Blood Vessels & Circulation

blood flows in 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 → vasoconstriction

Veins & Venules

60% of all blood is in veins
~10% in venules
low pressure:
- 12 – 8 mmHg venules
- 6 – 1 mmHg veins
- larger veins near 0

large veins also contain vasa vasorum
→ 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**
- 85 at beginning
- 35 at end

} 50 mmHg difference

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

mediated by autonomic nervous sytem

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 → vasoconstriction

cerebral cortex and hypothalamus can affect VMC
eg. hypothalamus
fight or flight → vasoconstriction
eg. cerebral cortex
emotions

<u>Local Regulation of Blood Distribution</u>

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 → triggers constriction
→ higher local BP
→ slows blood flow to tissue

reduced stretch → triggers dilation
→ reduces local BP
→ 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