BMS2031- Human Physiology

1. Explain the functions and controls of the cardiovascular, renal, respiratory, endocrine, reproductive and digestive systems in the human body.
2. Describe how the body systems integrate in order to maintain homeostasis following exercise or blood loss.
3. Plan and conduct scientific experiments and analyse and interpret the associated experimental data related to the effects of ventricular filling on cardiac contraction, the effect of exercise on cardiovascular function, the effect of a water loading on urinary excretion and the effects of autonomic nerves on gut motility.
4. Communicate experimental results in the format of scientific figures and written reports.

CVS Overview (8 Lectures):

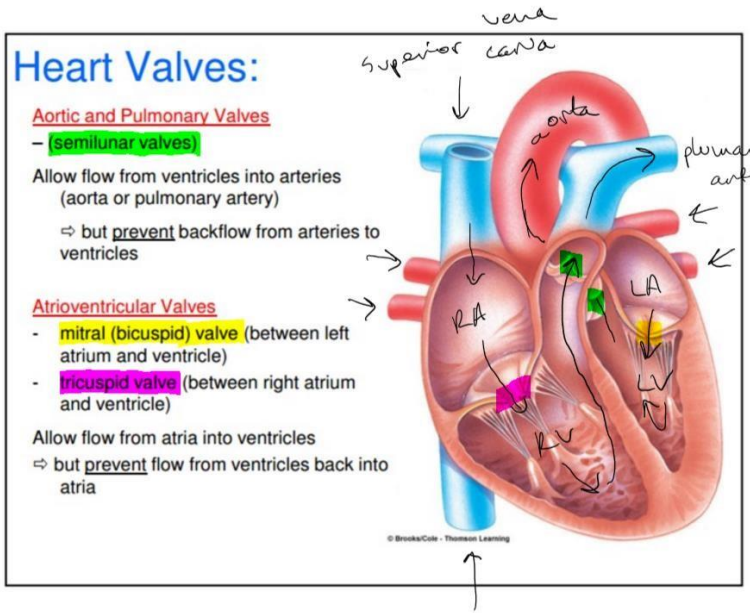
1. Overview of the cardiovascular system
2. Excitation of the heart
3. The heart as a muscular pump (contraction of the heart) and control of cardiac output
4. The vascular system: arteries, arterioles and the distribution of blood flow
5. The vascular system: capillary exchange and venous return
6. Regulation of arterial blood pressure
7. Integration of the cardiovascular and renal systems during haemorrhage (and cardiovascular revision)

CVS 1

1. Explain the basic anatomy of the heart and its arrangement into 4 chambers.
2. Describe the location and function of the heart valves.
3. List in sequence the direction of blood flow through the four chambers of the heart.
4. Appreciate that blood flows in series through the systemic and pulmonary circulations.
5. Explain what causes fluid to flow through a tube.
6. Understand the relationship between blood flow, pressure and resistance.
7. Appreciate the three factors that influence the resistance to flow through a tube.

ONE, TWO

Heart anatomy



vena superior cava

aorta

pulmonary artery

pulmonary vein from lungs

valves = passive depending on pressure

inferior vena cava

(no O_2 + full of CO_2)

THREE

Direction of Blood Flow:

1. Entry from blood vessels into heart via the superior and inferior vena cava.
2. Entre right atrium
3. Flow though tricuspid valve
4. Entre right ventricle
5. Exit through the semilunar valves through the pulmonary artery
6. Flows across the lungs to pick up O_2 and release CO_s
7. Entre the heart through the pulmonary vein into the left atrium
8. Flow through mitral (bicuspid) valve
9. Entre left ventricle
10. Exit heart into blood vessels through the semilunar valve via the aorta FOUR

Blood flows in series through the systemic and pulmonary circulations.

<u>Circulatory System</u>

- Transports nutrients and hormones
- Transports O_2
- Removal of waste and CO_2
- Thermoregulation
- Immunity
- Penile erecting FIVE

Heart values function due to pressure. The blood always flows from area of high pressure to area of low pressure.

SIX

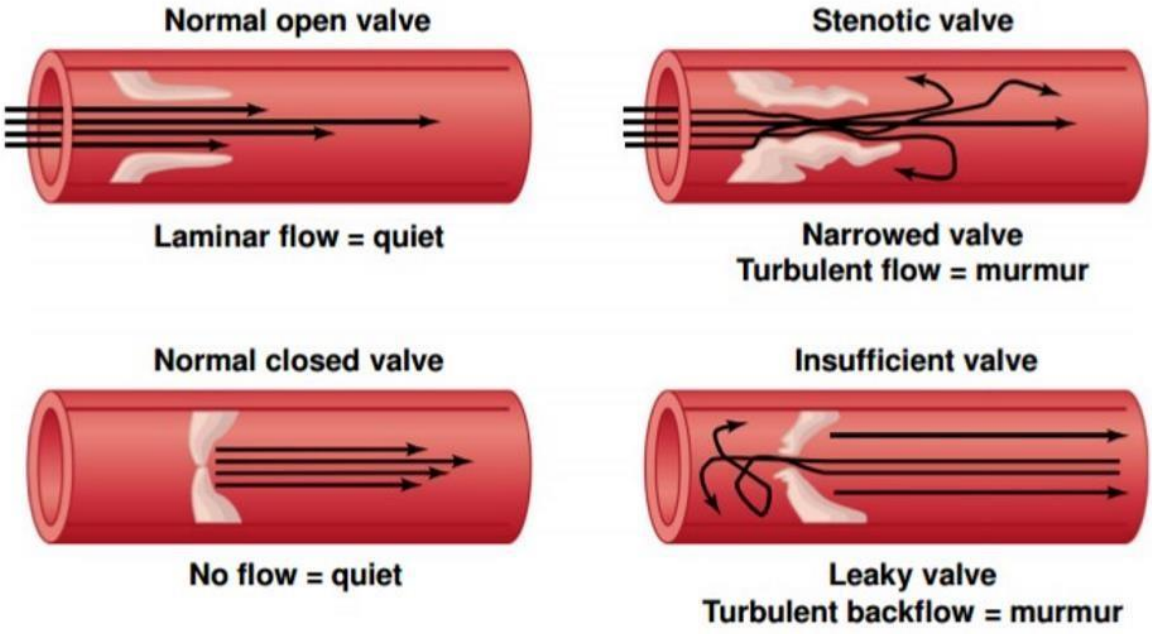
F α ΔP

Where:

F- flow

ΔP- change in pressure

- Only if blood flow is laminar (smooth and silent. Blood is usually laminar)
- It is the difference in pressure that matters
- The longer the blood vessel the greater the resistance
- The smaller the diameter the greater the resistance



$$R \alpha \frac{1}{r_4}$$

Where:

R-

Resistance r-

radius

SEVEN

Factors determining resistance:

- Length of tube
- Diameter of tube
- Viscosity of fluid

$$F \alpha \frac{1}{R}$$

$$P F \alpha \frac{\Delta}{R}$$

Haematocrit: percentage volume of blood occupied by blood cells

- Relatively constant
- Abnormally low in anaemia
- Abnormally high when severely dehydrated or erythropoietin (blood doping) Muscles Cells (Myocytes)

Relaxed:

- Increased diameter
- Decreased resistance
- Increased Flow

Contracted:

- Decreased diameter
- Increased resistance
- Decreased flow

CVS 2

1. Describe the conducting system of the heart and how electrical activity spreads from the sino-atrial node to the rest of the heart.
2. Describe the main ionic movements during a ventricular action potential.
3. Explain how sino-atrial node pacemaker cells spontaneously generate action potentials.
4. Describe the 3 phases of the ECG, including how they relate to excitation of the heart and the cardiac action potentials.
5. Describe some common cardiac arrhythmias.
6. Explain why the sino-atrial node acts as the normal pacemaker of the heart.
7. Explain how sino-atrial node pacemaking (i.e. heart rate) is regulated by the autonomic nervous system.

ONE

The Heart

- Can beat in isolation of the body due to pace making cells
- Heart rate increases in a linear fashion which increases O_2 delivery and activates muscles
- Extensive exercise decreases resting heart rate
- Max heart rate is no different between sedative individuals and elite athletes - Vasovagal Response:
    1. When the reflect occurs, the response is known as a **vasovagal syncope**
    2. Vasovagal syncope occurs in response to a trigger, with a corresponding malfunction in the parts of the nervous system that regulate heart rate and blood pressure. When heart rate slows, blood pressure drops, and the resulting lack of blood to the brain causes fainting and confusion.

Contraction Pathway:

- Heart myocytes are modified muscle cells
- Collagenases: endopeptidases that digests all types of collagen in the triple helix region.

1. Enzyme (collagenase) breaks down connective tissue to isolate action potential (AP)
2. Myocytes can function when separated due to presence of pace maker cells

Contractions:

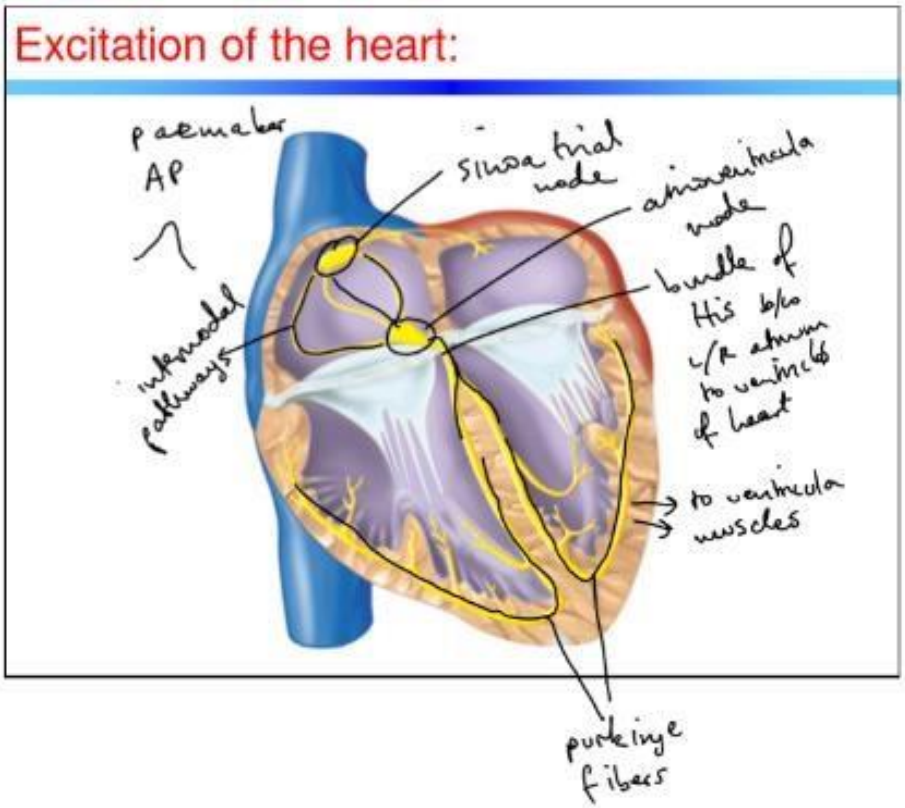
1. Shortening of the sarcomeres
2. Exaltation proceeds contrition i.e. without excitation, contraction will not occur

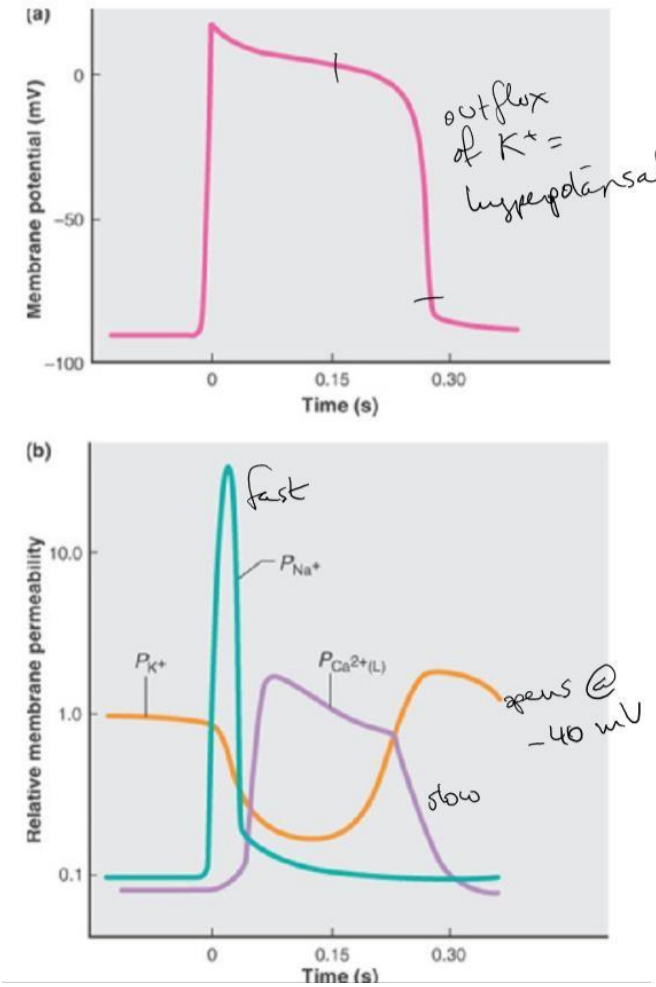
3. Cells contract individually for effective ejection of blood from heart
4. Cells are couple at intercalated disc region
5. Gap junctions exists at disk to facilitate constant ion flow
6. There is a long refractory period

Spread of excitation (depolarisation) though the heart:

1. Excitation originates in the sinoatrial node and atria myocytes
2. Internodal pathway to atria
3. Atrioventricular node (conduction slows to 0.05 m/s)
4. Bundle of His (2 branches)
5. Purkinje fibres (rapid conduction at 3-5 m/s)
6. Ventricular myocytes

- Cardiac Action Potential is the cause of heart cell excitation.





Membrane Potential:

- ΔV across cell membrane
- Nernst potential: calculates at what membrane potential would cell rest if only one particular ion was permeable

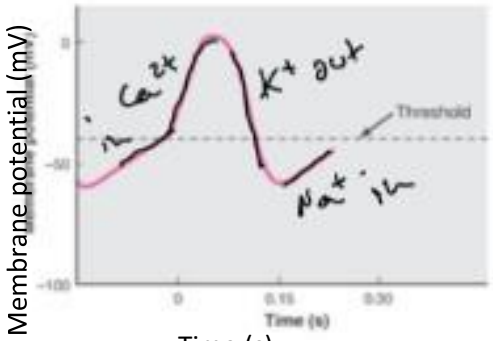
During ventricular myotic AP's:

1. Current stimulates opening of voltage-gated Na^+ channels, causing influx of sodium ions though N_{av} channels.
2. Calcium and potassium voltage-gated channels open while Na_v channel move into inactive state.
3. Ca^{2+} flows into cell more slowly.
4. K^+ flows out of cell and open K_v and K2P channels allow for hyperpolarisation of cell.
5. Channels close allowing sodiumpotassium pumps to restore resting membrane potential and allow for quicker restoration of Na_v channels into closed position.

The current of a pace maker cell is the only current that is opened during hyperpolarisation of normal myocytes and is largely influenced by a slow influx of Ca^{2+}. Slow influx of Na^+ also occurs but is not as influential as Ca^{2+} channels.

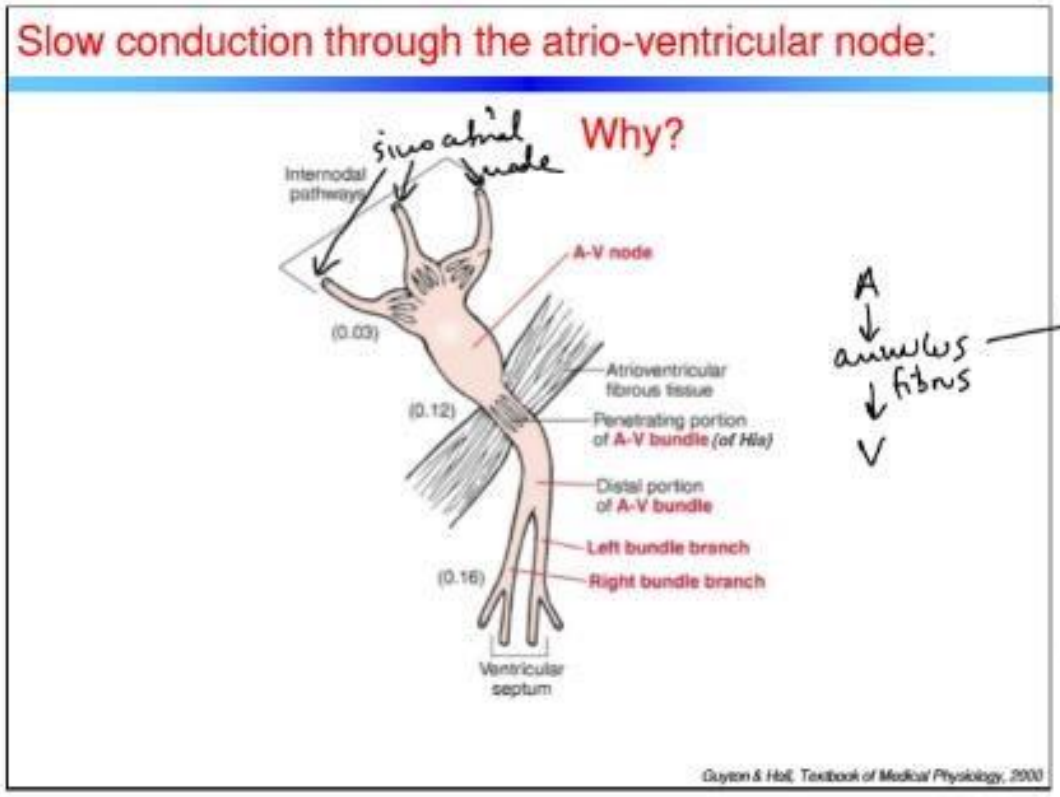
- There are 2 types of calcium channels
- At the Sino-atrial node pace maker action potentials occur:

1. Initiated by slow influx Na^+ 2. Transient influx of Ca^{2+}
3. Gradual out flux of K^+ causing plateau phase, activated at -40 mV but have a delayed reaction.



Time (s)

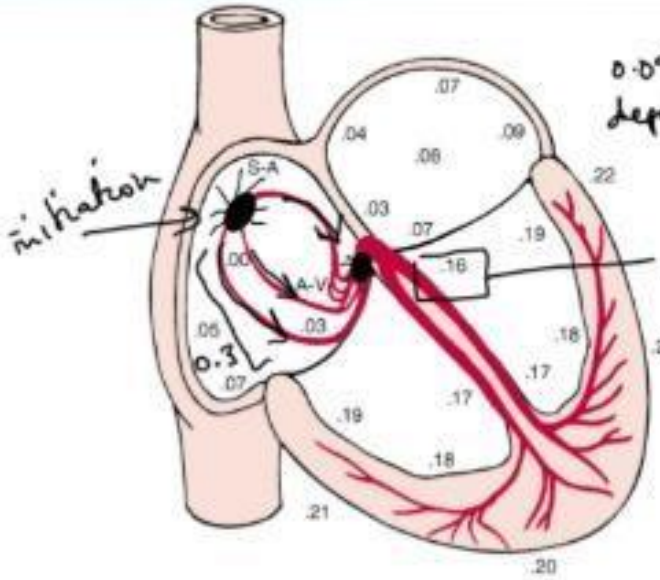
Slow conduction through the atrio-ventricular node:



A → annulus fibrus → V

→ only point to pass through. Delay = fewer gap junctions ∴ slower conduction rate to allow time for blood to fill A and move to V

Transmission of the cardiac impulse through the heart:
(time in s after initiation in the SA-node)



0.09 s for depol of the atria

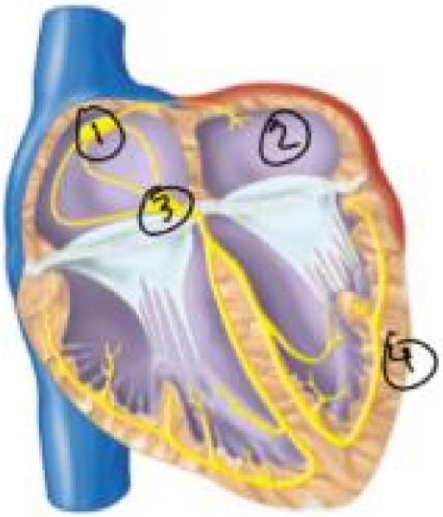
initiation

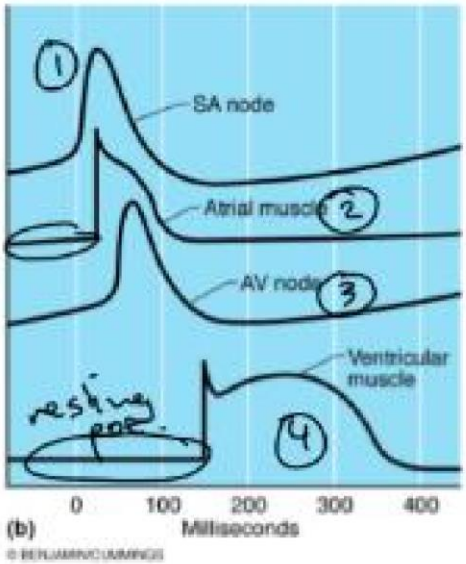
delay.
once @ bundle of His propagates through

0.06s for ventricular excitation/depol

Guyton & Hall, Textbook of Medical Physiology, 2000

Spontaneous generation of 'pacemaker' action potentials in SA- and AV-nodes:





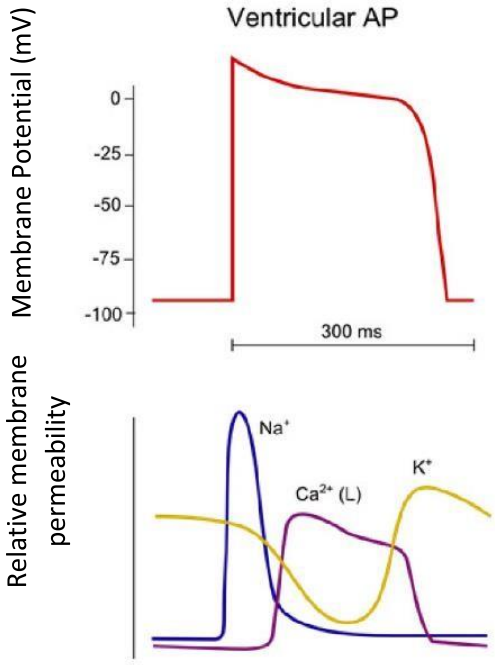
THREE

Sino-atrial Node (SAN) Pacemaker and Ventricular Action Potentials

Ventricular Action Potential:

- Stable resting membrane potential
- Resting membrane potential: -90 mV
- At resting mempot, distal blood pressure as ventricles fill
- Plateau phase at +20 mV
- Ventricular resting membrane potential:
    1. $Na_{+OUT} > Na_{+IN}$
    2. $Ca_{2+OUT} > Ca_{2+IN}$
    3. $K_{+IN} < K_{+OUT}$ - Depolarisation:

1. Opens 'fast' voltage-sensitive Na^+ channels 2. Plateau and 'slow' voltage-gated Ca^{2+} channels open - Repolarization:
    1. Voltage-sensitive K^+ channels open



Pacemaker action potential:

- Not stable at resting membrane potential
- Resting membrane potential: -65 mV
- -40 mV threshold
- 0 mV peak
- Plateau caused by K^+