

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ
(وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ)



Metabolism | Lecture 2

Principles of Bioenergetics



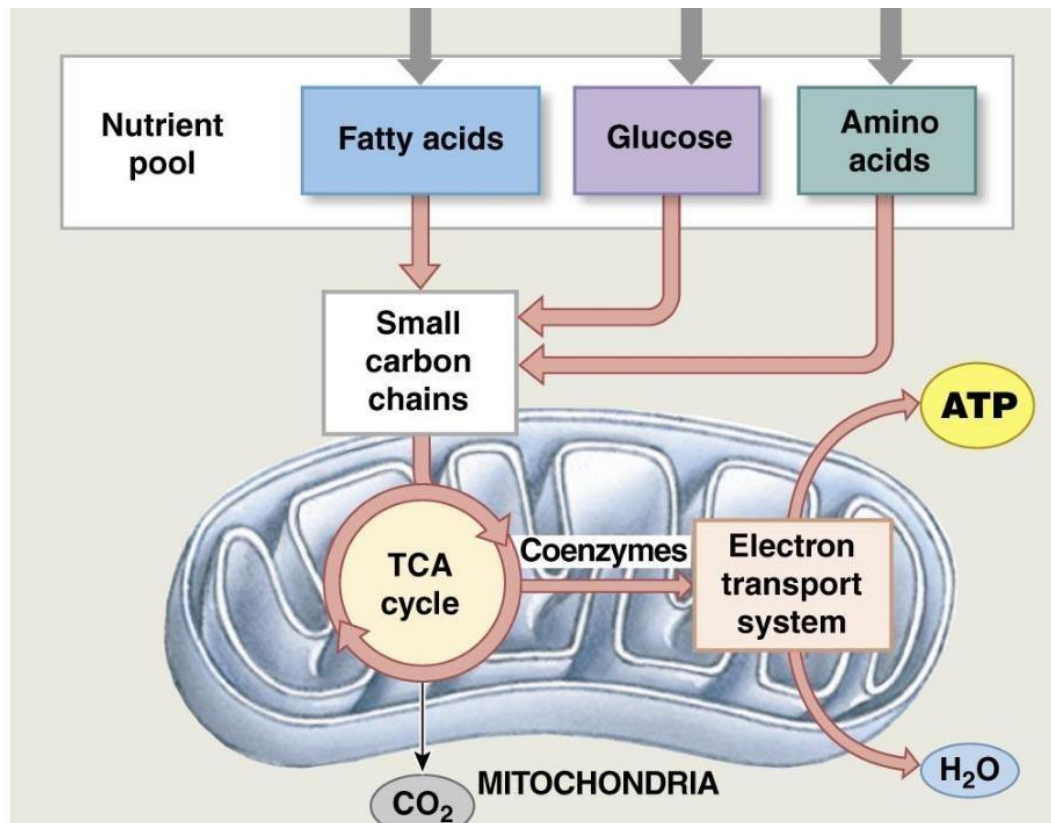
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Reviewed by : NST

Principles of bioenergetics

2-Phosphoryl Group Transfers and ATP

THE ENERGY FLOW



- Ingestion, digestion, & absorption
- Metabolism (Acetyl CoA)
- TCA
- Oxidative phosphorylation

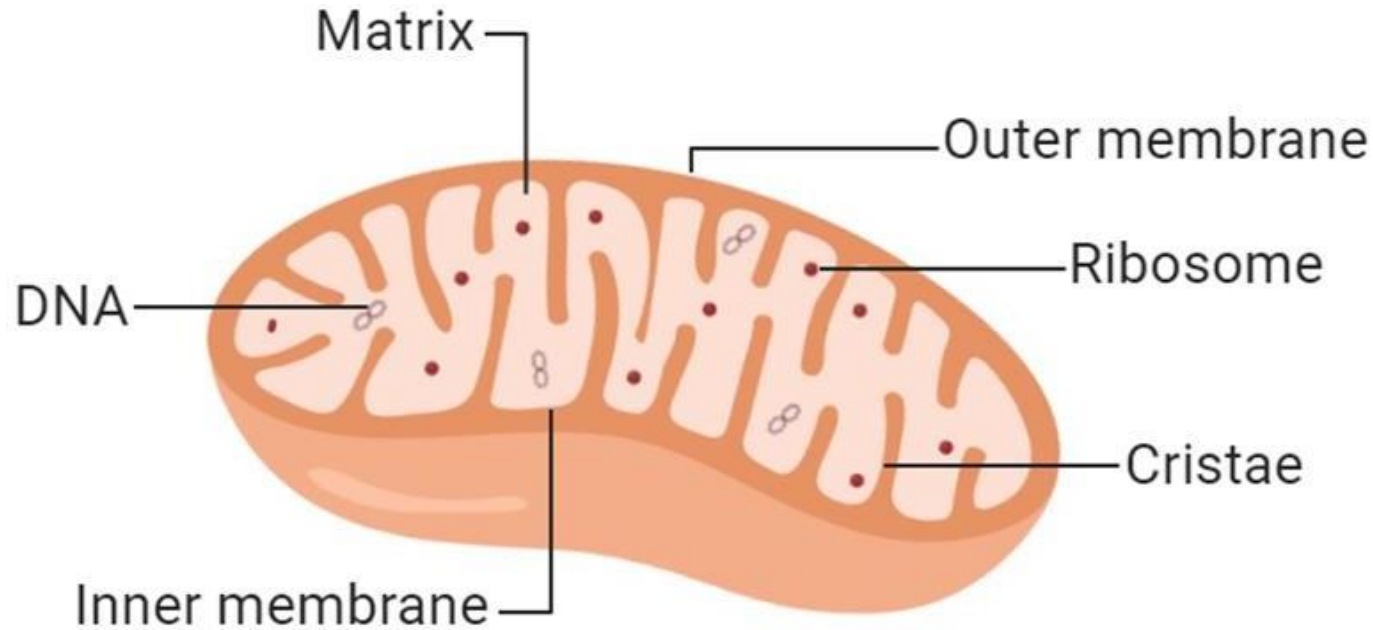
Energy flow stages

- First stage : ingestion ,digestion of food in GI tract , then absorption, molecules reach to the blood stream. Finally, it will be delivered to the cells .
- Second stage is (metabolism) the process through which the molecules from food are transformed inside the body to produce and use energy .
- and in this semester we are going to study the metabolism pathway, of carbs ,lipids , amino acids , nucleic acid .
- Acetyl CoA is a common shared molecule between more macromolecules that we are dealing with.

- Overview: How nutrients become Acetyl-CoA
- 1. Carbohydrates → Glucose → Pyruvate → Acetyl-CoA
- 2. Amino Acids → deamination → carbon skeleton → pyruvate Acetyl-CoA
- The acetyl CoA is the intermediate that enters (Krebs cycle , citric acid cycle) which is the third stage of energy metabolism
- Oxidative Phosphorylation is the forth stage of energy metabolism .

- Most of the second stage third stage and fourth stage happen in mitochondria Which is the organelle responsible for producing energy for your cells approximately 90% of your need 10% is produced by glycolysis which is in the cytoplasm.
- Why does glycolysis occur outside the mitochondria ? because some cells don't have mitochondria.

THE ENERGY MACHINERY OF THE CELL



- Prokaryotic cells vs. eukaryotic cells
- The mitochondria (singular, mitochondrion) (90% of the body's energy ATP)
- The number of mitochondria is greatest in eye, brain, heart, & muscle, where the need for energy is greatest
- The ability of mitochondria to reproduce (athletes)
- Maternal inheritance

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ
﴿إِنَّ اللَّهَ وَمَلَائِكَتَهُ يُصَلُّونَ عَلَى النَّبِيِّ يَا أَيُّهَا
الَّذِينَ آمَنُوا صَلُّوا عَلَيْهِ وَسَلِّمُوا تَسْلِيمًا﴾

اللَّهُمَّ صَلِّ وَسَلِّمْ وَبَارِكْ عَلَى نَبِيِّنَا مُحَمَّدٍ ﷺ

Evidences prove that mitochondria was bacteria :

1. It has its own DNA genetic material (circular as bacteria)
2. It has double membrane
 - A. The outer one (mammalian membrane) permeable to charged molecules dependent on their size if the are 5kdalton or less there pass it .
 - B. The inner one (mitochondrial membrane) which is not permeable to any charged molecules even protons (the smallest charged molecule) → Achieved by :
 - 1- cardiolipins
 - 2-the high density of proteins throughout the hole membrane .
-
- 3.It replicates/ reproduces independently of the mother cells , depending on the energy needs .
- 4.It replicates by fission like bacteria .

- Number of mitochondria per cell is 2000 .
- When the mother cell replicates to give daughter cells the mitochondria will distributed randomly .
- Mutation could happen in :
- 1- Nuclear DNA
→ produces proteins for mitochondria (13 subunit) if we have a mutation and a nuclear DNA for a protein directed to go to mitochondria it might result a disease . how can we detect it? By take blood sample (WBC) examine any cell in the body ; the nuclear genetic material is the same among cells because replication is mitotic .
- 2- Mitochondrial DNA
we can detect it by biopsy from the defective tissue .
- Why we can't examine any cell ? Because of the random distribution of mitochondria on germatic level .

- When an egg and sperm unite during fertilization, the egg provides almost all the cytoplasm and organelles, including mitochondria.
- The sperm's mitochondria are located in its tail, which usually does not enter the egg or is destroyed shortly after fertilization.
- Therefore, the embryo's mitochondria—and its mitochondrial DNA—come entirely from the mother's egg.
- So, if a mutation exists in the mother's mitochondrial DNA, all her children can inherit it, but only her daughters will pass it to the next generation.



ATP

- **ATP is the energy currency of the cell**
- **What is a high energy molecule?**
- **Why ATP?**
 - **Has an intermediate energy value, so can be coupled**

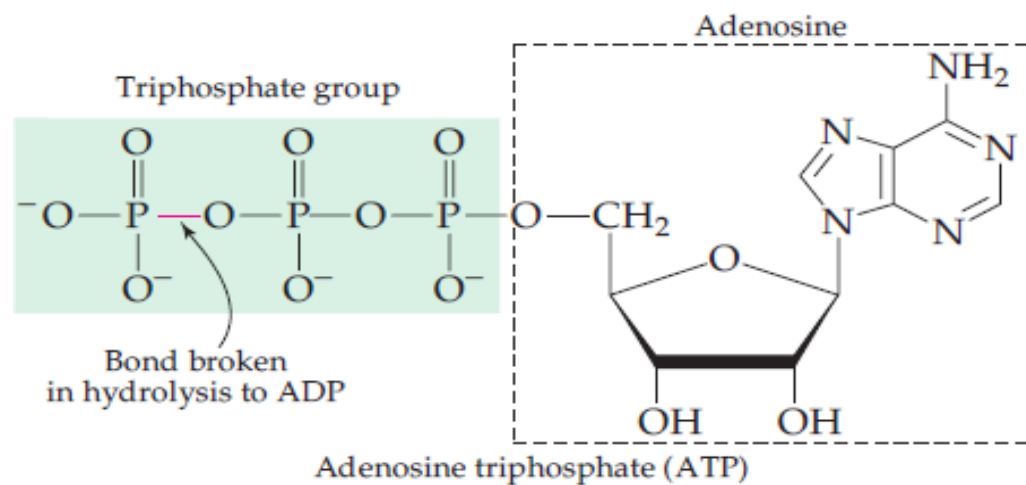


TABLE 13–6 Standard Free Energies of Hydrolysis of Some Phosphorylated Compounds and Acetyl-CoA (a Thioester)

	ΔG°	
	(kJ/mol)	(kcal/mol)
Phosphoenolpyruvate	−61.9	−14.8
1,3-bisphosphoglycerate ($\rightarrow$ 3-phosphoglycerate + P_i)	−49.3	−11.8
Phosphocreatine	−43.0	−10.3
ADP ($\rightarrow$ AMP + P_i)	−32.8	−7.8
ATP ($\rightarrow$ ADP + P_i)	−30.5	−7.3
ATP ($\rightarrow$ AMP + PP_i)	−45.6	−10.9
AMP ($\rightarrow$ adenosine + P_i)	−14.2	−3.4
PP_i ($\rightarrow$ 2 P_i)	−19.2	−4.0
Glucose 1-phosphate	−20.9	−5.0
Fructose 6-phosphate	−15.9	−3.8
Glucose 6-phosphate	−13.8	−3.3
Glycerol 1-phosphate	−9.2	−2.2
Acetyl-CoA	−31.4	−7.5

Why ATP?

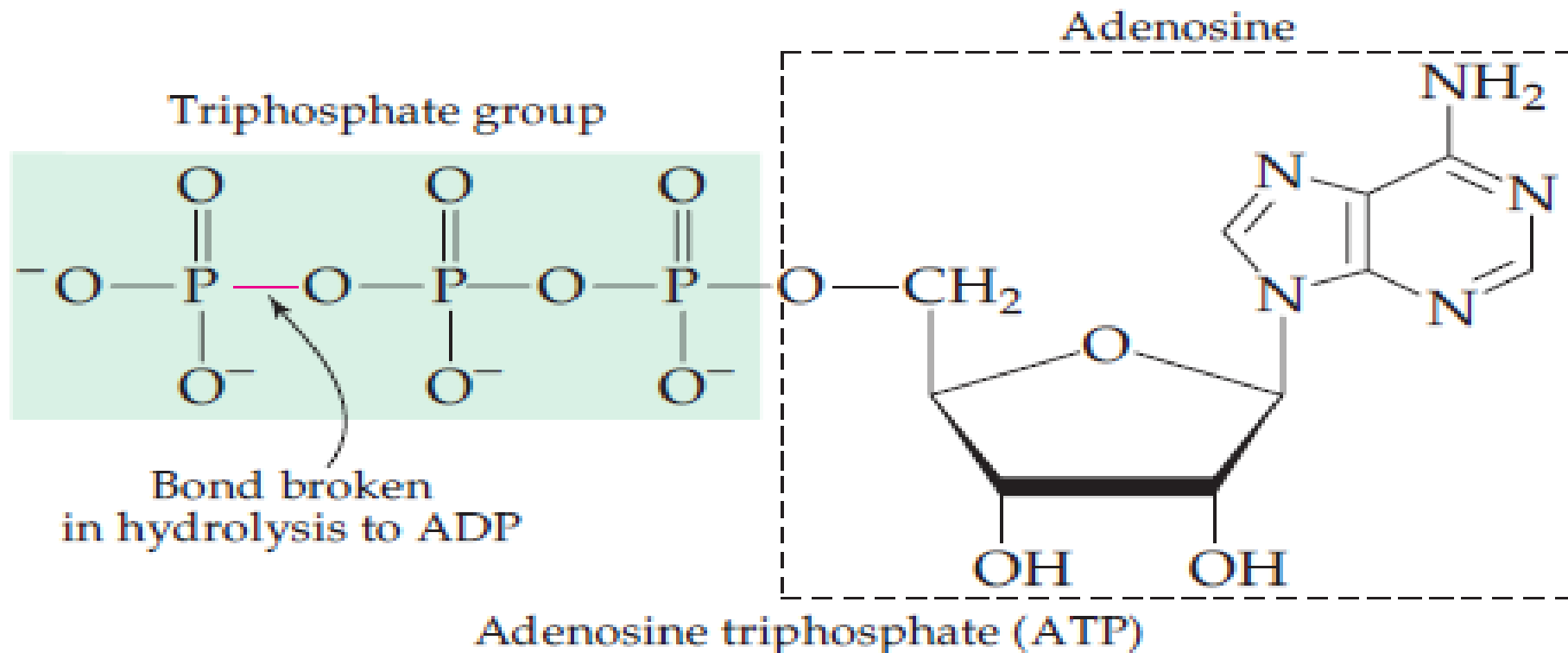
- **1- Has an intermediate energy value, so it can be coupled :**
- If ATP hydrolysis released too much energy, cells wouldn't be able to use it efficiently. The extra energy would turn into heat, damaging cellular structures and lowering the efficiency of biochemical reactions. Since energy can't be destroyed, only transformed, the wasted energy would disrupt the balance and require the cell to use more resources just to maintain ATP levels (according to the first law of thermodynamics).
- It would also be harder to produce ATP because forming it from ADP and P_i would require much more input energy.

□ Why ATP?

- If ATP had very low energy, the consequences would be:
- Insufficient energy release.
- More ATP needed over time.

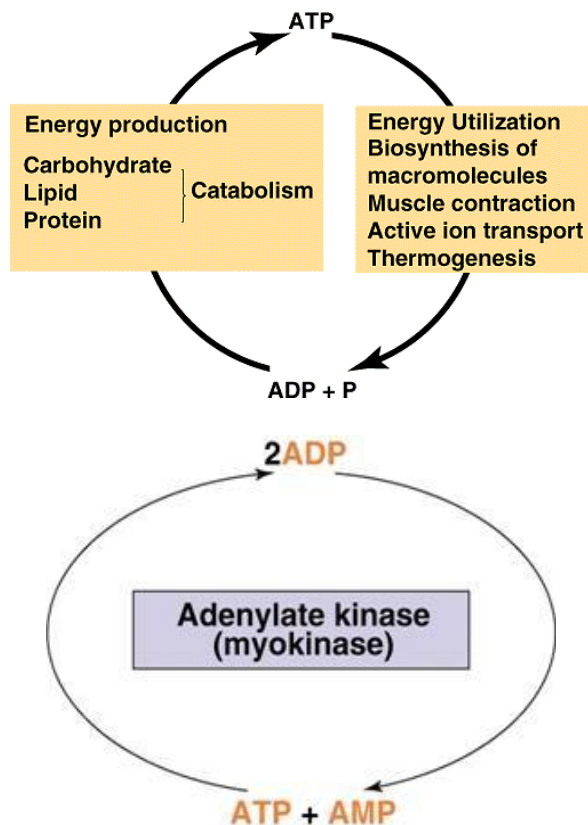


- The phosphate group on ATP is not a reason to choose ATP as a currency of the cell ; it's because ATP structure .
- ATP unstable because of negative charges on phosphate groups in it accordingly breaking down ATP into ADP and P make it more stable because of the **resonance** .



IS ATP A GOOD LONG-TERM ENERGY STORAGE MOLECULE?

- As food in the cells is gradually oxidized, the released energy is used to re-form the ATP so that the cell always maintains a supply of this essential molecule

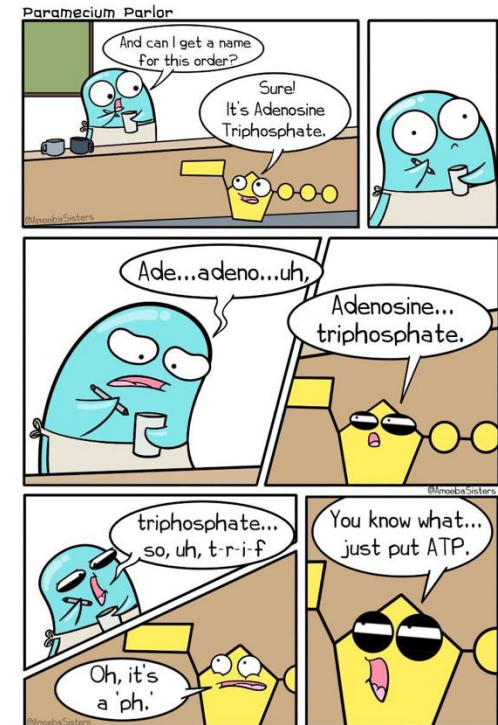


Tissue	ATP turnover (mole/day)
Brain	20.4
Heart	11.4
Kidney	17.4
Liver	21.6
Muscle	19.8
Total	90.6

$$90.6 * 551 \text{ (g/mole)} = 49,920 \text{ g ATP}$$

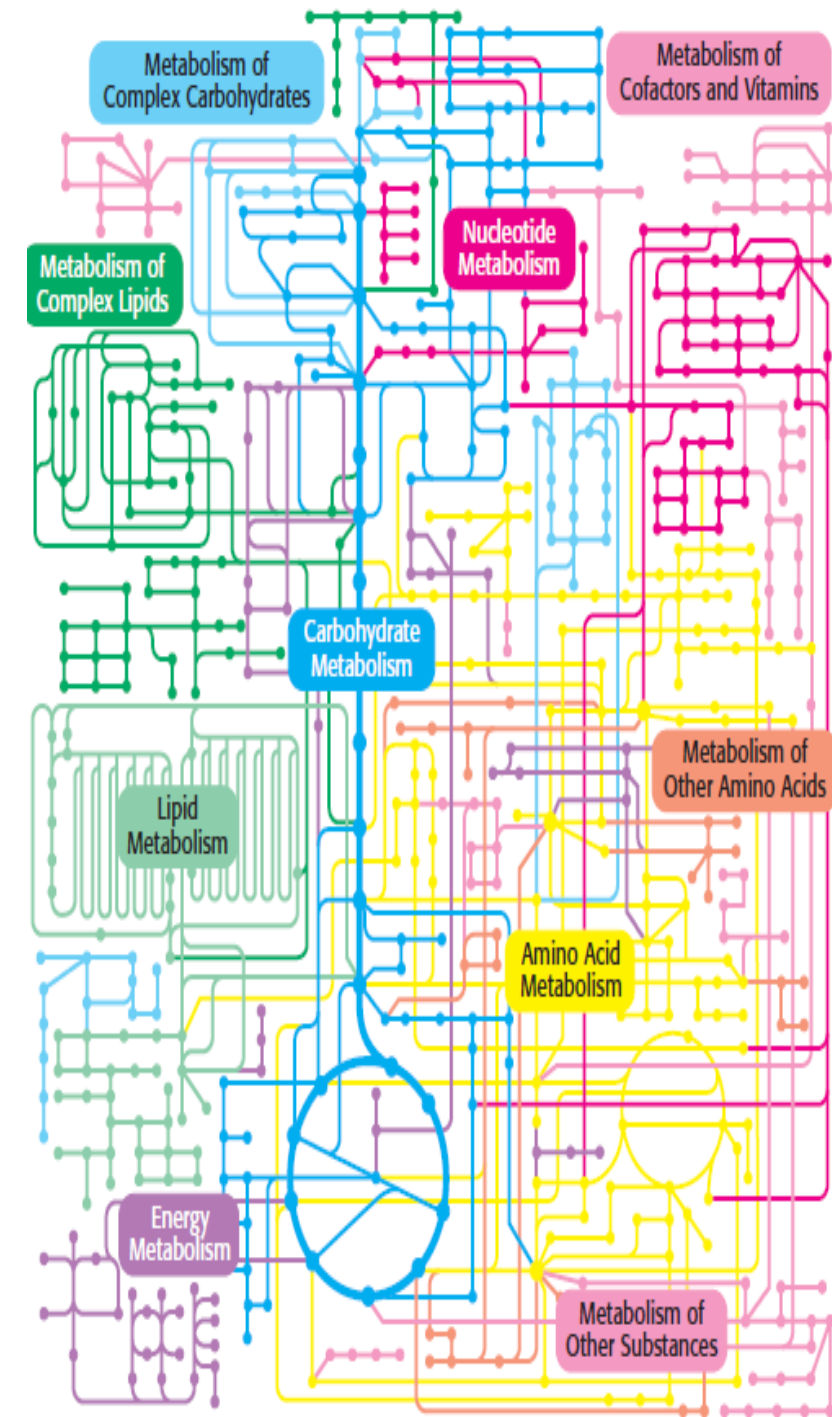
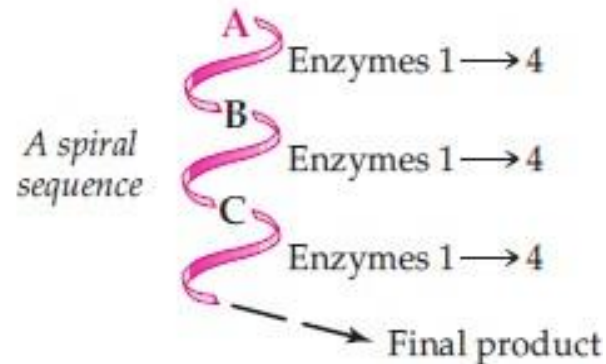
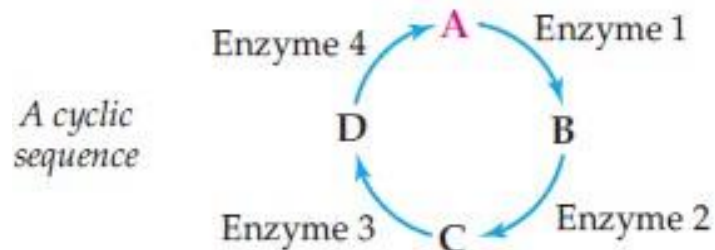
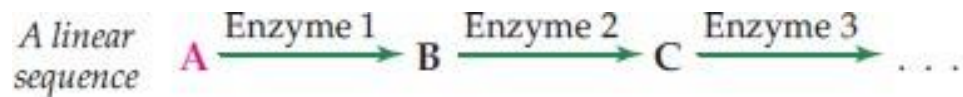
- ATP is not a long-term energy storage molecule.
- To understand why, first we need to know what molecular weight means – it is the total mass of one molecule based on the atoms it contains.
- ATP has a relatively high molecular weight, but the amount of energy released per molecule is quite low compared to its weight.
- That means its energy-to-mass ratio (energy density) is small.
- So, to store the amount of energy the cell needs, it would have to make and keep an enormous number of ATP molecules – which would be extremely heavy and inefficient.

- Therefore, ATP is not useful for long-term energy storage; instead, cells use fats and glycogen, which store much more energy in smaller, lighter amounts and are chemically more stable.
- The ATP turn over per day is 90.6 moles per day Equals near 50 kg of ATP (multiply by molar mass)



BIOCHEMICAL REACTIONS OR PATHWAYS!

- **Are interdependent**
- **Are subjected to thermodynamics laws**
- **Coordinated by sensitive means of communication**
- **Allosteric enzymes are the predominant regulators**
- **Pathways are linear, cyclic or spiral**



- linear pathways is series of biochemical reactions where every reaction leads to the other one until we achieve the final product , and every reaction is catalyzed by different enzyme.
- cyclic pathways is the same definition of linear but with addition that the final product can regenerate the first molecule that we started with.
- Spiral pathways (in fatty acids synthesis) in each step there is a set of enzymes that catalyses subsequent steps.

- These pathways intersect and are regulated in a coordinated way.
- They “communicate” through allosteric enzymes and their regulatory subunits, which control the overall metabolic flow.
- The product of one pathway can bind to an allosteric site on an enzyme from another pathway, thereby regulating its activity and linking the two pathways together



EXERGONIC REACTIONS AND PATHWAYS IN BIOCHEMISTRY

- Complex structures → simple structures

Proteins → amino acids

Starch → n glucose

glucose + O₂ → CO₂ + H₂O

- More specifically

- Hydrolysis reactions

- Decarboxylation reactions (release of CO₂)

pyruvate (C₃) → acetyl-CoA(C₂) + CO₂

- Oxidation with O₂

رسالة من الفريق العلمي:

لحظة تفكيرية في قوله تعالى

﴿وَأَنْ لَّيْسَ لِلْإِنْسَانِ إِلَّا مَا سَعَى﴾

فالإنسان لا يملك إلا سعيه ، لا سعي غيره !

اسعى ولا تفكر في النتيجة ، تيقن بأن لا شيء يضيع

عند ربك

﴿وَأَنْ سَعْيُهُ سَوْفَ يُرَى﴾

For any feedback, scan the code or click on it.



Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			