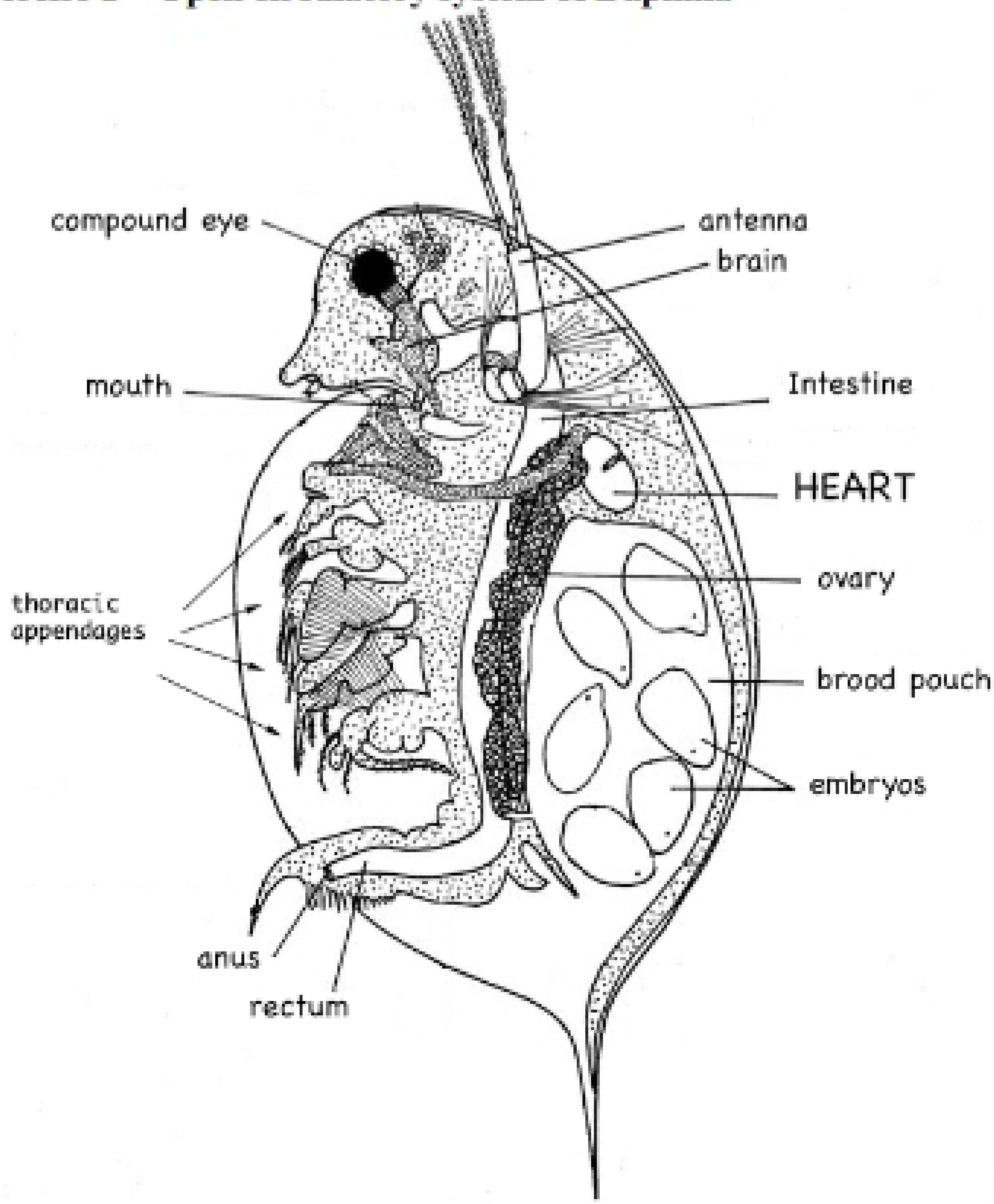
Circulation and Gas Exchange

Introduction

All animals need to obtain oxygen (O_2) and nutrients from the environment and get rid of carbon dioxide (CO_2) and wastes. For single-celled organisms, Sponges and Cnidarians, this can be accomplished by diffusion directly between the cells of the organism and the environment or through the gastrovascular cavity. However, for larger animals, the exchange of gases and nutrients is accomplished through specialized systems for circulation and gas exchange. Humans and other vertebrates have a closed circulatory system where blood is confined to the heart and blood vessels. Gas exchange with the environment occurs through the lungs. Today we will observe a small crustacean that uses a different strategy. We will also examine aspects of the human circulatory and respiratory system.

Exercise 1 – Open circulatory system of Daphnia



Daphnia magna, sometimes called the water flea, is a crustacean in the phylum Arthropoda. Like other arthropods, daphnia has an **open circulatory system.** Blood-like fluid, called **hemolymph**, is pumped throughout the body cavity. This type of cavity, called a **hemocoel**, is well developed in arthropods and mollusks where the coelom is small. An open circulatory system is not as efficient as a closed one, but for many **ectotherms**, it is perfectly adequate.

Procedure – work in pairs

1. Carefully pick up a single daphnia with a plastic pipette and place it on a depression slide. Use the pipette to remove all but a thin film of water covering the daphnia. This will immobilize the daphnia while still allowing it to breath. **Observe under a dissecting microscope. Don't let your specimen dry out. Add small amounts of water as necessary.**

2. Observe the various structures noted on the diagram. The thoracic appendages will be actively moving. These are used to generate feeding currents and for swimming. Find the oval shaped heart – it is almost transparent. The circulatory fluid, hemolymph, is clear also. **You may see reddish tissue running the length of the animal. What do you think this is?**

Can you count the rate of the heartbeat? Do you think this is the "normal" resting heart rate of daphnia? Why or why not?

How does the heart rate in daphnia compare to your own?

What would account for the difference?

How do you think daphnia acquires O_2 and expels CO_2?

Introduction to the Heart

The heart is a muscular organ that pumps circulatory fluid – blood or hemolymph – throughout the body. In Arthropods and Annelids, the simplified "heart" is just a thicker, more muscular part of the circulatory system, with no compartments or valves. We observed this in the two previous labs. Vertebrates have hearts with compartments and valves for more efficient circulation.

Can you think of characteristics of animals that would require more efficient circulation?

Different groups of vertebrates have different numbers of circuits in their circulatory systems and different numbers of chambers of the heart (see Fig. 42.5 in Campbell). Regardless of the number, there are two types of chambers: the **atrium** (plural atria), and the **ventricle**, the more muscular pump. Valves that separate the chambers insure that the blood flows in only one direction through the system.

The simplest of the chambered hearts is that of fish with a 2-chambered heart comprised of one atrium and one ventricle. The blood flows in a single circuit from the body to the heart, then to the gill, and on to the body again. The atrium is separated from the ventricle by a valve. When the ventricle pumps, it forces the valve closed so that the blood can only flow toward the gill capillaries where the blood is oxygenated. When the heart muscle relaxes, there is negative pressure so the valve opens and allows passive flow down the pressure gradient of blood from the atrium. Flow of blood in fish is also facilitated by muscular contractions of the body. We observed the 2-chambered heart in the fish we dissected last week.

Amphibians have a 3-chambered heart that pumps blood through two circuits. The first is the pulmocutaneous circuit (pulmo=*lung*, cutaneous=*skin*) where the blood is oxygenated. The second is a systemic circuit throughout the body to deliver O_2 and remove CO_2. The single ventricle pumps a mixture of oxygenated and deoxygenated blood to both circuits. Deoxygenated blood from the body goes into the right atrium whereas the oxygenated blood from the pulmocutaneous circuit enters into the left atrium. Reptiles (except crocodiles) also have a 3-chambered heart, but they have a partial division in the single ventricle that helps to separate the oxygenated and deoxygenated blood.

Mammals and birds (and crocodiles) have a 4-chambered heart with two atria and two ventricles. This allows the two blood circuits of oxygenated blood and deoxygenated blood to be completely separated, thus making for a very efficient circulatory system. In addition to the sheep heart dissection below, we dissected a quail in a last week. Look at Figure 42.5 in Campbell for comparison of vertebrate circulatory systems.

Exercise 2 – Sheep Heart Dissection

The sheep heart, like that of humans is a 4-chambered heart with 4 valves. First, observe the heart from the outside. The white areas are fat and the dark red areas, the muscle. The muscular ventricles comprise a great majority of the heart. Depending upon where the arteries and veins were cut, there may be four or more openings. The aorta comes out from the left ventricle where the oxygenated blood goes to the body. The pulmonary artery sends deoxygenated blood from the right ventricle to the lungs. The pulmonary vein then brings the oxygenated blood back to the left atrium. Finally, there are vena