Lecture 17, Mar 23, 2023

Smooth Muscle

- Smooth muscle is usually found in organs that aren't "solid"
- Found in STOVE:
  - Skin (the muscles that make your hair stand up)
  - Tracts (e.g. gastrointestinal, respiratory, reproductive)
  - hollow Organs (e.g. bladder, uterus)
  - Vessels (e.g. aorta, arterioles, but not capillaries)
  - Eye (controlling iris)

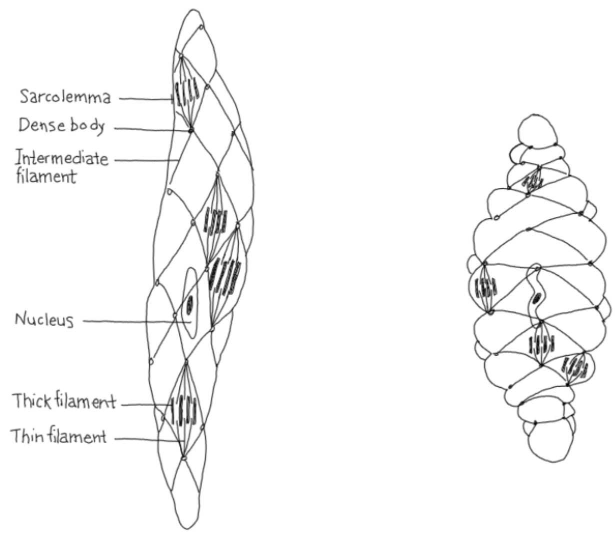

Figure 1: Structure of smooth muscle

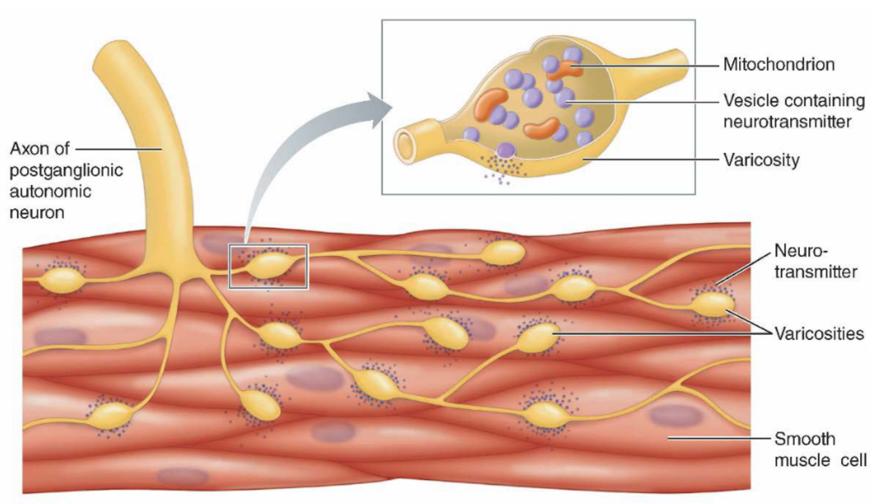

Figure 2: Innervation of smooth muscle

- Smooth muscle have a net-like structure connected by dense bodies; between all dense bodies are the thick and thin filaments (actin, myosin)
  - When smooth muscle contracts, the "net" squishes
- Smooth muscle is more flexible; generally very slow but efficient, and fatigues slowly

- Smooth muscles are innervated by the SNS and PNS; instead of a terminal junction, there are a network of varicosities
- Autonomic stimulation (neurotransmitters) change the availability of calcium ions in the cytosol of smooth muscle cells
- They have sufficient calcium levels to maintain a low level of tension, and are sensitive to neurotransmitters depending on the distribution of receptors

Characteristic	Smooth
Innervation	Autonomic nervous system
Initiation	Neurogenic & Myogenic
Role of nervous stimulation	Modifies contraction; Can excite or inhibit; Contributes to gradation
Gradation mainly accomplished via:	• Varying number of muscle fibres contracting • Varying cytosolic Ca2+ • Autonomic, hormonal, mechanical stretch, local metabolites
Modifying effect of hormones	Yes
Sarcoplasmic reticulum	Poorly developed
Source of increased cytosolic Ca^{2+}	Extracellular fluid; Sarcoplasmic reticulum
Presence of gap junctions	Yes

Figure 3: Characteristics of smooth muscle

Basic Structure of the Vascular System

- The aorta is the major systemic artery, which supplies blood to all the organs
  - Long, rigid, gets blood to where it needs to go
  - More of a conduit
- Veins have a much larger capacity; there is a reservoir where blood can pool as it returns
- Types of arteries:
  - Elastic arteries go from 3 cm in diameter to 250 microns
    - The structure makes it very flexible and elastic
  - Muscular arteries go from 100 to 40 microns
    - Less elastin, more smooth muscle (hence the name)
    - Smoot muscle dominates behavior
    - Can't stretch as much
  - Arterioles go from 40 to 10 microns
    - No elastin, only smooth muscle

Factors Effecting Arterioles

- Extrinsic factors (signals from the nervous system)
  - In the normal case, the blood vessel is slightly constricted
  - More sympathetic stimulation leads to more vasoconstriction, decreasing the diameter and leading to higher blood pressure
  - Less sympathetic stimulation leads to vasodilation, increasing the diameter
  - No parasympathetic innervation to arterioles
  - Different tissues have opposite responses to the SNS
    - All arteriolar smooth muscle (exception in the brain) all have $\alpha 1$ type receptors – they are excited by NE and constrict

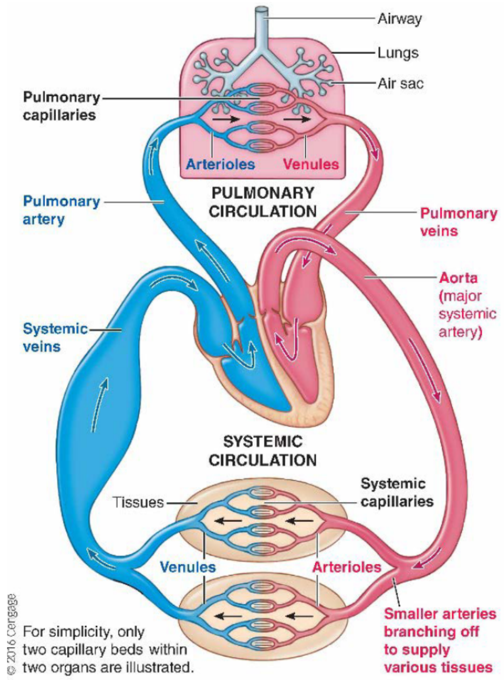

Figure 4: Basic structure of the cardiovascular system

  * However the arteriolar smooth muscle in the heart and skeletal muscle have $\beta 2$ receptors, which are more sensitive to E and are inhibited
  * Different types of receptors allow the SNS to either dilate or constrict

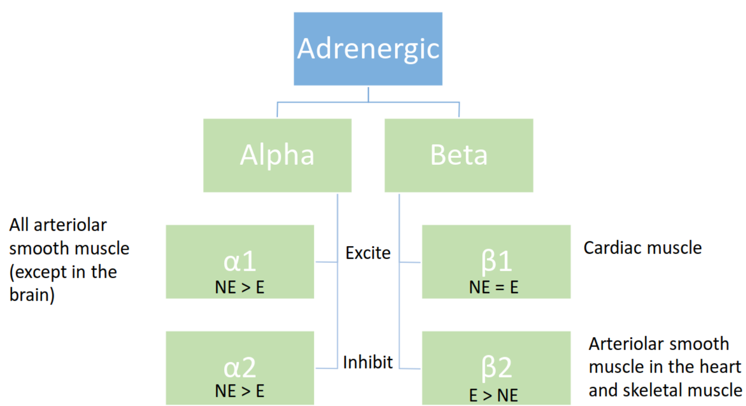

Figure 5: Types of receptors on smooth muscles

- Smooth muscles can myogenically contract due to intrinsic factors
  - More myogenic activity leads to more constricting
  - Less oxygen or more carbon dioxide leads to dilation; more oxygen or less carbon dioxide leads to constriction
    * More activity lowers the oxygen level in the blood; the vessels dilate to provide more oxygen to active muscles
  - The inner layer of cells around the vessel releases neurotransmitters that lead to myogenic behaviour
    * Endothelin leads to constriction, nitric oxide leads to dilation
    * e.g. beet juice contains nitric oxide, which dilates the vessels and increases muscle performance

- Stimulation from SNS leads to a global vasoconstriction effect, but local factors (depending on the muscle type or local muscle activity) will alter the local effects
  - e.g. during exercise, sympathetic stimulation causes constriction globally, but dilation to the exercising muscles; the lowered oxygen and increased carbon dioxide levels lead to vasodilation of exercising muscles
- Cold temperatures lead to constriction, hot temperatures lead to dilation
- Histamines released by the immune system also lead to dilation (helping the immune response)
  - This makes it possible to be allergic to the cold

Pressure and Flow Relationships in Vessels

- Hagen-Poiseuille equation: $\Delta P = Q\frac{8\eta L}{\pi r^4}$; ΔP is the pressure difference, Q is the flow, r is the vessel radius, L is the length, and η is the dynamic viscosity
  - $\frac{8\eta L}{\pi r^4}$ is referred to as the *total peripheral resistance* (TPR)
  - ΔP is the product of cardiac output (flow) and resistance
- $R \propto \frac{1}{r^4}$ so a small increase to the radius significantly lowers the resistance
  - Vessel radius can be effected by local metabolic control and extrinsic vasoconstrictor control (i.e. Sympathetic innervation)
- $R \propto \eta$ and viscosity can be effected by the number of red blood cells (e.g. dehydration leads to thicker blood, increasing resistance)

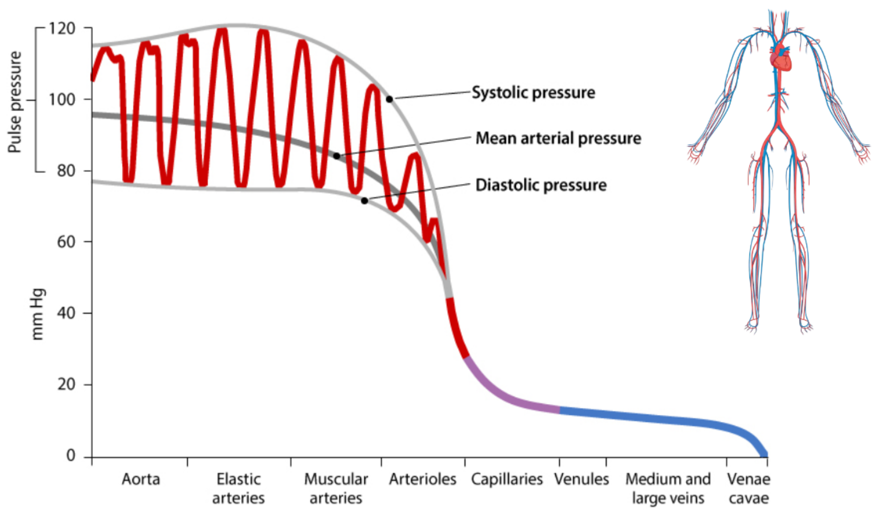

Figure 6: Blood pressure in different types of vessels

- The mean blood pressure is always lowering with smaller vessels; since pressure is the driving force for flow, the smaller vessels will have less flow
  - Pressure also fluctuate with every heart beat
  - The biggest pressure drop happens across the arterioles
  - Arterioles are called "resistance vessels" because of this, due to their inelasticity from only having smooth muscle
  - Barely any resistance happens on the venous side; only a small pressure changes happen in the arteries before arterioles
- The mean arterial pressure (MAP) is the average between the systole and diastole pressures
  - Since diastole occurs for much longer, the diastolic pressure has about twice the weight as the systolic pressure
  - $MAP \approx DBP + \frac{1}{3}PP$ where DBP is the diastolic blood pressure and PP is the pulse pressure

(difference between the 2)

– However with increased heart rate diastole shortens first (before systole shortens), so the weights can change

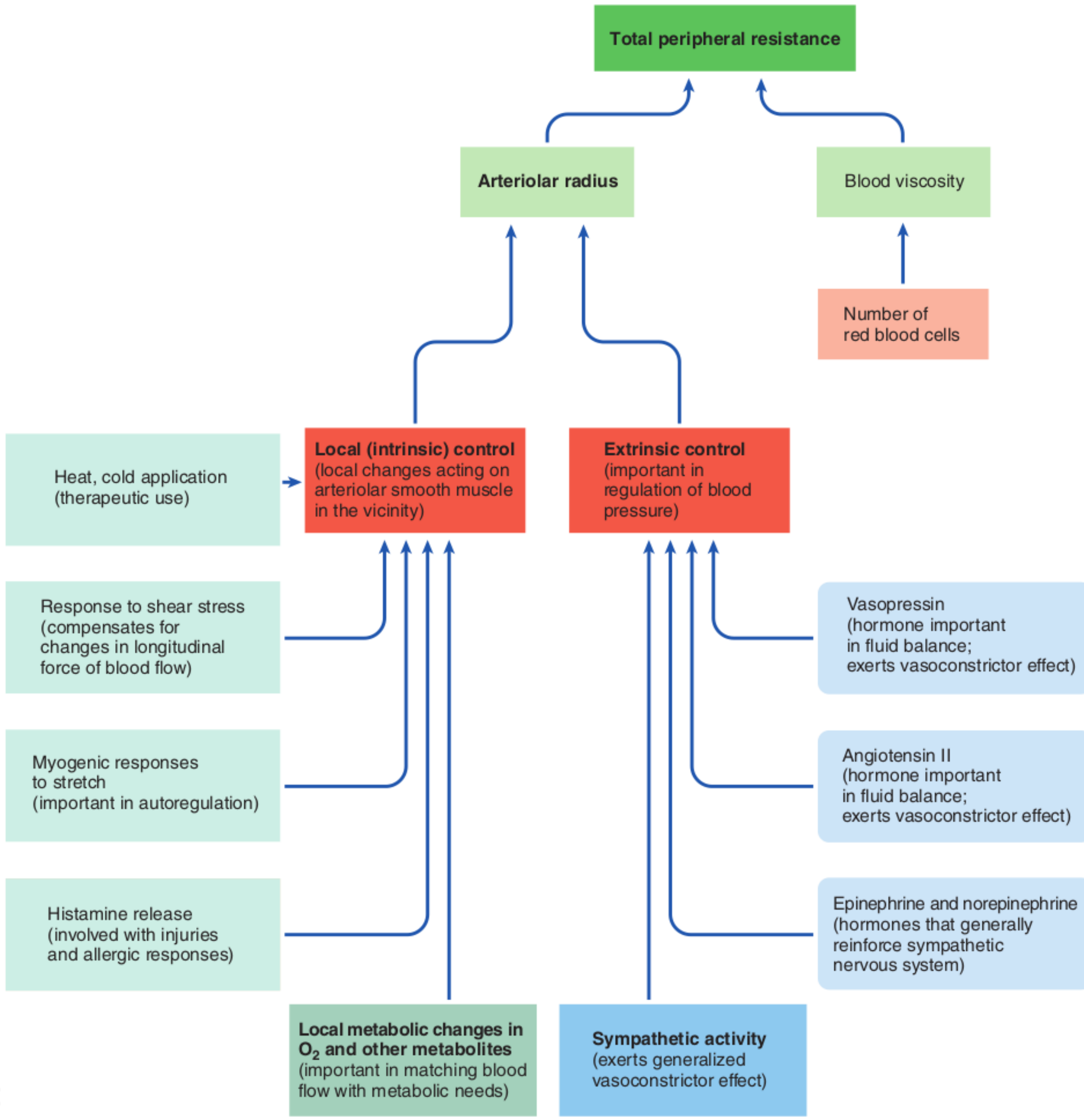

Figure 7: Summary of factors affecting total peripheral resistance