

Circulation and gas exchange:

Basic function - to provide the body with oxygen, nutrients, remove wastes and CO₂. (lungs/gills generally don't do much with nutrients and wastes, but, as usual, there are exceptions)

Reason for having a circulatory system: all cells in the body need access to oxygen, etc.

Methods of granting access to oxygen/nutrients [**Fig., similar to 23.1, p. 468**]:

- open circulatory system - some blood vessels may be present, but no capillaries. In other words, heart beats, fluid moves into some large vessels, and from there into the body. All parts of the body are therefore "bathed" in this fluid [e.g., insects, many arthropods].
- closed circulatory system - blood is always confined to blood vessels. Small blood vessels are present throughout the tissues and thus insure that blood can get to all parts of the body [e.g., cephalopods, earthworms, vertebrates].

Vertebrate cardiovascular systems:

- heart is composed of at least two parts: an atrium and a ventricle. But higher vertebrates may add to this (e.g., two atria).
- atrium receives blood from the body, then moves blood to ventricle, ventricle pumps blood out of heart.
- arteries -> arterioles -> capillaries (&capillary beds) -> venules -> veins

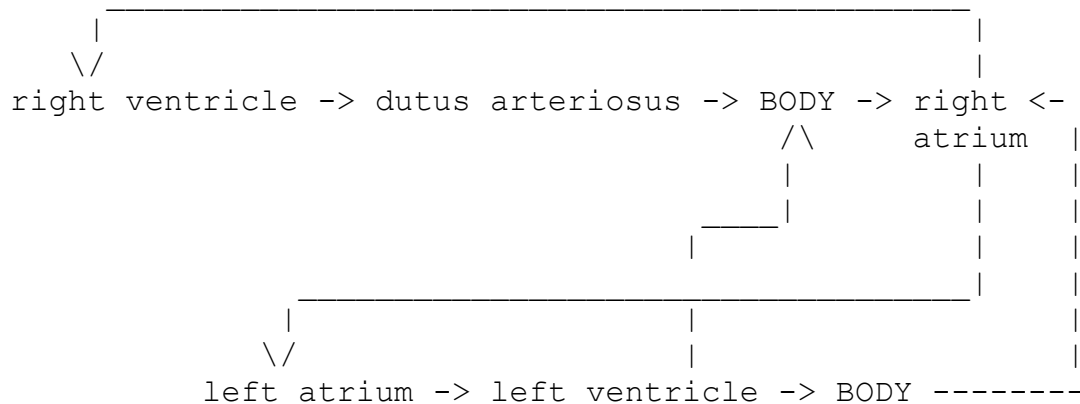
(NOTE that this says nothing about what parts of the body the blood is going to, just the names of the blood vessels)

The flow of blood in mammals [**Fig. 23.2, p. 469**]:

- compared to other animals, all parts of the body get newly oxygenated blood under high pressure.

Mammals: right ventricle -> lungs -> left atrium -> left ventricle -> body -> right atrium -> right ventricle.

But we need special arrangements in a fetus: **[Fig., not in book]**:



(note: the above “diagram” may not show up correctly using ASCII text (i.e., it might not look right on the web))

“body” is actually “body & placenta”

* Note that blood going to the lungs is considered to be in the “pulmonary circuit”, whereas blood going to the body is in the “systemic circuit”.

Human heart - details:

[Figs. 23.3A and 23.3B, p. 470].

- go through overheads, mention all parts (mostly a review of the above).

Cardiac cycle: basically, what happens from one heart contraction to the next. First a few terms:

heart rate - # of times heart beats in one minute (pulse is always recorded as beats/minute, though often is measured over 30 seconds or so - average is about 70).

stroke volume - amount of blood pumped by left ventricle with one beat (average, about 75ml per beat).

cardiac output - amount of blood pumped by left ventricle [Question - what about the right?] in one minute (cardiac output is about 5.25 L if heart rate is about 70. This is about the amount of blood present in humans).

steps in cardiac cycle **[Fig. 23.4, p. 471]**

systole (contraction phase)
diastole (relaxation phase)

1) atria and ventricles are relaxed

- 2) atria contract, ventricles remain relaxed
- 3) ventricles contract, atria relax

repeat.

during step 3, lub sound is produced as AV valves close.
during step 1, dub sound is heard as semilunar valves close.

Comments:

- AV valves prevent backflow of blood from ventricles to atria
- semilunar valves prevent backflow of blood from "aortas" to ventricles
- heart murmur can be caused by a backflow of blood against the valves.

Electrical properties of heart:

Cardiac muscle cells will contract without any kind of external stimulus.
[OVERHEAD, fig. 23.5A, p. 472]

Something needs to coordinate these cells -> the SA node which is located in the wall of the right atrium will release the signal to beat. Note: when cells do not beat in a coordinated fashion -> blood is not pumped, and heart needs to be "reset". This is when a defibrillator can be used.

Intercalated disks (at the ends of cardiac cells) allow rapid dissemination of electrical stimulus, and so the atria contract.

Then signal reaches AV node. Here signal is delayed (to ensure atria get done contracting), and then specialized muscle fibers transmit signal to ventricles which then contract.

These signals can be picked up with an EKG or ECG.

Note that these signals are electrical in nature, and while they correspond to various steps in the cardiac cycle, they do not directly measure such things as "ventricles contracting".

Stuff influencing heart rate:

- hormones (epinephrine causes an increase in heart rate)
- body temperature (fever increases the heart rate)
- stimuli from nerves reaching the heart (i.e., nerves coming from brain and elsewhere).
- condition - if one is in excellent condition, heart rate is often much lower (e.g., average rate is "70", but in good condition might be as low as 55 or

even 50).

Rate of blood flow is controlled by two things:

1) Heart rate -> how fast is the heart beating (already discussed).

2) Blood pressure:

Systolic pressure - maximum pressure when ventricles contract.

Diastolic pressure - minimum pressure when ventricles are relaxed.

Blood pressure is measured in mm Hg.

[Fig 23.9 page 476].

Why is there a minimum pressure? Why not "0"?

- elasticity of artery walls
- peripheral resistance
 - this is basically the resistance due to entering capillary beds.

- go through sphygmomanometer function using overhead.

- as one moves away from the heart, blood pressure drops. It makes a difference where you measure blood pressure (sometimes this is used diagnostically).

- Blood pressure drops and smooths out as you move into capillaries and finally veins **[Fig. 23.8A, p. 475].**

- Venous blood pressure is so low that blood needs assistance to move back to heart **[Fig. 23.8B, p. 475]:**

- valves in veins
- skeletal muscles contracting
- some contraction by muscles in veins

- more details in lab (nice demo of the valves in the veins)..

Capillary function:

- many capillary beds can be turned off by muscles (sphincters) that control access to capillaries **[Fig. 23.10, p.477].**

- useful, for instance:

- when exercising - for instance, diverts blood from digestive system

- when hot - shunts blood to skin
- when suffering from blood loss - shunts blood to vital systems.

- opposite - during anaphylactic shock, many capillary beds may open at once causing a drastic fall in blood pressure.

- details of how oxygen is diffused into the tissues are in your text if you're interested. Essentially substances are transferred through diffusion or differences in pressure.

Lymphatic system [**Fig., similar to fig. 24.3, p. 488**]:

- Fluid leaves capillaries as capillaries enter tissues. But not all fluid is returned to capillaries.

- Therefore there needs to be a way for fluid to be returned to the circulatory system.

- Fluid enters lymphatic system by diffusing into small "lymph" capillaries that then come together and eventually drain into the circulatory system near the junction of the vena cava with the right atrium.

- Lymph vessels function very much like veins in moving lymph back to heart.

- Throughout this system there are lymph nodes that filter lymph and attack viruses and bacteria that are in the lymph (details when we do the immune system).

- Blockage of the lymph system can be painful and cause serious deformities (e.g., filarial worms (nematodes) that causes elephantiasis).

Nature of blood - consists of [**Fig. 23.12 p. 479**]:

1) 55% blood plasma - fluid that contains water, solvents, ions, proteins, nutrients, etc.

2) 45% cells:

- red blood cells - transport of oxygen, carbon dioxide;
- white blood cells - body defense and immunity;
- platelets - blood clotting;

Some comments:

- each RBC contains about 250 million molecules of hemoglobin, a protein that can carry oxygen .

- cells are all generated from "stem cells" that exist in bone marrow. Occasionally, this may malfunction, leading to overproduction of certain

types - e.g. leukemia can be caused by overproduction of leukocytes. [Fig. 23.15, p. 481]

Blood clotting:

- involves a complicated pathway - see [Fig. similar to 23.14 A, p. 480]. Essentially, if platelets encounter a rough surface, it becomes sticky and releases a substance that causes nearby platelets to become sticky as well.
- If damage is more severe, this causes the release of substance that changes **prothrombin** into **thrombin**, which will then change **fibrinogen** into **fibrin**, which interweaves itself into the clot. (Note two steps are involved - [WHY MIGHT YOU WANT "TWO" STEPS HERE?]).

Addendum on Heart Disease:

I. Causes (risk factors):

- see [Fig., not in text]
- Preventable factors: diet/lack of exercise/smoking
- Factors that can't be prevented: aging/family history (& disease)/being male
- these can all contribute to heart disease. Some details on some of these:
- diet:
 - there is actually little direct evidence that cholesterol is bad, though a lot of indirect evidence.
 - cholesterol is thought to increase the tendency to form blockages in vessels (this is LDL cholesterol or "bad" cholesterol).
 - (though other types of cholesterol (HDL's) may actually help here.
- exercise (mostly aerobic):
 - helps strengthen the heart muscle and increase circulatory system efficiency. Also helps increase HDL levels (good cholesterol levels).
 - approximately halves the risk of having a heart attack.
- smoking:
 - decreases levels of HDL (good cholesterol)
 - constricts blood vessels surrounding the heart
 - see p. 457 to see what it does to lungs!

- approximately doubles the risk of having a heart attack.
- aging:
 - condition deteriorates as one gets older. Plaques and other blockages start to form.
- family history:
 - things like high cholesterol can run in families. Not much that can be done about genetic history (except take medication).
 - other diseases can cause heart disease (very high fevers can damage heart valves, various infections can interfere with the correct functioning of the heart).
- males:
 - are more subject to heart disease.

II. Hypertension:

- high blood pressure
- causes increased stress on the heart (has to work harder)
- increased pressure can cause damage to the blood vessels, which can cause the build up of plaque & atherosclerosis.
- often leads directly to heart attack, stroke, or kidney disease
- has many of the same risk factors as above, but the exact connections between some of these factors and hypertension are not understood very well.

III. Results of heart disease:

- Some can be minor (e.g., require a pacemaker), some major (e.g. heart attack).
- Lots of different “types” of heart disease:
 - congenital heart disease (genetic defect in the heart)
 - arrhythmias (irregular heart beat)
 - heart valve disease (e.g., mitral valve prolapse (usually, heart valves allow leakage to occur))
 - heart failure (heart does not work as well as it should)

- heart attack (in general “coronary heart disease”) [Fig. 23.6A & B, p. 473]

- often caused by a blockage of the coronary arteries
- coronary arteries supply the heart muscle
- blockage is formed by atherosclerosis

- deposits of plaque on the walls of the arteries, causing narrowing of the blood vessel. This narrowing is more likely to become blocked by a blood clot.

- as a result, the parts of the heart served by this vessel die. If a large enough area is affected, the result can be death.

- Heart disease can be treated with drugs or surgery. It can be prevented by life style changes (diet/exercise/stopping smoking).

- It is the # 1 killer in the U.S.

- Incidentally, strokes, 80% of which are caused by blockages in the blood vessels to the brain, are the # 3 killer [Fig., not in text].