This chapter is devoted to the pathway of blood as it travels to and from the heart. As you learned in the last chapter, the two upper chambers (atria) of the heart are fed by large blood vessels known as veins. After blood flows from the upper chambers to the lower chambers (ventricles), it is pumped throughout the body within other types of blood vessels known as arteries. This entire pathway is a closed system, with blood filling up every blood vessel and chamber of the heart. Bubbles are not something you want circulating within your blood! They take up space that is typically reserved for your blood and can restrict the flow of red blood cells (and oxygen) to vital areas of your body.

The following device can be used to remember the pathway of blood through the heart and body:

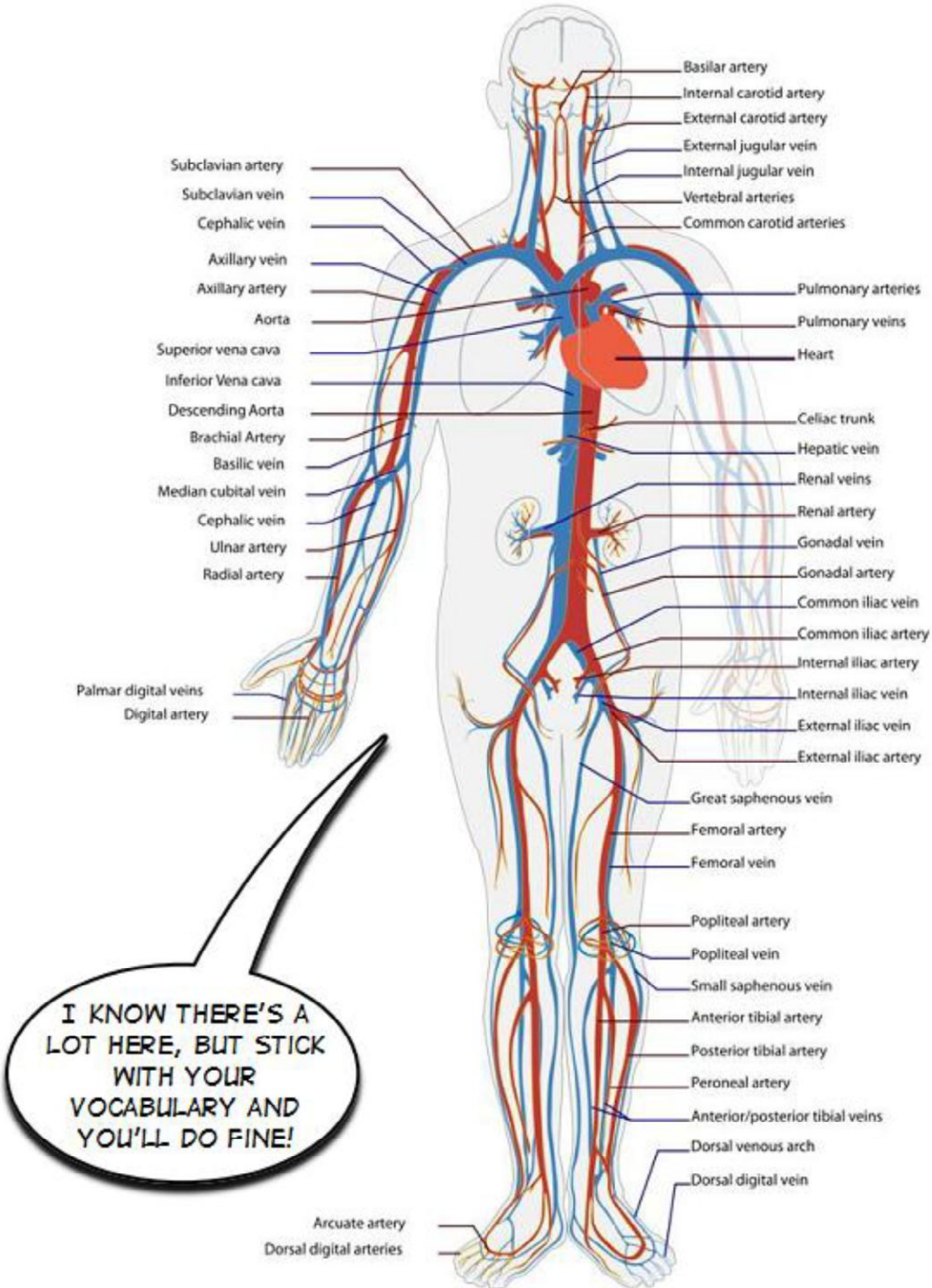
RA → RV → Artery → Vein → LA → LV → Artery → Vein → RA

In this pathway, the term "RA" refers to the right atrium and "RV" is the right ventricle. You can use the same abbreviations for "LA" and "LV". Take a closer look at this pathway and you will find another pattern that may help you out a great deal...

The pathway of blood always follows a pattern with alternating "A's" and "V's"

Atria → **V**entricle → **A**rtery → **V**ein → **A**tria → **V**entricle → and so on...

If you can trace the path of the "A's" and "V's", most of your job is done. The image on the next page will give you a thorough list of the arteries and veins within the human body.


Basilar artery
Internal carotid artery
External carotid artery
External jugular vein
Internal jugular vein
Vertebral arteries
Common carotid arteries
Subclavian artery
Subclavian vein
Cephalic vein
Axillary vein
Axillary artery
Aorta
Superior vena cava
Inferior Vena cava
Descending Aorta
Brachial Artery
Basilic vein
Median cubital vein
Cephalic vein
Ulnar artery
Radial artery
Pulmonary arteries
Pulmonary veins
Heart
Celiac trunk
Hepatic vein
Renal veins
Renal artery
Gonadal vein
Gonadal artery
Common iliac vein
Common iliac artery
Internal iliac artery
Internal iliac vein
External iliac vein
External iliac artery
Palmar digital veins
Digital artery
Great saphenous vein
Femoral artery
Femoral vein
Popliteal artery
Popliteal vein
Small saphenous vein
Anterior tibial artery
Posterior tibial artery
Peroneal artery
Anterior/posterior tibial veins
Dorsal venous arch
Dorsal digital vein
Arcuate artery
Dorsal digital arteries
I KNOW THERE'S A LOT HERE, BUT STICK WITH YOUR VOCABULARY AND YOU'LL DO FINE!

Arteries and veins have a similar anatomical structure with one very important difference. Both have three tissue layers which make up an inner lining of cells (**endothelial cells** or **endothelium**), a middle layer made of smooth muscle, and an outer layer made of connective tissue. However, since the arteries are responsible for pumping blood out the heart, its walls are much thicker because of the increased pressure it must maintain. In fact, blood leaves the left ventricle through the aortic semilunar valve and into a single large artery known as the **aorta**. The aorta is the largest artery in the human body and extends into the abdominal area with branches that carry blood to <u>nearly</u> all of the body's tissues.

Let's follow a drop of blood from the aorta to the rest of the body!

The blood within the aorta is full of oxygen gas which is used by the tissues of our body for all vital functions. The aorta carries blood away from the heart under high pressure and branches off towards all of the tissues/organs of the body <u>with the exception of the lungs</u>. These branches become smaller in diameter where they are known as **arterioles**. The walls of the arterioles continually become much thinner than the wall of the aorta. This fact is very important as the arterioles are attached to a web of very small blood vessels known as:

Capillaries

In the simplest definition, **capillaries** are the tiniest blood vessels in the human body with diameters as small as a single red blood cell. These vessels surround the organs and tissues of the body in tiny linkages of web-like "nets."

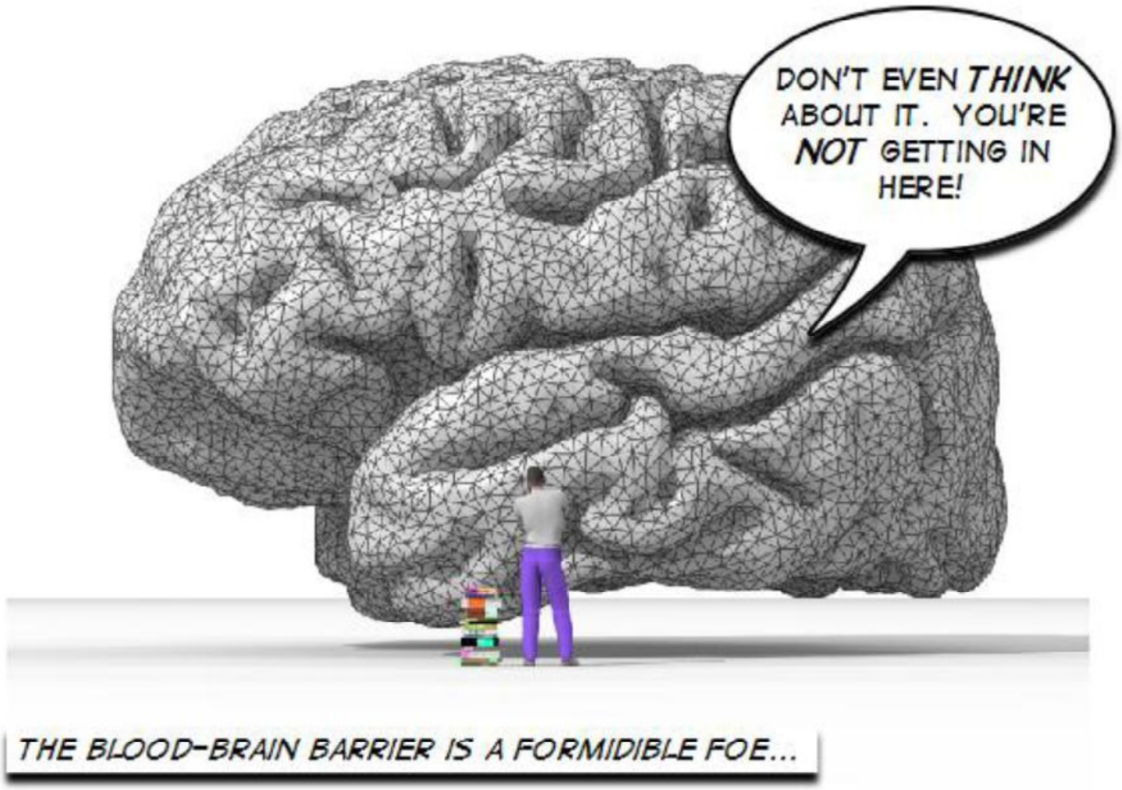
Because of their tiny size, you should be able to assume that the walls of capillaries are equally tiny as well. And you would be correct!

In fact, the walls of capillaries are so thin they allow gases to diffuse between the blood and the fluids which surround body tissues. You learned about this back in Chapter 2 when you first explored the concept of diffusion:

Diffusion is simply the movement of any substance from an area of high concentration to an area of low concentration.

The high concentration of oxygen within the blood from the aorta diffuses out of the network of capillaries and into the body tissues which they surround. As this is occurring, the body tissues have already used up their oxygen supply and have a surplus of the waste product - carbon dioxide gas (CO_2). The high concentration of CO_2 is then diffused out of the body tissues and into the capillaries. In addition to oxygen and carbon dioxide, the capillaries are responsible for transporting nutrients, hormones, and dozens of other molecules between the body tissues/organs and the cardiovascular system.

This network of capillaries works differently within the brain and CNS. The layers of endothelial cells within the capillaries surrounding these areas fit very tightly together. Because of the closeness of these cells, only the smallest of materials can diffuse through the vessel walls (i.e. oxygen, carbon dioxide, etc.). Large molecules such as fats and other foreign particles cannot pass through the vessel walls. This is known as the ***blood-brain barrier*** *and provides a very efficient level of protection for the organs of the central nervous system.*



After the exchange of oxygen for waste products from the body tissues, the capillaries leave the organs and begin to increase in diameter. As they grow into larger blood vessels, they are referred to as **venules**. Both the diameter and the wall thickness of the venules increase in size as they move away from the capillaries and towards the even larger veins.

You can easily find the veins in your body. Look for the "blue" blood vessels under your skin!

Many people believe that the blood in our veins is actually blue in color. This is absolutely false! Blood within the veins do not contain a high concentration of oxygen and, therefore, does not appear to be bright red in color, but a much darker red hue. Blood within arteries, however, do contain a high level of oxygen and therefore display a red color. The "blue" color of venous blood is actually caused by the way in which light is absorbed by the skin and the darker colored venous blood. Remember - none of your blood vessels are blue in color!

As the larger venules branch outwards from the capillaries and towards the larger veins, you might be wondering about one thing:

Where does the force needed to move the blood come from after passing through the capillaries?

This is a very good question, and to answer this we have to look at another system we discussed earlier - the muscular system. Whenever our body makes some form of movement, our muscles contract and relax back to their normal position. When a muscle contracts, it pushes against the veins which then helps to drive the blood towards the heart. Since the walls of the veins are thinner, they are able to be "squeezed" rather easily by its surrounding skeletal muscles. There's no need to be concerned about our muscles pushing the blood in the opposite direction - several tiny valves are present within the veins to prevent this from happening! In fact, muscular contraction is the primary method for pushing venous blood back towards the heart.

Now back to the pathway of blood...

It is important to note here that the path of the blood at this stage can be split in two separate sections of the human body – the upper and lower halves. Why is this important? Because both halves of the human body utilize its own large vein to deliver blood into the right atrium of the heart:

Inferior Vena Cava and the Superior Vena Cava

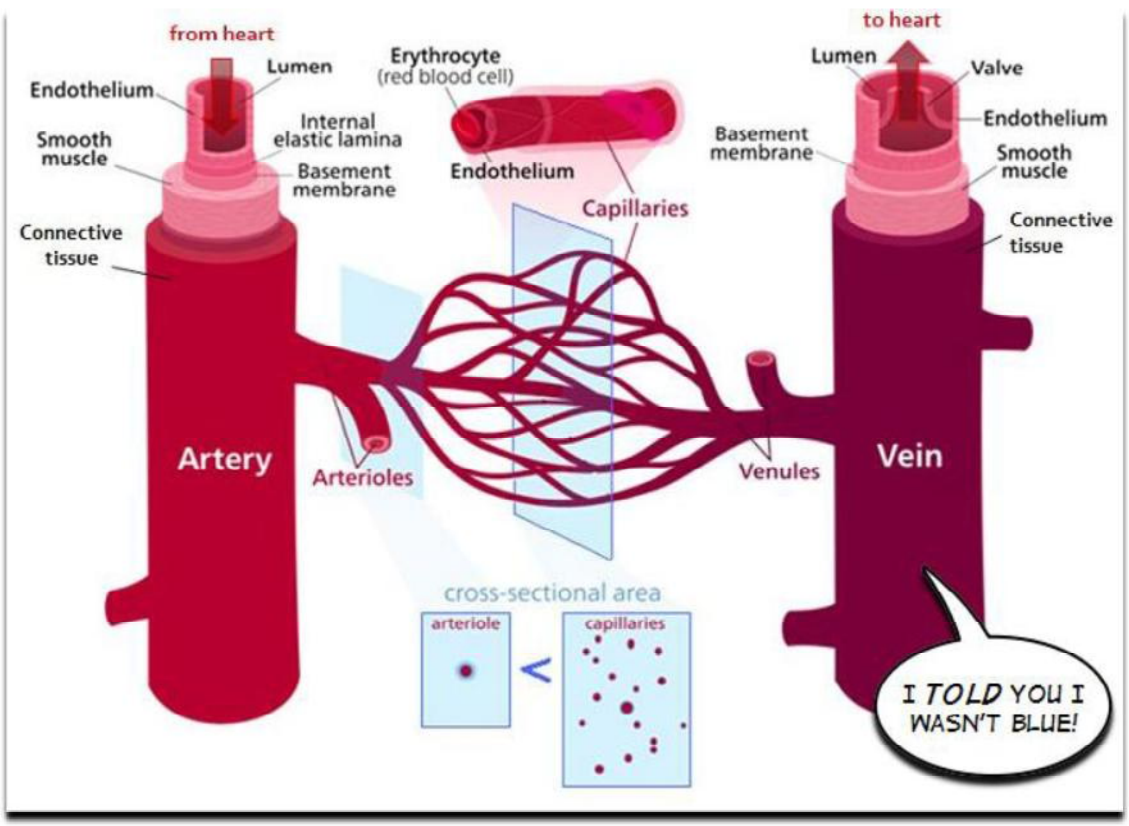
The **inferior vena cava** is a large vein that carries blood from the lower half of the body into the heart. Its colleague is the **superior vena cava** which delivers blood to the heart from the upper half of the body. Both of these large veins deliver its oxygen-poor blood into the right atrium of the heart. Its flow is controlled by the opening and closing of the tricuspid valve before it reaches the right ventricle of the heart.

Once blood reaches the right ventricle, it passes through the pulmonary semilunar valve before reaching the large **pulmonary artery**. Here it runs through the same pathway as the oxygen-rich blood you just learned. From the pulmonary artery, blood travels through smaller arterioles until they reach the web-like capillary network which surrounds the lungs.

The pulmonary artery only transports blood to the lungs and NOT the rest of the body!

As blood reaches the lungs, the high concentration of CO_2 diffuses out of the blood and into the lungs while the lungs' high concentration of oxygen diffuses into the blood. This transfer of CO_2 is aided by the increased blood pressure within the arteries (as compared to the veins). We will be focusing on this process in greater detail during our discussion on the respiratory system. For now, the pathway of our blood is of much more importance.

The now oxygen-rich blood travels out of the capillaries and moves through the larger venules before branching into four separate **pulmonary veins** (two from each lung). These veins carry blood back into the left atrium of the heart, through the biscupid valve, and into the left ventricle where we originally began this story!



Need a shortcut for this pathway? How about this:

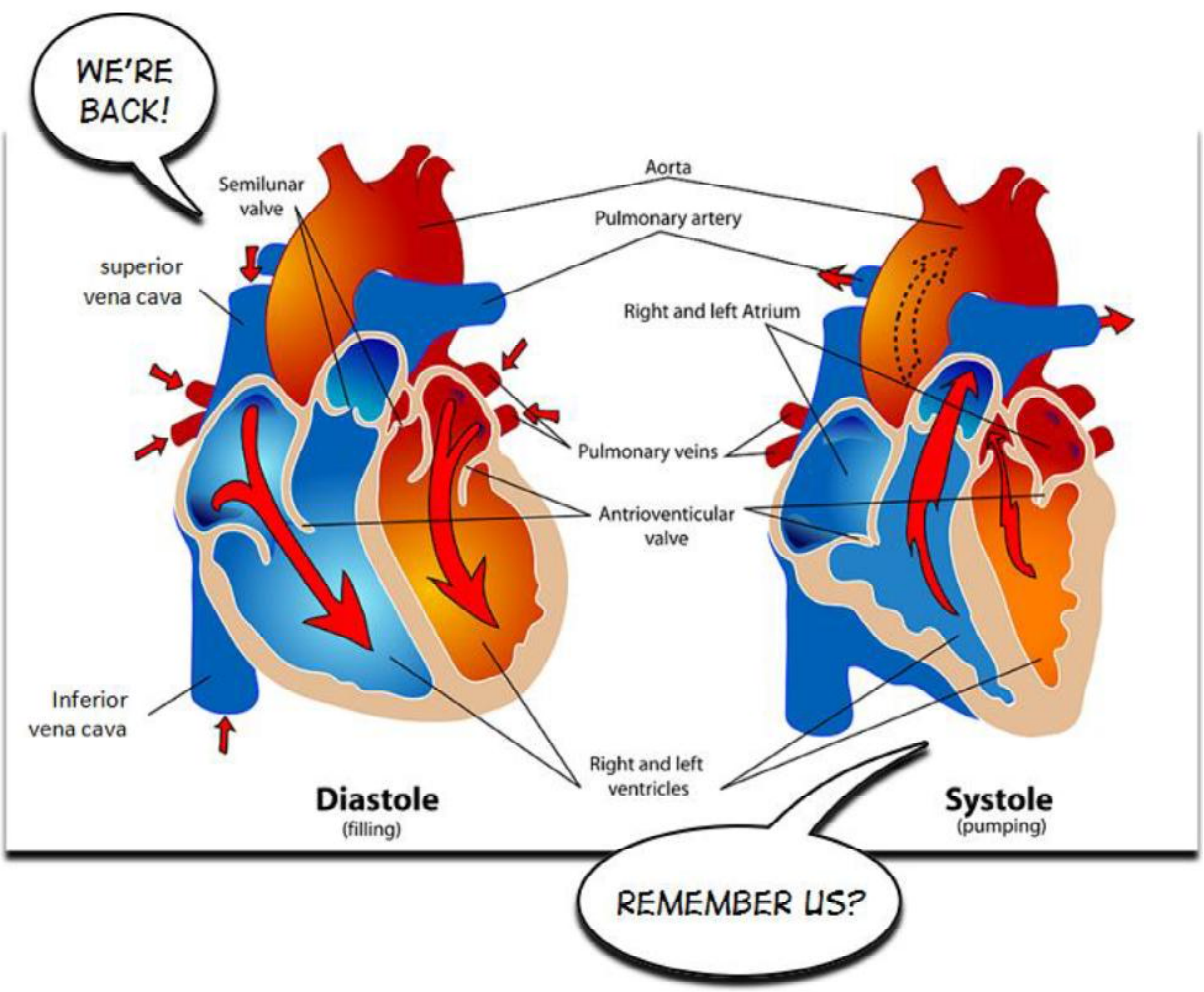
1. Left atrium
2. Bicuspid valve
3. Left ventricle
4. Aortic semilunar valve
5. Aorta
6. Arterioles
7. Capillaries throughout the body tissues/organs
8. Venules
9. Veins (Superior vena cava and Inferior vena cava)
10. Right atrium
11. Tricuspid valve
12. Right ventricle
13. Pulmonary semilunar valve
14. Pulmonary artery
15. Arterioles
16. Capillaries surrounding the lungs
17. Venules
18. Pulmonary veins (four of them)
19. Back to the left atrium (and the process begins again!)

We have a couple more concepts to briefly go through before our study of the cardiovascular system is over.

If you spend any time within the doctor's office, the attending nurse has likely taken two different readings about your body:

Blood pressure and Pulse

Blood pressure is a measured force of the blood pushing against the inner walls of the arteries near the heart. During each heartbeat, the blood pressure reaches a maximum amount (**systolic pressure**) and a minimum amount (**diastolic pressure**). In order to accurately measure one's blood pressure, both measurements must be recorded. The systolic pressure measures the pressure in the arteries when the heart muscles contract and blood is forced from the heart. The diastolic pressure measures the pressure that exists between heartbeats, when the heart is resting and filling with blood. If your blood pressure becomes too high (as during vasoconstriction), the heart rate will slow down as a reduced amount of blood flowing through the vessels will (hopefully) lower the pressure as well. The opposite is true when your blood pressure becomes too low as when the inner diameter of blood vessels become dilated as during vasodilation. This noticeable change undoubtedly affects our next topic of discussion…



Pulse is the rhythmical throbbing of arteries that can be felt through the skin as blood is forced through these vessels. This sensation is much like the feeling of water rushing through a hose after it has been partially blocked. The hose pulsates as the increased pressure within the hose is finally released and water rushes forward.

Let's wrap up this chapter with a look at a few more amazing heart facts!

If you could place all the capillaries end-to-end from one human body, its length would be approximately 25,000 miles (46,325 kilometers). This would easily reach across the equator of the Earth.

The length of **all** the blood vessels in the cardiovascular system is approximately 60,000 miles (96,500 kilometers).

The pressure produced by the human heart when it is beating is capable of pumping blood nearly thirty feet. (But let's keep our blood inside our bodies, okay?)

Anatomy & Physiology - Connections

How the following body systems affect the cardiovascular system		How the cardiovascular system affects the following body systems	
Integumentary	Vasodilation and vasoconstriction control the flow of blood through the skin	Delivery of immune cells to sites of injury; removal of waste products; provides warmth to tissues	**Integumentary**
Skeletal	Provides calcium needed for muscle contraction and bone marrow as site for red blood cell synthesis	Transportation of calcium, phosphorus, PTH, and CT for ossification	**Skeletal**
Muscular	Skeletal muscle contractions help to move blood through veins	Delivery of oxygen and nutrients to body tissues and removal of wastes	**Muscular**
Nervous	Regulation of heart rate and blood pressure	Endothelial cells protect the CNS via the blood-brain barrier	**Nervous**
Endocrine	Erythropoietin increases RBC production; epinephrine increases heart rate	Transports hormones throughout the body	**Endocrine**

Match the following vocabulary terms with their correct definition:

aorta	**diastolic pressure**	**pulse**
arterioles	**endothelial cells**	**superior vena cava**
blood pressure	**inferior vena cava**	**systolic pressure**
blood-brain barrier	**pulmonary artery**	**venules**
capillaries	**pulmonary veins**	

1)	______________	a large vein that carries blood from the lower half of the body into the right atrium of the heart
2)	______________	a measured force of the blood pushing against the inner walls of the arteries near the heart
3)	______________	branches of arteries whose diameters are smaller than that of the aorta
4)	______________	delivers blood to the heart from the upper half of the body
5)	______________	four veins which carry blood back into the left atrium of the heart, through the bicuspid valve, and into the left ventricle
6)	______________	innermost lining of cells within both arteries and veins; surrounded by layers of smooth muscle and connective tissue
7)	______________	large artery which carries all of the blood out of the left ventricle
8)	______________	large artery which carries blood from the right ventricle after it passes through the pulmonary semilunar valve
9)	______________	layer of endothelial cells within the capillaries surrounding the brain and CNS which fit very tightly together, allowing only the smallest of materials to diffuse through the vessel walls (i.e. oxygen, carbon dioxide, etc.)

10)	______________	the maximum blood pressure achieved during each heartbeat
11)	______________	the minimum blood pressure achieved during each heartbeat
12)	______________	the rhythmical throbbing of arteries that can be felt through the skin
13)	______________	the tiniest blood vessels in the human body
14)	______________	vessels attached to both the capillaries and veins; the diameter and the wall thickness of these vessels increase in size from the capillaries and towards the veins

Choose the correct answer from the following questions:

1) The path of blood through all of the vessels is:
- A) arterioles, arteries, capillaries, veins, venules
- B) arterioles, arteries, capillaries, venules, veins
- C) arteries, arterioles, capillaries, veins, venules
- D) arterioles, arteries, venules, veins, capillaries
- E) arteries, arterioles, capillaries, venules, veins

2) In which one of the following blood vessels is blood pressure the highest:
- A) arterioles
- B) arteries
- C) vena cava
- D) capillaries
- E) veins

3) Substances tend to leave the bloodstream from the arteries to the capillaries because:
- A) blood pressure is higher at the arterial end of the capillary
- B) the osmotic pressure of the blood is higher as it leaves the capillary and moves towards the veins
- C) blood pressure is higher from the capillaries to the veins
- D) the osmotic pressure of the blood is higher as it leaves the capillary and moves towards the arteries

4) Veins:
- A) carry blood away from the heart
- B) do not transport oxygen-rich blood
- C) branch into smaller vessels called arterioles
- D) operate under high pressure
- E) have valves to prevent the backflow of blood

5) Pulmonary veins:

A) split off the pulmonary trunk
B) transport oxygenated blood to the heart
C) return blood to the right atrium of the heart
D) transport oxygenated blood to the lungs
E) transport blood rich in carbon dioxide to the lungs

6) Which of the following reduces heart rate:

A) increased body temperature
B) exercise
C) high blood pressure
D) epinephrine

Application Question:

The following observations were made on a patient who had suffered a bullet wound: Heart rate was elevated and rising. Blood pressure was very low and dropping. After bleeding was stopped and a *blood transfusion* (the introduction of new blood from a donor) was given, blood pressure increased. Which of the following statements is consistent with these observations concerning blood pressure? Defend your answer.

a) Negative-feedback mechanisms are occasionally inadequate without medical intervention.
b) The transfusion interrupted a negative-feedback mechanism.
c) The transfusion was not necessary.