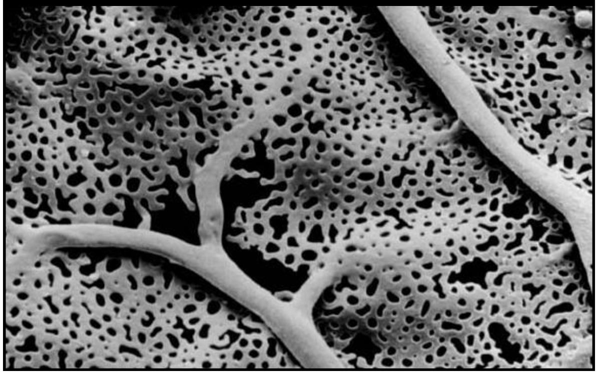
Cardiovascular System: Vessels

Over 60,000 miles of vessels per human body



Blood Vessel Anatomy:

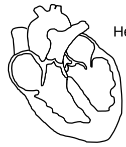
(branch / diverge / fork)

Elastic Arteries → Muscular Arteries → Arterioles

(nutrient exchange)

Capillaries → Venules → Veins

(join / merge / converge)

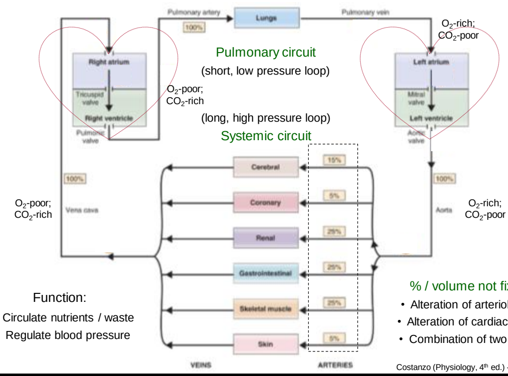


Heart

Vessel Types:

1) Arteries (away from heart)
2) Capillaries
3) Veins (toward heart)

Blood Vessel Anatomy:



Function:

1) Circulate nutrients / waste
2) Regulate blood pressure

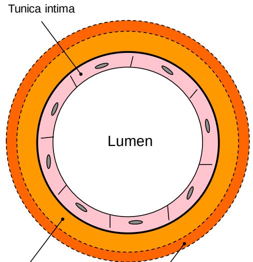
% / volume not fixed:

- Alteration of arteriole size
- Alteration of cardiac output
- Combination of two above

Costanzo (Physiology, 4th ed.) – Figure 4.1

Blood Vessel Anatomy:

Vessels composed of distinct tunics :



Only tunic present in capillaries

1) Tunica intima
   - Endothelium (simple squamous epithelium)
   - Connective tissue (↑ elastic fibers)
2) Tunica media
   - Smooth muscle / elastic fibers
   - Regulates pressure / circulation
     - Sympathetic innervation
3) Tunica externa
   - Loose collagen fibers
   - Nerves / lymph & blood vessels
   - Protects / anchors vessel

Vasa vasorum

Vasomotor stimulation = vasoconstriction

Vasomotor relaxation = vasodilation

Blood Vessel Anatomy:

Arteries:

Arteriosclerosis: Hardening / stiffening of arteries

Relative tissue makeup (Endothelium, Elastic tissue, Smooth muscle, Fibrous tissue)

Major groups:

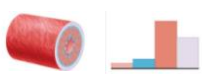
D = Diameter
T = Thickness

1) Elastic Arteries (conducting arteries):
   - Large, thick-walled (near heart)
   - ↑ [elastic fibers] (pressure reservior)

D: 1.5 cm
T: 1.0 mm

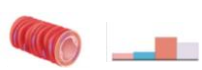
2) Muscular Arteries (distributing arteries):
   - Deliver blood to organs
   - ↑ [smooth muscle] (vasoconstriction)

D: 6.0 mm
T: 1.0 mm



3) Arterioles:
   - Control blood into capillaries
   - Neural / hormonal / local controls

D: 37.0 μm
T: 6.0 μm



Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Table 19.1

Blood Vessel Anatomy:

Capillaries:

Relative tissue makeup (Endothelium, Elastic tissue, Smooth muscle, Fibrous tissue)

1) Capillaries:
   - Location of blood / tissue interface
   - Stabilized by pericytes (smooth muscle cells)

D: 9.0 μm
T: 1.0 μm

Types of Capillaries:

A) Continuous
- Uninterrupted lining
- Found throughout body (most common type)

2) Fenestrated
- Oval pores present
- Located in high absorption / filtration regions (e.g., kidney)

3) Sinusoidal:
- Holes / clefts present
- Allow passage of large molecules (e.g., liver)

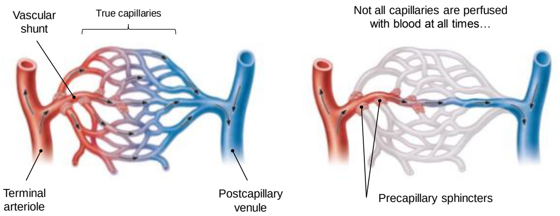
Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Table 19.1 / Figure 19.3

Blood Vessel Anatomy:

Capillaries:

Capillaries do not function independently – Instead they form interweaving networks called capillary beds

Not all capillaries are perfused with blood at all times…



- 10 - 100 capillaries / bed
  - a) Vascular shunt
  - b) True capillaries
- Sphincters control blood flow through capillary bed

Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Figure 19.4

Blood Vessel Anatomy:

Veins:

Relative tissue makeup

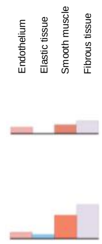
Major groups:

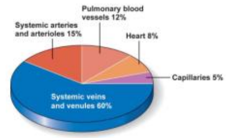
1) Venules:
   - Formed where capillaries unite
   - Extremely porous

D: 20.0 μm
T: 1.0 μm

2) Veins (capacitance vessels):
   - Large lumen; "volume" sink
   - Low pressure environment

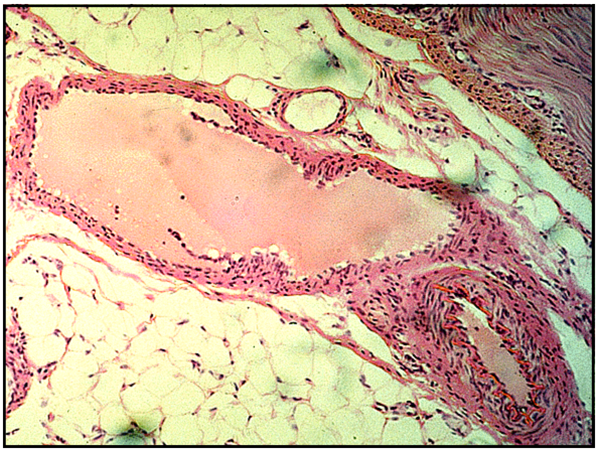
D: 5.0 mm
T: 0.5 mm





Venous sinuses:
Specialized, flattened veins composed only of endothelium; supported by surrounding tissues

Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Figures 19.3 / 19.5

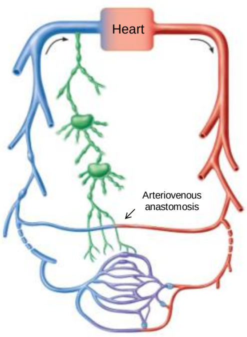


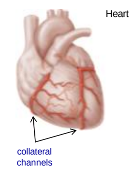
Blood Vessel Anatomy:

Vascular anastomoses:
Regions where vessels unite, forming interconnections

Venous anastomoses are common; vein blockages rarely lead to tissue death

Great saphenous vein harvest





Arterial anastomoses provide alternative channels for blood to reach locations
- Joints
- Abdominal organs
- Brain

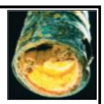
Retina, spleen, & kidney have limited collateral circulation

Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Figure 19.2

Pathophysiology:

Most common form of arteriosclerosis

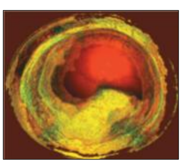
Would you want to find this pipe in your house?



Atherosclerosis:
Formation of atheromas (small, patchy thickenings) on wall of vessel; intrude into lumen

1) Endothelium injured
   - Infection / hypertension
2) Lipids accumulate / oxidize
   - LDLs collect on tunica intima

Foam cells:
Macrophages engorged with LDLs; form fatty streak



3) Fibrous plaque forms
   - Collagen / elastin fibers deposited around dying or dead foam cells
4) Plaque becomes unstable
   - Calcium collects in plaque
   - Vessel constricts; arterial wall frays / ulcerates (= thrombus)

Statins:
Cholesterol-lowering drugs

Outcome:
- Myocardial infarctions
- Strokes
- Aneurysms

Link

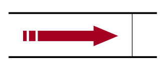
Angioplasty / Stent

Bypass surgery

Hemodynamics:

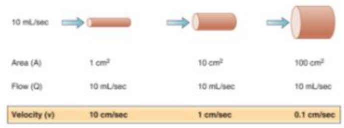
To stay alive, blood must be kept moving…

Blood Flow:
Volume of blood flowing past a point per given time (ml / min)



The velocity of blood flow is not related to proximity of heart, but depends on the diameter and cross-sectional area of blood vessels

$$v = Q / A$$



v = Velocity (cm / sec)
Q = Flow (mL / sec)
A = Cross-sectional area (cm²)

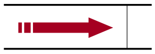
$$A = \pi r^2$$

Costanzo (Physiology, 4th ed.) – Figure 4.4

Hemodynamics:

To stay alive, blood must be kept moving…

Blood Flow:
Volume of blood flowing past a point per given time (ml / min)



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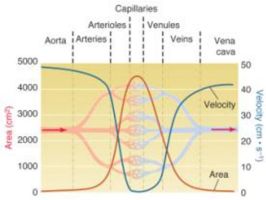
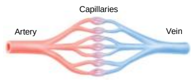


Blood velocity is highest in the aorta and lowest in the capillaries

$v = Q / A$



Randall et al. (Eckert Animal Physiology, 5th ed.) – Figure 12.23

$v = Q / A$

A man has a cardiac output of 5.5 L / min. The diameter of his aorta is estimated to be 20 mm, and the total cross-sectional area of his systemic capillaries is estimated to be 2500 cm².

What is the velocity of blood flow in the aorta relative to the velocity of blood flow in the capillaries?

cm³ ↓ (5500 mL)

$v_{capillaries} = \frac{5.5 \text{ L / min}}{2500 \text{ cm}^2}$

$v_{capillaries} = 2.2$ cm / min

$A = \pi r^2$ $\quad A = (3.14)(10 \text{ mm})^2$ (1 cm) $\quad A = 3.14 \text{ cm}^2$

$v_{aorta} = \frac{5500 \text{ cm}^3 / \text{min}}{3.14 \text{ cm}^2}$

$v_{aorta} = 1752$ cm / min

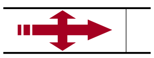
800x difference

Hemodynamics:

To stay alive, blood must be kept moving…

Blood flow through a blood vessel or a series of blood vessels is determined by blood pressure and peripheral resistance

Blood Pressure:
Force per unit area on wall of vessel (mm Hg)



- The magnitude of blood flow is directly proportional to the size of the pressure difference between two ends of a vessel

Blood Flow (Q) = Difference in blood pressure (Δ P)

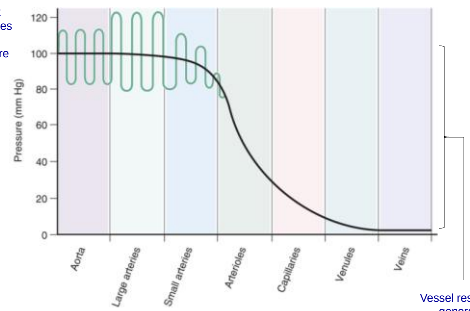
- The direction of blood flow is determined by the direction of the pressure gradient

↑ Always moves from high to low pressure

Hemodynamics:

To stay alive, blood must be kept moving…

Heart generates initial pressure



Vessel resistance generates pressure gradient

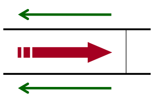
Costanzo (Physiology, 4th ed.) – Figure 4.8

Hemodynamics:

To stay alive, blood must be kept moving…

Blood flow through a blood vessel or a series of blood vessels is determined by blood pressure and peripheral resistance

Peripheral Resistance:
Amount of friction blood encounters passing through vessels
(mm Hg / mL / min)



- Blood flow is inversely proportional to resistance encountered in the system

$$\text{Blood Flow (Q)} = \frac{1}{\text{Peripheral resistance (R)}}$$

The major mechanism for changing blood flow in the cardiovascular system is by changing the resistance of blood vessels, particularly the arterioles

Hemodynamics:

To stay alive, blood must be kept moving…

$$\underset{\text{(current)}}{\text{Blood Flow (Q)}} = \frac{\overset{\text{(difference in voltage)}}{\text{Difference in blood pressure } (\Delta \text{ P})}}{\underset{\text{(electrical resistance)}}{\text{Peripheral resistance (R)}}}$$

Analogous to Ohm's Law ($\Delta V = I \times R$ OR $I = \Delta V / R$)

A man has a renal blood flow of 500 mL / min. The renal atrial pressure is 100 mm Hg and the renal venous pressure is 10 mm Hg.

What is the vascular resistance of the kidney for this man?

$Q = \Delta P / R$

$R = \Delta P / Q$

$R = \frac{100 \text{ mm Hg} - 10 \text{ mm Hg}}{500 \text{ mL / min}}$

$R = 0.18$ mm Hg / mL / min

To stay alive, blood must be kept moving…

Hemodynamics:

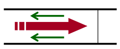
The factors that determine the resistance of a blood vessel to blood flow are expressed by Poiseuille's (pwä-zwēz) Law:

Powerful relationship!
Slight diameter change equals large resistance change

$$R = \frac{8L\eta}{\pi r^4}$$

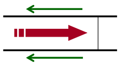
R = Resistance
η = Viscosity of blood
L = Length
r = Radius

1) Blood viscosity



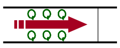
↑ viscosity = ↑ resistance

2) Vessel Length



↑ length = ↑ resistance

3) Vessel Diameter



↓ diameter = ↑ resistance

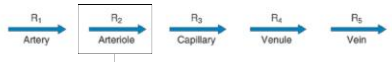
To stay alive, blood must be kept moving…

Hemodynamics:

The total resistance associated with a set of blood vessels also depends on whether the vessels are arranged in series or in parallel

A) Series resistance:

Sequential arrangement (e.g., pathway within single organ)



Arteriolar resistance is the greatest which equates to the area with the greatest decrease in pressure

The total resistance is equal to the sum of the individual resistances

$$R_{total} = R_1 + R_2 + R_3 + R_4 + R_5$$

Costanzo (Physiology, 4th ed.) – Figure 4.5

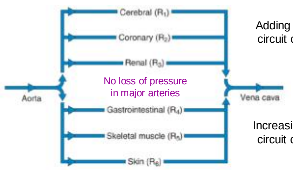
To stay alive, blood must be kept moving…

Hemodynamics:

The total resistance associated with a set of blood vessels also depends on whether the vessels are arranged in series or in parallel

B) Parallel resistance:

Simultaneous arrangement (e.g., pathway among various circulations)



Adding a new resistance to the circuit causes total resistance to decrease

Increasing the resistance in one circuit causes total resistance to increase

The total resistance is less than any of the individual resistances

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6}$$

Costanzo (Physiology, 4th ed.) – Figure 4.5

To stay alive, blood must be kept moving…

Hemodynamics:

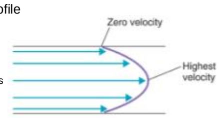
Ideally, blood flow in the cardiovascular system is streamlined

1) Laminar Flow: Characterized by parabolic velocity profile

- Flow is 0 velocity at wall; maximal at center
- Layers of fluid slide past one another

Viscosity:
Measure of the resistance to sliding between adjacent layers

Blood ~ 4x more viscous than water

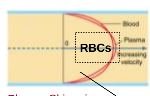


What would you expect to happen to blood viscosity as vessel diameter decreases?

↑ viscosity in capillaries – Why?

Fahraeus – Lindqvist Effect:
Relative viscosity of blood decreases with decreasing vessel diameter
(< 0.3 mm ~ 1.8x water)

Reduced energy required to drive blood through microcirculation



(↓) Hematocrit

Plasma Skimming

Exit to smaller vessels

Costanzo (Physiology, 4th ed.) – Figure 4.6

To stay alive, blood must be kept moving…

Hemodynamics:

Ideally, blood flow in the cardiovascular system is streamlined

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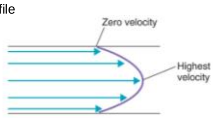
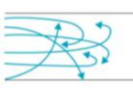


2) Turbulent Flow: Blood moves in directions not aligned with axis of blood flow

- More pressure required to propel blood
- Noisy (stethoscope)



Anemia
Thrombi

Reynolds Number:
Indicator of whether flow will be laminar or turbulent

↑ *Re* = turbulence (> 2000)

Factors affecting Reynolds Number:
1) Viscosity (↓ viscosity = ↑ Reynolds number)
2) Velocity (↑ velocity = ↑ Reynolds number)

Costanzo (Physiology, 4th ed.) – Figure 4.6

To stay alive, blood must be kept moving…

Hemodynamics:

The capacitance of a blood vessel describes the volume of blood a vessel can hold at a given pressure

$$\text{Compliance (mL / mm Hg)} = \frac{\text{Volume (mL)}}{\text{Pressure (mm Hg)}}$$

Compliance = slope of line

Compliance is high in veins
(large blood volumes @ low pressure)

Unstressed volume

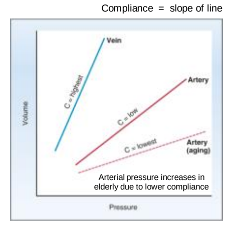
Compliance is low in arteries
(low blood volumes @ high pressure)

Stressed volume

Total blood volume = Unstressed volume + Stressed volume

Changes in compliance of the veins cause redistribution of blood between arteries and veins

- Venoconstriction



Arterial pressure increases in elderly due to lower compliance

Costanzo (Physiology, 4th ed.) – Figure 4.7

To stay alive, blood must be kept moving…

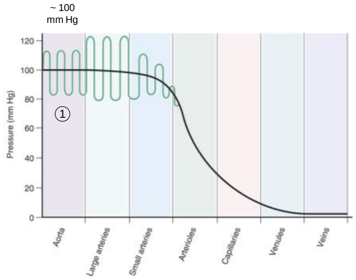
Hemodynamics:

As noted earlier, blood pressure is not equal throughout system

①

High initial pressure:

- Large volume of blood entering aorta
- Low compliance of aortic wall

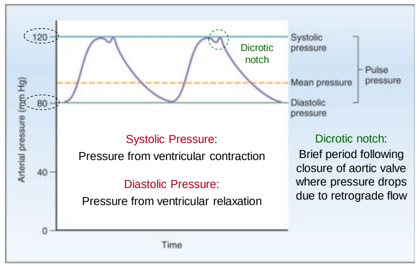


Costanzo (Physiology, 4th ed.) – Figure 4.8

To stay alive, blood must be kept moving…

Hemodynamics:

Although mean pressure is high and constant, there are pulsations of aortic (and arterial) pressure



Systolic Pressure:
Pressure from ventricular contraction

Diastolic Pressure:
Pressure from ventricular relaxation

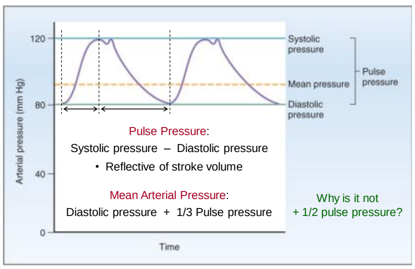
Dicrotic notch:
Brief period following closure of aortic valve where pressure drops due to retrograde flow

Costanzo (Physiology, 4th ed.) – Figure 4.9

To stay alive, blood must be kept moving…

Hemodynamics:

Although mean pressure is high and constant, there are pulsations of aortic (and arterial) pressure



Pulse Pressure:
Systolic pressure – Diastolic pressure
- Reflective of stroke volume

Mean Arterial Pressure:
Diastolic pressure + 1/3 Pulse pressure

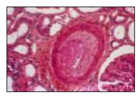
Why is it not + 1/2 pulse pressure?

Costanzo (Physiology, 4th ed.) – Figure 4.9

Pathophysiology:

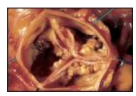
Several pathologic conditions alter the arterial pressure curve in a predictable way

Arteriosclerosis:

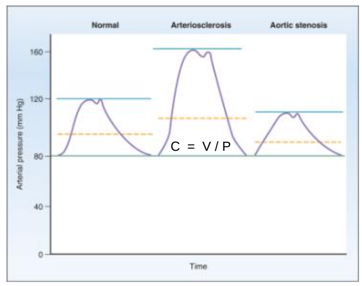


↓ compliance = ↑ systolic pressure

Aortic stenosis:



↓ Stroke volume = ↓ systolic pressure



Costanzo (Physiology, 4th ed.) – Figure 4.10

To stay alive, blood must be kept moving…

Hemodynamics:

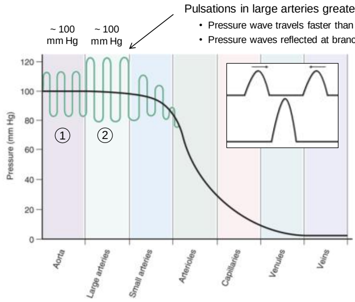
As noted earlier, blood pressure is not equal throughout system

②

Pressure remains high:

- High elastic recoil of artery walls
- Pressure reservoir

Pulsations in large arteries greater than aorta
- Pressure wave travels faster than blood
- Pressure waves reflected at branch points



Costanzo (Physiology, 4th ed.) – Figure 4.8

To stay alive, blood must be kept moving…

Hemodynamics:

As noted earlier, blood pressure is not equal throughout system

②

Pressure remains high:

- High elastic recoil of artery walls
- Pressure reservoir

③

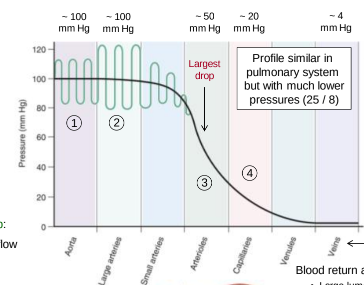
Dramatic drop in pressure:

- High resistance to flow

④

Pressure continues to drop:

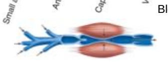
- Frictional resistance to flow
- Filtration of fluid out of capillaries



Profile similar in pulmonary system but with much lower pressures (25 / 8)

Energy consumed to overcome frictional forces

Blood return assisted by:
- Large lumen (↓ resistance)
- Valves
- Muscular pumps



Costanzo (Physiology, 4th ed.) – Figure 4.8

Blood Pressure Regulation:

Mean arterial pressure (P_a) is the driving force for blood flow, and must be maintained at a high, constant level

$$\text{Blood Flow (Q)} = \frac{\text{Difference in blood pressure } (\Delta P)}{\text{Peripheral resistance (R)}}$$

↓

Mean Arterial Pressure (P_a) = Cardiac Output (Q) x Peripheral Resistance (R)

Blood Pressure Regulation:

Note:
Equation deceptively simple; in reality, cardiac output and peripheral resistance are not independent of each other

Factors Affecting Blood Pressure:

Blood Volume *
($\uparrow$ Blood Volume = $\uparrow$ BP)

Mean Arterial Pressure (P_a) = Cardiac Output (Q) x Peripheral Resistance (R)

Cardiac Output *
($\uparrow$ CO = $\uparrow$ BP)

Vessel Diameter *
($\downarrow$ D = $\uparrow$ R = $\uparrow$ BP)

Blood Viscosity
($\uparrow$ V = $\uparrow$ R = $\uparrow$ BP)

Vessel Length
($\uparrow$ L = $\uparrow$ R = $\uparrow$ BP)

Vessel Elasticity
($\downarrow$ VE = $\uparrow$ R = $\uparrow$ BP)

P_a is regulated by two major systems that work via negative feedback to maintain ~ 100 mm Hg

* Variables that can be readily manipulated

Blood Pressure Regulation: System 1

Baroreceptor mechanisms are fast, neurally mediated reflexes that attempt to keep P_a constant via changes in cardiac output and vessel diameter

Baroreceptors:

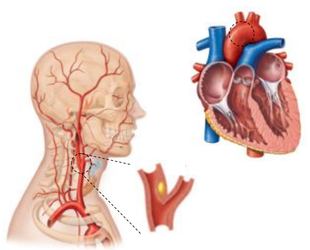
Function:

- Mechanoreceptors (respond to stretch)
  - $\uparrow$ Pa = $\uparrow$ stretch = $\uparrow$ firing rate
  - $\downarrow$ Pa = $\downarrow$ stretch = $\downarrow$ firing rate

While sensitive to absolute level of pressure, they are most sensitive rates of changes in pressure

Location:

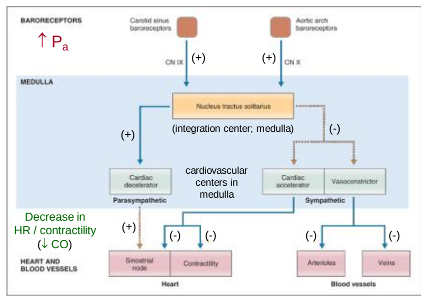
- Carotid sinus (increase / decrease in P_a)
  - Glossopharyngeal nerve (IX)
- Aortic arch (increase in P_a)
  - Vagus nerve (X)



Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Figures 18.4 / 19.22

Blood Pressure Regulation:

Baroreceptor mechanisms are fast, neurally mediated reflexes that attempt to keep P_a constant via changes in cardiac output and vessel diameter



Decrease in HR / contractility ($\downarrow$ CO)

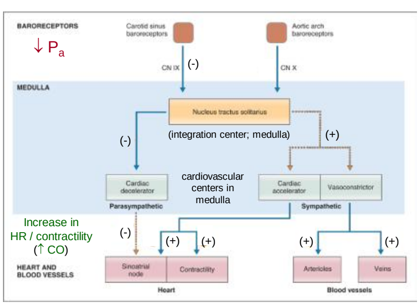
Increase in vessel diameter ($\downarrow$ PR)

Costanzo (Physiology, 4th ed.) – Figure 4.31

Blood Pressure Regulation:

Valsalva Maneuver:
Expiring against a closed glottis; used to test integrity of baroreceptor reflex

Baroreceptor mechanisms are fast, neurally mediated reflexes that attempt to keep P_a constant via changes in cardiac output and vessel diameter



Increase in HR / contractility ($\uparrow$ CO)

Decrease in vessel diameter ($\uparrow$ PR)

Costanzo (Physiology, 4th ed.) – Figure 4.31

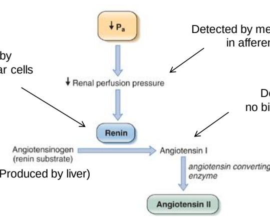
Blood Pressure Regulation: System 2

Renin-angiotensin II-aldosterone system is a slow, hormonally mediated response to keep P_a constant via changes in blood volume

Detected by mechanoreceptors in afferent arterioles

Released by juxtaglomerular cells (kidney)

Decapeptide; no biological activity



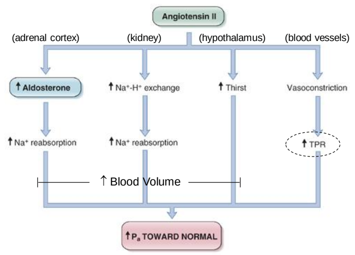
(Produced by liver)

(lungs / kidneys)

Costanzo (Physiology, 4th ed.) – Figure 4.33

Blood Pressure Regulation:

Renin-angiotensin II-aldosterone system is a slow, hormonally mediated response to keep P_a constant via changes in blood volume



Costanzo (Physiology, 4th ed.) – Figure 4.33

Cardiovascular System – Vessels

Blood Pressure Regulation:

Additional mechanisms aid in regulating mean arterial pressure

A) Peripheral chemoreceptors
(carotid bodies / aortic arch)

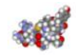
- Respond to ↓ P_{O_2} with vasoconstriction and increased heart rate

B) Central chemoreceptors
(medulla oblongata)

- Respond to primarily to ↑ P_{CO_2} and ↓ pH

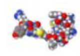
Brain becomes ischemic
↓ ↑ P_{CO_2} and ↓ pH
Increased sympathetic outflow
 ↓ BIG RED BUTTON
Intense arteriolar vasoconstriction in peripheral capillary beds ← Redirects blood to brain

C) Antidiuretic hormone (ADH)
(posterior pituitary)


aka vasopressin

- Respond to an ↑ serum osmolarity and a ↓ in blood pressure
- Triggers vasoconstriction (V_1 receptors)

D) Atrial natriuretic peptide (ANP)
(atria)

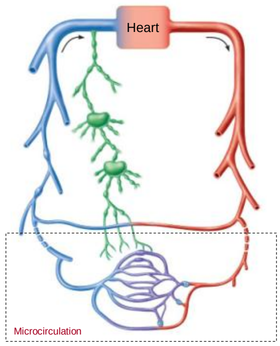


- Respond to an ↑ in blood pressure
- Triggers vasodilation and ↑ H_2O excretion

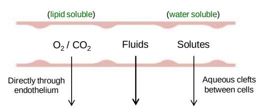
Cardiovascular System – Vessels

Microcirculation:

Functions of the arterioles, capillaries, lymphatic vessels, and veins



Exchange across capillary wall:



- Simple diffusion drives exchange of gases and solutes
- Fluid transfer across membrane occurs via osmosis
  - Hydrostatic pressure
  - Osmotic pressure

  } Starling forces

Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Figure 19.2

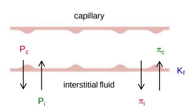
Cardiovascular System – Vessels

Microcirculation:

Fluid movement across a capillary wall is driven by the Starling pressures across the wall

Starling equation:

$$J_v = K_f [(P_c - P_i) - (\pi_c - \pi_i)]$$



J_v =	Fluid movement (mL / min)	
K_f =	Hydraulic conductance (mL / min • mm Hg)	Water permeability of capillary wall (structural property)
P_c =	Capillary hydrostatic pressure (mm Hg)	Capillary fluid pressure
P_i =	Interstitial hydrostatic pressure (mm Hg)	Interstitial fluid pressure
π_c =	Capillary osmotic pressure (mm Hg)	Capillary osmotic pressure (due to [protein])
π_i =	Interstitial osmotic pressure (mm Hg)	Interstitial osmotic pressure (due to [protein])

Direction of fluid movement (J_v) may be into or out of capillary

Filtration = Net fluid movement is out of capillary and into interstitial fluid ((+) number)

Absorption = Net fluid movement is into capillary and out of interstitial fluid ((-) number)

Cardiovascular System – Vessels

In a skeletal muscle of an individual, the following Starling pressures were measured:

P_c = 30 mm Hg
P_i = 1 mm Hg
π_c = 26 mm Hg
π_i = 3 mm Hg

Kf = 0.5 mL / min • mm Hg

What is the direction and magnitude of fluid movement across this capillary?

$$J_v = K_f [(P_c - P_i) - (\pi_c - \pi_i)]$$
$$J_v = 0.5 [(30 - 1) - (26 - 3)]$$
$$J_v = 0.5 [29 - 23]$$
$$J_v = 0.5 (6)$$

J_v = 3 mL / min
(filtration)

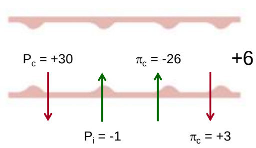
Cardiovascular System – Vessels

In a skeletal muscle of an individual, the following Starling pressures were measured:

P_c = 30 mm Hg
P_i = 1 mm Hg
π_c = 26 mm Hg
π_i = 3 mm Hg

Kf = 0.5 mL / min • mm Hg

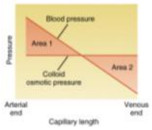
What is the direction and magnitude of fluid movement across this capillary?



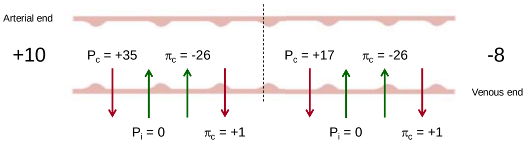
J_v = 0.5 (6)

J_v = 3 mL / min
(filtration)

Microcirculation:



Fluid movement across a capillary wall is not equal along the length of a capillary



J_v = 0.5 (2)

J_v = 1 mL / min

(net filtration)

What happens to the fluid not returned to the capillary?

Randall et al. (Eckert Animal Physiology, 5th ed.) – Figure 12.37

Microcirculation:

Lymphoid system returns excess fluid to bloodstream

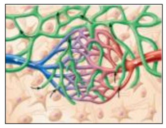
Additional Functions:

- Produce / maintain / distribute lymphocytes
- Distributes hormones / nutrients / waste products

➢ Lymph node biopsy

Lymph nodes filter fluids (99% purified)

Flow of Lymph:



- Originate as pockets
- Large diameters / thin walls
- One-way valves (external)

Lymphatic capillaries ⟶ Lymphatic vessels ⟶ Collecting Vessels ⟶ Lymphatic Trunks ⟶ Lymphatic ducts

One-way valves (internal)

Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Figure 20.1

Microcirculation:

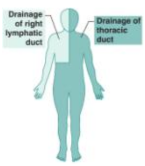
Flow of Lymph:

Thoracic Duct:

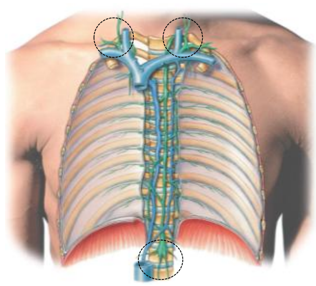
- Begins inferior to diaphragm
- Empties into left subclavian vein

Right Lymphatic Duct:

- Empties into right subclavian vein



- Lymph from right side of body above diaphragm
- Lymph from left side of head, neck, and thorax



Cisterna chyli:
Chamber that collects lymph from abdomen, pelvis, and lower limbs

Similar to Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Figure 20.2

Pathophysiology:

Edema (swelling) results from an increase in interstitial fluid volume

Forms when the volume of fluids filtered out of the capillaries exceeds the ability of the lymphatics to return it to circulation

$J_v = K_f [(P_c - P_i) - (\pi_c - \pi_i)]$

Causes:

1) Increased capillary hydrostatic pressure
   - Arteriole dilation
   - Deep vein thrombosis
   - Heart failure

2) Decreased capillary osmotic pressure
   - Severe liver failure (limited protein synthesis)
   - Protein malnutrition

3) Increased hydraulic conductance
   - Severe burn
   - Inflammation (leaky vessels)

Elephantiasis

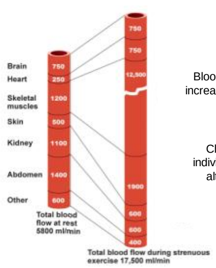
4) Impaired lymphatic drainage
   - Prolonged standing
   - Removal / irradiation of lymph nodes
   - Parasitic infection

Special Circulations:

Blood flow is variable between one organ and another, depending on the overall demands of each organ system

Interorgan differences in blood flow results from differences in vascular resistance

What about the lungs?



Blood flow to specific organs can increase or decrease depending on metabolic demands

Changes in blood flow to an individual organ are achieved by altering arteriolar resistance

Marieb & Hoehn (Human Anatomy and Physiology, 8th ed.) – Figure 19.13

Special Circulations:

The mechanisms that regulate blood flow are categorized as local (intrinsic) control and neural / hormonal (extrinsic) control

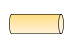
1) Local control:

Local controls are most important mechanism for regulating coronary, cerebral, skeletal muscle, pulmonary, and renal circulation

A) Autoregulation
   - Maintenance of constant blood flow in face of changing arterial pressure

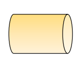
$Q = \Delta P / R$

Myogenic Hypothesis:
When vascular smooth muscle is stretched, it contracts

↑ BP = 

↑ BP = ↑ smooth muscle stretch = vasoconstriction

ALTERNATIVELY

↓ BP = 

↓ BP = ↓ smooth muscle stretch = vasodilation

Special Circulations:

The mechanisms that regulate blood flow are categorized as
local (intrinsic) control and neural / hormonal (extrinsic) control

1) Local control:

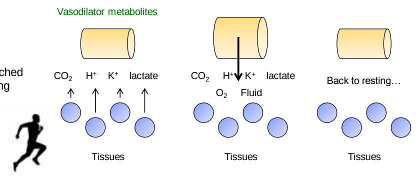
Local controls are most important mechanism for regulating coronary, cerebral, skeletal muscle, pulmonary, and renal circulation

B) Active hyperemia
- Blood flow to an organ is proportional to its metabolic activity

C) Reactive hyperemia (Repayment of oxygen 'debt')
- Blood flow to an organ is increased in response to a period of decreased blood flow

Metabolic Hypothesis:

O_2 delivery to a tissue is matched to O_2 consumption by altering arteriole resistance



Special Circulations:

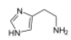
The mechanisms that regulate blood flow are categorized as
local (intrinsic) control and neural / hormonal (extrinsic) control

2) Neuronal / Hormonal controls:

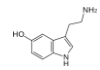
Neuronal / hormonal controls are most important mechanism for maintaining skin circulation

A) Neuronal
- Sympathetic innervation of vascular smooth muscle

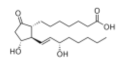
B) Hormonal



Histamine
- arteriodilator; venoconstrictor
- ↑ P_c = local edema

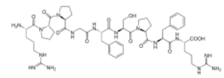


Serotonin
- local vasoconstriction



Prostaglandins
- local vasodilators / vasoconstrictors

Bradykinin
- arteriodilator; venoconstrictor
- ↑ P_c = local edema

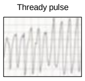


Pathophysiology:

Circulatory shock refers to any condition in which the blood vessels are inadequately filled

A) Hypovolemic Shock

Large-scale blood loss

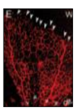


(↑ HR;extreme vasoconstriciton)

- Acute hemorrage
- Severe vomiting / diarrhea
- Extensive burns

B) Vascular Shock

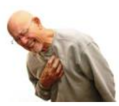
Abnormal expansion of vascular beds due to extreme vasodilation



- Anaphylaxis (allergies)
- Failure of ANS regulation
- Septicemia (bacteria)

C) Cardiogenic Shock

Heart malfunctions



- Myocardial infarction