Arteries

• AWAY
• Branch
• Typically oxygenated.
Capillaries

• Smallest.

• Most abundant.
  – 10 billion.
  – Huge surface area.

• Exchange
Veins

- TOWARDS

- Converge.

- Typically deoxygenated.
3 Layers of the Vascular Wall

- Tunica interna (intima)
- Tunica media
- Tunica externa (adventitia)
Tunica Interna/Intima

- Lining.
- Endothelium.
  - Simple squamous
- Continuous with endocardium
- Areolar CT.
- Only layer in capillaries.
Tunica Media

- Smooth muscle plus elastic fibers.
- Most prominent layer in arteries.
Tunica Externa/Adventitia

- Primarily collagen
- Anchors
- Most prominent layer in veins
Elastic Arteries

- Aorta and major branches.

- Act as AUXILIARY PUMPS.
**Ventricular contraction**

1. Ventricle contracts
2. Semilunar valve opens
3. Aorta and arteries expand and store pressure in elastic walls.

**Ventricular relaxation**

1. Isovolumic ventricular relaxation
2. Semilunar valve shuts
3. Elastic recoil of arteries sends blood forward into rest of circulatory system.
Muscular Arteries

• Regional distribution

• Significant layer
Arterioles

- Smallest.

- May or may not have an externa.

- Highly innervated by vasomotor neurons.

- Easy to change the diameter.

- Regulation of blood pressure and flow.
Tunica Media

- Smooth muscle tone

- Regulated by:
  - Metabolites
  - Hormones
  - Sympathetic vasomotor neurons.
Sympathetic neuron

Electrical signals from neuron

Time → Tonic activity

Change in signal rate

↑ Norepinephrine release onto a receptor → Blood vessel constricts

Increased signal rate

↓ Norepinephrine release onto a receptor → Blood vessel dilates

Decreased signal rate
Increased NE release by a vasomotor neuron causes:

– *Tunica media smooth muscle tone to:*

– *Vessel diameter to:*

– *Resistance to blood flow in the vessel to:*

– *Blood flow thru the vessel to:*
Capillaries

- Smallest.
- Thin walls
- Billions
- *Function?*
- Almost everywhere.
Continuous capillaries

– Most common and least permeable.

– Abundant in

– No endothelial “holes.”

– Intercellular clefts.
**Fenestrated capillaries**

- Found in
  - Intercellular clefts
  - Endothelial “holes”
**Sinusoids (Discontinuous Capillaries)**

- Most permeable and least common.
- Big endothelial “holes”
- Intercellular clefts.
- Macrophages in their lining.
- Found in...
How does aerobic training affect the density of capillaries in skeletal muscle tissue?
Endothelium

Thoroughfare channel

Postcapillary venule

Relaxed precapillary sphincters

Arteriole

Smooth muscle cells

Arterial end

Venous end

True capillaries

Endothelium
1. Precapillary sphincters in his rectus femoris would ...

2. Precapillary sphincters in his large intestine would...
• Thin walled w all 3 tunics.

• TE is the largest.

• Large lumens.

• Low Pressure & low resistance

• High compliance

• Smooth muscle prevents distention

• Blood reservoirs
Blood Distribution

- Pulmonary circulation ~18%
- Heart ~12%
- Systemic circulation ~70%
- Systemic veins 55%
- Systemic capillaries 5%
- Systemic arteries 10%
- Heart
Low venous pressure necessitates valves.
Capillary Exchange

• Btwn blood plasma and tissue fluid.

• Nutrients, wastes, signaling molecules – Diffusion!

• FLUID
Capillary Hydrostatic Pressure

- Capillary BP
- Pushes fluid from plasma to ISF
Capillary Osmotic Pressure

- Mostly due to albumin.
- Pulls fluid from ISF to plasma
Interstitial Hydrostatic Pressure

- Usually inconsequential b/c of low ISF volume
- *It would* push fluid from ISF to plasma
Interstitial Osmotic Pressure

- Usually inconsequential b/c of low ISF [protein]
- It *would* pull fluid from the plasma into the ISF
Net Filtration Pressure

- \( \text{NFP} = (\text{CHP} + \text{IOP}) - (\text{COP} + \text{IHP}) \)

- In effect: \( \text{NFP} = \text{CHP} - \text{COP} \)
Capillary Fluid Exchange

Distance along the capillary

Pressure

Arterial end  Venous end

CBP

COP
• Capillary HP usually slightly exceeds capillary OP.
Factors Affecting Local Blood Flow

- Degree of vascularization
- Concentration of local regulatory factors
- Total blood flow
Degree of Vascularization

- Depends on metabolic activity
Angiogenesis vs. Regression
Local Vasoactive Chemicals

EXERCISE

Tissue temp. ____

Tissue $CO_2$ levels ___

Tissue $O_2$ levels ___

Lactic acid levels ___

----- Arterioles serving tissue vaso________

----- blood flow to tissue

----- $CO_2$_______

----- Lactic acid_______

----- Heat_______

----- $O_2$_______
Inflammation

Damaged Tissues → Activate → WBCs

Release inflammatory chemicals (e.g. histamine, bradykinin)

Local vasodilation occurs

Increased blood flow delivers WBCs, immune proteins, etc.
Blood Pressure

• Force per unit area exerted on the vessel wall by blood.
• Millimeters of mercury (mmHg).
• All vessels

"Pull out, Betty! Pull out! . . . You've hit an artery!"
Systolic Blood Pressure

1. Ventricle contracts
2. Semilunar valve opens
3. Aorta and arteries expand and store pressure in elastic walls.
Diastolic Blood Pressure

Ventricular relaxation

1. Isovolumic ventricular relaxation
2. Semilunar valve shuts

3. Elastic recoil of arteries sends blood forward into rest of circulatory system.
Blood pressure (mm Hg)

Aorta
Arteries
Arterioles
Capillaries
Venules
Veins
Vena cava

Systolic pressure

Pressure gradient = 93 mm Hg

Diastolic pressure

MAP

Arterial end of capillary

Venous end of capillary
• What would happen to arterial BP if the amount of blood pumped into the arteries increased?

• What would happen to arterial BP if the resistance in the arterioles went up?

• What would happen to arterial BP if there was more blood in the entire system?
Phentolamine is a chemical that prevents norepinephrine from binding to (and affecting) the smooth muscle cells in blood vessels.

What would phentolamine do to:
- arteriole muscle tone
- arteriole radius
- arteriole diameter
- arteriole resistance
- blood pressure

Why might someone taking phentolamine experience some reflexive tachycardia?
Pulse

• What creates it?

• How/Where do you measure it?

• What’s its relationship to heart rate?
Pulse Pressure

- Δ in arterial pressure caused by ventricular systole.

- Varies directly with...

- PP = SBP – DBP.
Mean Arterial Pressure (MAP)

- Arterial BP fluctuates. *Why?*
- **MAP** is the pressure driving blood flow.
- MAP is a **weighted** average of SBP and DBP.
Mean Arterial Pressure (MAP)

- \( \text{MAP} = \frac{2}{3} \text{DBP} + \frac{1}{3} \text{SBP} \)
- \( \text{MAP} = \text{DBP} + \frac{1}{3} \text{PP} \)
Capillary Blood Pressure

- Low BP. Good for exchange.
- Declines from 40 mmHg to 20 mmHg.
Venous Blood Pressure

- Even lower BP.
- Very small gradient.
What is responsible for **venous return**?

• Remaining force imparted by ventricular systole.

• Gravity.

• Skeletal muscle pump.

• Respiratory pump.

• Venoconstriction.
Gravity
Skeletal Muscle Pump

When skeletal muscles contract, they increase pressure, which opens a valve. This allows blood to flow from the tissues to the heart. Then, the valve closes to prevent blood backflow. Veins with these valves help maintain proper blood flow during activity.
Thoracic cavity

Expiration
Increases blood flow into heart and abdominal veins

Increased intrathoracic pressure
Diaphragm relaxes
Decreased intra-abdominal pressure

Inspiration
Increases blood flow into thoracic veins

Decreased intrathoracic pressure
Diaphragm contracts
Blood moves superiorly
Increased intra-abdominal pressure

Compression

Inspiratory Pump
Venoconstriction

• An increase in sympathetic activity causes:
  – NE release on the TM of medium/large veins to…
  – Venous pressure to…
  – Venous return to…
Relationship Btwn Venous Return and Cardiac Output

Frank Starling Law of the Heart

Cardiac Output (Ventricular Function) vs. End Diastolic Volume (Preload) = Stretching of the Myocardium
Resistance

• Opposition to flow

• Measure of friction.

• Peripheral resistance.

• Direction!
Sources of Resistance

- Blood viscosity.
- Total vessel length.
- Vessel radius.
Viscosity $\propto$ Resistance
• What is the major contributor to blood viscosity?

• Does viscosity change in a healthy person?

• An increase in plasma EPO will cause resistance to...
Total Vessel Length $\propto$ Resistance
Vessel Radius

- $(1/\text{radius}^4) \propto \text{resistance}$
• Does vessel radius change in a normal healthy person?

• Which vessels?

• How is the change achieved?
Which tube has the greater intrinsic resistance?

What layer of the vessel wall has the greatest effect on vessel resistance?

a. Interna
b. Media
c. Externa
Resistance $\propto \frac{(\text{length})(\text{viscosity})}{(\text{radius})^4}$
Which tube has the LEAST resistance?
Which tube has the GREATEST resistance?

1.

2.

3.

4.
An increase in cardiac output causes a steeper pressure gradient.

Less resistance, which is caused by vasodilation, reduction in vessel length, or decrease in blood viscosity.

\[
\text{FLOW} \propto \frac{1}{\text{RESISTANCE}}
\]

Increased pressure gradient

Distance from heart
FLOw $\propto$ PRESSURE GRADIENT
RESISTANCE

A decrease in cardiac output causes a smaller pressure gradient.

Greater resistance, which is caused by vasoconstriction, increase in vessel length, or increase in blood viscosity.
Brain Centers for Short Term BP Control

- Vasomotor
- Cardioinhibitory
- Cardioacceleratory
Increased vasomotor center activity

\[ \rightarrow \]

creased sympathetic output to arterioles

\[ \rightarrow \]

Vaso__________

\[ \rightarrow \]

creased peripheral resistance

\[ \rightarrow \]

creased blood pressure
Increased cardioacceleratory center activity

crease sympathetic output to heart

crease heart rate and stroke volume

crease cardiac output

crease blood pressure
Increased cardioinhibitory center activity

\[ \text{increased parasympathetic output to heart} \]

\[ \text{increased heart rate} \]

\[ \text{increased cardiac output} \]

\[ \text{increased blood pressure} \]
Baroreceptor Reflex

Carotid sinus baroreceptor

Common carotid arteries (Blood to the brain)

Neural signals to cardiovascular control center in medulla

Aortic arch baroreceptor

Aorta (Blood to rest of body)
Baroreceptor Reflex

• Baroreceptors signals the cardiac and vasomotor centers via CN IX and X.

• Frequency of these impulses is proportional to MAP.

• Cardiac and vasomotor centers adjust their output accordingly.
A Fun Way to Demonstrate the Baroreceptor Reflex

- Take the subject’s radial pulse.
- Find the carotid pulse point and GENTLY press on it.
- What will happen to the radial pulse?
- Why?
Adrenal Medullary Mechanism

- Release epinephrine (and a small amt of NE) in response to:
  - Large drops in MAP.
  - Increases in physical activity.
  - Stressful situations.
Adrenal Medullary Mechanism

• How would activation of the adrenal medulla affect:
  – HR
  – SV
  – CO
  – TPR
  – BP
Renin-Angiotensin-Aldosterone System

Renin

Angiotensin II
Renin-Angiotensin-Aldosterone System

Angiotensin II

Vasoconstriction

Increased TPR

Aldosterone & Antidiuretic hormone

Thirstiness

Increased BV

Increased BP
A 25yo woman complains to her doctor of headaches and blurred vision. Her blood pressure is 200/130 mmHg. After the BP has been reduced, investigations are made to find the cause of the problem. It’s discovered that her left renal artery is narrowed.

*Why would this cause the rise in BP?*
Atrial Natriuretic Peptide

- Increased atrial stretch
- Atrial cells release ANP
- ANP is a vasodilator
- ANP increases urine sodium and thus urine output
- ________ TPR
- ________ blood volume
- ________ BP
Blood Distribution During Exercise