University of Jordan
Faculty of Medicine

Medical Committee
The University of Jordan

Biochemistry

● **Sheet** ○ **Slides**

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Title: Human Metabolism & Energy Coupling

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Price: ....

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I. The energy machinery of the cell (Mitochondria) :

- The Mitochondria are responsible for 90% of the energy production inside the cell. The other 10% is produced in the cytosol.
- The number of mitochondria varies according to the energy need of the tissue/cell. The muscles of an athlete, for example, contain more mitochondria than a normal person.
- What would the cell do if it needed more mitochondria?
  A message would be sent to the mitochondria to start reproducing. Mitochondria reproduce by binary fission.
- In the theory of evolution, mitochondrion is described as a bacterial cell which infected a eukaryotic cell, where a symbiotic relationship developed.
- After cell division would the number of mitochondria be distributed equally to daughter cells?
  No, they will be distributed randomly, as there is nothing to control the distribution of mitochondria upon division of the cell.
- The replication of mitochondria is separate from the replication of the cell. They contain their own genetic material.
- At fertilization, the sperm donates the genetic material **ONLY**. The cellular material is from the ovum, which means that the mitochondria, including their genetic material, are inherited from the mother. So, any disease in the mitochondria came from the mother's side.

II. The stages of energy production.

- Stage 1: digestion of macromolecules ➔ absorption of the monomers of those macromolecules ➔ transfer to blood ➔ arrival to destination cells.
- Stage 2: different metabolic pathways break down different molecules (products of the first stage), and produce Acetyl (acetate connected to coenzyme A) CoA (a common product of all pathways).
- Stage 3: Acetyl CoA (2 carbon molecules) enters the citric acid cycle (Krebs cycle, tricarboxylic acid cycle).
  **Why does it enter the citric acid cycle?
  After breaking down the molecules until you get to two carbon atoms (organic molecules). These molecules go to Krebs cycle, and the carbons are extracted as CO_2. Then we extract the electrons from organic molecules, and transfer them to electron carrier molecules.
  ** There are two types of electron carrier molecules:
  1) NAD^+ ➔ NADH (accepts two electrons)
  2) FAD ➔ $FADH_2$ (accepts two electrons)
- Stage 4: the electron transfer chain and oxidative phosphorylation: a series of protein molecules that undergo redox reactions to transfer electrons while reducing oxygen to water. The difference in energy is used to pump out protons. This process manufactures ATP.

III. ATP (Adenosine Tri Phosphate)

- It's the energy currency of the cell, but why?
  Because it contains high energy phosphate bonds and produces an intermediate value of energy (neither the highest, nor the lowest.)

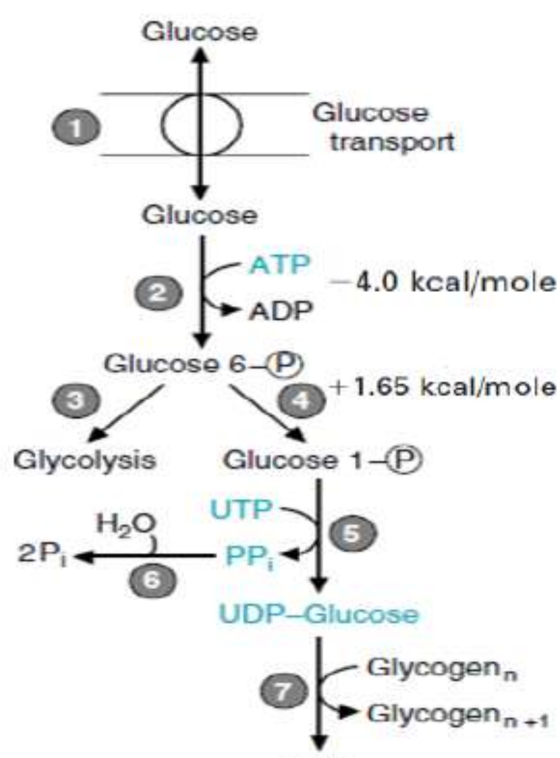
- High energy molecules are molecules that provide more than 7 Kcal/mole. They cannot be used in place of ATP, as they need a lot of energy and multiple steps to regenerate.
- It is easy to regenerate (1 step regeneration)
- It can be broken down and rebuilt using coupling reactions.

- Structure of ATP:
  ATP = Adenosine + 3 phosphate groups
  Adenosine = Adenine + Ribose
- The energy produced at breakdown of a molecule depends on the atoms in it, and the strain applied on the bonds. The strain in the ATP molecule is due to the electron cloud made of 3 electron pairs. When ATP loses its first and second phosphate molecules it produces 7.3 kcal/mole. However, at the loss of third phosphate group, only 3.4 kcal/mole is produced. This is because the first and second groups are identical, while the third is bound to adenosine.

IV. The usage of energy:

- ATP can be used for:
  a)Movement
  b)Transport
  c)Biochemical work
- How is it used?
  The energy produced from the hydrolysis of ATP (ATP ➔ ADP + Pi) is used to change protein conformation, which allows the protein to have an effect. Example: Actin walking on myosin, Na+/K+ pump.
- Why can't we store energy in the form of ATP?
  Because a huge amount of ATP would be needed to store energy. For example, a 70kg person would need about 70-90 kg of ATP for everyday usage. It is constantly being used in our body!

V. How do our cells get energy for unfavorable biochemical work?



- By coupling. Coupling is the occurrence of reactions in the same place at the same time, where energy needed to drive endergonic reactions is obtained from exergonic reactions.

- **The concept of coupling: (example used: Glycogenesis, turning glucose into glycogen)**

  1) ΔG° values are additive
     How?
     a) Through phosphoryl transfer reactions. (coupled with ATP hydrolysis)

     In step 2, which needs +3.3 kcal/mole, occurs

by coupling this reaction with ATP hydrolysis, which produces -7.3 kcal/mole.
end result: -7.3 + 3.3 = -4 kcal/mole

In step 4, which needs 1.65 kcal/mole, is uses the excess energy from ATP hydrolysis in step 2.
end result: -4 + 1.65 = -2.35 kcal/mole
The combination of these two steps produces an overall exergonic reaction.

b)Activated intermediates:
In step 5+6, UTP is hydrolyzed and UDP-Glucose is produced. It is a high energy molecule, which upon breaking down will produce enough energy for step 7 (addition of glucose to glycogen).

2) The body plays with the concentration of the reactants and products. In this example, by constantly removing the product, the ΔG changes and the endergonic reaction becomes exergonic.

3) Activated intermediates other than ATP are used.
UTP ➔ Combining sugars
CTP ➔ Lipid metabolism
GTP ➔ Protein metabolism
Some high energy molecules are also produced:

Compound + H_2O	Product + phosphate	ΔG°
Phosphoenol pyruvate	Pyruvate	-14.8
1,3 bisphosphoglycerate	3 phosphoglycerate	-11.8
Creatine phosphate	Creatine	- 10.3

لن نحترق من أجل آرائنا لأننا غير متأكدين منها، لكن يمكننا الاحتراق من أجل حق امتلاك وتعديل آرائنا. - فريدريك نيتشه