OVERVIEW OF THE CIRCULATION

- FUNCTIONS OF THE CIRCULATION IS TO SERVICE THE NEEDS OF THE TISSUES:
  - Transport **nutrients**
  - Remove **waste**
  - **Hormonal** transport
- PHYSICAL CHARACTERISTICS OF THE CIRCULATION:
  - Circulation divided into two components:
    - Systemic
    - Pulmonary
  - Functional parts of the circulation:
    - Arteries ->transport blood under high pressure to the tissues
    - Arterioles->last small branches of the arterial system and act as control conduits through which blood is passed into the capillaries
      - Strong muscle wall, capable of vastly altering blood flow
    - Capillaries->function is to exchanges fluid, nutrients, electrolytes, hormones
      - Possess numerous minute pores increasing permeability
    - Venules->collect blood from the capillaries, gradually coalescing into progressively larger veins
    - Veins->function as conduits for transport of blood from the tissues back to the heart.
      - Also function as a major reservoir of blood
  - Volumes of blood in various parts of the circulation:
    - **~84% in systemic circulation, 16% in pulmonary circulation**
    - Of systemic circulation, **2/3 in the veins**, 13% in the arteries and 7% in the systemic arterioles and capillaries
  - Effect of cross-sectional area:
    - Veins have much larger cross-sectional area, facilitating storage of large volumes of blood
    - Velocity of blood flow is inversely proportional to vascular cross-sectional area, hence high rate of the flow in the aorta (33cm/sec) versus slow flow in the capillaries (0.3mm/sec)

Resistance to Blood Flow

Poiseuille equation

$$R = \frac{8\eta L}{\pi r^4}$$

R = resistance
η = viscosity of blood
L = length of blood vessel
r^4 = radius of blood vessel raised to the fourth power

If radius decreases by one half,
resistance increases by 16-fold (= 2^4)!!!

(πr^4 = area)

- Pressures in the various portions of the circulation:
  - MAP in the aorta is high (100mgHg)
  - As blood flows through the systemic circulation, its mean pressure falls progressively to zero by the right atrium
  - Systemic capillaries:
    - **Arteriolar end 35 mmHg, venous end ~10mmHg**
    - A pressure low enough that little of the plasma leaks out of the porous capillaries
  - Pulmonary circulation:
    - Much lower pressure:
      - **Systolic 25mmHg**, diastolic 8
      - MAP 17mmHg
      - Yet **same volume of blood** must flow through
      - Lower pressure allows greater time for oxygen exchange at the alveolus

- **Systemic: 120/80 (100)**
- **Pulmonary: 25/8 (15)**

- BASIC THEORIES OF CIRCULATORY FUNCTION:
  - The blood flow to each tissue of the body is almost always precisely controlled in relation to tissue needs:
    - Active tissues may need up to 20-30 times the resting level of cardiac output
    - Heart can only normally increase output by 7 fold

        - Thus it is not possible to increase the blood flow everywhere in the body when a particular tissue demands increased flow
        - Microvessels continuously monitor tissue needs via:
            - Availability of oxygen
            - Accumulation of CO_2 and other waste products
            - These in turn act directly on local vessels
    - Cardiac output is controlled mainly by the sum of all local tissue flows.
    - In general, arterial pressure is controlled independently of either local blood flow control or cardiac output control:
        - For example, if pressure falls significantly, within seconds a barrage of nervous reflexes elicit a series of circulatory changes to raise the pressure back toward normal
        - The nervous signals increase the force of heart contraction, initiate contraction of venous reservoirs and facilitate generalised contraction of the arterioles, so more blood accumulates in the arterial tree
        - Kidneys play a role over prolonged control of BP

- RELATIONSHIPS BETWEEN PRESSURE, FLOW AND RESISTANCE:
    - Flow through a vessel is determined by two factors:
        - Pressure difference of the blood between the two ends of the vessel
        - The impediment to blood flow through the vessel (vascular resistance)
    - Flow through a vessel can be calculated according to **OHM'S LAW**:
        - **FLOW = CHANGE IN PRESSURE/RESISTANCE**
        - Essentially blood flow is directly proportional to the pressure difference but inversely proportional to the resistance
    - Blood flow means simply the quantity of blood that passes a given point in a given period of time
        - 5L/MIN
        - Blood flow also equates to cardiac output
- LAMINAR FLOW OF BLOOD IN VESSELS:
    - When blood flows at a steady rate through a long , smooth vessel, it flows in STREAMLINES, with each layer staying the same distance from the vessel wall
    - Opposite to turbulent flow, blood flowing in all directions and continually mixing within the vessel
    - When laminar flow occurs, the velocity of flow in the centre of the vessel is greater than that toward the outer edges
        - **PARABOLIC VELOCITY PROFILE**
        - Caused because molecules touching the vessel wall hardly move because of adherence to the wall, with progressively increasing slippage

- RESISTANCE TO BLOOD FLOW:
  - **Resistance is the impediment to blood flow in a vessel**
  - If the pressure difference between two points is 1mmHg and the flow is 1ml/sec, the resistance is said to be one peripheral resistance unit (PRU)
  - **TPR usually 1 PRU, but can increase to 4 PRU**
  - Pulmonary resistance generally 0.14 PRU (allows same flow of blood at much lower pressures.

- CONDUCTANCE:
  - **Conductance is a measure of the blood flow through a vessel for a given pressure difference**
  - Inversely proportional to resistance
  - **Conductance = 1/resistance**

- DIAMETER CHANGES AND CONDUCTANCE:
  - Slight changes in the diameter of a vessel changes the vessels ability to conduct blood tremendously
  - Roughly speaking, **conductance is proportional to diameter^4**

- POISEUILLE'S LAW:
  - In very small vessels, the central, very rapidly moving portion of blood DOES NOT occur as essentially all the blood is near the wall

  - **Poiseuilles's Law** states:
    - **Resistance = (8 x viscosity x length) / (Pi x radius power 4)**
    - Flow = pressure / resistance
    - Flow = Pi x **change in pressure x r^4** / 8 x **viscosity** x **length**
    - Blood flow is <u>directly proportional</u> to:
      - **The fourth power of the radius**
      - **Pressure**
    - <u>Inversely proportional</u> to
      - **Viscosity**
      - **Length of the vessel**

  - About **2/3 of the total systemic-arteriolar resistance is in the small arterioles**
    - Strong walls of arterioles allow large change in internal diameter and hence large change in blood flow across them
  - Also of note, the **greater the viscosity, the less the flow**
    - Hence, increased haematocrit (as in polycythaemia) can decrease flow
    - At normal haematocrit (0.40, i.e 40% of blood is cells), the viscosity of blood is 3 times that of water