Circulation & Respiration

[Note: This is the text version of this lecture file. To make the lecture notes downloadable over a slow connection (e.g. modem) the figures have been replaced with figure numbers as found in the textbook. See the full version with complete graphics if you have a faster connection.]

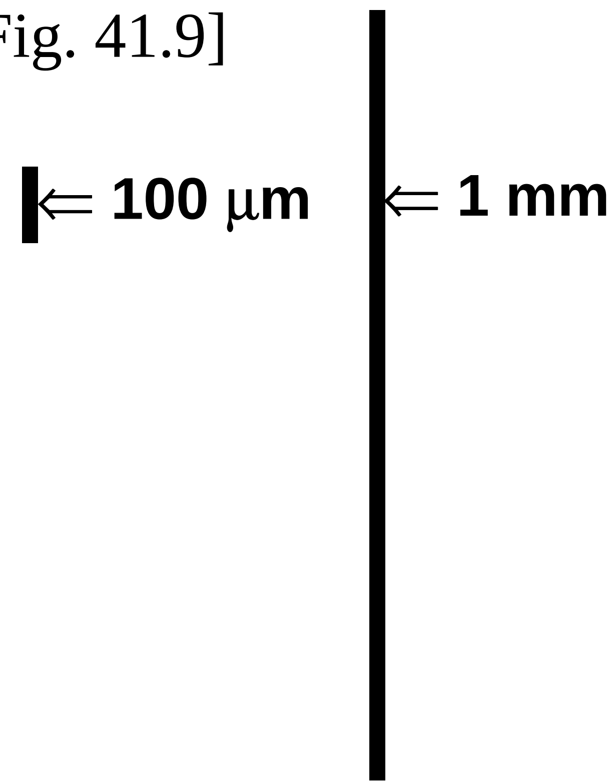
• Diffusion of gases and nutrients into cells only works for small animals with a simple organization.

The gastrovascular cavity of hydra is one example

• Diffusion time is proportional to the square of the distance:

if 100 μm takes 1 sec then 1 mm (10X further) will take 100 sec (100X longer)

[See Fig. 41.9]



<u>Circulatory systems</u> are required in larger animals

The two major types of circulatory systems are <u>open</u> and <u>closed</u>

[See Fig. 42.2]

- **Closed circulatory systems come in two basic types: <u>single and double circulation</u>.**
- **Diagrams of anatomy are usually labeled as if you are <u>facing</u> the body (left side is on the right)**
- **<u>Arteries</u> carry blood <u>away</u> from heart (not always oxygenated)**
- **<u>Veins</u> carry blood <u>towards</u> heart (not always deoxygenated)**

[See Fig. 42.3]

Diagram of the mammalian cardiovascular system

[See Fig. 42.4]

The mammalian heart

- Ventricles are thicker and stronger than atria because they do most of the pumping.

- The left ventricle is largest since it perfuses more of the body

- The sounds of the heart “lub-dup” come from blood interacting with the AV and semilunar valves

- The pulse you feel is caused by the stretching of arteries (e.g. radial, carotid).

[See Fig. 42.5]

The cardiac cycle

- **The cycle includes periods of <u>systole</u> (contraction) and <u>diastole</u> (relaxation).**

- **<u>Cardiac output</u> is the volume of blood pumped by the left ventricle each minute (L/min).**

- **<u>stroke volume</u> is the volume pumped per beat.**

cardiac output = stroke volume X pulse

= 75 ml/min X 70 beats/min = 5.25 L/min

- **cardiac output can increase 5X during exercise**

[See Fig. 42.6]

• **The electrical activity of the heart is measured with an <u>electrocardiogram</u> (ECG or EKG from German *kardio*)**

• **The sinoatrial (SA) node generates the cardiac rhythm (70 bpm). It is regulated by:**

1) sympathetic nervous system (speeds heart rate, ≤ 230 bpm), <u>norepinephrine</u>
2) parasympathetic nervous system (slows, from 100 ≥ 20 bpm), <u>vagus</u> nerve releases <u>acetylcholine</u>
3) hormones released by the body, drugs, blood pressure, temperature

[See Fig. 42.7]

[See Fig. 42.8]

Relationship between blood velocity, pressure, and cross-sectional area of blood vessels

[See Fig. 42.10]

How does blood in capillaries get back to the heart?

1) <u>Smooth muscle</u> around the veins <u>contracts rhythmically</u>
2) <u>Inhilation</u> (breathing) decreases pressure in the thoracic cavity and pulls blood towards heart
3) Movement of body by <u>skeletal muscle</u> also contracts veins and pushes blood past valves.

[See Fig. 42.9]

How is blood pressure controlled?

1) Contraction of <u>smooth muscle</u> around arterioles is regulated (tonic contraction)

2) Contraction of <u>precapillary sphincters</u> is also controlled:

Brain, liver, heart, and kidneys need a constant supply, but the rest of the body gets a variable supply (e.g. digestive tract needs more after meals; skin and muscles need more during exercise).

[See Fig. 42.11]

Movement of fluid between capillaries and interstitial fluid

- 85% returns to veins, remaining 15% is in interstitial fluid and lymphatic system

[See Fig. 42.12]

Measurement of arterial blood pressure

- sphygmomanometer used to measure pressure in the brachial artery
- blood flow is usually cut off at 200 mm Hg

[See Methods: 42.11.5]

[See Fig. 42.13]

Red blood cells (erythrocytes)

- cytoplasm primarily filled with hemoglobin (binds O_2 and NO)
- no nucleus (more room for hemoglobin)
- anaerobic metabolism (conserves oxygen)
- small size (12 μm) means larger surface/volume
- live about 3-4 months, are recycled by the liver and spleen
- born in bone marrow from pleuripotent cells when stimulated by erythropoietin

[See Fig. 5.23]

[See Fig. 42.15]

- **A <u>thrombus</u> is a spontaneous blood clot without injury**
- **A dislodged thrombus is an <u>embolus</u> and causes a heart attack or stroke**
- **<u>hemophilia</u> is a genetic disorder at any step in clotting pathway. Minor injuries lead to life-threatening blood loss.**

Cardiovascular Disease

• cardiovascular disease is the leading cause of death in the USA and other developed nations

• heart attack and stroke result from atherosclerosis

  plaques are characterized by 1) thickened smooth muscle, 2) more fibrous connective tissue, 3) lipid and cholesterol deposition on arteries

• arteriosclerosis is a form of atherosclerosis where arteries are hardened with calcium deposits

• angina pectoris (chest pain) is caused by reduced blood supply to the heart

[See Fig. 42.16]

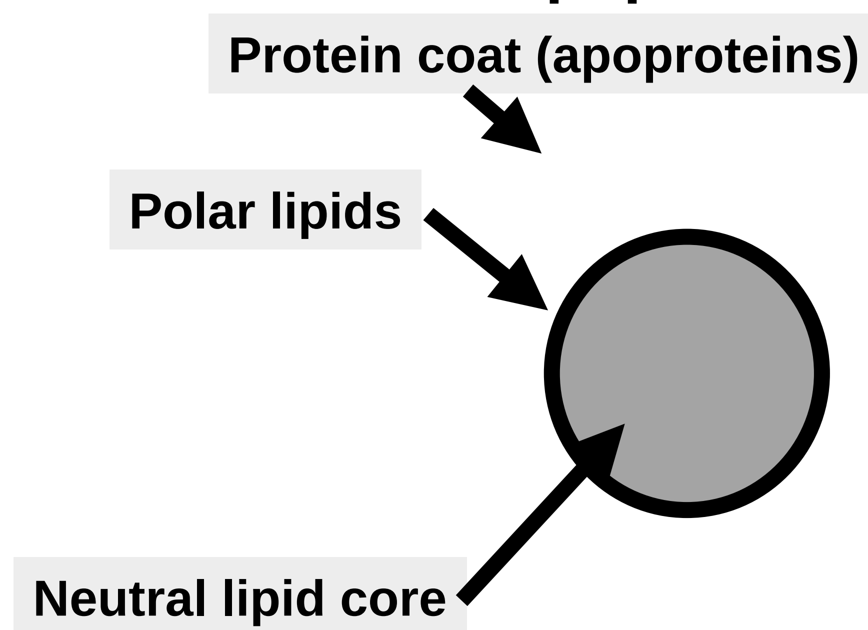
Causes of atherosclerosis

- **hypertension (high blood pressure) with a diastolic pressure > 90 mm Hg can damage vessels**
- **diet high in animal fat increases cholesterol and other lipids that form plaques**
- **smoking decreases High Density Lipoprotein (HDL), HDL = “good” cholesterol that scavenges (removes) lipids from plaques**
- **lack of exercise also decreases HDL**
- **foods high in cholesterol (even with low fat) increase LDL/HDL ratio. LDL = Low Density Lipoprotein, “bad” cholesterol that forms plaques**

Cholesterol

[See Fig. 5.14]

Lipoprotein



What does my cholesterol test mean?

Test	Your level (in mg/dl)*		
	Desirable	**Borderline**	**Undesirable**
Total cholesterol	Below 200	200-240	Above 240
HDL cholesterol	Above 45	35-45	Below 35
Triglycerides	Below 200	200-400	Above 400
LDL cholesterol	Below 130	130-160	Above 160
Total cholesterol divided by HDL	Below 4.5	4.5-5.5	Above 5.5
LDL divided by HDL	Below 3	3-5	Above 5

Gas Exchange (respiration)

- **The atmosphere contains 21% O_2**

- **Water should contain $\geq$5 mg/L of dissolved O_2 for animal life**

- **The respiratory surfaces for exchanging gasses are usually <u>gills</u>, <u>lungs</u>, or <u>trachea</u>, but some animals can use skin (e.g. frogs, turtles, worms)**

[See Fig. 42.17]

<u>Ventilation</u> of gills in fish with water

[See Fig. 42.19]

Parallel current doesn't exchange as much oxygen

[See Fig. 42.20]

Countercurrent exchange maximizes exchange of gasses

- **Tracheal systems and lungs offer access to the higher O_2 content of air compared to water, but must solve the problem of water loss (evaporation)**

- **Direct contact between cells and <u>tracheoles</u> insures rapid exchange of gasses**

[See Fig. 42.21]

- **Lungs are found in vertebrates, spiders, and terrestrial snails. Breathing = ventilation of lungs**
- **In humans, the lung surface is about 100 m^2 due to multiple branches and alveoli**

[See Fig. 42.22]

- **Breathing and vocalization requires coordination with swallowing**
- **<u>Vocal cords</u> in the larynx are stretched to vibrate and make sound when air passes over them**

[See Fig. 41.12]

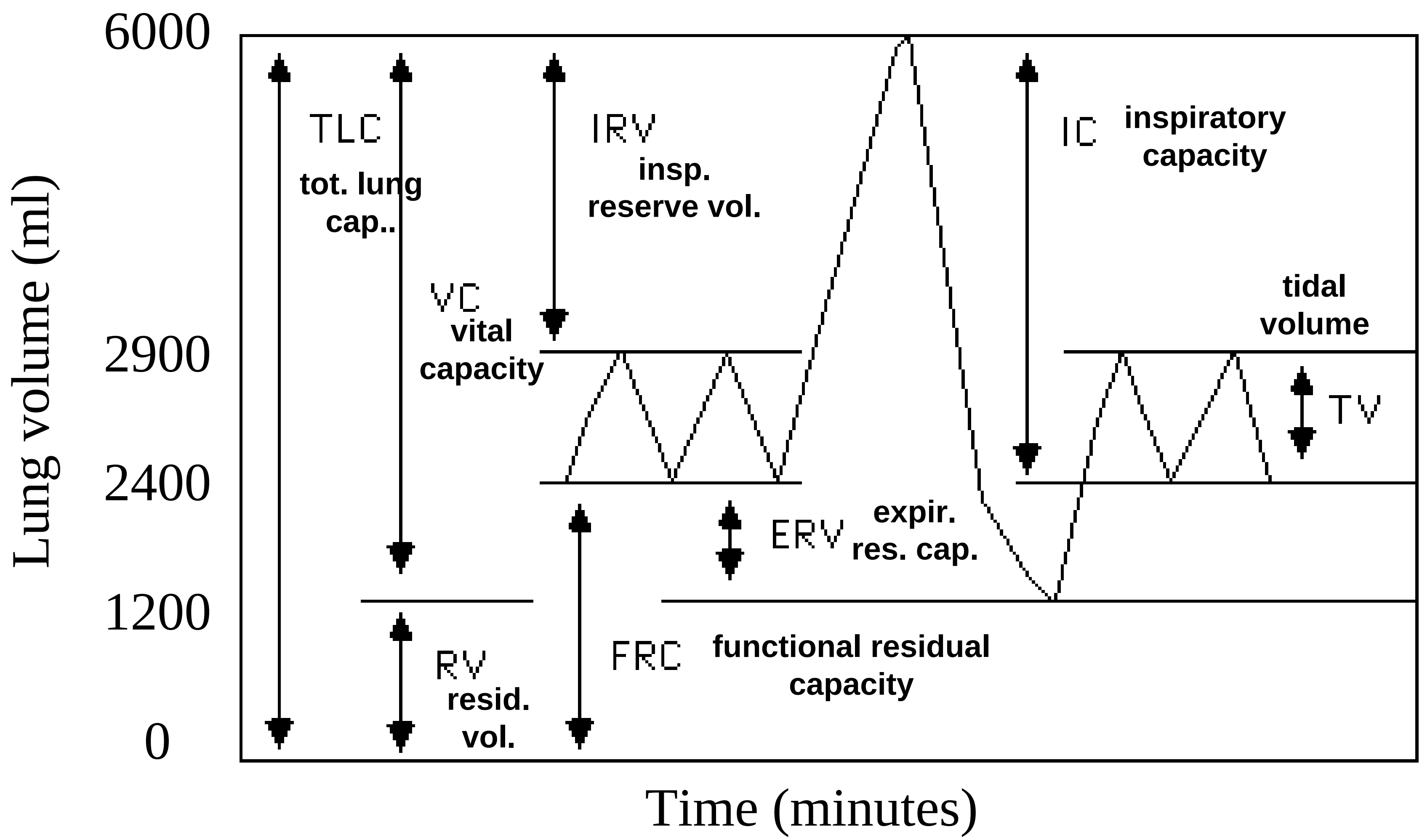
Two ways of breathing

1) <u>Positive pressure:</u> using the mouth to "swallow" air into lungs (e.g. frogs)

2) <u>Negative pressure:</u> increasing volume of thoracic cavity to "suck" air into lungs (e.g. mammals)

[See Fig. 42.23]

Measurement of lung volumes: spirometer readings



- **TV = volume of normal breath**
- **VC = collapsible volume of lung, <u>decreases</u> with aging, disease**
- **RV is <u>uncollapsible</u> volume of lung. <u>Increases</u> with aging, disease**

Control of breathing

- CO_2 in blood and cerebrospinal fluid (CSF) ⇒ carbonic acid ⇒ ⇓ pH ⇒ ⇑ breathing

- O_2 sensors are used mainly for extreme depletion

- The diaphragm and intercostals are used for normal breathing, but extra muscles of the neck, back, and chest can be used to increase lung volume during extreme activity

[See Fig. 42.25]

Dissociation curve of hemoglobin describes the exchange capacity of blood: cooperative binding of O_2

[See Fig. 42.27a]

Partial pressure of gasses (proportional to concentration) determines the direction of exchange

- **0$_2$ is 21% in air and atmospheric pressure is 760 mm Hg so P_{O2} = 0.21 X 760 mm Hg = 160 mm Hg. P_{CO2} = 0.23 mm Hg**

[See Fig. 42.26]

CO_2 transport in the blood: role of bicarbonate

[See Fig. 42.28]