CHAPTER 34

Circulation & Gas Exchange
Mammalian Respiratory System

- Lungs located in thoracic cavity
- Double layered sac encloses lungs

**INTERESTING FACT:** The average human lung has a respiratory surface of about 100 m² - approximately = to the size of a racquetball court.
Air is conveyed to the lungs by a system of branching ducts:

1. Air enters **nostrils**
   - filtered by hairs, warmed, sampled for odors (nasal cavity)
   - can breathe through mouth but air is not processed by nasal cavity
2. Air goes to **pharynx** (crosses w/food path)

- epiglottis is open except when we swallow
- air enters windpipe’s opening called the glottis

(Notice the pharynx has 3 regions.)
3. Glottis leads to larynx (voice box)

- air is exhaled through a chamber where a pair of vocal cords vibrate

- vibration produces sound:
  - tensed muscles are high pitch,
  - relaxed are low
4. Air passes into **trachea** where rings of cartilage maintain its shape  

5. Trachea branches into two **bronchi** (each one leading to a lung) - bronchus (of each lung) branches into finer tubes called **bronchioles** - tips of bronchioles are grape-like clusters of air sacs called **alveoli**
Bronchial tree.
- epithelium lining trachea, bronchi, & all but smallest bronchioles are covered by cilia and a thin layer of mucus

  mucus traps small particles & cilia sweep them out of lungs to pharynx to be swallowed
6. **Gas exchange** takes place in each alveolus

- the $O_2$ in inhaled gases dissolves in a film of moisture (covers entire respiratory lining) on epithelial cells

- $O_2$ then diffuses across epithelium & into capillaries surrounding each alveolus
Assaults on Respiratory System

• Epithelial tissue lining respiratory system is very delicate & exposed to chemicals they are not adapted to tolerate every day

• Air pollutants: $\text{SO}_2$, $\text{CO}$, $\text{O}_3$, asbestos all associated w/serious respiratory diseases/cancer
• one of the worst is tobacco smoke (single drag exposes a person to over 4,000 chemicals, more than 50 of which are carcinogens) (See next slide.)

• excessive exposure of alveoli to these pollutants causes them to become brittle, thin walled, & rupture (nonfunctional)
  - emphysema
This guy is a moron!

Every year in the U.S. alone, 444,000 people die from smoking-related illnesses; more than all deaths caused by traffic accidents, alcohol and drug abuse, HIV, and murders combined.

Young children are very susceptible, with increased risk of asthma, bronchitis, and pneumonia caused by smoking. Tobacco smoke damages cilia, reducing their ability to sweep mucus and trapped particles out of the respiratory tract. The body compensates by coughing.
Ventilating the Lungs

- Breathing: alternate between inhaling and exhaling

- Use a process known as **negative pressure breathing**: to inhale, we increase the volume of air in lungs by expanding the rib cage and contracting the diaphragm
- contracting the diaphragm (flattening) causes the thoracic cavity to enlarge

- to exhale, the ribcage contracts and the diaphragm relaxes

- maximum volume of air inhaled and exhaled during forced breathing (strenuous exercise) is the vital capacity
Control of Breathing

- Involuntary based on CO₂ level (pH)
- Controlled by breathing control center - pons & medulla (stem of brain)
- Sends impulses to muscles between ribs & diaphragm, causing contractions
• hyperventilating – rapid breathing that purges so much CO$_2$ from the blood that the control centers temporarily cease sending signals to the breathing muscles and breathing temporarily stops
Transport of Respiratory Gases in the Body

1. Blood Diffusion of Gases
   - $O_2$ & $CO_2$ & other gases diffuse down a pressure gradient to move in the body

2. Each kind of gas in the air mixture accounts for its own portion called **partial pressure** ($O_2$ diffuses from high [ ] to low [ ] w/regard to the [ ] of other gases)
3. Hemoglobin (a red blood cell protein) contains 4 Fe atoms that allow it to carry 4 O\textsubscript{2} molecules to body cells (4 polypeptide chains)

4. Hemoglobin is part of the blood-buffer system
   - Carries CO\textsubscript{2} from body cells to within the red blood cell’s hemoglobin in the form of carbonic acid
B. CO₂ transport in lungs

ALVEOLAR SPACE IN LUNG

CO₂

CO₂

H₂O

CO₂

H₂CO₃⁻ + H⁺

HCO⁻₃

Hemoglobin releases CO₂ and H⁺

• but depending on the blood pH, varying amounts of carbonic acid will breakdown into bicarbonate ions and H\(^+\) ions

• helps the blood from acidifying (normal pH ~ 7.4)

• Chicken eggs & bicarbonate
Fetal Gas Exchanges

- Fetal hemoglobin is different from adult hemoglobin (greater affinity for oxygen)
- Fetal blood in the placenta and maternal blood flow in the uterus in opposite directions also enhancing the exchange of oxygen between mother and child
Gas exchange between the human fetus and the mother

- Placenta, containing maternal blood vessels and fetal capillaries
- Umbilical cord, containing fetal blood vessels
- Amniotic fluid
- Uterus
Component Parts

- **Heart:**
  - atria – receive blood returning to heart (thin walled)
  - ventricles – pump blood out of heart (thick walled)
• **Blood Vessels:**
- **arteries** – carry blood from heart to body & branch into **arterioles** once inside organs
- **veins** – return blood to heart & **venules** are small vessels leading from organs to veins
- **capillaries** – network of tiny vessels which infiltrate each organ/are attached to **arterioles** on 1 side & **venules** on the other
Mammal Circulation Schemes

- 4 chambered heart (2 atria, 2 ventricles)
  - R atrium & R ventricle receive & pump blood, respectively, to pulmonary circuit
  - L atrium & L ventricle receive & pump blood, respectively, to systemic circuit
- Entire process is double circulation
Pulmonary Circuit – carries blood between the heart and the gas exchange tissues in the lungs

Systemic Circuit – carries blood between the heart and the rest of the body
- R ventricle pumps poor blood towards lungs
- 2 pulmonary arteries (1 leading to each lung)
- Lungs: \( CO_2 \) is exchanged for \( O_2 \) within capillaries (\( O_2 \)-rich blood now)
- 2 pulmonary veins (1 returning from each lung)
- L atrium receives \( O_2 \)-rich blood, pumps it to L ventricle
Flow of Blood
(Systemic Circuit)

• L ventricle pumps $O_2$ rich blood
• Aorta (largest artery) splits into smaller arteries to service various parts of body
• Arterioles to capillaries in organs where $O_2$ is exchanged for $CO_2$ (blood now $O_2$ poor)
• Venules to veins to vena cavae (inferior & superior)
• R atrium receives $O_2$ poor blood, pumps it to R ventricle
Blood Vessel Structure (General Makeup)

• **Connective tissue** – outside covering, elastic for stretching

• **Smooth muscle** – middle layer, allows arteries & veins to regulate blood flow by constricting

• **Epithelium** – smooth lining
Blood Vessel Structure (Arteries)

- Are the thickest walled blood vessels because they are nearest to the heart and must be able to withstand the greatest blood pressure.
Blood Vessel Structure (Veins)

- Are thinner walled than arteries
- Blood pressure is less
- Have interior valves & flaps projecting toward the heart to prevent back-flow, permitting blood flow only toward the heart
Blood Vessel Structure (Capillaries)

- The thinnest walled vessels where gas exchange takes place
- Fig. 34.9 p. 691
The Heart

• **Cardiac cycle** – sequence of events alternating between relaxation & contractions

• **Diastole** – the heart is relaxed, blood flows into all 4 chambers

• **Systole** – the heart muscles contract and the chambers pump
The Heart

• **Cardiac output** – volume of blood per minute that the left ventricle pumps into the aorta

• **Heart murmur** – occurs when there is a defect in 1 or more of the valves regulating the blood flow through the heart (blood squirts backwards through the valve)
WHEN GOOD VALVES GO BAD

Valves control the flow of blood through the heart. Women seem to have more defects in the mitral valve, while men have more defects in the aortic valve.

Healthy
The mitral valve has two leaflets—flaps that allow oxygen-rich blood to pass from the left atrium to the left ventricle, and close to prevent it from flowing back.

Floppy
Sometimes the flaps don’t close evenly, allowing a backflow of blood. If the flow is large, it can cause enlargement or thickening of the heart muscle.

Healthy
The aortic valve, with three leaflets, opens so the left ventricle can shoot blood into the aorta and then to the rest of the body.

Fused
Sometimes two of the leaflets are fused together, a congenital defect. This can lead to a narrowed opening or backflow through the valve.
Control of the Heart

- Sinoatrial (SA) node (pacemaker) sets the rate of contraction
- It is located in right atrium wall
- Maintains heart’s steady rhythm of beats – a self-pacing system

- Atrioventricular (AV) node is located at bottom of the wall separating the 2 atria
- When the wave of excitation initiated by the SA node reaches the AV node, it is delayed for 0.1 seconds
- It is then relayed to ventricles
• Heart disease can cause the SA node to not function normally – artificial pacemaker is implanted
Brain also influences heart rate:
- increase rate – excitement, exercise (sympathetic nervous system)
- decrease rate – depressed, asleep (parasympathetic nervous system)
Cardiovascular Disease
Heart Attack

• Death of cardiac muscle cells & the resulting failure of the heart to deliver enough blood to the rest of the body
- cells are nourished & supplied w/O\textsubscript{2} by the coronary arteries
- a blockage would cut off blood supply to part of the heart muscle
- cardiac muscle affected will die & be replaced w/scar tissue (but scar tissue doesn’t expand)
Cardiovascular Disease (Plaque)

• Plaques on the inner walls of the arteries could cause vessel blockage (called **atherosclerosis**) - it can make the opening of the artery smaller

- may cause occasional chest pains known as **angina pectoris**
Blood flow is prone to a problem called atherosclerosis. Arteries that supply blood can become narrowed as plaques grow within their walls, forming out of cholesterol, fatty compounds, calcium, and a tough, fibrous material. These plaques lead to clots, dangerously irregular heartbeats, and heart attacks.

1. A plaque, starting as a fatty streak, builds in an artery's inner lining.

2. The plaque swells as cholesterol and fat collect at the site. A thin, fibrous cap forms on the surface.

3. A rupture in the plaque surface can cause a clump of red blood cells and sticky platelets to form. This “red clot” can lead to a heart attack.
• **Blood pressure** – the force that blood exerts against the wall of our blood vessels

- much greater in arteries than in veins

- pressure in veins approaches zero
• Blood pressure depends partly on cardiac output & by the resistance to blood imposed by the blood vessels.

- measured in terms of systolic/diastolic pressure in mm Hg
- normal: 120/70
• **Hypertension** – (high blood pressure) persistent pressure at or above 140/90
- can promote atherosclerosis
- can increase the risk of heart attacks & strokes
- can result in kidney failure

*NOTE: strokes caused by Bruggies (pieces of plaque that have broken off & block the carotid artery)*
Chronic high blood pressure (hypertension) left untreated can lead to:

- Blood vessel damage (arteriosclerosis)
- Heart attack or heart failure
- Kidney failure

**BLOOD VESSELS**

**BURST VESSEL**
A blood vessel bursts, accounting for 20% of strokes

**CLOGGED VESSEL**
A blood clot forms, accounting for 80% of strokes
• **Pulse** rhythmic stretching of the arteries by the powerful contractions of the ventricles during the systole (reflects the # of heartbeats per minute)
Controls on the Distribution of Blood

• Only 5-10% of capillaries have blood flowing through them (exceptions: brain, heart)

• 2 mechanisms that control the distribution of blood to capillaries of the various organs (both depend on smooth muscle)
2 Mechanisms

- Constriction of arteriole walls decreases blood flow & relaxing of arteriole walls increases blood flow to capillaries

- Precapillary sphincters are rings of smooth muscle that when contracted can cut off blood supply to a particular region
  - allows for distribution of limited blood supply to areas of greatest need
Capillary Exchange

- Allow for transfer of materials between the blood & interstitial fluid
- Diffusion of molecules can occur across epithelial cells of the capillary wall & in between clefts adjoining epithelial cells
- water and small solutes such as sugar, salts, oxygen, and urea move freely

- proteins and blood cells are too large to pass
Blood has 4 Main Components:
The Blood

**Plasma**

- Liquid matrix of blood in which cells are suspended
- Variety of solutes
  - inorganic salts (electrolytes) help maintain osmotic balance & help buffer blood
  - also contains dissolved nutrients, waste products, hormones, etc.
Found in **PLASMA**

血被抽出...并放入管中。

55% PLASMA

<table>
<thead>
<tr>
<th>Contents</th>
<th>Basic functions</th>
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</thead>
<tbody>
<tr>
<td>water</td>
<td>a solution for transporting other substances</td>
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<tr>
<td>salts (electrolytes)</td>
<td>regulation of osmotic balance, pH balance and membrane permeability</td>
</tr>
<tr>
<td>Sodium</td>
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<td>Potassium</td>
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<td>Chloride</td>
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<td>Bicarbonate</td>
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<tr>
<td>plasma proteins</td>
<td>osmotic balance, pH balance, Blood clotting</td>
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<tr>
<td>Fibrinogen</td>
<td>Defense (antibodies) and fat transportation</td>
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<tr>
<td>Globulins</td>
<td>Substances carried in the blood</td>
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<tr>
<td>Nutrients (glucose, vitamins, amino acids)</td>
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<tr>
<td>Metabolism wastes (urea, uric acid)</td>
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<td>Respiratory gasses (CO2 and O2)</td>
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<td>Hormones</td>
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Red Blood Cells [RBC]

• Called erythrocytes
• Biconcave disk (flatter in center than on its edge)
• Contains molecules of hemoglobin
• transport $O_2$ from lungs & $CO_2$ back to lungs
• Formed in red marrow of bone
Anemia – low # of RBCs or an abnormally low amount of hemoglobin
White Blood Cells [WBC]

- Called leukocytes
- Used to fight infection
- 5 types of leukocytes – some eat bacteria & some produce antibodies
- Made in bone marrow & mature in lymphoid organs
The cancer is being killed by immune system's killer T-cells. The red object on this picture is the cancer, and the long green objects are the killer T-cells.
Platelets

- Chips of cytoplasm involved in clotting process
- When you cut yourself, a sealant called fibrinogen (plasma protein) activates
  - converts to its active form fibrin
  - fibrin forms threads, which clot blood
Platelet Problems

- Hemophilia – defect in clotting process
- Spontaneous clotting in the absence of injury can occur
  - clotting can block a vessel (called a thrombus)
  - blocked coronary artery leads to heart attack
Stem Cells

- WBCs, RBCs, & platelets arise from cells within bone marrow known as stem cells.
- When WBCs become malignant it results in a cancer called leukemia.
• A new technique is to isolate the master blood-forming stem cells
  - injection of these cells into an individual could completely repopulate the person’s blood & immune system
  - could be a treatment for leukemia, AIDS, etc
Hematopoetic stem cell

Stromal stem cells

Natural killer cell

Lymphoid Progenitor cell

Multipotential stem cells

Myeloid progenitor cell

B lymphocyte

T lymphocyte

Neutrophil

Basophil

Eosinophil

Monocyte macrophage

Platelets

Red Blood Cells

Bone (or cartilage) Osteoblast Lining cell

Pre-osteoblast Osteocyte

Skeletal muscle stem cell

Hepatocyte stem cell

Hematopoetic supportive stroma

Marrow adipocyte