Problems with heart rhythm

AV node rhythm is slower - bradycardia

Heart block - a type of bradycardia.
Ventricles pump slowly and out of rhythm of atria

Ventricular fibrillation

Atrial fibrillation
**Action potential in cardiac muscle**

- **Plateau phase**: These are contractile cells, not pacemaker cells.
- **Threshold potential**: Relaxation of cardiac muscles is essential.
- **Long refractory period ensures no summation of twitches**.

**Electrocardiogram**

- Currents from heart spread to body tissues and fluid.
- Sum of all electrical activity spread to electrodes and recorded.

**Key Points**:
- PR interval
- ST interval
- TP interval
Cardiac cycle

Ventricular and atrial diastole

Cardiac cycle

Atrial contraction

Cardiac cycle

Isovolumetric ventricular contraction

“Lub”

End diastolic volume is in the ventricles
Cardiac cycle

Ventricular ejection

Cardiac cycle

Isovolumetric ventricular relaxation

“Dub”

End systolic volume is in ventricles

---

Heart murmurs

Systolic or diastolic murmurs

Often due to stenosis or regurgitation at a valve (“whistle” vs. “swish”)

- **Normal heart**
  - "lub-dup"

- **Diastolic mitral stenosis**
  - "lub-dup-whistle"

- **Diastolic aortic regurgitation**
  - "lub-dup-swish"

- **Systolic aortic stenosis**
  - "lub-whistle-dup"

- **Systolic tricuspid regurgitation**
  - "lub-swish-dup"

- **Diastolic patent ductus arteriosus**

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Extrinsically:
- Conduction speed
- Contraction strength

Sympathetic signals increase stroke volume

- Stroke volume
- Strength of cardiac contraction
- Sympathetic activity (and epinephrine)
- End-diastolic volume
- Venous return

Recall: muscle length and force

Frank Starling law
(intrinsic increase in stroke volume)

Optimal length

(Cardiac muscle does not normally operate within the descending limb of the length-tension curve.)

End-diastolic volume (EDV) (ml)
Would you expect type 1 or type 2 fibers in heart muscle?

Heart disease
How do heart attacks occur, what leads to them?

Myocardial infarction
Coronary artery disease
Coronary arteries nourish cardiac cells

Blockage due to plaques, embolisms, vascular spasm

How cholesterol is carried in the blood:

- **High-density lipoprotein** - helps move cholesterol back to liver for removal
- **Low-density lipoprotein** - used by cells, excess LDL infiltrates artery walls

Saturated fats and trans fats in diet raise LDLs and promote plaque formation

Development of atherosclerosis involves these factors:

- **Inflammation along vessel**, triggered by various factors (ox.LDLs, signals from fat, other inflam., smoking, hypertension)

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This area bulges into middle of vessel, can possibly rupture, ‘snowball’ effect
Inflammation along vessel, triggered by various factors (ox.LDLs, signals from fat, other inflam., smoking, hypertension)

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Smooth muscle and fibroblasts (repair cells) may attempt to seal over the inflamed area, thickening it.

**Development of atherosclerosis involves these factors:**

<table>
<thead>
<tr>
<th>EARLY ATHEROSCLEROSIS</th>
<th>ADVANCED ATHEROSCLEROSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle layer of artery</td>
<td>Fat globule</td>
</tr>
<tr>
<td>Fat globule</td>
<td>Fatty deposit</td>
</tr>
<tr>
<td>Fatty deposit</td>
<td>New muscle cell</td>
</tr>
<tr>
<td>New muscle cell</td>
<td>Narrowed artery</td>
</tr>
<tr>
<td>Narrowed artery</td>
<td>Thickened muscle layer</td>
</tr>
</tbody>
</table>

**Coronary bypass**

- Grafted arteries
- Blockage

**Heart disease**

Often due to:
- Poor circulation to heart muscle (blockage)
- High blood pressure makes heart work harder
- Insufficient valve
Heart disease

Continued sympathetic action can temporarily alleviate heart failure effects on output

Kidney \( \uparrow \) fluid retention thus \( \uparrow \) stroke volume

Congestive heart failure

Stroke volume is so low that blood backs up in blood vessels leading to heart

Failure on left side - blood collects in pulmonary circuit and causes pulmonary edema. Oxygenation decreases.

Response of kidneys to fluid retention is now problematic.

Congestive heart failure

Stroke volume is so low that blood backs up in blood vessels leading to heart

Failure on left side - blood collects in pulmonary circuit and causes pulmonary edema. Oxygenation decreases.

What causes an enlarged heart?

Due to thickening of heart muscle:

- \( \bowtie \) To pump against high pressure
- \( \bowtie \) Leaking or stiffness in heart valves

Stiffness in aortic valve
**What causes an enlarged heart?**

Due to thickening of heart muscle:
- To pump against high pressure
- Leaking or stiffness in heart valves

Due to over-dilation due to heart failure (usually pulmonary edema)

**What are heart arrhythmias?**

- Arrhythmia: an irregularity in heart beat. There is an issue with electrical conductivity and/or rate (fibrillations, tachycardia, bradycardia)
- Arrhythmias don’t necessarily mean the person has heart disease (but can be a result)

**Blood vessels are more than little tubes bringing blood to your body**

They are dynamic, changing flow, growing branches according to conditions

**Reconditioning of blood**

Intestines, kidneys, and skin receive blood flow in excess to their needs
Resistance is the opposition to blood flow through a vessel. It depends on:
- blood viscosity
- vessel length
- vessel radius

Flow rate of blood

\[
F = \frac{\text{pressure gradient}}{\text{resistance}} \quad \text{or} \quad F = \frac{\Delta P}{R}
\]

Effect of radius on surface area

Friction increases as surface area of contact increases

- More vessel wall in contact with blood
- Less contact

Effect of radius on resistance

- Same pressure gradient
- Radius in vessel 2 = 2 times that of vessel 1
- Resistance in vessel 2 = 1/16 that of vessel 1
- Flow in vessel 2 = 16 times that of vessel 1

Arteries are a pressure reservoir

Large radius of arteries, little resistance

- Elastic recoil from arteries drives flow of blood during diastole
- Arteries temporarily expand and hold pumped blood
Mean arterial pressure is the driving force for blood flow.

\[
\text{mean arterial pressure} = \text{diastole pressure} + \frac{1}{3} \times \text{the pulse pressure}
\]

\[
80 + \frac{1}{3} (40) = 93
\]

Blood pressure drops sharply once in arterioles.

Arterioles give most resistance

Arteriole radius changes to alter the distribution of blood and regulate blood pressure.

Vascular tone is a baseline of vascular resistance - changes in radius are possible.

Local control of arteriolar resistance

Mean blood pressure is identical to all organs.

Differences in arteriolar resistance determines the distribution of blood to different organs.

Mechanisms: endothelium cells release chemicals when \( \downarrow \text{O}_2 \) and \( \uparrow \text{CO}_2 \), \( \uparrow \text{acidity} \).
Increased flow to skeletal muscles due to exercise

Extrinsic (outside) controls on arterioles:
Sympathetic signals cause general arteriole constriction, increasing mean pressure

Local controls dilate arterioles where blood is needed.

Increased SNS

Local controls using signals from tissues
**Capillaries**
- $O_2, CO_2$ nutrients and wastes passively diffuse
- Thin vessels increase surface area of vessel wall contact

**Diffusion at capillaries**
- **Distance:** Walls are one cell thick
- **Area:** small radius, high surface area of contact
- **Speed:** small radius causes slow flow

**Capillary walls have pores**
- Pores allow the passage of small, water-soluble molecules (ions, glucose)
- Lipid-soluble substances dissolve through cell membrane

**Bulk flow**
Some substances cross the capillary wall by bulk flow of fluids
- Ultratration
- Reabsorption
Bulk flow at capillaries

Bulk flow occurs by the changing differences in hydrostatic and osmotic pressures between plasma (inside) and interstitial fluid (outside).

When fluids leave capillaries, most plasma proteins remain.

Plasma has a higher concentration of proteins, producing osmotic pressure from interstitial fluid to plasma. “Plasma-colloid osmotic pressure”

Forces of bulk flow:

- Arteriole: Plasma colloid pressure (25)
- Interstitial pressure (11)
- Venule: Plasma colloid pressure (25)

Ultrafiltration

Blood pressure (hydrostatic): 37
**Bulk flow**

- Fluid is exchanged b/w plasma and interstitial fluid
- Site of short-term maintenance of fluid balance

**Lymphatic System**

Lymph formed from interstitial fluid

Functions:
- Drainage channels
- Absorption of fats from intestine
- Deliver pathogens to "nodes" where there are many lymphocytes

**Lymph nodes**

Interstitial fluid that is not absorbed by veins drains into lymphatic system
Lymphatic vessels

Fluid pressure

fluid cannot push out from inside