Seeleys Anatomy and Physiology 11th edition VanPutte Solutions Manual

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Instructor's Manual

to accompany

Seeley's Anatomy and Physiology Laboratory Manual

Eleventh Edition

Eric Wise
Santa Barbara City College

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INTRODUCTION

This instructor's resource manual was written to assist you in the preparation of the lab portion of the course. It serves to coordinate the labs with the ordering of material, aid the instructor or lab technician in preparing material for the lab, provide a detailed list of preparations and sources for ordering and instructional aids in the running of the lab. This manual also provides answers to the review questions at the back of each exercise.

The lab manual contains 43 exercises that cover the breadth of human anatomy and physiology. Each exercise can be used in its entirety or shortened depending on the time available or according to your interest. Labs vary in terms of equipment. Some exercises may need to be modified or deleted entirely due to the physical constraints of the institution. The text is written for students who are introductory students to the material and may have little or no chemistry background.

Orders must be made ahead of time for items such as sterilized blood, live frogs, enzymes, and other materials for the preparation of solutions. Many supply companies will take orders early and ship material to arrive at the scheduled time. As labs are being prepared, specific quantities of materials need to be prepared. A general rule of thumb is to calculate the total amount of material that will be used in lab and double that amount.

Materials listed in this lab manual are generally indicated as per student, per table (assuming a table of 4), or per lab section (25 students). Test all reagents and experiments prior to trying them in lab. Note any modifications to the experiments for future use. I would be very happy to hear from your regarding comments or suggestions concerning the lab. You can contact me through McGraw-Hill or at Santa Barbara City College.

Instructor's resources such as PowerPoint reviews at the end of lab, videos, computer presentations, additional texts or illustrations add to students' comprehension of the material. Some students want to go beyond the material at hand and available references are wonderful to have in the lab.

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SAFETY IN THE LAB

Safety in the lab is one of the primary concerns of any instructor teaching anatomy and physiology. Safety guidelines are printed in the lab manual and should be thoroughly covered by the instructor prior to beginning the lab. Several potential hazards occur in the lab including:

1. Sharp objects such as broken glassware, razor blades, scalpel blades and other potentially dangerous cutting or puncturing objects. Proper disposal of sharp objects is essential as is the handling of these objects.

2. Infectious diseases - students should wear barrier gloves and protective eyewear when handling bodily fluids. Students should handle only their own fluids unless closely supervised by the instructor or other qualified personnel. Students need to be prepared to work with infectious agents. Those students entering the health profession will potentially encounter lethal diseases in their profession and an early protocol that influences safety should constantly be stressed. Even if you know material is non-pathogenic, students should treat it as if it is. Material that has come into contact with bodily fluids must be placed in a 10% bleach solution or deposited in a sharps container.

3. Disposal of animal wastes – Proper disposal of animal waste is critical. If your institution does not have an incinerator you should check with universities nearby or animal control facilities. Material preserved with formaldehyde should not be disposed of in local landfills.

4. Flames or hot surfaces - Most of the experiments requiring heating in these exercises can be done using hot plates. It is important to use heat-proof glassware on the hot plates. Glass fingerbowls and household jars are not heat proof and should not be heated on hot plates.

5. Toxic materials - Some of the material in lab is toxic. Students should not eat food in lab and make sure they wash their hands after handling material in lab. Spills must be cleaned-up immediately. All reagents used in lab that are potentially dangerous should have a manufacturer's safety data sheet (MSDS) that can be consulted if spills occur.

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CORRELATIONS

This lab manual was written in conjunction with *Seeley's Anatomy and Physiology,* 11th edition. I have provided correlations between the Lecture text and the Lab Manual, yet the lab manual can be used with any standard college anatomy and physiology text.

Chapters in Seeley's *Anatomy and Physiology, 11th edition,* by VanPutte, et al.	**Corresponding Exercises in *Anatomy and Physiology Laboratory Manual,* by Eric Wise**
1 The Human Organism	1 Introduction to Lab Science, Chemistry, Organs, Systems, and Organization of the Body
2 The Chemical Basis of Life	1 Introduction to Lab Science, Chemistry, Organs, Systems, and Organization of the Body
3 Structure and Function of the Cell	2 Microscopy 3 Cell Structure and Function
4 Histology: The Study of Tissues	4 Tissues
5 Integumentary System	5 Integumentary System
6 Skeletal System: Bones and Bone Tissue	6 Introduction to the Skeletal System
7 Skeletal System: Gross Anatomy	7 Appendicular Skeleton 8 Axial Skeleton: Vertebrae, Ribs, Sternum, Hyoid 9 Axial Skeleton-Skull
8 Articulations and Movement	10 Articulations
9 Muscular System: Histology and Physiology	11 Muscle Physiology
10 Muscular System: Gross Anatomy	12 Overview of Muscles and Muscles of the Shoulder and Upper Extremity 13 Muscles of the Hip, Thigh, Leg and Foot 14 Muscles of the Head and Neck 15 Muscles of the Torso
11 Functional Organization of Nervous Tissue	16 Introduction to the Nervous System 19 Nervous System Physiology-Stimuli and Reflexes
12 Spinal Cord and Spinal Nerves	18 Spinal Cord and Somatic Nerves
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EXERCISE 1
Introduction to Lab Science, Chemistry, Organs, Systems, and Organization of the Body

INTRODUCTION

This lab introduces the student to the fields of anatomy and physiology, discusses science as a general field of study, and provides a very basic introduction to chemistry. The "scientific method" is a description of a broad number of procedures and experimental techniques. The goals of valid science have criteria of experimental repeatability and prior publication rights that are followed by members of the scientific community.

Terms such as *hypothesis*, *control group*, *experimental group*, *theory,* and *law* can help students distinguish the specific parameters of scientific study from what is commonly perceived as science by the layperson. Another important area for discussion is the topic of honesty in science. Court cases involving interpretation of data by "paid consultants" has blurred the objectivity of the scientific experience yet good discussions can be had by opening-up the topic of honesty in the commercial development of new drugs and the need for honest appraisal of one's work when the efforts of science are used for purposes that concern the health or well-being of people.

Another part of the lab is to introduce the student to the idea of data collection, working with data, graphing results and interpreting the data in a very simple format. Some students will have no difficulty with the numerical portion of the exercise while others may feel frustrated. It is a good time to make an early evaluation of students' relationships to math and the potential need for an augmentation of their efforts in math. Some anatomy and physiology courses have chemistry as a prerequisite and some do not. This lab exercise involves some basic and fundamental concepts of chemistry but is not meant to cover even the essentials of chemistry needed for the course. A good reference to the study of chemistry is important for those students who have had no chemistry background.

When discussing the atomic level of organization having available MRI graphics from local hospitals or physicians allows students to examine the importance of anatomic study from various perspectives and technologies. It is also important to compare directional terms for quadrupeds with those for humans as *superior* and *inferior* are specific terms for humans. The terms *anterior/ventral* and *posterior/dorsal* are synonymous in humans while the anterior end of a quadruped is toward the nose while the dorsal side is along the vertebral column.

Planes of sectioning are also important concepts in the study of anatomy. Illustrations of organs that have been sectioned or thin sections of organs embedded in plastic make good tools for discussing sectioning planes. Likewise the use of torso models for the discussion of body cavities provides a good visual medium for demonstration.

Most students have an intuitive sense and some familiarity with the regions of the body. Particular notice should be given to specific anatomic terms such as "arm" (from the shoulder to the elbow) and "leg" (from the knee to the ankle). Descriptions of the abdominal region are usually easily understood. The term "hypochondriac" comes from the Greek words meaning "under the cartilage". In earlier times the hypochondriac area was thought to be the center of melancholy.

TIME 1.5-2 hours

Acid/Base

Safety goggles and gloves
Five 10 mL test tubes
Test tube rack
10 mL graduated cylinder
Permanent marker
Distilled water in dropper bottle
0.1 M HCl in dropper bottle

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0.1 M NaOH in dropper bottle
Baking soda (sodium bicarbonate)
Sodium chloride (table salt)
Wide-ranging pH paper (pH 1-14)
Parafilm®
Small metal spatula
Balance and weigh paper

Ionic and Covalent Molecules

18 gauge wire
Alligator clips
9 volt battery
6 volt flashlight bulb
Miniature screw lamp receptacle (Carolina #756481 or Sargent Welch #CP 33008-00)
Two 50 mL beakers
15% sucrose solution in dropper bottle
15% sodium chloride solution in dropper bottle

Hydrogen Bonds

Graduated cylinder
Two 50 mL beakers
Small bottle of distilled water
Small bottle of ethanol (70% or greater)
Hot plate (do not use open flame)

Heart Rate and Exercise

Clock or watch with accuracy in seconds
Calculator

Organ Systems Section

Models of Human Torso
Charts of Human Torso

ANSWERS TO IN-TEXT QUESTIONS

Page 2

1 centigram
1 kilosecond
1 decameter
1 nanoliter

4.3×10^{6}
3.4×10^{-5}
2.2×10^{3}
1.9×10^{-3}

Figure 1.8

1. Respiratory
2. Urinary
3. Nervous
4. Muscular
5. Reproductive (female)
6. Skeletal
7. Lymphatic

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8. Integumentary
9. Digestive
10. Endocrine
11. Cardiovascular

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Find the following locations on your body and provide the appropriate anatomical description for these regions.

Shin	Crural
Elbow	Cubital
Neck	Cervical
Toes	Digital
Shoulder	Acromial
Thigh	Femoral
Kneecap	Patellar

REVIEW ANSWERS

1. In terms of base units
   a. The meter is the base unit of length in the metric system.

   b. The liter is the base unit of volume in the metric system?

2. Cubic centimeters and milliliters are interchangeable, therefore there are 200 cubic centimeters in 200 mL.

3. There are 1000 mg in one gram so there would be 0.35 grams of medication in 350 mg.

4. 3.45×10^{-4} liters is 0.000345 liter in scientific notation.

5. There are 4,500,000 milligrams in 4.5 kilograms.

6. 0.25 meters

7. If given a length of 1/10,000 of a meter
   a. 0.0001
   b. 1×10^{-4}

8. Use a word to describe
   a. A millisecond is one-thousandth of a second:

   b. A kiloliter is one-thousand liters:

   c. A centimeter is one-hundredth of a meter:

9. Determined by experimentation. Heart rate generally increases with exercise up to a certain point. There is a maximum heart rate so the trend would not continue.

10. In this case, exercise is the independent variable and heart rate is the dependent variable.

11. Determined by experimentation

12. A chemical that dampens the change in pH when acid or base is added to solution

13. 7 is the neutral pH

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14. A pH of 8 is more basic than a pH of 6

15. The hydrogen ion concentration increases

16. Solutions with more electrolytes conduct electricity more easily than solutions of pure water.

17. Covalent bonds

18. Hydrogen bonds are weak bonds

19. physiology

20. organ systems

21. anatomical position

22. abdominal cavity

23. thoracic cavity

24. pelvic cavity

25. a. shoulder and elbow

26. b. knee and ankle

27. c. organelle

28. epigastric and right hypochondriac

29. superior

30. distal

31. deep

32. anterior/ventral

33. respiratory

34. digestive

35. muscular

36. d. dorsal

37. The abdomen is the region of the belly and the abdominal cavity is a space in the abdominal region.

38.
a. cervical
b. acromial
c. pectoral
d. axillary
e. brachial
f. abdominal

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g. antebrachial
h. carpal
i. genital
j. femoral
k. crural
l. pedal
m. cephalic
n. frontal
o. sternal
p. coxal

39.
a. midsagittal (median)
b. transverse
c. frontal

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EXERCISE 2
Microscopy

INTRODUCTION
Microscopy and beginning students are an interesting combination. In any introductory science class there are usually students who have had no experience with microscopes, those who have had some experience (but it has been limited, or with other types of microscopes than those found in this particular lab), and students with quite a bit of microscope experience. Another interesting factor is the great reluctance on the part of many students to admit that they do not know how to use a microscope (or do not know how to use it correctly).

It is worth the effort to do a demonstration of the microscope before letting students use the instruments. Frequently when they have a microscope at their desks and you are demonstrating, they pay no attention to you but fiddle with the mechanisms in front of them. Once they have been shown the microscope and learn the parts then they seem to have an easier time with the exercise.

Discussions about care of the microscope vary from instructor to instructor but I think that you cannot assume that your students will know anything about microscope care unless you provide them with specific guidelines. Some of these are listed in this exercise. Likewise the knowledge of the parts of the microscope is important. Students who know the structure of the microscope will have a good understanding of the functions of the parts. Microscope models vary by manufacturer so you may wish to provide students with a labeled illustration of the microscopes in your particular lab.

To understand the field of view I like to have students measure it directly under low power. Clear plastic metric rulers work well. You can also take standard metric rulers and place several of them on a photocopy machine and run a piece of overhead transparency acetate through the machine. Cut the acetate sheets into small (10 - 15 cm) sections. Students can place the thin strips of acetate on their microscope stages, examine them under low power and directly measure the field of view.

Once they have obtained this value they can switch to the next higher objective lens and make their count to determine the diameter of the field of view. The diameter decreases in inverse proportion to the magnification of the lens. Thus if the diameter is 4 mm at 40 X then the diameter will be 0.4 of that (or 1.6 mm) at 100 X. The magnification of 100 X is 2.5 times greater than 40 X so the field of view is 2.5 times smaller.

When working with students in lab it is good to have them get started on their microscope work then walk around the room to see if the students have put the microscope slides on the stage correctly. Determine if they know how to adjust the light, move the slide around, focus correctly, etc. Sometimes students will not ask for help but it is apparent from a little observation that they need it. One quick method that I have used in lab is to walk around the lab as students just start to examine their first slide. If the tip of the high power objective lens is 3-4 cm above the mechanical stage it is easy to determine that students need a little help focusing the microscope.

Students usually have no problem with the preparation of wet mounts other than sometimes trapping air bubbles under the coverslip or not putting on a coverslip at all. Prepared slides are easy to begin with, though more expensive to replace than the wet mounts prepared in lab.

TIME 1.5 hours

MATERIALS
Compound light microscopes
Prepared slide with the letter *e* (or newsprint and razor blades)
Transparent metric rulers or sections of overhead acetates of rulers
Glass microscope slides
Coverslips
Lens paper
Kimwipes or other cleaning paper
Lens cleaner

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Small dropper bottle of water (1 per table)
1% methylene blue solution (1 part methylene blue crystals in 100 parts absolute alcohol)
Toothpicks
Histological slides of kidney, stomach, or liver
Silk threads prepared slide

REVIEW ANSWERS

1.
a. 70X
b. 150X
c. 200X

2. Coverslip

3. a. compound microscope

4. Field of view

5. To control the amount of light entering the microscope and adjust the depth of field

6. 2.8 mm

7.
a. ocular lens
b. body tube
c. arm
d. coarse-focus knob
e. base
f. objective lens
g. stage
h. light source

8. There is less working distance.

9. The field of view decreases with increasing magnification.

10. You should use the low-power objective lens when you first examine the microscope slide.

11. You should clean the lenses of the microscope with special lens paper by using the paper once, then throwing it away.

12. It is important to carry the microscope upright and with two hands.

13. It is approximately 1.5 mm

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Chapter 1
The Human Organism

Student Learning Outcomes

After reading this chapter, students should be able to:

1.1A Define anatomy and describe the levels at which anatomy can be studied.
1.1B Define physiology and describe the levels at which physiology can be studied.
1.1C Explain the importance of the relationship between structure and function.
1.2A Name the six levels of organization of the body, and describe the major characteristics of each level.
1.2B List the 11 organ systems, identify their components, and describe the major functions of each system.
1.3A List and define the six characteristics of life
1.4A Explain why it is important to study other organisms along with humans.
1.5A Define homeostasis and explain why it is important for proper body function.
1.5B Describe a negative-feedback mechanism and give an example.
1.5C Describe a positive-feedback mechanism and give an example.
1.6A Describe a person in the anatomical position.
1.6B Define the directional terms for the human body, and use them to locate specific body structures.
1.6C Know the terms for the parts and regions of the body.
1.6D Name and describe the three major planes of the body.
1.6E Name and describe the three major ways to cut an organ.
1.6F Describe the major trunk cavities and their divisions.
1.6G Locate organs in their specific cavity, abdominal quadrant, or region.
1.6H Describe the serous membranes, their locations, and functions.

Chapter Outline

1.1 Anatomy and Physiology

1. Anatomy is the study of the body's structures.
   - Developmental anatomy considers anatomical changes from conception to adulthood. Embryology focuses on the first 8 weeks of development.
   - Cytology examines cells, and histology examines tissues.
   - Gross anatomy studies organs from either a systemic or a regional perspective.
2. Surface anatomy uses superficial structures to locate deeper structures, and anatomical imaging is a noninvasive technique for identifying deep structures.
3. Physiology is the study of the body's functions. It can be approached from a cellular or a systems point of view.
4. Pathology deals with all aspects of disease. Exercise physiology examines changes caused by exercise.

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1.2 Structural and Functional Organization of the Human Body

1. Basic chemical characteristics are responsible for the structure and functions of life.
2. Cells are the basic structural and functional units of organisms, such as plants and animals. Organelles are small structures within cells that perform specific functions.
3. Tissues are composed of groups of cells of similar structure and function and the materials surrounding them. The four primary tissue types are epithelial, connective, muscle, and nervous tissues.
4. Organs are structures composed of two or more tissues that perform specific functions.
5. Organs are arranged into the 11 organ systems of the human body.
6. Organ systems interact to form a whole, functioning organism.

1.3 Characteristics of Life

Humans share many characteristics with other organisms, such as organization, metabolism, responsiveness, growth, development, and reproduction.

1.4 Biomedical Research

Much of our knowledge about humans is derived from research on other organisms.

1.5 Homeostasis

Homeostasis is the condition in which body functions, body fluids, and other factors of the internal environment are maintained at levels suitable to support life.

Negative Feedback

1. Negative-feedback mechanisms maintain homeostasis.
2. Many negative-feedback mechanisms consist of a receptor, a control center, and an effector.

Positive Feedback

1. Positive-feedback mechanisms usually increase deviations from normal.
2. Although a few positive-feedback mechanisms normally exist in the body, most positive-feedback mechanisms are harmful.
3. Normal positive-feedback mechanisms include blood clotting and childbirth labor. Harmful positive-feedback examples include decreased blood flow to the heart.

1.6 Terminology and the Body Plan

Body Positions

1. A human standing erect with the face directed forward, the arms hanging to the sides, and the palms facing forward is in the anatomical position.
2. A person lying face upward is supine; a person lying face downward is prone.

Directional Terms

Directional terms always refer to the anatomical position, no matter what the actual position of the body.

Body Parts and Regions

1. The body can be divided into a central region, consisting of the head, neck, and trunk, and the upper limbs and lower limbs.
2. Superficially, the abdomen can be divided into quadrants or into nine regions. These divisions are useful for locating internal organs or describing the location of a pain or a tumor.

Planes

1. Planes of the Body

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- A sagittal plane divides the body into right and left parts. A median plane divides the body into equal right and left halves.
- A transverse (horizontal) plane divides the body into superior and inferior portions.
- A frontal (coronal) plane divides the body into anterior and posterior parts.

2. Sections of an Organ
   - A longitudinal section of an organ divides it along the long axis.
   - A transverse (cross) section cuts at a right angle to the long axis of an organ.
   - An oblique section cuts across the long axis of an organ at an angle other than a right angle.

Body Cavities

1. The mediastinum subdivides the thoracic cavity.
2. The diaphragm separates the thoracic and abdominal cavities.
3. Pelvic bones surround the pelvic cavity.

Serous Membranes

1. Serous membranes line the trunk cavities. The parietal portion of a serous membrane lines the wall of the cavity, and the visceral portion is in contact with the internal organs.
   - The serous membranes secrete fluid, which fills the space between the visceral and parietal membranes. The serous membranes protect organs from friction.
   - The pericardial cavity surrounds the heart, the pleural cavities surround the lungs, and the peritoneal cavity surrounds certain abdominal and pelvic organs.
2. Mesenteries are parts of the peritoneum that hold the abdominal organs in place and provide a passageway for blood vessels and nerves to the organs.
3. Retroperitoneal organs are located “behind” the parietal peritoneum.

Topics Related to the Study of Anatomy and Physiology

The use of animals in research is relevant, and the students may have strong opinions about the ethical issues involved. Discuss pros and cons (including financial considerations) for alternatives to animal experimentation, such as tissue culture and computer simulation.

Anatomical anomalies can be used for discussion concerning the concept of normal. Anatomy and physiology are replete with references to normal and abnormal structures and values. Students will benefit from the clarification of the meaning of the word “normal" as it will be used within the context of the course.

Newspaper, magazine, or internet sources related to the new imaging technologies can help students appreciate the amount of knowledge of anatomy and physiology a diagnostician must possess in order to interpret those potentially meaningless images. Use the **Clinical Impact: Anatomical Imaging,** as the starting point for a homework assignment to find out more information.

The excellent photographs found on the first page of every chapter illustrate technological advances in imaging techniques. The advents of the electron microscope, patch-clamping, micro-electrodes, and radio-immunoassay have increased our ability to investigate cell structures

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and cell membrane transport. The newest scanning tunneling electron microscopes have taken resolution down to the level of individual molecules. Class discussion could focus on the intriguing area of cellular research. The **Clinical Impact: Microscopic Imaging,** provides more information.

Themes in Chapter 1

Structure and Function

Medical Terminology

"When in Rome…" is a concept that could be applied to knowing and using anatomical and medical terminology. Students must use their language in order to communicate with other scientists and healthcare professionals. Students need to learn that there is value in the precision of anatomical terminology. The notion that the body is a collection of interlocking parts is a concept foreign to many students, who view the body as a singular and solid entity. Students may not realize there is a connection between the words that are used in class and their own bodies. Point out the valuable list of prefixes, suffixes, and combining forms on the back cover of the book and the **Glossary (pages G-1 to G-32)** that will help them gain a mastery of this "new" language. Also useful is Table 1.2, Directional Terms for Humans.

Homeostasis

Feedback

Spend time on the concepts of positive and negative feedback to ensure student understanding. Provide examples in addition to those provided in the text. Ask students to think about and then discuss examples of events that push the body out of homeostasis and how the body returns to homeostasis. Discuss ways the body can be helped to return to homeostasis in emergencies. Be sure students understand how to interpret the Process Figure 1.5 and Homeostasis Figure 1.6, because this format is used throughout the book and can be an invaluable tool in understanding complex body processes.

Cell Theory and Biochemistry

Students must assimilate this foundational knowledge before they can grasp more complex physiological processes like cell membrane transport and cell-to-cell communication. Stress the pivotal position of cells and biochemistry in understanding higher levels of organization.

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Changes through Time
Students must grasp the difference between structures/parts and functions/processes. Introduce the element of time and the possibility of change through time (moment to moment, over the life span, and evolutionarily) in both structures and functions.

Learning Outcomes Correlation with Predict Question Types

Question Type	Question #	Bloom's level	Learning Outcome
Learn to Predict	1	Application	1.5b
Predict	2	Evaluation	1.5b
Predict	3	Evaluation	1.2a
Predict	4	Evaluation	1.5b
Predict	5	Comprehension	1.5b
Predict	6	Comprehension	1.5b,c
Predict	7	Comprehension	1.6a,b
Predict	8	Comprehension	1.6b
Predict	9	Comprehension	1.6f,g,h

Chapter 2
The Chemical Basis of Life

Student Learning Outcomes

After reading this chapter, students should be able to:

2.1A Define matter, mass, and weight.
2.1B Distinguish between elements and atoms, and state the four most abundant elements in the body.
2.1C Name the subatomic particles of an atom, and indicate their mass, charge, and location in an atom.
2.1D Define atomic number, mass number, isotope, atomic mass, and mole.
2.1E Compare and contrast ionic and covalent bonds.
2.1F Differentiate between a molecule and a compound.
2.1G Explain what creates a hydrogen bond and relate its importance.
2.1H Describe solubility and the process of dissociation, and predict if a compound or molecule is an electrolyte or nonelectrolyte.
2.2A Summarize the characteristics of synthesis, decomposition, reversible, and oxidation-reduction reactions.
2.2B Illustrate what occurs in dehydration and hydrolysis reactions.
2.2C Explain how reversible reactions produce chemical equilibrium.
2.2D Contrast potential and kinetic energy.

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2.2E Distinguish between chemical reactions that release energy and those that take in energy.
2.2F Describe the factors that can affect the rate of chemical reactions.
2.3A Distinguish between inorganic and organic compounds.
2.3B Describe how the properties of water contribute to its physiological functions.
2.3C Describe the pH scale and its relationship to acidic, basic, and neutral solutions.
2.3D Explain the importance of buffers in organisms.
2.3E Compare the roles of oxygen and carbon dioxide in the body.
2.4A Describe the structural organization and major functions of carbohydrates, lipids, proteins, and nucleic acids.
2.4B Explain how enzymes work.
2.4C Describe the roles of nucleic acids in the structures and functions of DNA, RNA, and ATP.

Chapter Outline

2.1 Basic Chemistry

Matter, Mass, and Weight

1. Matter is anything that occupies space and has mass.
2. Mass is the amount of matter in an object.
3. Weight results from the force exerted by earth's gravity on matter.

Elements and Atoms

1. An element is the simplest type of matter having unique chemical and physical properties.
2. An atom is the smallest particle of an element that has the chemical characteristics of that element. An element is composed of only one kind of atom.
3. Atoms consist of protons, neutrons, and electrons.
   - Protons are positively charged, electrons are negatively charged, and neutrons have no charge.
   - Protons and neutrons are in the nucleus; electrons are located around the nucleus, and can be represented by an electron cloud.
4. The atomic number is the unique number of protons in an atom. The mass number is the sum of the protons and the neutrons.
5. Isotopes are atoms that have the same atomic number but different mass numbers.
6. The atomic mass of an element is the average mass of its naturally occurring isotopes weighted according to their abundance.
7. A mole of a substance contains Avogadro's number (6.022×10^{23}) of atoms, ions, or molecules. The molar mass of a substance is the mass of 1 mole of the substance expressed in grams.

Electrons and Chemical Bonding

1. The chemical behavior of atoms is determined mainly by their outermost electrons. A chemical bond occurs when atoms share or transfer electrons.
2. Ions are atoms that have gained or lost electrons.
   - An atom that loses 1 or more electrons becomes positively charged and is called a cation. An anion is an atom that becomes negatively charged after accepting 1 or more electrons.

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- An ionic bond results from the attraction of the oppositely charged cation and anion to each other.

3. A covalent bond forms when electron pairs are shared between atoms. A polar covalent bond results when the sharing of electrons is unequal and can produce a polar molecule that is electrically asymmetric.

Molecules and Compounds

1. A molecule is two or more atoms chemically combined to form a structure that behaves as an independent unit. A compound is two or more different types of atoms chemically combined.
2. The kinds and numbers of atoms (or ions) in a molecule or compound can be represented by a formula consisting of the symbols of the atoms (or ions) plus subscripts denoting the number of each type of atom (or ion).
3. The molecular mass of a molecule or compound can be determined by adding up the atomic masses of its atoms (or ions).

Intermolecular Forces

1. A hydrogen bond is the weak attraction between the oppositely charged regions of polar molecules. Hydrogen bonds are important in determining the three-dimensional structure of large molecules.
2. Solubility is the ability of one substance to dissolve in another. Ionic substances that dissolve in water by dissociation are electrolytes. Molecules that do not dissociate are nonelectrolytes.

2.2 Chemical Reactions and Energy

Synthesis Reactions

1. A synthesis reaction is the chemical combination of two or more substances to form a new or larger substance.
2. A dehydration reaction is a synthesis reaction in which water is produced.
3. The sum of all the synthesis reactions in the body is called anabolism.

Decomposition Reactions

1. A decomposition reaction is the chemical breakdown of a larger substance to two or more different and smaller substances.
2. A hydrolysis reaction is a decomposition reaction in which water is depleted.
3. The sum of all the decomposition reactions in the body is called catabolism.

Reversible Reactions

Reversible reactions produce an equilibrium condition in which the amount of reactants relative to the amount of products remains constant.

Oxidation-Reduction Reactions

Oxidation-reduction reactions involve the complete or partial transfer of electrons between atoms.

Energy

1. Energy is the ability to do work. Potential energy is stored energy, and kinetic energy is energy resulting from the movement of an object.
2. Chemical energy
   - Chemical bonds are a form of potential energy.
   - Chemical reactions in which the products contain more potential energy than the reactants require the input of energy.

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- Chemical reactions in which the products have less potential energy than the reactants release energy.

3. Heat energy
   - Heat energy is energy that flows between objects that are at different temperatures.
   - Heat energy is released in chemical reactions and is responsible for body temperature.

Speed of Chemical Reactions

1. Activation energy is the minimum energy that the reactants must have to start a chemical reaction.
2. Enzymes are specialized protein catalysts that lower the activation energy for chemical reactions. Enzymes speed up chemical reactions but are not consumed or altered in the process.
3. Increased temperature and concentration of reactants can increase the rate of chemical reactions.

2.3 Inorganic Chemistry

Inorganic chemistry is mostly concerned with non-carbon-containing substances but does include some carbon-containing substances, such as carbon dioxide and carbon monoxide that lack carbon-hydrogen bonds. Some inorganic chemicals play important roles in the body.

Water

1. Water is a polar molecule composed of one atom of oxygen and two atoms of hydrogen.
2. Because water molecules form hydrogen bonds with each other, water is good at stabilizing body temperature, protecting against friction and trauma, making chemical reactions possible, directly participating in chemical reactions (e.g., dehydration and hydrolysis reactions), and serving as a mixing medium (e.g., solutions, suspensions, and colloids).
3. A mixture is a combination of two or more substances physically blended together, but not chemically combined.
4. A solution is any liquid, gas, or solid in which the substances are uniformly distributed with no clear boundary between the substances.
5. A solute dissolves in the solvent.
6. A suspension is a mixture containing materials that separate from each other unless they are continually, physically blended together.
7. A colloid is a mixture in which a dispersed (solutelike) substance is distributed throughout a dispersing (solventlike) substance. Particles do not settle out of a colloid.

Solution Concentrations

1. One measurement of solution concentration is the osmole, which contains Avogadro's number (6.022×10^{23}) of particles (i.e., atoms, ions, or molecules) in 1 kilogram of water.
2. A milliosmole is 1/1000 of an osmole.

Acids and Bases

1. Acids are proton (H^+) donors, and bases (OH^-) are proton acceptors.

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2. A strong acid or base almost completely dissociates in water. A weak acid or base partially dissociates.
3. The pH scale shows the H^+ concentrations of various solutions.
   - A neutral solution has an equal number of H^+ and OH^- and is assigned a pH of 7.
   - Acidic solutions, in which the number of H^+ is greater than the number of OH^-, have pH values less than 7.
   - Basic, or alkaline, solutions have more OH^- than H^+ and a pH greater than 7.
4. A salt is a molecule consisting of a cation other than H^+ and an anion other than OH^-. Salts form when acids react with bases.
5. A buffer is a solution of a conjugate acid-base pair that resists changes in pH when acids or bases are added to the solution.

Oxygen and Carbon Dioxide

Oxygen is necessary for the reactions that extract energy from food molecules in living organisms. When the organic molecules are broken down during metabolism, carbon dioxide and energy are released.

2.4 Organic Chemistry

Organic molecules contain carbon and hydrogen atoms bound together by covalent bonds.

Carbohydrates

1. Monosaccharides are the basic building blocks of other carbohydrates. Examples are ribose, deoxyribose, glucose, fructose, and galactose. Glucose is an especially important source of energy.
2. Disaccharide molecules are formed by dehydration reactions between two monosaccharides. They are broken apart into monosaccharides by hydrolysis reactions. Examples of disaccharides are sucrose, lactose, and maltose.
3. A polysaccharide is composed of many monosaccharides bound together to form a long chain. Examples include cellulose, starch, and glycogen.

Lipids

1. Triglycerides are composed of glycerol and fatty acids. One, two, or three fatty acids can attach to the glycerol molecule.
   - Fatty acids are straight chains of carbon molecules with a carboxyl group. Fatty acids can be saturated (having only single covalent bonds between carbon atoms) or unsaturated (having one or more double covalent bonds between carbon atoms).
   - Energy is stored in fats.
2. Phospholipids are lipids in which a fatty acid is replaced by a phosphate-containing molecule. Phospholipids are a major structural component of plasma membranes.
3. Steroids are lipids composed of four interconnected ring molecules. Examples are cholesterol, bile salts, and sex hormones.
4. Other lipids include fat-soluble vitamins, prostaglandins, thromboxanes, and leukotrienes.

Proteins

1. The building blocks of a protein are amino acids, which are joined by peptide bonds.
2. The number, kind, and arrangement of amino acids determine the primary structure of a protein. Hydrogen bonds between amino acids determine secondary structure, and hydrogen bonds between amino acids and water determine tertiary structure. Interactions between different protein subunits determine quaternary structure.

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3. Enzymes are protein catalysts that speed up chemical reactions by lowering their activation energy.
4. The active sites of enzymes bind only to specific reactants.
5. Cofactors are ions or organic molecules, such as vitamins, that are required for some enzymes to function.

Nucleic Acids: DNA and RNA

1. The basic unit of nucleic acids is the nucleotide, which is a monosaccharide with an attached phosphate and an organic base.
2. DNA nucleotides contain the monosaccharide deoxyribose and the organic base adenine, thymine, guanine, or cytosine. DNA occurs as a double strand of joined nucleotides. Each strand is complementary and antiparallel to the other strand.
3. A gene is a sequence of DNA nucleotides that determines the structure of a protein or RNA.
4. RNA nucleotides are composed of the monosaccharide ribose. The organic bases are the same as for DNA, except that thymine is replaced with uracil.

Adenosine Triphosphate

Adenosine triphosphate (ATP) stores energy derived from catabolism. The energy released from ATP is used in anabolism and other cell processes.

Topics Related to Levels of Organization and the Chemical Basis of Life

Many people enter their first course in anatomy and physiology envisioning the body as a solid and singular entity that has teleological control of its internal functions. To increase student understanding develop a short written assignment that asks them to integrate the various levels of organization that are introduced here and in Chapter 1. Here's an example: Choose any body part or organ, such as the hand or heart. Name all structural levels of the choice including molecules, organelles, cells, tissues, organs, etc.

Introduce the production and uses of radioactive isotopes during the discussion of atomic structure. Use the **Clinical Impact: Applications of Atomic Particles** as a reading assignment and ask students to think about the possible damage to other macromolecules, such as the cellular DNA, and to weigh that risk against the potential therapeutic benefits of radiation therapy.

Many clinical tests have a chemical basis. For homework have students research diagnostic tests and procedures and determine the chemical foundation of each.

Engineering and biological problems are associated with the bioengineering of synthetic substances that replace body chemicals or tissues. Have the class discuss the chemical and biological considerations of such new technologies such as: Teflon hip replacements, synthetic hormones, artificial heart valves, and synthetic blood.

Themes in Chapter 2
Structure and Function
Enzyme Specificity and Protein Functions Although there are many examples of structural and functional relationships with a chemical

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basis, perhaps the example that students can most readily grasp is the lock and key model of enzyme/substrate interactions. This metaphor easily expands to the next levels of organization, which are other functions of protein in the cell membrane, cell, tissues, and the body. Proteins have a complex structure and a variety of functions that depend on specific structural parameters. Ask students, "How does the structure of a protein affect its function?" (Examples: collagen, insulin, hemoglobin) Changing the structure of a protein will alter its functional capabilities. This theme recurs in the study of anatomy and physiology.

Functions of Organic Molecules
The following tables are excellent resources about the function of the different organic molecules in the body: Table 2.6, Role of Carbohydrates in the Body, Table 2.7, Role of Lipids in the Body, and Table 2.8, Role of Proteins in the Body.

Homeostasis

Chemical Equilibrium
The concept of chemical equilibrium is, in essence, a simpler form of the dynamic equilibrium established and maintained by the body. Help students explore the similarities and differences between chemical equilibrium and biological homeostasis.

Learning Outcomes Correlation with Predict Question Types

Question Type	Question #	Bloom's level	Learning Outcome
Learn to Predict	1	Application	2.2a,f
Predict	2	Comprehension	2.1a
Predict	3	Comprehension	2.1d
Predict	4	Comprehension	2.2a,c
Predict	5	Comprehension	2.2a
Predict	6	Comprehension	2.2e
Predict	7	Application	2.3d

Chapter 3
Structure and Function of the Cell

Student Learning Outcomes

After reading this chapter, students should be able to:

3.1A List the general parts of a cell.
3.1B Relate and explain the four main functions of cells.
3.2A Relate the kinds of microscopes used to study cells.
3.3A Describe the functions and general structure of the plasma membrane.
3.3B Relate why a membrane potential is formed.

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3.4A List and describe the functions of membrane lipids.
3.4B Explain the nature of the fluid-mosaic model of membrane structure.
3.5A List and explain the functions of membrane proteins.
3.5B Describe the characteristics of specificity, competition, and saturation of transport proteins.
3.6A Describe the nature of the plasma membrane in reference to passage of materials through it.
3.6B List and explain the three ways that molecules and ions can pass through the plasma membrane.
3.6C Discuss the process of diffusion and relate it to a concentration gradient.
3.6D Explain the role of osmosis and osmotic pressure in controlling the movement of water across the plasma membrane. Illustrate the differences among hypotonic, isotonic, and hypertonic solutions in terms of water movement.
3.6E Describe mediated transport.
3.6F Compare and contrast facilitated diffusion, active transport, and secondary active transport.
3.6G Describe the processes of endocytosis and exocytosis.
3.7A Describe the composition and functions of the cytoplasm.
3.7B Describe the composition and function of the cytoskeleton.
3.8A Define organelle.
3.8B Describe the structure and function of the nucleus and nucleoli.
3.8C Explain the structure and function of ribosomes.
3.8D Compare the structure and functions of rough and smooth endoplasmic reticula.
3.8E Discuss the structure and function of the Golgi apparatus.
3.8F Describe the role of secretory vesicles in the cell.
3.8G Compare the structure and roles of lysosomes and peroxisomes in digesting material within the cell.
3.8H Relate the structure and function of proteosomes.
3.8I Describe the structure and function of mitochondria.
3.8J Explain the structure and function of the centrosome.
3.8K Compare the structure and function of cilia, flagella, and microvilli.
3.9A Describe the two-step process that results in gene expression.
3.9B Explain the roles of DNA, mRNA, tRNA, and rRNA in the production of a protein.
3.9C Explain what the genetic code is and what it is coding for.
3.9D Describe what occurs during posttranscriptional processing and posttranslational processing.
3.9E Describe the regulation of gene expression.
3.10A Describe the stages of the cell life cycle.
3.10B Give the details of DNA replication.
3.10C Explain what occurs during mitosis and cytokinesis.
3.10D Define apoptosis.
3.11A List the major hypotheses of aging.

Chapter Outline

3.1 Functions of the Cell

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1. The plasma membrane forms the outer boundary of the cell.
2. The nucleus directs the cell's activities.
3. The cytoplasm, between the nucleus and the plasma membrane, is where most cell activities take place.
4. Cells perform the following functions:
   - Cells metabolize and release energy.
   - Cells synthesize molecules.
   - Cells provide a means of communication.
   - Cells reproduce and provide for inheritance.

3.2 How We See Cells

1. Light microscopes allow us to visualize the general features of cells.
2. Electron microscopes allow us to visualize the fine structure of cells.

3.3 Plasma Membrane

1. The plasma membrane passively or actively regulates what enters or leaves the cell.
2. The plasma membrane is composed of a phospholipid bilayer, in which proteins are suspended (commonly depicted by the fluid-mosaic model).

3.4 Membrane Lipids

Lipids give the plasma membrane most of its structure and some of its function.

3.5 Membrane Proteins

1. Membrane proteins function as marker molecules, attachment proteins, transport proteins, receptor proteins, and enzymes.
2. Transport proteins include channel proteins, carrier proteins, and ATP-powered pumps.
3. Some receptor proteins are linked to and control channel proteins.
4. Some receptor molecules are linked to G protein complexes, which control numerous cellular activities.

3.6 Movement Through the Plasma Membrane

1. Lipid-soluble molecules pass through the plasma membrane readily by dissolving in the lipid bilayer. Small molecules diffuse between the phospholipid molecules of the plasma membrane.
2. Large non-lipid-soluble molecules and ions (e.g., glucose and amino acids) are transported through the membrane by transport proteins.
3. Large, non-lipid-soluble molecules, as well as very large molecules and even whole cells, can be transported across the membrane in vesicles.

Passive Membrane Transport

1. Diffusion is the movement of a substance from an area of higher solute concentration to one of lower solute concentration (down a concentration gradient).
2. The concentration gradient is the difference in solute concentration between two points divided by the distance separating the points.
3. The rate of diffusion increases with an increase in the concentration gradient, an increase in temperature, a decrease in molecular size, and a decrease in viscosity.
4. The end result of diffusion is uniform distribution of molecules.
5. Diffusion requires no expenditure of energy.
6. Osmosis is the diffusion of water (solvent) across a selectively permeable membrane.
7. Osmotic pressure is the force required to prevent the movement of water across a selectively permeable membrane.

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8. Isosmotic solutions have the same concentration of solute particles, hyperosmotic solutions have a greater concentration of solute particles, and hyposmotic solutions have a lesser concentration of solute particles.
9. Cells placed in an isotonic solution neither swell nor shrink. In a hypertonic solution, they shrink (crenate); in a hypotonic solution, they swell and may burst (lyse).
10. Mediated transport is the movement of a substance across a membrane by means of a transport protein. The substances transported tend to be large, water-soluble molecules.
11. Facilitated diffusion moves substances down their concentration gradient and does not require energy (ATP).

Active Membrane Transport

1. Active transport can move substances against their concentration gradient and requires ATP. An exchange pump is an active transport mechanism that simultaneously moves two substances in opposite directions across the plasma membrane.
2. In secondary active transport, an ion is moved across the plasma membrane by active transport, and the energy produced by the ion diff using back down its concentration gradient can transport another molecule, such as glucose, against its concentration gradient.
3. Vesicular transport is the movement of large volumes or release of substances across the plasma membrane through the formation or release of a vesicle.
4. Endocytosis is the bulk movement of materials into cells.
   - Phagocytosis is the bulk movement of solid material into cells by the formation of a vesicle.
   - Pinocytosis is similar to phagocytosis, except that the ingested material is much smaller and is in solution.
5. Receptor-mediated endocytosis allows for endocytosis of specific molecules.
6. Exocytosis is the secretion of materials from cells by vesicle formation.
7. Endocytosis and exocytosis both require energy.

3.7 Cytoplasm

The cytoplasm is the material outside the nucleus and inside the plasma membrane.

Cytosol

1. Cytosol consists of a fluid part (the site of chemical reactions), the cytoskeleton, and cytoplasmic inclusions.
2. The cytoskeleton supports the cell and is responsible for cell movements. It consists of protein fibers.
   - Microtubules are hollow tubes composed of the protein tubulin. They form spindle fibers and are components of centrioles, cilia, and flagella.
   - Actin filaments are small protein fibrils that provide structure to the cytoplasm or cause cell movements.
   - Intermediate filaments are protein fibers that provide structural strength to cells.
3. Membranes do not surround cytoplasmic inclusions, such as lipochromes.

3.8 The Nucleus and Cytoplasmic Organelles

Organelles are subcellular structures specialized for specific functions.

The Nucleus

1. The nuclear envelope consists of a double membrane with nuclear pores.

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2. DNA and associated proteins are found inside the nucleus as chromatin.
3. DNA is the hereditary material of the cell. It controls cell activities by producing proteins through RNA.
4. A gene is a portion of a DNA molecule. Genes determine the proteins in a cell.
5. Nucleoli consist of RNA and proteins and are the sites of ribosomal subunit assembly.

Ribosomes

1. Ribosomes consist of small and large subunits manufactured in the nucleolus and assembled in the cytoplasm.
2. Ribosomes are the sites of protein synthesis.
3. Ribosomes can be free or associated with the endoplasmic reticulum.

Endoplasmic Reticulum

1. The endoplasmic reticulum is an extension of the outer membrane of the nuclear envelope; it forms tubules or sacs (cisternae) throughout the cell.
2. The rough endoplasmic reticulum has ribosomes and is a site of protein synthesis and modification.
3. The smooth endoplasmic reticulum lacks ribosomes and is involved in lipid production, detoxification, and calcium storage.

Golgi Apparatus

The Golgi apparatus is a series of closely packed, modified cisternae that modify, package, and distribute lipids and proteins produced by the endoplasmic reticulum.

Secretory Vesicles

Secretory vesicles are membrane-bound sacs that carry substances from the Golgi apparatus to the plasma membrane, where the contents of the vesicles are released by exocytosis.

Lysosomes

1. Lysosomes are membrane-bound sacs containing hydrolytic enzymes. Within the cell, the enzymes break down phagocytized material and nonfunctional organelles (autophagy).
2. Enzymes released from the cell by lysis or enzymes secreted from the cell can digest extracellular material.

Peroxisomes

Peroxisomes are membrane-bound sacs containing enzymes that digest fatty acids and amino acids, as well as enzymes that catalyze the breakdown of hydrogen peroxide.

Proteasomes

Proteasomes are large, multienzyme complexes, not bound by membranes that digest selected proteins within the cell.

Mitochondria

1. Mitochondria are the major sites for the production of ATP, which cells use as an energy source.
2. The mitochondria have a smooth outer membrane and an inner membrane that is infolded to form cristae.
3. Mitochondria contain their own DNA, can produce some of their own proteins, and can replicate independently of the cell.

Centrioles and Spindle Fibers

1. Centrioles are cylindrical organelles located in the centrosome, a specialized zone of the cytoplasm that serves as the site of microtubule formation.

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