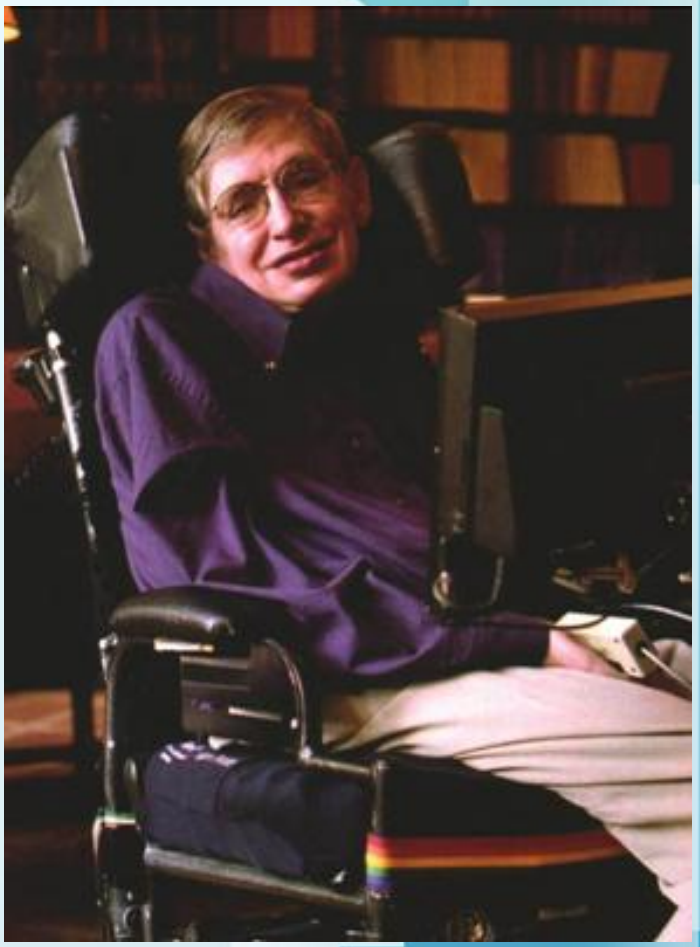
Physiology of Cells

Cellular Processes

Steven Hawking

Leaky blood vessels that lose their ability to protect the spinal cord from toxins may play a role in the development of amyotrophic lateral sclerosis, better known as ALS or Lou Gehrig's disease



Vocabulary

- **Impermeable –**
  - substance may not cross the membrane
- **Freely permeable –**
  - any substance may cross the membrane
- **Selectively permeable –**
  - passage of some substances and not others
- **Concentration gradient –**
  - difference in dissolved particles

Membrane Transport

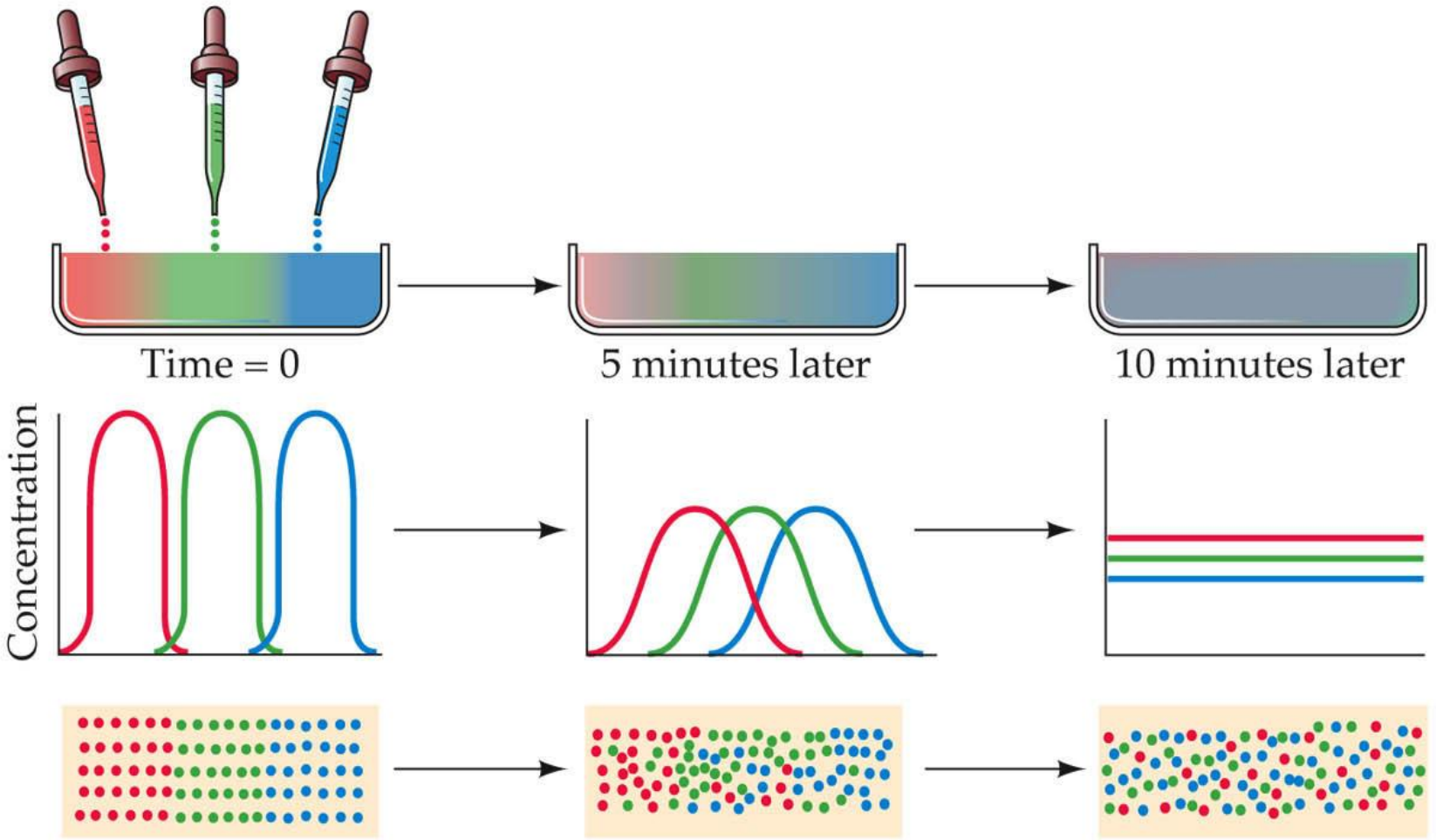
1. **Passive Transport**
   - **Simple diffusion down concentration gradient**
   - **Facilitated Diffusion occurs through channel proteins (helpers)**
2. **Active Transport**
   - **Requires energy (ATP)**

Diffusion

- Molecules always move from high to low concentrations
- Occurs down a concentration gradient
- Effective only across small distance.
- Important to eliminate local concentrations
- Move molecules through lipid portion or through protein channel

EXPERIMENT

Question: Does diffusion lead to uniform distribution of solutes?



Conclusion: Solutes distribute themselves by diffusion, uniformly and independently of each other.

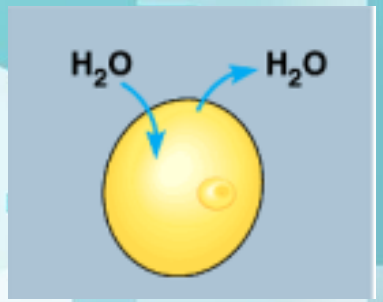
LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 5.7 Diffusion Leads to Uniform Distribution of Solutes

Permeability

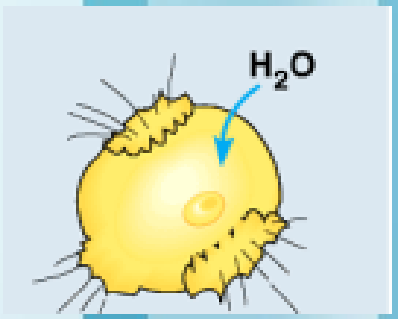
- Alcohol, fatty acids, steroids,O_2 & CO_2 easily diffuse through the membranes
- **Aquaporins** are special channels that move water across the plasma membrane

Solute Concentrations

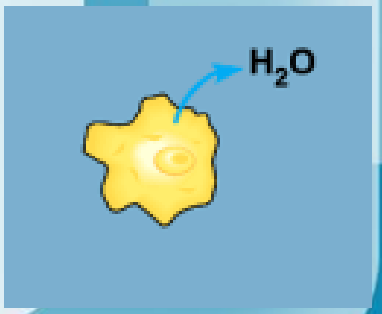
- **Isotonic**- equal amount of solutes



- **Hypotonic**- solution has lower solute concentration

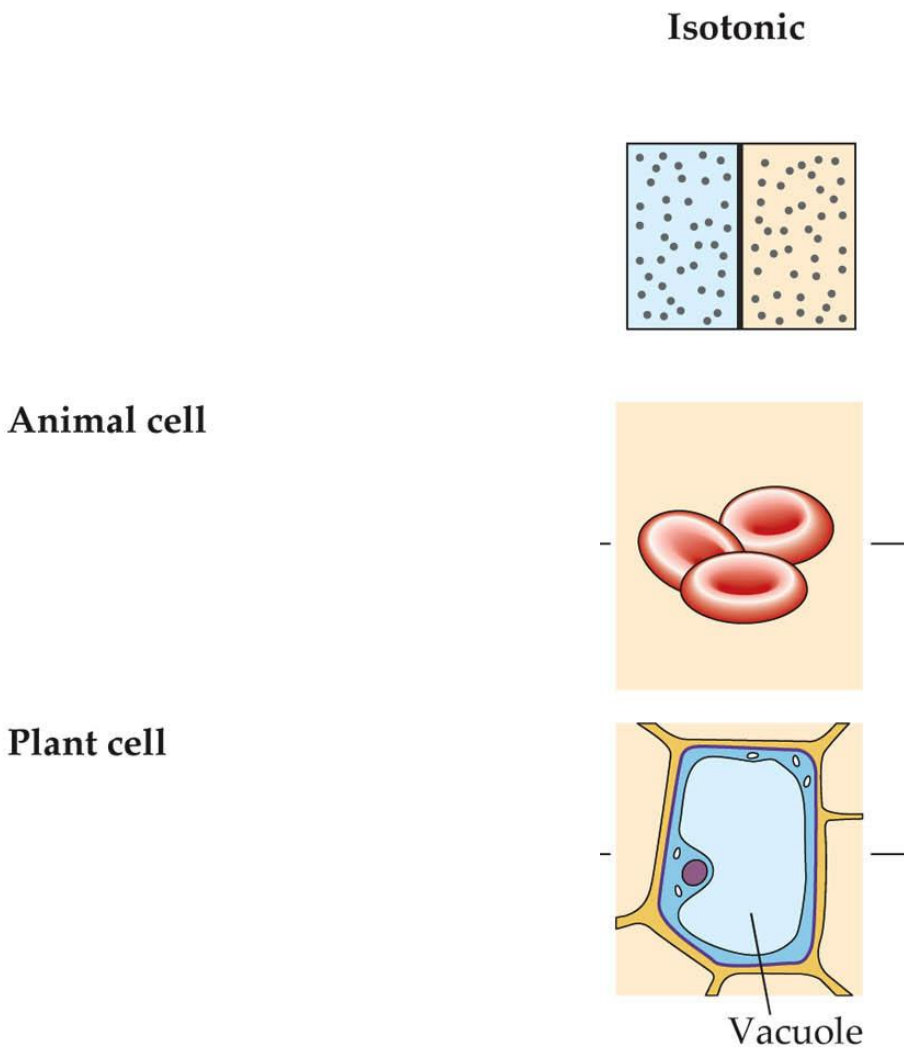


- **Hypertonic**- solution has higher concentration of solutes



Osmosis

- Diffusion of water
- Occurs easily through bi-lipid layer
- Aquaporins allow for quicker movement of water



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 5.8 Osmosis Modifies the Shapes of

Inverse relationship

Where this is high solute concentration ….there is low water content

Interesting factoid

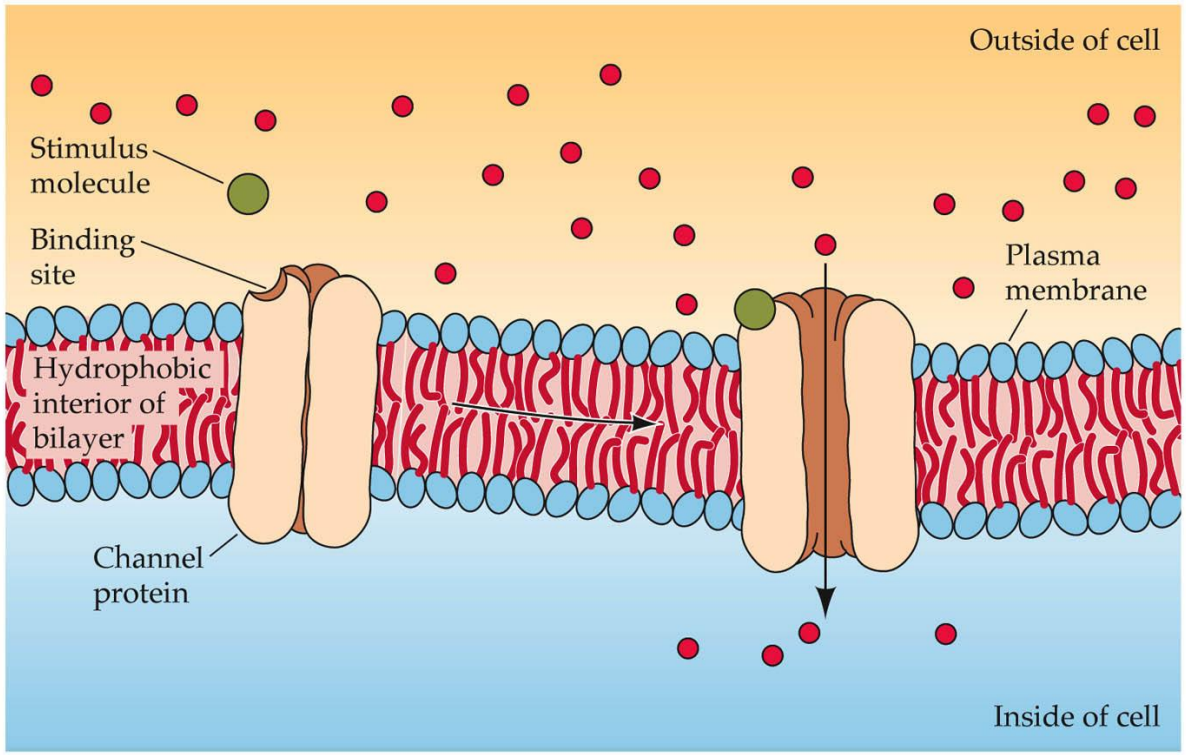
Our bodies are 0.9 % salinity

Filtration & Hydrostatic Pressure

- Movement of particles across a membrane from and area of high pressure to low pressure
- Hydrostatic / osmotic pressure is the pushing force of water when acting as a solvent.
  - Ex- heart pumping causes blood pressure, kidneys filter out blood

Facilitated Diffusion

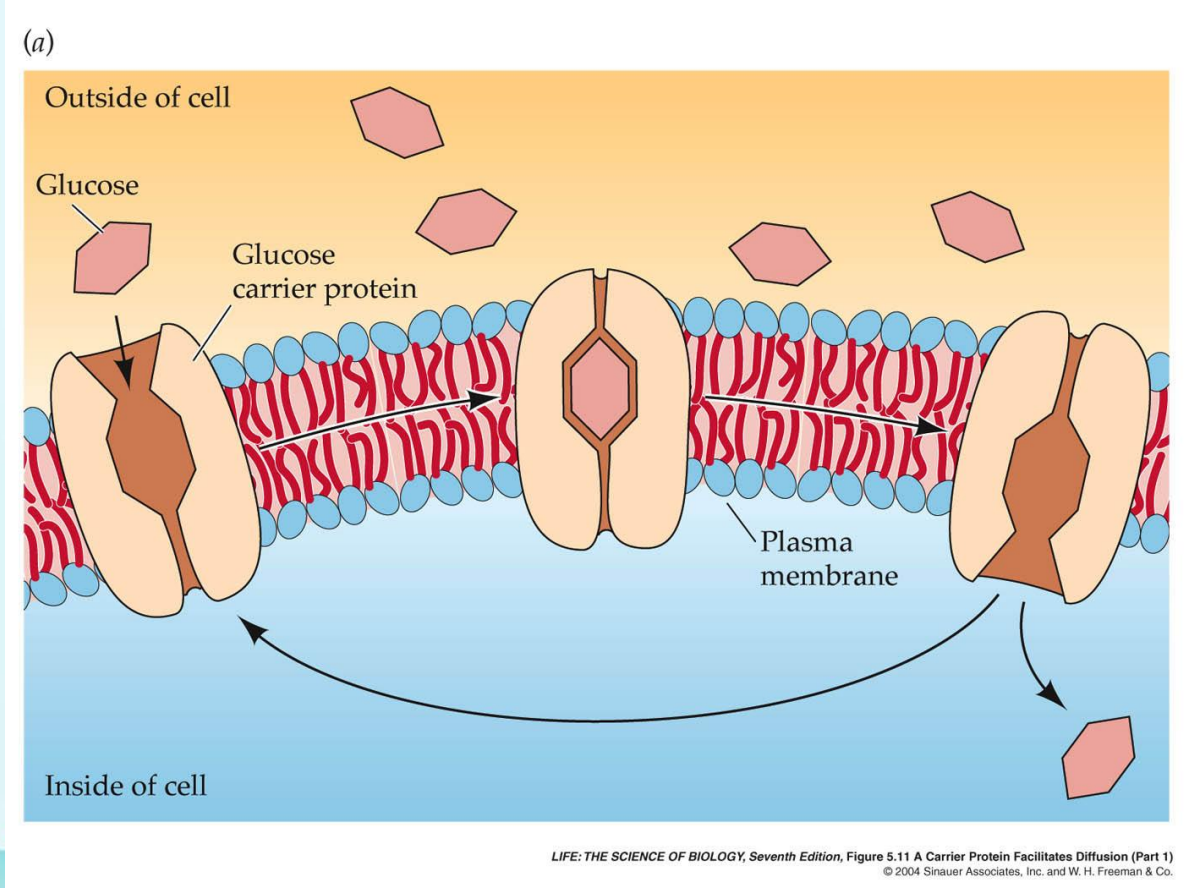
- **When a molecule either passes through or binds to an channel protein to cross a membrane.**



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 5.9 A Gated Channel Protein Opens in Response to a Stimulus

Carrier Proteins

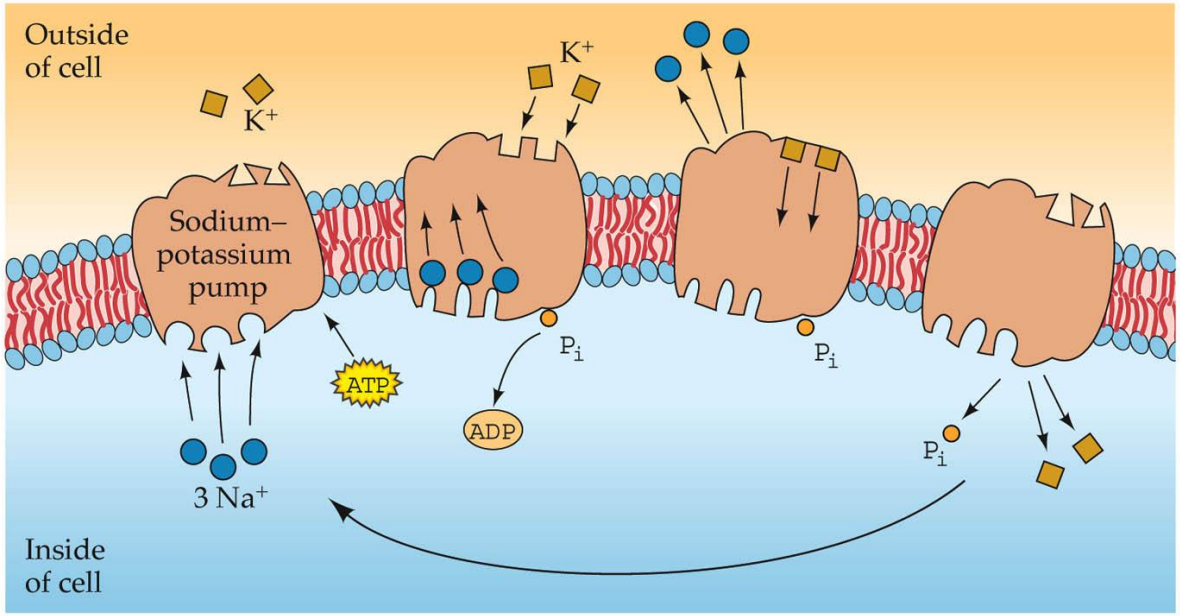
- **When substances being transported binds to protein**



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 5.11 A Carrier Protein Facilitates Diffusion (Part 1)

Active Transport

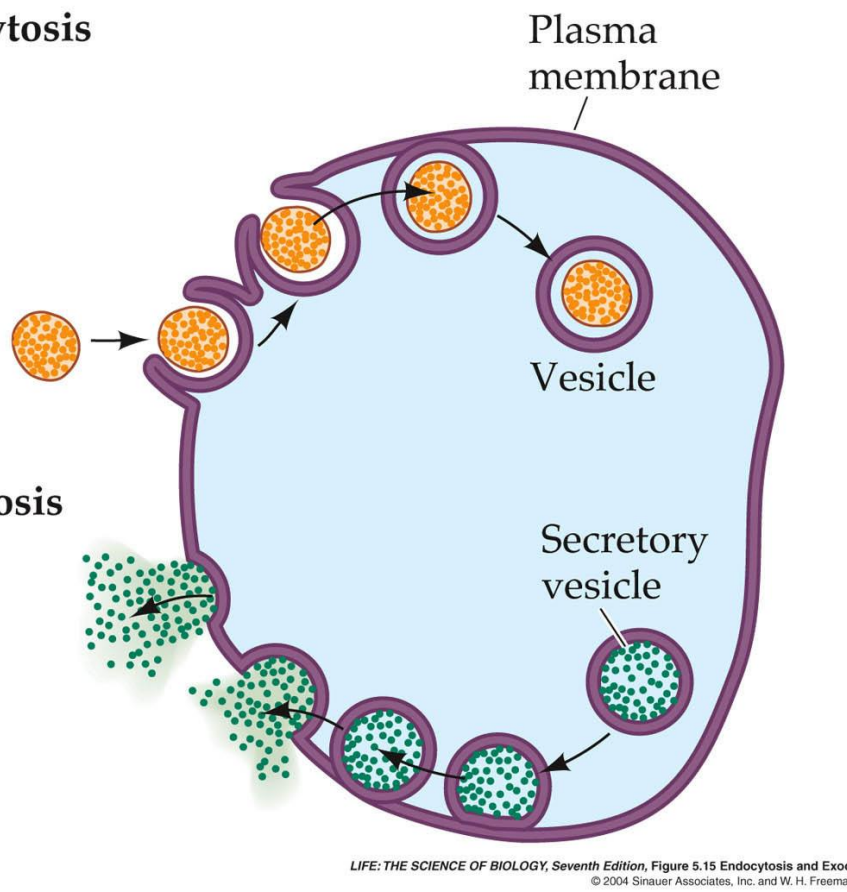
- Moves substances against concentration gradient
- Solutes move from low→high
- Sodium-Potassium pump



- **Work on packets**

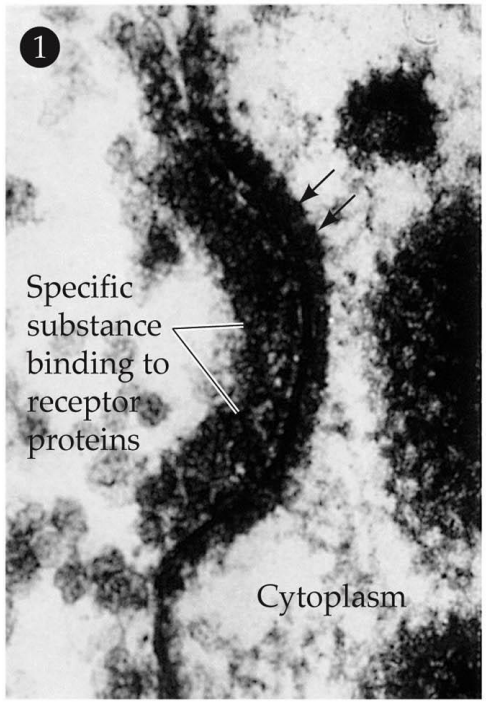
Bulk Transport

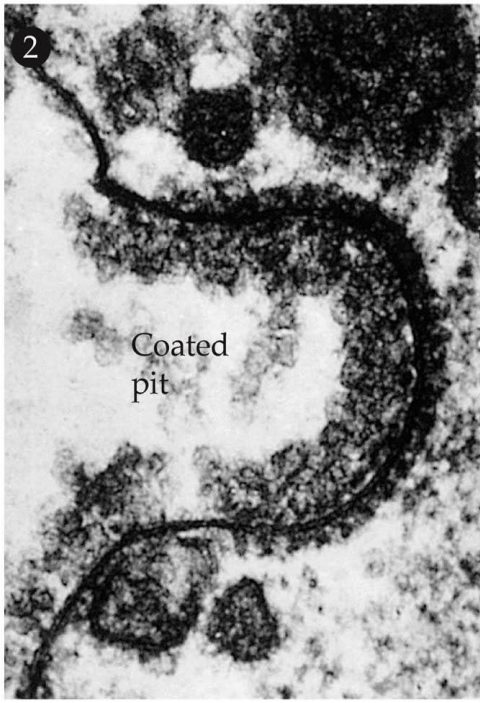
- **Endocytosis**
  - Phagocytosis movement of large molecules into the cell
  - Pinocytosis is the ingestion of fluid
- **Exocytosis** moves large molecules out of cell
  - Ex: proteins, waste/toxins

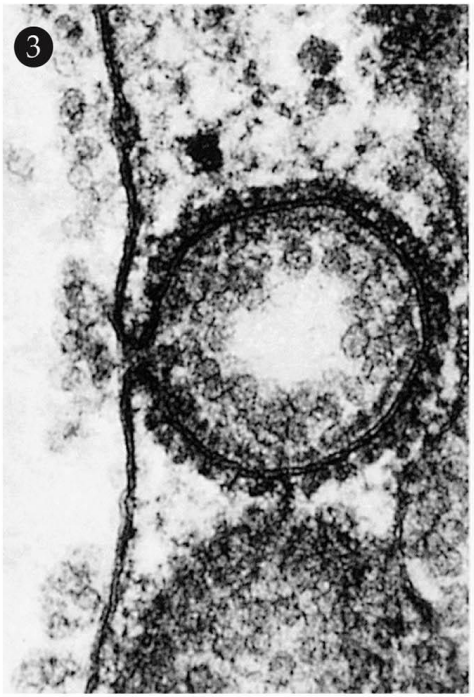


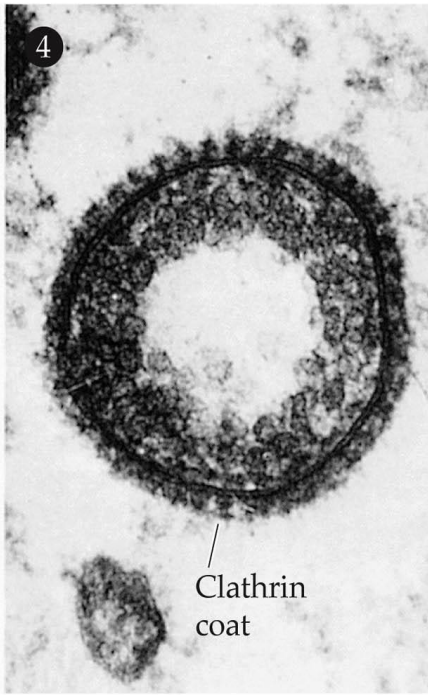
LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 5.15 Endocytosis and Exo

Cell Transport





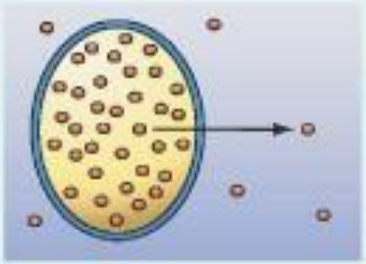
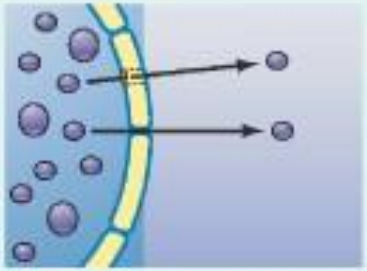
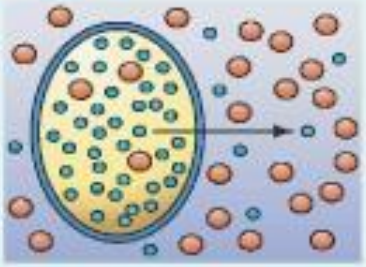
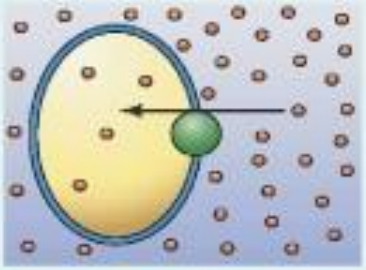


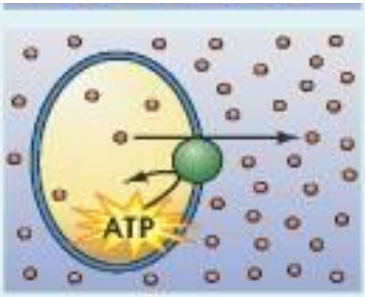
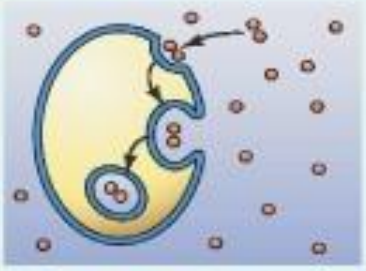


LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 5.16 Formation of a Coated Vesicle (Part 1

LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 5.16 Formation of a Coated Vesicl

Table 4-1 Some Important Transport Processes

Process	Type	Description		Example
Simple diffusion	Passive	Movement of particles through the phospholipid bilayer or through channels from an area of high concentration to an area of low concentration—that is, down the concentration gradient		ovement of carbon dioxide out of all cells; movement of sodium ions into nerve cells as they conduct an impulse
Dialysis	Passive	Diffusion of small solute particles, but not larger solute particles, through a selectively permeable membrane; results in separation of large and small solutes		During procedure called *peritoneal dialysis*, small solutes diffuse from blood vessels but blood proteins do not (thus removing only small solutes from the blood)
Osmosis	Passive	Diffusion of water through a selectively permeable membrane in the presence of at least one impermeant solute		Diffusion of water molecules into and out of cells to correct imbalances in water concentration
Facilitated diffusion	Passive	Diffusion of particles through a membrane by means of carrier molecules; also called *carrier-mediated passive transport*		Movement of glucose molecules into most cells

Active transport	Active	Movement of solute particles from an area of low concentration to an area of high concentration (up the concentration gradient) by means of a carrier molecule		In muscle cells, pumping of nearly all calcium ions to special compartments—or out of the cell
Phagocytosis	Active	Movement of cells or other large particles into cell by trapping it in a section of plasma membrane that pinches off to form an intracellular vesicle; type of *endocytosis*		Trapping of bacterial cells by phagocytic white blood cells
Pinocytosis	Active	Movement of fluid and dissolved molecules into a cell by trapping them in a section of plasma membrane that pinches off to form an intracellular vesicle; type of *endocytosis*		Trapping of large protein molecules by some body cells
Exocytosis	Active	Movement of proteins or other cell products out of the cell by fusing a secretory vesicle with the plasma membrane		Secretion of the hormone, rolactin, by pituitary cells

Diseases of Cell Membrane

- **Cystic Fibrosis**
  - does not allow Cl^- to pumped across the membrane
  - Mucus and secretions in lungs, pancreas thicken
- **Duchenne Muscular Dystrophy**
  - "leaky" Ca^{++} channels
- **Type II Diabetes**
  - Cells become less sensitive to insulin

Cell Energy

Cellular Respiration

- How the cell carries out carbohydrate metabolism.
- Occurs in the cytosol & mitochondria
- Produces net gain of 36 ATP from one glucose (with O_2)

1. Glycolysis
2. Pyruvate Oxidation (formation)
3. Kreb's cycle
4. Electron Transport Chain

FORMULA

$C_6H_{12}O_6 + 6O_2 + ADP \rightarrow 6CO_2 + 6H_2O + ATP$

(36 net gain)

Glucose the body's fuel

- Complex carbs are broken down into glucose (monosaccharide)
- Glucose is preferred source of fuel for the human body
- Glucose can power the formation of amino acids, which then can be incorporated into proteins.
- Excess glucose can be stored by liver and skeletal muscles as glycogen.
- If glycogen storage areas fill up, liver cells and fat cells can convert glucose to glycerol and fatty acids.

Glycolsis –First step

- **Glycolysis takes place in cytoplasm of cell(outside the mitochondria)**

- **Creates 2 ATP(net)**

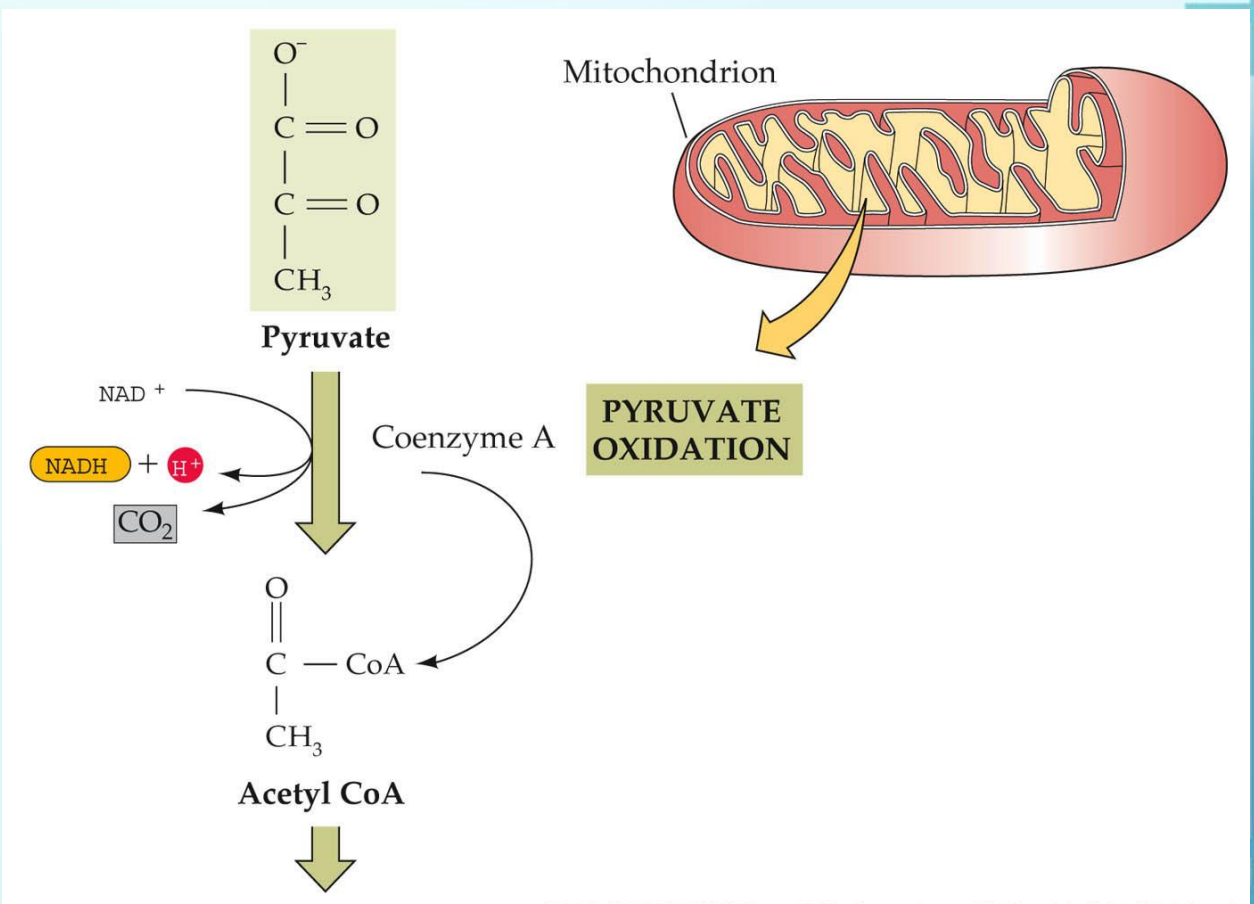
<<takes energy to make energy>>

- **Breaks glucose in half**

- **Creates pyruvates (energy transferring molecule)**
- **Does not use oxygen(anaerobic)**

Pyruvate Oxidation

- Pyruvate is oxidized to Acetyl CoA



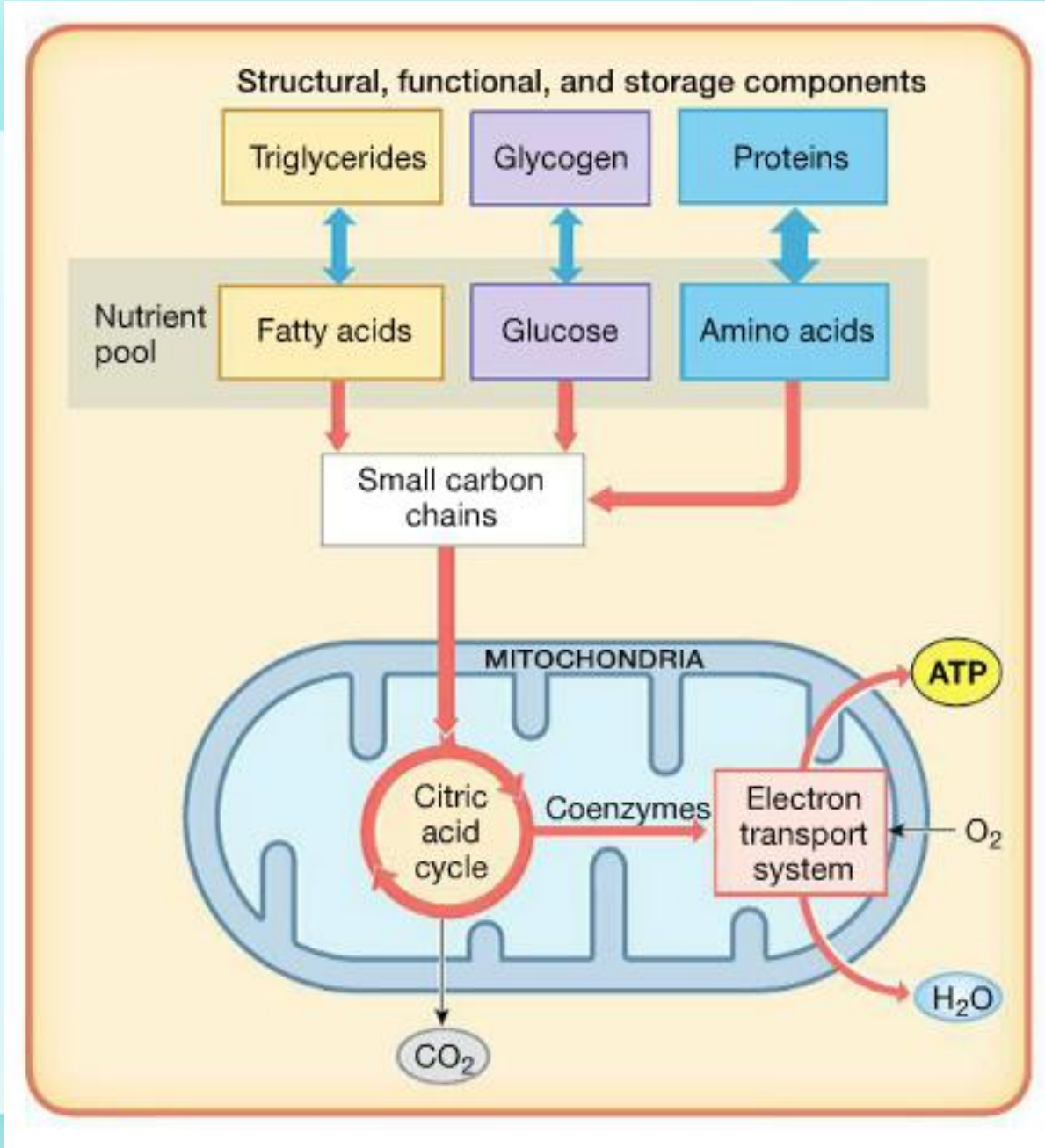
Pyruvate + NAD^+ + CoA → Acetyl CoA + NADH + H^+ + CO_2

Kreb's (Citric Acid) Cycle- Second Step

- Most CO_2 is produced in this step
- Acetyl-CoA produces CO2
- Electron acceptors NAD^+ & FADH pick up electrons to carry to next step

Electron Transport Chain

- As electrons pass through the respiratory chain, protons are pumped by active transport into the intermembrane space against their concentration gradient.
- The protons then diffuse down the concentration gradient creating ATP in the process.
- **Chemiosmosis** is the coupling of the potential energy and ATP synthesis.
- The final electron acceptor is O_2 which binds with H_2 to create water


Structural, functional, and storage components
Triglycerides
Glycogen
Proteins
Nutrient pool
Fatty acids
Glucose
Amino acids
Small carbon chains
MITOCHONDRIA
ATP
Citric acid cycle
Coenzymes
Electron transport system
O_2
H_2O
CO_2

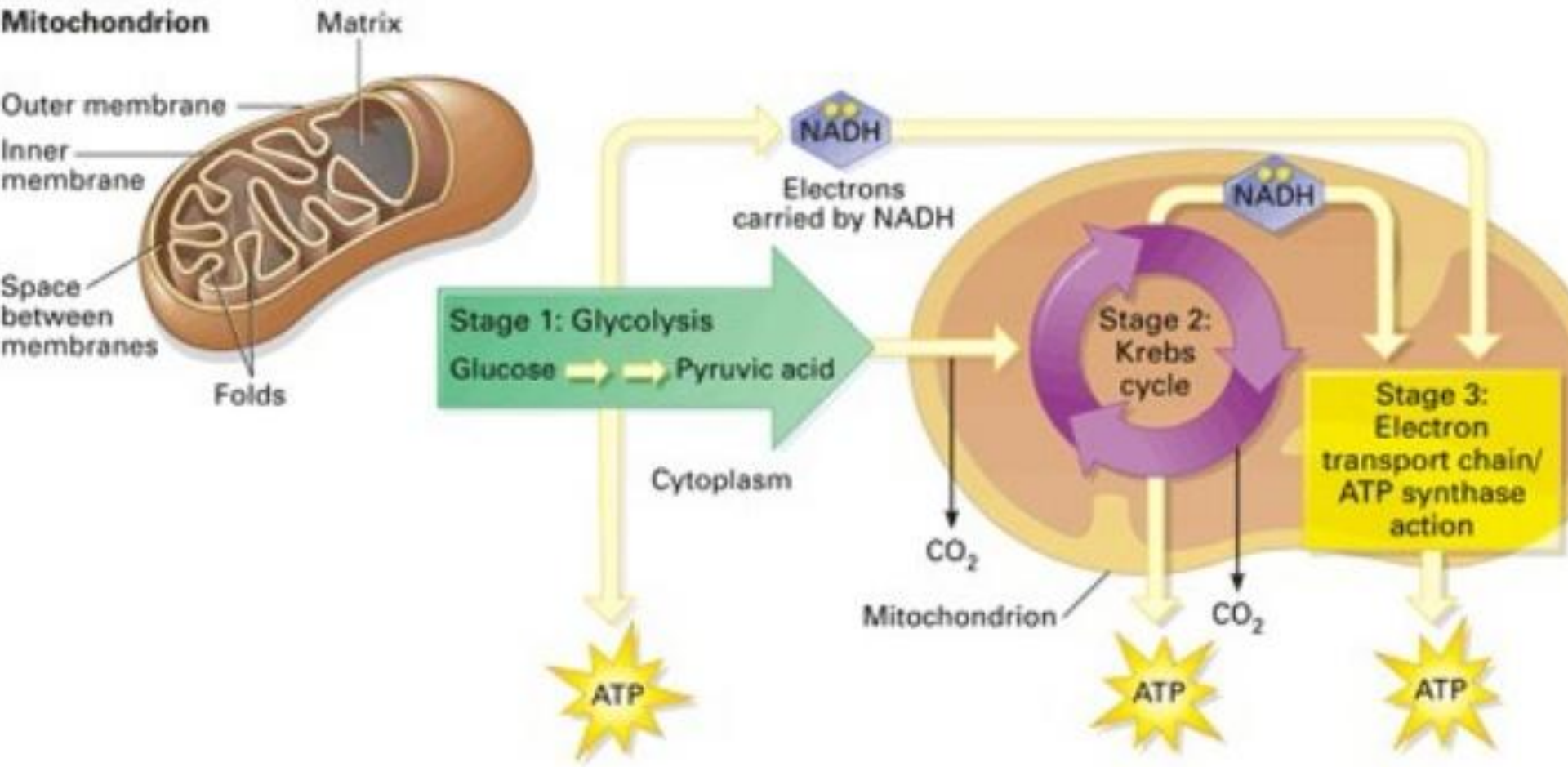
Relationships between Metabolic Pathways

- Catabolic interconversions:
  1. **Polysaccharides are hydrolyzed into glucose, which passes on to glycolysis.**
  2. **Lipids are converted to fatty acids, which later becomes acetyl CoA**
  3. **Proteins are hydrolyzed into amino acids, which feed into glycolysis or the citric acid cycle.**

Relationships between Metabolic Pathways

- **What happens if inadequate food molecules are available?**
  - **Glycogen stored in muscle and liver are used first.**
  - **Fats are used next. But the brain can only use glucose, so it must be synthesized by gluconeogenesis which uses amino acids.**
  - **Therefore, proteins must be broken down.**
  - **After fats are depleted, proteins alone provide energy.**

Cellular Respiration: Energy for Life



- **Transcription is RNA processing in nucleus**
- **Translation is the processes making a protein from mRNA in the ribosome**

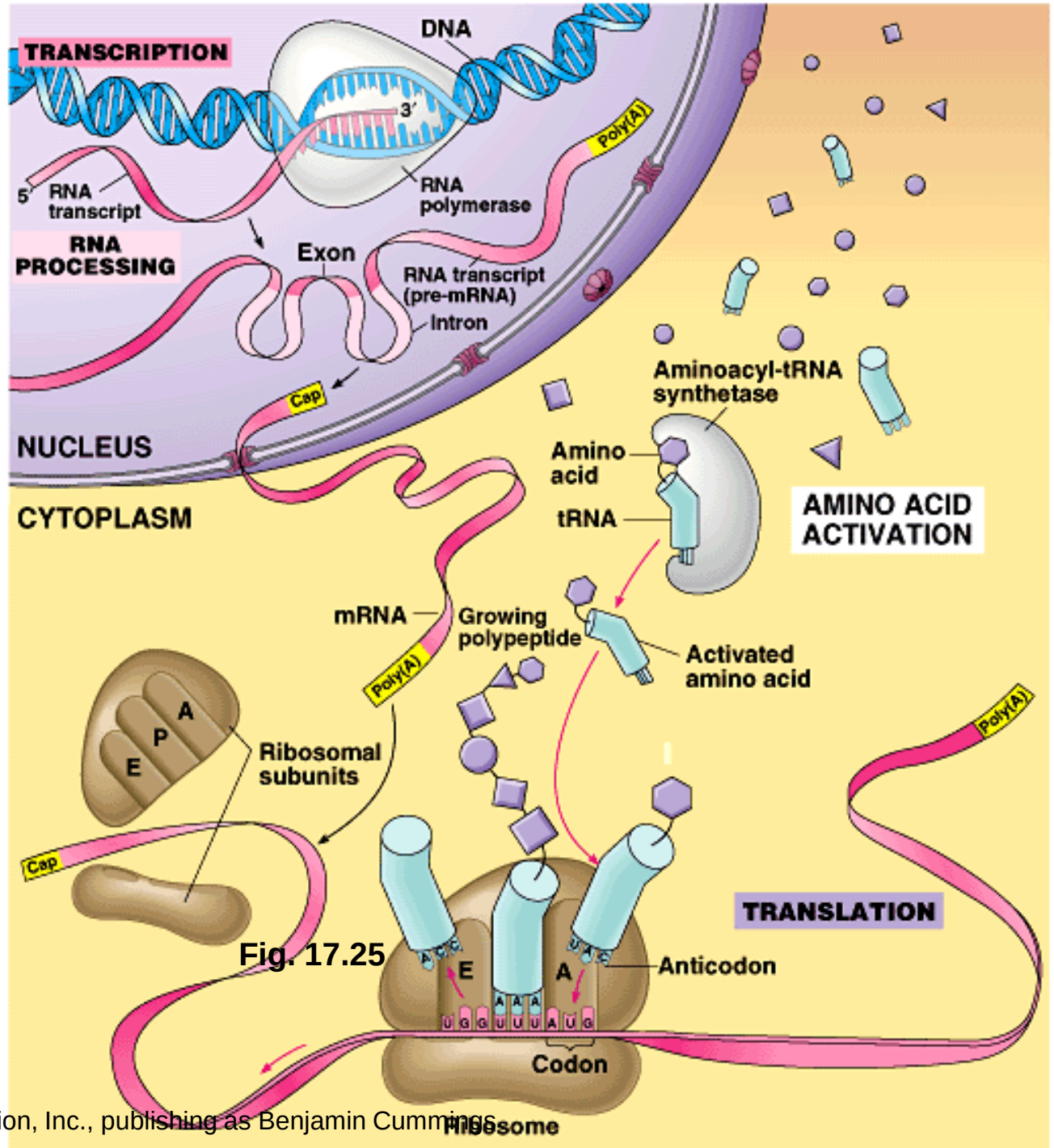


Fig. 17.25