

Energy Metabolism & Control

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363 219 Biochemistry for Physical Therapist Student, Jan 2020

To maintain living status, living system
(cells / organisms) require...

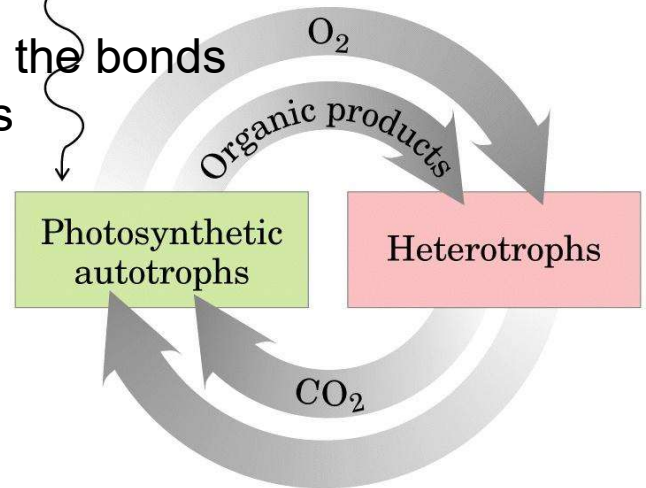
- Molecular building blocks
- Biochemical catalyst
- Genetic information
- Energy

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Energy conversion in biosphere

From environment into living systems:

- Electromagnetic (solar) energy
- Chemical energy which exist in the bonds of biological (organic) molecules



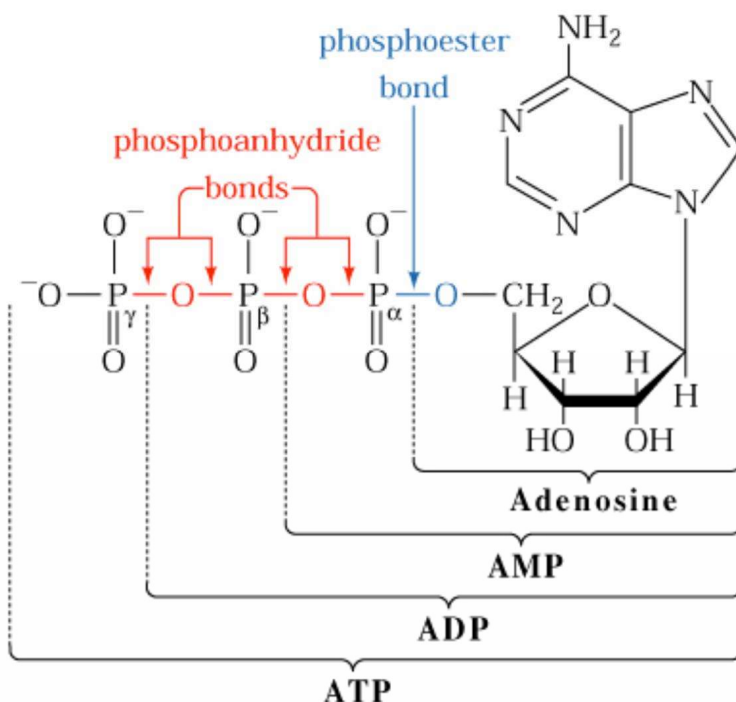
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ATP is the universal currency in biological system



Chapter 15 opener part 1
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- Hydrolysis of each phosphoanhydride bond generate -30.5 kJ/mol(-7.3 kcal/mol)



GTP

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Biological energy transformations obey the laws of thermodynamics

- **The First Law of Thermodynamics**; energy cannot be created or destroyed, it can only be transformed from one system to another...
- **The Second Law of Thermodynamics**; the disorder or randomness (entropy, S) of the universe increases during all chemical and physical processes...
- **Gibbs free energy, G** , expresses the amount of energy capable of doing work during a reaction at constant temperature and pressure. **Enthalpy, H** , is the heat content of the reacting system. It reflects the number and kinds of chemical bonds in the reactants and products. **Entropy, S** , is a quantitative expression for the randomness or disorder in a system.
- under conditions existing in biological systems, changes in free energy, enthalpy, and entropy are related to each other quantitatively by the equation,

$$\Delta G = \Delta H - T\Delta S$$

Amino acids \rightarrow protein

ΔG_1 is positive (endergonic)

$\text{ATP} \rightarrow \text{AMP} + \textcircled{\text{P}}-\textcircled{\text{P}}$

ΔG_2 is negative (exergonic)

[or $\text{ATP} \rightarrow \text{ADP} + \textcircled{\text{P}}$]

Coupling reactions

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Energy transformation in the living systems

- **Biosynthetic work**, formation of new bonds and generation of new biomolecules
- **Mechanical work**, movement of cells and muscular contraction
- **Concentration work**, transportation of molecules across plasma membrane
- **Electrical work**, transportation of proton across plasma membrane
- **Thermal regulation**, 2/3 of metabolic energy in warmed- blood animal is heat to maintain body temperature
- **Bioluminescence**, firefly use energy from ATP hydrolysis to generate photon

Metabolism is a highly coordinated cellular activity in which many multienzyme systems (metabolic pathways) cooperate to

- obtain chemical energy by capturing solar energy or degrading energy-rich nutrients from the environment
- convert nutrient molecules into the cell's own characteristic molecules, including precursors of macromolecules
- polymerize monomeric precursors into macromolecules: proteins, nucleic acids, and polysaccharides
- synthesize and degrade biomolecules required for specialized cellular functions, such as membrane lipids, intracellular messengers, and pigments.

From; Lehninger Principles of Biochemistry (7th, Nelson & Cox 2017, Part II)

Types of Metabolism

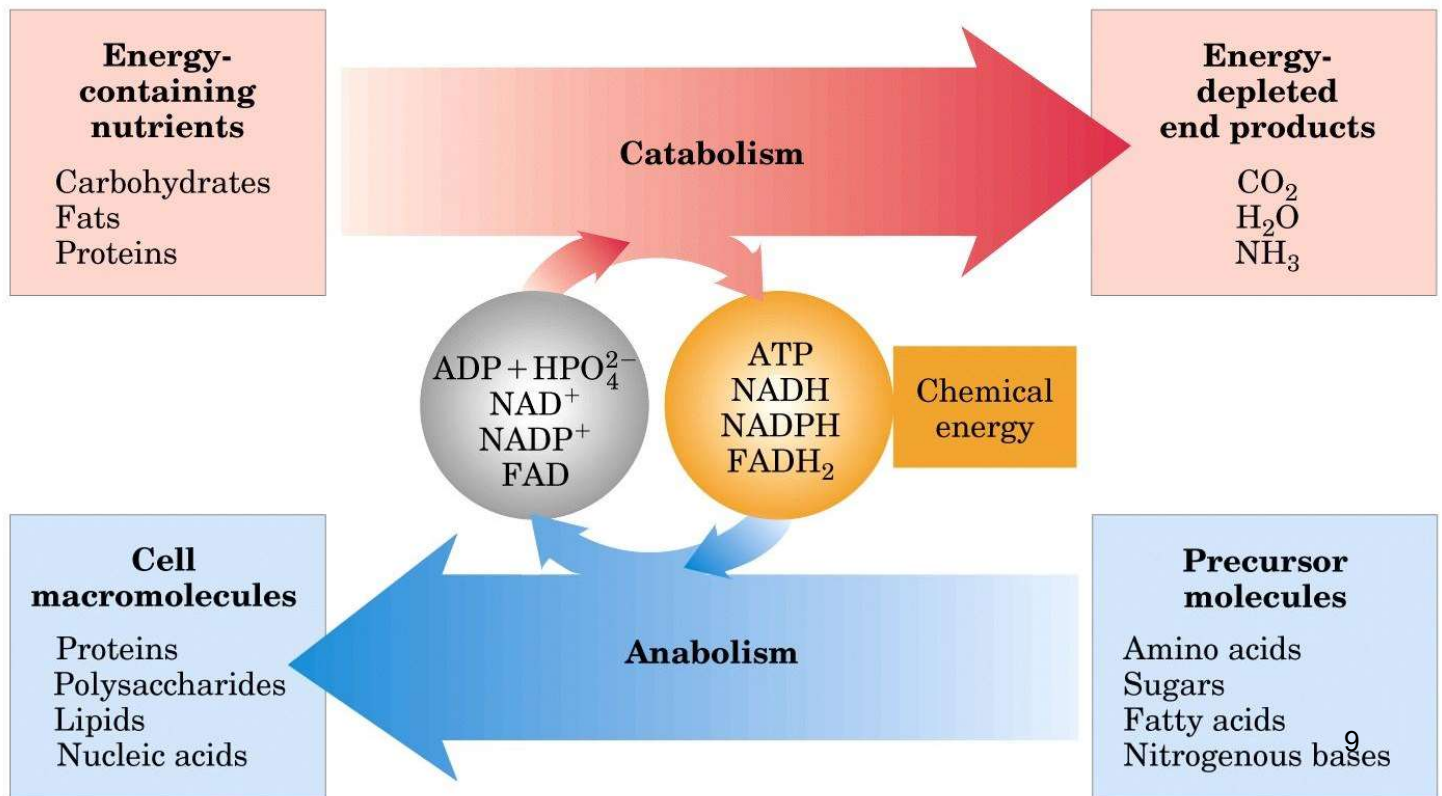
- ***Catabolism***

Biochemical processes by which nutrients and cellular components are broken down to generate energy and small biomolecules

- ***Anabolism***

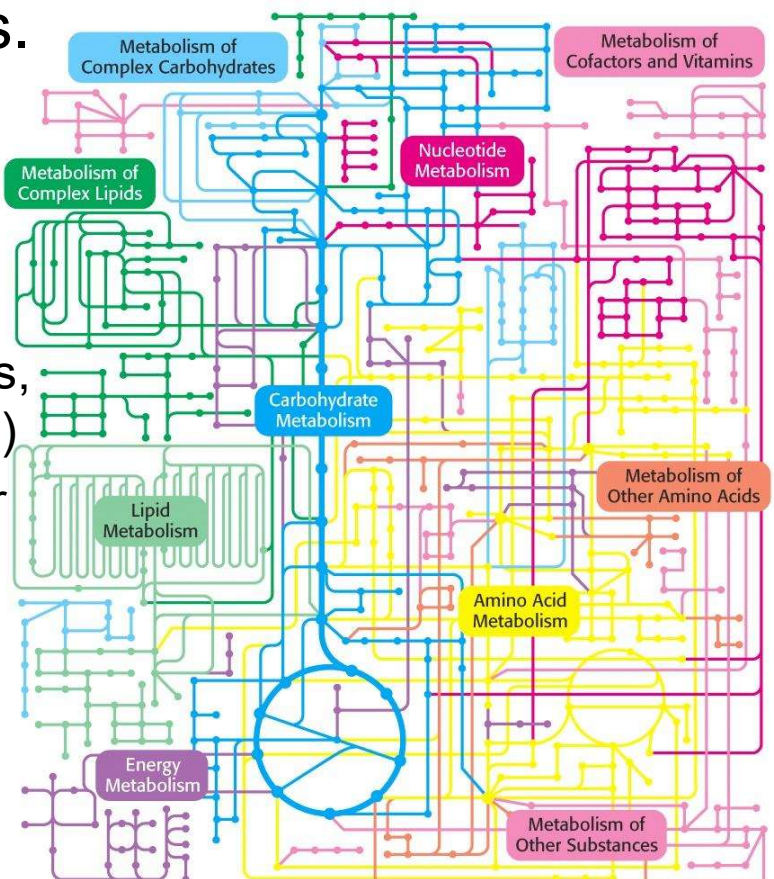
Biochemical processes to synthesize new biomolecules from precursors, building blocks & energy from catabolic processes

Relationship between catabolic and anabolic pathways

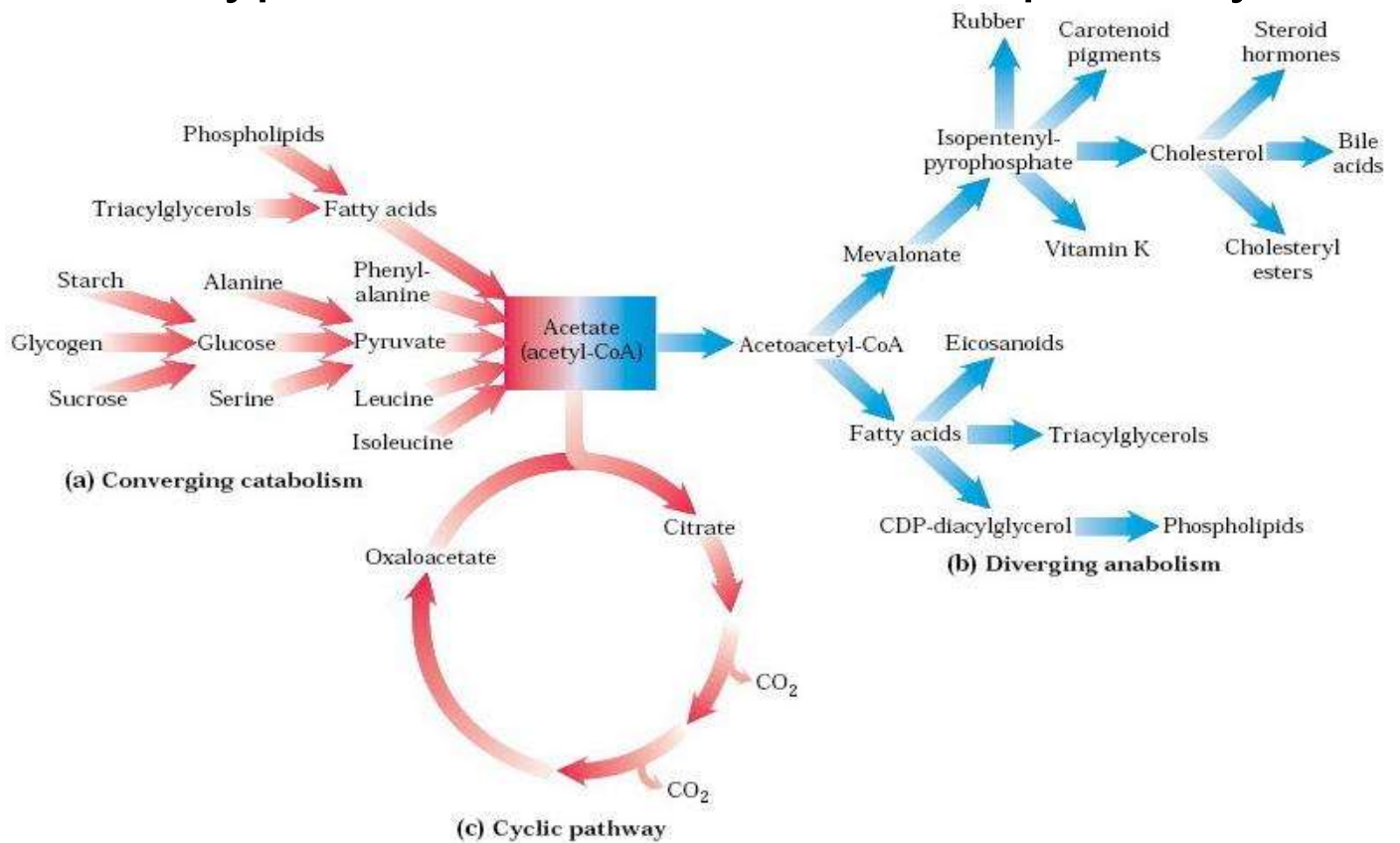


Metabolism is highly integrated network of biochemical pathways.

- Enzymes catalyse all the biochemical reactions
- Most enzymes are proteins, a few are RNAs (ribozyme)
- Enzyme functions alone or requires 'cofactor' / 'coenzyme'



Three types of nonlinear metabolic pathways

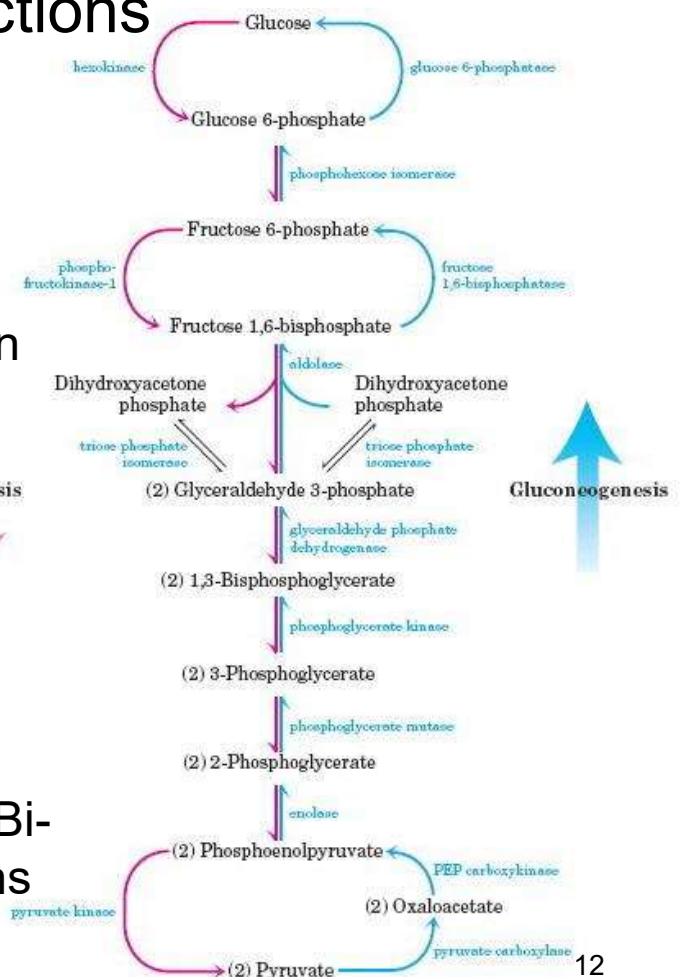


Precursor(s) >>>> Intermediate Metabolites >>>> Product(s)

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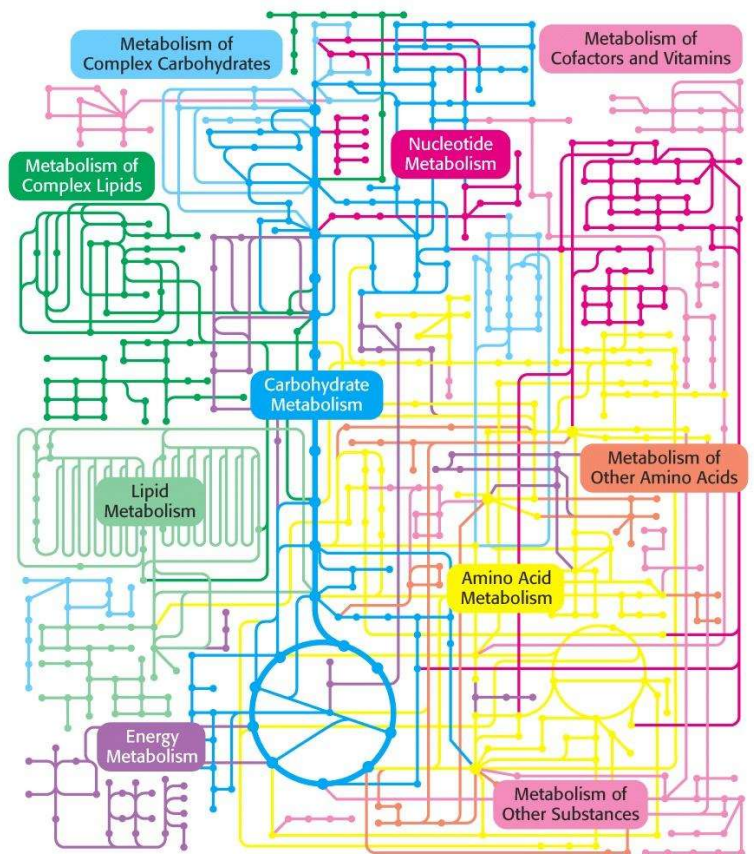
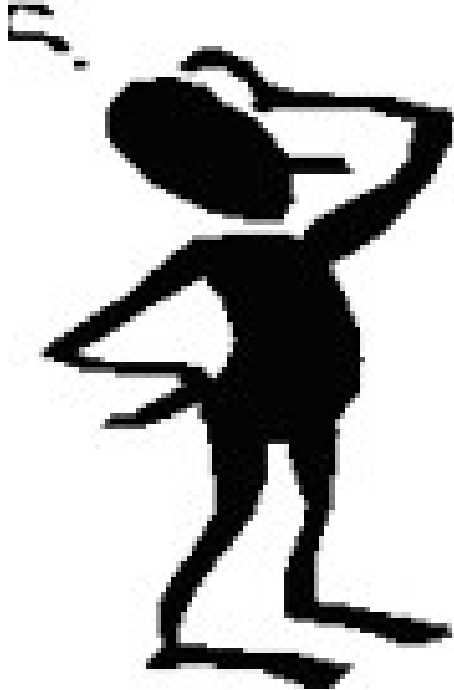
Types of biochemical reactions

- Oxidation-reduction reactions
- Functional group transfer within or between molecules
- Addition and removal of water
- Bond-breaking reactions
- Unidirectional (irreversible) or Bi-directional (reversible) reactions



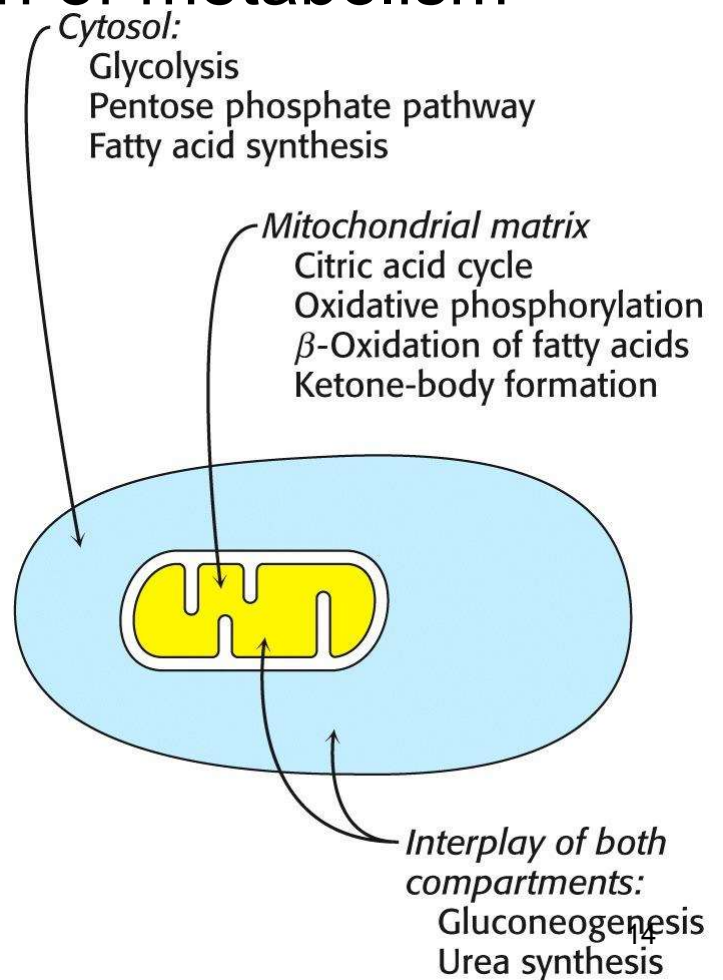
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How metabolisms are regulated?

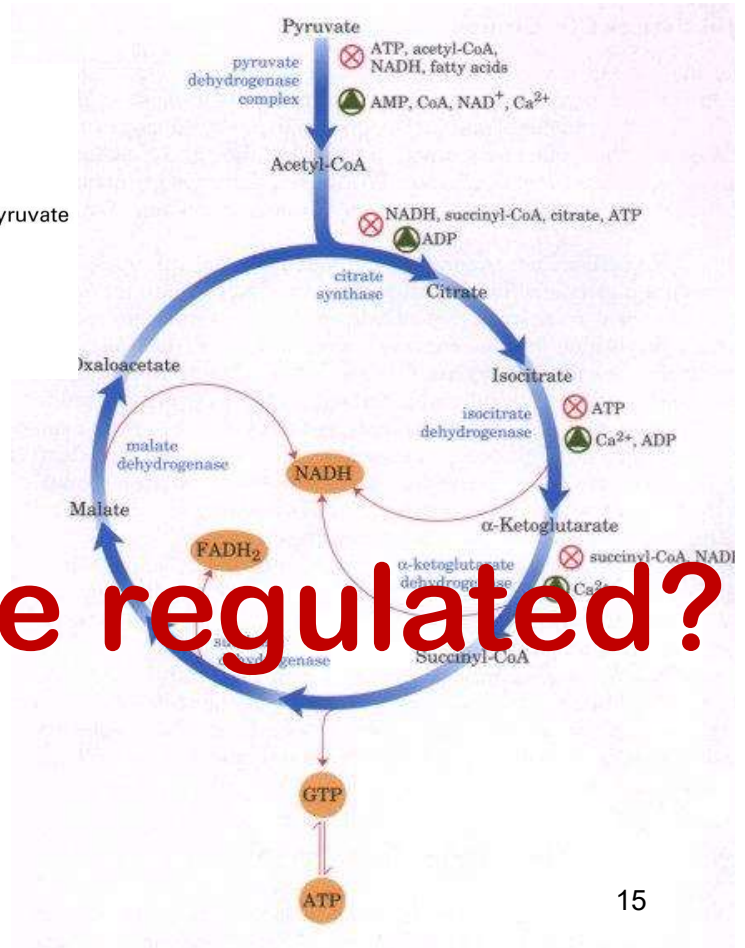
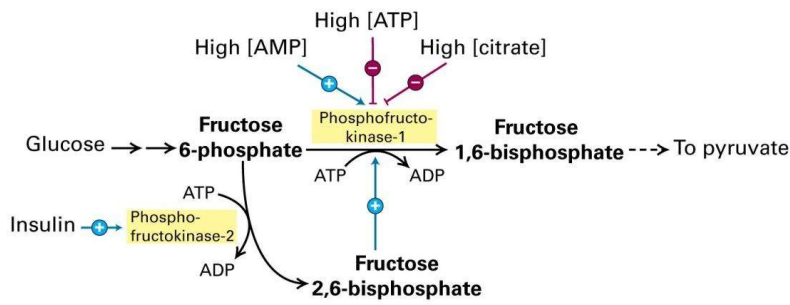


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Compartmentalization of metabolism



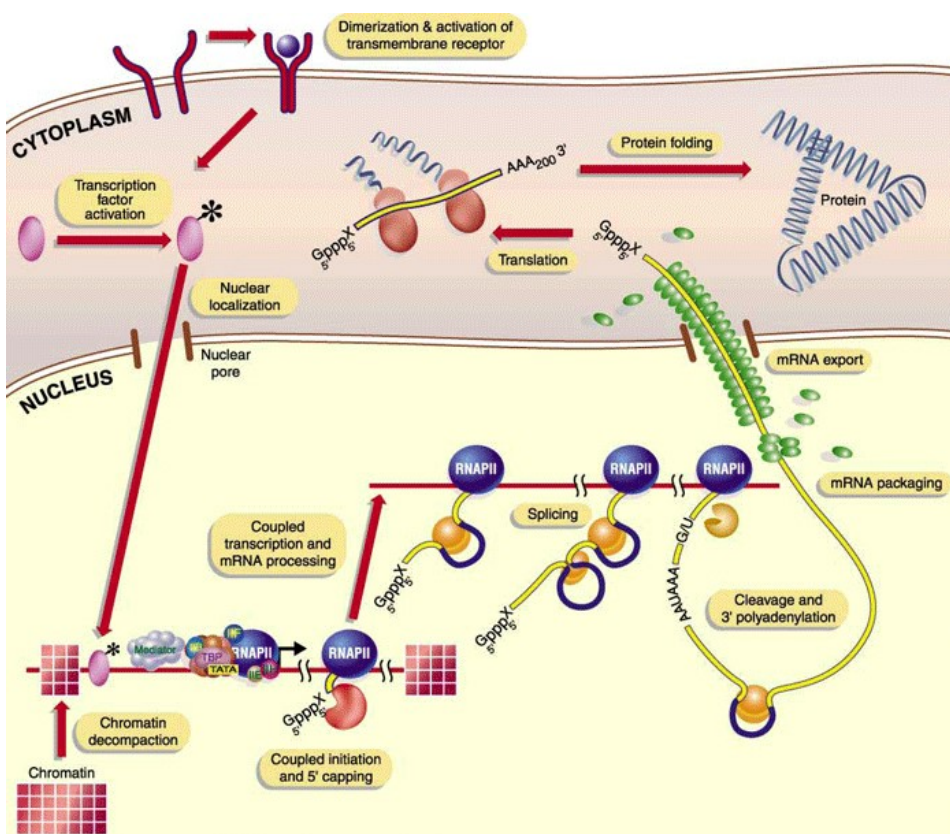
Regulation of key enzymes



How they are regulated?



Biosynthesis & degradation of key enzymes



Function

Degradation

Allosteric regulation of *phosphofructokinase* by ATP & AMP

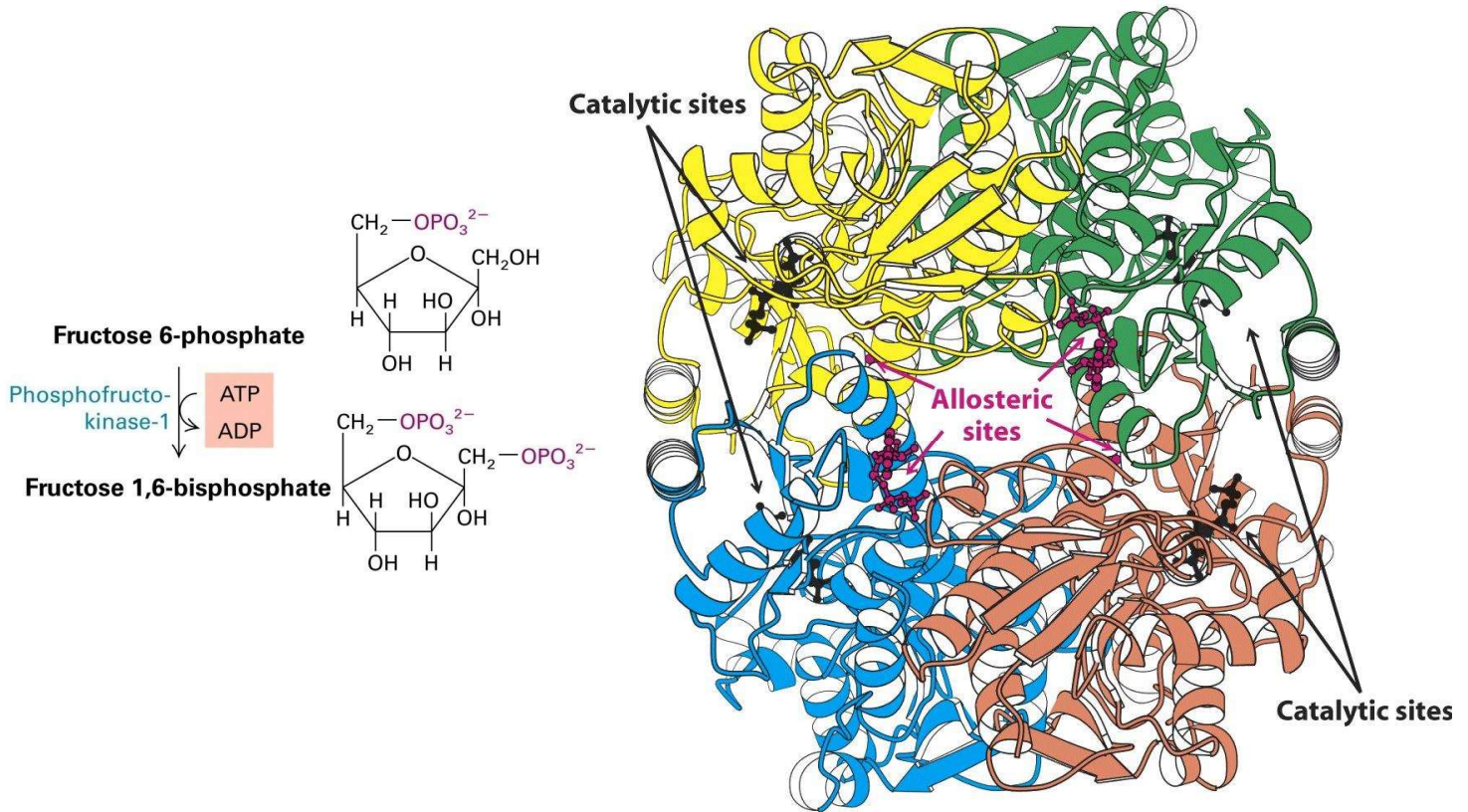


Figure 16-15
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Covalent modification (phosphorylation) and allosteric regulation (ATP & alanine) of *pyruvate kinase*

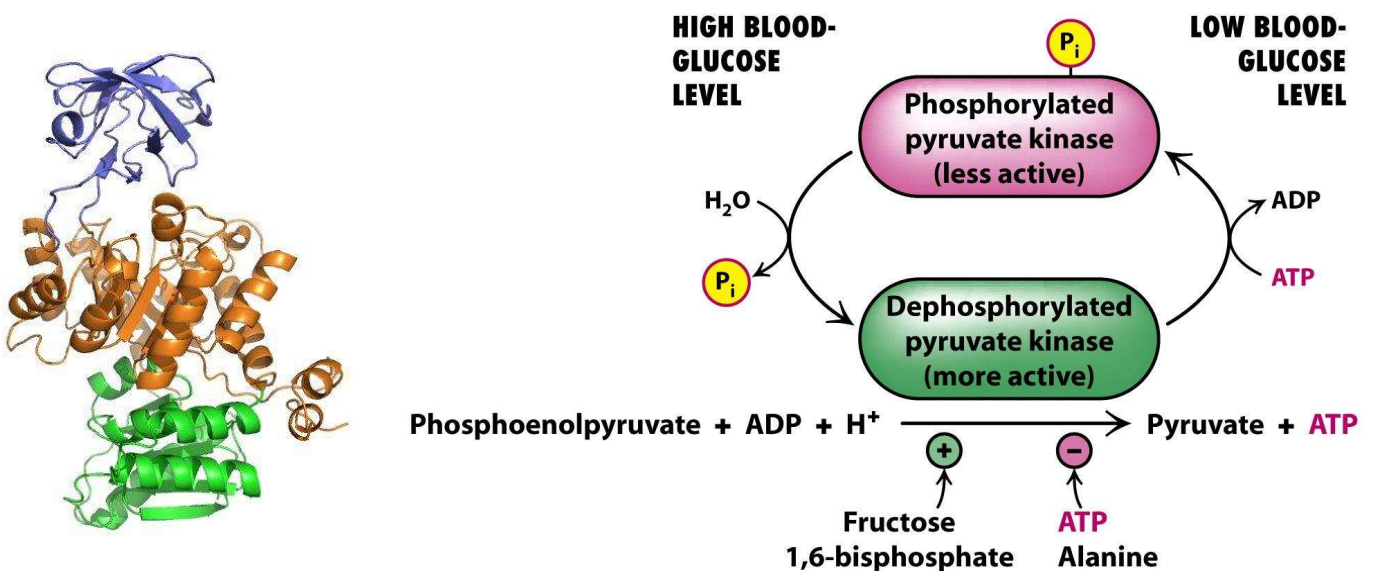


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Energy sources for muscular contraction

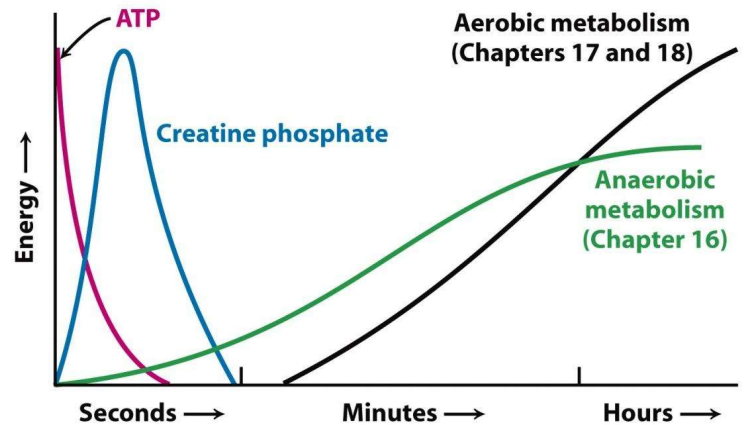
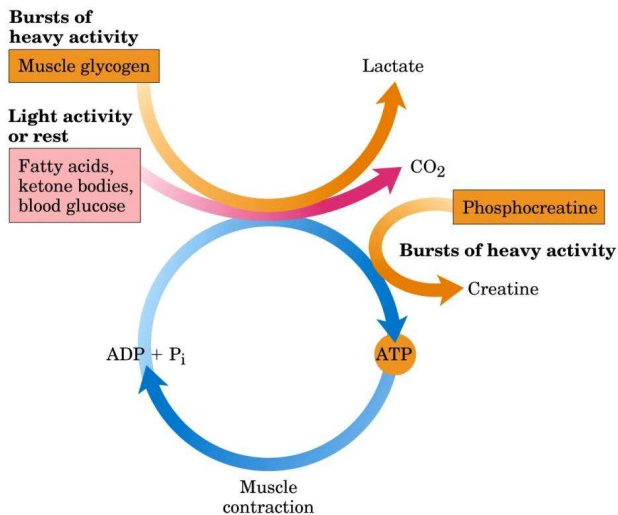
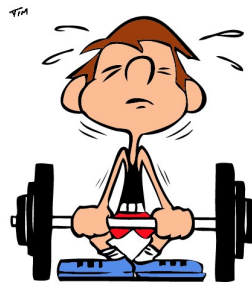


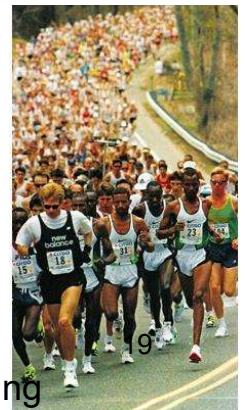
Figure 15-7
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100 metre sprint



weight-lifting



marathon running

What you have learn from this 2 hours?

- How **energy** is transduced from environment into living system?
- **ATP** is an important metabolic fuel for biochemical reactions and cell functions
- Definition and types of **metabolism**
- **Enzymes**, metabolic catalysts and ways to regulate their function

