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
Problems with heart rhythm

- Atrial fibrillation
- Ventricular fibrillation

Action potential in cardiac muscle

- Plateau phase
- Threshold potential

Long refractory period ensures no summation of twitches

Relaxation of cardiac muscles is essential
Electrocardiogram
Currents from heart spread to body tissues and fluid
Sum of all electrical activity spread to electrodes and recorded

Recorded potential

R
P
Q
T
S

200 msec

PR
ST
TP interval

Electrocardiogram

NORMAL RHYTHM AND RATE

ABNORMALITIES IN RATE
Tachycardia
Bradydysrhythmias
Ventricular tachycardia
ABNORMALITIES IN RHYTHM
Sinus tachycardia
Ventricular tachycardia
Complete heart block
Cardiac hypertrophy
Monosystolic ventricular heart attack
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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(a) Normal stroke volume

End-diastolic volume 135 ml

Stroke volume 70 ml

End-systolic volume 65 ml

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Sympathetic signals increase stroke volume

Extrinsically:
- ↑ conduction speed
- ↑ contraction strength

Intrinsic control:
- ↑ Stroke volume
  - Strength of cardiac contraction
  - End-diastolic volume
  - Venous return

Sympathetic activity (and epinephrine)
Recall: muscle length and force

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

End-diastolic volume (EDV) (ml)

Frank Starling law
(intrinsic increase in stroke volume)

Stroke volume (SV) (ml)

End-diastolic volume (EDV) (ml)

Would you expect type 1 or type 2 fibers in heart muscle?
**Adjustments to stroke volume**

- End-diastolic volume: 135 ml
  - Stroke volume: 70 ml
  - End-systolic volume: 65 ml

- End-diastolic volume: 135 ml
  - Stroke volume: 100 ml
  - End-systolic volume: 35 ml

- End-diastolic volume: 175 ml
  - Stroke volume with combination of sympathetic stimulation and increased end-diastolic volume: 140 ml

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**Heart disease**

How do heart attacks occur, what leads to them?

- Pain radiating down left arm might signal a heart attack.

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**Myocardial infarction**

- Heart muscle
- Stressed heart muscle
- Bad heart muscle
- Heart muscle death
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)
Inflammation promoted (LDL buildup, oxidation, WBCs are attracted and engulf LDLs) This area bulges into middle of vessel, can possibly rupture, ‘snowball’ effect

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

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 fluid retention thus 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**.

**What causes an enlarged heart?**
Due to thickening of heart muscle:
- To pump against high pressure
- Leaking or stiffness in heart valves
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 bc of 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.

Flow rate of blood

\[ F = \frac{\text{pressure gradient}}{\text{resistance}} \]

or

\[ F = \frac{\Delta P}{R} \]

Resistance is the opposition to blood flow through a vessel. It depends on:
- blood viscosity
- vessel length
- vessel radius

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

- Resistance = 1/4 * Flow = r^2
- (b) Influence of vessel radius on resistance and flow

**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.**

Mean arterial pressure = diastole pressure plus 1/3 the pulse pressure

80 + 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 $\downarrow$O$_2$ and $\uparrow$CO$_2$, acidity
Increased flow to skeletal muscles due to exercise

Sympathetic signals cause general arteriole constriction, increasing mean pressure.

Local controls dilate arterioles where blood is needed.

Extrinsic (outside) controls on arterioles:

Increased SNS
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
- Ultrafiltration
- 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"
Bulk flow

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

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

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

Fluid pressure

Lymphatic vessels

Fluid cannot push out from inside