FCB Unit IV

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Cellular respiration

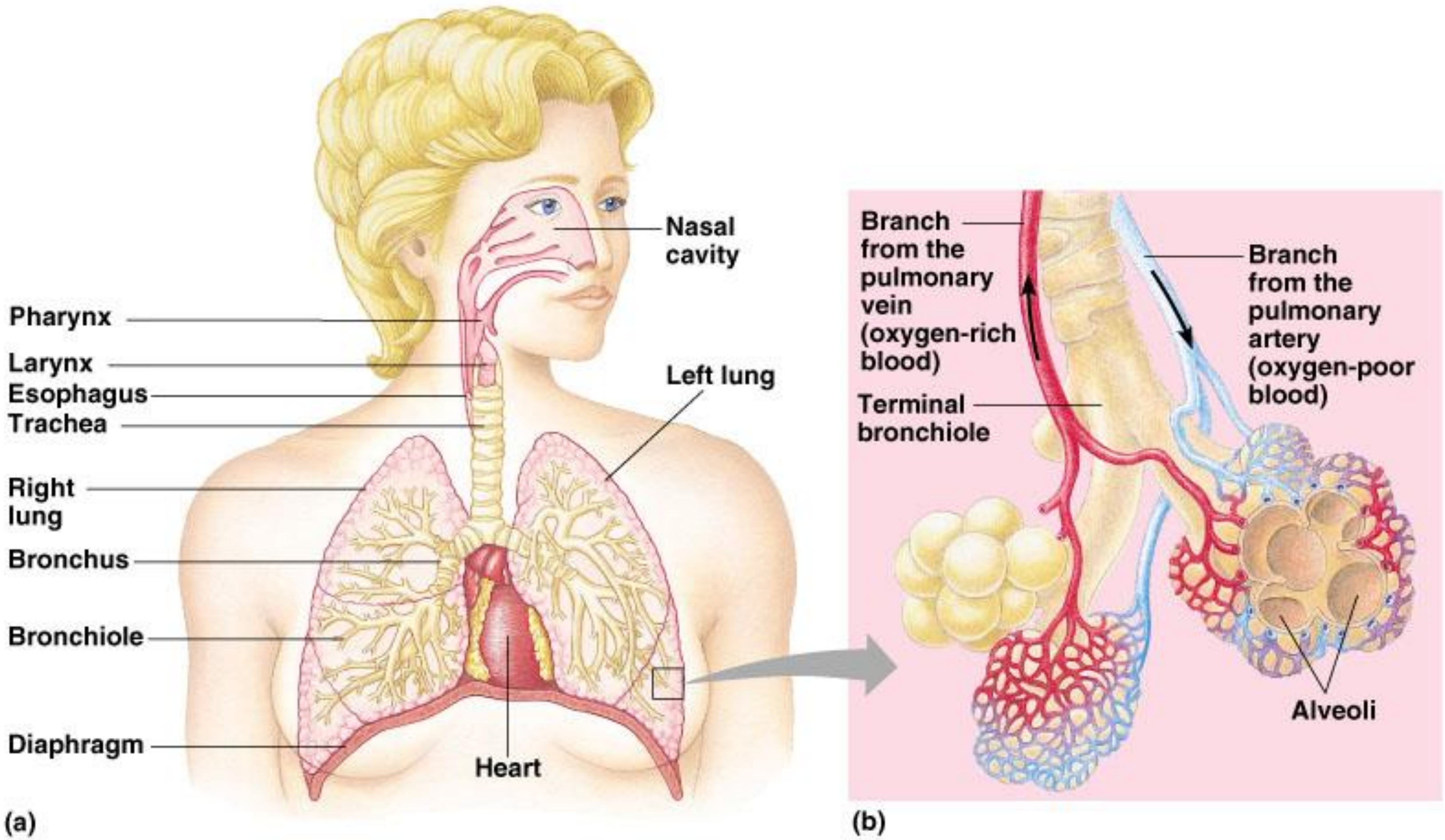
Cellular Respiration

- How energy is produced in all living system?
  - Most energy used thru conversion of ATP molecules into ADP molecules
  - Thus cells must continually convert ADP molecules back into ATP molecules
  - This process is known as respiration

- There is a difference between breathing and respiration
  - Breathing: physical process that involve exchange of gases from environment to cells.

  - Cellular respiration: chemical process that releases energy from organic compounds (food), gradually converting it into energy that is stored in ATP molecules

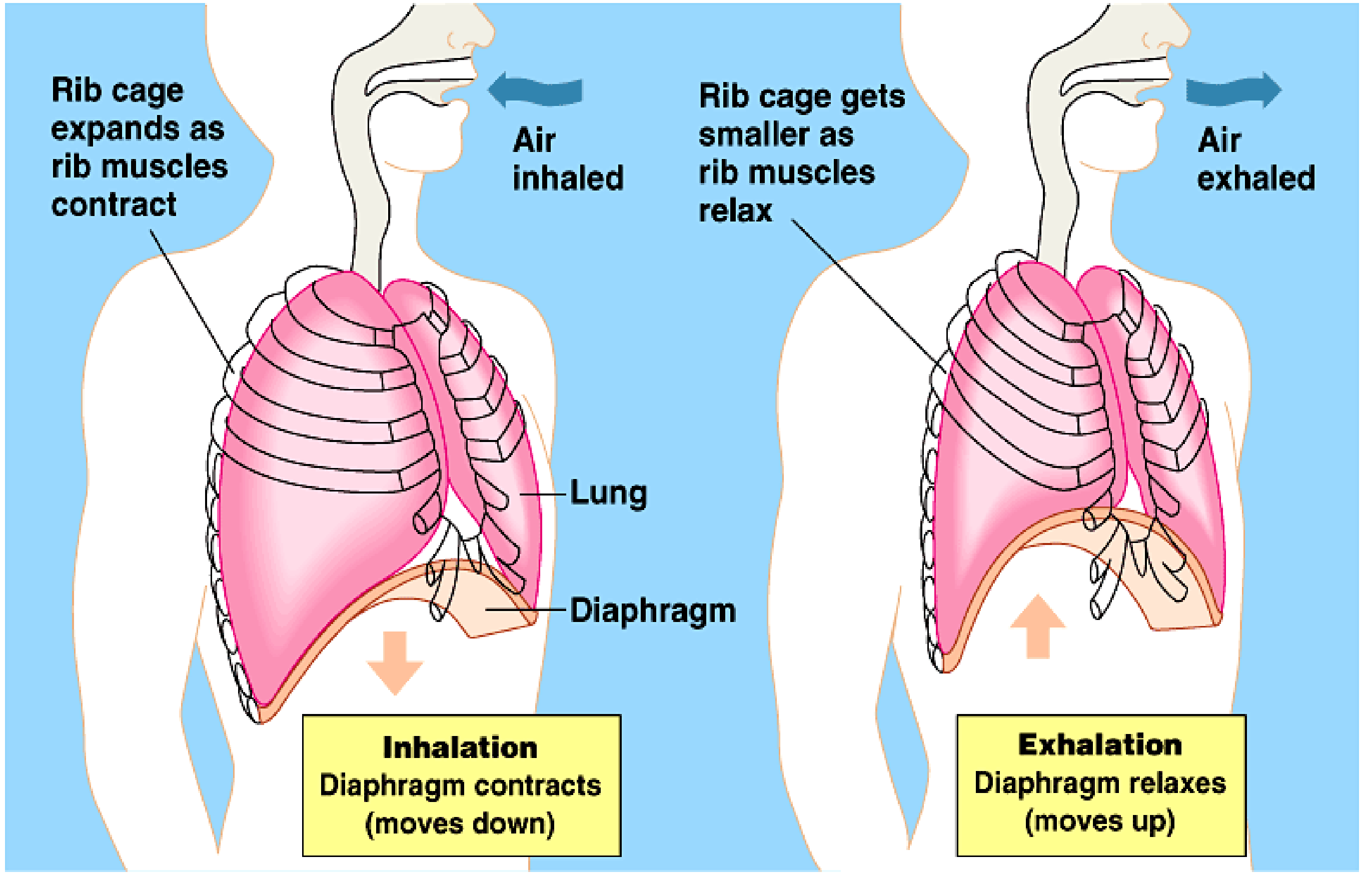
Breathing



Nasal cavity
Pharynx
Larynx
Esophagus
Trachea
Left lung
Right lung
Bronchus
Bronchiole
Diaphragm
Heart
(a)
Branch from the pulmonary vein (oxygen-rich blood)
Terminal bronchiole
Branch from the pulmonary artery (oxygen-poor blood)
Alveoli
(b)

Gas exchange

- Oxygen diffuses from alveoli→capillaries
- It loosely bonds to hemoglobin, forming oxyhemoglobin
- The oxygen separates from the blood in the body tissues
- Carbon Dioxide and water diffuse from cells into capillaries
- Carbon dioxide is carried in the form of bicarbonate ions (HCO_3-)
- In lungs, these wastes diffuse from the capillaries into alveoli

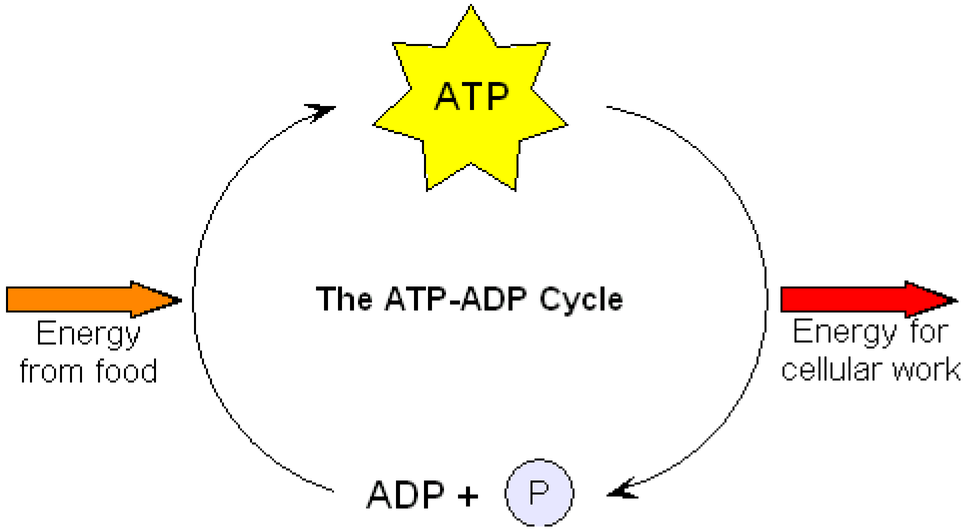


Disorders of the Respiratory System

- Asthma: Allergic reaction where bronchial tubes narrow and make breathing difficult
- Bronchitis: Inflammation of bronchial tube linings. Swelling causes air passages to become narrowed and mucus filled. Coughing and difficulty breathing is a result
- Emphysema: Walls of the alveoli break down. This decreases surface area. Shortness of breath, difficulty in breathing, decreased lung capacity is a result

Cellular respiration

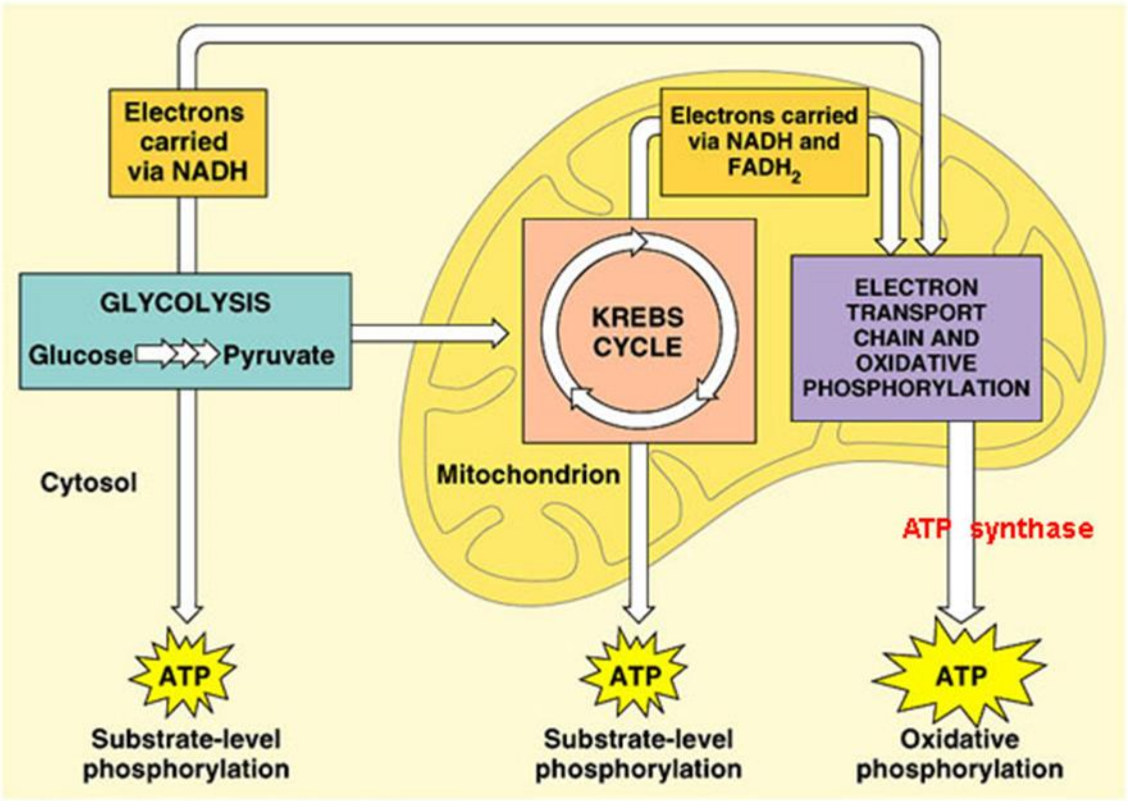
- A series of enzyme-controlled reactions in which the chemical bond energy released by the breakdown of glucose is transferred to the bonds of ATP.
  - This happens in the mitochondria for aerobic cellular respiration
  - It happens in the cytoplasm for anaerobic cellular respiration



Cellular respiration

- Three pathways:
  - Glycolysis
  - Krebs cycle
  - ETC

- **glycolysis**: releases only a small amount of energy (2 net ATP)
  - If oxygen present, it will lead to two other pathways that release a lot of energy: Krebs cycle & Electron Transport Chain
  - If oxygen absent glycolysis is followed by a different pathway: Alcoholic Fermentation or Lactic Acid Fermentation



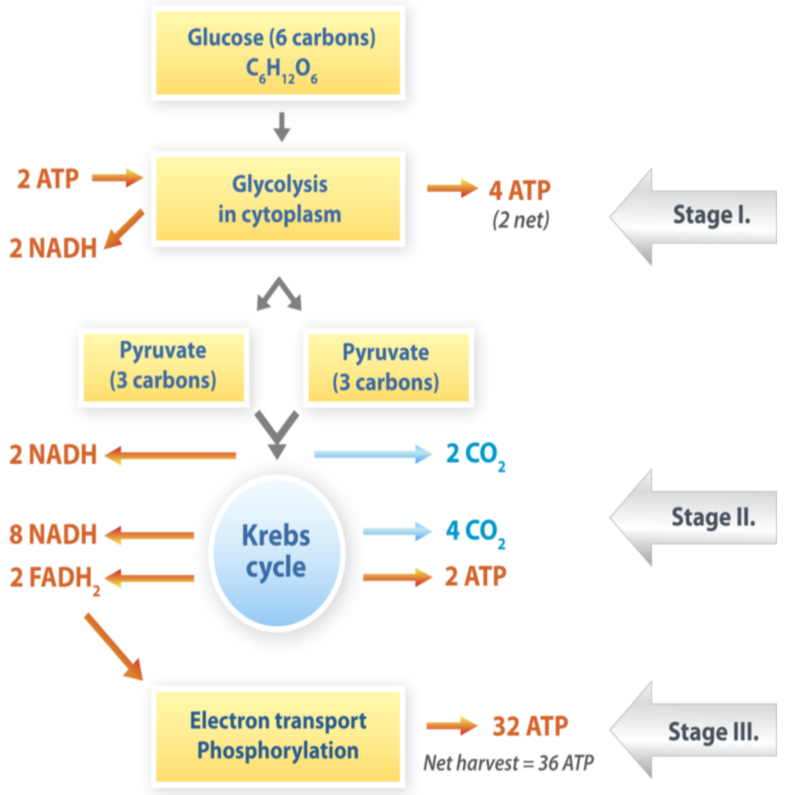
Respiration equation

- All three combined make up Cellular Respiration: Glycolysis + Krebs Cycle + Electron Transport Chain

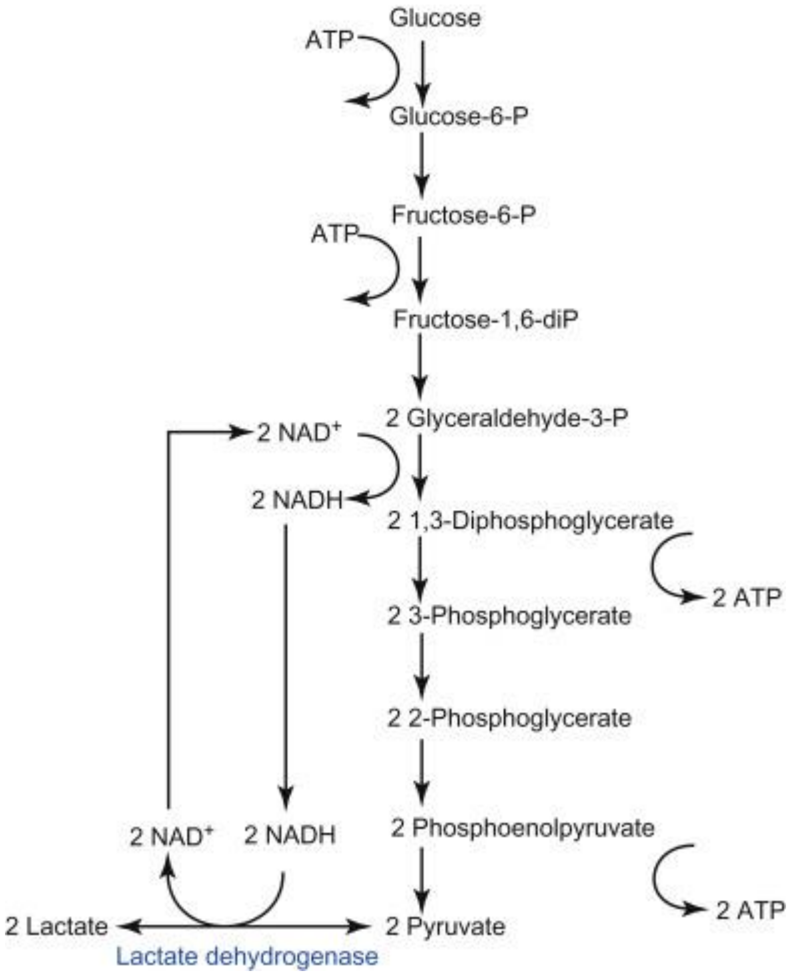
Equation for cellular respiration:

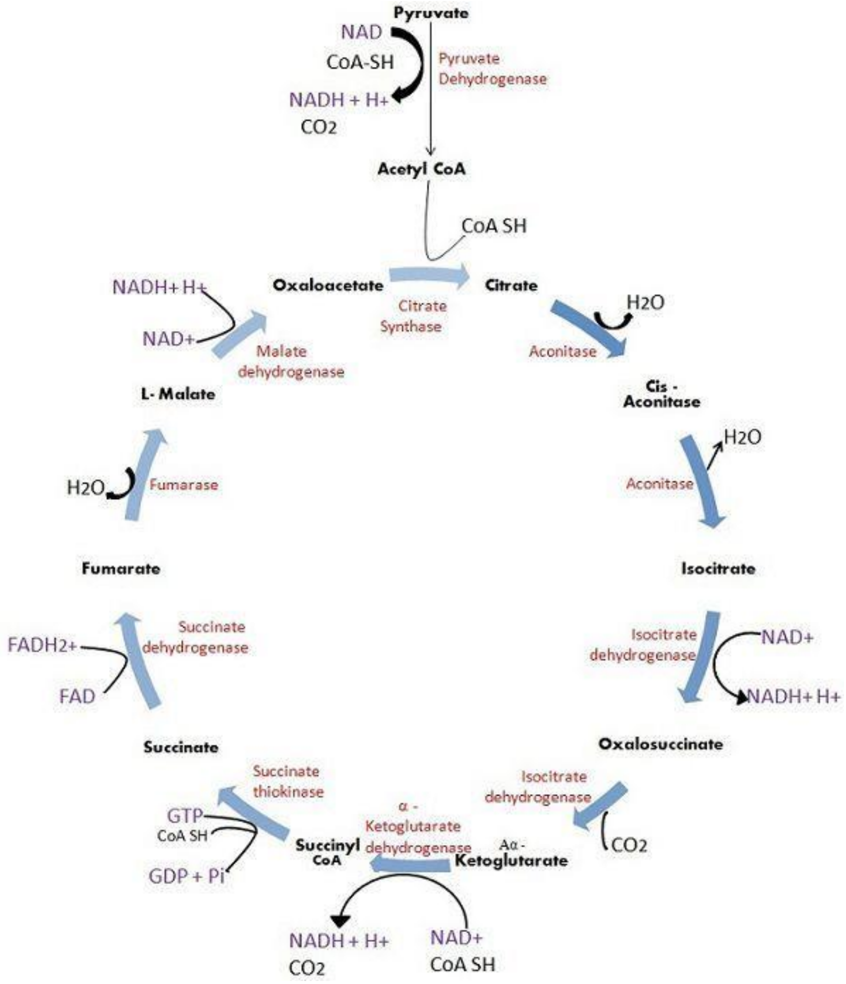
$6O_2$ + $C_6H_{12}O_6$ -------→ $6CO_2$ + $6H_2O$ + energy (ATP)

oxygen + glucose -----→ carbon dioxide + water + energy

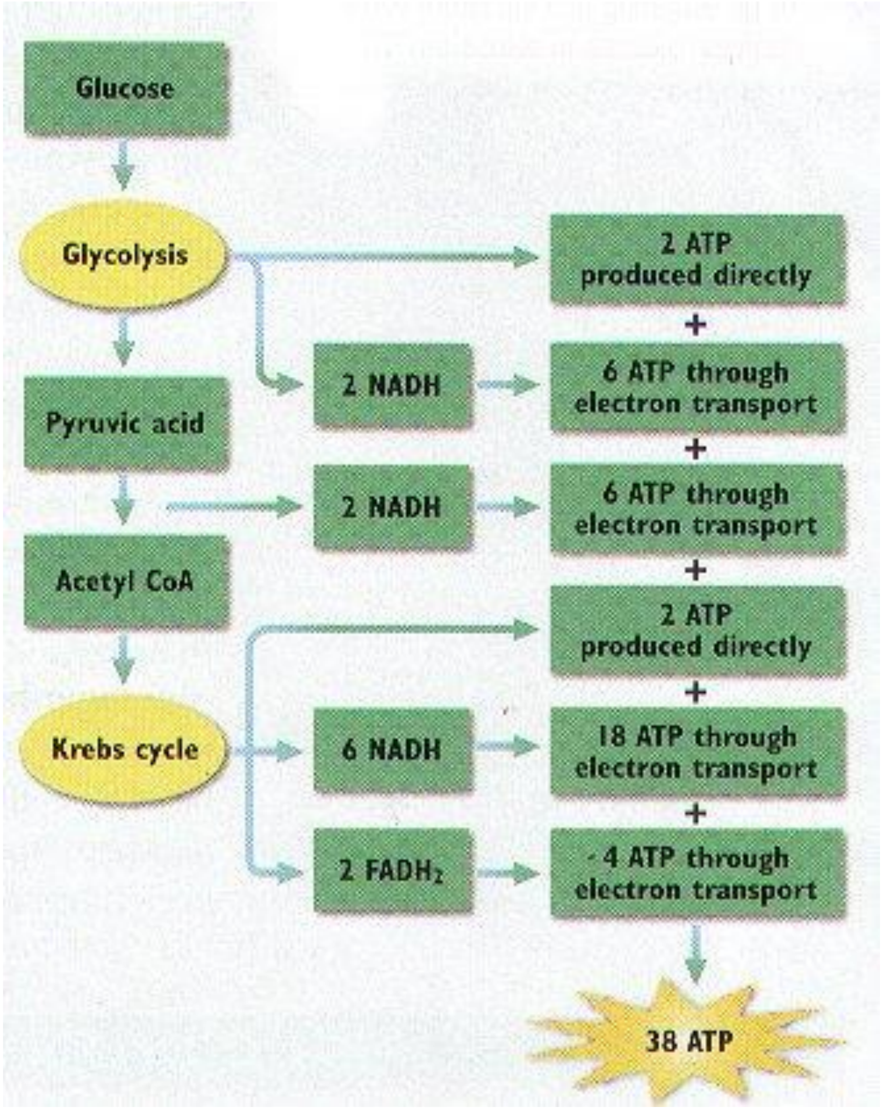


Pathway mechanism





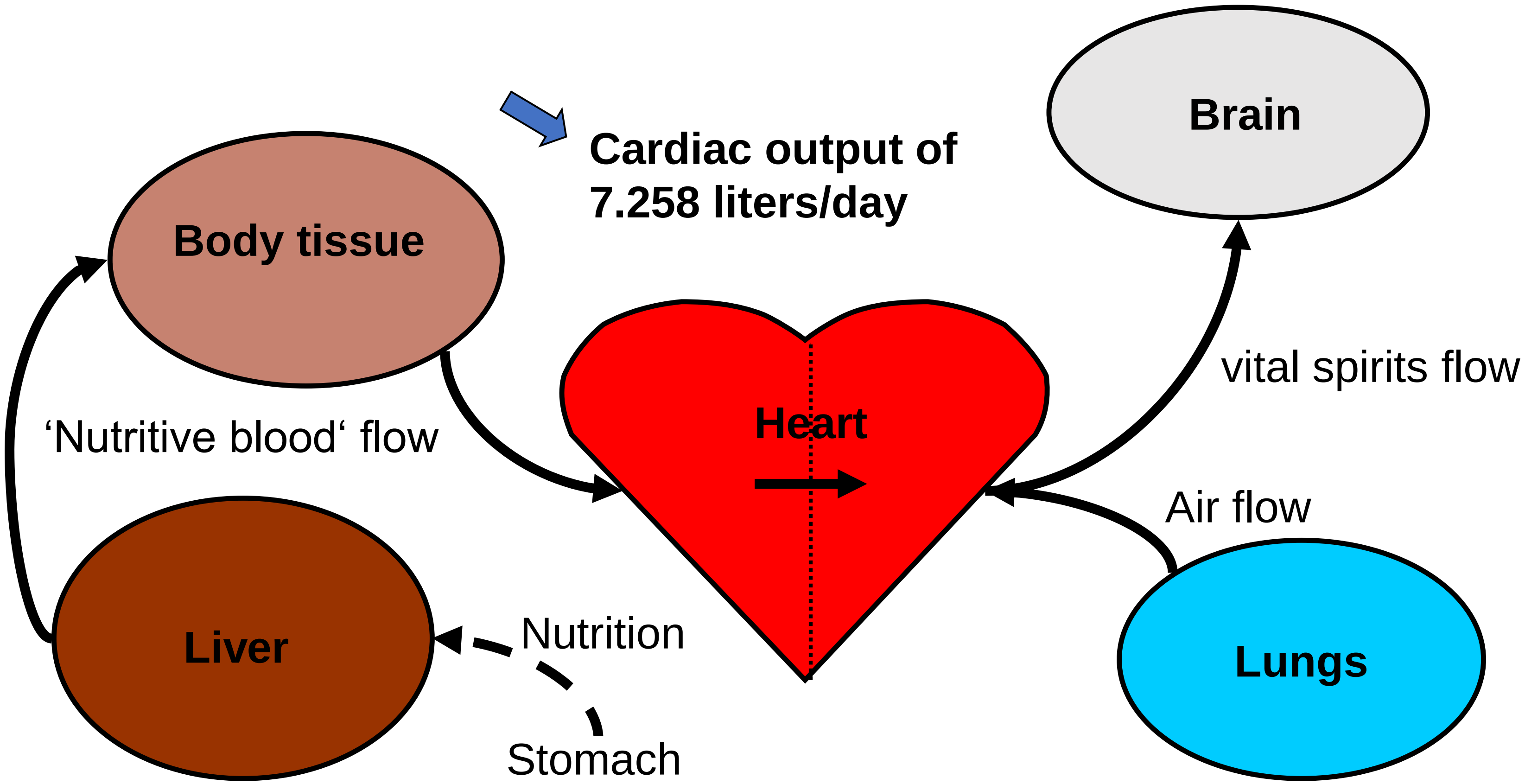
Total ATP Gain from 1 molecule of ATP



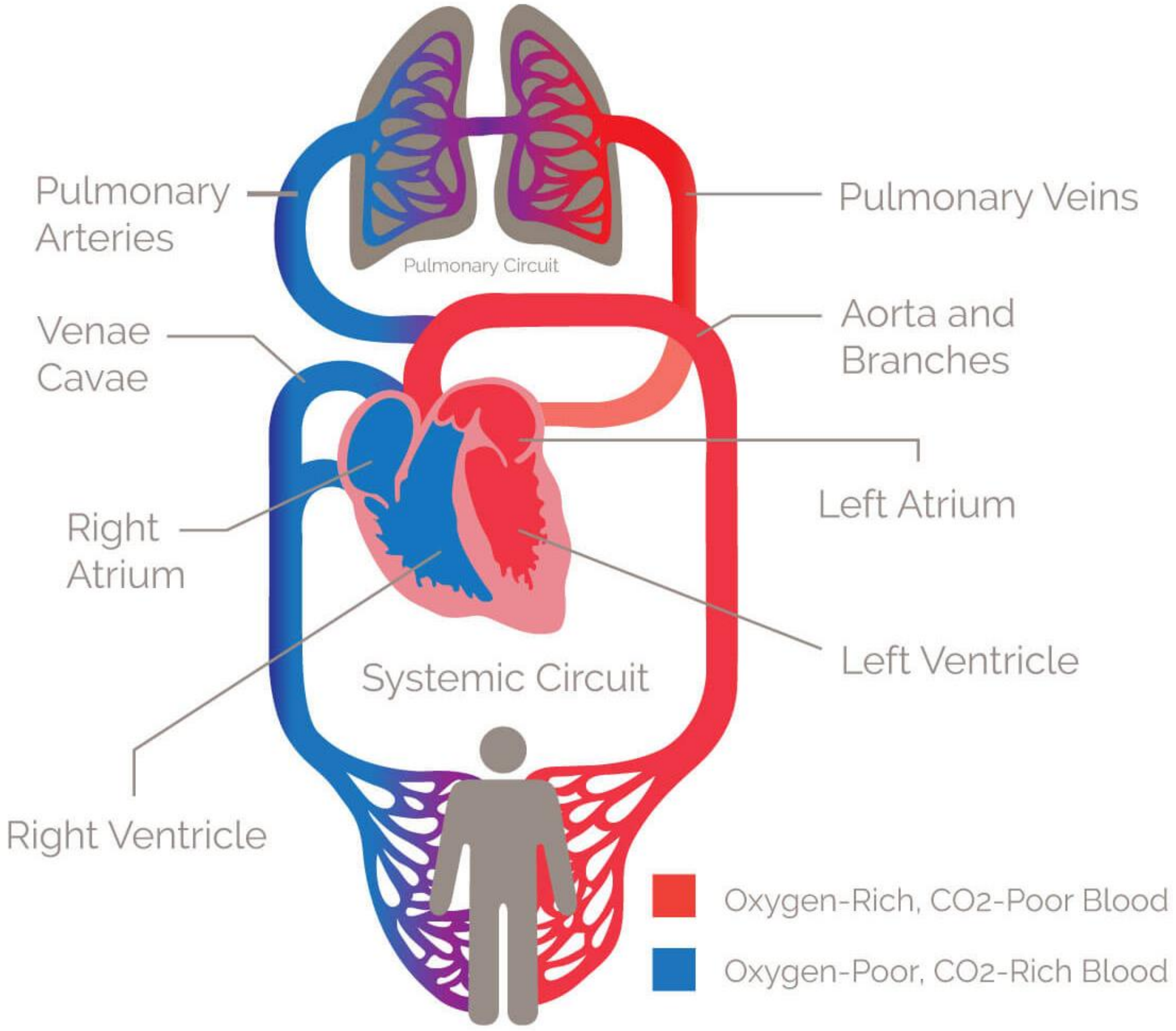
Blood/fluid circulation in humans

Ancient View

- William Harvey’s 1628 modeling:

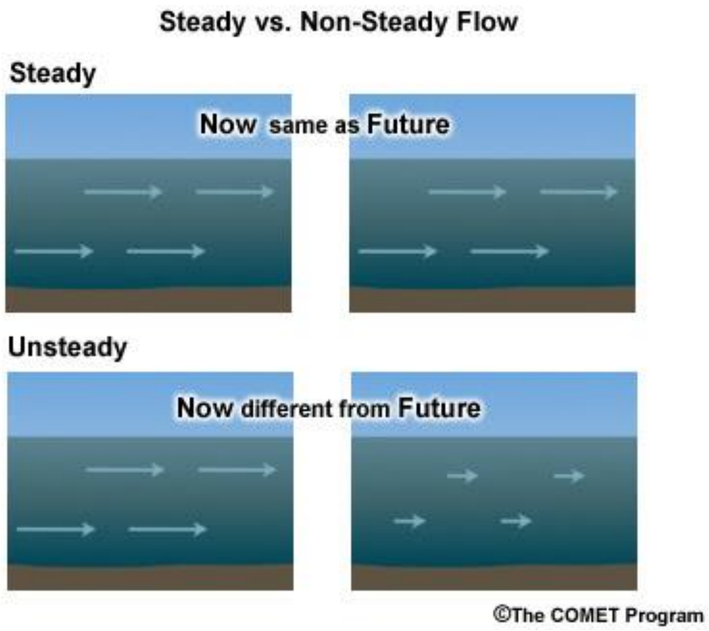


Current understanding



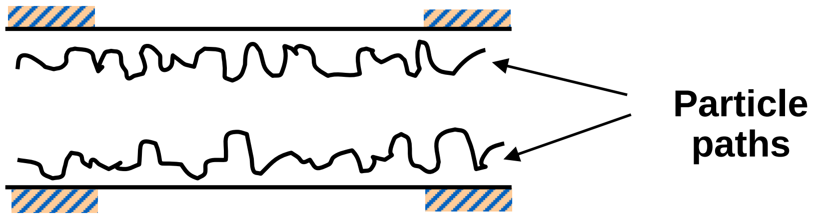
Flow properties

- Types of flow
  - Steady Flow- The flow in which the velocity of fluid is constant at any point is called as steady flow.
  - Unsteady Flow-When the flow is unsteady , the fluid velocity differs between any two points.

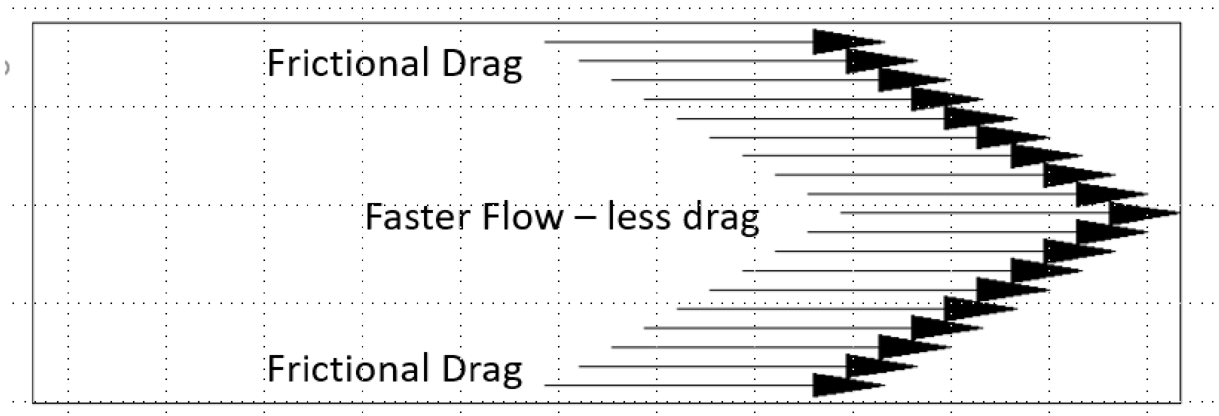


Flow properties

- Laminar and Turbulent Flow
  - Laminar flow: all the particles proceed along smooth parallel paths and all particles on any path will follow it without deviation. Hence all particles have a velocity only in the direction of flow.
  - Turbulent Flow: The particles move in an irregular manner through the flow field. Each particle has superimposed on its mean velocity fluctuating velocity components both transverse to and in the direction of the net flow.



Flow properties



- Newtonian fluid: A Newtonian fluid is a fluid that the viscosity stays the same when the shear rate changes. The viscosity will still change with a change in temperature or pressure, but as we push it faster, the viscosity stays constant.

- Non-Newtonian fluid: A non-Newtonian fluid is a fluid that the viscosity changes (drops) as we increase the shear rate.

Flow rates

- *mass flow rate = m =* $\dfrac{\textit{mass of fluid}}{\textit{time taken to collect the fluid}}$

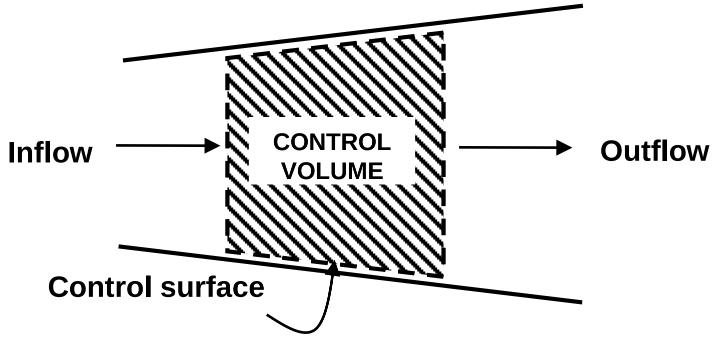
- *volumetric flow rate = Q =* $\dfrac{\textit{volume of fluid}}{\textit{time}}$

- Continuity Equation (*Principle of Conservation of Mass*)

$$M_1V_1 = M_2V_2$$

$$\rho A_1V_1 = \rho A_2V_2$$

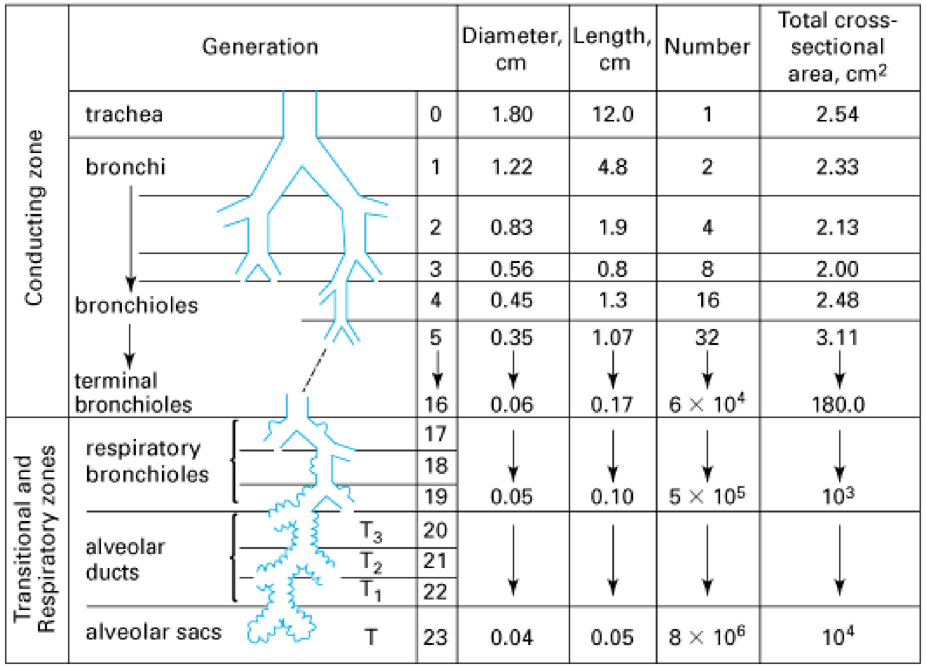
$$A_1V_1 = A_2V_2$$



Diffusion

Diffusion of a Gas

- Net movement of the molecules of a gas from a region of higher concentration to a region of lower concentration.
- Net movement of the molecules of a gas from a region in which it exerts a higher partial pressure to an area in which it exerts a lower partial pressure.



Zone	Generation		Diameter, cm	Length, cm	Number	Total cross-sectional area, cm^2
Conducting zone	trachea	0	1.80	12.0	1	2.54
	bronchi	1	1.22	4.8	2	2.33
		2	0.83	1.9	4	2.13
		3	0.56	0.8	8	2.00
	bronchioles	4	0.45	1.3	16	2.48
		5	0.35	1.07	32	3.11
	terminal bronchioles	16	0.06	0.17	6×10^4	180.0
Transitional and Respiratory zones	respiratory bronchioles	17				
		18				
		19	0.05	0.10	5×10^5	10^3
	alveolar ducts T_3	20				
	T_2	21				
	T_1	22				
	alveolar sacs T	23	0.04	0.05	8×10^6	10^4

Source: Levitzky MG: *Pulmonary Physiology*, 7th Edition: http://www.accessmedicine.com

$$\text{Linear Velocity} = \text{Flow} \ / \ \text{Cross sectional Area}$$

$$(\text{cm/sec}) \qquad (\text{cm}^3/\text{sec}) \qquad (\text{cm}^2)$$

Fick's law

- Diffusion through alveolar-capillary membrane (Fick's Law)

$$V_g = \frac{A \text{ x } D \text{ x } (P_1 - P_2)}{T}$$

V_{gas} = volume of gas diffusing through the tissue barrier per time (ml/min)

A = surface area available for diffusion *(70 m^2 in a healthy adult)*

D = diffusion coefficient, or diffusivity, of the particular gas

$P_1 - P_2$ = partial pressure difference of the gas across the barrier

T = thickness of the barrier or the diffusion distance *(0.2 to 0.5 μm)*