Chapter 13 Blood Vessels and Circulation
I. **Peripheral Circulation:**
   excludes heart

1. **Systemic:** to body
   (LV=>RA)

2. **Pulmonary:** to lungs
   (RV=>LA)
II. **Function**: transport; immunity; pressure; 1-way flow
Blood vessels

**VEIN**
- Adventitia
- Muscularis (tunica media)
- Intima
- Valve
- Endothelium (tunica interna)

**ARTERY**
- Adventitia
- Muscularis (tunica media)
- Elastic lamina
- Intima
- Endothelium (tunica interna)

**ARTERIOLE AND CAPILLARY**
- Arteriole
- Capillary
- Precapillary sphincters (smooth muscle cells)

**HEART TISSUE**
- Fatty connective tissue
- Coronary artery and vein
- Pericardium
- Pericardial space
- Epicardium
- Myocardium
- Endocardium
III. Features: Arteries (away) to Arteries to Veins (toward)

A. Vessel Wall Layers (Tunica):

1. T. adventitia-outer CTissue
2. T. media-middle SMuscle
3. T. intima-inner Endothelium
B. Arteries:

1. Elastic Arteries:
   - large; mainly elastic fibers w/↓ SM (aorta)
   - Elastic recoil helps maintain BP
2. **Muscular Arteries**: med/sm; more S muscle

This picture shows a diagrammatic representation of a muscular artery.
a) Distributing - control flow w/ $\uparrow$ S muscle

- **Vasoconstriction**: contracts $\downarrow$ diameter = $\uparrow$ frictn $\downarrow$ flow
- **Vasodilatation**: relaxes $\uparrow$ diameter = $\downarrow$ frictn $\uparrow$ flow
b) Arterioles: smallest w/3 layers (S mscl)
C. Capillaries: flat endothelium/1 cell thick

1. Branching network:
   - Precapillary sphincter: sm mscl/regulate flow

2. 1 RBC at a time (↑matri exchg)

3. ↑ Lngs, livr, kidys, Sk mscl

Figure 23-23 Capillary bed. Precapillary sphincters control the flow of blood through the capillary network. Thoroughfare channels (i.e., arteriovenous shunts) allow blood to move directly from the arteriole into the venule without moving through nutrient channels of the capillary.
D. Veins:
1. Venules: endothelium (slightly larger)
2. Small veins: sm muscle
3. Med Veins: w/valves (folded intima); ↑lower limb
Blood Vessels
<table>
<thead>
<tr>
<th>Structure</th>
<th>Mean Diameter</th>
<th>Mean Intimal Thickness</th>
<th>Endothelium</th>
<th>Elastic Tissue</th>
<th>Smooth Muscle</th>
<th>Fibrous Tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artery</td>
<td>4.0 mm</td>
<td>1.0 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arteriole</td>
<td>30.0 μm</td>
<td>6.0 μm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capillary</td>
<td>8.0 μm</td>
<td>0.5 μm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venule</td>
<td>20.0 μm</td>
<td>1.0 μm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vein</td>
<td>5.0 mm</td>
<td>0.5 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IV. Physiology of Circulation: blood flow to tissues

A. Blood pressure = force against vessel walls
   - Cyclic: max = LV systole/min = LV diastole
1. **Auscultatory Method**: body sounds to find BP
   a) Sphygmomanometer (BP cuff) & stethoscope
      - Measured at brachial artery
   b) **Korotkoff sounds**: 1st systole/2nd diastole
B. **BP/Resistance:** \( \downarrow \text{dia} = \uparrow \text{resist} = \downarrow \text{flow} (\downarrow \text{BP}) \\
1. Rapid decline in arteries \\
2. Large vein size = Lo resistance + valves + Sk M compression moves bld back to heart

---

**Changing Parameters in the Circulation**

A comparison of total vascular components (not of individual blood vessels).

**Capillaries** have the greatest cross-sectional area, and as a result, the lowest velocity. Both facilitate transport.

4. **Hypertension** (Hi BP): > 140/90; 20% of pop
   - ↑ Workload: enlarged LV = heart failure
   - **Arteriosclerosis** = BV may rupture
   - Treat: dilate BV w/Nitro; ↑ urine w/diuretic, ↓ salt intake
C. Pulse pressure

- Difference btwn systolic/diastolic: $120 - 80 = 40$
- $\uparrow$ W/ exercise (stroke volume $\uparrow$ systolic more)
- Arteriosclerosis (less elasticity): $\uparrow$ systolic pressure (same amt bld less elastic vessel= hrt works harder)
- **Pulse**: aortic presssure wave: lg surface arteries
D. Capillary exchange (billions in body)

➢ Initial net flow out w/bp; then in w/osmosis

1. At the arterial end of the capillary, the movement of fluid out of the capillary due to blood pressure is greater than the movement of fluid into the capillary due to osmosis.

2. At the venous end of the capillary, the movement of fluid into the capillary due to osmosis is greater than the movement of fluid out of the capillary due to blood pressure.

3. Approximately nine-tenths of the fluid that leaves the capillary at its arterial end reenters the capillary at its venous end. About one-tenth of the fluid passes into the lymphatic capillaries.
V. **Local BV Control**: metabolic tissue needs

1. **Precapillary sphincters** (SMus relax/contract)

   - ↑ Bld flow w/ ↓ O₂/↓ nutrients (glucose)/↓ pH/↑ CO₂

![Arteriovenous Anastomosis](image_url)
B. **Nervous BV Control**

1. **Vasomotor center**: Medulla O.
   - Continual sympathetic AP to BV (AP frequency => BV size)

2. **Vasomotor tone** = slight constricted state (↑ or ↓ w/need)
   - Exer: ↑ skin BV tone + ↓ SkMscl tone = ↑ bld to mscl
   - All BV except capillaries/sphincters

---

*Figure 13.26 Nervous Regulation of Blood Vessels*

Most arteries and veins are innervated by sympathetic nerve fibers. The vasomotor center within the medulla oblongata regulates the frequency of action potentials in nerve fibers that innervate blood vessels. In most blood vessels, increased action potential frequencies cause vasoconstriction, and decreased action potential frequencies cause vasodilation.
Blood Distribution at Rest and With Exercise

The brain maintains constant flow under all conditions.

Muscles experience exercise hyperemia, a 10 X increase in perfusion during exercise.

The skin needs more blood for thermoregulation.

Kidney and GI function are significantly reduced during strenuous exercise.

Total blood flow at rest 5,800 ml/min

Brain: 750
Heart: 250
Skeletal muscle: 1200
Skin: 500
Kidney: 1100
Abdomen: 1400
Other: 600

Total blood flow during strenuous exercise 17,500 ml/min

© BENJAMIN/CUMMINGS
VI. Regulation of Arterial Pressure

A. Mean Arterial Pressure (MAP) = CO (HR X SV) X PR

1. Cardiac output x peripheral resistance
2. Slightly less than ave of BP
3. Change w/body needs

- Hemorrhage (↓ BP) = ↑ HR, SV & PR so ↑ BP
B. Baroreceptor reflex: large artery stretch

- Short-term/quick medullary response w/sudden BP change
- Stand too quick: ↓BP = ↓AP to Moblgta = ↑symp.
Baroreceptors in the carotid arteries and aorta detect an increase in blood pressure.

The cardio regulatory center and the vasomotor center in the brain alter activity of the heart and blood vessels (baroreceptor reflex), and the adrenal medulla decreases secretion of epinephrine.

Heart rate and stroke volume decrease; blood vessels dilate.

Blood pressure increases:
**Homeostasis Disturbed**

Baroreceptors in the carotid arteries and aorta detect a decrease in blood pressure.

The cardio regulatory center and the vasomotor center in the brain alter activity of the heart and blood vessels (baroreceptor reflex), and the adrenal medulla increases secretion of epinephrine (adrenal medullary mechanism).

Blood pressure decreases: **Homeostasis Disturbed**

Blood pressure decreases: **Homeostasis Restored**

Blood pressure increases: **Homeostasis Restored**

**Homeostasis Figure 13.28** Baroreceptor Effects on Blood Pressure
C. Chemoreceptor reflex: aortic/carotid bodies

- Short-term medullary response to levels of $O_2$, $CO_2$, pH
- Also emergency situations w/$\downarrow O_2 = \downarrow$ para/$\uparrow$ sym

1. Chemoreceptors in the carotid and aortic bodies monitor blood $O_2$, $CO_2$, and pH.
2. Chemoreceptors in the medulla oblongata monitor blood $CO_2$ and pH.
3. Decreased blood $O_2$, increased $CO_2$, and decreased pH decrease parasympathetic stimulation of the heart, which increases the heart rate.
4. Decreased blood $O_2$, increased $CO_2$, and decreased pH increase sympathetic stimulation of the heart, which increases the heart rate and stroke volume.
5. Decreased blood $O_2$, increased $CO_2$, and decreased pH increase sympathetic stimulation of blood vessels, which increases vasoconstriction.

PROCESS Figure 13.29 Chemoreceptor Reflex Mechanisms
The chemoreceptor reflex helps control blood pressure.
D. Hormonal Mechanisms:
- Long-term gradual control to small changes

1. **Adrenal Medullary**
   - epinephrine (adrenaline) \( \uparrow \) bld to SkMscl (w/exer)
2. **Renin-Angiotensin-Aldosterone:**

- W/lo BP affects kidney: constricts BV & reduce urine

1. The kidneys detect decreased blood pressure, resulting in increased renin secretion.

2. Renin converts angiotensinogen, a protein secreted from the liver, to angiotensin I.

3. Angiotensin-converting enzyme in the lungs converts angiotensin I to angiotensin II.

4. Angiotensin II is a potent vasoconstrictor, resulting in increased blood pressure.

5. Angiotensin II stimulates the adrenal cortex to secrete aldosterone.

6. Aldosterone acts on the kidneys to increase Na⁺ reabsorption. As a result, urine volume decreases and blood volume increases, resulting in increased blood pressure.

**PROCESS Figure 13.31** Hormonal Regulation: Renin-Angiotensin-Aldosterone Mechanism
3. **Antidiuretic Hormone-ADH** (vasopressin): pituitary gland

- W/lo BP affects kidney H₂O reabsrptn =↓ urine/ ↑ bld vol
4. **Atrial Natriuretic – RAtrium (opposite of Renin Mech)**

- w/↑BP affects kidneys to ↑Na loss/↑urine output = ↓ bld vol

**Atrial natriuretic mechanism:**
Cardiac muscle cells detect increased atrial blood pressure; secretion of atrial natriuretic hormone increases.

**Renin-angiotensin-aldosterone mechanism:**
The kidneys detect increased blood pressure; production of angiotensin II and secretion of aldosterone from the adrenal cortex decrease.

**Blood pressure increases:** *Homeostasis Disturbed*

**Blood pressure decreases:** *Homeostasis Disturbed*

**Renin-angiotensin-aldosterone mechanism:**
The kidneys detect decreased blood pressure; production of angiotensin II and secretion of aldosterone from the adrenal cortex increase.

**ADH (vasopressin) mechanism:**
Baroreceptors detect decreased blood pressure, resulting in decreased stimulation of the hypothalamus and increased ADH secretion by the posterior pituitary.

**Vasodilation decreases peripheral resistance to blood flow. More Na⁺ and water are lost in the urine, decreasing blood volume.**

**Vasoconstriction increases peripheral resistance to blood flow. Less Na⁺ and water are lost in the urine, increasing blood volume.**

*Homeostasis Figure 13.33  Long-Term Control of Blood Pressure*
Coronary Artery Disease

A normal coronary artery, unaffected by atherosclerosis. Note the clear open lumen, smooth endothelium, and normal dense tunica media.

This coronary artery has narrowing of the lumen due to build up of atherosclerotic plaque (1). Severe narrowing can lead to angina, ischemia, and infarction. Disruption of the endothelium can also trigger thrombosis formation.

There is a severe degree of narrowing in this coronary artery. It is "complex" in that there is a large area of calcification (2) on the lower right, which appears bluish on this H&E stain. Complex atheroma have calcification, thrombosis, or hemorrhage, which would make coronary angioplasty difficult.

This patient underwent coronary artery bypass grafting with autogenous ('derived from oneself', the saphenous vein) vein grafts. The largest of these (1) runs down the center of the heart to anastomose distally with the left anterior descending artery (anterior interventricular). Another graft (2) extends in a "Y" fashion just to the right of this to branches of the circumflex artery. A white temporary pacing wire (3) extends from the mid left surface.
VII. Aging of Arteries: less elastic

1. **Arteriosclerosis**: arteries harden
   - **Atherosclerosis**: plaque formation
   ∨ Exer/diet (fat/chol)/smkg/obesity/genes
   ∨ Resist bld flow: attract platelets=clotting