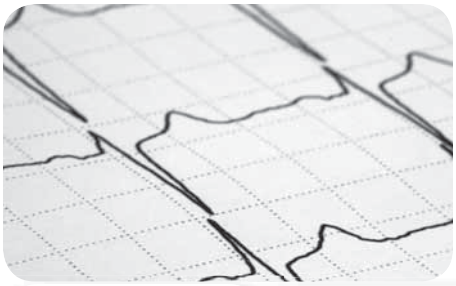

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10 Laboratory

Diversity in Transport

Week I

LEARNING OBJECTIVES

Students will….

- demonstrate how various treatment conditions affect transport in plants by conducting an experiment to measure transpiration rates of a plant specimen under a control and treatment setting, graphing their data, and discussing findings with the class.
- observe prepared and live plant specimens to identify key structures in the leaf of plants that are associated with transport.
- compare open and closed circulatory systems of small invertebrates by conducting a dissection of organisms with each type of system and identifying key structures associated with transport in animals.
- distinguish other anatomical structures in the two dissected organisms by pointing them out and describing their functions to their peers and instructor.
- extend their knowledge of plant and animal transport by answering specific questions at the end of lab.

INTRODUCTION

Once again you will be examining diversity in function in plants and animals by looking at responses to environmental changes in transport systems. Transport systems are characteristic of multicellular plants and animals. They are necessary for transporting needed water, gases, and nutrients from one part of the body to another, as well as

transporting wastes away from these body parts. In animals and plants, hormones are transported via the transport systems. In humans, the lymphatic and circulatory transport systems play an important role in the body's defense via the immune response. Thus, transport systems can become an integral part of many other systems in an organism, including excretory, digestive, and immune systems. You may explore some of these functions of transport systems in greater depth in lecture.

In week one of this laboratory, you will determine the rate of transpiration in a plant under different environmental conditions. You will also examine two different types of circulatory systems found in animals. During week two, you will observe the structure of a mammalian heart, and record electrocardiograms to determine the effect of stress on heart rate.

Activity One: Transpiration in Higher Plants

BACKGROUND

The transport of water and nutrients in higher plants is accomplished by a vascular system composed of two tissues, the **xylem** and **phloem** (Figure 10-1). In the phloem, metabolites such as sugars, amino acids, hormones, and minerals are shuttled by a process called **translocation** from supply areas to places where they are used. Consequently, the movement of materials may be up the stem from photosynthetically active leaves to the meristematic (growing) regions of the plant, or the movement may be down toward the storage areas in the roots. The direction of movement may change depending on environmental conditions.

In the xylem, water and dissolved minerals move unidirectionally, from the roots through the stems to the leaves. Water is lost from the leaves by evaporation in a process called **transpiration**. The water exits from openings, or stomata, in the spongy mesophyll (Figure 10-2). Facilitating transpiration is one function of the stomata.

The process of transpiration is responsible for providing the necessary force for lifting water from the roots to the top of a plant. The **cohesion–tension theory** is commonly used to explain the process that causes water to rise through the xylem of the plant as a result of transpiration. As water rises in the xylem it forms a continuous water column that is somewhat like a string or chain due to the cohesion between water molecules.

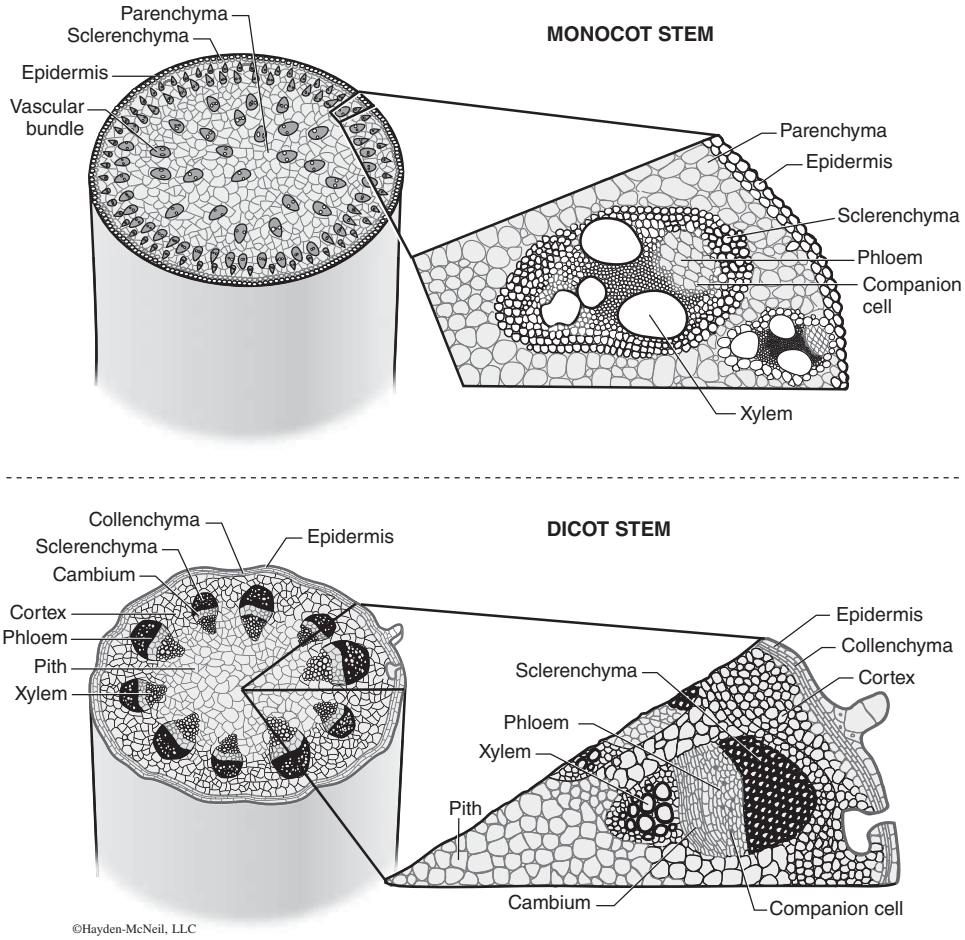


Figure 10-1. Cross Section of a Monocot and a Dicot Plant

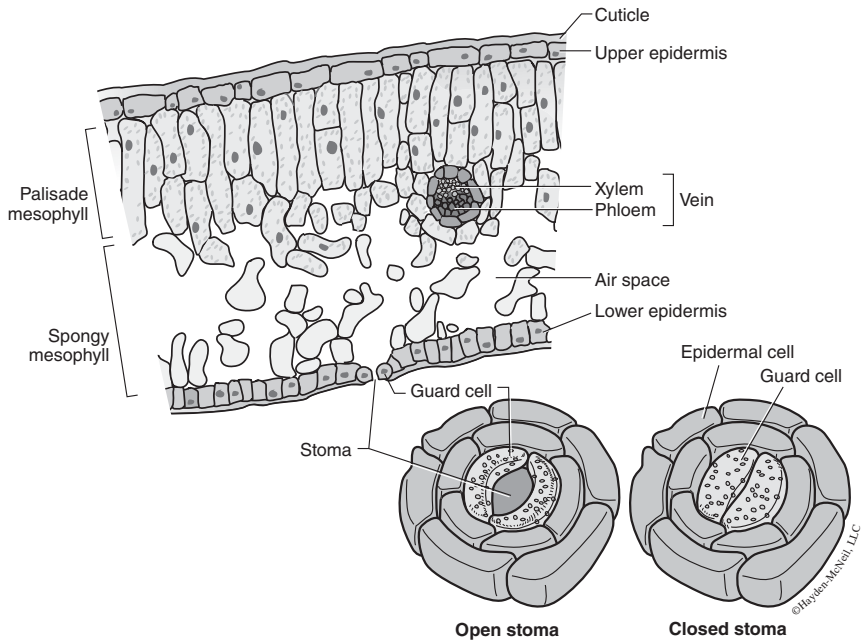


Figure 10-2. Cross Section of a Leaf with Stomata Inset

The rate of transpiration is influenced by temperature, light, relative humidity, and other environmental factors. In this experiment, we will measure the rate of transpiration under different environmental conditions or stresses. A device called a **potometer** will be used to measure the water loss through a small branch of a woody plant species. First you will conduct one trial under standard laboratory conditions. Your table will then be assigned one of the experimental treatments outlined in Activities 1A through 1F in which you will measure how the stem is affected by environmental conditions or **stresses**.

▶PROCEDURE

1. Collect a leaf stem from the side counter.
2. Push the bottom of the stem through the hole in the rubber stopper provided, being careful not to strip the bark off the stem. If the stem is too thick, trim it until it will fit snugly into the rubber stopper hole. *Do not* use stems that fit loosely into the stopper.
3. Continue to push the stem through the stopper until there is about 1 cm of bark-covered stem below the stopper.
4. Immediately place the stem bottom in water until you are ready to insert it into the potometer.
5. Observe the potometer setup in the clamp on the ring stand (see Figure 10-3) and adjust the potometer so that it is level.

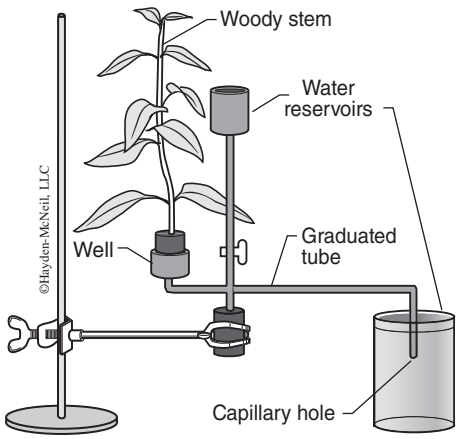


Figure 10-3. Custom-made Potometers

6. Place the open pipette end of the potometer above a beaker with water.
7. Overfill the well and *carefully* put the plant stem stopper into the well.

8. Support the glass from below with gentle pressure while placing the stopper in the well. The well should not have any air bubbles in it. If air bubbles start to form, the stem is too small for the stopper. Select a new stem and continue.
9. Lower the open pipette end into the beaker of water.
10. Fill the upper reservoir with water.
11. Place a pipe cleaner in the upper reservoir opening directed down toward the stopcock.
12. Open the stopcock and quickly pull the pipe cleaner up. This action should pull any air bubbles out of the water column.
13. Close the stopcock and repeat the above procedure six to eight times, until all the air bubbles are removed.
14. Before transpiration data can be collected, an air bubble must be positioned at the 0 mL mark on the calibrated pipette. Depending upon the situation, one of two things can be done:
    a. Introduce an air bubble into the calibrated pipette end by pressing gently, but firmly, on the stopper assembly positioned in the potometer well and then releasing the stopper. **NOTE: Be sure to support the well so that it does not snap while being pressed**. This action will push water out of the pipette and then will draw air into the tube. You may need to wiggle the stopper a bit to adjust the location of the bubble.
    b. Slowly open the stopcock to allow the reservoir water to push the air bubble back toward the 0 mL mark.
15. Once the air bubble is in position, record this starting position in Table 10-1 in the **Time = 0 min** location of the **Control Run** column.
16. Record the position of the bubble at one-minute intervals for a period of ten minutes. Transpiration may occur fast enough so that your air bubble will reach the other end of the pipette before the ten minutes is up. If this occurs, set the air bubble back to 0 and continue recording data through the ten-minute period, adding the new volume to the last recorded volume.

STRESSES

In this portion of the activity, your table will be assigned one of the experimental treatments (environmental conditions or stresses) below.

Activity 1A: Effect of Light Intensity

Place a portable light source, such as a desk lamp, at the designated distance from your plant.

Activity 1B: Effect of Air Movement

Use a small electric fan to generate air currents across the leaves of your plant.

Activity 1C: Effect of Increased Humidity

Mist your plant, then cover it with a plastic bag to retain the moisture.

Activity 1D: Effect of Surface Area I

Remove half of the branches or every other leaf from your plant, completely removing half of the leaf area.

Activity 1E: Effect of Surface Area II

Cut each individual leaf in half.

Activity 1F: Effect of Surface Area III

Spread a thin film of Vaseline on the bottoms of half of the leaves.

▶PROCEDURE

1. When the control run is completed, check with your laboratory instructor to determine which stress to apply to your plant. Apply this stress and then allow the plant and potometer to equilibrate for 5 minutes.
2. After equilibration, reset the air bubble by opening the stopcock and then closing it again so that the bubble is positioned at the 0 mL mark.
3. Once the air bubble is in position, record this starting position in Table 10-1 in the **Time = 0 min** location of the **Experimental Run** column.
4. Record the position of the bubble at 1-minute intervals for a period of 10 minutes in the following table. Make sure you add to the last number recorded if you ever have to reset the potometer to 0 during the 10 minute run.

Table 10-1. Transpiration measurements under varying environmental conditions

CONTROL RUN		EXPERIMENTAL RUN	
		STRESSOR APPLIED:	
TIME (MIN)	WATER UPTAKE (mL)	TIME (MIN)	WATER UPTAKE (mL)
0		0	
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
9		9	
10		10	

5. Graph your control and experimental data using Excel and present your results to the class.
6. Why must you complete one trial under standard laboratory conditions before applying the stresses?

A COMPARATIVE EXAMINATION OF OPEN AND CLOSED CIRCULATORY SYSTEMS

Many small invertebrates do not have a circulatory system at all. Their cells are close enough to their environment for oxygen, other gases, nutrients, and waste products to simply diffuse into and out of their cells. For most other animals of a larger size and length, transport is often accomplished by a series of interconnected tubes and other organs that form a **circulatory system**. For example, in the earthworm that you will be dissecting, gas exchange is still principally accomplished by diffusion across the skin. However, earthworms have a fairly complex closed circulatory system that is principally involved in the transport of nutrients and other substances.

There are two basic plans of construction of a circulatory system in animals: open and closed. **Closed circulatory systems** are found in all vertebrates as well as most annelids (earthworms and their relatives) and cephalopods (squids and octopi). By definition, a closed circulatory system consists of interconnected vessels throughout the body containing blood (fluid and cellular entities) such that most of the blood will not leave the system. Blood passes from **hearts** to **arteries** to **veins** through **capillaries**. The capillaries are the thinnest and most numerous of the blood vessels. Exchange of nutrients, gases, and other substances between the blood and the **interstitial fluid** surrounding the cells takes place in the capillaries (Figure 10-4).

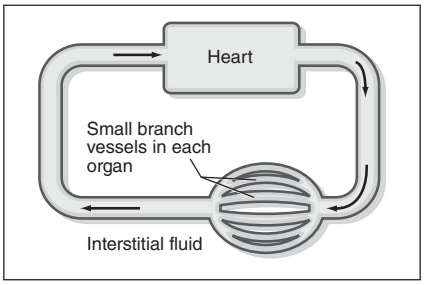


Figure 10-4. Closed Circulatory System

An **open circulatory system** is the type found in animals such as arthropods (insects, spiders, shrimp) and most molluscs (snails and clams). In an open circulatory system, fluid is pumped from vessels directly into the body cavity, **hemocoel**, or into spaces known as **sinuses**. There is no distinction in these systems between blood, or fluid found in the vessels, and interstitial fluid bathing the tissues. Thus, the fluid found in the hemocoel is known simply as **hemolymph** (Figure 10-5).

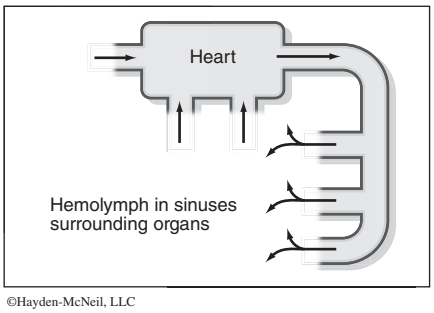


Figure 10-5. Open Circulatory System

Muscular movements by the animal facilitate hemolymph movement. When the heart relaxes, blood is drawn back toward the heart and moves into the heart through **ostia** (singular for **ostium**), which are valved openings on the heart wall.

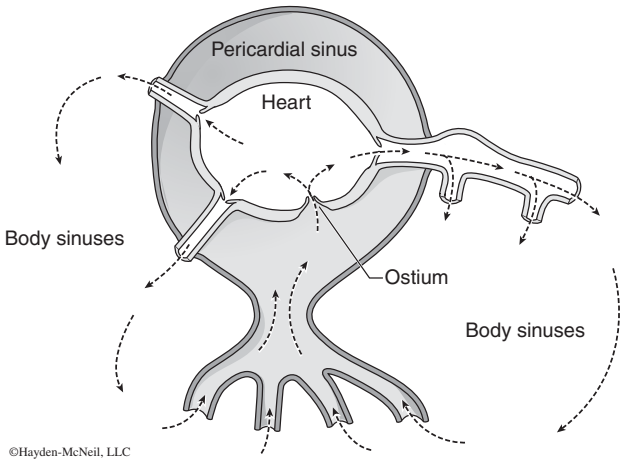


Figure 10-6. Heart Found in Open Circulatory System (note direction of hemolymph flow into and out of the heart)

Activity Two: Earthworm Dissection

BACKGROUND

The earthworm is a representative of the phylum Annelida meaning "little rings." Annelids are segmented worms in which the body is divided into similar segments. Segmentation is not merely an external feature that gives the body of the worm the appearance of repeating units, internal structures also are repetitive in the individual segments. Although an earthworm may be the annelid species most familiar to us, the vast majority of the members of this phylum are marine worms that live in sandy or muddy ocean bottoms.

Earthworms typically live in burrows or tunnels in the soil. These animals are also known as "night crawlers" because at night they commonly come to the soil surface and scavenge for food. The tunnels are formed as the earthworm ingests the soil and strains out the organic food material. Aeration of the soil provided by these tunnels enhances the growth of plants by making oxygen more readily available to their roots.

▶ PROCEDURE

1. Observe and describe the external morphology of the earthworm prior to beginning the dissection. Note the arrangement of the body into a linear series of **segments**. Locate the **mouth** in the first anterior segment and the **anus** in the last posterior segment. Identify the prominent **clitellum** that covers several anterior segments. Locate the paired **setae** (bristles) on each segment. Refer to Figure 10-7 as you continue with your dissection.
2. With small, sharp scissors, make a single **dorsal** cut through the body wall about 3 inches below the tip of the mouth. Pull up with your scissors, lifting the outer layer away from the internal body organs. Extend the cut up into the head to the second segment. You'll also want to cut down the length of the worm through the clitellum. Do not cut deeply.
3. Pin back the body wall so that the contents of the **coelom** (body cavity) are easily observed. Note the **septa** (partitions) that divide the organism into segments.
4. Identify the **dorsal vessel**, which runs along the top of the intestine. Follow it forward toward the **esophagus**. Gently move aside any organs that obscure your view so that you can see the **aortic arches** or hearts around the esophagus. Cut one end of the intestine so that you can see the **ventral vessel**, which runs along the ventral surface of the digestive tract. Share these observations with your tablemates.

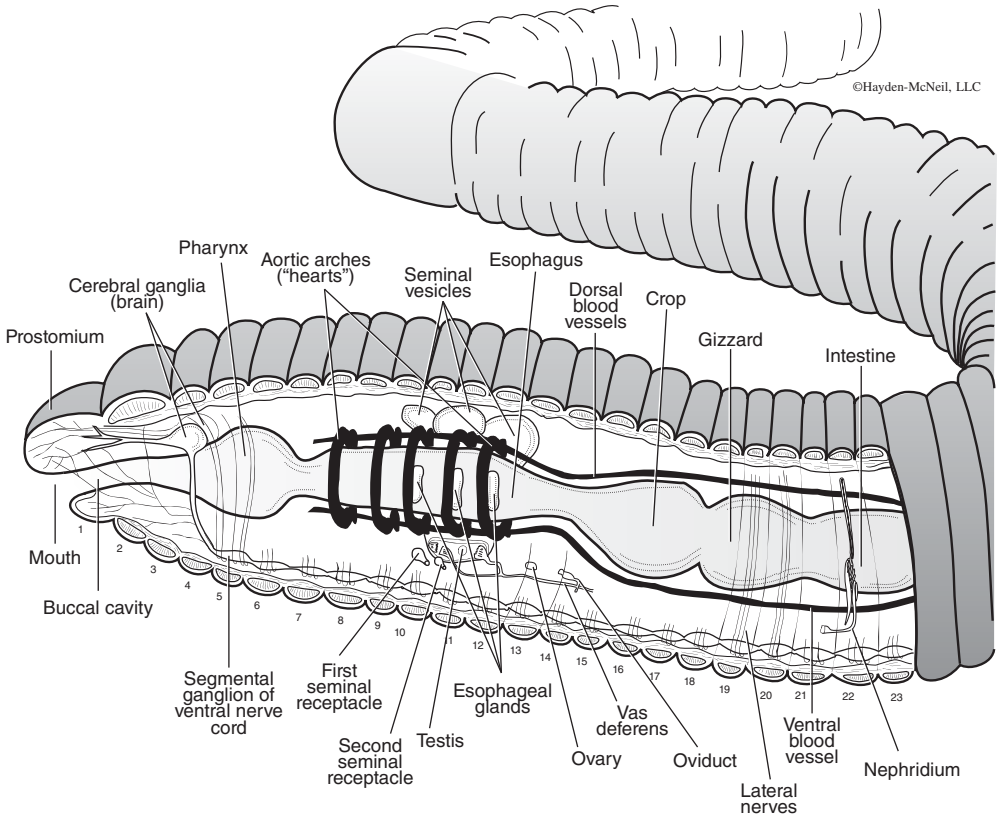


Figure 10-7. Anatomy of the Earthworm

5. Trace the digestive system beginning with the mouth and the **prostomium** (the portion anterior to the mouth) of the first segment and ending with the anus in the last segment. Note the components of the digestive system, including the **pharynx**, **esophagus**, **crop**, **gizzard**, and **intestine**.
6. If time permits, locate the **reproductive organs: seminal receptacles (ovary and testes)** and **seminal vesicles**.
7. The gonads (testes and ovaries) may be too small to see, but many of the associated reproductive structures are clearly visible. Note the large, cream-colored structures associated with segments 9–12. These are seminal vesicles. Testes are associated with the seminal vesicles. Sperm are passed from the testes to the seminal vesicles for storage prior to copulation.

Earthworms are hermaphroditic, meaning that they contain both male and female reproductive structures. However, self-fertilization does not occur. When earthworms mate, they exchange sperm, which later will fertilize the eggs produced by the ovaries. Sperm are produced and stored in the seminal vesicles. Sperm received from another animal in mating are stored in the two pairs of seminal receptacles.

Activity Three: Crayfish Dissection

BACKGROUND

The crayfish is a crustacean belonging to the phylum **Arthropoda**, which is the largest of the animal phyla. Arthropodans include crabs and lobsters (other Crustaceans), insects, spiders, millipedes, and others. Most members of this phylum actively forage for food. Insects dominate the terrestrial environment while crustaceans dominate the aquatic environments.

▶ PROCEDURE

1. Obtain a preserved specimen and a dissecting pan. Observe and identify the major structures of the external anatomy of your crayfish. The entire crayfish is covered by the **exoskeleton**. The crayfish, and any arthropod, is able to grow by **molting** or shedding their exoskeleton. The body consists of two regions, the anterior **cephalothorax** and the posterior **abdomen**, composed of a number of independently movable segments. Refer to Figures 10-8 and 10-9 as you complete your dissection.

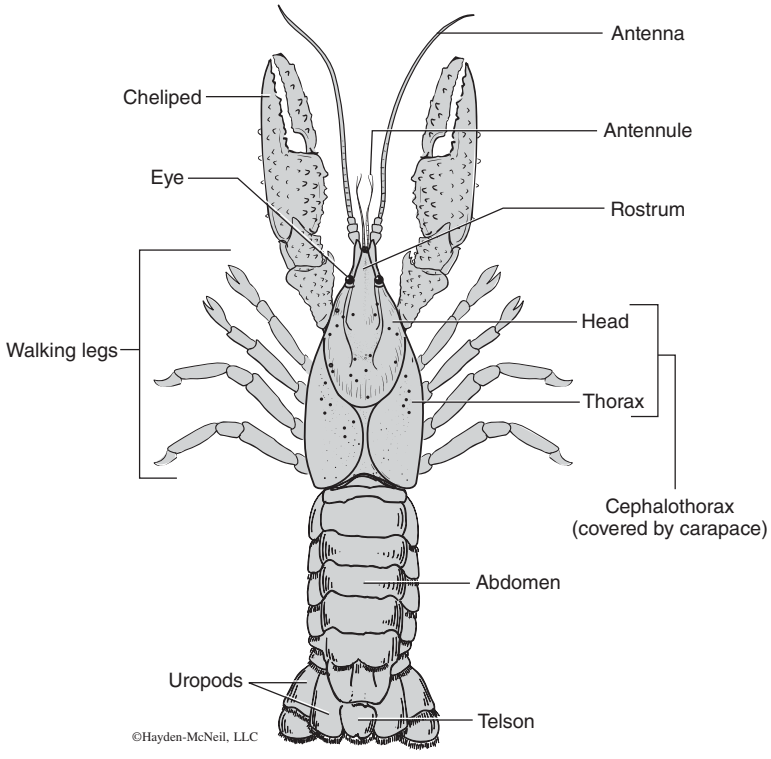


Figure 10-8. External Anatomy of a Crayfish

2. Place the specimen in the dissecting tray dorsal side up. Insert your scissors under the anterior edge of the cephalothorax, about midway between its dorsal and ventral margins, and carefully cut toward the tail. Repeat this procedure on the other side. Carefully lift the central carapace section up slightly and, using a dissecting needle, separate any connections between the carapace and the internal organs.

3. Cut from the beginning and end of your incisions down toward the legs. Remove as much of the exoskeleton as possible.

   NOTE: You may not be able to separate some of the exoskeleton that is attached at the area of the leg. Simply cut off as much of the cephalothorax exoskeleton as you can in order to expose the organs underneath.

4. Locate two large light colored masses extending on each side of the body into the head. These are the **digestive glands**. They secrete enzymes and store food.

   What part of your digestive system on the bullfrog that you dissected last week corresponds to this organ in the crayfish?

5. Carefully separate the thin dorsal layer of muscles in the thorax to locate the light colored **heart** just underneath. It will be posterior to the digestive glands and on the underside of the dorsal median head region of the cephalothorax exoskeleton. It is "diamond to rectangular shaped." If the heart is not immediately apparent, read the note below and refer to Figure 10-9. Using a dissecting microscope, find the ostia or openings in the heart. Share these observations with your tablemates.

   NOTE: In injected specimens, the pink injection material may have filled the heart and vessels as well as the **pericardial sinus** (cavity around the heart). If after separating the thin dorsal layer of muscles this appears to be the case, simply use a probe to carefully push this material away until you find the heart.

6. Now that you have found the heart, examine the rest of the circulatory system. From the top, the crayfish circulation cannot be distinguished as an open system. To convince yourself that this is the case, insert the point of the scissors under the dorsal exoskeleton of the abdomen and cut back at least 1/2 way to the tail. Insert a probe under the **major dorsal artery**, just posterior to the heart. Follow the vessel leading toward the abdomen. Note that there are no branching vessels leading from these arteries except in the area of the gills. Blood is pumped through these arteries by the heart into large sinuses or spaces in the body cavity (hemocoel). The organ most closely associated with the posterior dorsal artery is the intestine. Share these observations with your tablemates.

7. Locate the exposed **gills** or feathery like structures on the sides of the animal. Circulation is more controlled in the area of the gills. Can you hypothesize why?

   NOTE: If you look just underneath the heart, you may be able to locate arteries that direct the flow from the heart and main dorsal arteries to the vicinity of the gills. In well-injected specimens, you may be able to locate pink-filled arteries leading to the gills. If so, share these observations with your tablemates.

8. Examine the exposed gills. The gills are located on the outside of the body cavity in a space between the body wall and the carapace. Remove a small portion of the gill and observe it under the dissecting microscope. Note that the gills are well vascularized or associated with vessels. Share these observations with your tablemates. Why is it important that the gills are well vascularized?

9. Locate where the gills are attached to the body. Note that the appendages and mouthparts are structures that are attached to the gills. Movement of the appendages and mouthparts moves the gills as well, producing a continuous flow of fresh water over the gills.

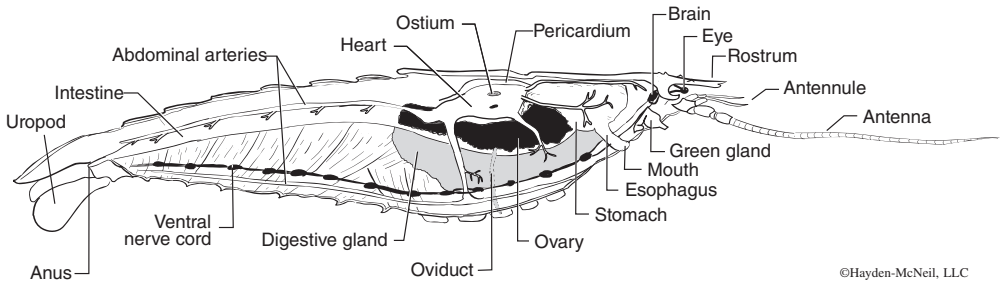


Figure 10-9. Internal Anatomy of a Crayfish

NOTE: The heart sends blood into the spaces around the organs through several arteries. After passing through the gills, the blood drains back into the heart through the openings (ostia) in the heart.

Blood reaches all parts of the body from the heart through the arteries and collects in the ventral sinus that extends through the cephalothorax and abdomen. From the sinus it passes through vessels to the gills and then to the pericardial sinus and back to the heart via the ostia.

10. Using a probe, trace the digestive system from the mouth through the esophagus to the cardiac stomach, where the food is ground up. Remove the cardiac stomach, open it, and observe the **grinding structures** under the stereoscope. Share these observations with your tablemates.

11. From the stomach, food travels to the intestine where it is absorbed into the bloodstream. Relocate the **intestine** and note again the intimate connection between it and the **dorsal posterior artery**.

12. Find the **green glands** located internally, just behind each antenna and right under the brain. These structures filter fluid waste from the blood.

13. If time permits, turn the animal over and carefully make a vertical cut where the abdomen meets the thorax. Peel back the exoskeleton slowly. If you are lucky enough not to injure it, you should see the **ventral nerve cord** that is just underneath that exoskeleton. You can also locate a "brain" inside the head under the eye region.

[Questions]

Name | Lab/Section

Partner's Name (if applicable) | Date (of Lab Meeting)

Transpiration

1. What plant structures regulate the rate of transpiration in a vascular plant?

2. How do these structures affect water movement throughout the plant?

3. How do environmental effects like humidity, temperature, and wind currents influence the rate of transpiration? Use your class data and graphs to answer this question. Why do these changes occur? Attach your graph(s) here.

Invertebrate Circulatory System

4. In the earthworm, what circulatory structures can you see? Is this an example of an open or closed circulatory system? How do gases enter/leave this system?

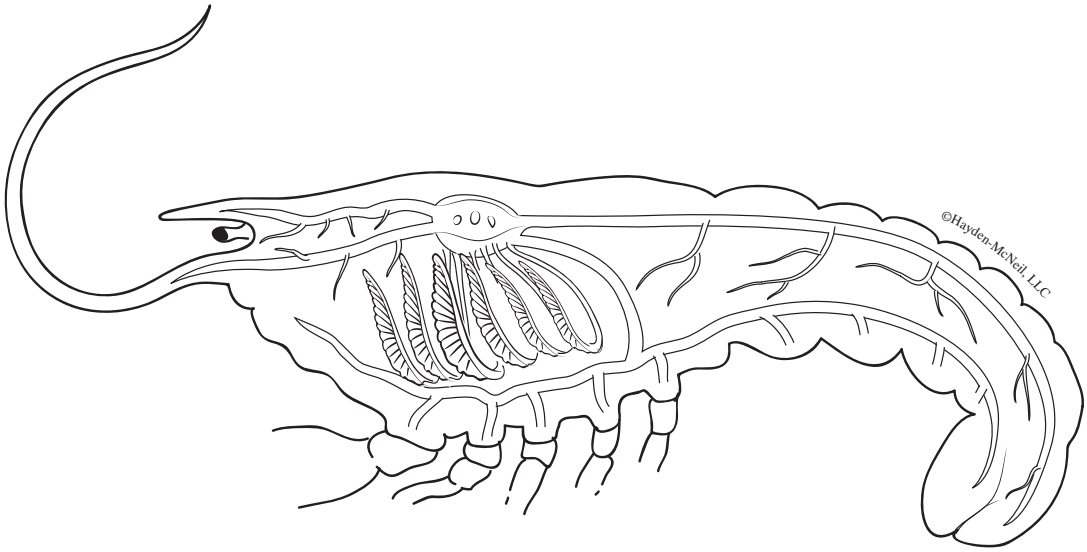
5. How do the earthworm and bullfrog obtain oxygen? What similarities can you see between their circulatory systems? How are they different?

   How does the earthworm's diet and digestive system compare to the bullfrog's?

6. Compare and contrast open and closed circulatory systems. Give an example of animals exhibiting both types.

7. Explain why blood/hemolymph circulates to and from the heart in an open circulatory system.

8. On the following diagram, trace the flow of blood in the crayfish. Label gills, heart, and ostia.



Week II

LEARNING OBJECTIVES

Students will….

- identify the major chambers, blood vessels, and associated structures of the mammalian heart by using a dissected heart specimen and pointing out structures and blood flow through the heart to their peers and instructor.
- review blood flow through the heart and body by labeling a diagram as they follow an in-class discussion on pulmonary and systemic circulation.
- run an electrocardiograph study to describe the electrical activity through the heart by following the waveforms of an electrocardiogram and by matching the electrical circuit to the physical contraction and relaxation of cardiac muscle.
- analyze a peer's electrocardiogram at rest and during an activity to record changes in heart activity and to label each electrocardiogram with the correct waveform designations.
- extend their knowledge of animal transport by answering specific questions through class discussion and written responses.

INTRODUCTION

The mammalian heart has two thin-walled **atrial** chambers that receive blood into the heart, and two thick-walled **ventricle** chambers that pump blood out of the heart. The right atrium receives blood from the **vena cava**, a large blood vessel returning blood to the heart from the body. The circuit of blood from the body to the heart and from the heart to the body is termed **systemic circulation**.

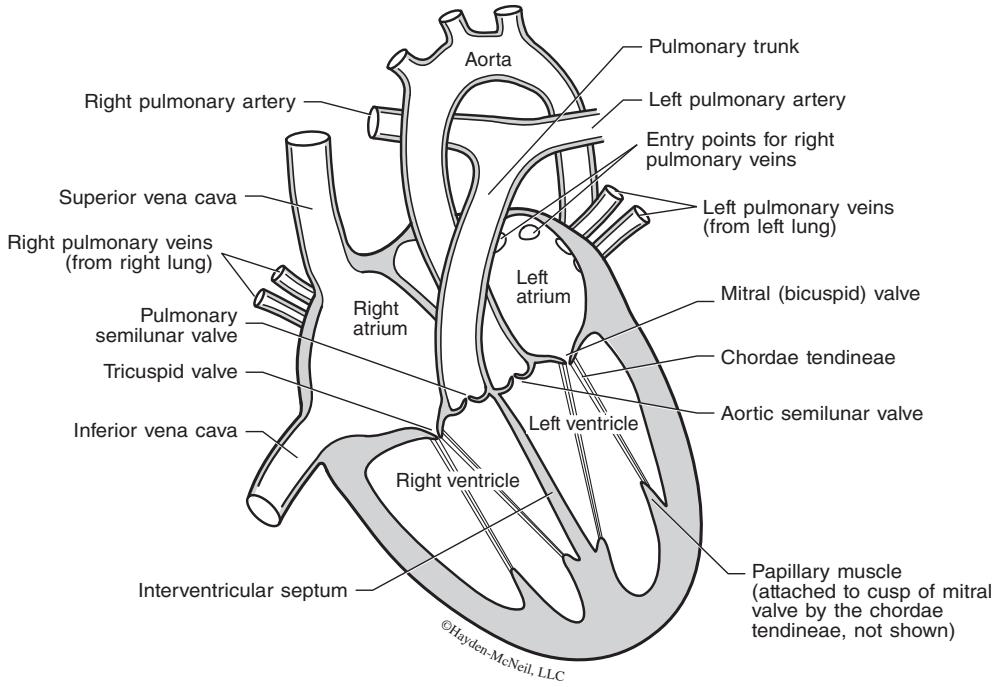


Figure 10-10. Blood Flow in the Heart

Blood flows from the right atrium into the right ventricle, where it is pumped to the lungs via the **pulmonary artery**. After the blood is oxygenated, it returns to the heart via the **pulmonary vein** and enters the left atrium. The circuit from the heart to the lungs and from the lungs back to the heart is called **pulmonary circulation**. Blood leaves the left atrium and enters the left ventricle, and is then pumped from the left ventricle out the aorta, once again entering into **systemic circulation**. A diagram of the mammalian heart is included so you may follow the blood circulation in relationship to the ECG recordings (Figure 10-10).

Activity One: Heart Structure and Double Circulation

▶ PROCEDURE

1. When examining the mammalian heart available in the laboratory it is easy to distinguish the two ventricles by observing the thickness of the muscle that surrounds them. The left ventricle is considerably more muscular since its job is to pump blood into the systemic circuit. **Valves** are present between all chambers of the heart in order to impart direction of flow. The **chordae tendineae** are chordlike fibrous structures that anchor the valves and assist in their opening and closing.
2. Identify the following structures in the heart:
   a. Left atrium
   b. Right atrium
   c. Left ventricle
   d. Right ventricle
   e. Atrial-ventricular valves (bicuspid/tricuspid)
   f. Chordae tendineae
3. You may need to examine more than one of the specimens to clearly see all of the structures.

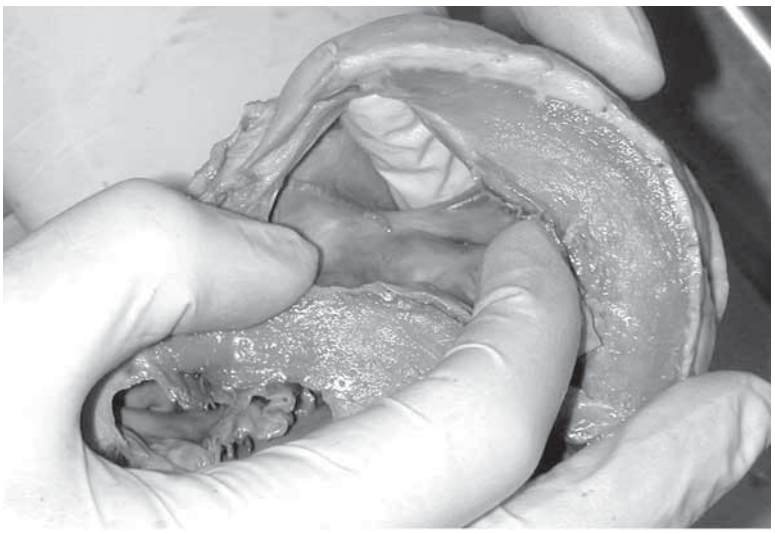


Figure 10-11. Examining Interconnections among Chambers and Vessels

4. As shown in Figure 10-11, use a gloved finger to clearly **identify major blood vessels** and to trace the movement of fluid throughout the heart and associated blood vessels. Put your gloved fingers inside a ventricle or atrium and see where it leads. Identify the following major blood vessels:
   a. Pulmonary vein
   b. Vena cava
   c. Aorta
   d. Pulmonary artery
   e. Coronary artery

Activity Two: Heart Function and ECG

BACKGROUND

The **electrocardiogram** (ECG or EKG) is a graphic record of the rhythmic electrical potential changes that occur during each heartbeat. This electrical activity is caused by changes in the selective permeability of cardiac muscle cell membranes to sodium and potassium ions. In the relaxed state, a difference in electrical potential exists between the inside and outside of each cardiac muscle cell. Outside the cell, the sodium ion concentration is very high and that of potassium is low. Inside the cell, the potassium concentration is higher than that of sodium. Overall, there are more positive ions outside than inside the cell; therefore, the inside of each resting cardiac muscle cell is electrically negative with respect to the exterior.

Cardiac muscle cells must be stimulated before they will contract. The source of stimulation is a small patch of specialized heart muscle, the **sinoatrial (SA) node**, located in the floor of the right atrium. The SA node, also called the **pacemaker** of the heart, generates a small electrical impulse in a rhythmic manner (60 to 80 times per minute in the normal heart at rest). Each impulse travels along a pathway of specialized **conductile fibers** that ultimately deliver it to all of the cardiac muscle cells. The stimulatory impulse causes the muscle cell membranes to become highly permeable to sodium ions. In an event known as **depolarization**, sodium ions enter the cell rapidly, causing the electrical field to reverse its polarity. The cardiac muscle cells are then able to contract. In a process called **repolarization**, the sodium ions are "pumped" out of the cell by an active transport mechanism to return the electrical field to the resting state. These cyclical changes in electrical potential are transmitted through the tissue fluids to the surface of the body. Metal electrodes placed on the skin and amplified by a unit, which displays them as an electrocardiogram, can then measure these weak signals. The ECG is characterized by a **waveform** containing five distinct components: **P**, **Q**, **R**, **S**, and **T**, as shown in Figure 10-12.

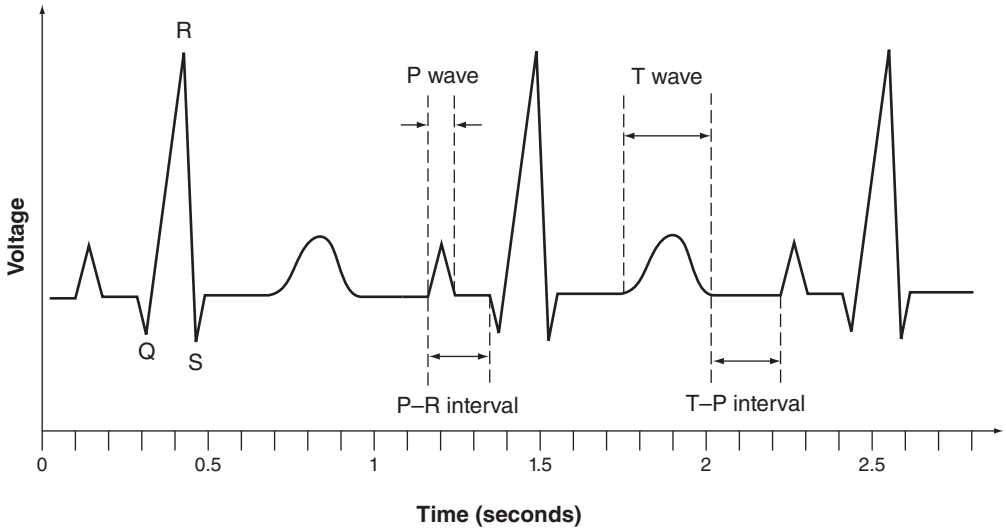


Figure 10-12. ECG Waveform

At the beginning of the cardiac cycle, the electrical impulse from the SA node spreads across the atria, causing them to depolarize and contract. This is represented by the **P wave**. The depolarization impulse proceeds along the conductile pathway to the **atrioventricular (AV) node**, located between the atria and the ventricles. A delay of approximately 0.1 second occurs as the depolarization wave passes through the AV node. This delay ensures that the atria pump blood into the ventricles before the ventricles depolarize and contract (the ventricles *must* be relaxed to accept blood). After passing through the AV node, the depolarization impulse proceeds through the **bundle of His**, the **bundle branches**, and the **Purkinje fibers**. The impulse, delivered to all parts of the ventricular muscle mass by the Purkinje fibers, enables the ventricles to depolarize and contract in unison. This contraction pushes the blood out of the ventricles (to the lungs from the right ventricle and to the body from the left ventricle). Ventricular depolarization produces the **QRS component** or **wave complex** of the ECG waveform. After the completion of ventricular contraction, the cardiac muscle cells repolarize and resume the initial resting state. Repolarization (relaxation) of the ventricles is responsible for the **T wave** of the ECG.

The function of the heart depends upon a continual repetition of the depolarization–repolarization cycle to initiate the mechanical events necessary for pumping blood throughout the body. During the relaxation phase of this cycle, called **diastole**, the chambers of the heart (atria or ventricles) fill with blood. The contraction phase, termed **systole**, is the part of the cardiac cycle in which blood is actually pumped from the atria to the ventricles and from the ventricles out of the heart.

Heart action in humans and many animals is automatic; the contraction is **myogenic**, meaning it originates in the heart muscle and is not dependent upon outside impulses for the initiation of contraction. In fact, a heart removed from the body continues to contract when placed in a nutrient-rich and osmotically balanced environment. However, the rate of the contraction or heartbeat is regulated by multiple factors. Some of these factors include age, physical condition, and fever. From ECG recordings, a trained

technician or physician can detect abnormal activities (**arrhythmias**) in the heart. The exact location of such deviations and their causes can also be diagnosed.

In this activity you will run an ECG. One student per group should act as the "volunteer," who will have his or her ECG taken.

▶ PROCEDURE

1. On the desktop of your computer, click on the "Logger Pro" icon from the application dock.
2. Next click on the small icon at the top with a clock on an axis graph. Change the length of data collection from 3 to 10 seconds. Click **Done**.
3. Place one electrode patch at each of the locations designated below. Then connect the appropriate colored lead to the correct location by pinching the electrode clip onto the patch.
   a. Green lead (–) = right inner elbow
   b. Black lead (ref) = right inner wrist
   c. Red lead (+) = left inner elbow

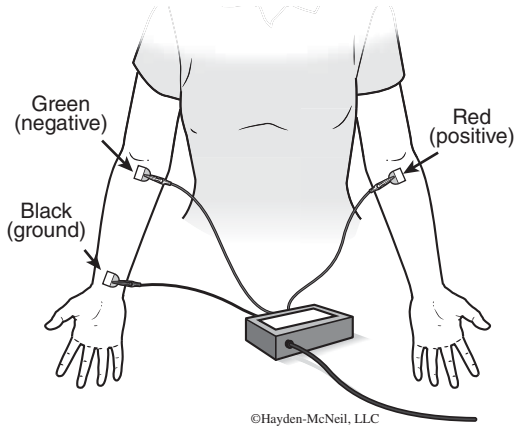


Figure 10-13. ECG Lead Connections

4. The student volunteer should sit still during data collection. Do not remove the electrode patches until you are finished with all of the data collection activities. You should disconnect the leads from the patches between data collections.
5. When the leads have been attached, click on the green arrow button (collect) at the top right of the screen. You will see the electrical activity associated with each heartbeat for a period of 10 seconds. This will be your resting ECG.
6. To save this file, click on **File**, then pull down to **Save As** and name your file:
   a. YourName**Resting**.
7. Save this file to the **Desktop**.
8. The volunteer should then be active for 5 to 10 minutes. Be sure to disconnect the ECG leads when not sitting at the table.

9. The volunteer should return to the ECG unit and reconnect the leads. Quickly click the green arrow button and record for another 10 seconds.
10. To save this file, click on **File**, then pull down to **Save As** and name your file:
    a. YourName**Active**.
11. Again, save this file to the **Desktop.**
12. In order to analyze your ECGs you will need to fill in the table, recording information for two students at your table, individuals A and B, using the following instructions:
    a. On your ECG, highlight from one QRS complex to the next.
    b. Look down in the bottom left-hand corner and find the delta X (ΔX). This is actually your delta T (ΔT or change in time) for one heartbeat.
    c. Follow the lab instructor's directions on how to calculate BPM.
    d. To calculate your mean BPM (beats per minute) from your ECG waves, count the number of heartbeats in 10 seconds, then multiply by 6. (Mean BPM = # beats in 10 seconds × 6.)

Table 10-2. ECG analysis of student "A"

NAME OF STUDENT A						
RESTING MEASUREMENT	1	2	3	4	5	MEAN
ΔT (TIME)						
BPM						
ACTIVE MEASUREMENT	1	2	3	4	5	MEAN
ΔT (TIME)						
BPM						

Table 10-3. ECG analysis of student "B"

NAME OF STUDENT B						
RESTING MEASUREMENT	1	2	3	4	5	MEAN
ΔT (TIME)						
BPM						
ACTIVE MEASUREMENT	1	2	3	4	5	MEAN
ΔT (TIME)						
BPM						

Table 10-4. Student ECG comparison

	STUDENT A	STUDENT B
RESTING (MEAN)		
ΔT		
BPM		
EXERCISE (MEAN)		
ΔT		
BPM		

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[Questions]

Name Lab/Section

Partner's Name (if applicable) Date (of Lab Meeting)

ECGs

1. Attach/tape below one section of an ECG printout containing 1–2 heartbeats. Label the P, Q, R, S, and T waves. What is an electrocardiogram? What kind of information might a physician obtain about a patient's heart from reading an electrocardiogram?

2. How did the ΔT change from resting to active in one of your test subjects?

3. How does the amplitude (the height of the waves) and the wavelength (the distance from one wave top to the next) change between rest and activity conditions?

   Why are these changes occuring?

4. What differences in the data and ECG recorded did you observe between student A and B? Explain why these two individuals may differ.

5. Scientists have shown that proper conditioning can protect an athlete against the effects of stress, in part, by slowing the rate of the heartbeat during rest and at work. If so, how would a trained athlete respond to the same exercise stress you underwent in laboratory?

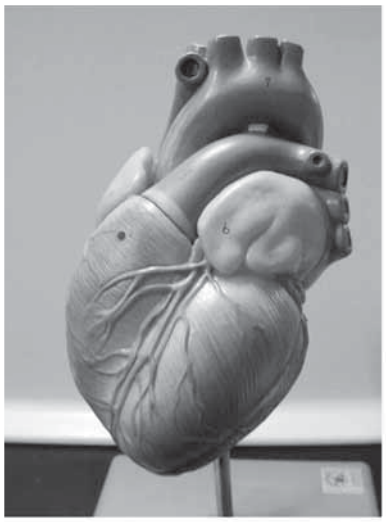
[Questions]

Name | Lab/Section

Partner's Name (if applicable) | Date (of Lab Meeting)

Mammalian Heart

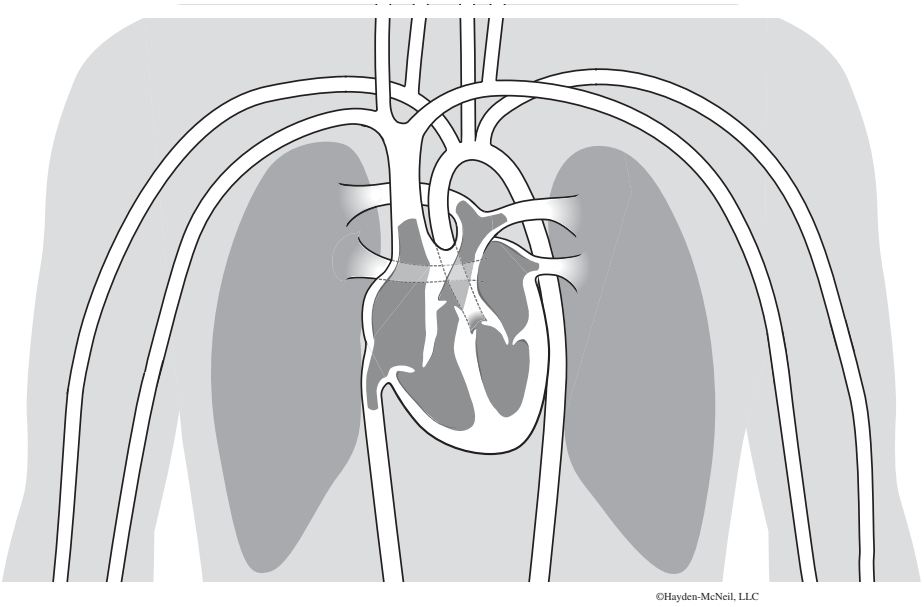
1. Label the four chambers of the mammalian heart on the following photos. What other structures can you identify?

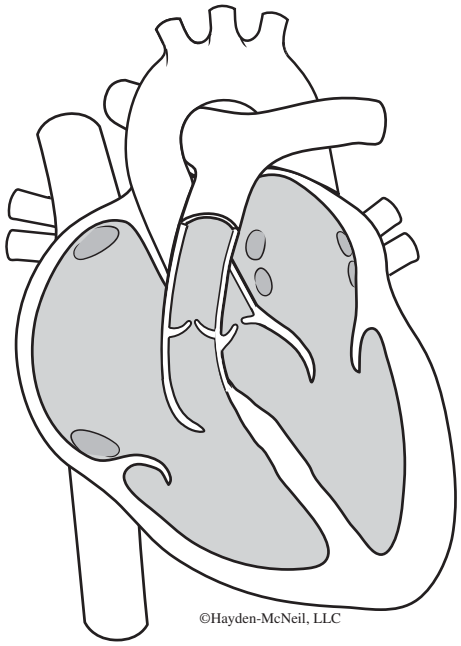


2. Label the orientation for the left and right sides of the body.

   Use a **dotted line** to trace the pulmonary circulation and a **solid line** to trace the systemic circulation.

   Label the following structures: aorta, pulmonary artery, pulmonary vein, and the vena cava.





[Questions]

Name Lab/Section

Partner's Name (if applicable) Date (of Lab Meeting)

Circulatory System Overview

1. It would seem that the closed circulatory system would be more efficient than the open circulatory system. Why do you think this would be true? Fairly active animals such as insects and crustaceans have open circulatory systems and fairly inactive animals such as earthworms have closed circulatory systems. Indicate what factors may influence the distribution of closed and open circulatory systems in animals to explain these observations.

2. You have now dissected a fish, a frog, a crayfish, and an earthworm in this laboratory. Construct a table comparing the circulatory and digestive systems in these animals. For the circulatory system for example, you may want to consider whether the system was closed or open, the number of hearts, the number of chambers of the heart, etc. For the digestive system, you might want to list the parts of the digestive tract. For example, frogs have a stomach, but what organ in the crayfish would be comparable? Which of the digestive tracts that you have worked with so far seems the most complex (has the most parts)? Correlate complexity with diet. Also, give some accessory organs of the digestive system, such as the liver for the fish and the frog, and discuss their functions.