The cardiovascular system

Structure of the heart

The cardiac cycle

Structure and organization of blood vessels
What is the cardiovascular system?

The heart is a double pump

heart → arteries → arterioles

↑                                    ↓

veins ← venules ← capillaries
The double pump
Serous membrane

Continuous with blood vessels

- Pericardial cavity
- Parietal pericardium
- Fibrous pericardium
- Endocardium
- Myocardium
- Epicardium (visceral pericardium)
- Coronary blood vessel
Chambers of the heart; valves
Valves control flow of blood from one chamber to another

Prevent backflow
Blood supply to the heart

Coronary artery and vein system

Right and left coronary arteries branch off of aorta
Branch into smaller vessels

Cardiac veins deliver blood to coronary sinus, and back to the right atrium
Coronary artery disease results when coronary arteries cannot deliver blood adequately

Usual cause: plaques in arterial walls

Angina pectoris (pain) when body is not receiving adequate oxygen

Myocardial infarction (heart attack) when blood supply to heart is completely blocked; muscle dies
Coordination of chamber contraction, relaxation
Conduction system of the heart

Heart contracts as a unit

Atrial and ventricular syncytia help conduct electrical signals through the heart

Sinoatrial (S-A) node is continuous with atrial syncytium

S-A node cells can initiate impulses on their own; activity is rhythmic
Electrocardiogram (ECG) can trace conduction of electrical signals through the heart.
Aberrant ECG patterns indicate damage
Regulation of heart rate

Blood pressure and its control

What is hypertension and how is it treated?

The heart rate and exercise

Characteristics of arteries and veins

Organization of the vascular system and responses to physiological needs
Regulation of the cardiac cycle

Sympathetic and parasympathetic nervous systems

Parasympathetic: from medulla oblongata (vagus nerve)
Nerve branches to S-A and A-V nodes, and secretes acetylcholine (slows rate)

Parasympathetic activity can increase (slow heart rate) or decrease (increase heart rate)
Sympathetic nervous system through celiac plexus to heart secretes norepinephrine increases force of contractions

Cardiac control center in medulla oblongata maintains balance between the two

Normally both sympathetic and parasympathetic function at a steady background level
Baroreceptors detect changes in blood pressure

Rising pressure stretches receptors
  vagus nerve → parasympathetic system

Increased temperature increases heart rate

Ions and heart rate:
  excess potassium decreases it
  excess calcium increases it
Blood pressure

Blood flow is generally equal to cardiac output

Blood flow affected by pressure and resistance

Blood pressure: the force that is exerted by blood against blood vessel walls

Resistance depends on size of blood vessel and thickness (viscosity) of blood
Blood pressure is highest in large arteries will rise and fall as heart pumps

highest with ventricular systole
lowest with ventricular diastole
pulse pressure is the difference between the two

Resistance is highest in capillaries
Blood volume increases

Heart rate increases

Stroke volume increases

Blood pressure increases

Blood viscosity increases

Peripheral resistance increases

More cells

Constriction of blood vessel walls
Control of blood pressure

Regulation of cardiac output
  contraction strength
  heart rate
  venous return
  skeletal muscles
  breathing rate
Cardiac output increases

Blood pressure rises

Baroreceptors in aortic arch and carotid sinuses are stimulated

Sensory impulses to cardiac center

Parasympathetic impulses to heart

S-A node inhibited

Heart rate decreases

Blood pressure returns toward normal
Long term regulation of blood flow (hormones)

If blood pressure is too low:

ADH (antidiuretic hormone) promotes water retention

Angiotensin II- in response to renin signal (renin) produced by kidney- why? drop in blood pressure stimulation by sympathetic nervous system sodium levels too low
What happens?
vasoconstriction (by angiotensin II)
what will that do to blood pressure?
ADH is secreted
aldosterone is secreted

EPO (erythropoietin) secreted by kidneys
if blood volume is too low

ANP secreted if blood pressure is too HIGH
What is hypertension?

Arterial pressure is too high

Sometimes cause is unknown, or is secondary to disease

Variety of causes/risk factors are known

- sedentary lifestyle
- smoking
- obesity
- diet (excess sodium; cholesterol; calories in general)
- stress
- arteriosclerosis
- genetic factors
Consequences?
heart has to work harder; left ventricle enlarges
atherosclerosis may affect coronary arteries as well (which have to work harder anyway) → heart disease
deficient blood supply to other parts of body
damage to blood vessels accumulates
heart failure
Treatment of high blood pressure

Quit smoking; adjust diet; exercise

Drug therapies- strategies differ

Reduce heart rate
  calcium channel blockers
    reduce calcium flow into heart muscle and therefore heart rate
    relax smooth muscle lining coronary arteries
  beta blockers (reduce stimulation by sympathetic nervous system)
Diuretics reduce blood volume
ACE inhibitors interfere with renin-angiotensin pathway

Vasodilators (such as nitroglycerin) open up blood vessels (reduce resistance)

If heart is actually failing, digitalis increases efficiency of heart muscle

Anti-hypertensive drugs may be taken in combination
Why is exercise good for the heart?

A trained heart is bigger
- pumps blood more efficiently (at a lower rate)
- stroke volume increases (due to stronger contractions, allowing for lower rate)

Other benefits: higher aerobic capacity (contributing to efficiency)

Note that this takes training!
Characteristics of blood vessels

Arteries and arterioles carry blood away from heart

Capillaries- site of exchange

Venules, veins- return blood to heart
Endothelium- prevents platelet aggregation secretes substances that control diameter of blood vessel

Tunica media- smooth muscle and connective tissue. Innervated by sympathetic nerves (vasoconstriction) Missing in smallest arteries

Tunica externa- connective tissue; is vascularized
Capillaries most permeable (and more permeable in some parts than others)

Especially so in liver, spleen and red marrow (so cells can enter and leave circulation)

Blood flow can vary to different parts of the body, too
What does this mean?
Blood is forced through arteries and arterioles; vessel walls are too thick for blood components to pass through.

In capillaries, oxygen and nutrients move out by diffusion; \( \text{CO}_2 \) in (via lipid membrane, channels, etc.)

Blood pressure moves molecules out by filtration.

Plasma proteins maintain osmotic pressure of blood.
Returning blood to the heart

Venules are continuous with capillaries; take in some returned fluid (rest is retained by tissues or returned to blood via lymphatic system)

Veins have thinner walls; less muscle; but can hold much more blood

Many veins in limbs have valves to prevent backflow
(Varicose veins arise when pressure on valves is prolonged)
One-way Venous Valves

To heart

Valve closed

Relaxed skeletal muscles

Vein

Valve open

Contracted skeletal muscles

Vein

To heart
See pp. 351-359 for all circuits
Distribution of Blood Flow (Cardiac Output) During Rest and Heavy Exercise

Cardiac output = 25 L/min

- Heavy exercise: ~20 L/min
- Rest: ~0.75 L/min
- Cardiac output = 5 L/min
Summary

The heart is a double pump, delivering blood to the lungs for oxygenation, and then to the body.

Blood leaves the heart through arteries, and returns to the heart through veins.

The heart rate is regulated by a conducting system (the heart beats about 100,000 times per day!)
The cardiac cycle is regulated by the cardiac center in the medulla oblongata which regulates sympathetic and parasympathetic input.

Exercise (i.e., needs), temperature and ion balance also affect heart rate.

Cardiac rate is also controlled by long-term responders such as ADH, angiotensin, EPO and ANP.
Blood (arterial) pressure is affected by heart action, blood volume, peripheral resistance, and blood viscosity.

Inability to regulate blood pressure can contribute to disease.

Arteries and veins have structural characteristics appropriate to bringing blood to the cells and then back to the heart.

Circulatory system allows for adjustments to exercise, digestion and other necessary functions.