Chapter 4 – Cardiovascular System: Heart and Blood Vessels

Objectives

Given the synopsis in this chapter, competence in each objective will be demonstrated by responding to multiple choices or matching questions, completing fill-in questions, or writing short answers, at the level of 75% or greater proficiency for each student.

A. To describe the flow of blood through the circulatory system; including the heart, systemic arteries and veins, and pulmonary arteries and veins.
B. To identify major features, chambers, and valves of the heart.
C. To identify major arteries leaving the heart and major veins entering the heart.
D. To explain the pumping of blood through the heart and the functions of the phases of the cardiac cycle.
E. To identify major arteries carrying blood to the upper body, trunk, and lower body.
F. To identify major veins carrying blood from the upper body, trunk, and lower body back to the heart.

Cardiovascular Organization

The primary function of the cardiovascular system is to transport oxygen and nutrients to the tissues of the body, and to transport carbon dioxide and other metabolic byproducts away from these tissues. It is of course the responsibility of the respiratory system to obtain oxygen and remove carbon dioxide, the digestive system to initially obtain nutrients and metabolic substrates, and the digestive and urinary systems to remove excess metabolic byproducts.

Circulatory Circuits

The cardiovascular system basically consists of the heart, the pulmonary circuit, and the systemic circuit, as shown in Figure 4.1.

The pulmonary circuit is composed of blood vessels that carry blood to and from the lungs.

- Pulmonary arteries carry blood away from the heart and to the lungs.
- Pulmonary veins carry blood from the lungs and to the heart.

The systemic circuit is composed of blood vessels that carry blood to and from all organs of the body except the lungs.

- Systemic arteries carry blood from heart and to the other organs.
- Systemic veins carry blood from the other organs to the heart.

In addition, lymphatic vessels carry lymph from tissues to systemic veins.

Relationship between the Heart and Blood Vessels

Figure 4.2 illustrates the basic organization of the heart and complements Figure 4.1.

The right side of the heart receives and pumps oxygen poor and carbon dioxide rich blood.

- The **right atrium** receives blood from the systemic circuit via the inferior and superior vena cava.
- The **right ventricle** discharges blood into pulmonary circuit via the pulmonary trunk and arteries.
- The **right atrioventricular valve** (right AV, tricuspid) controls movement of blood between the right atrium and right ventricle.
- The **pulmonary semilunar valve** controls movement of blood between the right ventricle and the pulmonary circuit.

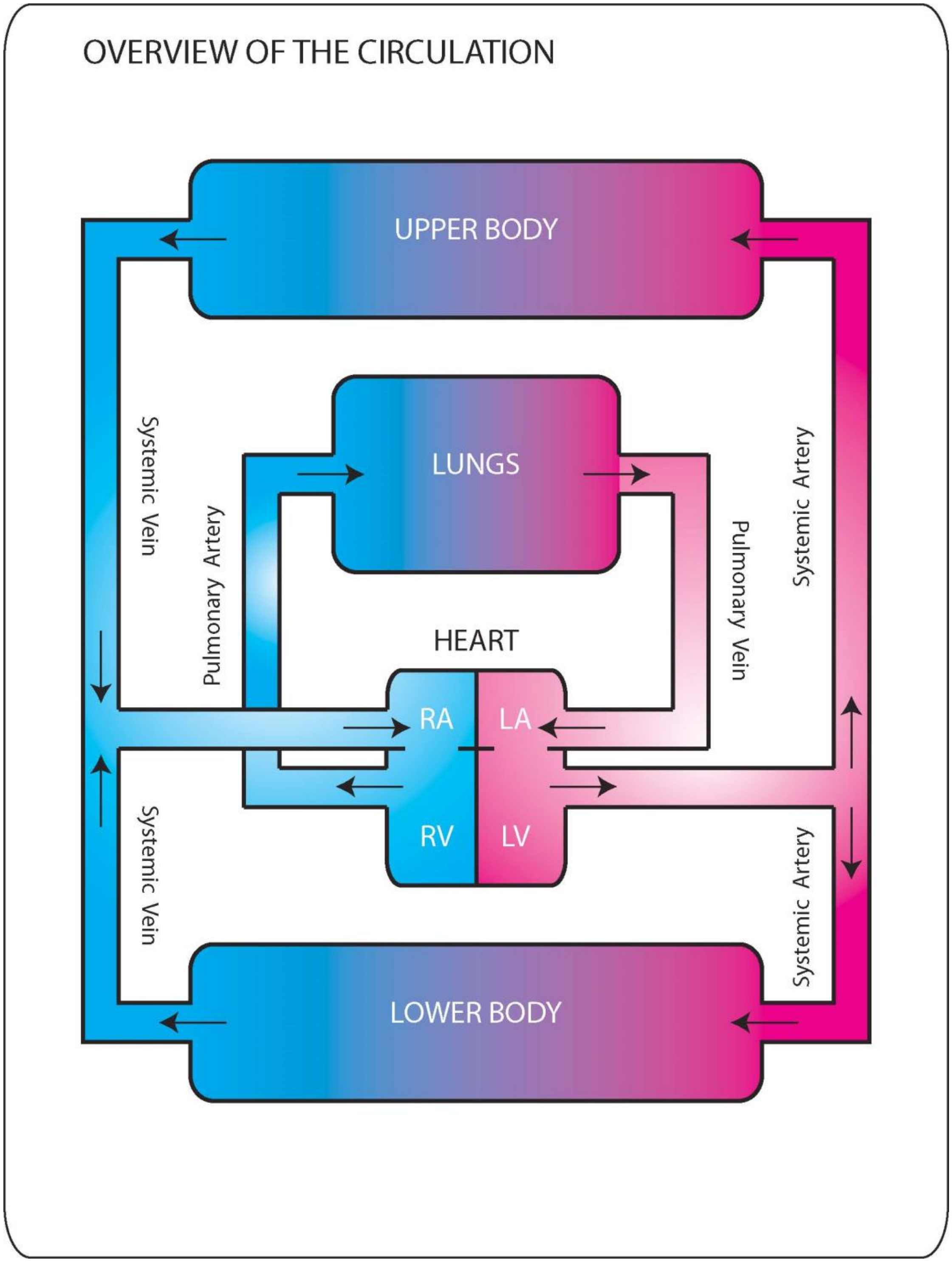


Figure 4.1 © 2007 David G. Ward, Ph.D.

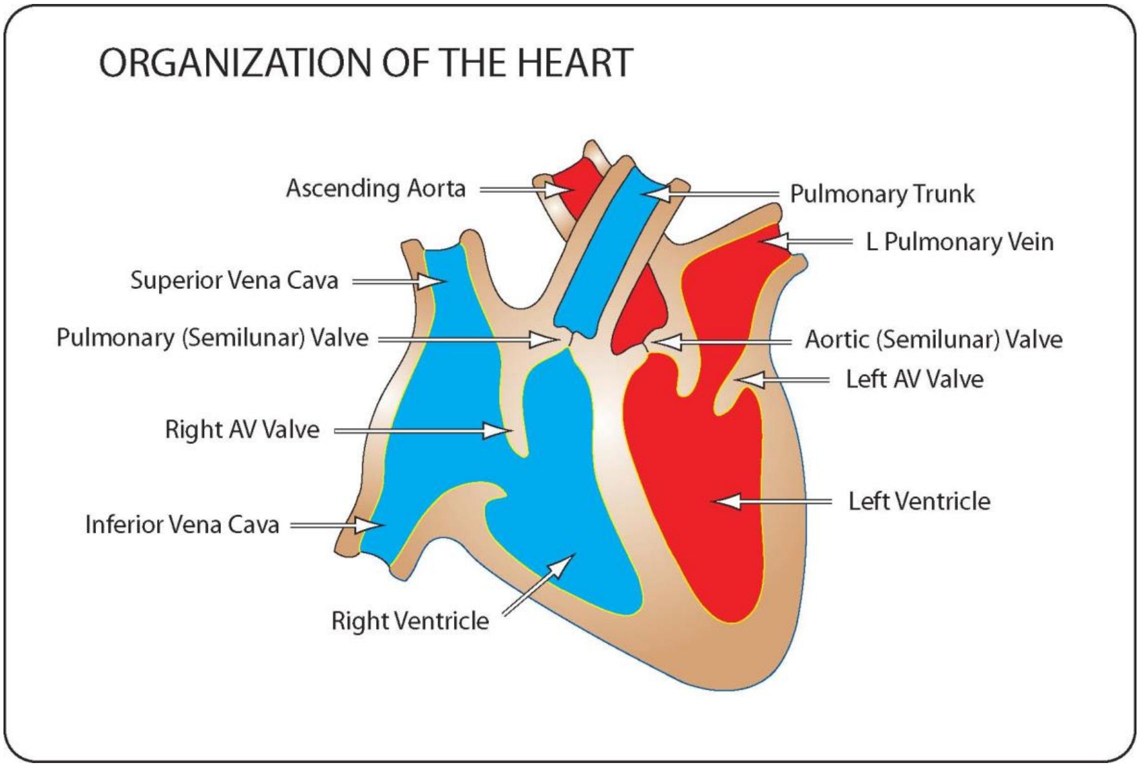


Figure 4.2 © 2007 David G. Ward, Ph.D.

The left side of the heart receives and pumps oxygen rich and carbon dioxide poor blood.

- The **left atrium** receives blood from the pulmonary circuit via the **pulmonary veins.**
- The **left ventricle** discharges blood into systemic circuit via the **aorta.**
- The **left atrioventricular valve** (left AV, bicuspid, mitral) controls movement of blood between the left atrium and the left ventricle.
- The **aortic semilunar valve** controls movement of blood between the left ventricle and the systemic circuit.

Anatomy of the Heart

Anterior and posterior views of the heart are should in Figures 4.3 and 4.4

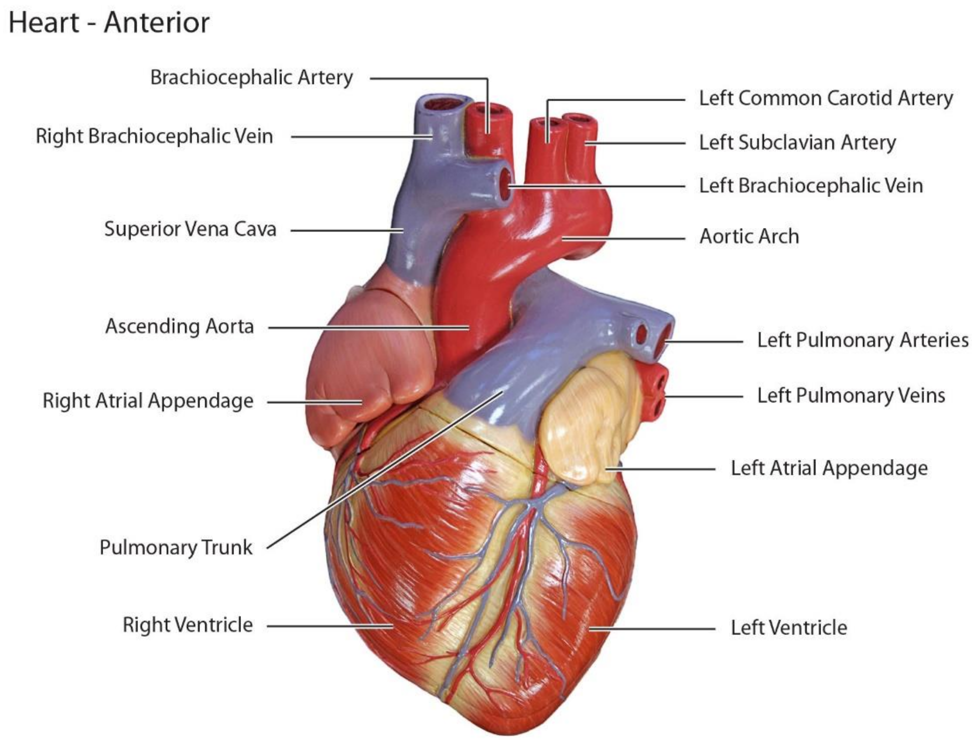


Figure 4.3 © 2014 David G. Ward, Ph.D., Atlas of Anatomy for Allied Health.

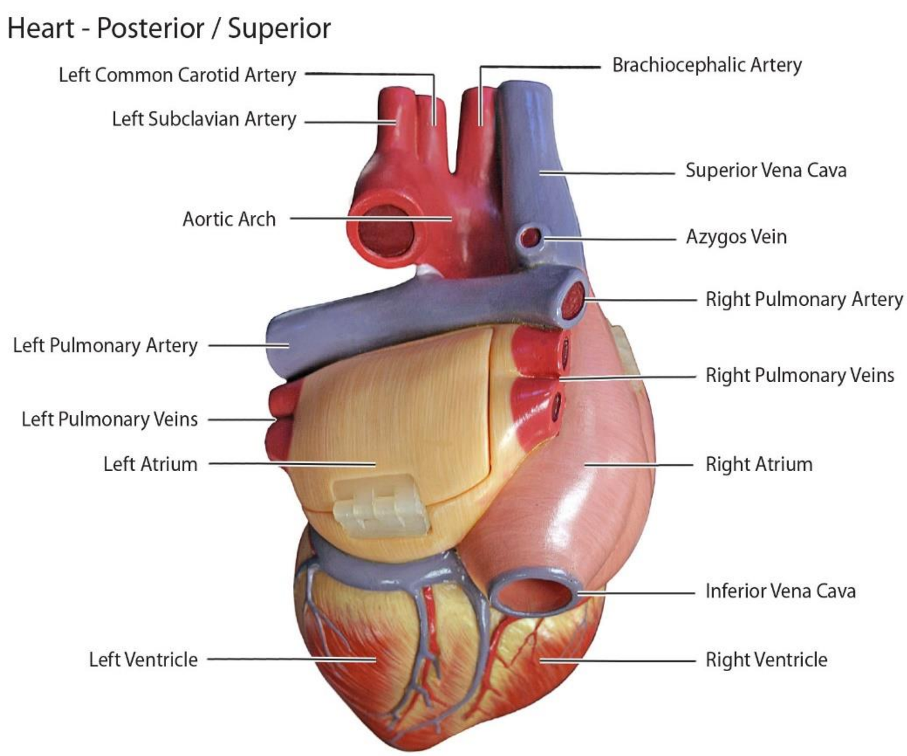


Figure 4.4 © 2014 David G. Ward, Ph.D., Atlas of Anatomy for Allied Health.

Cardiac Pumping

Cardiac cycle and pumping action of the heart

The cardiac cycle corresponds to the period between one heart beat and the next. It is important to recognize that during most of the cardiac cycle the atria and/or the ventricles are relaxing. As the atria relax and the ventricles relax blood is drawn into the heart. Unless there is blood in the heart, contraction of the heart cannot pump out blood. For this reason I chose, in Figure 4.5, to show the pumping actions of the heart starting with atrial relaxation.

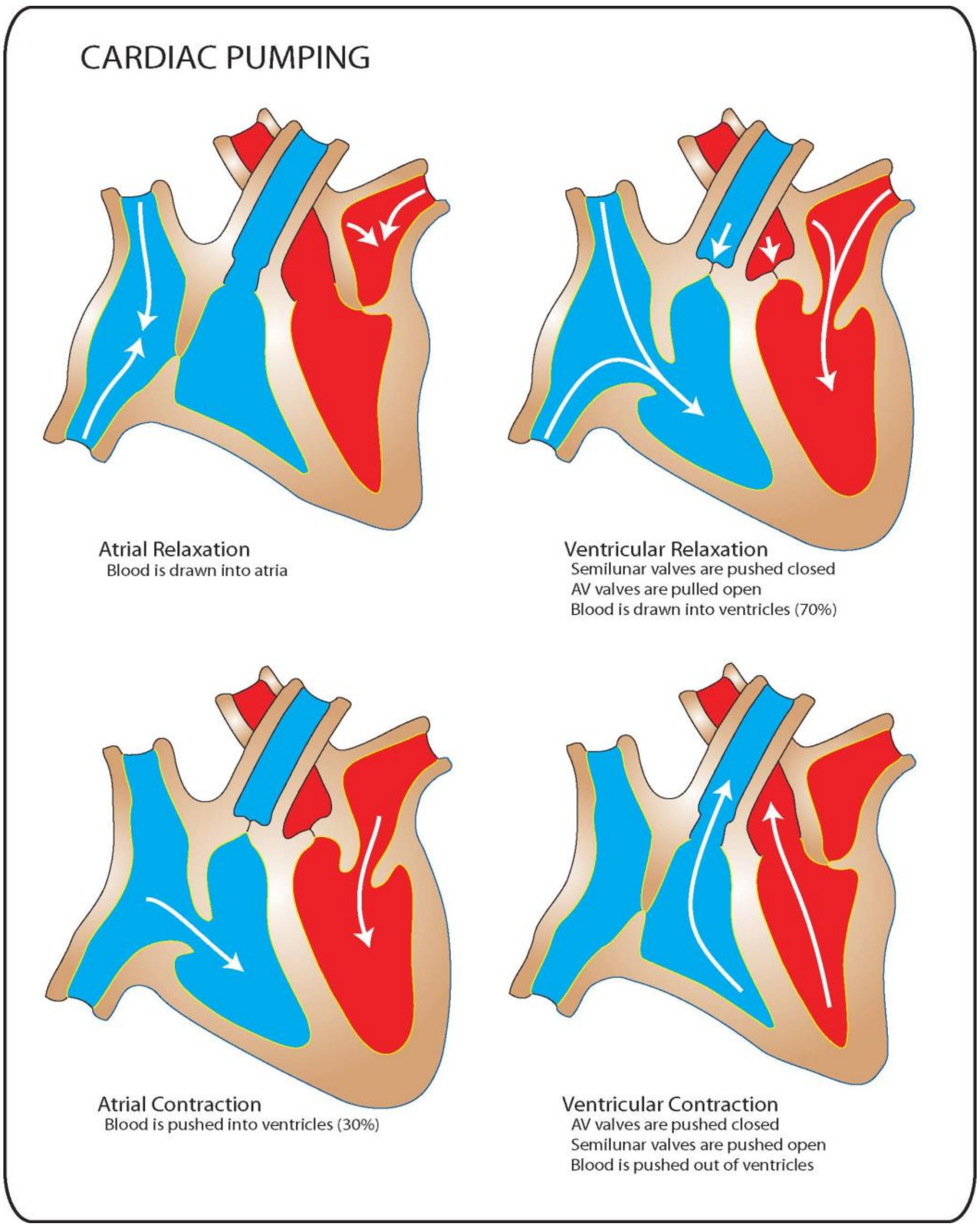


Figure 4.5 © 2007 David G. Ward, Ph.D.

Coordination of Cardiac Muscle Contraction

We need to remember that there are no valves between the veins and the atria and that the semilunar valves and corresponding arteries are at the top of the heart (base). In order to optimize the movement of blood from the atria into the ventricles during atrial contraction, the atria must contract from the atrial appendages toward the AV valves. In order to optimize the movement of blood from the ventricles into the arteries the ventricles must contract from the bottom of the heart (apex) toward the semilunar valves.

Cardiac conduction system

The coordination of the contraction of the cardiac muscle cells is mediated by the cardiac conduction system, as shown in Figure 4.5.

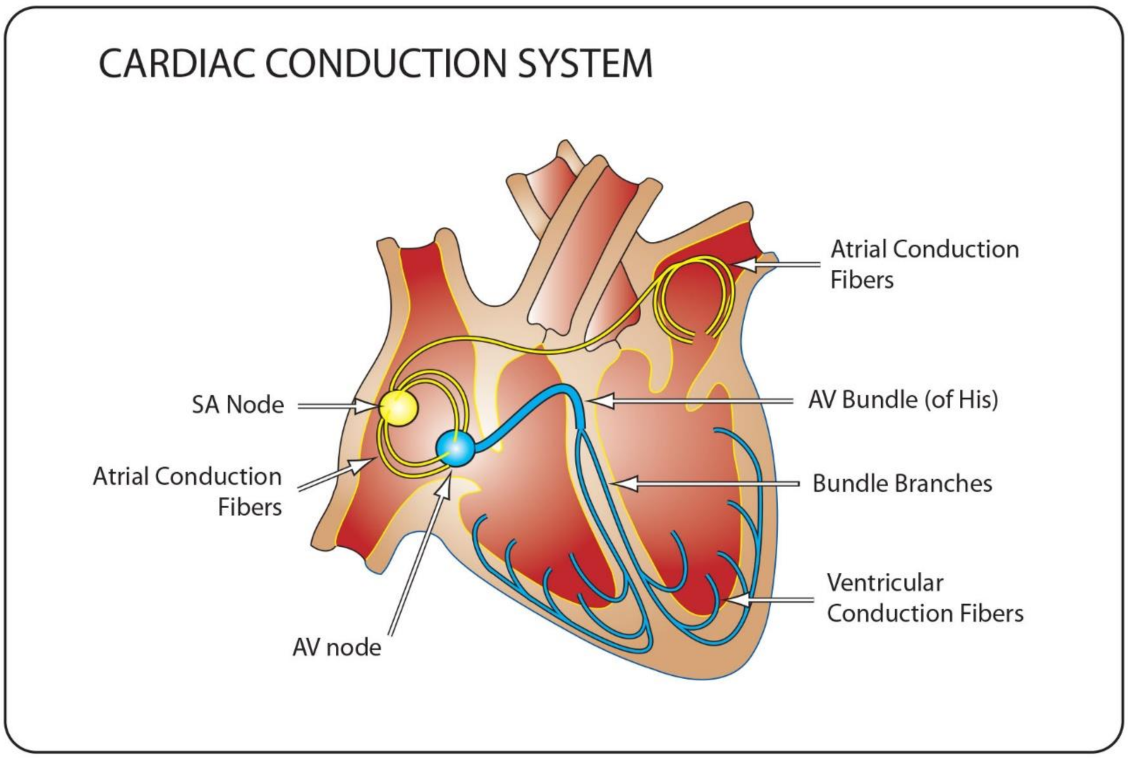


Figure 4.5 © 2014 David G. Ward, Ph.D.

Some cardiac muscle cells are specialized to generate and conduct action potentials. These include cells of the:

- Sinoatrial (SA) node in the posterior wall of the right atrium
- Atrial conduction fibers in the right and left atria
- Atrioventricular (AV) node in the floor of the right atrium near the ventricle
- AV bundle (of His) in the interventricular septum
- Bundle branches in the interventricular septum
- Ventricular conduction fibers (Purkinje fibers) in the right and left ventricles

Pacemaker signals originate in the SA node and travel through atrial conduction fibers into both atria. As signals pass through the conduction fibers, cardiac muscle cells in the atria are stimulated and contract toward the AV valves. In addition, the pacemaker signals that travel through the right atrial conduction fibers synchronize the activity of the AV node. The AV node in turn generates pacemaker signals that travel through the AV bundle and bundle branches in the interventricular septum to the apex of the heart. Both the AV bundle and the bundle branches are isolated from cardiac muscle cells. However, at the apex the bundle branches divide into ventricular conduction fibers that stimulate cardiac muscle cells. The ventricular muscle cells contract toward the semilunar valves.

Electrocardiogram (EKG)

The electrocardiogram measures the changes in membrane potential of the cardiac muscle during the cardiac cycle. The changes in membrane potential of the cardiac muscle cells are measured from the surface of the body.

EKG waves

In the EKG tracing several waves are prominent, as shown in Figure 4.6.

- The P wave measures depolarization of the atrial muscle.
- The QRS waves measures depolarization of the ventricular muscle.
- The T wave measures repolarization of the ventricular muscler.

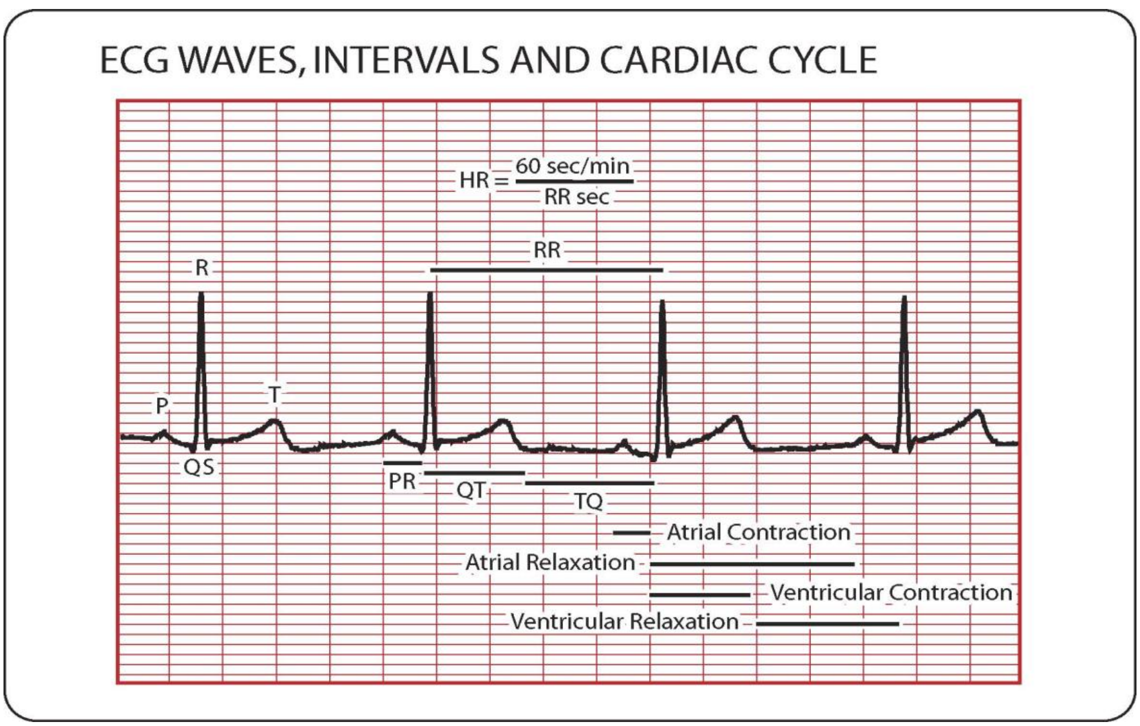


Figure 4.6 © 2007 David G. Ward, Ph.D.

The RR interval (AKA pulse interval) is the time between the peak of one R wave and the peak of the next R wave

$$\text{Heart Rate} = \frac{60 \text{ sec/min}}{\text{RR interval (sec)}}$$

Cardiac Output

The purpose of cardiac pumping is of course to pump blood out of the heart, to the lungs, back to the heart, to the rest of the body, and back to the heart. The amount of blood pumped out of the heart (left ventricle) each minute is called **cardiac output**. A normal cardiac output is about 7% of body weight in kg. For an average person of about 70 kg, their cardiac output would be about 4.9 L / min (or 4900 mL / min).

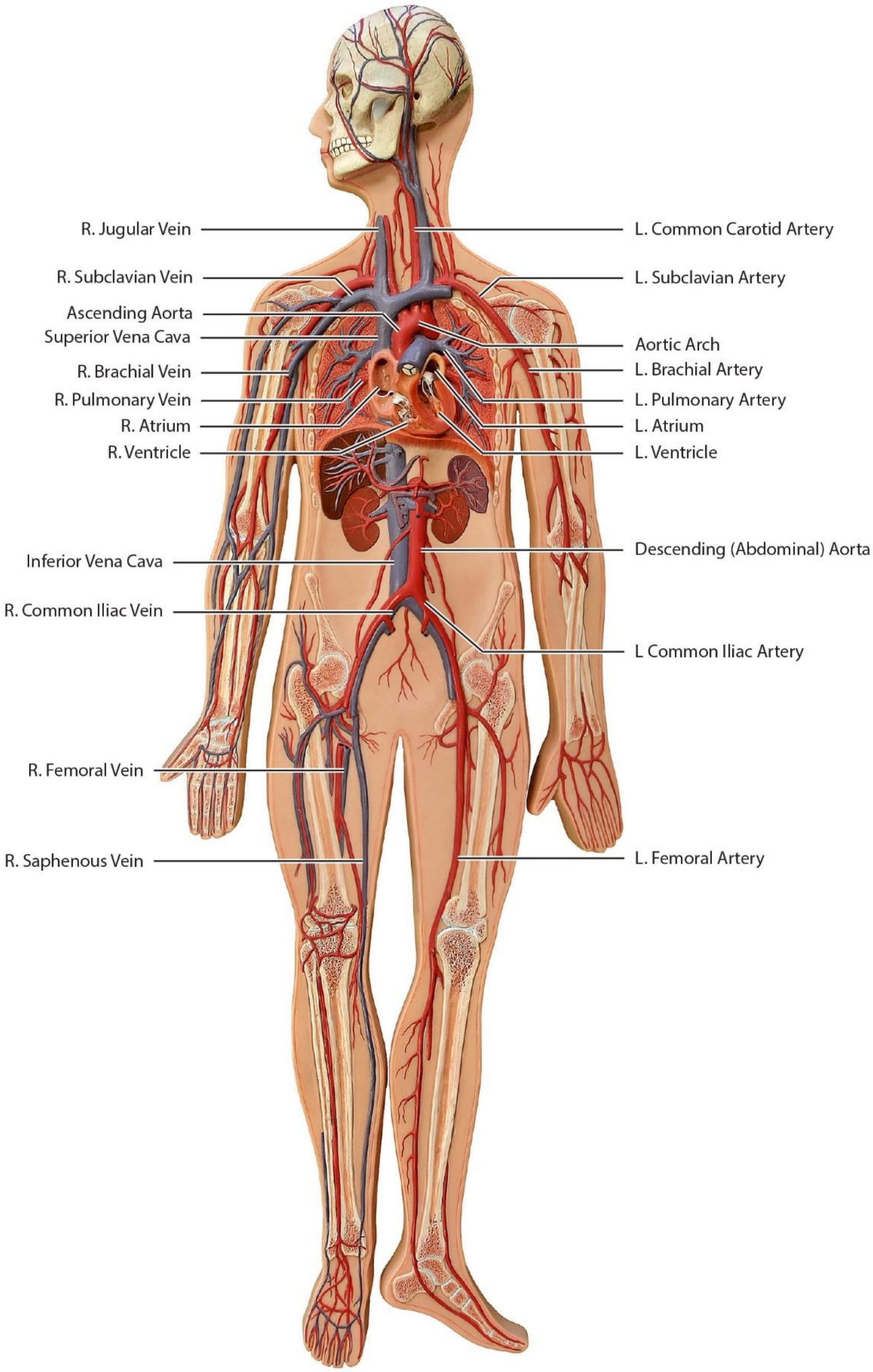
Cardiac output is influenced by two major factors, the stroke volume and the heart rate.

Cardiac output (CO) = Stroke volume (SV) x Heart rate (HR)

- Stroke volume (SV) is the amount of blood pumped out of the heart (left ventricle) with each contraction.
- Heart rate (HR) is the number of contractions per minute.

The blood that is pumped out of the right ventricles travels through arteries that go to the lungs. The blood that is pumped out of the left ventricle travels through arteries that go to the rest of the body. The basic anatomical organization of the heart and major blood vessels is shown in figure 4.7.

The Heart and Major Veins and Arteries



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