Animal physiology- /2022-2023/2nd semester
Lecture1
The circulatory system

The term **circulatory system** refers to the heart, blood vessels, and blood. The term **cardiovascular system**, however, refers only to the passages through which the blood flows—the **heart**, a four-chambered muscular pump; **arteries**, the vessels that carry blood away from the heart; **veins**, the vessels that carry blood back to the heart; and **capillaries**, microscopic blood vessels that connect the smallest arteries to the smallest veins. Cardiovascular system has two major divisions: a **pulmonary circuit**, which carries blood to the lungs for gas exchange and then returns it to the heart, and a **systemic circuit**, which supplies blood to every organ of the body (fig.1-1) and (fig.1-2).

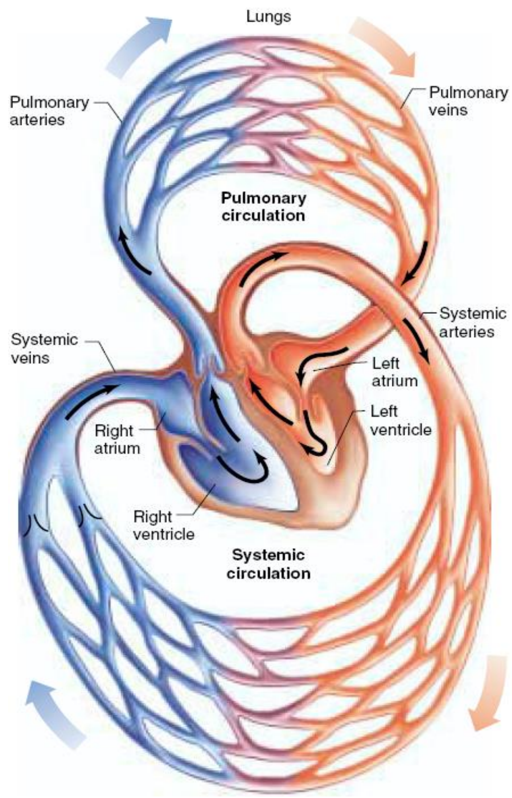

Figure 1-1: General schematic of the cardiovascular system.

The fig. 1-2 shows the pathway of the blood as it travels from the right atrium through the body and back to the starting point. (*1*) Right atrium → (*2*) right AV valve → (*3*) right ventricle → (*4*) pulmonary valve → (*5*) pulmonary trunk → (*6*) pulmonary arteries to lungs → (*7*) pulmonary veins returning from lungs → (*8*) left atrium → (*9*) left AV valve → (*10*) left ventricle → (*11*) aortic valve → (*12*) aorta → (*13*) other systemic vessels → (*14*) inferior and superior venae cavae → (*1*) back to the right atrium. The pathway from *5* to *7* is the pulmonary circuit, and the pathway from *12* to *14* is the systemic circuit.

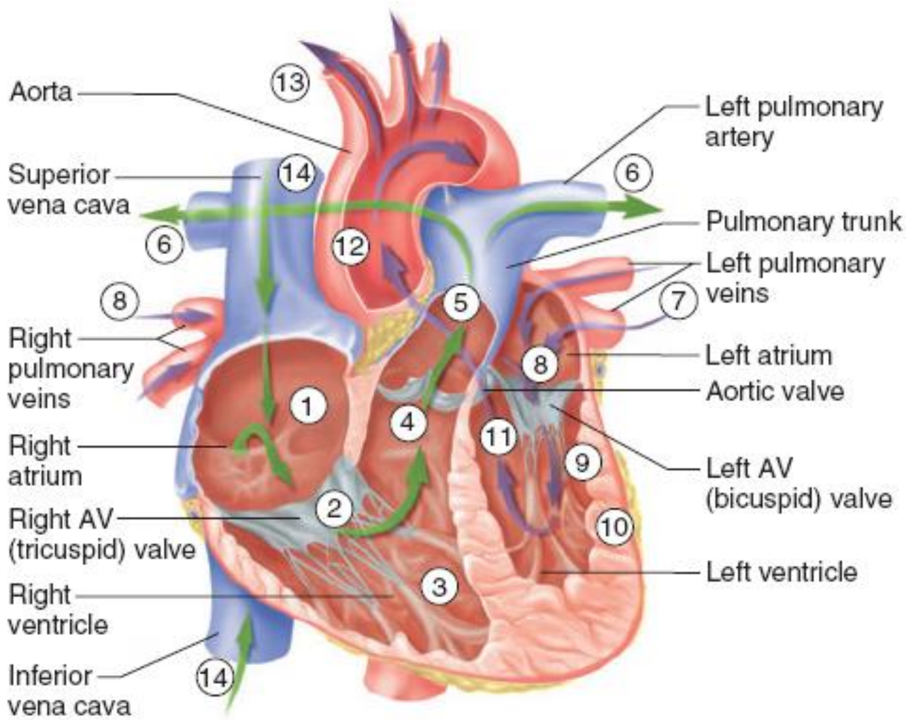

Figure 1-2: The Pathway of blood from the right atrium and back.

Conducting system of the heart

1-Action potentials originate in the sinoatrial (SA) node and travel across the wall of the atrium (arrows) from the SA node to the atrioventricular (AV) node.
2-Action potentials pass through the AV node and along the atrioventricular (AV) bundle, which extends from the AV node, through the fibrous skeleton, into the interventricular septum.
3-The AV bundle divides into right and left bundle branches, and action potentials descend to the apex of each ventricle along the bundle branches.
4-Action potentials are carried by the Purkinje fibers from the bundle branches to the ventricular walls (fig.1-3).

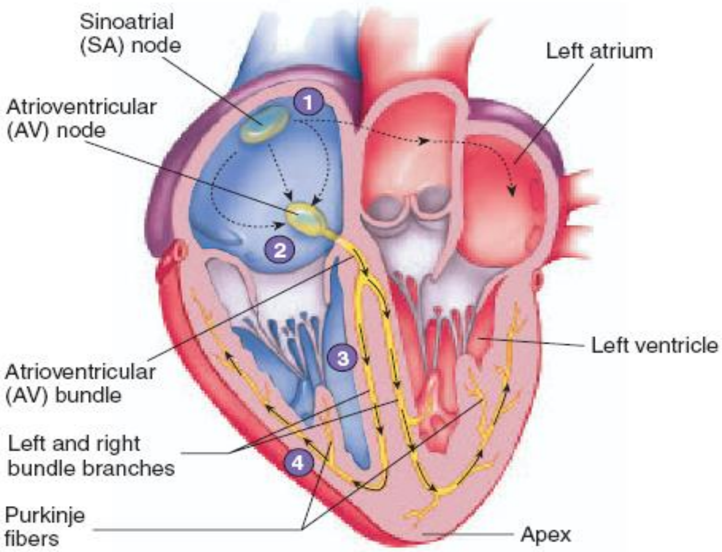

Figure 1-3: The Cardiac conduction system. Electrical signals travel along the pathway indicated by the arrows

Spread of the cardiac impulse through the heart

The impulse spreads at moderate velocity through the atria but is delayed more than 0.1 second in the A-V nodal region before appearing in the ventricular septal A-V bundle. Once it has entered this bundle, it spreads very rapidly through the Purkinje fibers to the entire endocardial surfaces of the ventricles. Then the impulse once again spreads slightly less rapidly through the ventricular muscle to the epicardial surfaces (fig.1-4).

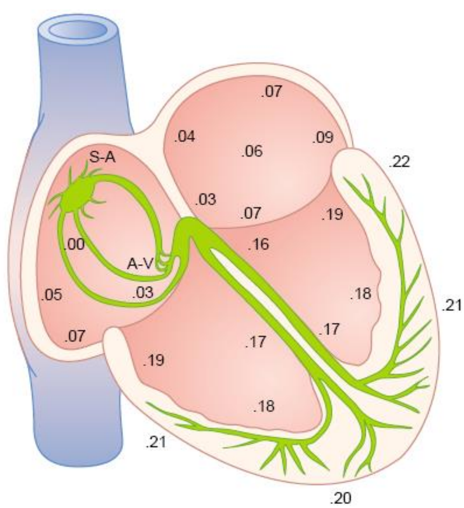

Figure 1-4: Transmission of the cardiac impulse through the heart, showing the time of appearance (in fractions of a second after initial appearance at the sinoatrial node) in different parts of the heart.

Physiology of the SA node

The cells of the SA node do not have a stable resting membrane potential. Their membrane potential starts at about - 60 mV and drifts upward, showing a gradual depolarization called the **pacemaker potential.** This is thought to result from a slow inflow of Na^+ without a compensating outflow of K^+. When the pacemaker potential reaches a threshold of - 40 m, **voltage-regulated fast calcium channels** open and Ca^{2+} flows in from the extracellular fluid (ECF), this produces the rising (depolarizing) phase of the action potential, which peaks slightly above 0 mV. At that point, K^+ channels open and K^+ leave the cell. This makes the cytosol increasingly negative and creates the falling (repolarizing) phase of the action potential. When repolarization is complete, the K^+ channels close and the pacemaker potential starts over, on its way to producing the next heartbeat (fig.1-5). Each depolarization of the SA node sets off one heartbeat. When the SA node fires, it excites the other components in the conduction system; thus, the SA node serves as the system's pacemaker. At rest, it fires every 0.8 second or so, creating a heart rate of about 75 bpm.

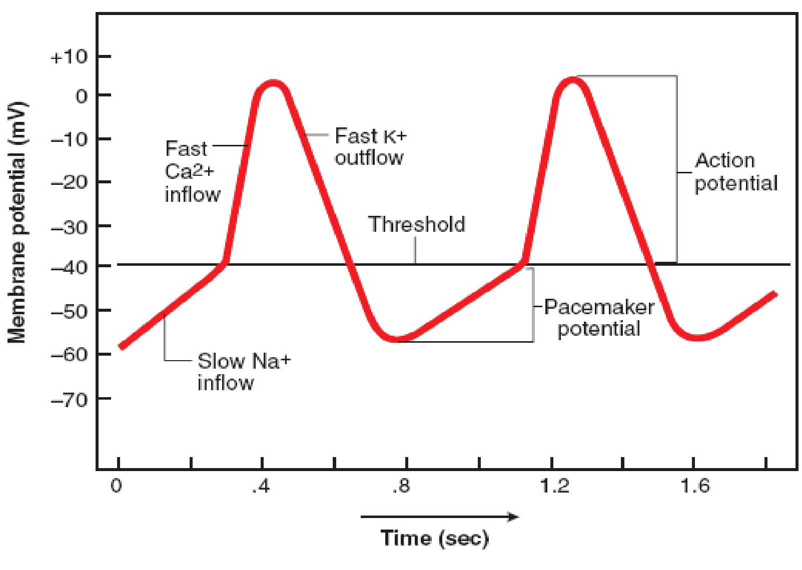

Figure 1-5: Pacemaker potentials and action potentials of the SA node.

The Electrocardiogram (ECG)

The figure of ECG shows three principal deflections above and below the baseline (fig.1-6): the **P wave**, **QRS complex**, **and T wave**. The **P wave** is produced when a signal from the SA node spreads through the atria and depolarizes them. Atrial systole begins about 100 msec after the P wave begins, during the *P–Q segment.* This segment is about 160 msec long and represents the time required for impulses to travel from the SA node to the AV node. **QRS** marks the firing of the AV node and the onset of ventricular depolarization. Ventricular systole begins shortly after the QRS complex in the *S–T segment.* Atrial repolarization and diastole also occur during the QRS interval. The **T wave** is generated by ventricular repolarization immediately before diastole

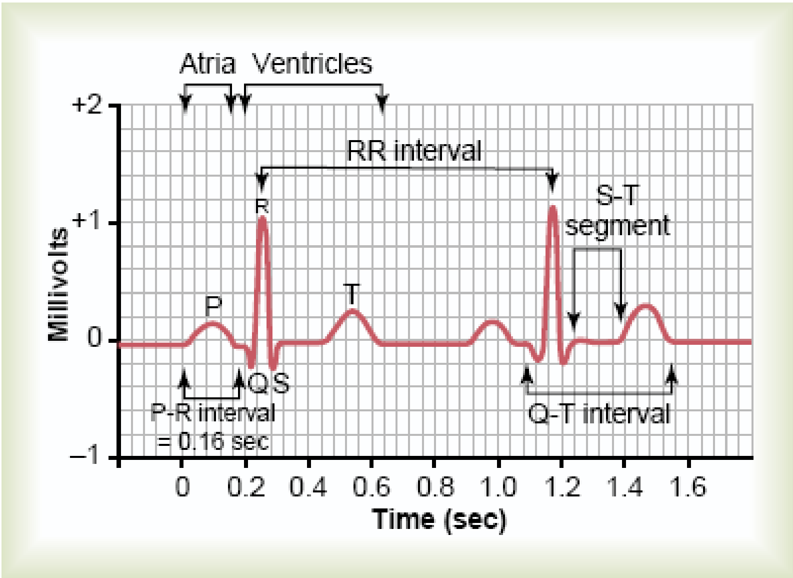

Figure 1-6: Normal electrocardiogram (ECG)

Relationship of the electrocardiogram (ECG) to electrical activity and contraction of the myocardium

1- Atria begin depolarizing.

2- Atrial depolarization complete.

3- Ventricular depolarization begins at apex and progresses superiorly as atria repolarize.

4-Ventricular depolarization complete.

5- Ventricular repolarization begins at apex and progresses superiorly.

6-Ventricular repolarization complete; heart is ready for the next cycle (fig. 1-7).

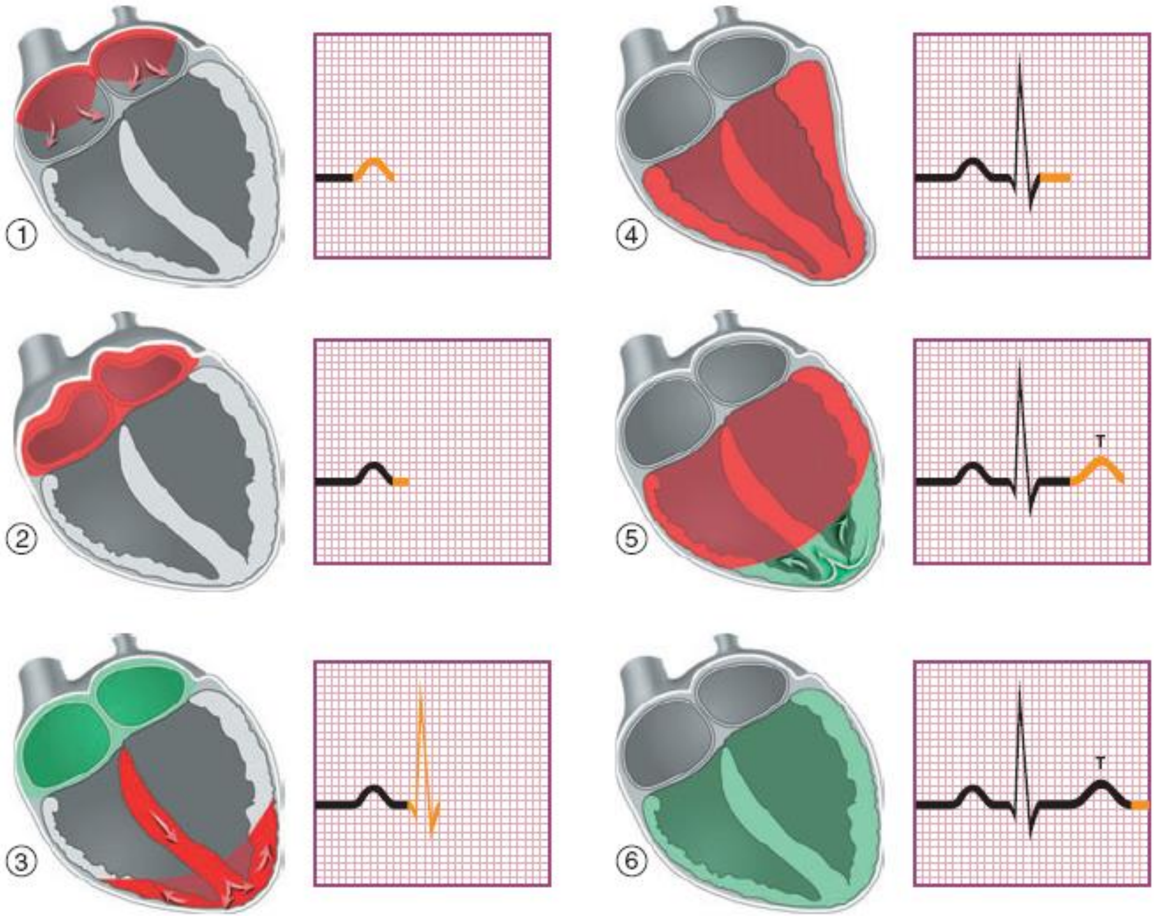

Figure 1-7: Relationship of the electrocardiogram (ECG) to electrical activity and contraction of the myocardium. Each heart diagram indicates the events occurring at the time of the colored segment of the ECG. Red indicates depolarizing or depolarized myocardium, and green indicates repolarizing or repolarized myocardium. Arrows indicate the direction in which a wave of depolarization or repolarization is traveling.

Flow of electrical currents in the chest around the heart

The fluids in tissues surrounding the heart conduct electricity. Therefore, the heart is actually suspended in a conductive medium. When one portion of the ventricles depolarizes and therefore becomes electronegative with respect to the remainder, electrical current flows from the depolarized area to the polarized area in large circuitous routes, as noted in the fig. 1-8.

Electrocardiographic Leads

Three bipolar limb Leads

Lead I. In recording limb lead I, the negative terminal of the electrocardiograph is connected to the right arm and the positive terminal to the left arm.

Lead II. To record limb lead II, the negative terminal of the electrocardiograph is connected to the right arm and the positive terminal to the left leg.

Lead III. To record limb lead III, the negative terminal of the electrocardiograph is connected to the left arm and the positive terminal to the left leg (fig.1–9).

Einthoven's Triangle

Einthoven's triangle (fig.1-9), is drawn around the area of the heart. This illustrates that the two arms and the left leg form apices of a triangle surrounding the heart.

Einthoven's Law

The sum of the voltages in leads I and III equals the voltage in lead II; that is, 0.5 plus 0.7 equals 1.2 (fig.1–9). Mathematically, this principle, called Einthoven's law, holds true at any given instant while the three "standard" bipolar electrocardiograms are being recorded.

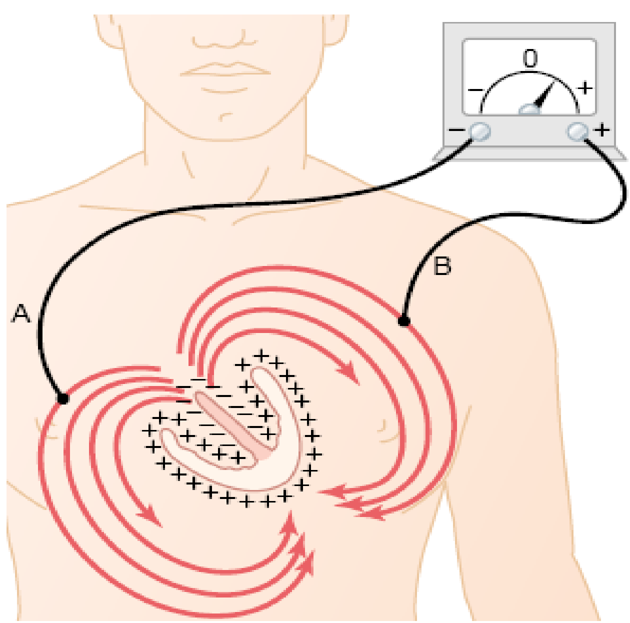

Figure 1-8: Flow of current in the chest around partially depolarized ventricles.

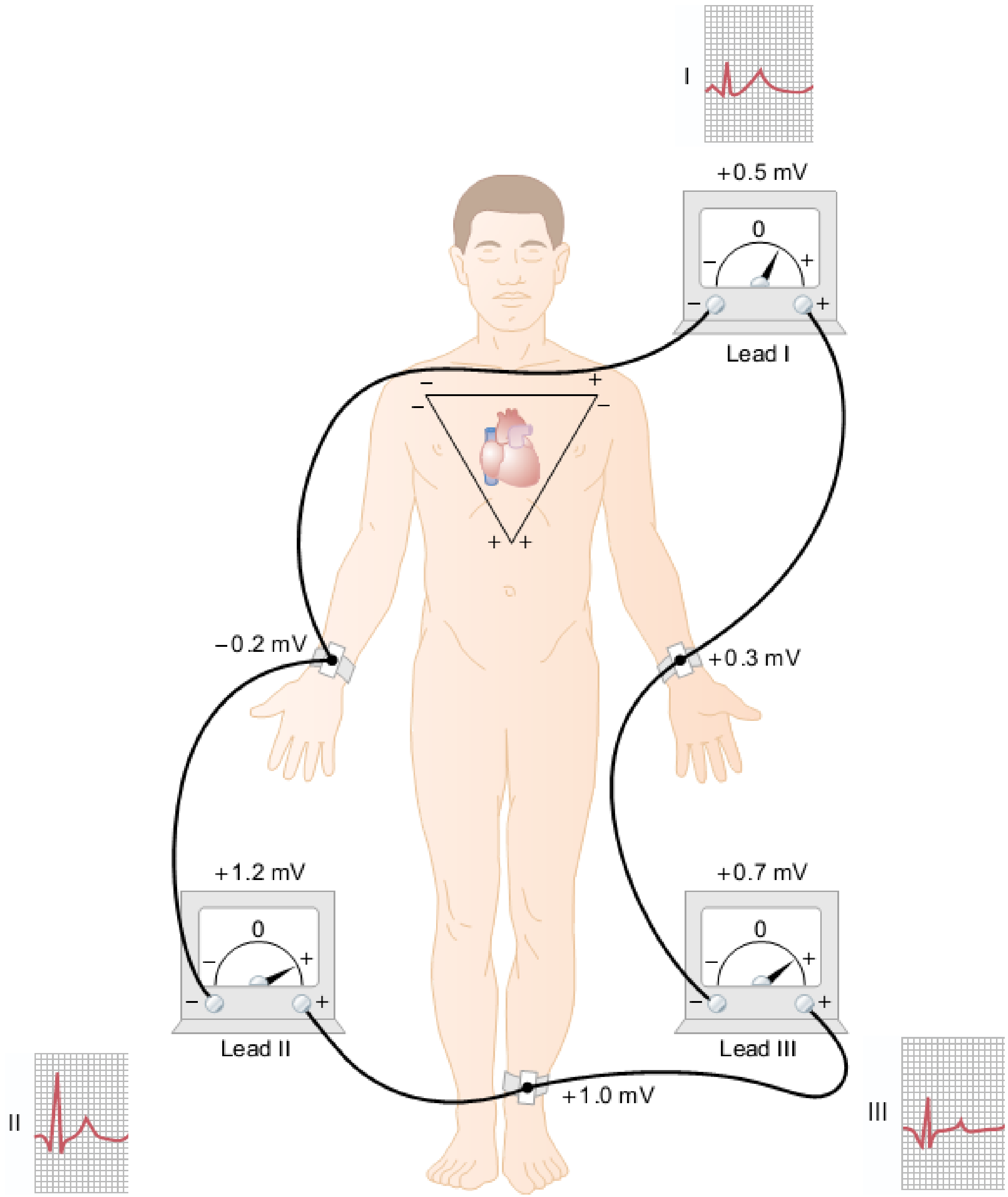

Figure 1–9: Conventional arrangement of electrodes for recording the standard electrocardiographic leads. Einthoven's triangle is superimposed on the chest.

Normal and Pathological Electrocardiograms

Normal and some pathological electrocardiograms are given in fig. 1-10.

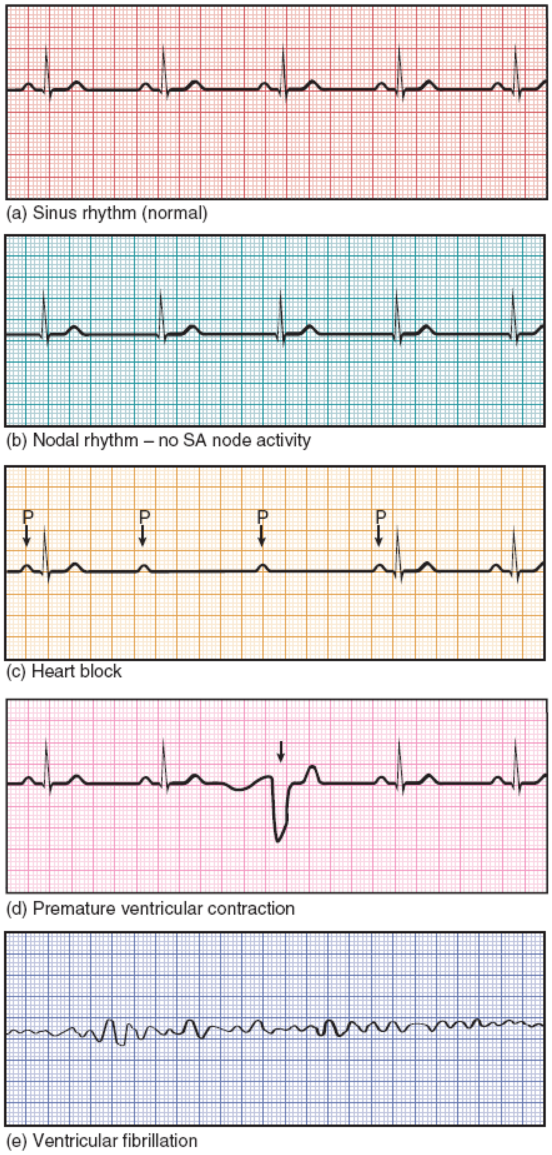

Figure 1-10: Normal and pathological electrocardiograms. (*a*) Normal sinus rhythm. (*b*) Nodal rhythm generated by the AV node in the absence of SA node activity; note the lack of P waves. (*c*) Heart block, in which some P waves are not transmitted through the AV node and do not generate QRS complexes. (*d*) Premature ventricular contraction (PVC), or extrasystole; note the inverted QRS complex, misshapen QRS and T, and absence of a P wave preceding this contraction. (*e*) Ventricular fibrillation, with grossly irregular waves of depolarization

Questions

1- What is the difference between circulatory system and cardiovascular system

2- Explain physiology of S A node

3- Draw normal ECG and of heart block with labeling

4- Describe einthoven's triangle and einthoven's law

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