Organ Systems Overview

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

OBJECTIVES
1. Name the human organ systems, and indicate the major functions of each system.
2. List several major organs of each system, and identify them in a dissected rat, human cadaver or cadaver image, or dissectible human torso model.
3. Name the correct organ system for each organ studied in the laboratory.

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

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

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

Read through this summary of the body’s organ systems before beginning your rat dissection or examination of the predissected human cadaver. If a human cadaver is not available, photographs provided in this exercise (Figures 2.3 through 2.6) will serve as a partial replacement.
### Table 2.1 Overview of Organ Systems of the Body

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

## DISSECTION AND IDENTIFICATION

### The Organ Systems of the Rat

Many of the external and internal structures of the rat are quite similar in structure and function to those of the human, so a study of the gross anatomy of the rat should help you understand our own physical structure. The following instructions include directions for dissecting and observing a rat. In addition, instructions for observing organs (Activity 4, “Examining the Ventral Body Cavity,” page 18) also apply to superficial observations of a previously dissected human cadaver. The general instructions for observing external structures also apply to human cadaver observations. The photographs (Figures 2.3 through 2.6) will provide visual aids.
Note that four of the organ systems listed in the table (Table 2.1) ( integumentary, skeletal, muscular, and nervous) will not be studied at this time because they require microscopic study or more detailed dissection. 

**ACTIVITY 1**

**Observing External Structures**

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

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

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

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

**ACTIVITY 2**

**Examining the Oral Cavity**

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

**ACTIVITY 3**

**Opening the Ventral Body Cavity**

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

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

2. Lift the abdominal skin with a forceps, and cut through it with the scissors (Figure 2.1b). Close the scissor blades, and insert them flat under the cut skin. Moving in a cephalad direction, open and close the blades to loosen the skin from the underlying connective tissue and muscle. Now cut the skin along the body midline, from the pubic region to the lower jaw (Figure 2.1c, page 18). Finally, make a lateral cut about halfway down the ventral surface of each limb. Complete the job of freeing the skin with the scissor tips, and pin the flaps to the tray (Figure 2.1d). The underlying tissue that is now exposed is the skeletal musculature of the body wall and limbs. It allows voluntary body movement. Notice that the muscles are packaged in sheets of pearly white connective tissue (fascia), which protect the muscles and bind them together.

3. Carefully cut through the muscles of the abdominal wall in the pubic region, avoiding the underlying organs. Remember, to dissect means "to separate"—not mutilate! Now, hold and lift the muscle layer with a forceps and cut through the muscle layer from the pubic region to the bottom of the rib cage. Make two lateral cuts at the base of the rib. 

![Figure 2.1](image) Rat dissection: Securing for dissection and the initial incision. (a) Securing the rat to the dissection tray with dissecting pins. (b) Using scissors to make the incision on the median line of the abdominal region.
cage (Figure 2.2). A thin membrane attached to the inferior boundary of the rib cage should be obvious; this is the diaphragm, which separates the thoracic and abdominal cavities. Cut the diaphragm where it attaches to the ventral ribs to loosen the rib cage. Cut through the rib cage on either side. You can now lift the ribs to view the contents of the thoracic cavity. Cut across the flap at the level of the neck, and remove it.

**ACTIVITY 4**

Examining the Ventral Body Cavity

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

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

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

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

   **Lungs:** Lateral to the heart on either side.

   Now observe the throat region to identify the trachea.

   **Trachea:** Tubelike “windpipe” running medially down the throat; part of the respiratory system.

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

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

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

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

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

   Follow the esophagus through the diaphragm to its junction with the stomach.
Figure 2.3 Superficial organs of the thoracic cavity. (a) Dissected rat. (b) Human cadaver.
20 Exercise 2

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

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

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

Cecum: The initial portion of the large intestine.

Follow the course of the large intestine to the rectum, which is partially covered by the urinary bladder.

Rectum: Terminal part of the large intestine; continuous with the anal canal (not visible in this dissection).

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

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

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

Locate the remaining abdominal structures.

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

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

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

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

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

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

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

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

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

Urinary bladder: The sac that serves as a reservoir for urine.
4. In the midline of the body cavity lying between the kidneys are the two principal abdominal blood vessels. Identify each.

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

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

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

**Male Animal**

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

**Figure 2.5** Deep structures of the abdominopelvic cavity. (a) Human cadaver. (b) Dissected male rat. (Some reproductive structures also shown.) (c) Dissected female rat. (Some reproductive structures also shown.)
Female Animal
Inspect the pelvic cavity to identify the Y-shaped uterus lying against the dorsal body wall and beneath the bladder (Figure 2.5c). Follow one of the uterine horns superiorly to identify an ovary, a small oval structure at the end of the uterine horn. (The rat uterus is quite different from the uterus of a human female, which is a single-chambered organ about the size and shape of a pear.) The inferior undivided part of the rat uterus is continuous with the vagina, which leads to the body exterior. Identify the vaginal orifice (external vaginal opening).

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

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

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

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

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

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

2. Using the terms to the right of the figure (Figure 2.7), label each organ supplied with a leader line in the figure (Figure 2.7).

3. Place each of the organs listed in the correct body cavity or cavities. For organs found in the abdominopelvic cavity, also indicate which quadrant they occupy.

Dorsal body cavity

Thoracic cavity

Abdominopelvic cavity

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

Figure 2.7 Human torso model.
4. Determine which organs are found in each abdominopelvic region, and record below.

Umbilical region: ____________________________________________
Epigastric region: ____________________________________________
Hypogastric region: ____________________________________________
Right iliac region: ____________________________________________
Left iliac region: ____________________________________________
Right lumbar region: ____________________________________________
Left lumbar region: ____________________________________________
Right hypochondriac region: __________________________________
Left hypochondriac region: __________________________________

Now, assign each of the organs just identified to one of the organ system categories listed below,

Digestive: __________________________________________
Urinary: __________________________________________
Cardiovascular: __________________________________________
Endocrine: __________________________________________
Reproductive: __________________________________________
Respiratory: __________________________________________
Lymphatic/immune: __________________________________________
Nervous: __________________________________________

GROUP CHALLENGE

Odd Organ Out

Each box below contains four organs. One of the listed organs in each case does not share a characteristic that the other three do. Circle the organ that doesn’t belong with the others, and explain why it is singled out. What characteristic is it missing? Sometimes there may be multiple reasons why the organ doesn’t belong with the others. Include as many as you can think of, but make sure the organ does not have the key characteristic(s). Use the table (Table 2.1) and the pictures in your lab manual to help you select and justify your answer.

<table>
<thead>
<tr>
<th>1. Which is the “odd organ”?</th>
<th>Why is it the odd one out?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td></td>
</tr>
<tr>
<td>Teeth</td>
<td></td>
</tr>
<tr>
<td>Small intestine</td>
<td></td>
</tr>
<tr>
<td>Oral cavity</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Which is the “odd organ”?</th>
<th>Why is it the odd one out?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyroid gland</td>
<td></td>
</tr>
<tr>
<td>Thymus</td>
<td></td>
</tr>
<tr>
<td>Spleen</td>
<td></td>
</tr>
<tr>
<td>Lymph nodes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Which is the “odd organ”?</th>
<th>Why is it the odd one out?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ovaries</td>
<td></td>
</tr>
<tr>
<td>Prostate gland</td>
<td></td>
</tr>
<tr>
<td>Uterus</td>
<td></td>
</tr>
<tr>
<td>Uterine tubes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Which is the “odd organ”?</th>
<th>Why is it the odd one out?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td></td>
</tr>
<tr>
<td>Small intestine</td>
<td></td>
</tr>
<tr>
<td>Esophagus</td>
<td></td>
</tr>
<tr>
<td>Large intestine</td>
<td></td>
</tr>
</tbody>
</table>
Organ Systems Overview

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

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

1. rids the body of nitrogen-containing wastes
2. is affected by removal of the thyroid gland
3. provides support and levers on which the muscular system acts
4. includes the heart
5. protects underlying organs from drying out and from mechanical damage
6. protects the body; destroys bacteria and tumor cells
7. breaks down ingested food into its building blocks
8. removes carbon dioxide from the blood
9. delivers oxygen and nutrients to the tissues
10. moves the limbs; facilitates facial expression
11. conserves body water or eliminates excesses
12. facilitate conception and childbearing
13. controls the body by means of chemical molecules called hormones
14. is damaged when you cut your finger or get a severe sunburn

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

1. thymus, spleen, lymphatic vessels
2. bones, cartilages, tendons
3. pancreas, pituitary, adrenal glands
4. trachea, bronchi, lungs
5. epidermis, dermis, cutaneous sense organs
6. testis, ductus deferens, urethra
7. esophagus, large intestine, rectum
8. muscles of the thigh, postural muscles
3. Using the key below, place the following organs in their proper body cavity. Letters may be used more than once.

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

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

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

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

5. The levels of organization of a living body are as follows: chemicals, ____________, ____________, ____________, ____________, and organism.

6. Define organ.

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

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

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

MATERIALS

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

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

OBJECTIVES

1. Identify the parts of the microscope, and list the function of each part.
2. Describe and demonstrate the proper techniques for care of the microscope.
3. Demonstrate proper focusing technique.
4. Define total magnification, resolution, parfocal, field, depth of field, and working distance.
5. Measure the field size for one objective lens, calculate it for all the other objective lenses, and estimate the size of objects in each field.
6. Discuss the general relationships among magnification, working distance, and field size.

PRE-LAB QUIZ

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

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

Care and Structure of the Compound Microscope

The compound microscope is a precision instrument and should always be handled with care. At all times you must observe the following rules for its transport, cleaning, use, and storage:
When transporting the microscope, hold it in an upright position with one hand on its arm and the other supporting its base. Avoid swinging the instrument during its transport and jarring the instrument when setting it down.

- Use only special grit-free lens paper to clean the lenses. Use a circular motion to wipe the lenses, and clean all lenses before and after use.

- Always begin the focusing process with the lowest-power objective lens in position, changing to the higher-power lenses as necessary.

- Use the coarse adjustment knob only with the lowest-power lens.

- Always use a coverslip with wet mount preparations.

- Before putting the microscope in the storage cabinet, remove the slide from the stage, rotate the lowest-power objective lens into position, wrap the cord neatly around the base, and replace the dust cover or return the microscope to the appropriate storage area.

- Never remove any parts from the microscope; inform your instructor of any mechanical problems that arise.

**Activity 1**

**Identifying the Parts of a Microscope**

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

- Record the number of your microscope in the Summary Chart (on page 31).

Compare your microscope with the illustration (Figure 3.1), and identify the following microscope parts:
**Base:** Supports the microscope. (Note: Some microscopes are provided with an inclination joint, which allows the instrument to be tilted backward for viewing dry preparations.)

**Substage light or mirror:** Located in the base. In microscopes with a substage light source, the light passes directly upward through the microscope; light controls are located on the microscope base. If a mirror is used, light must be reflected from a separate free-standing lamp.

**Stage:** The platform the slide rests on while being viewed. The stage has a hole in it to permit light to pass through both it and the specimen. Some microscopes have a stage equipped with spring clips; others have a clamp-type mechanical stage (Figure 3.1). Both hold the slide in position for viewing; in addition, the mechanical stage has two adjustable knobs that control precise movement of the specimen.

**Condenser:** Small substage lens that concentrates the light on the specimen. The condenser may have a rack and pinion knob that raises and lowers the condenser to vary light delivery. Generally, the best position for the condenser is close to the inferior surface of the stage.

**Iris diaphragm lever:** Arm attached to the base of the condenser that regulates the amount of light passing through the condenser. The iris diaphragm permits the best possible contrast when viewing the specimen.

**Coarse adjustment knob:** Used to focus on the specimen.

**Fine adjustment knob:** Used for precise focusing once coarse focusing has been completed.

**Head or body tube:** Supports the objective lens system, which is mounted on a movable nosepiece, and the ocular lens or lenses.

**Arm:** Vertical portion of the microscope connecting the base and head.

**Ocular (or eyepiece):** Depending on the microscope, there are one or two lenses at the superior end of the head or body tube. Observations are made through the ocular(s). An ocular lens has a magnification of 10X; it increases the apparent size of the object by ten times, or ten diameters. If your microscope has a pointer to indicate a specific area of the viewed specimen, it is attached to one ocular and can be positioned by rotating the ocular lens.

**Nosepiece:** Rotating mechanism at the base of the head. Generally carries three or four objective lenses and permits sequential positioning of these lenses over the light beam passing through the hole in the stage. Use the nosepiece to change the objective lenses. Do not directly grab the lenses.

**Objective lenses:** Adjustable lens system that permits the use of a scanning lens, a low-power lens, a high-power lens, or an oil immersion lens. The objective lenses have different magnifying and resolving powers.

2. Examine the objective lenses carefully; note their relative lengths and the numbers inscribed on their sides. On many microscopes, the scanning lens, with a magnification between 4X and 5X, is the shortest lens. If there is no scanning lens, the low-power objective lens is the shortest and typically has a magnification of 10X. The high-power objective lens is of intermediate length and has a magnification range from 40X to 50X, depending on the microscope. The oil immersion objective lens is usually the longest of the objective lenses and has a magnifying power of 95X to 100X. Some microscopes lack the oil immersion lens.

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

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

**Magnification and Resolution**

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

The total magnification (TM) of any specimen being viewed is equal to the power of the ocular lens multiplied by the power of the objective lens being used. For example, if the

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

- \[ \text{Total Magnification} = \text{Ocular Magnification} \times \text{Objective Magnification} \]

- \[ \text{Ocular Magnification} = 10X \]

- \[ \text{Objective Magnification} = 40X \]

- \[ \text{Total Magnification} = 10X \times 40X = 400X \]
ocular lens magnifies 10X and the objective lens magnifies 45X, the total magnification is 450X (or 10 X 45).

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

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

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

**Activity 2**

**Viewing Objects Through the Microscope**

1. Obtain a millimeter ruler, a prepared slide of the letter e or newsprint, a dropper bottle of immersion oil, and some lens paper. Adjust the condenser to its highest position, and switch on the light source of your microscope. If the light source is not built into the base, use the curved surface of the mirror to reflect the light up into the microscope.

2. Secure the slide on the stage so that you can read the slide label and the letter e is centered over the light beam passing through the stage. If you are using a microscope with spring clips, make sure the slide is secured at both ends. If your microscope has a mechanical stage, open the jaws of its slide holder by using the control lever, typically located at the rear left corner of the mechanical stage. Insert the slide squarely within the confines of the slide holder. Check to see that the slide is resting on the stage, not on the mechanical stage frame, before releasing the control lever.

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

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

5. Sketch the letter e in the circle on the Summary Chart just as it appears in the field (the area you see through the microscope). How far is the bottom of the objective lens from the specimen? In other words, what is the **working distance**? Use a millimeter ruler to make this measurement.

Record the working distance in the Summary Chart.

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

Record the working distance in the Summary Chart.

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

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

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

At first this change in orientation may confuse you, but with practice you will learn to move the slide in the desired direction with no problem.

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

Approximately how much of the letter e is visible now?

Is the image larger or smaller?

Is the field larger or smaller?

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

Move the iris diaphragm lever while observing the field. What happens?
### Summary Chart for Microscope #

<table>
<thead>
<tr>
<th></th>
<th>Scanning</th>
<th>Low power</th>
<th>High power</th>
<th>Oil immersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnification of objective lens</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Magnification of ocular lens</td>
<td>10 ×</td>
<td>10 ×</td>
<td>10 ×</td>
<td>10 ×</td>
</tr>
<tr>
<td>Total magnification</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Working distance</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>Detail observed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter e</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field size (diameter)</td>
<td>mm μm</td>
<td>mm μm</td>
<td>mm μm</td>
<td>mm μm</td>
</tr>
</tbody>
</table>

Is it more desirable to increase or decrease the light when changing to a higher magnification?

Why?

---

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

---

Record the working distance in the Summary Chart.

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

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

---

Is the field again decreased in size?

---

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

---

Compare your observations on the relative working distances of the objective lenses with the illustration (Figure 3.3). Explain why it is desirable to begin the focusing process in the lowest power.

---

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

---

**Figure 3.3** Relative working distances of the 10×, 45×, and 100× objectives.
Table 3.1  Comparison of Metric Units of Length

<table>
<thead>
<tr>
<th>Metric unit</th>
<th>Abbreviation</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meter</td>
<td>m</td>
<td>(about 39.3 in.)</td>
</tr>
<tr>
<td>Centimeter</td>
<td>cm</td>
<td>10^{-2} m</td>
</tr>
<tr>
<td>Millimeter</td>
<td>mm</td>
<td>10^{-3} m</td>
</tr>
<tr>
<td>Micrometer (or micron)</td>
<td>μm (μ)</td>
<td>10^{-6} m</td>
</tr>
<tr>
<td>Nanometer (or millimicron)</td>
<td>nm (mμ)</td>
<td>10^{-9} m</td>
</tr>
<tr>
<td>Ångstrom</td>
<td>Å</td>
<td>10^{-10} m</td>
</tr>
</tbody>
</table>

The Microscope Field

By this time you should know that the size of the microscope field decreases with increasing magnification. For future microscope work, it will be useful to determine the diameter of each of the microscope fields. This information will allow you to make a fairly accurate estimate of the size of the objects you view in any field. For example, if you have calculated the field diameter to be 4 mm and the object being observed extends across half this diameter, you can estimate the length of the object to be approximately 2 mm.

Microscopic specimens are usually measured in micrometers and millimeters, both units of the metric system. You can get an idea of the relationship and meaning of these units from the table (Table 3.1). (A more detailed treatment appears in Appendix A.)

ACTIVITY 3

Estimating the Diameter of the Microscope Field

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

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

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

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

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

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

   \[ \text{Field diameter } B = \frac{(2 \text{ mm} \times 50)}{100} = 1 \text{ mm} \]

3. Estimate the length (longest dimension) of the following microscopic objects. Base your calculations on the field sizes you have determined for your microscope.

   a. Object seen in low-power field:
      approximate length:
      ______ mm

   b. Object seen in high-power field:
      approximate length:
      ______ mm
      or ______ μm

   c. Object seen in oil immersion field:
      approximate length:
      ______ μm

4. If an object viewed with the oil immersion lens looked as it does in the field depicted just below, could you determine its approximate size from this view?
If not, then how could you determine it?  


Perceiving Depth

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

**ACTIVITY 4**

Perceiving Depth

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

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

If the stage descends, how is the order affected?

Record your observations as to which color of thread is uppermost, in the middle, or lowest:

Top thread

Middle thread

Bottom thread


Viewing Cells Under the Microscope

There are various ways to prepare cells for viewing under a microscope. Cells and tissues can look very different with different stains and preparation techniques. One method of preparation is to mix the cells in physiological saline (called a wet mount) and stain them with methylene blue stain.

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

**ACTIVITY 5**

Preparing and Observing a Wet Mount

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

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

3. Add a tiny drop of the iodine or methylene blue stain to the preparation. (These epithelial cells are nearly transparent and thus difficult to see without the stain, which colors the nuclei of the cells and makes them look much darker than the cytoplasm.) Stir with a clean toothpick.

4. Hold the cover slip with your fingertips so that its bottom edge touches one side of the fluid drop (Figure 3.4b), then

![Figure 3.4 Procedure for preparing a wet mount.](a) The object is placed in a drop of water (or saline) on a clean slide, (b) a cover slip is held at a 45° angle with the fingertips, and (c) it is lowered carefully over the water and the object.)

![Figure 3.4 Procedure for preparing a wet mount.](b) The object is placed in a drop of water (or saline) on a clean slide, (b) a cover slip is held at a 45° angle with the fingertips, and (c) it is lowered carefully over the water and the object.)

![Figure 3.4 Procedure for preparing a wet mount.](c) The object is placed in a drop of water (or saline) on a clean slide, (b) a cover slip is held at a 45° angle with the fingertips, and (c) it is lowered carefully over the water and the object.)
carefully lower the coverslip onto the preparation (Figure 3.4c). Do not just drop the coverslip, or you will trap large air bubbles under it, which will obscure the cells. Always use a coverslip with a wet mount to prevent soilng the lens if you should misfocus.

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

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

6. Place the slide on the stage, and locate the cells in low power. You will probably want to dim the light with the iris diaphragm to provide more contrast for viewing the lightly stained cells. Furthermore, a wet mount will dry out quickly in bright light because a bright light source is hot.

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

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

![Figure 3.5 Epithelial cells of the cheek cavity (surface view, 630×).](image)

Use information on your Summary Chart (page 31) to estimate the diameter of cheek epithelial cells.

____ μm

Why do your cheek cells look different from those illustrated in the figure (Figure 3.5)? (Hint: What did you have to do to your cheek to obtain them?)

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

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

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

____ μm

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

11. Before leaving the laboratory, make sure all other materials are properly discarded or returned to the appropriate laboratory station. Clean the microscope lenses, and put the dust cover on the microscope before you return it to the storage cabinet.
The Microscope

Care and Structure of the Compound Microscope

1. Label all indicated parts of the microscope.
2. Determine whether each of the following statements is true or false. If it is true, write T on the answer blank. If it is false, correct the statement by writing on the blank the proper word or phrase to replace the one that is underlined.

1. The microscope lens may be cleaned with any soft tissue.  
   Corrected: The microscope lens may be cleaned with a soft tissue.

2. The microscope should be stored with the oil immersion lens in position over the stage.  
   Corrected: The microscope should be stored with the oil immersion lens in position over the stage.

3. When beginning to focus, the lowest-power lens should be used.  
   Corrected: When beginning to focus, the lowest-power lens should be used.

4. When focusing, always focus toward the specimen.  
   Corrected: When focusing, always focus toward the specimen.

5. A coverslip should always be used with wet mounts and the high-power and oil lenses.  
   Corrected: A coverslip should always be used with wet mounts and the high-power and oil lenses.

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

   **Column A**
   1. platform on which the slide rests for viewing
   2. lens located at the superior end of the body tube
   3. secure(s) the slide to the stage
   4. delivers a concentrated beam of light to the specimen
   5. used for precise focusing once initial focusing has been done
   6. carries the objective lenses; rotates so that the different objective lenses can be brought into position over the specimen
   7. used to increase the amount of light passing through the specimen

   **Column B**
   a. coarse adjustment knob
   b. condenser
   c. fine adjustment knob
   d. iris diaphragm
   e. mechanical stage or spring clips
   f. movable nosepiece
   g. objective lenses
   h. ocular
   i. stage

4. Explain the proper technique for transporting the microscope.

   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________

5. Define the following terms.

   *real image:* ____________________________________________________________
   *resolution:* ____________________________________________________________
Viewing Objects Through the Microscope

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

1. The distance from the bottom of the objective lens in use to the specimen is called the _____________.
2. Assume there is an object on the left side of the field that you want to bring to the center (that is, toward the apparent right). In what direction would you move your slide?
3. The area of the specimen seen when looking through the microscope is the _____________.
4. If a microscope has a 10X ocular and the total magnification at a particular time is 950X, the objective lens in use at that time is _____________.
5. Why should the light be dimmed when you are looking at living (nearly transparent) cells?
6. After focusing in low power, you find that you need to use only the fine adjustment to focus the specimen at the higher powers. The microscope is therefore said to be _____________.
7. You are using a 10X ocular and a 15X objective. If the field size is 1.5 mm, the approximate field size with a 30X objective is _____________.
8. If the size of the high-power field is 1.2 mm, an object that occupies approximately a third of that field has an estimated diameter of _____________.

7. You have been asked to prepare a slide with the letter k on it (as shown below). In the circle below, draw the k as seen in the low-power field.

8. The numbers for the field sizes below are too large to represent the typical compound microscope lens system, but the relationships depicted are accurate. Figure out the magnification of fields 1 and 3, and the field size of 2. (Hint: Use your ruler.)

   5 mm
   0.5 mm

   1. ____________ 2. ____________ 3. ____________

9. Say you are observing an object in the low-power field. When you switch to high power, it is no longer in your field of view.

   Why might this occur? _____________.

   What should you have done initially to prevent this from happening? _____________.

10. Do the following factors increase or decrease as one moves to higher magnifications with the microscope?

- resolution: ___________________________
- amount of light needed: ___________________________
- working distance: ___________________________
- depth of field: ___________________________

11. A student has the high-dry lens in position and appears to be intently observing the specimen. The instructor, noting a working distance of about 1 cm, knows the student isn't actually seeing the specimen. How so? ___________________________

12. Describe the proper procedure for preparing a wet mount.

_________________________

_________________________

_________________________

13. Indicate the probable cause of the following situations arising during use of a microscope.

a. Only half of the field is illuminated: ___________________________

_________________________

b. Field does not change as mechanical stage is moved: ___________________________

_________________________