Bioenergetics

Kuntarti

Principles of Bioenergetics

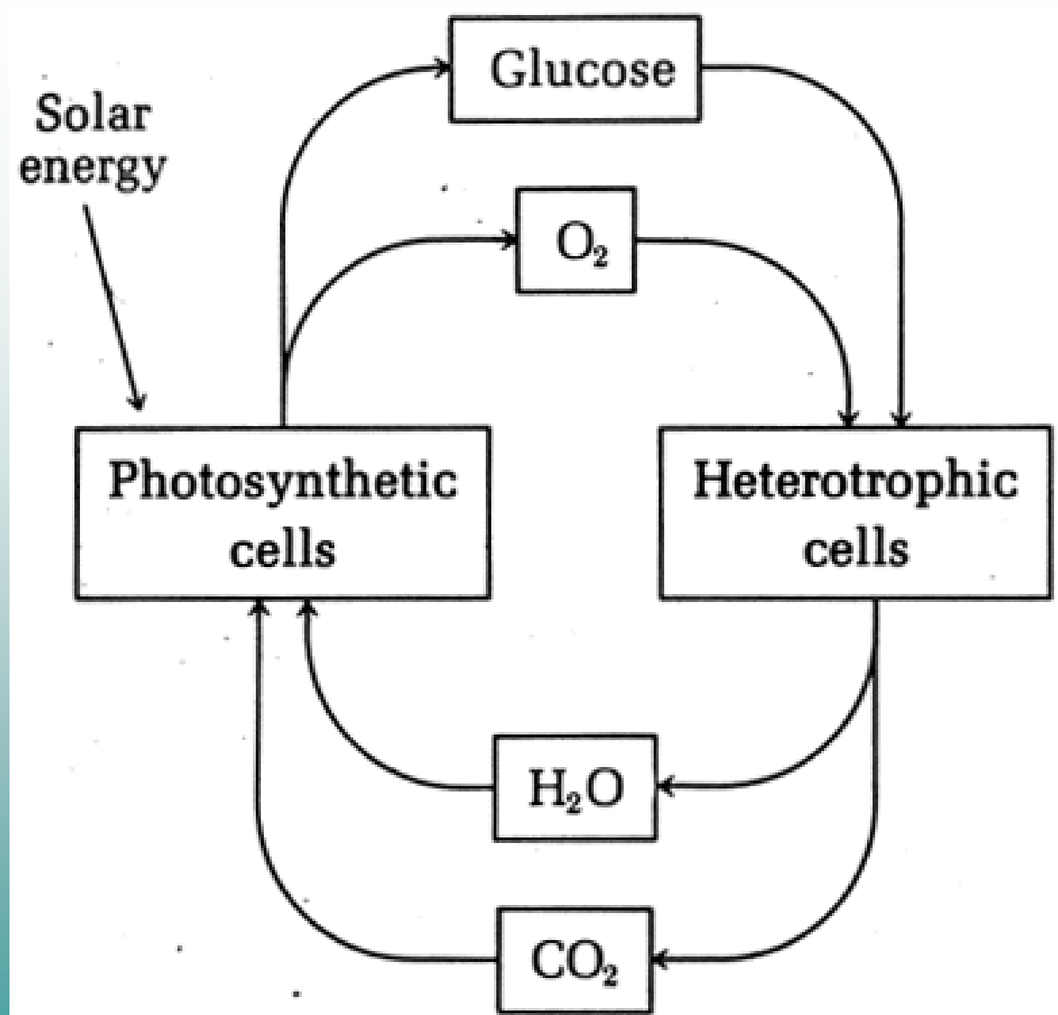
Definitions

- the study of energy transformations in living organism (Albert L Lehninger)
- the study of the balance between energy intake in the form of food and energy utilization by living organism for life-sustaining processes (Joe M Fox)
- the study of energy changes accompanying biochemical reactions (Peter A Mayes)

1. Unidirectional Flow of Energy Through The Biosphere

- Key event: photosynthesis → the capture of the sun's energy & its transduction into chemical energy
- 2 phase: an oxidation – reduction reaction
  1) water is oxidized;
     light energy → chemical energy (ATP & NADPH)
     water is the primary reductant (electron donor)
  2) the synthesis of a reduced product of CO_2
     CO_2 is electron acceptor

The carbon-oxygen Cycle



2. Free Energy is the Useful Energy in System

- The 1st law thermodynamics = the law conservation of energy
  "the total energy of a system, including its surroundings, remains constant"
  ➔ within in the system, energy may be transferred or transformed from one part to another or into another form of energy
- The 2nd law thermodynamics
  "the total entropy of a system must increase if a process is to occur spontaneously"

The 2nd Law thermodynamics

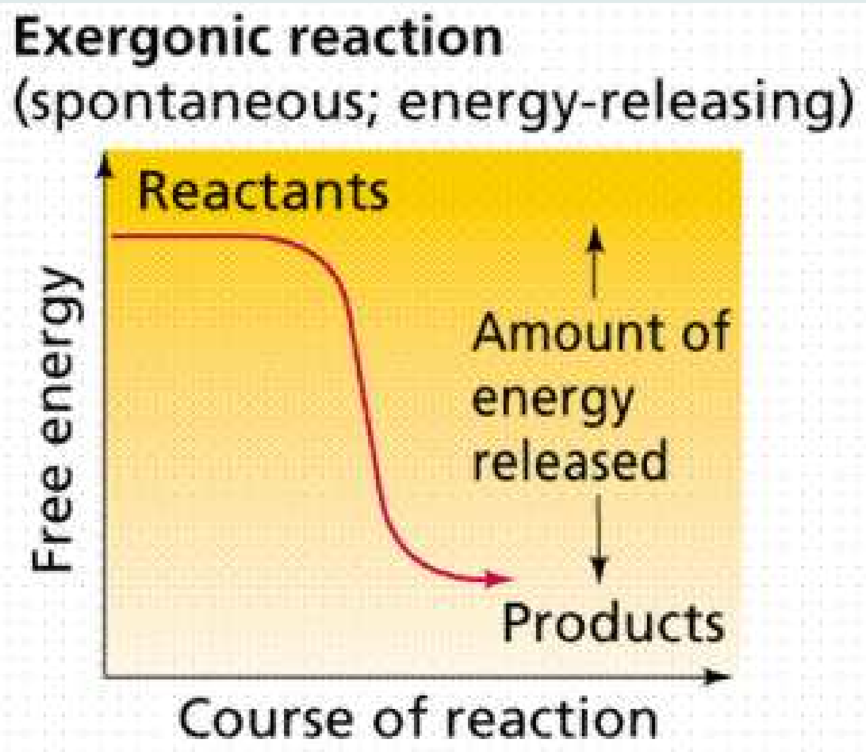
- Entropy represents the extent of disorders or randomness of the systems; the entropy will continue to increase until equilibrium is reached.

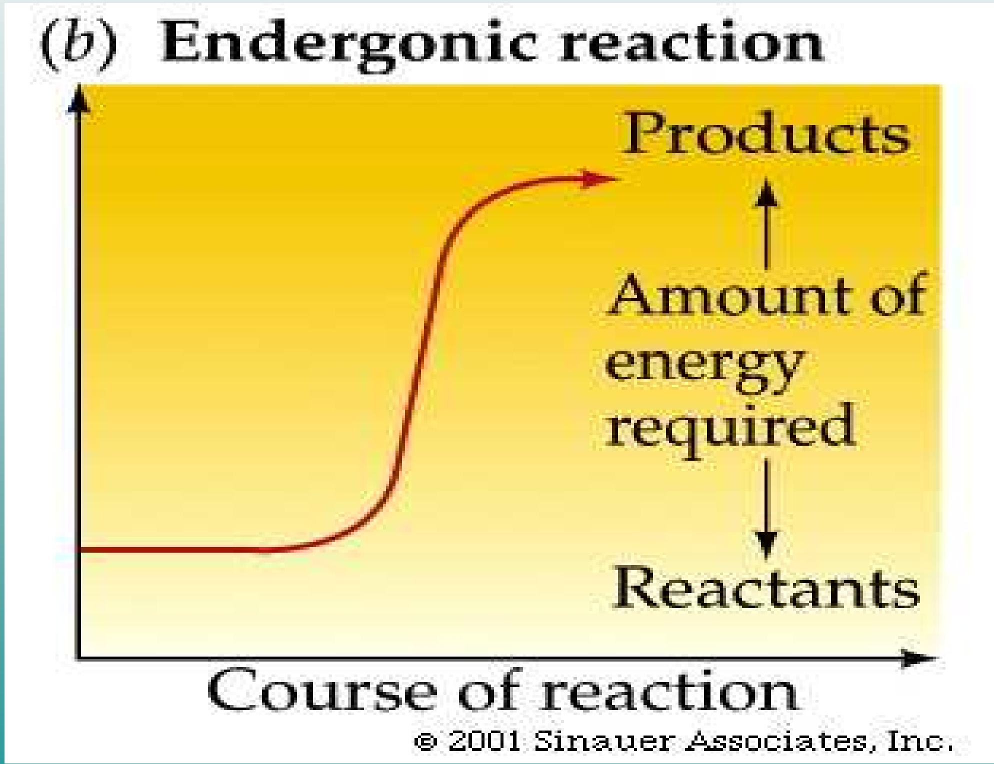
$$\Delta G = \Delta H - T\Delta S$$

- ΔG (free energy change); ΔH (enthalpy/ heat)
  T (absolute temperature); ΔS (change in entropy)
- If ΔG is negative → loss of free energy ➔ **exergonic**
- If ΔG is positive → free energy can be gained ➔ **endergonic**
- If ΔG is great ➔ the system is stable
- If ΔG is zero ➔ the system is at equilibrium

3. Transfer of Free Energy in Consecutive Reactions Coupled by a Common Intermediate

- Endergonic processes (gain of free energy) proceed by coupling to exergonic processes (loss of free energy)





- The transfer of energy through a common intermediate of sequential is the hallmark of metabolic process in biologic systems.
- The common intermediate: organophosphate derivates → Adenosine triphosphate (ATP)

Phosphoeneolpiruvate + D-glukose ↔ pyruvate + glocose-6-phosphate

1. Phosphoeneolpiruvate + ADP ↔ ATP + pyruvate
2. ATP + glucose ↔ glucose-6-phosphate + ADP

1. ATP → ADP + phosphate ((hydrolisis) with large & (-) ΔG/ exergonic)
2. Glucose + phosphate → glucose-6-phosphate;(with (+) ΔG/ endergonic)

Net: ATP + glucose → ADP + glucose-6-phosphate; with a large & (-) ΔG

4. High-Energy Phosphates play a Central Role in Energy Capture & Transfer

- Lipmann ➔ the concept role of the high-energy phosphates & the high-energy phosphate bond in bioenergetics
- *Low-energy phosphates* → the ester phosphates has $\Delta G < \Delta G$ ATP
  ➔ ADP, pyrophosphate, glucose-1-phosphate, fructrose-6-phosphate, AMP, glucose-6-phosphate, glycerol-3-phospate
- High-energy phosphates → has $\Delta G > \Delta G$ ATP
  ➔ phosphoenolpyruvate, carbamoyl phosphate, 1,3-diphosphoglycerate, creatine phosphate, coenzyme-A (acetyl-CoA), etc

5. High-energy phosphates act as the "Energy Currency" of the cell

- An ATP/ADP cycle generate ~(P)
- Three major sources of ~(P)

  1. Oxidative phosphorylation
     → is the greatest quantitative source of ~(P) in aerobic organism
     → the free energy comes from respiratory chain oxidation within mitochondria
  2. Glycolysis
  3. The Citric acid cycle

- Phosphagens: storage of high-energy phosphate
  ➔ creatine phosphate in vertebrate skeletal muscle, heart, spermatozoa & brain
  ➔ arginine phosphate in invertebrate muscle

References:

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2. Murray, R.K., Granner, D.K., Mayes, P.A., & Rodwell, V.W. 1996. *Harper's Biochemistry.* 24th edition. London: Prentice-Hall International, Inc.

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