**Circulatory / vascular System**

* **Aorta => artery => arteriole => capillary => venule => vein => vena cava**
  + End goal is capillary exchange
* **Microcirculation**: arterioles, capillaries, and venules; within organs
* Rest: digestive 27%, kidney 20%, brain 13%, muscles 15%
* Exercise: digestive 5%, kidney 4%, brain 13%, muscles 64%

**Blood flow**

* Text

  Description automatically generated**Flow rate**: volume of blood passing / time, pressure / resistance or velocity / area
  + **Pressure gradient**: towards lower pressure vessels
  + **Resistance**:
    - **Radius**:
      * Main determinant, vasodilation and vasoconstriction
    - Length:
    - Viscosity of blood: , viscosity primarily determined by # of RBCs

**Vessel Anatomy:**

* Tunica adventitia (**connective tissue**) > external elastic lamina (elastic fibre) > tunica media (**smooth muscle**) > internal elastic lamina > tunica intima (**endothelial**)
  + Arteries more muscles & very elastic
  + Arterioles more muscles & less elastic
  + Capillaries only endothelial
  + Veins have valves
* **Multi-unit smooth muscle**: smooth muscle => **not striated**, has **tone**, more **economic**
  + **Neurogenic**, contract only when stimulated
  + Act as **independent units** (single cell or motor units), few gap junctions
  + Various configurations:
    - **Sheets** (walls of blood vessels)
    - **Bundles** (iris)
    - **Single cell** (capsule of spleen)

**Arteries**

* 2 main functions:
  + **Rapid-transit**: large radius => little resistance
  + **Pressure reservoir**: many elastic fibers (balloon like), provides driving force for blood when heart is relaxing
* **Blood pressure**: depends on distensibility (stretchability), **pulsatile** from elasticity
  + **Systolic** (max ~**120** mmHg): only **1/3** blood entering arteries go to arterioles
  + **Diastolic** (min ~**80** mmHg): no blood entering arteries but still leaving
  + **Pulse pressure**: pressure difference (why you fell pulse),
  + **Mean arterial pressure**: average pressure, in systole,
    - Specifically, MAP = **cardiac output** (CO) \* **total peripheral resistance**
* **Diagram

  Description automatically generated**Diagram

  Description automatically generated with low confidence**Sphygmomanometer**: detect when Korotkoff (turbulent) sounds appear/disappear

**Arterioles**

* **Major resistance vessels** (much smaller radius)
  + Lowers pressure to maintain pressure gradient
  + Converts pulsatile pressure to **non-pulsatile** (not elastic)
* **Variable radius** (little elastic, thick smooth muscles)
  + Vary distribution of blood between organs
  + Text

    Description automatically generatedRegulates arterial pressure
* **Vasoconstriction** and **vasodilation**: SNS, chemical changes, hormone
  + ***Vascular tone****: baseline state of partial constriction*
  + ***Intrinsic*** *(local) control: chemical and physical*
    - ***Endothelial cells****: respond to chemical and physical changes, release local vasoactive mediators which act on smooth muscles*
      * ***Nitrate oxide*** *(NO): inhibit Ca, vasodilation*
      * ***Endothelin****: vasocontraction*
      * *Some are long term*
      * *Some triggers* ***angiogenesis*** *(new vessel growth)*
    - *Chemical triggers:*
      * *Local metabolic changes (alters local chemicals)*
        + ***Active hyperaemia****: dilation for cells metabolically active (acid (lactic, carbonic))*
      * ***Histamine*** *(not by endothelial) - vasodilation in injured area*
    - *Physical triggers:*
      * *Local change in* ***temperature*** *(clinical usage)*
        + *Heat – dilation, cold - contraction*
      * ***Shear****: friction of blood on endothelial cells => release NO*
      * ***Autoregulation*** *(Myogenic response): more blood => stretch => strength increase => contraction => less blood, vice versa*
        + ***Reactive hyperaemia****: dilation respond to blockage (chemical build up and no stretch)*
  + ***\*Extrinsic*** *(SNS) control: neural and hormonal*
    - *SNS* ***constrict*** *vessels except in brain (mostly local) for* ***pressure***
      * *Has a baseline tone (decrease SNS is dilation)*
      * *Direct distribution of blood while maintaining pressure*
        + *Actual dilation (skeletal/cardiac) is local (****override SNS****)*
    - ***Cardiovascular control centre*** *(medulla, same as for heart)*
    - *Hormones:*
      * ***Graphical user interface, text, application

        Description automatically generatedEpinephrine*** *(mostly ) &* ***norepinephrine*** *() reinforce SNS*
      * *Fluid control:*
        + ***Vasopressin*** *(ADH): maintain water balance by regulating urine formation (how much water kidney retain)*
        + *Angiotensin II: salt conservation during urine formation*
        + *Potent constrictors, essential in blood lose (need more water to increase plasma volume, constrict to maintain P)*

*Pulmonary Circulation*

* *Much* ***lower pressure*** *(lots of branching => high resistance)*
* *\*****Constricts with low and high , dilates with high and low*** 
  + *Allows blood to be directed to oxygen filled lung segments*
  + *Can cause High Altitude Pulmonary Edema*
* *Fetal circulation: lungs collapsed, constricting mechanism help bypass lung*

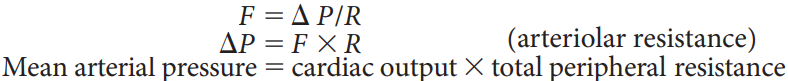
**Capillaries**

* Extensively **branched** vessels with **small radii**
  + Parallel connection with small radii minimizes resistance
  + Maximized **surface area**, minimize **resistance** and **diffusion distance**
  + **Low velocity** of flow (10 mm/s)
* Single layer of **endothelial** cells
* Surrounded by **precapillary sphincters**: rings of smooth muscle at beginning of vessel
  + Resting: many capillaries are closed
* **Metarterioles**: surrounded by smooth muscle and run between **arteriole** and **venules** (instead of capillary), no gas exchange occurs, shunt only for homeostatic regulation

**Veins**

* **Blood reservoir** / capacitance vessels, **volume control**
  + large radius, little resistance, low pressure
  + highly distensible with little elastic recoil (little elastic, many collagen)
* Venous capacitance: blood in veins
* Venous **valves**: around muscles in veins, prevent backflow & counter gravity
* *\*****Venous return****: blood entering each atrium per minute, 1/capacitance, 5 factors*
  + ***Vasoconstriction*** *(SNS): increase return => increase flow (opposite from artery)*
  + *Blood volume: more blood = more return*
  + *Skeletal muscle pump: muscle contraction constricts veins, counter gravity*
  + *Venous valves: around muscles in veins, prevent backflow & counter gravity*
    - *Varicose veins: incompetent valves, blood pool in veins*
  + *Respiratory pump: lowered chest pressure from breathing enhance return*
  + *Cardiac suction: ventricular contraction lower atrial pressure (+ return)*

**Regulating Blood Pressure**

* The blood pressure monitored and regulated in the body is **mean arterial pressure**
  + must be high enough to ensure sufficient driving pressure
  + must not be so high to creates extra work for the heart and increases the risk of vascular damage / rupture of small blood vessels
  + Short term (constrict vessels) vs long term (increase fluid, viscosity)
* **Baroreceptor reflex**: blood pressure regulation
  + Receptors: **carotid sinus** (on vessels to brain) and **aortic arch** (at start of aorta) baroreceptors detects mean arterial pressure and pulse pressure
    - Frequency of firing AP BP
  + Integrating centre: **cardiovascular control centre** (medulla)
    - Controls ratio between SNS and PNS
    - **Negative feedback**
* Other reflexes and responses:
  + Left atrial volume receptors: water and salt balance
  + Chemoreceptors (oxygen in arteries): increase respiratory activity & BP
  + Fight or flight: increase HR and BP
  + Exercising: increase HR, CO, BP; mostly constrict, dilate in skeletal muscles
  + Temperature regulation: dilation to eliminate heat
* A picture containing text, screenshot, sign, several

  Description automatically generated**\*Hypotension** (low BP, high BP is hypertension)
  + **Orthostatic hypotension**: insufficient compensatory response to gravity shift
    - Stand up => gravity => pool in veins / low return => low SV, CO, BP
    - Prolonged bed rest: reduced baroreceptor reflex, low blood volume => BP too low, dizziness / faint
  + **Circulatory shock**: BP too low, inadequate flow; 4 types
    - Hypovolemic (low-volume) shock: low blood volume (bleed/dehydration)
    - Cardiogenic (heart-produced) shock: heart too weak
    - Vasogenic (vessel-produced) shock: widespread dilation
      * Septic shock: dilation caused by infections (release chemicals)
      * Anaphylactic shock: dilation caused by histamine
    - **Diagram

      Description automatically generated**Neurogenic (nerve-produced) shock: SNS problem (deep pain can cause)

Timeline

Description automatically generated

Diagram

Description automatically generated

* Ex: haemorrhage
  + **Baroreceptor reflex** – SNS response – increase CO & R – increase BP
  + **Autotransfusion**: low BP cause some interstitial fluid to flow into capillaries
  + **Fluid** **control**– reduced urinary output – increases thirst – water salt balance
  + RBC reproduction