Grade 11 Biology

Animals – Structure and Function

Class 12

Aerobic Cellular Respiration

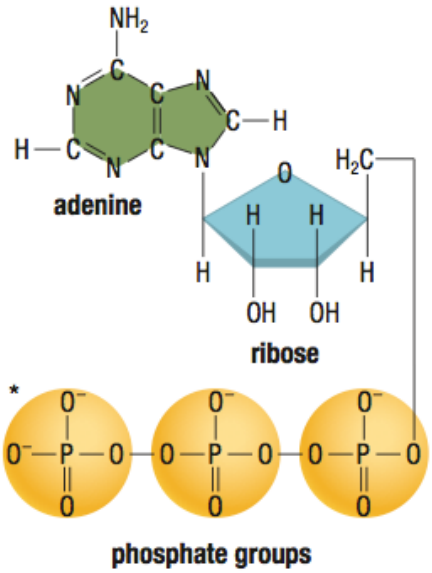
- The series of chemical reactions that occur in the cell that provide energy and consume oxygen

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

(glucose + oxygen → carbon dioxide + water + energy)

- 64% of the energy is released as thermal energy
- 36% of the energy is stored as adenosine triphosphate (ATP)

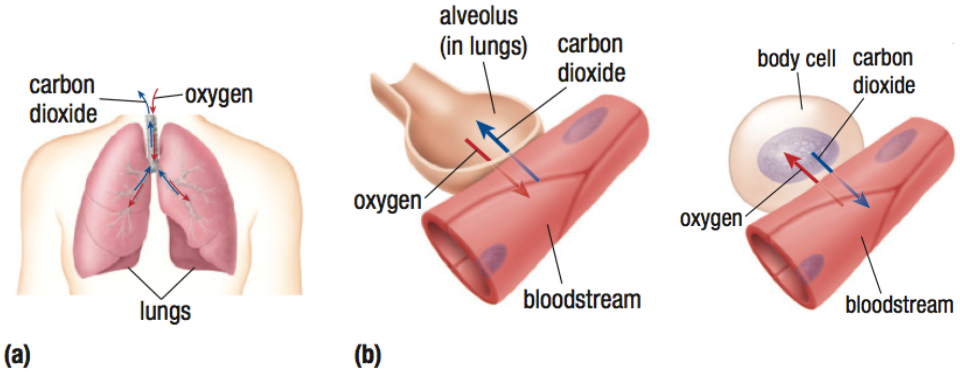
Adenosine Triphosphate (ATP)



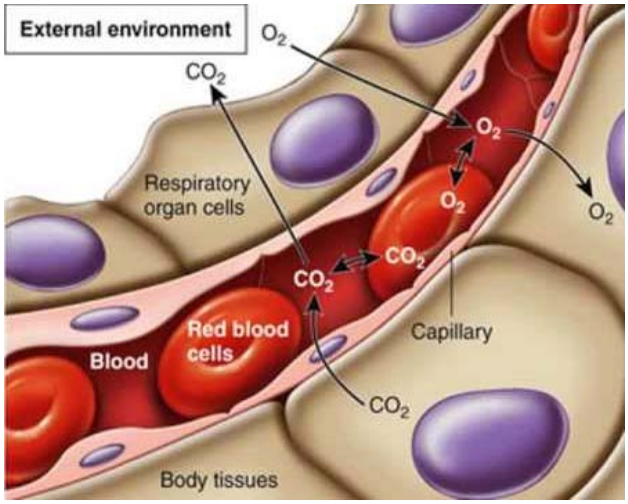
- Phosphorylation – formation of ATP from ADP and an inorganic phosphate
- Removal of one phosphate group from ATP releases energy to do work in the cell

Gas Exchange and Ventilation

- Gas exchange – diffusion of oxygen into the body and diffusion of CO_2 out of the body
- Ventilation - the process of breathing



- **External Respiration**: Exchange of gases between alveoli and capillaries
- **Internal Respiration:** Exchange of gases between capillaries and tissue



Respiratory Structures

- Consists of:
  - Thin, permeable membrane for diffusion
  - Large surface area for gas exchange
  - Dense network of capillaries
  - Breathing system for bringing air to the membrane
- Lungs are enclosed within the thoracic cavity and are protected by a rib cage

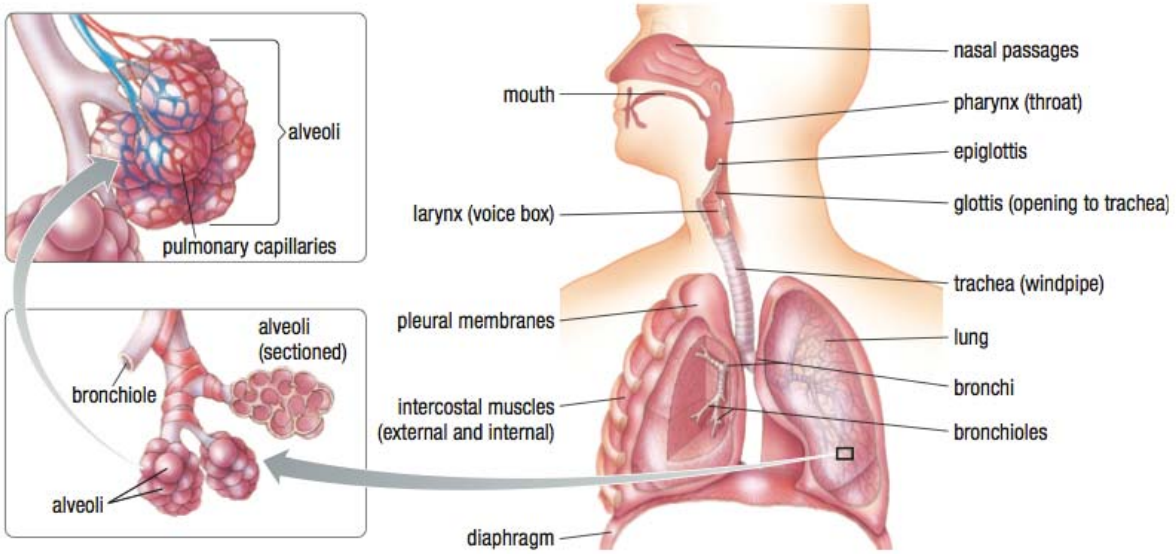
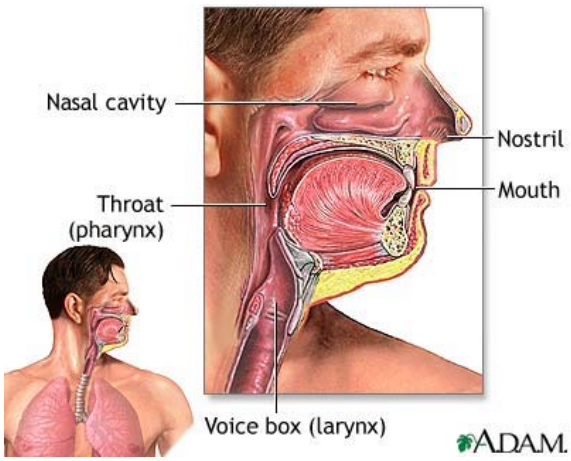


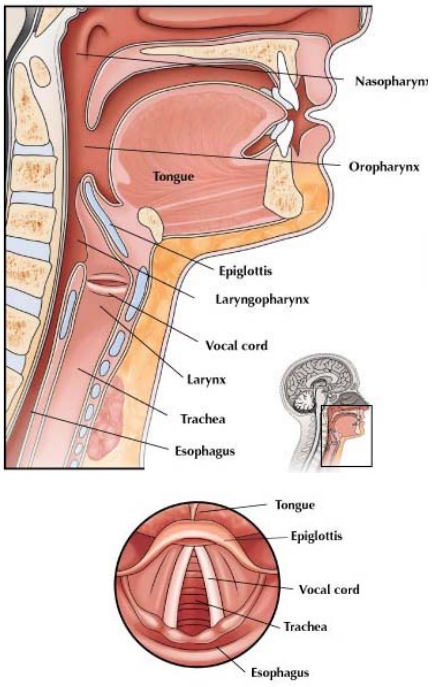
Figure 1 The human respiratory system

Nasal Cavity/Mouth



- Passage allowing air to enter the body
- Capillaries: warm air, oxygen utilization
- Mucus: Moisten and filter the air
- Cilia/Hair: Filter out debris and large particles

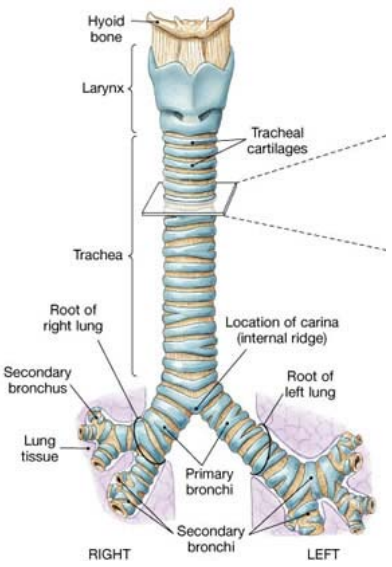
Throat

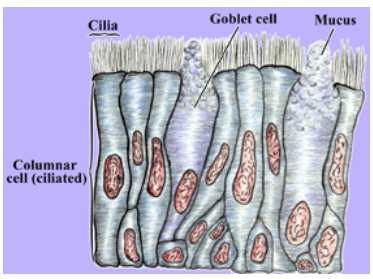


- **Pharynx** – passage for air to reach the trachea
- **Epiglottis** – tiny flap that remains open to allow air to enter trachea
- **Larynx** – vocal cords: highly elastic folds that produce sound when air passes between them; protected by cartilage rings

Trachea

- Passage for air to reach bronchi
- Surrounded by cartilage rings – tough but flexible rings that prevent collapse
- Contains mucus-secreting cells to trap particles
- Cilia on the lining brush upward (escalator) to remove dirt and debris



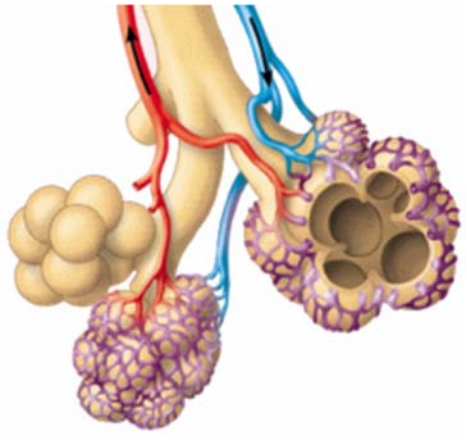


Coughing vs. Sneezing

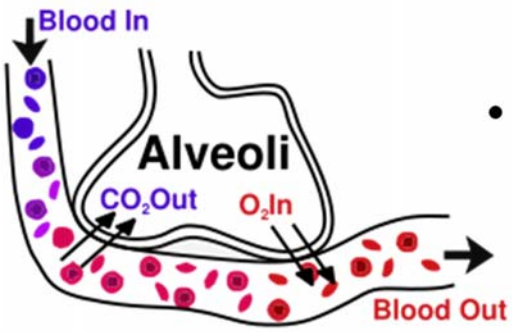
- Why do we cough?
  - To get rid of irritants in the pharynx-trachea area
  - A rush of air (160km/h) to remove the irritant
- Why do we sneeze?
  - To get rid of irritants in the nasal cavity

Bronchi and Bronchioles

- **Bronchi** – right/left passages to move air into bronchioles, lined with cilia, contains cartilage rings
- **Bronchioles** – Small air passages to move air into alveoli, large ones have cilia, no cartilage rings



From the Heart



To the Heart

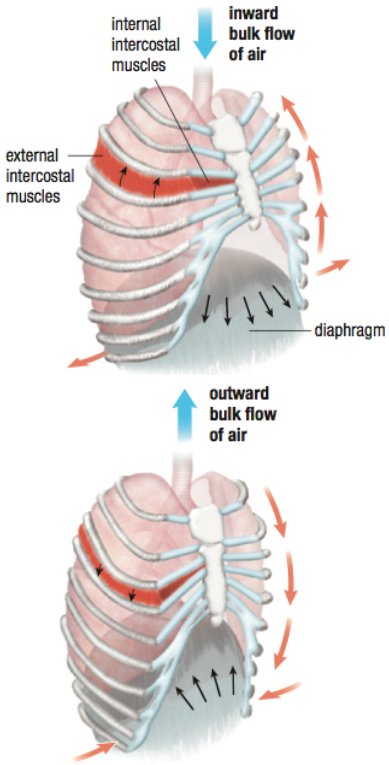
Alveoli

- Clusters of tiny hollow air sacs measuring 0.1µm to 0.2µm in diameter
- One-cell thick for gas exchange with the capillary network
- Increased surface area available for maximum gas diffusion

Mechanism of Ventilation

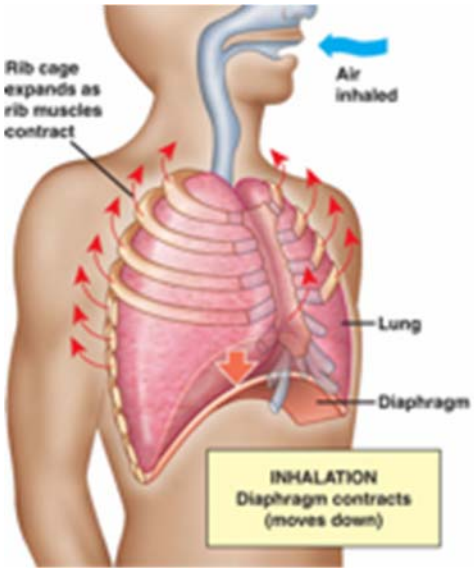
- Gases move from an area of high pressure to low pressure
- When air pressure inside the lungs is lower than the atmospheric pressure, air is forced into the lungs
- When air pressure inside the lungs is higher than the atmospheric pressure, air is forced out of the lungs

Diaphragm



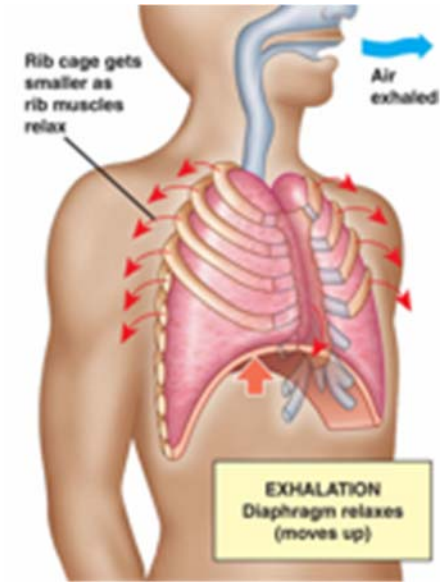
- Large dome-shaped sheet of muscle called **diaphragm** separates thoracic from abdominal cavity
- **External intercostal muscles** contract and pull the ribs upward and outward
- **Internal intercostal muscles** pull ribs downward increasing the pressure inside and forcing air out of the lungs

Inspiration



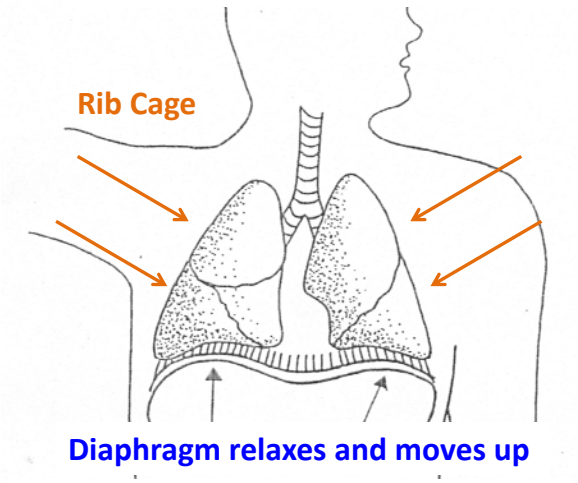
- Diaphragm pulls downward
- Chest cavity increases
- Pressure in the lungs decreases
- Atmosphere pressure is greater than lung pressure, so air moves into the lungs

Expiration



- Diaphragm relaxes and moves upward
- Chest cavity decreases
- Pressure in the lungs increases
- Atmospheric pressure is less than lung pressure so air moves out of lungs

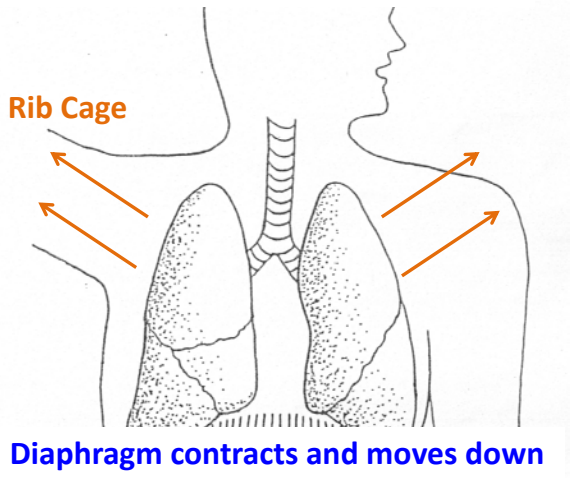
External intercostal muscles relax
Internal intercostal muscles contract
= Rib cage moves down and in



Lung volume decreases
Internal pressures increases
= Air moves from lungs to atmosphere

Expiration

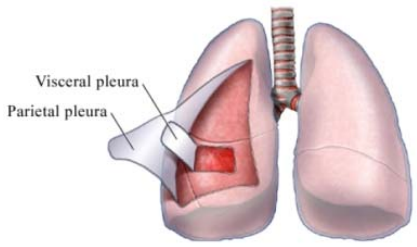
External intercostal muscles contract
Internal intercostal muscles relax
= Rib cage moves up and out

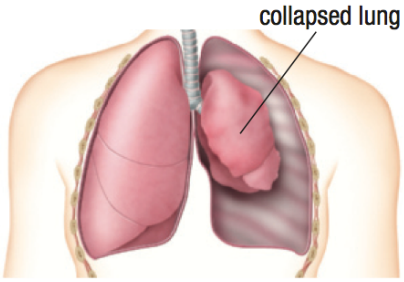


Lung volume increases
Internal pressures decreases
= Air moves from atmosphere to lungs

Inspiration

Pleural Membranes



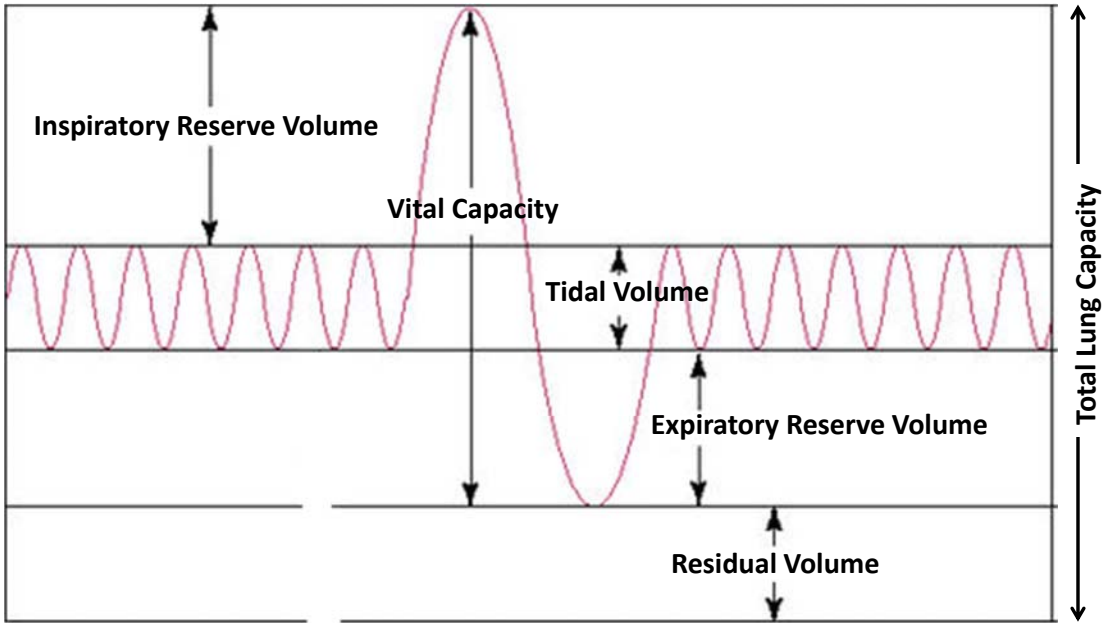


- Pleural membranes cover the lungs and line the thoracic cavity
- Pleural cavity is filled with fluid to allow membranes to slide past each other
- Pneumothorax – a collapsed lung caused by the introduction of air between the pleural membranes; lung cannot inflate

Lung Capacity

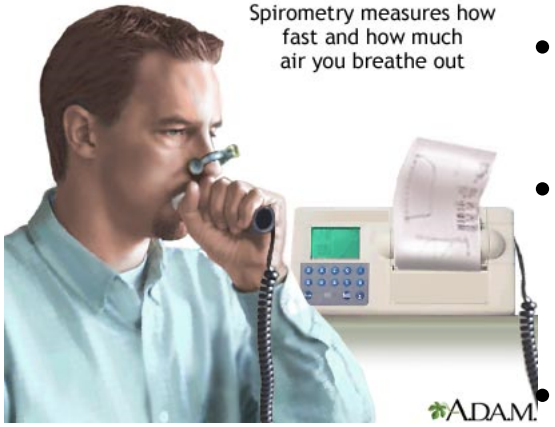
- Lung volume depends on sex, body type, and lifestyle
- On average, males, non-smokers and athletes have larger lung volumes than females, smokers and non-athletes
- **Total Lung Capacity** – the maximum volume of air that can be inhaled during a single breath

- **Tidal Volume -** the amount of air that passes in and out of the lungs with each breath under normal conditions; around 0.5L
- **Vital Capacity** – the maximum tidal volume
  - Males: 4.4-4.8L; Females: 3.4-3.8L
- **Expiratory Reserve Volume -** the amount of air that can be forcefully exhaled after the normal tidal volume is exhaled
- **Inspiratory Reserve Volume -** the extra volume of air that can be taken in after the normal tidal volume is inhaled
- **Residual Volume** – the air remaining in the lungs to prevent the lungs from collapsing



Spirometry

- Tests to measure how fast and how much you breathe out



- Breathe through a mouthpiece
- Machine traces the rate of air moving through the lungs
- Calculates VO_2

Oxygen Usage

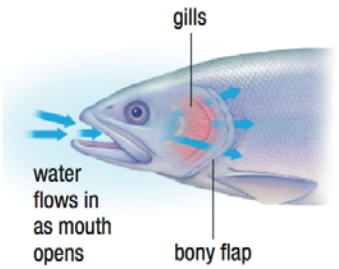
- **VO_2** – rate at which oxygen is used in the body, measured in mL/kg/min

Table 1 VO_2max Norms for Men (M) and Women (F) (mL/kg/min)

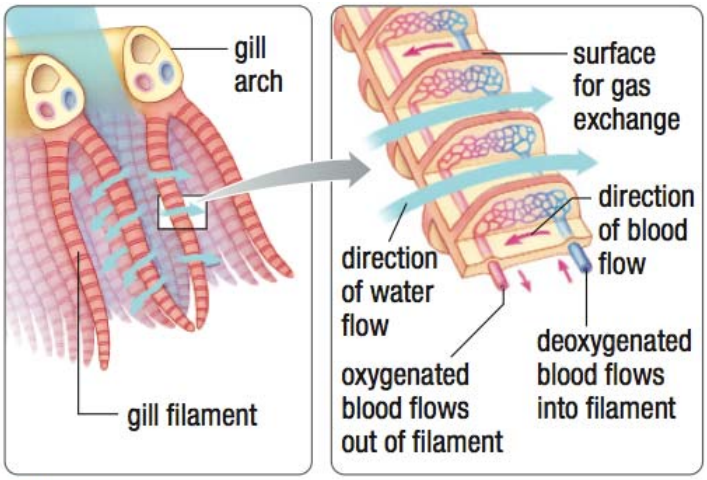
Age	M/F	Very poor	Poor	Fair	Good	Excellent	Superior
13–19	M	<35.0	35.0–38.3	38.4–45.1	45.2–50.9	51.0–55.9	>55.9
	F	<25.0	25.0–30.9	31.0–34.9	35.0–38.9	39.0–41.9	>41.9
20–29	M	<33.0	33.0–36.4	36.5–42.4	42.5–46.4	46.5–52.4	>52.4
	F	<23.6	23.6–28.9	29.0–32.9	33.0–36.9	37.0–41.0	>41.0
30–39	M	<31.5	31.5–35.4	35.5–40.9	41.0–44.9	45.0–49.4	>49.4
	F	<22.8	22.8–26.9	27.0–31.4	31.5–35.6	35.7–40.0	>40.0
40–49	M	<30.2	30.2–33.5	33.6–38.9	39.0–43.7	43.8–48.0	>48.0
	F	<21.0	21.0–24.4	24.5–28.9	29.0–32.8	32.9–36.9	>36.9
50–59	M	<26.1	26.1–30.9	31.0–35.7	35.8–40.9	41.0–45.3	>45.3
	F	<20.2	20.2–22.7	22.8–26.9	27.0–31.4	31.5–35.7	>35.7
60+	M	<20.5	20.5–26.0	26.1–32.2	32.3–36.4	36.5–44.2	>44.2
	F	<17.5	17.5–20.1	20.2–24.4	24.5–30.2	30.3–31.4	>31.4

Respiratory Structures in Fish

- Aquatic organisms obtain oxygen from water using their gills
- Gills have several gill arches with gill filaments to provide maximum surface area for gas exchange
- Surrounded by capillaries which undergoes countercurrent exchange to maximize gas exchange



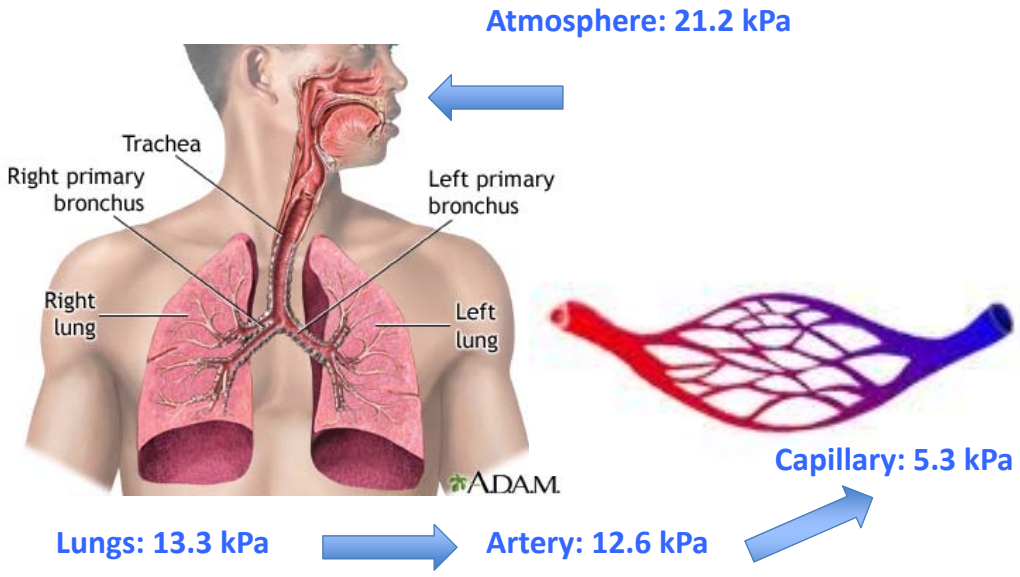
(a)



(b)

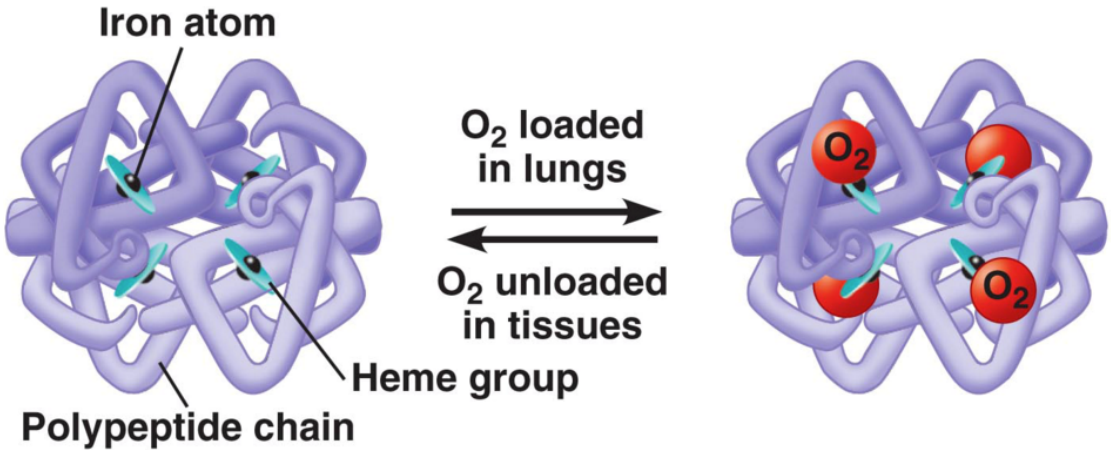
Transport and Diffusion of Gases

- Gases diffuse from an area of high pressure to an area of low pressure
- Highest pressure of oxygen is found in the atmosphere (21.17 kPa)
- Lowest pressure of oxygen is found in the capillaries (5.3 kPa)
- Pressure gradient allows oxygen to diffuse from the air into the alveoli and into the blood plasma



Oxygen Transport

- Oxygen is transported by two ways:
  - Hemoglobin in red blood cells (98.5%)
  - Blood plasma (1.5%)
- Oxygen binds to hemoglobin, an iron-containing protein in red blood cells to form oxyhemoglobin
- Hemoglobin increases the blood's capacity to carry oxygen by 70 times



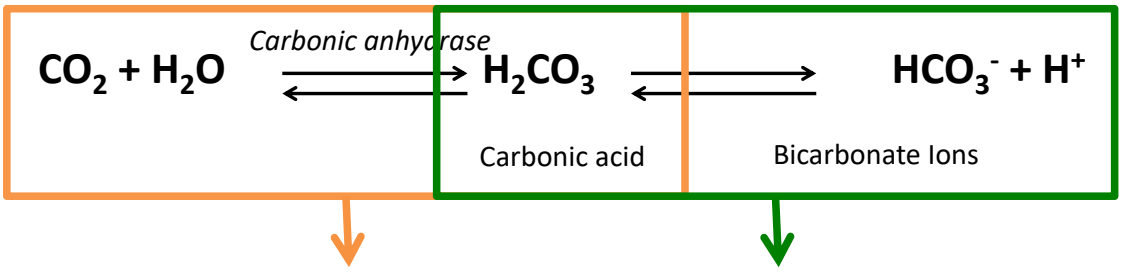
Carbon Dioxide Transport

- Carbon dioxide is transported by three ways:
  - Dissolves in plasma (7%)
  - Combines with hemoglobin to form carbaminohemoglobin (20%)

$$\mathbf{CO_2 + Hemoglobin \rightleftharpoons Carbaminohemoglobin}$$

  - Reacts with water to form H_2CO_3 which turns into HCO_3^- and H^+ (70%)

Carbonic acid and Bicarbonate ions



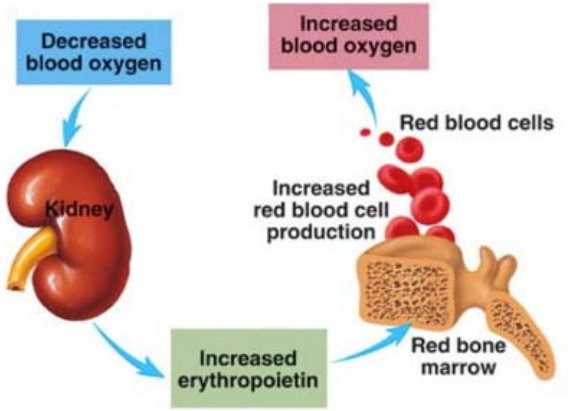
- Occurs in the red blood cell
- Rapid conversion of free CO_2 decreases the concentration of CO_2 in the plasma
- More CO_2 can continue to diffuse into the blood

- H_2CO_3 dissociates into bicarbonate ions and hydrogen atoms
- H^+ causes acidity = acidic blood?
- H^+ binds with hemoglobin = buffer

Effect of Altitude on Respiration

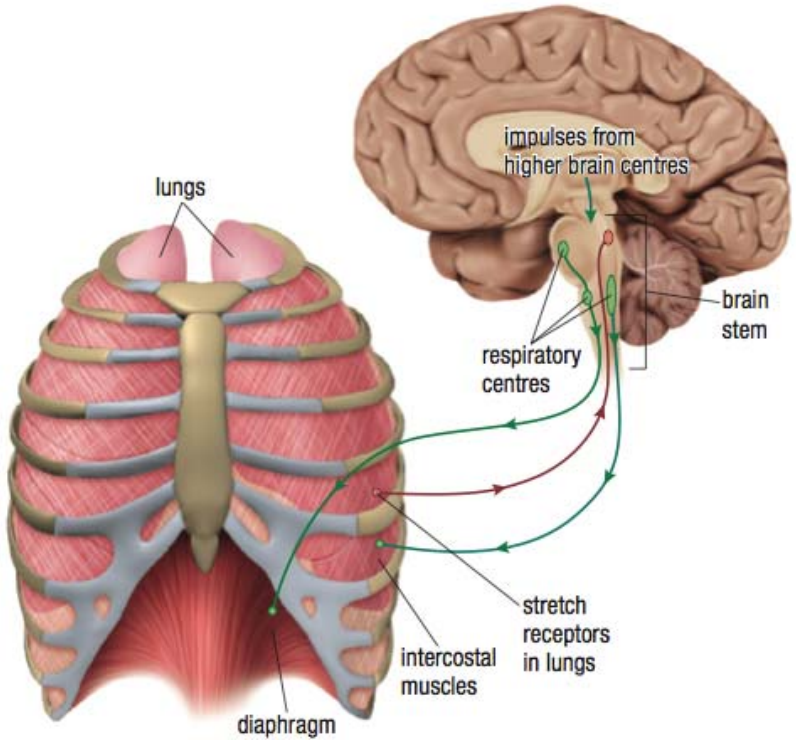
- Less oxygen at higher altitudes
- Pressure gradient of oxygen is reduced so the rate of diffusion decreases and oxygen supply is reduced
- Causes altitude sickness
  - Shortness of breath
  - Headache
  - Dizziness
  - Nausea

- Kidneys increase erthropoietin (EPO) secretion which stimulates production of red blood cells to allow more oxygen to be absorbed
- Synthetic EPO is used to treat anemia but it is banned in many sports competition; considered blood doping



Control of Breathing

- Breathing is mostly an involuntary action
- Rhythmic inhalation and exhalation are controlled by the respiratory centre in the brain stem
- Brain sends signals to cause diaphragm and external intercostal muscles to contract
- Stretch receptors in the lungs sends signals to the brain indicating that the lungs have expanded
- Brains stops the signals and muscles relax

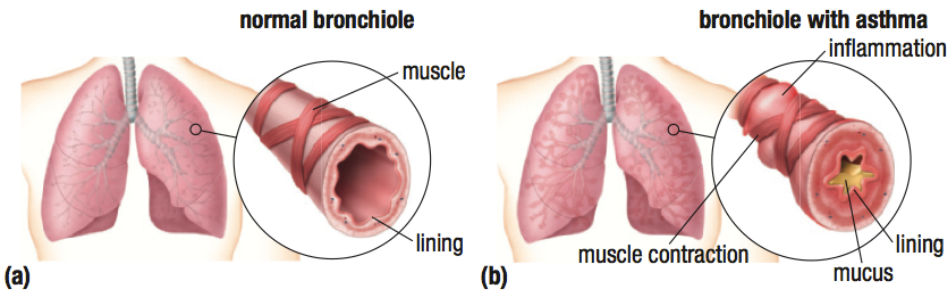


- Oxygen and CO_2 levels are monitored by chemical receptors in the brain and in the arteries in the neck and the arteries leaving the heart
- Increase in cellular respiration causes blood to become acidic, which is detected by the chemical receptors
- Brain signals for rapid and forceful breathing and increased heart rate to remove carbon dioxide
- Monitoring of oxygen levels is a secondary breathing control mechanism; not as significant as CO_2

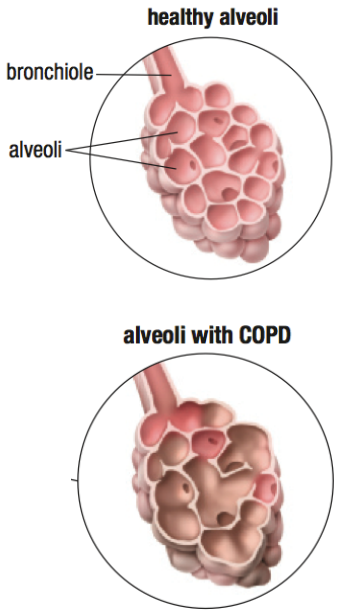
Disorders of the Respiratory System

Asthma

- 10% of Canadian have asthma
- Chronic, long term inflammation of the lining of the bronchi and bronchioles which causes swelling and reduced airflow



- Symptoms of Asthma
  - Coughing, wheezing, tightness in the chest, shortness of breath, asthma attack
- Causes of Asthma
  - Cigarette smoke, dust, cold air, physical exertion, allergens, pollution, dust mites and animal dander
- Treatment of Asthma
  - Avoiding the triggers
  - Medication to dilate the bronchi and bronchioles via inhalers (puffers) or to reduce inflammation in the air passages



Chronic Obstructive Pulmonary Disease (COPD)

- Long-term respiratory disease that combines bronchitis and emphysema
- Bronchitis is an irritation and inflammation of the airways reducing airflow to the lungs
- Emphysema causes permanent damage in the walls of the alveoli leading to reduced surface area for gas exchange

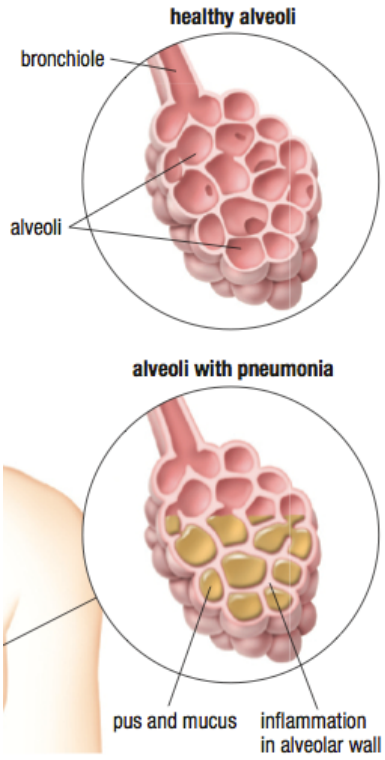
- Symptoms of COPD
  - Coughing, wheezing, chest tightness, shortness of breath even when at rest
- Causes of COPD
  - Cigarette smoke, marijuana smoke, air pollution, dust or fumes
  - Genetic disorder
- Treatment of COPD
  - Lifestyle changes
  - Oxygen therapy
  - Lung transplants

Influenza (flu)

- Caused by a virus
- Symptoms: fever, dry cough, sore throat, runny nose, and muscle/joint aches
- Can be transmitted from droplets in the air, physical contact with person or contaminated surface
- Vaccines can be used to prevent the infection but it takes 6 months to develop and test the vaccine

Tuberculosis (TB)

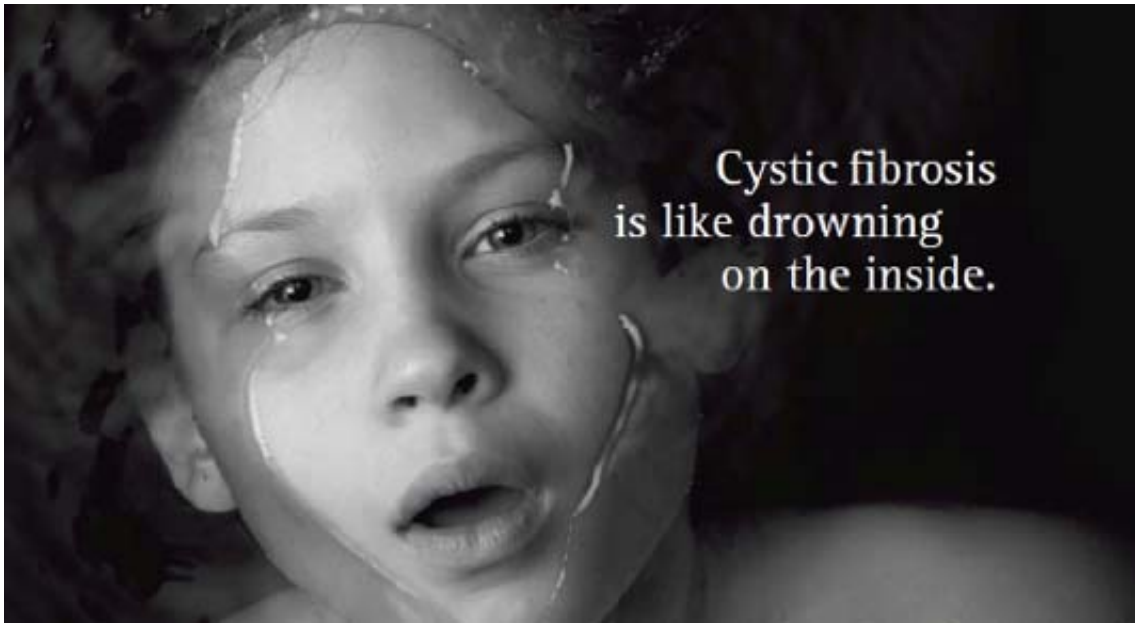
- Caused by bacterial infection *M. tuberculosis*
- Symptoms: coughing, chest pain, weight loss, night sweats and coughing up blood
- Infected person may show no symptoms until their immune system is weakened
- Vaccines have been developed to protect children against TB
- Treatment consists of a 6-month course of antibiotics



Pneumonia

- Infection of the lungs caused by bacteria, viruses or fungi
- Causes inflammation of the bronchi, bronchioles and alveoli
- Formation of pus and mucous in the alveoli, preventing gas exchange

- Symptoms of Pneumonia:
  - Fever, cough, shortness of breath
  - Can be diagnosed by analyzing the phlegm or X-rays
- Pneumonia can be fatal for those with weakened immune systems such as seniors and infants
- Bacterial pneumonia can be treated with antibiotics



Cystic Fibrosis (CF)

- Hereditary disorder where there is an overproduction of mucous that clogs airways
- Symptoms: persistent cough and excess mucous
- CF makes individual more susceptible to lung infections due to growth of bacteria and fungi
- Patients require ongoing and continuous therapy to alleviate their symptoms and prevent worsening of the condition

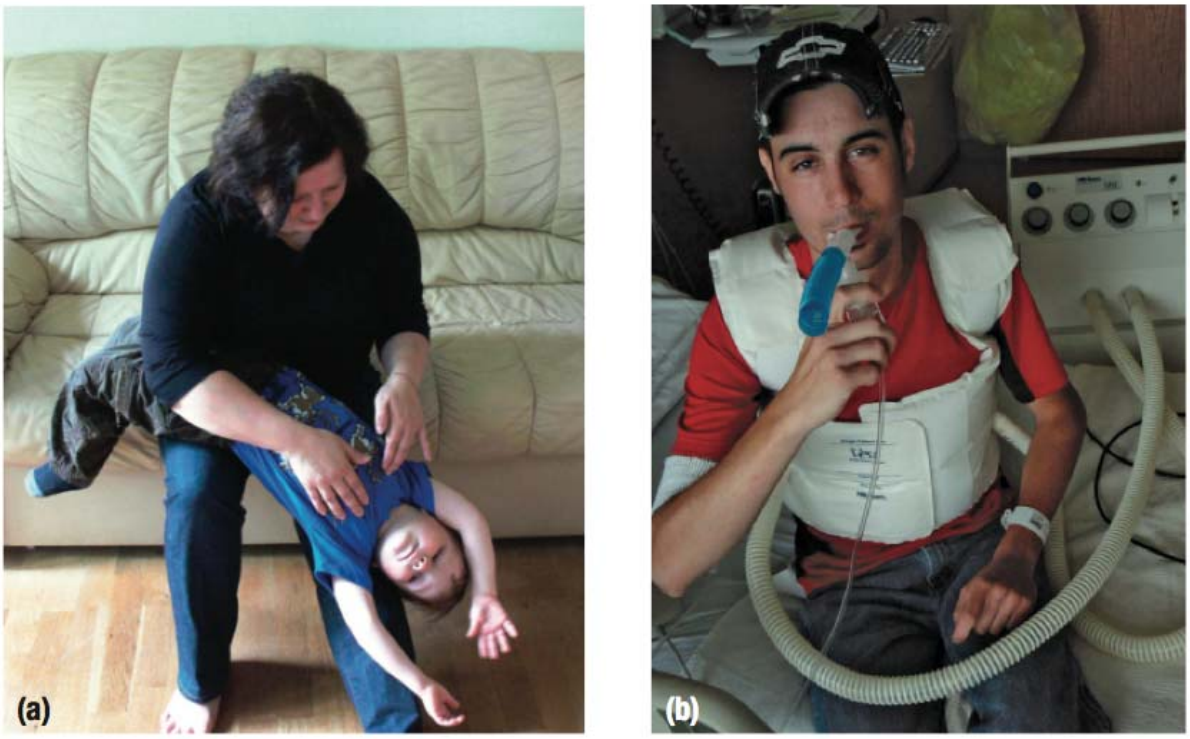
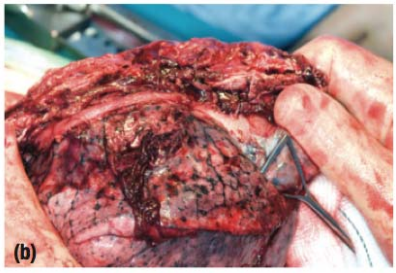


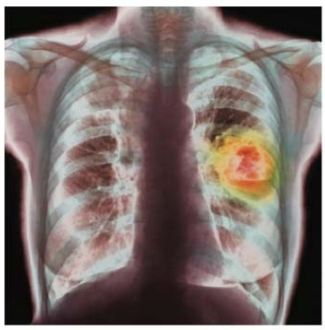
Figure 7 (a) Regular percussion (gentle pounding) of the chest is a standard CF therapy that helps loosen the mucus so that it can be coughed up more easily. (b) A mechanical vest has been developed to simulate the pounding of the chest.

Effects of Smoking

- Most problematic substances in cigarettes:
  - **Nicotine** – addictive chemical produced by the tobacco plant; produces dopamine and endorphins which lasts for 40 min
  - **Carbon monoxide** – hemoglobin prefers to bind to carbon monoxide than oxygen; reduced oxygen to the cells
  - **Tar** – black, sticky substance that accumulates in the alveoli preventing gas exchange; inactivates cilia; increases mucous production and inflammation

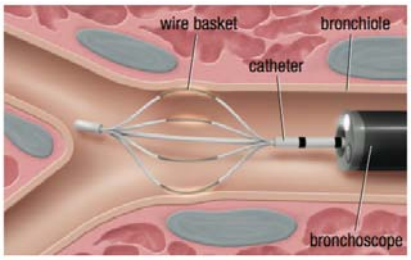
- Cigarette smoke also contains carcinogenic substances such as formaldehyde, benzene and hydrogen cyanide
- Lung cancer can originate in the lungs and spread to other parts of the body



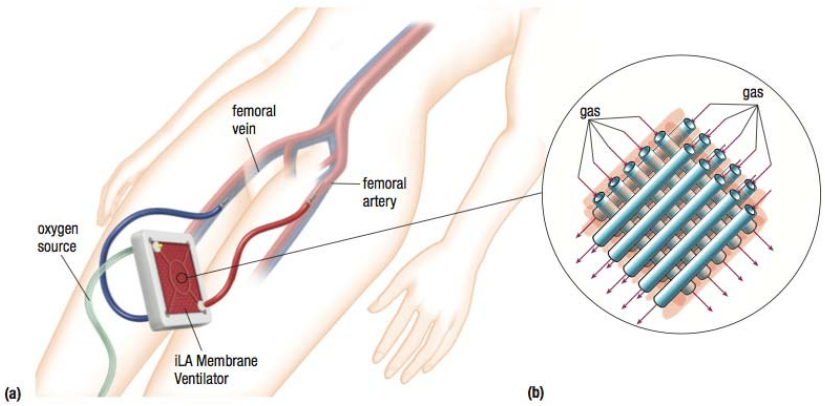


New Technologies

- FLAP inhibitors – drugs that interfere with the production of chemicals that cause inflammation
- Bronchial Thermoplasty – uses thermal energy to reduce the thickness of muscles in the bronchioles thereby reducing constriction

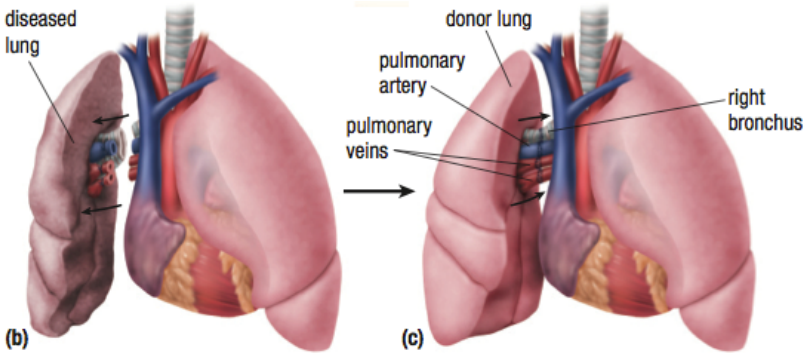


- Artificial Lungs – the iLA Membrane Ventilator connects to the body by two tubes that are inserted into the femoral blood vessels in the thigh
  - Removes carbon dioxide from the blood
  - Adds oxygen into the blood



Lung Transplant

- Involved replacing one or both diseased lungs with healthy lungs from a deceased donor
- Sections of lungs can also be transplanted from living donors



- Patient must use immunosuppressant drugs to prevent rejection of the donated lung
- Survival rate of lung transplant patients is around 60%
- Main problem is the shortage of organs
- In Canada, 40 patients every year while waiting for a donor lung