Blood Vessels & Circulation

Blood flows in a closed system of vessels.
Over 60,000 miles of vessels (mainly capillaries)

**arteries → capillaries → veins**
(25%) (5%) (70%)

**arteries & arterioles**
- Take blood away from heart to capillaries

**capillaries**
- Actual site of exchange

**venules & veins**
- Bring blood from capillaries back to heart

Arranged in two circuits:

**pulmonary:** heart → lungs → heart
  rt ventricle → pulmonary arteries (trunk) → lungs → pulmonary veins → left atrium

**systemic:** heart → rest of body → heart
  left ventricle → aorta → body → vena cava → rt atrium

Heart is a double pump

**Physiology of Blood Vessels**

**Arteries**
- Contain ~ 15% of all blood
- Pressure is variable
  - MAP ~ 93 varies from 100 – 40 mmHg
- Most organs receive blood from >1 arterial branch provides alternate pathways

  vasa vasorum = blood vessels within walls of large arteries
  sympathetic innervation

**Arterioles**
- ~ 10% of all blood
- Average pressure ~ 40 – 25 mmHg
- Pressure decreases drastically in arterioles
  → Most resistance is here
  → ~ 1/2 of whole system
- Muscle tissue makes up major bulk of walls
- Innervated by vasomotor nerve fibers of autonomic NS
- Major role in controlling the distribution of blood in body
sympathetic stimulation $\rightarrow$ vasoconstriction

**Veins & Venules**

60% of all blood is in veins

$\sim$10% in venules

low pressure:

- 12 – 8 mmHg venules
- 6 – 1 mmHg veins
- larger veins near 0

large veins also contain vasa vasorum

$\rightarrow$ blood vessels in walls with sympathetic nerve innervation

major factor moving blood through arteries and arterioles is **pulse pressure** of the heart

movement of blood in veins is not pressure driven by the heart

venous blood flows due to:

1. **constriction of walls by ANS**
   minor effect
   muscle layer is very thin,
   veins are very compliant

2. **1-way valves**
   prevent backflow
   most abundant in veins of limbs

   quiet standing can cause blood to pool in veins
   and may cause **fainting**

   **varicose veins:** "incompetent" valves
   esp. superficial veins
   may be due to
   heredity
   prolonged standing
   obesity
   pregnancy
   increased venous pressure

   **hemorrhoids:**
   varicosities of anal veins
   due to excessive pressure from birthing or bowel movements

3. **venous pumps**

   **muscular pump** (=skeletal muscle pump)
during contraction veins running thru muscle are compressed and force blood in one direction (toward heart)

**respiratory pump**

inspiration:

- intrapleural pressure falls from $-2.5$ mm Hg to $-6$ mmHg while abdominal pressure increases
- creates pressure gradient in Inferior Vena Cava to move blood toward heart

expiration:

- increasing pressure in chest cavity forces thoracic blood toward heart

veins function to collect blood and act as blood reservoirs

- with large lumens and thin walls they can accommodate relatively large volumes of blood
- 60-70% of all blood is in veins at any time

largest veins = **sinuses**

eg. coronary sinus, dural sinus

blood “stored” in venous sinuses can be used as a **self transfusion** when stimulated in an emergency

most organs are drained by >1 venous branch

- even more common than alternate arterial pathways

- occlusion of veins rarely blocks blood flow

removal of veins during bypass surgery usually not traumatic

**Capillaries**

- actual site of exchange of materials
  - the rest is pumps and plumbing
- most of 62,000 miles of vessels
- usually no cell >.1 mm away from a capillary
- each capillary <1mm long
- but only contains ~5% of blood in body
- variable pressure 35 – 15 mm Hg;
  - ave=25-12 mmHg
- thin walled - single cell layer thick
- extremely abundant in almost every tissue of body

Factors important in capillary function:

**1. Density**
2. Ease of exchange of materials
3. Velocity of blood flow

1. **density** of capillaries varies with metabolic rate
   - eg. cartilage, epithelial tissue and cornea have no capillaries
   - eg. tendons and ligaments are poorly vascularized
   - eg. muscle, liver, lungs, kidneys have rich blood supply
     - eg. 1 inch$^3$ of muscle = 1.5 million capillaries

2. **types of capillary structure:**
   - affects the rate of exchange in tissues
   - most materials pass to tissues by **diffusion**:
     - fat soluble, CO2, O2 go through cell membrane
     - ions and small molecules go through pores (passive ion channels)
     - large molecules pass by **exocytosis**

   a. **continuous**
     - lining is uninterrupted
     - adjacent cells joined by tight junctions
     - but with intracellular clefts to allow passage of fluids and small solute
     - most common type
       - eg. skin, muscles, lungs, adipose

   (b.) **blood-brain barrier**
     - specialized kind of structure
     - capillary walls are continuous but with no clefts
     - are surrounded by astrocytes
     - passage of materials is very restricted

   c. **fenestrated**
     - similar to above but some cells are riddled with pores
     - much greater permeability
     - eg. kidneys, endocrine glands, intestinal mucosa

   d. **sinusoidal (discontinuous)**
     - highly modified “leaky” capillaries
     - large clefts and fenestrae
     - allows large molecules and cells to pass
     - eg. bone marrow, liver, spleen

3. **Velocity of blood flow**
   - blood flows slowest in capillaries
   - due to greater **cross-sectional area** of all capillaries
combined:
→ 600 – 1000 x’s cs of aorta

provides greatest opportunity for exchange to occur

**Capillary Beds**

functional groupings of capillaries = **capillary beds** → functional units of circulatory system

arterioles and venules are joined directly by **metarterioles** (=thoroughfare channels)

capillaries branch from metarterioles
1-100/bed

cuff of smooth muscle surrounds origin of capillary branches = **precapillary sphincter**

amount of blood entering a bed is regulated by:
  a. vasomotor nerve fibers
  b. local chemical conditions
Vasomotor Control System

circulation involves **differential distribution** of blood to various body regions
active body parts receive more blood than inactive parts
blood volume must be shifted to parts as they become more active
blood circulates because of **pressure gradients**

pressure gradients are created through

- **cardiac output**
- **peripheral resistance**

the greatest peripheral resistance is found in the **arterioles**

\[
\begin{align*}
85 & \text{ at beginning} \\
35 & \text{ at end}
\end{align*}
\]

50 mmHg difference

individual arterioles can increase or decrease their resistance to blood low by constricting or dilating

mediated by autonomic nervous system

**vasomotor control center** in medulla

works in conjunction with cardiac centers

mainly sympathetic control

both arteries and veins can dilate

vasomotor control system can also shift blood to or from **blood reservoirs** in veins as needed:

- large veins
- sinuses
- skin
- liver
- spleen

control center receives sensory input from:

1. **baroreceptors** in
   - carotid sinus
   - aortic arch

→ stretch inhibits VMC → vasodilation
2. **chemoreceptors**
   in aortic arch and carotid sinus
   monitor oxygen and pH
   these receptors also help to control respiration
   lower pH or O2 $\rightarrow$ vasoconstriction

cerebral cortex and hypothalamus can affect VMC
   eg. hypothalamus  fight or flight $\rightarrow$ vasoconstriction
   eg. cerebral cortex  emotions

**Local Regulation of Blood Distribution**

in addition to vasomotor reflex, local regulation of specific arterioles can also
direct blood to organs needing it most

individual tissues can control the amount of blood they receive through some **autoregulation** (=intrinsic controls)

largely independent of systemic factors (VMC) noted above

Autoregulation involves:

1. **Myogenic controls**
2. **Metabolic controls**

1. **Myogenic controls**
   inadequate blood flow to an organ can cause cell damage or death
too much blood flow may rupture fragile vessels
the physical effects of blood flowing to an organ
causes direct local stimulation of its vascular tissue:

   passive stretch $\rightarrow$ triggers constriction
   $\rightarrow$ higher local BP
   $\rightarrow$ slows blood flow to tissue

   reduced stretch $\rightarrow$ triggers dilation
   $\rightarrow$ reduces local BP
   $\rightarrow$ increases blood flow to tissue

2. **Metabolic controls**
   changes in the concentrations of specific nutrients or waste products can
cause vasodilation and relaxation of precapillary sphincters in
affected tissues
   eg. reduction in esp O$_2$
   eg. increases in potassium
eg. increase in Hydrogen ions (lower pH), lactic acid

**Angiogenesis**

if short term changes cannot supply adequate oxygen or nutrients
the body can respond by increasing the number of blood vessels
supplying the area

the number of blood vessels to a high demand area will increase

eg. heart with occluded vessels grows new ones

eg. people at high altitudes have greater number of vessels in
tissues throughout their bodies