Chapter 20

The Heart

heart anatomy

located in the mediastinum, the medial cavity, of the thorax

lungs flank the heart and partially obscure

lies slightly to the left of the midline

apex points down towards the left

base is the broader upper aspect where the great vessels emerge

layers of the heart wall

1. epicardium or visceral pericardium

outer thin layer of mesotheium

is simple sqamous epithelium

some areolar tissue

has adipocytes

2. myocardium

1. mainly cardiac muscle
2. thickest layer
3. contains tissue to conduct electrical current
4. contains a connective tissue **fiber skeleton**: the fibrous skeleton of the heart
    1. anchors cardiac muscle
    2. reinforces cardiac muscle
    3. provides support for great vessels
    4. limits spread of action potentials to specific pathways

3. endocardium

1. single layer of endothelium attached to a thin layer of connective tissue
2. lines the heart chambers
3. is continuous with the endothelial linings of the blood vessels

provides a none clotting surface

chamber and great vessels of the heart

heart has four chambers

right and left atria

right and left ventricles

atria

are the **receiving chambers** and receive blood returning to the heart

only need to contract enough to push blood into the ventricles

thus are thin walled

don’t contribute to the pumping of blood throughout the body

ventricles

1. right and left are separated by interventricular septum

2. make up most of the heart mass

3. are the **discharging chambers** thus are more massive

right ventricle pumps out the **pulmonary trunk** to the lungs (low oxygen blood) so generate little pressure

left pumps out the **rest of the body** (the systemic circulation) and must generate greater pressure so is larger than right

Blood flow through the chambers of the heart (pp. 723)

1. blood enters **right atria** via three vessels
    1. inferior vena cava
    2. superior vena cava
    3. coronary sinus

2. blood passes by right AV valve (**tricuspid valve**)
3. blood enters **right ventricle**
4. blood is forces out the right ventricle passed the **pulmonary semilunar** valve
5. blood enters **pulmonary trunk** with splits into **right and left pulmonary arteries**
6. blood is sent to **lungs**

7. blood returns form lungs via one of four **pulmonary veins** (two rights and two lefts
8. blood enters **left atria**
9. blood passes left AV valve (**bicuspid valve**)

10 blood enters **left ventricle**
11. blood is forced passed **aortic semilunar valve**
12. blood enters **aorta** and is sent to body minus the lungs via
brachiocephalic a,
left carotid a,
left subclavian a
descending aorta

1. out the aorta return to right atria = **systemic circulation**
2. out the pulmonary trunk return to left atria = **pulmonary circulation**

equal volume of blood passes through both circuits but work load is different

pulmonary circuit is short and low pressure circuit so right ventricle has to pump less

systemic circuit is long and requires high pressure
thus the left ventricle is much larger (3X)

The heartbeat

Cardiac Physiology

The primary function of the heart is to propel blood though out the pulmonary and systemic circulatory loops.

This is accomplished by the contraction of the cardiocytes that make up the heart

contraction of the heart's contractile cells is triggered by **action potentials** that originate at the heart

There are types of cardiocytes

1. Specialized **conduction cells**
   that make up the conduction system and are designed to rapidly conduct electrical current

2. **Contractile cells**
   These are the cells that shorten which pushes the blood from the heart
   Are 99% of all cardiocytes

   Contractile cells are more common

All cardiocytes have the ability to depolarize spontaneously producing action potentials

For example:

isolated atrial cells depolarize thus contract (beat) 60 times per min
isolated ventricular cells depolarize thus contract 20-40 times per min

The cells that depolarize fastest will set the rate or **pace** of heart contractions

Under normally conditions the cells that pace the heart are located at the top of the right atrium.

This piece of tissue is called the **Sinoatrial node (SA node)** or the **pacemaker**

from these pacemaker cells the action potentials spread across the heart along a **conduction pathway**

Conduction system for the spread of electrical activity across the heart

Sinoatrial node

located in rear wall of **right atrium** near opening of superior vena cava

has fastest rhythm (80-100 a.p./min) & normally overrides all others

this is were the **pacemaker cells are found** and is also called the **cardiac pacemaker**

action potential travels through walls of atria causing wave of atrial depolarization followed by a wave of **atrial contraction**

its rate of depolarization sets the heart rate **(sinus rhythm)**

Internodal pathways

Connects SA node to atrioventricular (AV) node,

Consists of three major bands of conduction cells that branch through out the atria

Takes about 50 msec for the action potential to travel the internodal pathway

Along the way the contractile cells of the atria are stimulated to depolarize and produce action potentials

Action potentials spread form cell-to-cell via gap junctions (electrical synapses)
Following depolarization the contractile cells of the atria contract and push blood into the ventricles

The electrical events occurring in the atria do not pass to the ventricles due to a band of tissue called the fibrous skeleton that breaks the gap junction connections between atrial cells and ventricular cells
Due to a slow conduction speed down the internodal pathway the atria will completely depolarize before the action potential reaches the next part of the conduction pathway, the AV node

Atrioventricular node

Large node located at the junction between the atria and the ventricles
in right posterior portion of interatrial septum

AV nodal cells are smaller in diameter and have few gap junctions thus has a much slower rate of action potential propagation
Takes about 100 msec for action potential to through AV node

Slower conduction speed in nodal fibers, allows complete atrial depolarization before action potential spreads to ventricles
Thus allow the atria to contract and finish filling the ventricles with blood before the ventricles contract

Under normal conditions the AV node can generate action potentials at a max rate of 230/min. This sets the maximum ventricular contraction rate (heart rate) at 230 beats/min
If the SA node and thus atria contract faster it can not result in a faster rate of ventricular contraction (the AV is the bottle neck)

After the AV node depolarizes the action potential next spreads to the AV bundle of His

AV Bundle of His

Only electrical connection between atria & ventricles
fiber skeleton insulates the rest of the atria from ventricles

Divides into right & left bundle branches as it passes through the ventricular septum

Left is larges and supplies the larger left ventricle

Both braches travel down towards the apex of the heart were they fan out into smaller Purkinje fibers

Purkinje fibers

Pass through ventricular myocardium

Fast rate of action potential generation and serve to synchronizes ventricular contraction

the contraction of the **ventricles** starts at the apex so that all blood is forced up and out

action potentials spreads from cell to cell via **gap junctions** all alone the conduction pathway and from cardiocyte to cardioocyte

By the time the action potential has reach the ventricular muscle at the apex the atria have completed their contraction maximizing the blood in the ventricles and the ventricles can now start to contract to expel the blood form the heart

Generation of the electrical activity of the heart

The heart generates its own electrical activity and this electrical activity triggers the heart (cardiocytes) to contract which pumps the blood

What is responsible for this electrical activity (action potentials)?

Generation of the action potential at the <u>pacemaker cells</u>

The SA node (pacemaker cells) spontaneously depolarizes (fires) 70-80 times per minute

This occurs because the SA nodal cells have an unstable resting membrane potential

1. negative charges accumulate inside the cells as it repolarizes from the last action potential

2. the negative charges repel negative charges that are part of a special type of sodium channel

3. this repulsion opens the sodium channel and now a lots of sodium enters the cell (sodium permeability goes up)

This sodium channel is called the **slow spontaneously opening sodium channel**

4. now the membrane potential drops from -60mv until it reaches a **threshold** value (around -40mv)

this opens **fast voltage-sensitive calcium channels**

5. now calcium rapidly enter to further depolarize the cell (not sodium like in nerve and skeletal muscle)

6. the entry of calcium neutralizes negative charges further, opening adjacent voltage sensitive calcium channels

thus the action potential is propagated by calcium channels

5. the fast calcium channels and the slow spontaneously opening sodium channel close while voltage- sensitive potassium channels open this causes repolarization

As the cell repolarizes negative charges are accumulating inside the pacemaker cell

This will now start to repel the negative charges on the spontaneously opening sodium channel starting the cycle over

Thus the pacemaker cells have an unstable resting membrane potential

Spread of electrical activity

Once a pacemaker cell has depolarized (generated an action potential) this electrical charge spreads by the passing of positive charges from one cell to the next via gap junctions

Thus the first cell to generate an action potential will force the adjacent cells to depolarize due to the attachment through gap junctions

Therefore the action potential will spread quickly across and down the conduction pathway until it reaches the atria and ventricles where the contractile cells are

electrical events at the contractile cells

1. through gap junctions positive charges enters the cells and depolarizes a small area of membrane opening **fast voltage-sensitive sodium channels**

2. this allows more sodium to enter thus opening adjacent fast voltage-sensitive sodium channels

thus the action potential is propagated by sodium channels

3. as the fast voltage-sensitive sodium channels start to close a second type of channel opens called the **slow voltage-sensitive calcium channel**

4. this channel lets positively charged calcium enter the cell and holds the cell depolarized for about 150 msec

(this results in a **plateau** on the action potential)

5. repolarization begins when the voltage sensitive calcium channel will slowly close and voltage-sensitive potassium channels will slowly open to repolarize the cell

Reason for a plateau:

results in a long depolarization (200msec) thus have strong muscle contraction

(not a twitch)

a long absolute refractory period so no tetanus

absolute refractory period lasts until relaxation phase of contraction begins

Role of the action potential

Results in opening calcium channels that let in 20% of the total calcium

Makes the heart very sensitive to changes in blood calcium levels

Makes these channels important targets for drug therapies

Stimulates the smaller sarcoplasmic reticulum to release the other 80% of calcium

Role of calcium

excitation-contraction-coupling

1. the action potential will be propagated down the T tubules causing the sarcoplasmic reticulum to release calcium

2. the calcium from the ER and the calcium that entered from ion channels will bind to troponin

This moves tropomyosin exposing a myosin binding site on actin

Now have cross bridge formation and power stroke resulting in filaments sliding = contraction

contraction = pumping

Innervation of the heart