BIOENERGETICS AND INTRODUCTION TO METABOLISM

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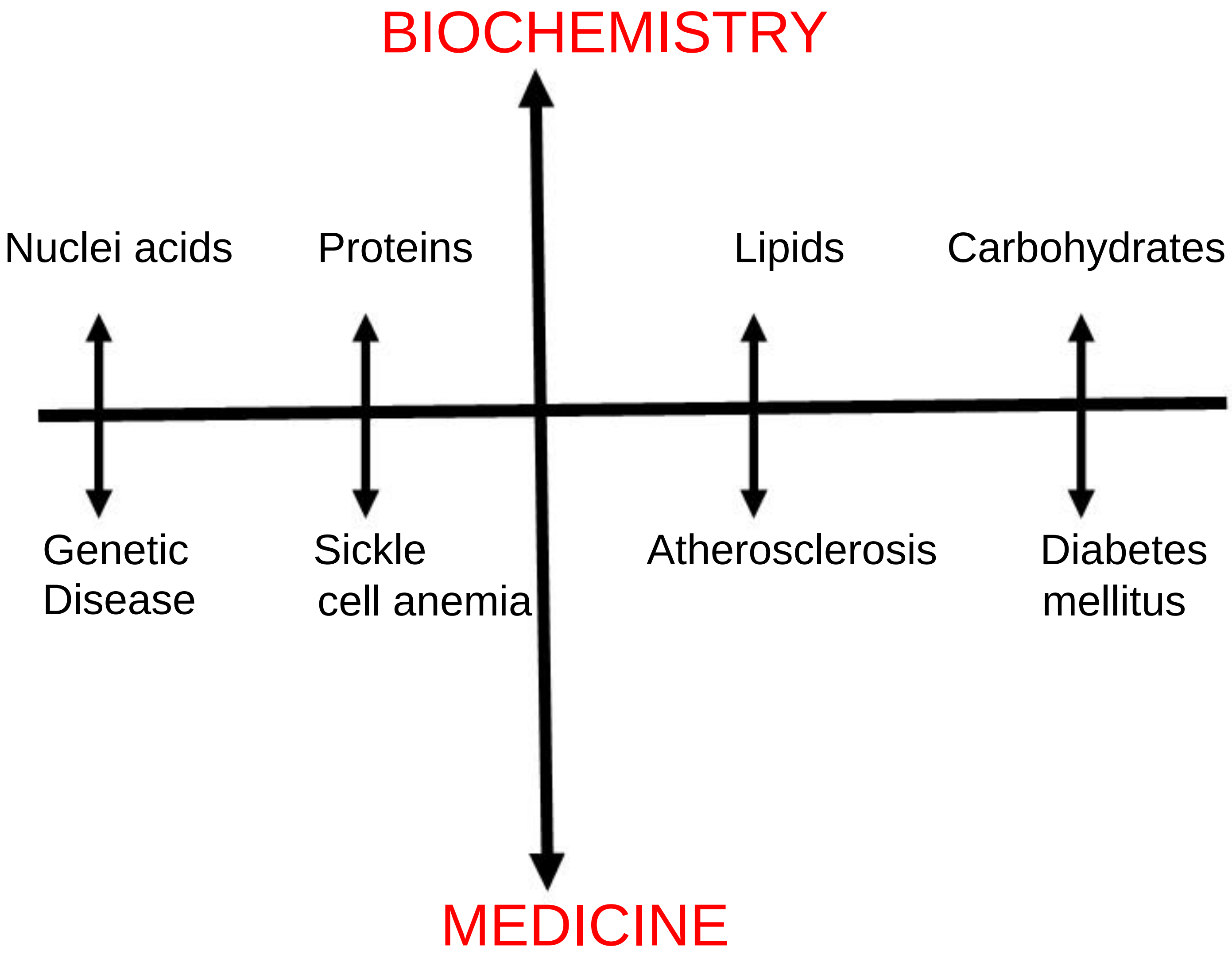
BIOCHEMISTRY

Definition: Biochemistry deals with the study of chemical reactions and energy transfer processes that occur our in the body.

BIOCHEMISTRY & MEDICINE

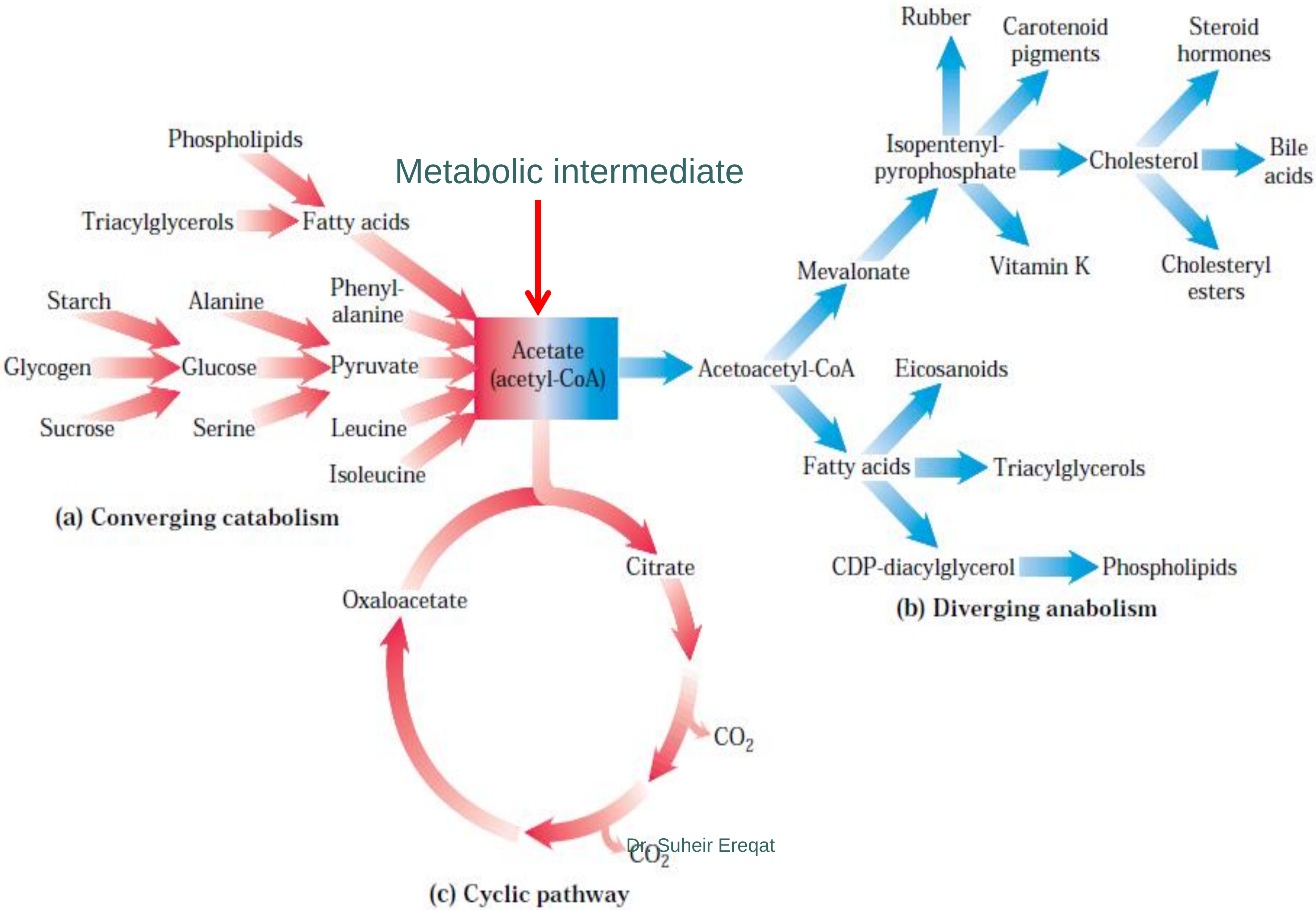
Biochemistry has a great impact on medicine as it:

- helps understand and maintain health.
- Helps understand disease and its effective treatment.
- health & disease studies opened up new areas in biochemistry.


BIOCHEMISTRY
Nuclei acids
Proteins
Lipids
Carbohydrates
Genetic Disease
Sickle cell anemia
Atherosclerosis
Diabetes mellitus
MEDICINE

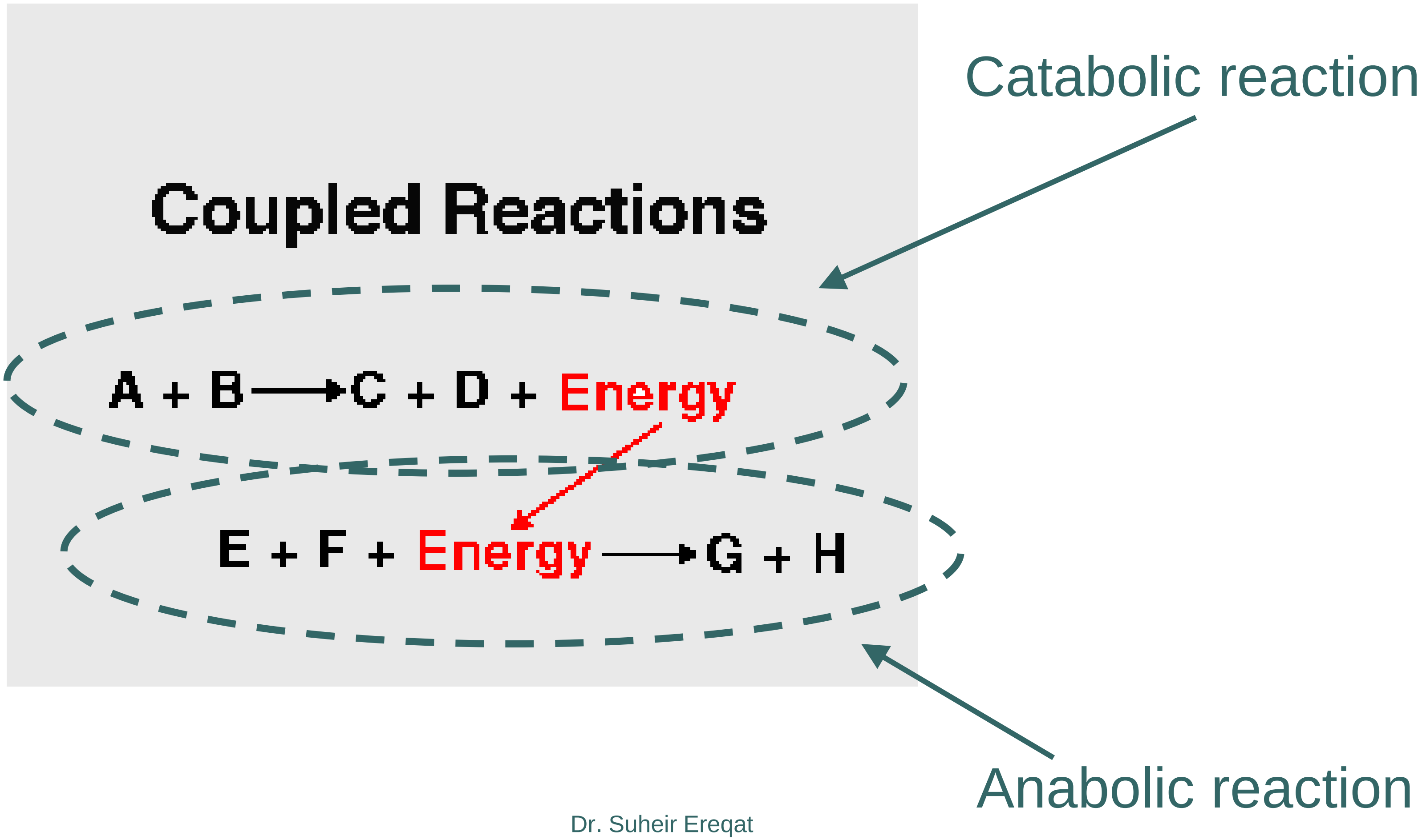
- **Metabolism** = Catabolism + Anabolism
- Catabolic reactions are energy ***yielding***
- They are involved in the breakdown of more-complex molecules into simpler ones
- Anabolic reactions are energy ***requiring***
- They are involved in the building up of simpler molecules into more-complex ones
- We can consider these bioenergetics in terms of the physical laws of thermodynamics

Metabolic Pathways



Energy Coupling in Metabolism

Catabolic Reactions provide the energy that drives Anabolic Reactions forward



Thermodynamics& Bioenergetics

- Thermodynamics: is the study of energy.

Bioenergetics describe the

transfer and utilization of energy in living systems.

Energy Laws - Laws of Thermodynamics

Energy exists in many forms, such as heat, light, chemical energy, and electrical energy.

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The First Law of Thermodynamics (Conservation) states that energy is always conserved, it cannot be created or destroyed*.* In essence, energy can be converted from one form into another.

Energy Laws - Laws of Thermodynamics

The Second Law of Thermodynamics:

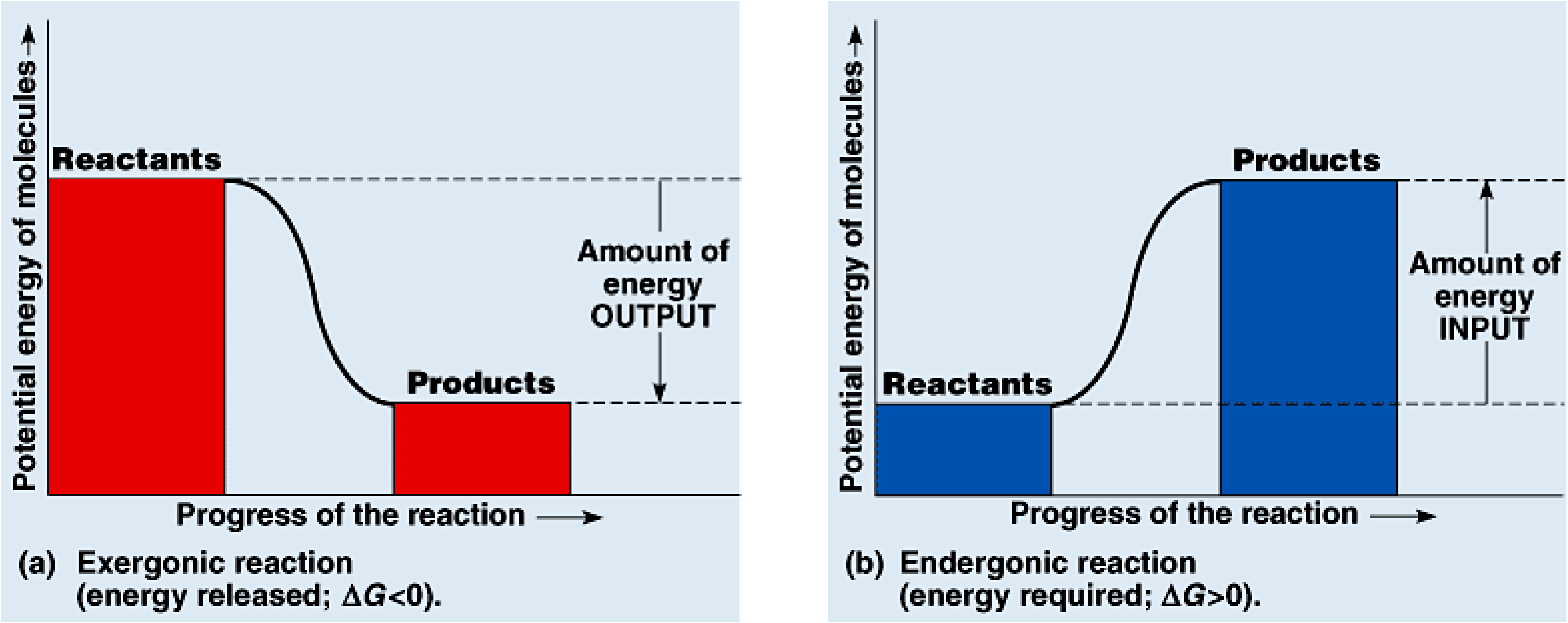
The universe always tends toward more and more disorder "ENTROPY"

Example : Diffusion

cells are NOT disordered and so have low entropy.

Free Energy

- *Free energy*: portion of system's E that can perform work (at a constant T)
- Exergonic reaction: net release of free E to surroundings
- Endergonic reaction: absorbs free E from surroundings



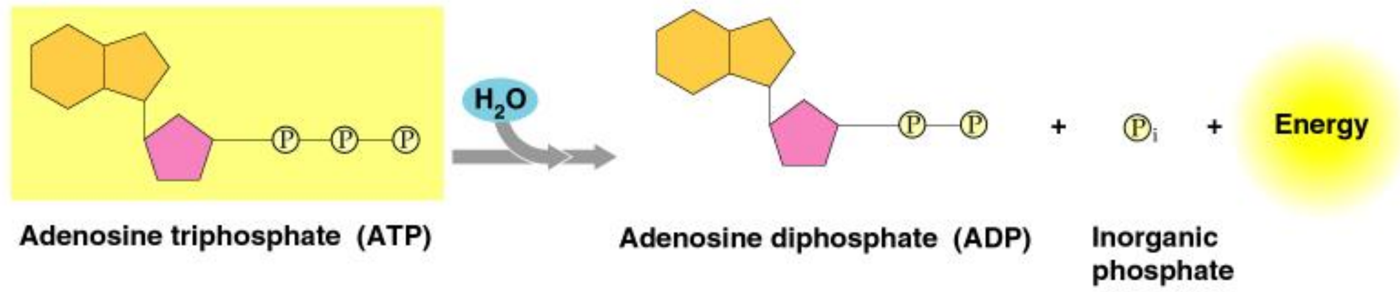
When reactions go to equilibrium, **$\Delta G = 0$**

“High energy compound”

Compounds with “high energy bonds” are said to have **high group transfer potential.**

For example, P_i may be spontaneously cleaved from ATP for transfer to another compound (e.g., to a hydroxyl group on glucose).

ATP

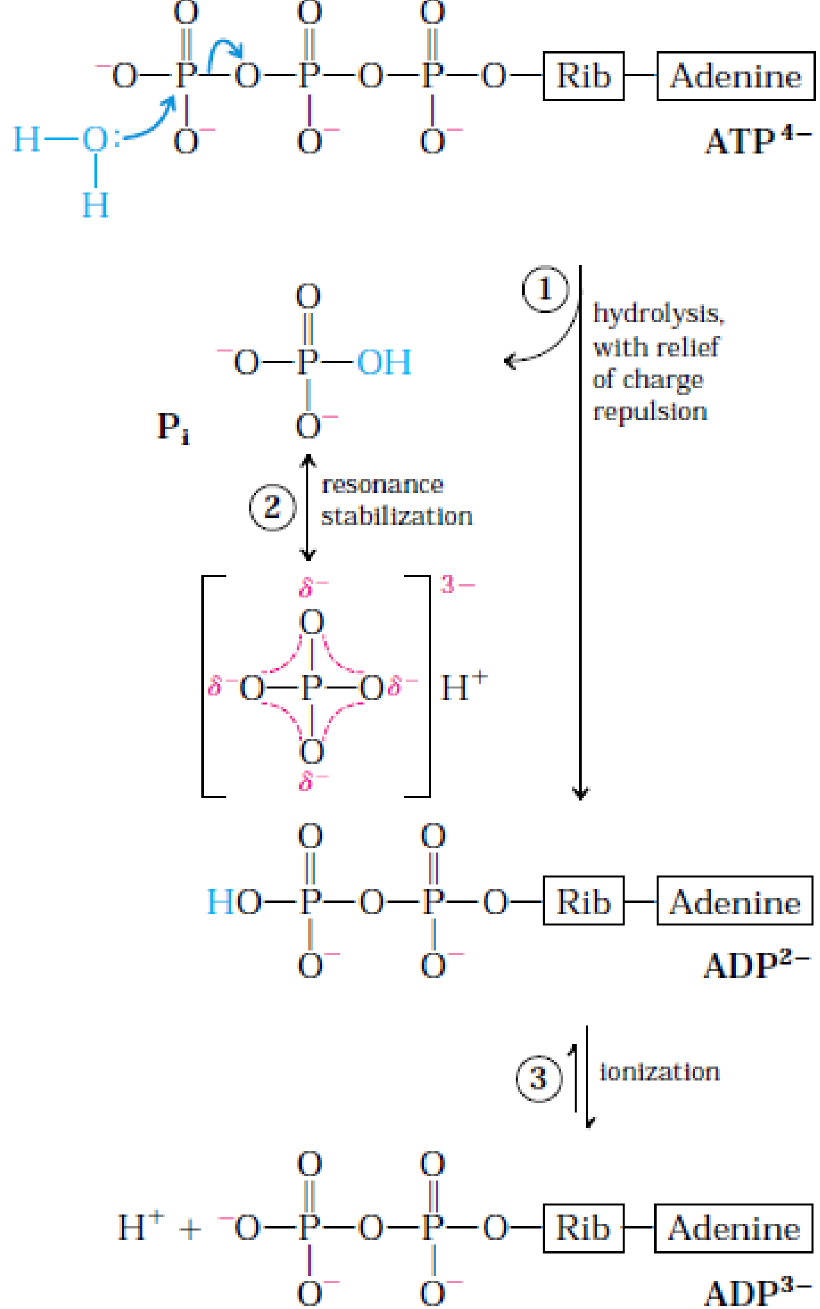


(b) Hydrolysis of ATP

- Energy is released from ATP through the loss of phosphate groups
- Catabolic reaction resulting from hydrolysis producing ADP + P_i (inorganic Phosphate) + energy

$$ATP^{4-} + H_2O \longrightarrow ADP^{3-} + P_i^{2-} + H^+$$

$$\Delta G'^{\circ} = -30.5 \text{ kJ/mol}$$



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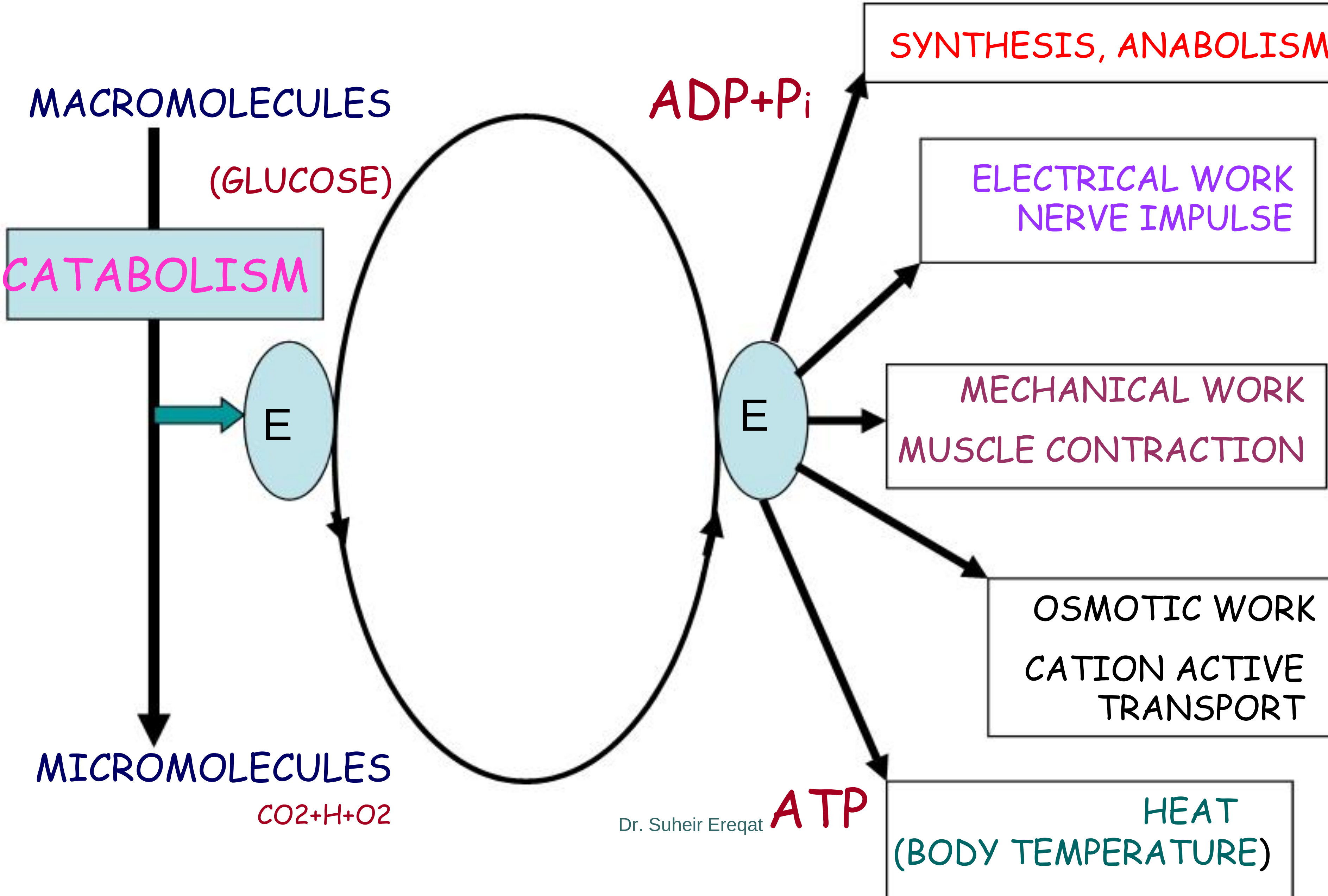
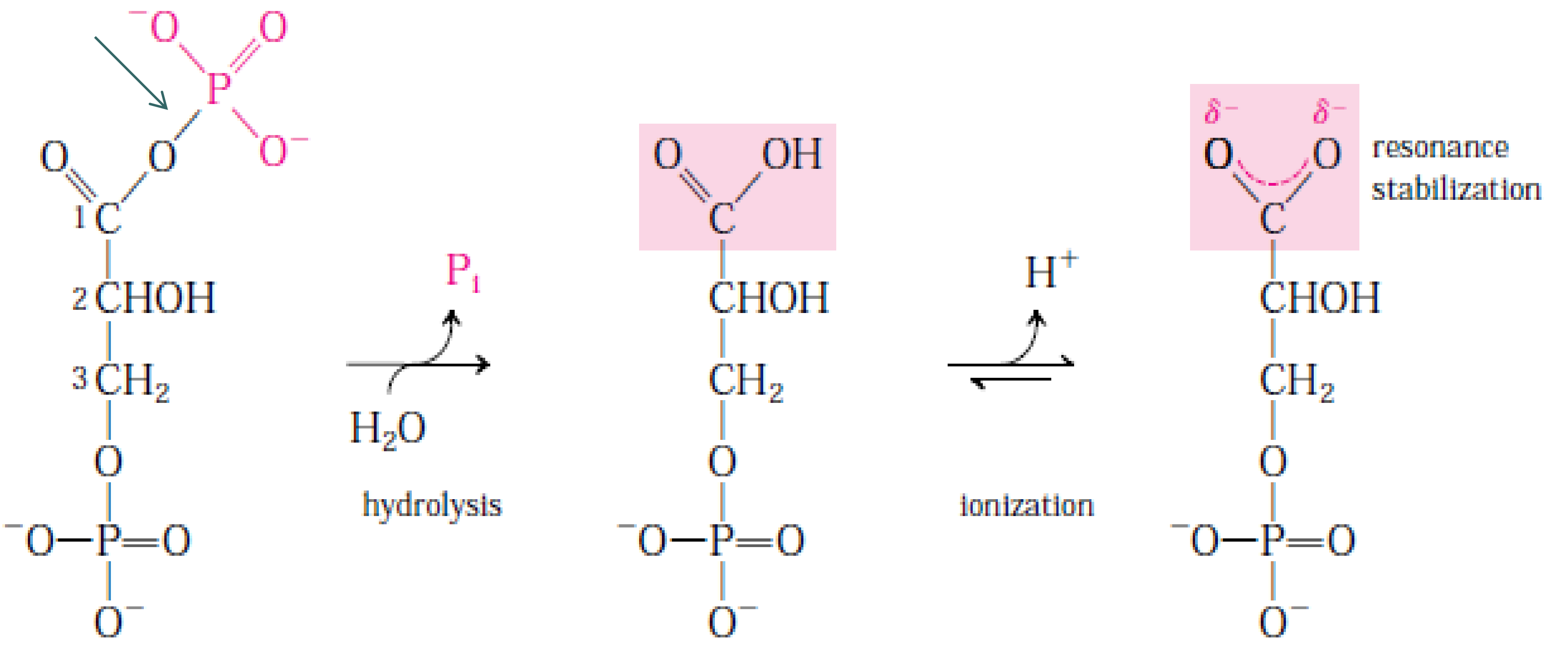


MACROMOLECULES
(GLUCOSE)
CATABOLISM
E
MICROMOLECULES
CO2+H+O2
ADP+Pi
E
ATP
SYNTHESIS, ANABOLISM
ELECTRICAL WORK
NERVE IMPULSE
MECHANICAL WORK
MUSCLE CONTRACTION
OSMOTIC WORK
CATION ACTIVE
TRANSPORT
HEAT
(BODY TEMPERATURE)

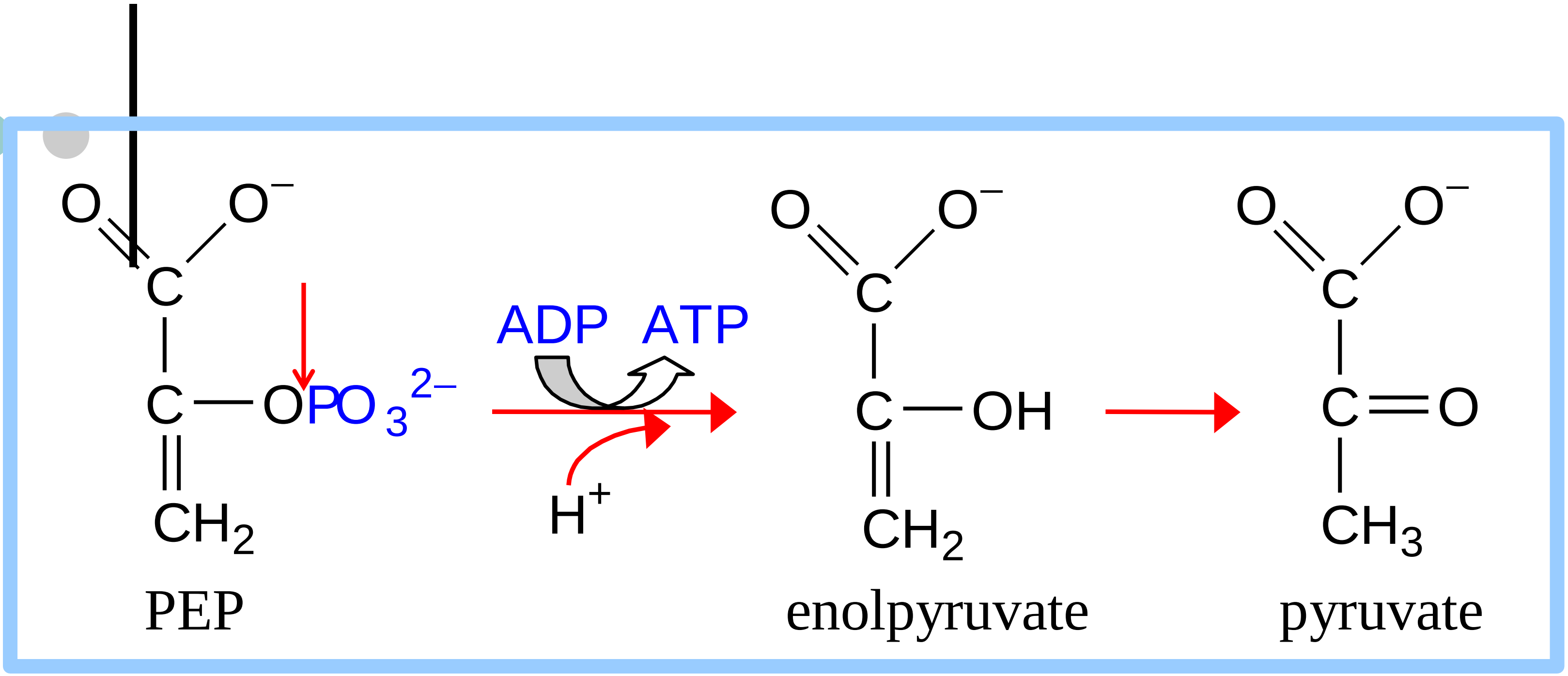
1,3 bisphosphoglycerate



1,3-Bisphosphoglycerate 3-Phosphoglyceric acid 3-Phosphoglycerate

$$\text{1,3-Bisphosphoglycerate}^{4-} + H_2O \longrightarrow \text{3-phosphoglycerate}^{3-} + P_i^{2-} + H^+$$

$$\Delta G'^{\circ} = -49.3\ \text{kJ/mol}$$



Phosphoenolpyruvate (PEP), involved in ATP synthesis in Glycolysis, has a very high ΔG of P_i hydrolysis.

Removal of P_i from ester linkage in PEP is spontaneous because the enol spontaneously converts to a ketone.

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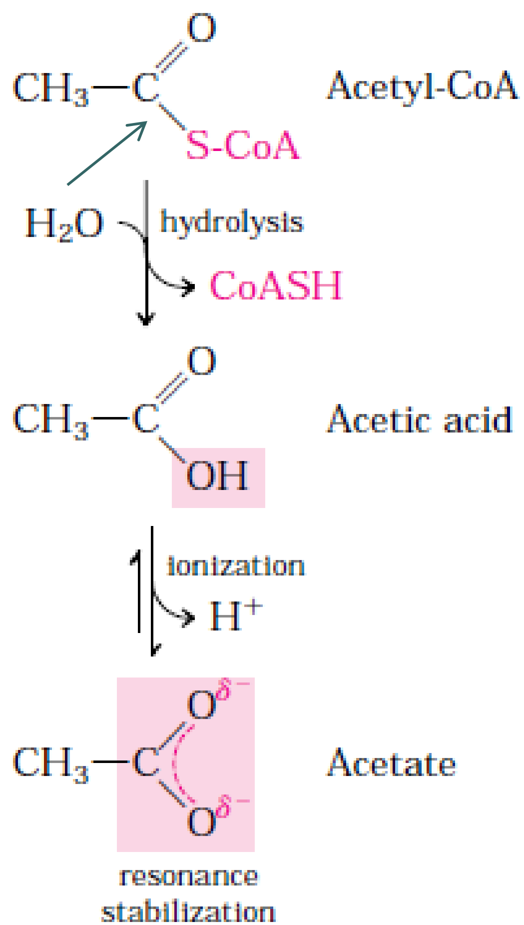
$$PEP^{3-} + H_2O \longrightarrow pyruvate^{-} + P_i^{2-}$$
$$\Delta G'^{\circ} = -61.9 \text{ kJ/mol}$$

Thioester: Acetyl-coA



$$\text{Acetyl-CoA} + H_2O \longrightarrow \text{acetate}^- + \text{CoA} + H^+$$
$$\Delta G'^\circ = -31.4 \text{ kJ/mol}$$

To Summarize

compounds with large, negative, standard free energies of hydrolysis give products that are more stable than the reactants because of one or more of the following:

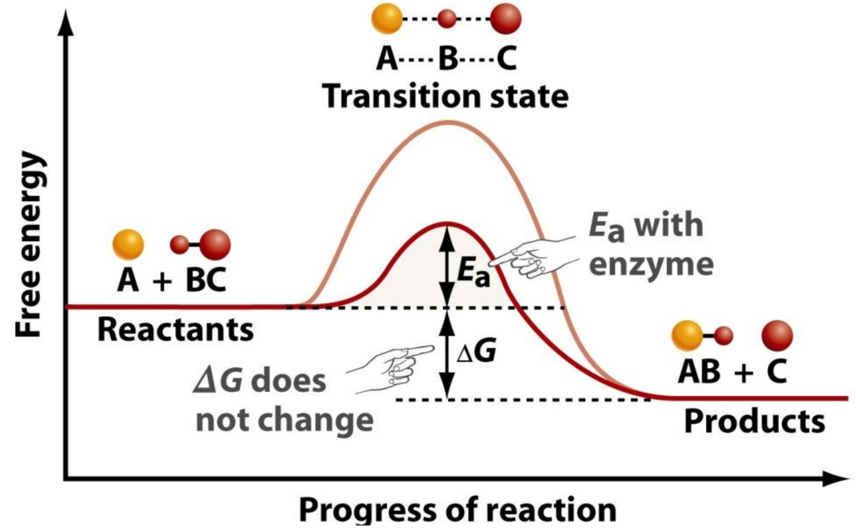
(1) the bond in reactants due to electrostatic repulsion is relieved by charge separation, as in the case of ATP

(2) the products are stabilized by ionization, as in the case of ATP, acyl phosphates, and thioesters,

(1) the products are stabilized by isomerization (tautomerization), as for phosphoenolpyruvate

How Enzymes Work

- Enzymes are substrate specific
  - **Substrate**: any molecule to which an enzyme will bind
- Although an enzyme can be a large protein, only a specific region of the enzyme interacts with the substrate
  - **Active Site**: region of enzyme that "reacts" to substrate
- As enzyme and substrate bind, the enzyme shape is modified to better fit the substrate
  - Induced fit occurs as a result of the enzyme substrate complex



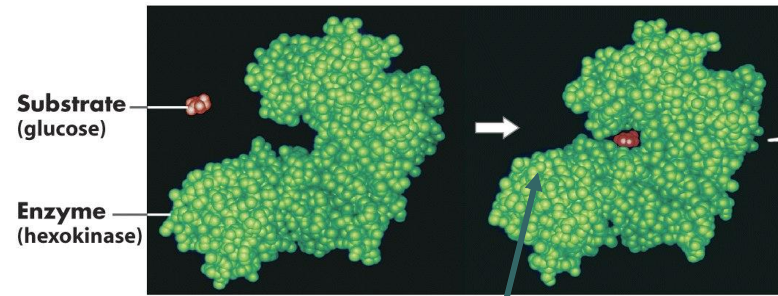


Figure 3-22 Biological Science, 2/e

Control of Metabolism

- **Allosteric Regulation**: enzyme function may be stimulated or inhibited by attachment of molecules to an **allosteric site**
- **Feedback Inhibition**: end product of metabolic pathway may serve as allosteric inhibitor