2.4 Circulatory Systems

Features of a transport system and types of circulatory system

As covered in 2.1 Special Surfaces for Exchange, the size and surface-area-to-volume ratio have a big impact on the need for a transport system. Single-celled organisms do not need a specialised transport system because materials can be transported via simple diffusion, whereas larger animals require a more elaborate transport system.

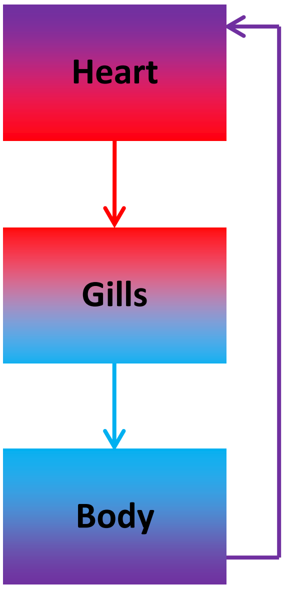
Another factor affecting the need for a specialised system is the **level of activity**. Animals need energy from food so that they can move around, and releasing this energy from food requires *oxygen*. If an animal is very active, it is clearly going to need a decent supply of nutrients and oxygen to supply the energy to cater for its movement. Animals which keep themselves warm (e.g. mammals) need even more energy.

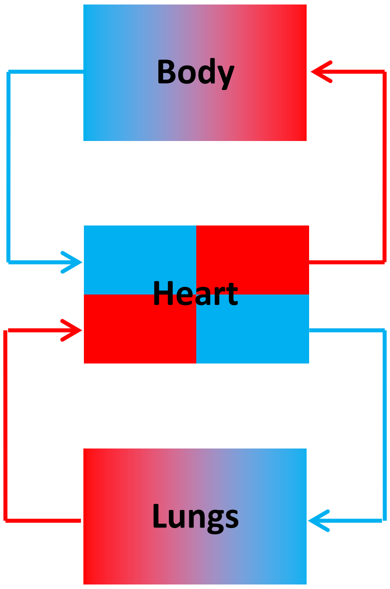
An effective transport system will include:

- a fluid or medium to carry nutrients and oxygen around the body (**blood**)
- a pump to create pressure that will push the fluid around the body (**heart**)
- exchange surfaces that enable oxygen and nutrients to enter the blood and leave it again where they are needed

More efficient transport systems also have:

- tubes or vessels to carry the blood
- two circuits – one to pick up oxygen and another to deliver it to the places it is needed in the body





Fish are organisms which have a **single circulatory system**. In fish, the blood flows from the heart to the gills and then onto the body, and back to the heart. This is shown in the left-hand flow chart.

Mammals have a circulation which uses two circuits; this is a **double circulatory system**. One carries blood to the lungs to pick up oxygen (this is the **pulmonary circulation**) and the other carries the oxygenated blood around the body to the tissues where it's needed (**systemic circulation**). The mammalian heart (see 2.6 The Mammalian Heart) is adapted to form two pumps, one for each circuit. Blood flows through the heart twice for each circulation of the body. This is shown in the right-hand flow chart.

There are advantages attached to a double circulatory system:

- ✓ Blood can be maintained at a higher pressure in the systemic circuit, so it is delivered more quickly
- ✓ A slightly lower pressure can be maintained in the pulmonary circuit to prevent damage to capillaries of the lungs

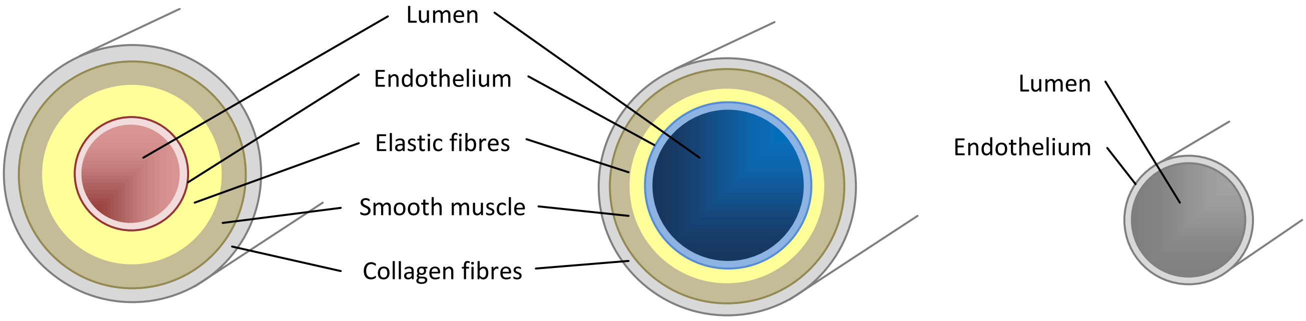
For an animal to be active, it needs a good supply of oxygen and nutrients (such as glucose, amino acids and fatty acids) and the rapid removal of carbon dioxide. In mammals, blood is never released into the body cavity, it is always confined within **blood vessels**. This is called a **closed circulatory system**. However, many animals, including all insects, have an **open circulatory system**. This means that the blood isn't always held within vessels, instead, it is free to circulate the body cavity, so any cells, tissues and organs of the organism are bathed in blood.

In an insect, there is a muscular pumping organ much like a heart. This is a long tube that lies under the **dorsal** (upper) **surface** of the insect. Blood from the body enters the heart through pores called **ostia**. The heart then pumps the blood towards the head via **peristalsis**. At the forward end of the heart (nearest the head), the blood simply pours out into the body cavity.

The open circuit works for insects because they are small, so the blood doesn't have to travel far, and because they do not rely on blood for the transport of oxygen and carbon dioxide – they have a separate transport system for this. Larger organisms need the blood to transport these, so a closed circuit is necessary. In these organisms, the blood always remains inside blood vessels, and a separate fluid (**tissue fluid**) bathes the organs and tissues.

BLOOD VESSELS

Blood flows through a series of vessels. Each one is specially adapted for its function, which is affected by its distance from the heart. Each vessel has an inner layer called **endothelium** which is one cell thick. It is smooth to reduce the friction of the blood flow.



Arteries (left diagram) carry blood away from the heart. They have a small **lumen** to maintain a high pressure and relatively thick walls containing collagen to give it strength and to make the walls able to withstand the pressure. There is also **elastic tissue** present which can stretch and then recoil the artery when the heart pumps; and smooth muscle which contract to narrow the size of the lumen. The **endothelium** is folded, and unfolds when the artery stretches.

Veins (centre diagram) carry blood back to the heart. The blood is at a relatively low pressure, and so the walls are not as thick as in arteries. The lumen is significantly larger, to ease the flow of blood. The levels of collagen fibres, smooth muscle and elastic fibres are lower, because a vein does not need to stretch and do not actively constrict to reduce blood flow. Veins contain **valves** to prevent the backflow of blood in the opposite direction. The movement of blood in the veins is enables by the contraction of muscles surrounding the veins. For example, in the legs, it is the leg muscles which allow the blood to flow upwards in the veins by contracting (NOT the muscle in the vein wall, but the skeletal muscles surrounding them).

Capillaries (right diagram) have very thin walls. This creates a short diffusion pathway. The endothelium is composed of squamous (pavement) epithelial cells which have small gaps called **fenestrations** separating the cells. Having a small lumen means that all the red blood cells are constantly in contact with the vessel wall, to allow for quicker diffusion of oxygen from the oxyhaemoglobin (see 2.8 Carriage of Oxygen). There is no muscle tissue or elastic tissue in capillaries. The vessels come in packs of many because the high pressure from arteries needs to be evenly spread out. Therefore, it is not a huge concern when one capillary becomes broken or damaged.