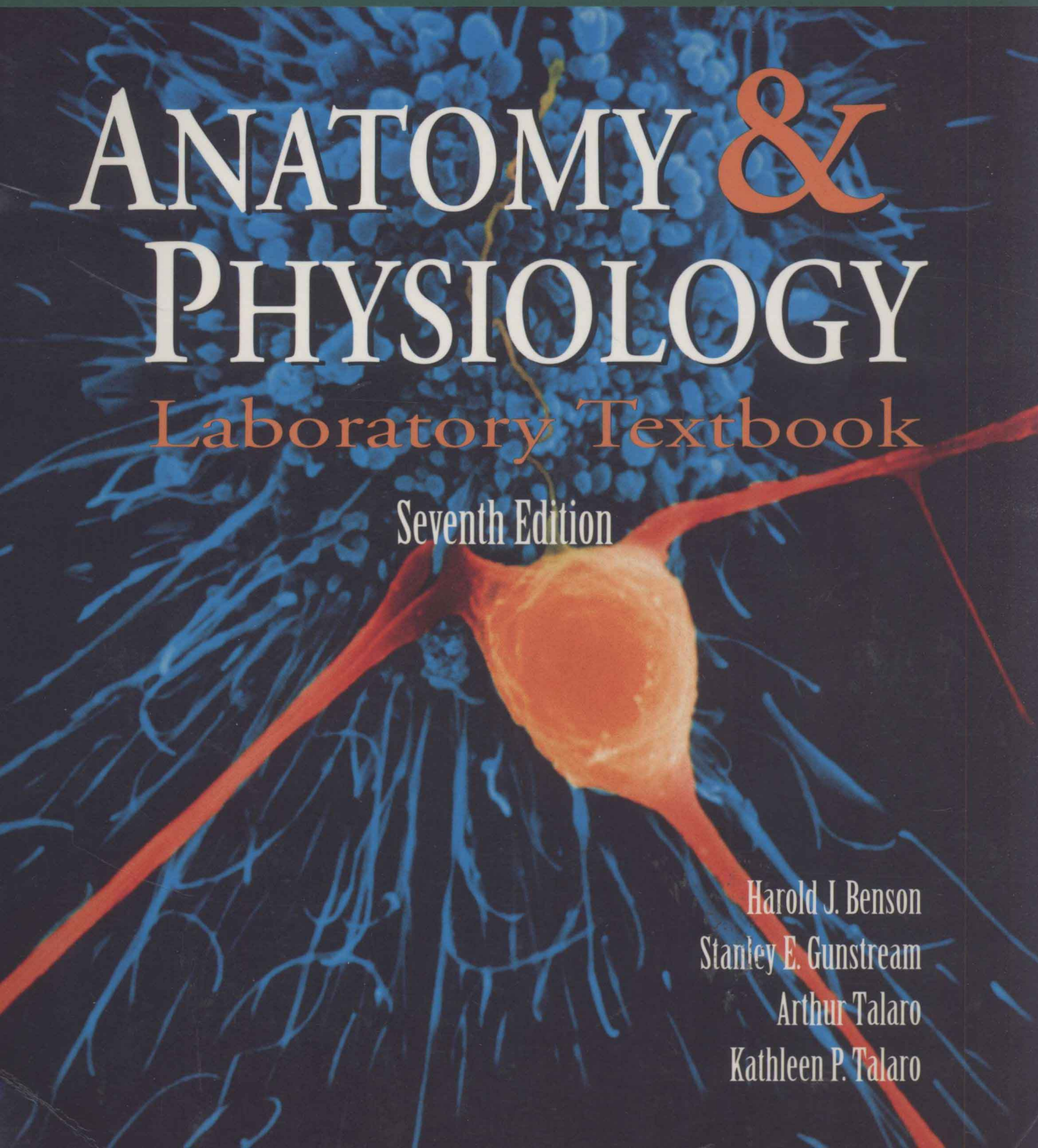
Short Version

Anatomy & Physiology

Laboratory Textbook

Seventh Edition



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Preface

In this seventh edition of the short version of the *Anatomy and Physiology Laboratory Textbook* we have done the following: (1) expanded the Histology Atlas to incorporate new material, (2) provided four histology self-quizzes, (3) expanded the instructions for using Intelitool equipment, (4) upgraded many of the anatomical illustrations, (5) updated certain concepts that shed new light on previously little understood theories, (6) shortened some exercises and transferred some material to the Instructor's handbook to make room for new material, and (7) changed many illustrations to improve visualization.

The Histology Atlas has been expanded to forty pages from thirty-six. Although much of the Atlas remains essentially the same, additions and alterations were made that relate to the skin, tongue, respiratory passages, lungs, female reproductive organs, and spermatogenesis.

One of the shortcomings of previous editions has been the inability to measure the extent of a student's comprehension of histology. Although some questions in the Laboratory Reports do address this problem, we have felt for some time that more testing was needed.

At many institutions students are subjected to laboratory practical examinations in which microscopes are set up with various types of tissues displayed for identification by the student. This type of exam can be quite traumatic to the student the first time it is experienced. To give the student an opportunity to see how he or she might do on such an exam, we have developed four "Self-Quizzes". In laboratories where practical exams are used, these self-quizzes can do much to show the student ahead of time what type of questions might be asked. Even if no laboratory practical is used, the self-quizzes are helpful review tests.

The four Self-Quizzes are located at the end of Exercise 66. They encompass eighty-six microscope set-ups with 261 questions. Answers to the quizzes are located on pages 178 and 280. At appropriate places in the manual students are prompted to take each quiz.

Another shortcoming of the previous edition was that we didn't have complete instructions for performing Intelitool experiments on all computer platforms. At the time of publication of the sixth edition, only instructions for the Apple II were available. Since then software and instructions for IBM (or compatible PC), and Macintosh have been developed. On one system (Spirocomp) instructions for Windows 95 are also available. In this edition we have included instructions for running all the Intelitool experiments on all platforms.

The expansion of the Intelitool exercises and the addition of the histology self-quizzes has resulted in the addition of 32 pages of new material to this edition. To accommodate this information without increasing the size of the book we have had to eliminate some less important material, compacted some exercises, and transferred some information to the Instructor's Handbook. The bar codes for the *Slice of Life* discs fall in this last category. Instructors that use these bar codes may wish to provide students with Xerox copies of the codes.

One other item that was transferred from the manual to the Instructor's Handbook was the former Appendix B that contains recipes for the various solutions and reagents that are used in the experiments. Since students don't generally need this information, it was felt that placement in the I.H. was appropriate.

In previous editions, a set of $2'' \times 2''$ Kodachrome slides pertaining to the Histology Atlas illustrations was made available to users of the manual. They are still available to those who do not have a set. A legend explaining the slides is provided in the back of the Instructor's Handbook that is helpful when projecting the slides to groups of students. The slides can be had at no cost by simply contacting the Educational Services Department at McGraw-Hill in Dubuque, IA.

The changes in this edition are partially the result of suggestions made by the following individuals who currently use the complete and short versions of this manual: James Ezell and Barbara L. Stewart of J. Sargeant Reynolds Community College, Richmond, VA; Ralph E. Reiner of College of the Redwoods, Eureka, CA; A. Scott Helgeson of Des Moines Area Community College, Des Moines, IA; Juville Dario-Becker of Central Virginia Community College, Lynchburg, VA; Donna Sasnow of South Suburban College, South Holland, IL; and Marian G. Langer of St. Francis College, Loretto, PA. Our sincerest gratitude is extended here for their valuable assistance. Although we haven't been able to incorporate all the changes requested, most ideas have been included in this edition.

Introduction

These laboratory exercises have been developed to provide you with a basic understanding of anatomical and physiological principles that underlie medicine, nursing, dentistry, and other related health professions. Laboratory procedures that reflect actual clinical practices are included wherever feasible. In each exercise you will find essential terminology that will become part of your working vocabulary. Mastery of all concepts, vocabulary, and techniques will provide you with a core of knowledge crucial to succeed in your chosen profession.

During the first week of this course your instructor will provide you with a schedule of laboratory exercises in the order of their performance. There is an implied expectation that you will have familiarized yourself with the content of each experiment prior to the week's session, thus ensuring that you will be properly prepared so as to minimize disorganization and mistakes.

The *Laboratory Reports* coinciding with each exercise are located in the back of the book. They are perforated for easy removal; be sure to remove each sheet as necessary. This will facilitate data collection, completion of answers, and grading. Your instructor may give further procedural details on the handling of these reports.

The exercises in this laboratory guide consist essentially of four kinds of activities: (1) illustration labeling, (2) anatomical dissections, (3) physiological experiments, and (4) microscopic studies. The following suggestions should be helpful in performing these assignments.

Labeling The activity of labeling illustrations is essentially a determination of your understanding of the written text. Since all labeled structures are explicitly described in the manual, all that is necessary is to read the manual very carefully. Incorrectly labeled illustrations usually indicate a lack of comprehension.

Once the illustrations are labeled, they can be useful to you in two other ways. First, the illustrations may be used for reference purposes in dissections or examinations of anatomical specimens. This is particularly true in the skeletal and nervous systems. Secondly, the illustrations can be used for review purposes. If the number legend of the labels is covered over as you mentally attempt to name the structures on the illustration, you can easily determine your level of comprehension. Periodic reviews of this type during the semester will be very helpful.

In general, the labeling of illustrations will usually be performed prior to coming to the laboratory. In this way the laboratory time will be used primarily for dissections, experimentation, or microscopic examination.

Dissections Unlike other versions of this laboratory manual, the cat or fetal pig is not used for dissection. At some institutions the human cadaver is used with this manual for some anatomical studies. Although Exercise 3 does involve dissection of a rat, the experience is only a cursory one to present an overview of the various organ systems. Occasionally, sheep and beef organs will be studied. For certain types of physiological experiments, frogs are used to demonstrate certain phenomena.

When using live animals in experimental procedures it is imperative that they be handled with great care. Consideration must be exercised to minimize pain in all experiments on vertebrate animals. Inconsiderate or haphazard treatment of any animal will not be tolerated.

Physiological Experiments Before performing any physiological experiments be sure that you understand the overall procedure. Reading the experiment prior to entering the laboratory will help a great deal.

Handle all instruments carefully. Most pieces of equipment are expensive, may be easily damaged, and are sometimes irreplaceable. The best insurance against breakage or damage is to thoroughly understand how the equipment is expected to function.

Maintain astuteness in observations and record keeping. Record data immediately; postponement detracts from precision. Insightful data interpretation will also be expected.

Microscopic Studies Cytological and histological studies will be made to lend meaning to text descriptions. Familiarize yourself with the contents of the *Histology Atlas,* which includes photomicrographs of most of the tissues you will study in this course. Note that the Atlas is located in the middle of the book and is readily located due to the color band on the edges of its pages. If drawings are required, execute them with care and label those structures that are significant.

Histology Self-Quizzes Periodically you will be prompted to test your comprehension of histological studies by taking *Histology Self-Quizzes* that are located on pages 373 to 388. Note that here are four of them. The answers to each self-quiz are included on designated pages so that you can determine for yourself your degree of understanding. You should find them quite helpful, particularly if lab practical exams are a part of this course.

Laboratory Efficiency Success in any science laboratory situation requires a few additional disciplines:

1. Always follow the instructor's verbal comments at the beginning of each laboratory session. It is at this time that difficulties will be pointed out, group assignments will be made, and procedural changes will be announced. Take careful notes on substitutions or changes in methods or materials.
2. In view of the above statement, it is obvious that the beginning of each laboratory period is a critical time. It is for this reason that tardiness is intolerable. If you are late to class, don't expect your instructor to be very helpful.
3. Keep your work area tidy at all times. Books, bags, purses, and extraneous supplies should be located away from the work area. Tidiness should also extend to assembly of all apparatus.
4. Abstain from eating, drinking, or smoking within the confines of the laboratory.
5. Report immediately to the instructor any injuries that may occur.
6. Be serious-minded and methodical. Horseplay, silliness, or flippancy will not be tolerated during experimental procedures.
7. Work independently, but cooperatively, when performing team experiments. Attend to your assigned responsibility, but be willing to lend a hand to others where necessary. Participation and development of laboratory techniques are an integral part of the course.

Laboratory Reports When seeking answers to the questions and problems on the Laboratory Reports, work independently. The effort you expend to complete these reports is as essential as doing the experiment. The easier route of letting someone else solve the problems for you will handicap you at examination time. You are taking this course to learn anatomy and physiology. No one else can learn it for you.

Some of the laboratory experiments included in this book may be hazardous if materials are handled improperly or if procedures are conducted incorrectly. Safety precautions are necessary when you are working with chemicals, glass test tubes, hot water baths, sharp instruments, and the like, or for any procedures that generally require caution. Your school may have set regulations regarding safety procedures that your instructor will explain to you. Should you have any problems with materials or procedures, please ask your instructor for help.

Contents

Anatomical Terminology

1

Anatomical description would be extremely difficult without specific terminology. A consensus prevails among many students that anatomists synthesize multisyllabic words in a determined conspiracy to harass the beginner's already overburdened mind. Naturally, nothing could be further from the truth.

Scientific terminology is created out of necessity. It functions as a precise tool that allows us to say a great deal with a minimum of words. Conciseness in scientific discussion not only saves time, but it promotes clarity of understanding as well.

Most of the exercises in this laboratory manual employ the terms defined in this exercise. They are used liberally to help you locate structures that are to be identified on the illustrations. If you do not know the exact meanings of these words, obviously you will be unable to complete the required assignments. Before you attempt to label any of the illustrations in this exercise, read the text material first.

Relative Positions

Descriptive positioning of one structure with respect to another is accomplished with the following pairs of words. Their Latin or Greek derivations are provided to help you understand their meanings.

Superior and Inferior These two words are used to denote vertical levels of position. The Latin word *super* means *above;* thus, a structure that is located above another one is said to be superior. Example: The nose is *superior* to the mouth.

The Latin word *inferus* means *below* or *low;* thus, an inferior structure is one that is below or under some other structure. Example: The mouth is *inferior* to the nose.

Anterior and Posterior Fore and aft positioning of structures are described with these two terms. The word *anterior* is derived from the Latin, *ante,* meaning *before.* A structure that is anterior to another one is in front of it. Example: Bicuspids are *anterior* to molars.

Anterior surfaces are the most forward surfaces of the body. The front portions of the face, chest, and abdomen are anterior surfaces.

Posterior is derived from the Latin *posterus,* which means *following.* The term is the opposite of anterior. Example: The molars are *posterior* to the bicuspids.

When these two terms are applied to the surfaces of the hand and arm, it is assumed that the body is in the *anatomical position,* which is as shown in figures 1.1 and 1.2. In the anatomical position the palms of the hands face forward.

Cranial and Caudal When describing the location of structures of four-legged animals, these terms are often used in place of anterior and posterior. Since the word *cranial* pertains to the skull (Greek: *kranion,* skull), it may be used in place of anterior. The word *caudal* (Latin: *cauda,* tail) may be used in place of posterior.

Dorsal and Ventral These terms, as used in comparative anatomy of animals, assume all animals, including humans, to be walking on all fours. The dorsal surfaces are thought of as *upper* surfaces, and the ventral surfaces as *underneath* surfaces.

The word *dorsal* (Latin: *dorsum,* back) not only applies to the back of the trunk of the body but may also be used in describing the back of the head and the back of the hand.

Standing in a normal posture, a human's dorsal surfaces become posterior. A four-legged animal's back, on the other hand, occupies a superior position.

The word *ventral* (Latin: *venter,* belly) generally pertains to the abdominal and chest surfaces. However, the underneath surfaces of the head and feet of four-legged animals are also often referred to as ventral surfaces. Likewise, the palm of the hand may also be referred to as being ventral.

Proximal and Distal These terms are used to describe parts of a structure with respect to its point of attachment to some other structure. In the case of the arm or leg, the point of reference is where the

limb is attached to the trunk of the body. In the case of a finger, the point of reference is where it is attached to the palm of the hand.

Proximal (Latin: *proximus,* nearest) refers to that part of the limb nearest to the point of attachment. Example: The upper arm is the *proximal* portion of the arm.

Distal (Latin: *distare,* to stand apart) means just the opposite of proximal. Anatomically, the distal portion of a limb or other part of the body is that portion that is most remote from the point of reference (attachment). Example: The hand is *distal* to the arm.

Medial and Lateral These two terms are used to describe surface relationships with respect to the median line of the body. The *median line* is an imaginary line on a plane that divides the body into right and left halves.

The term *medial* (Latin: *medius,* middle) is applied to surfaces of structures that are closest to the median line. The medial surface of the arm, for example, is the surface next to the body because it is closest to the median line.

As applied to the appendages, the term *lateral* is the opposite of medial. The Latin derivation of this word is *lateralis,* which pertains to *side.* The lateral surface of the arm is the outer surface, or that surface farthest away from the median line. The sides of the head are said to be lateral surfaces.

Body Sections

To observe the structure and relative positions of internal organs it is necessary to view them in sections that have been cut through the body. Considering the body as a whole, there are only three planes to identify. Figure 1.1 shows these sections.

Sagittal Sections A section parallel to the long axis of the body (longitudinal section) that divides the body into right and left sides is a *sagittal section.* If such a section divides the body into equal halves, as in figure 1.1, it is said to be a *midsagittal section.*

Frontal Section A longitudinal section that divides the body into front and back portions is a *frontal* or *coronal* section. The other longitudinal section seen in figure 1.1 is of this type.

Transverse Sections Any section that cuts through the body in a direction that is perpendicular to the long axis is a *transverse* or *cross section.*

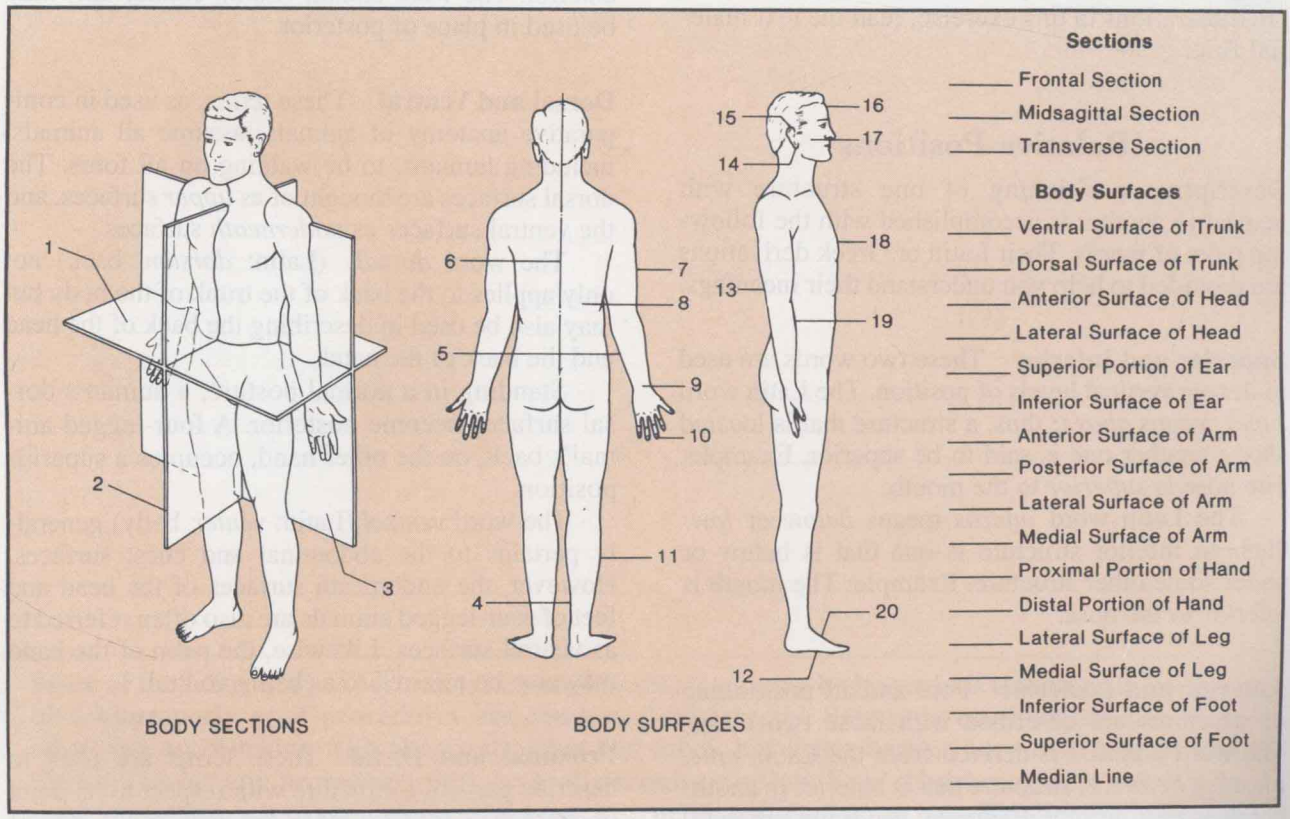


Figure 1.1 Body sections and surfaces.

This is the third section shown in figure 1.1. In this case it is parallel to the ground.

Although these sections have been described here only in relationship to the body as a whole, they can be used on individual organs such as the arm, finger, or tooth.

Assignment:

To test your understanding of the above descriptive terminology, identify the labels in figure 1.1 by placing the correct numbers in front of the terms to the right of the illustrations. Also, record these numbers on the Laboratory Report.

Regional Terminology

Various terms such as *flank, groin, brachium,* and *hypochondriac* have been applied to specific regions of the body to facilitate localization. Figures 1.2 and 1.3 pertain to some of the more predominantly used terminology.

Trunk

The anterior surface of the trunk may be subdivided into two pectoral, two groin, and the abdominal regions. The upper chest region may be designated as **pectoral** or **mammary** regions. The anterior trunk region not covered by the ribs is the **abdominal** region. The depressed area where the thigh of the leg meets the abdomen is the **groin.**

The posterior surface, or dorsum, of the trunk can be differentiated into the costal, lumbar, and buttocks regions. The **costal** (Latin: *costa,* rib) portion is the part of the dorsum that lies over the rib cage. The lower back region between the ribs and hips is the **lumbar** or **loin** region. The **buttocks** are the rounded eminences of the rump formed by the gluteal muscles; this is also called the **gluteal** region.

The side of the trunk that adjoins the lumbar region is called the **flank.** The armpit region that is between the trunk and the arm is the **axilla.**

Upper Extremities

To differentiate the parts of the upper extremities, the term **brachium** is used for the upper arm and **antebrachium** for the forearm (between the elbow and wrist). The elbow area on the posterior surface of the arm is the **cubital** area. That area on the opposite side of the elbow is the **antecubital** area. It is also correct to refer to the entire anterior surface of the antebrachium as being antecubital.

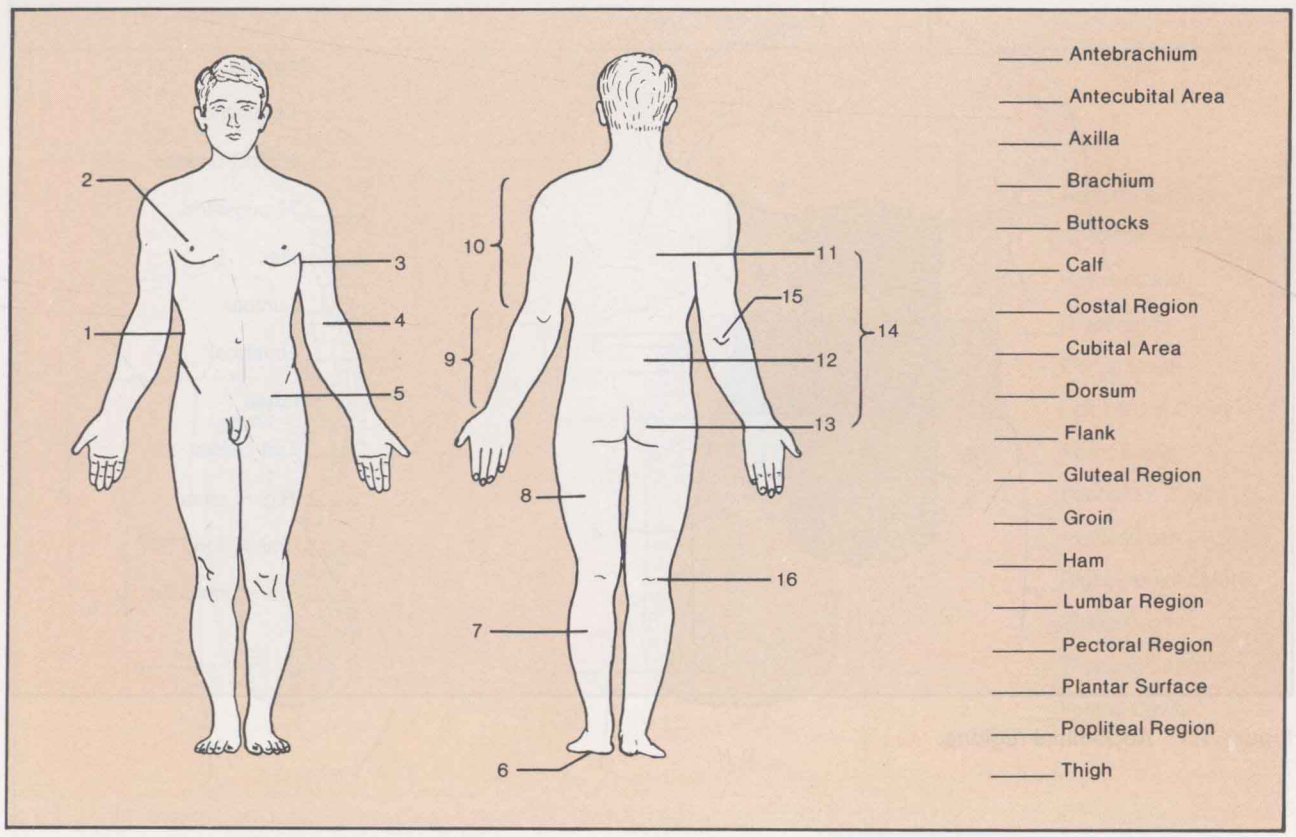


Figure 1.2 Regional terminology.

Lower Extremities

The upper portion of the leg is designated as the **thigh,** and the lower fleshy posterior portion is called the **calf.** Between the thigh and calf on the posterior surface, opposite to the knee, is a depression called the **ham** or **popliteal** region. The sole of the foot is the **plantar** surface.

Abdominal Divisions

The abdominal surface may be divided into quadrants or into nine distinct areas. To divide the abdomen into nine regions one must establish four imaginary planes: two that are horizontal and two that are vertical. These planes and areas are shown in figure 1.3. The **transpyloric plane** is the upper horizontal plane, which would pass through the lower portion of the stomach (pyloric portion). The **transtubercular plane** is the other horizontal plane that touches the top surfaces of the hipbones (iliac crests). The two vertical planes, or **right** and **left lateral planes,** are approximately halfway between the midsagittal plane and the crests of the hips.

The planes describe the umbilical, epigastric, hypogastric, hypochondriac, and lumbar regions. The **umbilical** area lies in the center, includes the navel, and is bordered by the two horizontal and two vertical planes. Immediately above the umbilical area is the **epigastric,** which covers much of the stomach. Below the umbilical zone is the **hypogastric,** or *pubic area.* On each side of the epigastric are a right and left **hypochondriac** areas, and beneath the hypochondriac areas are the right and left **lumbar** areas. (Note that although we tend to think of only the lower back as being the lumbar region, we see here that it extends around to the anterior surface as well.)

Assignment:

Label figures 1.2 and 1.3 and transfer these numbers to the Laboratory Report.

Laboratory Report

After transferring all the labels from figures 1.1 through 1.3 to the proper columns on Laboratory Report 1,2, answer the questions that pertain to this exercise.

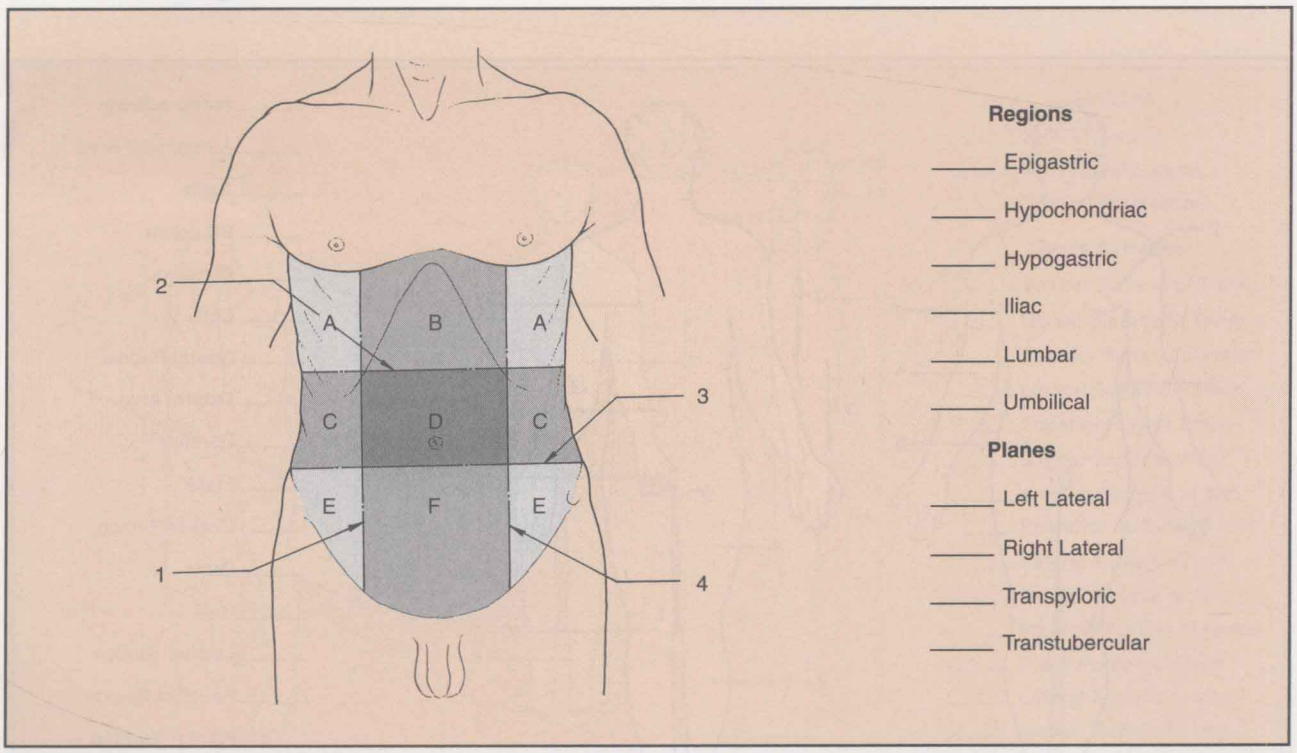


Figure 1.3 Abdominal regions.

Body Cavities and Membranes

2

All the internal organs *(viscera)* are contained in body cavities, which are completely or partially lined with smooth membranes. The relationships of these cavities to each other, the organs they contain, and the membranes that line them will be studied in this exercise.

Body Cavities

Figure 2.1 illustrates the seven principal cavities of the body. The two major cavities are the dorsal and ventral cavities. The **dorsal cavity,** which is nearest to the dorsal surface, includes the cranial and spinal cavities. The **cranial cavity** is the hollow portion of the skull that contains the brain. The **spinal cavity** is a long tubular canal within the vertebrae that contains the spinal cord. The **ventral cavity** is the largest cavity and encompasses the chest and abdominal regions.

The superior and inferior portions of the ventral cavity are separated by a dome-shaped thin muscle, the **diaphragm.** The **thoracic cavity,** which is that part of the ventral cavity superior to the diaphragm, is separated into right and left compartments by a membranous partition or septum called the **mediastinum.** The lungs are contained in these right and left compartments. The heart, trachea, esophagus, and thymus gland are enclosed within the mediastinum.

Figure 2.2 reveals the relationship of the lungs to the structures within the mediastinum. Note that within the thoracic cavity there exists a pair of right and left **pleural cavities** that contain the lungs and a **pericardial cavity** that contains the heart.

The **abdominopelvic cavity** is the portion of the ventral cavity that is inferior to the diaphragm. It consists of two portions: the abdominal and pelvic

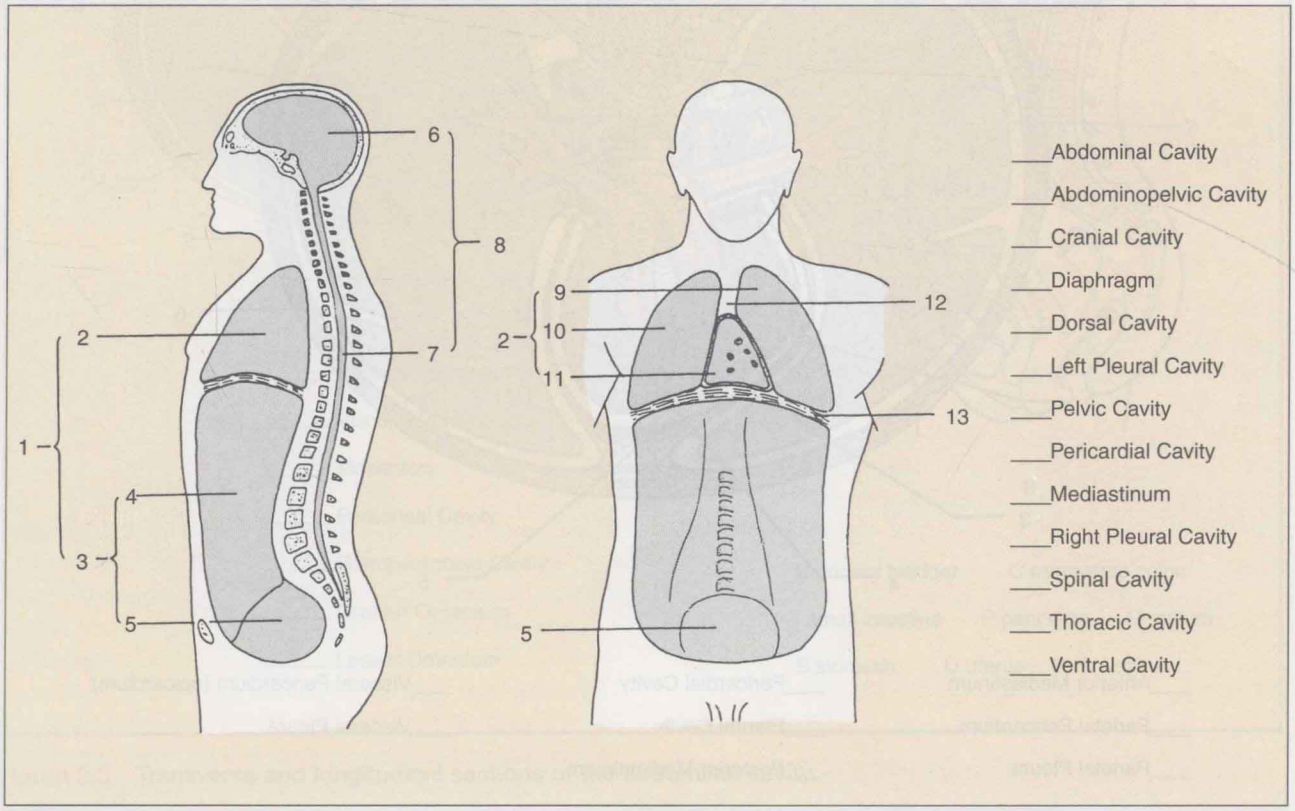


Figure 2.1 Body cavities.

cavities. The **abdominal cavity** contains the stomach, liver, gallbladder, pancreas, spleen, kidneys, and intestines. The **pelvic cavity** is the most inferior portion of the abdominopelvic cavity and contains the urinary bladder, sigmoid colon, rectum, uterus, and ovaries.

Body Cavity Membranes

The body cavities are lined with serous membranes that provide a smooth surface for the enclosed internal organs. Although these membranes are quite thin, they are strong and elastic. Their surfaces are moistened by a self-secreted *serous fluid* that facilitates ease of movement of the viscera against the cavity walls.

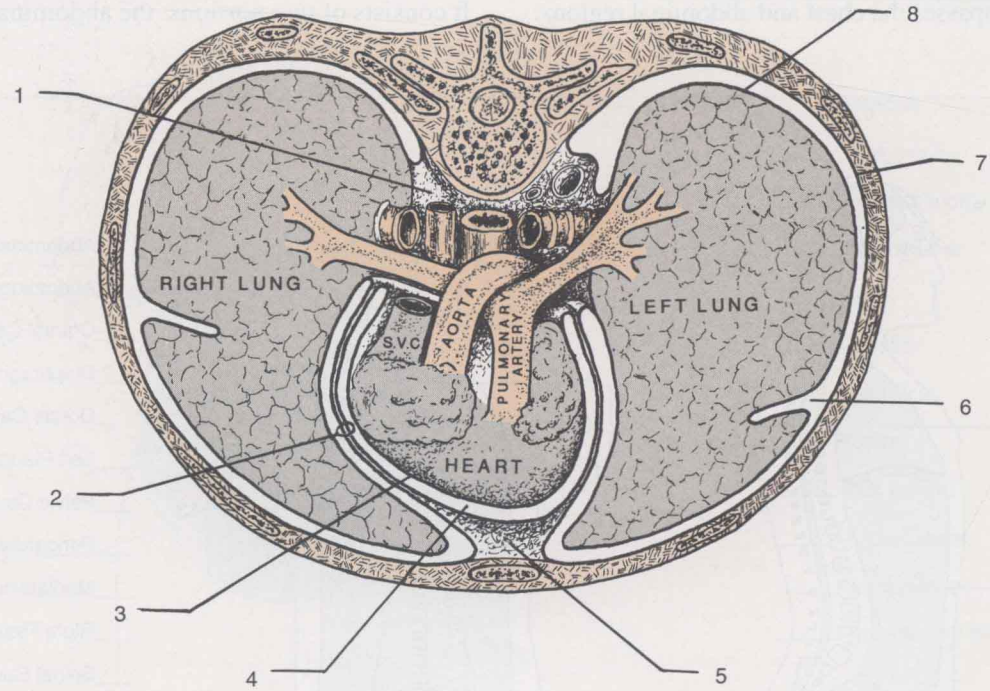
Thoracic Cavity Membranes

The membranes that line the walls of the right and left thoracic compartments are called **parietal pleurae** (*pleura,* singular). The lungs, in turn, are covered with **visceral** (pulmonary) **pleurae.** Note in Figure 2.2 that these pleurae are continuous with each other. The potential cavity between the parietal and visceral pleurae is the **pleural cavity.** Inflammation of the pleural membranes results in a condition called *pleurisy.*

Within the broadest portion of the mediastinum lies the heart. It, like the lungs, is covered by a thin serous membrane, the **visceral pericardium,** or **epicardium.** Surrounding the heart is a double-layered fibroserous sac, the **parietal pericardium.** The inner layer of this sac is a serous membrane that is continuous with the epicardium of the heart. Its outer layer is fibrous, which lends considerable strength to the structure. A small amount of serous fluid produced by the two serous membranes lubricates the surface of the heart to minimize friction as it pulsates within the parietal pericardium. The potential space between the visceral and parietal pericardia is called the **pericardial cavity.**

Abdominal Cavity Membranes

The serous membrane of the abdominal cavity is the peritoneum. It does not extend deep down into the pelvic cavity, however; instead, its most inferior



___Anterior Mediastinum
___Parietal Pericardium
___Parietal Pleura
___Pericardial Cavity
___Pleural Cavity
___Posterior Mediastinum
___Visceral Pericardium (epicardium)
___Visceral Pleura

Figure 2.2 Transverse section through thorax.

boundary extends across the abdominal cavity at a level that is just superior to the pelvic cavity. The top portion of the urinary bladder is covered with the peritoneum.

In addition to lining the abdominal cavity, the peritoneum has double-layered folds called **mesenteries,** which extend from the dorsal body wall to the viscera, holding these organs in place. These mesenteries contain blood vessels and nerves that supply the viscera enclosed by the peritoneum.

That part of the peritoneum attached to the body wall is the **parietal peritoneum.** The peritoneum that covers the visceral surfaces is the **visceral peritoneum.** The potential cavity between the parietal and visceral peritoneums is called the **peritoneal cavity.**

Extending downward from the inferior surface of the stomach is a large mesenteric fold called the **greater omentum.** This double membrane structure passes downward from the stomach in front of the intestines, sometimes to the pelvis, and back up to the transverse colon, where it is attached. Because it is folded upon itself it is essentially a double mesentery consisting of four layers. Protuberance of the abdomen in obese individuals is due to fat accumulation in the greater omentum.

A smaller mesenteric fold, the **lesser omentum,** extends between the liver and the superior surface of the stomach and a short portion of the duodenum. Illustration B of figure 2.3 shows the relationship of these two omenta to the abdominal organs.

Assignment:
Label figures 2.1, 2.2, and 2.3

Laboratory Report

Complete Laboratory Report 1,2 by answering the questions that pertain to this exercise.

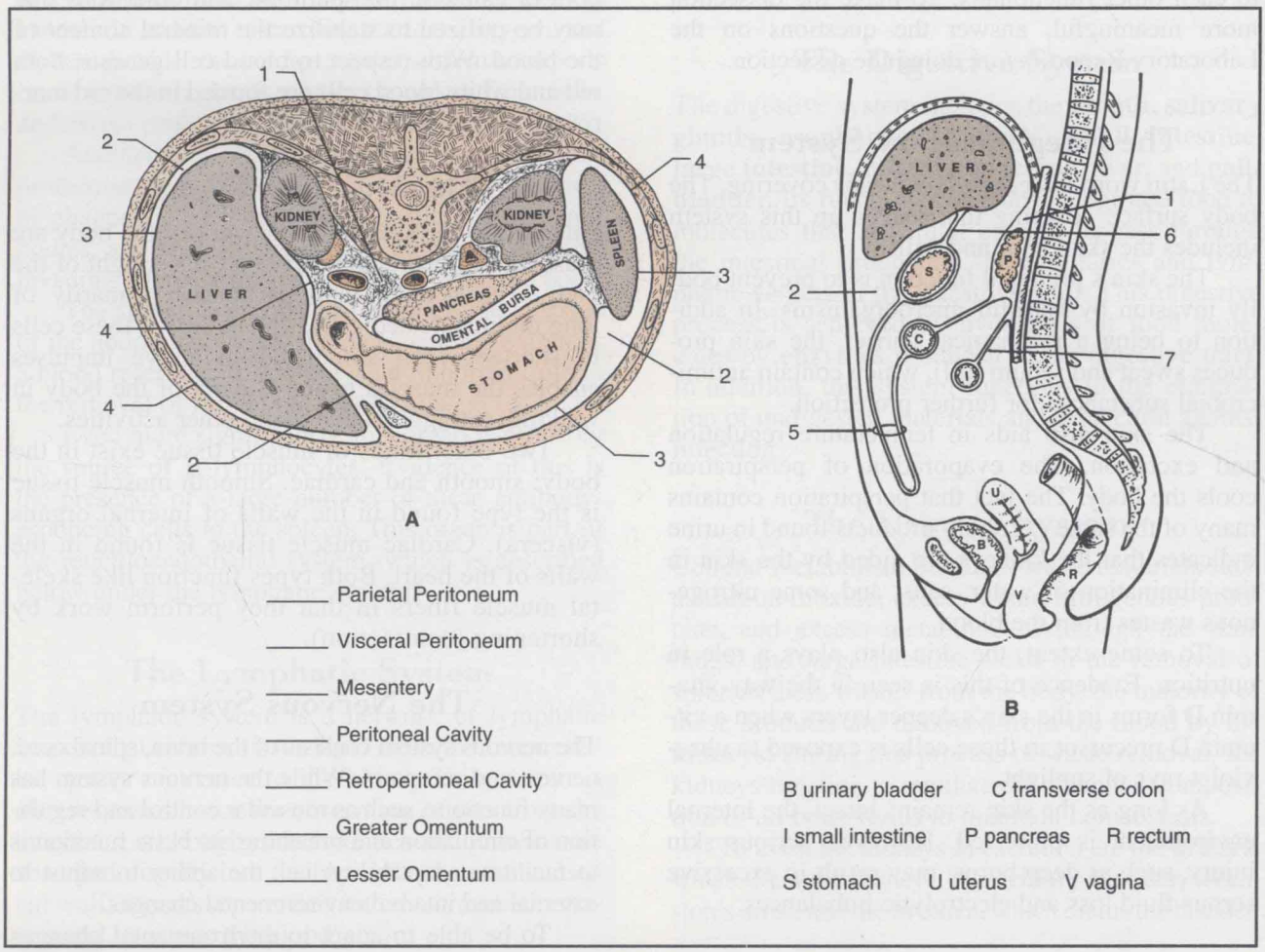


Figure 2.3 Transverse and longitudinal sections of the abdominal cavity.

3 Organ Systems: Rat Dissection

During this laboratory period we will dissect a freshly killed rat to perform a cursory study of the majority of the organ systems. Since rats and humans have considerable anatomical and physiological similarities, much will be learned here about human anatomy.

Before beginning the dissection, however, it will be necessary to review the eleven systems of the body. A brief description of each system follows. Keep in mind that an **organ** is defined as a structure composed of two or more tissues that performs one or more physiological functions. A **system,** on the other hand, is a group of organs that directly relate to each other functionally. To make the dissection more meaningful, answer the questions on the Laboratory Report *before* doing the dissection.

The Integumentary System

The Latin word *integumentum* means covering. The body surface covering that makes up this system includes the skin, hair, and nails.

The skin's principal function is to prevent bodily invasion by harmful microorganisms. In addition to being a mechanical barrier, the skin produces sweat and sebum (oil), which contain antimicrobial substances for further protection.

The skin also aids in temperature regulation and excretion. The evaporation of perspiration cools the body. The fact that perspiration contains many of the same excretory products found in urine indicates that the kidneys are aided by the skin in the elimination of water, salts, and some nitrogenous wastes from the blood.

To some extent, the skin also plays a role in nutrition. Evidence of this is seen in the way vitamin D forms in the skin's deeper layers when a vitamin D precursor in those cells is exposed to ultraviolet rays of sunlight.

As long as the skin remains intact, the internal environment is protected. However, serious skin injury, such as deep burns, may result in excessive serous fluid loss and electrolytic imbalances.

The Skeletal System

The skeletal system forms a solid framework around which the body is constructed. It consists of bones, cartilage, and ligaments. This system provides support and protection for the softer parts of the body. Delicate organs such as the lungs, heart, brain, and spinal cord are protected by the bony enclosure of the skeletal system.

In addition to protection, the bones provide points of attachment for muscles, which act as levers when the muscles contract. This arrangement makes movement possible.

Two other important functions of the skeletal system are mineral storage and blood cell production. The mineral component of bones provides a pool of calcium, phosphorous, and other ions that may be utilized to stabilize the mineral content of the blood. With respect to blood cell genesis, both red and white blood cells are formed in the red marrow of certain bones of the body.

The Muscular System

Attached to the skeletal framework of the body are muscles that make up nearly half the weight of the body. The skeletal muscles consist primarily of long multinucleated cells. The ability of these cells to shorten when stimulated by nerve impulses enables the muscles to move parts of the body in walking, eating, breathing, and other activities.

Two other kinds of muscle tissue exist in the body: smooth and cardiac. Smooth muscle tissue is the type found in the walls of internal organs (viscera). Cardiac muscle tissue is found in the walls of the heart. Both types function like skeletal muscle fibers in that they perform work by shortening (contraction).

The Nervous System

The nervous system consists of the brain, spinal cord, nerves, and receptors. While the nervous system has many functions, such as muscular control and regulation of circulation and breathing, its basic function is to facilitate adaptability; i.e., the ability to adjust to external and internal environmental changes.

To be able to adapt to environmental changes there are, first of all, a multitude of different kinds of **receptors** throughout the body that are activated by various kinds of stimuli. A receptor may be stimulated by changes in such things as temperature,

pressure, chemicals, sound waves, or light. Once activated, nerve impulses pass along **conduction pathways** (nerves and spinal cord) to **interpretation centers** in the brain where recognition and evaluation of stimuli occur. Correct responses, which may be muscular or glandular, are then achieved by the nervous system via outgoing conduction pathways.

The Cardiovascular System

The cardiovascular system consists of the heart, arteries, veins, capillaries, blood, and spleen. The **heart** is a muscular pump that moves blood throughout the body. **Arteries** are thick-walled vessels that carry blood from the heart to the microscopic **capillaries** that permeate all the tissues. **Tissue fluid,** containing nutrients and oxygen, leaves the blood through the capillary walls and passes into the spaces between the cells. **Veins** are large blood vessels that convey blood from the capillaries back to the heart.

Thus, we see that this system provides transportation of various materials from one part of the body to another. In addition to carrying nutrients, oxygen, and carbon dioxide, the cardiovascular system transports hormones from glands, metabolic wastes from cells, and excess heat from muscles to the skin.

Another very important function of the blood is protection against microbial invasion. The presence of phagocytic (cell-eating) white blood cells, antibodies, and special enzymes in the blood prevents invading microorganisms from destroying the body.

The **spleen** is an oval structure on the left side of the abdominal cavity that acts to some extent as a blood reservoir. It also plays an important role in the removal of fragile red blood cells.

Even more significantly, this organ is probably the source of B-lymphocytes. Evidence of this is the presence of a large number of these antibody-producing cells in the spleen. This organ is part of the reticuloendothelial system, which is described below under the lymphatic system.

The Lymphatic System

The lymphatic system is a network of lymphatic vessels that returns tissue fluid from the intercellular spaces of tissues to the blood. This system is also responsible for the absorption of fats from the intestines. Although carbohydrates and proteins are absorbed directly into the blood through the intestinal wall, fats must pass first into the lymphatic system and then into the blood.

Once tissue fluid enters the lymphatic vessels it is called **lymph.** As this fluid moves through the lymphatic vessels it passes through nodules of lymphoid tissue called **lymph nodes.** Stationary phagocytic cells in these nodes remove bacteria and other foreign material, purifying the lymph before it is returned to the blood. Lymphocytes are also produced here.

Lymphoid tissue, as seen in the nodes, is also seen in the thymus gland, liver, spleen, tonsils, adenoids, appendix, Peyer's patches (in the digestive tract), and bone marrow. This diverse collection of lymphoidal tissue is collectively referred to as the **reticuloendothelial system,** an important component of the immune system.

The Respiratory System

The respiratory system consists of two portions: the air passageways and the respiratory portion. The actual exchange of gases between the blood and the air occurs in the respiratory portion. The lungs contain many tiny sacs called **alveoli,** which greatly increase the surface area for the transfer of oxygen and carbon dioxide in breathing. The passageways consist of the **nasal cavity, nasopharynx, larynx, trachea,** and **bronchi.**

The Digestive System

The digestive system includes the **mouth, salivary glands, esophagus, stomach, small intestine, large intestine, rectum, pancreas, liver,** and **gallbladder.** Its function is to convert ingested food to molecules that are small enough to pass through the intestinal lining into the capillaries and lymphatic vessels of the intestinal wall. This digestive process is achieved by hydrolysis of food molecules by **enzymes** produced in the digestive tract. In addition, this system functions in the elimination of undigested materials and protection against infection.

The Urinary System

Cellular metabolism produces waste materials such as carbon dioxide, excess water, nitrogenous products, and excess metabolites. Although the skin, lungs, and large intestine assist in the removal of some of these wastes from the body, the majority of these products are removed from the blood by the **kidneys.** During this process of waste removal, the kidneys function to regulate the chemical composition of all body fluids to maintain homeostasis.

To assist the kidneys in excretion are the **ureters,** which drain the kidneys, the **urinary bladder,** which stores urine, and the **urethra,** which drains the bladder.

The Endocrine System

This system consists of a number of widely dispersed **endocrine glands** that dispense their secretions