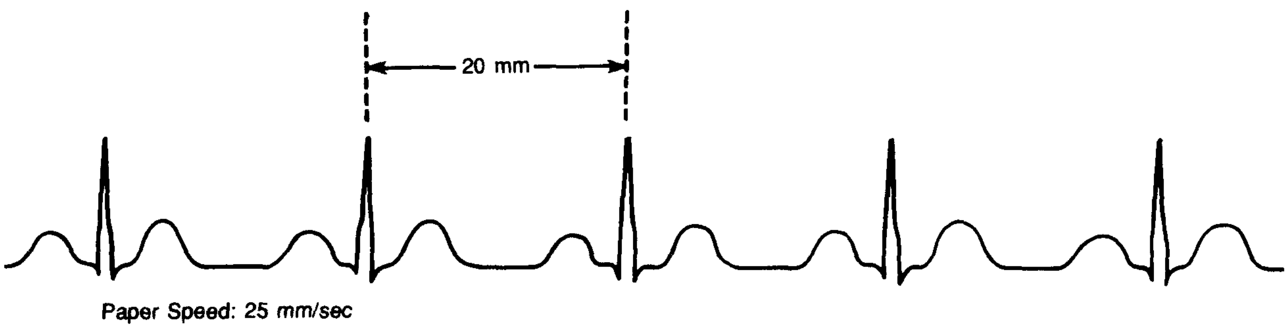


FIGURE **1.2** Electrocardiogram

animal weighed 1 kilogram, it would be necessary to convert one of the units of weight to the other (i.e., grams to kilograms, or kilograms to grams) before expressing the comparison in the form of a ratio. One kilogram equals 1,000 grams; therefore, the ratio between the first animal's weight and the second animal's is 300/1,000 or 3/10.

A **proportion** is simply a mathematical statement of the equality of two ratios. By arbitrarily using the letters A, B, C, and D to express quantities, a proportion can be stated in the following manner:

$$\frac{A}{B} = \frac{C}{D}$$

The statement says A is to B as C is to D. Mathematically, it is also valid to say A times D equals B times C.

For example, if A = 15, B = 25, C = 3, D = 5, then

$$\frac{(A)}{(B)} = \frac{(C)}{(D)} \text{ or } \frac{(15)}{(25)} = \frac{(3)}{(5)}$$

and

$$A \times D = B \times C,\ 15 \times 5 = 25 \times 3.$$

Therefore, it follows that if three of the quantities are known, the value of the fourth can be determined.

For example, assume that an electrocardiogram is being recorded on a moving strip of paper (figure 1.2). The speed of the moving paper is 25 mm/sec. If each repeating cycle of the electrocardiogram represents one heartbeat, how many heartbeats are occurring each minute?

The problem can be solved as follows:

1. Distance between cycles = 20 mm (as measured from record).
2. Time interval between cycles = X sec.

$$\frac{25 \text{ mm}}{1 \text{ sec}} = \frac{20 \text{ mm}}{X \text{ sec}}$$

$$25X = 20$$

$$X = 20/25 = 0.8 \text{ sec}$$

3. If the interval between cycles is 0.8 sec, then the number of cycles occurring each minute is

$$60 \text{ seconds} \div 0.8 \text{ second} = 75 \text{ beats/minute.}$$

Another example of how ratios and proportions can be used to solve problems is the determination of time in the events of muscle contraction. When a single stimulus of sufficient strength and duration is applied to an isolated skeletal muscle, the resultant contraction is known as a *twitch.* The mechanical record of a skeletal muscle twitch (figure 1.3) indicates a period between the time the stimulus is applied and the beginning of the contractile response. This interval of time is known as the *latent period.* Following the latent period, the muscle responds to the stimulus by shortening (the contraction phase) and then returning to its original length (the relaxation phase). Given a paper recording speed of 50 mm per second, determine the duration of the latent period, the contraction period, and the relaxation period as shown in figure 1.3.

The problem can be solved as follows:

1. Determine the time value of 1 mm of distance on the record:

$$\frac{50 \text{ mm}}{1 \text{ sec}} = \frac{1 \text{ mm}}{X \text{ sec}}$$

Cross-multiplying:

$$50X = 1$$

Solving for X:

$$X = 1/50 \text{ sec} = 0.02 \text{ sec}$$

2. Measure the length of the latent period, contraction period, and relaxation period in millimeters and multiply each value by 0.02 sec to obtain durations.
   a. Latent period = 3 mm × 0.02 sec/mm = 0.06 sec.
   b. Contraction period = 5 mm × 0.02 sec/mm = 0.10 sec.
   c. Relaxation period = 11 mm × 0.02 sec/mm = 0.22 sec.

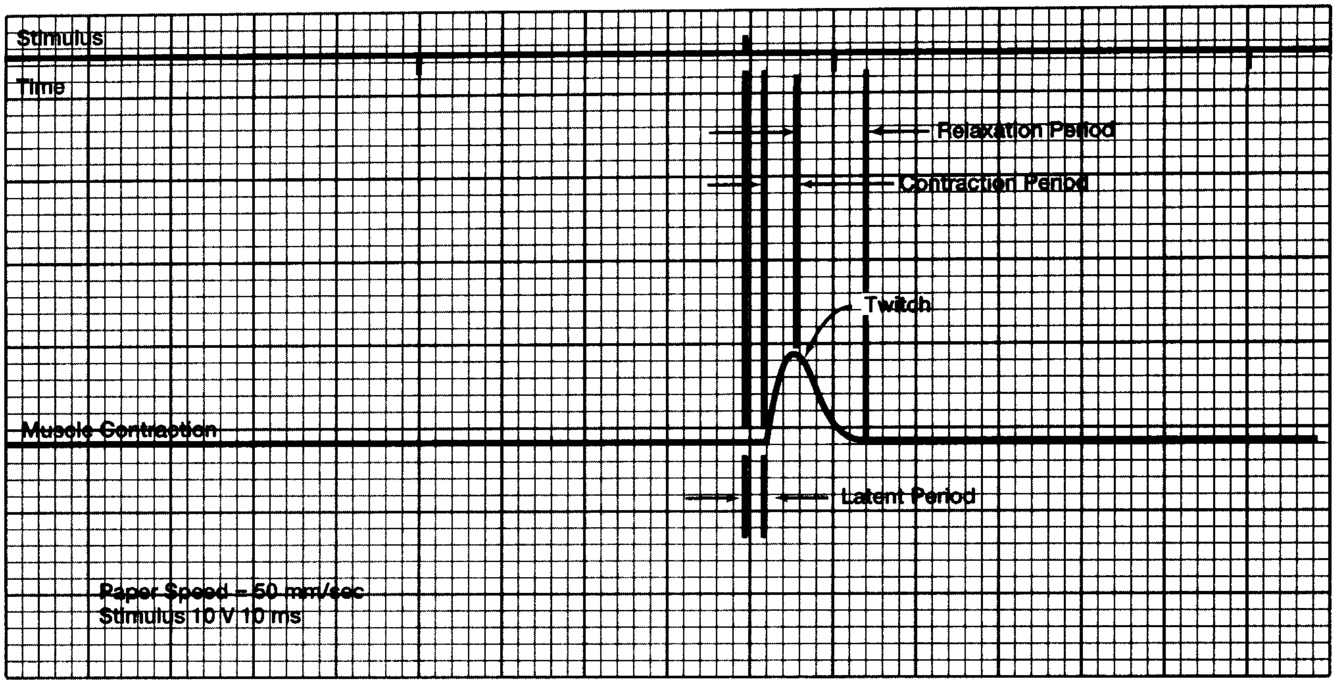


FIGURE 1.3 The skeletal muscle twitch

TABLE 1.5 Calculation of arithmetic mean

Subject	*Resting systolic pressure (mm Hg)*
1. RGP	120
2. DKK	135
3. ALB	126
4. RWK	133
5. WGB	127
6. RSS	140
7. FAJ	110
8. NDL	117
9. WSC	125
10. RCS	129
$N = 10$	$\Sigma \bar{X} = 1{,}262$ $\bar{X} = 1{,}262/10 = 126$ mm Hg

Computation of Arithmetic Mean

It is often useful in comparing groups of numerical data to calculate the arithmetic mean or average. It may be calculated by using the following formula:

$$\bar{X} = \frac{\Sigma X}{N}$$

where $\bar{X}$ = the mean of X, ΣX = the sum of all values of X in each group, and N = the number of individual values for X in each group.

For example, assume that as part of a study resting systolic blood pressure was recorded from 10 male subjects each aged 21 years, and you wish to calculate the mean systolic blood pressure and compare it to another group. Table 1.5 indicates the data as recorded and the calculation of the arithmetic mean.

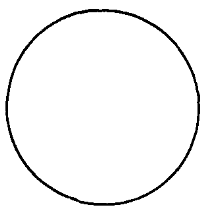
Metrics, Measurements, and Computations Report

Name: ______________________________

Lab Section: ______________________________

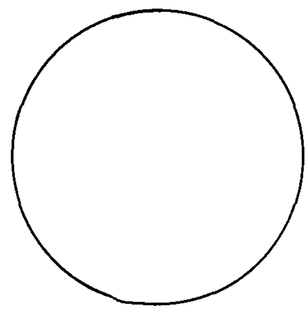
Date: ______________________________

1. Use a small metric rule to measure the diameter of the one inch and one and one-half inch circles below. Record the measurements in millimeters and centimeters.



______ mm

______ cm



______ mm

______ cm

2. Use the laboratory scale to measure your weight and height. Record weight in kilograms and pounds. Record height in centimeters and inches.

   weight ______________ kg ______________ lbs

   height ______________ cm ______________ inches

3. Compute the following conversions:

   a. 242 mg = ______________ g

   b. 6 g = ______________ cg

   c. 4 lbs = ______________ kg

   d. 0.83 cm = ______________ mm

   e. 3450 ml = ______________ l

   f. 243 mm = ______________ cm

   g. 10° C = ______________ ° F

   h. 72° F = ______________ ° C

4. Solve the following proportions for *X*:

   a. 6/36 = *X*/48, *X* = ______________

   b. 9:72 as *X*:64, *X* = ______________

   c. 24/144 = 18/*X*, *X* = ______________

   d. *X*/27 = 17/81, *X* = ______________

5. At rest, the left ventricle of the heart pumps 5.0 liters of blood per minute. Blood flow to the kidneys is approximately 1,200 ml per minute at rest. Assuming a proportionate increase in renal blood flow, what will be the blood flow to the kidneys if the heart pumps 7.0 l/min?

____

____

____

6. An electrocardiogram is recorded on mm grid paper moving at a speed of 25 mm/sec. If the distance between cycles as recorded is 15 mm, what is the subject's heart rate in beats per minute?

____

____

____

7. Express the following numbers using scientific notation:

a. 1563 = ____

b. 0.364 = ____

c. 1.000 = ____

d. 5.463 = ____

8. Compute the arithmetic mean (average) of the following body weights:

a. 76 kg
b. 63 kg
c. 81 kg
d. 59 kg
e. 68 kg
f. 74 kg

Mean body weight = ______________________________ kg.