Ch 14:

14.1 Cardiac Output

14.2 Blood Volume

14.6 Blood pressure

14.7 Hypertension and Shock
SLOs

- Describe the extrinsic regulation of HR and contractility
- Explain the Frank-Starling Law of the heart
- Explain cardiac output as a measure of cardiac performance
- Explain why velocity of blood flow is fastest in arteries and slowest in caps.
- Explain how colloid osmotic P (π) and hydrostatic P lead to net filtration at the arterial end of a capillary and net absorption at the venous end.
- Describe how the lymphatic system interacts with the cv system.
- Explain blood pressure and the factors that determine it.
- Define all terms in the following mathematical relationships and explain why these relationships are valid:
  - Pulse pressure = systolic pressure – diastolic pressure
  - MAP = diastolic P + 1/3(systolic P – diastolic P)
- Diagram the baroreceptor reflex and explain orthostatic hypotension
14.1: Cardiac Output (CO) – a Measure of Cardiac Performance

\[ \text{CO} = \text{HR} \times \text{SV} \]

calculate for average person!

**HR** controlled by ANS

1. parasympathetic influence ?
2. sympathetic influence ?
3. without ANS, SA node fires 90-100x/min

ANS activity when resting HR goes up (e.g. during exercise)?
Effects of ANS on the SA Node

Fig 14-1
Stroke Volume (SV)

= Ventricular blood volume pumped in one contraction

= mL / beat

= EDV - ESV

For average person:

SV = EDV - ESV

70 mL = 135 mL - 65 mL
Force of contraction (contractility)

Length of cardiac muscle fibers (varies according to EDV)

\[ \text{CO} = \text{HR} \times \text{SV} \]

Stroke Volume Influenced by Multiple Factors
Length-Force Relationship in Heart

Starling Law: SV↑ if EDV↑

Graph question: What is the maximum stroke volume achieved in this experiment? At what end-diastolic volume is maximum stroke volume first achieved?
1. **Foxglove for a Failing Heart**

1. **Cardiac glycosides from *Digitalis purpurea***

\[ \downarrow \]

**digitoxin**

2. Highly toxic in large dosage: destroys all Na\(^+\)/K\(^+\) pumps

3. In low dosage: partial block of Na\(^+\) removal from myocardial cells

Your book is incorrect with this

Make flow chart to explain mechanism of action!
14.2: Blood Volume

2/3 of body water is found
____________________.

Osmotic forces control the movement of water between the interstitial spaces and the capillaries.

Urine formation and water intake (drinking) also play a role in blood volume.
Exchange of Fluid Between Capillaries and Tissue

- Capillaries anatomically designed for exchange

- Capillary blood flow: Large cross sectional area ⇒ Velocity?

- Most cells within ____ µm of capillary – why?

- Direct correlation between # of caps and metabolic needs of tissue
Distribution of fluid across walls of a capillary

\[
\begin{align*}
(P_c + \pi_i) - (P_i + \pi_p) \\
(\text{Fluid out}) & - (\text{Fluid in})
\end{align*}
\]

Arterial end of capillary  Venous end of capillary

\[
\begin{align*}
(37 + 0) - (1 + 25) &= 11 \text{ mmHg} \\
(17 + 0) - (1 + 25) &= -9 \text{ mmHg}
\end{align*}
\]

Net filtration Net absorption

Where \(P_c\) = hydrostatic pressure in the capillary  
\(\pi_i\) = colloid osmotic pressure of interstitial fluid  
\(P_i\) = hydrostatic pressure of interstitial fluid  
\(\pi_p\) = colloid osmotic pressure of blood plasma
Two Forces Regulate Capillary Bulk Flow

**Hydrostatic P**: lateral component of fluid flow

**Colloid Osmotic P**: Due to osmotic P created by ________________.

*In capillary bed:*

Net filtration at ________________ end

Net re-absorption at ________________ end
Fluid Exchange

Numbers slightly different from Fox. Don’t pay attention to this!

(b) Filtration in systemic capillaries

Net pressure = hydrostatic pressure ($P_H$) – colloid osmotic pressure ($\pi$)

$P_H = 32 \text{ mm Hg}$
$\pi = 25 \text{ mm Hg}$

Net filtration

$P_H > \pi$

Net absorption

$P_H < \pi$

$P_H = 15 \text{ mm Hg}$
$\pi = 25 \text{ mm Hg}$

7200 L/day

Net flow out = 3 L/day
Lymphatic System

Close **functional** association with three other systems

1.

2.

3.
Edema

Due to disruption of capillary exchange

2 major causes:

1. Blockage of lymph drainage
   A. Cancer & fibrotic growth
   B. Pathogens

Wuchereria bancrofti, the nematode that causes lymphatic filariasis, also known as ______________.
Edema cont.

2. Capillary filtration > absorption
   A. Increased venous pressure \textit{due to} ________
      
      ________
      
      ________
   
   B. Decreased Plasma protein concentration \textit{due to} ________
      
      ________
      
      severe malnutrition (Kwashiorkor)
Right or Left Heart Failure?

a) Right
b) Left

Alveolar Flooding
14.6 Blood Pressure

Pressure created by ventricular contraction is driving force for blood flow

Pulsatile blood flow in arteries → Elastic arteries expand and recoil for continuous blood flow

Pulse wave disappears past arterioles
Pressure Differences in Different Parts of Systemic Circulation

![Graph showing pressure differences in different parts of the systemic circulation.](image)
What influences Blood Pressure?

- **Blood volume**
  - determined by
    - Fluid intake
    - Fluid loss
      - may be
        - Passive
        - Regulated at kidneys

- **Effectiveness of the heart as a pump (cardiac output)**
  - determined by

- **Resistance of the system to blood flow**
  - determined by

- **Relative distribution of blood between arterial and venous blood vessels**
  - determined by
Baroreceptor Reflex

Blood pressure

Firing of baroreceptors in carotid arteries and aorta

Sensory neurons

Cardiovascular control center in medulla oblongata

Sympathetic output

- Less NE released

- \( \alpha \) receptor

- Arteriolar smooth muscle

- Vasodilation

- Peripheral resistance

Parasympathetic output

- More ACh on muscarinic receptor

- \( \beta_1 \) receptor

- Ventricular myocardium

- Force of contraction

- Cardiac output

- SA node

- Heart rate

- Blood pressure

Negative feedback

KEY
- Stimulus
- Receptor
- Afferent pathway
- Integrating center
- Efferent pathway
- Effector
- Tissue response
- Systemic response
Blood Pressure Regulation via Baroreceptor Reflex

= 1º homeostatic control for BP

Baroreceptors = _______ receptors in _______ and _______ artery

Medullary vasomotor control center integrates neural control
Clinical Application: Orthostatic Hypotension

Aka postural hypotension

Baroreceptor reflex fails in

- Patients with extended bed rest
- Astronauts
- Dehydration
- Medication (beta blockers)
- Postbrandial hypotension in elderly
Assessing Postural Hypotension

After measuring the blood pressure (BP) and pulse (P) in the supine position, leave the blood pressure cuff in place and assist the person in sitting. Remeasure the blood pressure within 15 to 30 seconds. Assist the person in standing, and measure again. A drop of more than 20 mm Hg systolic and more than 10 mm Hg diastolic accompanied by a 10%-20% increase in heart rate (pulse) indicates postural hypotension. Sample measurements are given. (From Black JM, Hawks JH, Keene AM: Medical-surgical nursing: clinical management for positive outcomes, ed 9, St Louis, 2015, Elsevier.)

FIGURE 12-15 Assessing postural hypotension.
Measurement of BP: Sphygmomanometry

Auscultation of ________________________artery with stethoscope in
______________________________

Based on effects of laminar flow vs. turbulent flow
Principles of Sphygmomanometry

Cuff inflated until brachial artery compressed and blood flow stopped \[\Rightarrow\] *kind of sound?*

Compare to Fig 14-30
Slowly release pressure in cuff:

Cuff pressure between 80 and 120 mm Hg

turbulent flow through compressed artery sets up vibrations that are heard as Korotkoff sounds.
Pressures at which . . .

. . . sound (= blood flow) first heard:
. . . sound disappeared:
Ventricular pressure difficult to measure ⇒ measure arterial BP

BP highest in arteries – falls continuously throughout systemic circulation

Read as “Systolic over diastolic”– normal value = or < _________________

2003: “Prehypertension” for readings between 120/80 and 139/89

Diastolic pressure in ventricle: _______ mm Hg
Mean Arterial Pressure

Sometimes useful to have single value for driving pressure: **Mean Arterial Pressure**

**MAP = Diastolic P + 1/3 Pulse Pressure** (for 60 - 80 bpm)

**Pulse Pressure = ?**

MAP for 120/80 = ?

MAP closer to diastolic pressure – why?
BP too low:

-⇒ Driving force for blood flow unable to overcome gravity
-⇒ $O_2$ supply to brain ____?
- Symptoms?
Circulatory Shock

Shock = generalized circulatory failure

- **Hypovolemic** shock $\rightarrow$ volume loss (dehydration, blood loss, burns)
- **Distributive** shock $\rightarrow$ loss of vascular tone (anaphylactic, septic, toxic)
- **Cardiogenic** shock $\rightarrow$ ________________
- Dissociative shock $\rightarrow$ inability of RBC to deliver $O_2$ (CO poisoning)

Cardiac Output ____? Peripheral BP ____?
Cell damage due to inadequate perfusion

*Signs and symptoms?*
*Management?*
BP too high: 
1° or essential Hypertension
2° Hypertension

- Weakening of arterial walls lead to
  ____________________________ ⇒ Risk of ?

- Cerebral hemorrhage =
  _______________________

- Rupture of major artery

THE END