Cardiovascular System: The Heart and Vessels of Mammals, Birds, Fish and Amphibians

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Throughout history, people have believed the heart plays a vital role in the body. The ancients supposed it was the seat of the spirit, the center of happiness, and in control of both the emotions and the intellect. Even today, we place the heart at the root of our emotions when we speak of being heartbroken or brave at heart. It is true that the heart plays an essential, life-giving role in an animal's body, but the mystery of what function it actually performs has been solved. The heart is the pump that drives the cardiovascular system.

Function of the Cardiovascular System

By circulating blood throughout the body, the cardiovascular system functions to supply the tissues with oxygen and nutrients, while removing carbon dioxide and other metabolic wastes. As oxygen-rich blood from the heart flows to the tissues of the body, oxygen and other chemicals move out of the blood and into the fluid surrounding the cells of the body's tissues. Waste products and carbon dioxide move into the blood to be carried away. As blood circulates through organs such as the liver and kidneys some of these waste products are removed. Blood then returns to the lungs (or gills, in the case of fish), receives a fresh dose of oxygen and gives off carbon dioxide. Then the cycle repeats itself. This process of circulation is necessary for continued life of the cells, tissues, and ultimately the whole organism. Up and down the evolutionary ladder, there are different forms of cardiovascular systems with different levels of efficiency, but they all perform this same basic function.

Mammalian Anatomy and Physiology

The cardiovascular systems of mammals, birds, amphibians, reptiles, and fish are all slightly different. The following is an overview of the main components of the mammalian system €“ the heart and blood vessels. A discussion of the other systems will follow.

Heart

The heart is composed of cardiac muscle that differs slightly from the skeletal and smooth muscle found elsewhere in the body. This special type of muscle adjusts the rate of muscular contraction, allowing the heart to maintain a regular pumping rhythm. The main parts of the heart are the chambers, the valves, and the electrical nodes.

Heart Chambers: There are two different types of heart chambers. The first is the atrium (plural is atria), which receives blood returning to the heart through the veins. The right atrium pumps blood to the right ventricle, and the left atrium pumps blood into the left ventricle. This blood is then pumped from the atrium into the second chamber called the ventricle. The ventricles are much larger than the atria and their thick, muscular walls are used to forcefully pump the blood from the heart to the body and lungs (or gills). See illustration below.

Valves: The valves found within the heart are situated between the atria and ventricles, and also between the ventricles and major arteries. These valves are opened and closed by pressure changes within the chambers, and act as a barrier to prevent the backflow of blood. The characteristic "lub-dub, lub-dub" heart sounds heard through a stethoscope are the result of vibrations caused by the closing of the respective valves.

Electrical Nodes: There are two different electrical nodes, or groups of specialized cells, located in the cardiac tissue. The first is the sinoatrial (SA) node, commonly called the pacemaker. The pacemaker is embedded in the wall of the right atrium. This small patch of tissue experiences rhythmic excitation and the impulse rapidly spreads throughout the atria, causing a muscular contraction and the pumping of blood from the atria to the ventricles. The other node, the atrioventricular (AV) node, relays the impulse of the SA node to the ventricles. It delays the impulse to prevent the ventricles from contracting at the same time as the atria, thus giving them time to fill with blood. The cycle of contraction of the heart muscle is called a heartbeat, the rate of which varies greatly between organisms. The following table gives the average heart rates of some common mammals.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Average Rate</th>
<th>Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>70</td>
<td>58 - 104</td>
</tr>
<tr>
<td>Cat</td>
<td>120</td>
<td>110 - 140</td>
</tr>
<tr>
<td>Cow</td>
<td>65</td>
<td>60 - 70</td>
</tr>
<tr>
<td>Dog</td>
<td>115</td>
<td>100 - 130</td>
</tr>
<tr>
<td>Guinea Pig</td>
<td>280</td>
<td>260 - 400</td>
</tr>
</tbody>
</table>

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Vessels

A vessel is a hollow tube for transporting something, like a garden hose transporting water. A blood vessel is a hollow tube for transporting blood. There are three main types of blood vessels:

- Arteries
- Capillaries
- Veins

These main blood vessels function to transport blood through the entire body and exchange oxygen and nutrients for carbon dioxide and wastes.

The arteries carry blood away from the heart, and are under high pressure from the pumping of the heart. To maintain their structure under this pressure, they have thick, elastic walls to allow stretch and recoil. The large pulmonary artery carries unoxygenated blood from the right ventricles to the lung, where it gives off carbon dioxide and receives oxygen. The aorta is the largest artery. It carries oxygenated blood from the left ventricle to the body. The arteries branch and eventually lead to capillary beds.

The capillaries make up a network of tiny vessels with extremely thin, highly permeable walls. They are present in all of the major tissues of the body and function in the exchange of gases, nutrients, and fluids between the blood, body tissues, and alveoli of the lungs.

At the opposite side of the capillary beds, the capillaries merge to form veins, which return the blood back to the heart. The veins are under much less pressure than the arteries and therefore have much thinner walls. The veins also contain one-way valves in order to prevent the blood from flowing the wrong direction in the absence of pressure. The pulmonary vein returns oxygenated blood from the lungs to the left atria. The vena cava returns blood from the body to the right atria. The blood that is returned to the heart is then recycled through the cardiovascular system.

Comparative Anatomy

Mammals and Birds

Mammalian and avian hearts have four chambers – two atria and two ventricles. This is the most efficient system, as deoxygenated and oxygenated bloods are not mixed. The right atrium receives deoxygenated blood from the body through both the inferior and superior vena cava. The blood then passes to the right ventricle to be pumped through the pulmonary arteries to the lungs, where it becomes oxygenated. It returns to the left atrium via the pulmonary veins, this oxygen-rich blood is then passed to the left ventricle and pumped through the aorta to the rest of the body. The aorta is the largest artery and has an enormous amount of stretch and elasticity to withstand the pressure created by the pumping ventricle. The four-chambered heart ensures that the tissues of the body are supplied with oxygen-saturated blood to facilitate sustained muscle movement. Also, the larger oxygen supply allows these warm-blooded organisms to achieve thermoregulation (body temperature maintenance).

Amphibians and Reptiles

Amphibians and reptiles, by contrast, have a three-chambered heart. The three-chambered heart consists of two atria and one ventricle. (The crocodile is sometimes said to have a four-chambered heart. The separation of the
ventricles is not complete, however, because a hole remains in the septum (wall) that divides the two chambers.) Blood leaving the ventricle passes into one of two vessels. It either travels through the pulmonary arteries leading to the lungs or through a forked aorta leading to the rest of the body. Oxygenated blood returning to the heart from the lungs through the pulmonary vein passes into the left atrium, while deoxygenated blood returning from the body through the sinus venosus passes into the right atrium. Both atria empty into the single ventricle, mixing the oxygen-rich blood returning from the lungs with the oxygen-depleted blood from the body tissues. While this system assures that some blood always passes to the lungs and then back to the heart, the mixing of blood in the single ventricle means the organs are not getting blood saturated with oxygen. This is not as efficient as a four-chambered system, which keeps the two circuits separate, but it is sufficient for these cold-blooded organisms.

The heart rate of amphibians and reptiles is very dependent upon temperature. For example, the following table gives the approximate heart rate of a crocodile at the indicated temperatures. Notice that the higher the temperature, the faster the heart beat.

<table>
<thead>
<tr>
<th>Temperature (Celsius)</th>
<th>Average Rate (beats/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 C</td>
<td>1 - 8</td>
</tr>
<tr>
<td>18 C</td>
<td>15 - 20</td>
</tr>
<tr>
<td>28 C</td>
<td>24 - 40</td>
</tr>
<tr>
<td>&gt;40 C</td>
<td>Irreversible cardiac damage</td>
</tr>
</tbody>
</table>

Fish

Fish possess the simplest type of true heart—a two-chambered organ composed of one atrium and one ventricle. A rudimentary valve is located between the two chambers. Blood is pumped from the ventricle through the conus arteriosus to the gills. The conus arteriosus is like the aorta in other species. At the gills, the blood receives oxygen and gets rid of carbon dioxide. Blood then moves on to the organs of the body, where nutrients, gases, and wastes are exchanged. There is no division of the circulation between the gills and the body. That is, the blood travels from the heart to the gills, and then directly to the body before returning to the atrium through the sinus venosus to be circulated again. The heart rates of fish fall within the wide range of 60-240 beats per minute, depending upon species and water temperature. The fish's heart rate will be slower at lower temperatures.

Conclusion
The cardiovascular system of animals consists of the heart and blood vessels. It is responsible for providing each cell of the body with the oxygen and nutrients it needs, while removing waste products.