Medical Committee
The University of Jordan

SLIDE SHEET

LECTURE#: 7

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Biochemistry

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Bioenergetics

In the previous lecture we talked about : energy and its types (kinetic and potential), thermodynamics, bioenergetics, why and how do chemical reactions occur, reversible reactions and equilibrium . We also talked about the equilibrium constant (the concentration of products over the concentration of reactants) , if it's less than 1 ,more than 1, or equals to 1 . And the effect of that on the direction of the reaction and how to relate the rate of equilibrium with ΔG

☺The effect of changing conditions on equilibria :

☝. Effect of changes in temperature :

Endothermic reaction are favored by the increase in Temperature , While exothermic reactions are favored by the decrease in Temperature .

✌. Effect of a catalyst on equilibrium:

ΔG expresses the favorability of the reaction , and the equilibrium is the result of that favorability ,so when you have two materials : the reactants will react to give products , and products will be degraded back to give reactants until equilibrium is reached.

The catalyst doesn't affect the initial and final states of the reaction (ΔG is not affected) , so it doesn't change the equilibrium .

👌. Effect of changes in concentration :

When you change the concentration of reactants or products (at equilibrium) , what will happen ?

There will be a shift in equilibrium, if you increase the Conc. of reactants the reaction will shift forward until you reach a new equilibrium ,if you increase the Conc. of products the equilibrium will shift in the reverse direction , same story with temperature (endothermic reactions absorb heat so if you increase temperature the equilibrium will be shifted forward and vice versa).

☺Metabolism:

Metabolism is the total sum of all biochemical reactions that occur in the cell (cellular metabolism).

Body metabolism is the sum of all reactions that occur in the body. So metabolism -generally- is the sum of all processes and activities of the body.

It includes degradation to make energy and building up molecules using energy.

✍Now, what is the source of all energy of this life?

Autotrophs "plants "can generate their own energy using the sun light ⟹ animals eat plants ⟹ humans eat animals and plants .

So the source of all energy in life is the sun.

✍ Why do we need energy within our bodies ?

✌. The performance of mechanical work (muscle contractions and cellular movements).

✌. The active transport of molecules and ions (generating chemical and electrical potential).

👌. The synthesis (building) of macromolecules from simple precursors .

Also energy is important in reproduction and controlling the body temperature.

✍. **How do we keep / store energy in the body ?**

We store energy as bonds, you break down bonds in every macromolecule in your body to get energy (glycogen, lipids, nucleic acids ...). So you store energy within all these macromolecules.

☺ **Metabolism is divided into two pathways :**

☝. **Anabolic pathways** ⟹ building up molecules ⟹ consumption of energy (endergonic reactions) .

✌. **Catabolic pathway** ⟹ breaking down complex molecules ⟹ release of energy (exergonic reactions) .

☺**Biochemical (metabolic) pathways :**

Metabolism occurs in pathways (biochemical pathways),the pathway is a (sequence / series) of biochemical reactions .

The metabolic pathways are highly interdependent(متشابكة ومترابطة وتعتمد على بعضها البعض بدرجة كبيرة).So, how can we link the catabolic pathway of carbohydrates with the anabolic one , with the lipid pathways or with the nucleic acid pathways ....how can we link all these Metabolic pathways together to make them interdependent ?

we need **allosteric enzymes** to connect these pathways together , because allosteric enzymes - as the name implies - have more than one place for binding other materials which we call " allosteric effectors " either inhibitors or activators . For example , if we have an allosteric enzyme which works in carbohydrate metabolism , and this enzyme has a site where a product of lipid metabolism can bind to , this product can tell the carbohydrate to go on /off . That's how we can make metabolic pathways connected together.

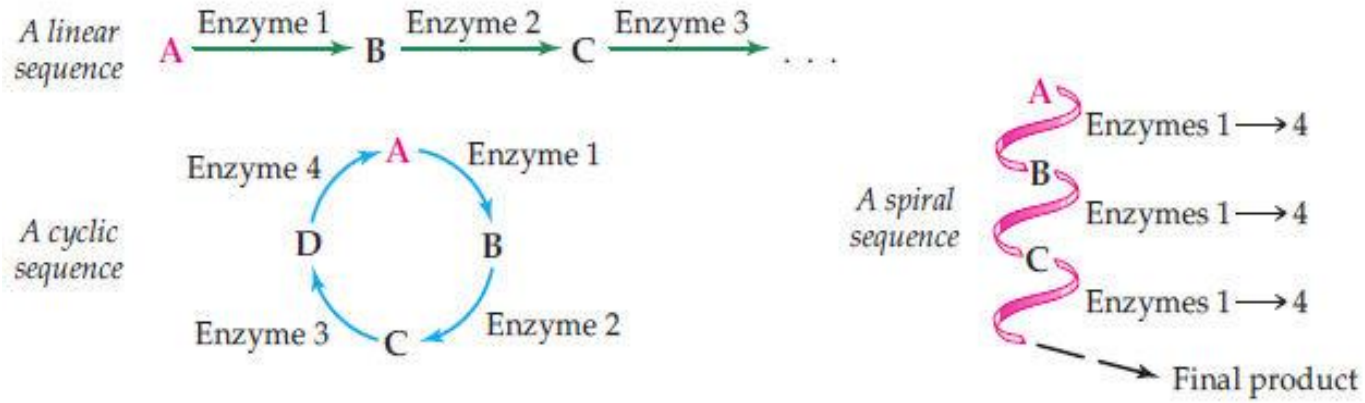
Another thing is acetyl coA (the most common material that is integrated in many pathways) . Carbohydrates , proteins and lipids could be broken , and result in acetyl coA , which from there can go for energy metabolism (citric acid cycle) or to any other pathway (may be anabolic one for fatty acids synthesis).

☺Note : take a look at the image in slide #14 which shows all the chemical pathways of the body (carbohydrates , lipids ....) and because it's not that complicated you have to memorize it (pathway by pathway):P ☺

*Biosynthetic pathways occur at different places than where the degradative pathways occur , **Why do we need to separate them ?**

In fact, Sometimes both of these metabolic pathways require the same enzymes , which means if they are occuring at the same place , they'll be mixed up . Also, distinct pathways are regulated better.

☺ metabolic pathways occur in different forms :



☝. **Linear sequence** : series of biochemical reactions where the product of the first reaction is a substrate for the second reaction and each step is catalysed by a different enzyme .

✌. **Cyclic sequence** : series of biochemical reactions , where the first product is a substrate for the second reaction , at the end of these biochemical reactions the first material you started with will be regenerated , and each step is catalysed by a different enzyme .

The most common example of cyclic pathways is krebs cycle .

👌. **Spiral sequence** : series of biochemical reactions where the first product is a substrate for the second reaction . However, each step is catalyzed by the same enzyme / enzymes.

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☺The energy machinery of the cell:

✍Where do we generate our energy ?

In the mitochondria (but not exclusively) , all energy requiring and producing pathways occur in mitochondria except for **glycolysis** (which occurs in the cytosol which is the fluid part of the cytoplasm).

About 90% of our need of ATP is generated from mitochondria , 10% is generated from different pathways mainly glycolysis .

✍Now, how do bacteria generate their energy ?

Some bacteria -the photosynthetic bacteria- generate their energy by photosynthesis, but mostly they (bacteria)

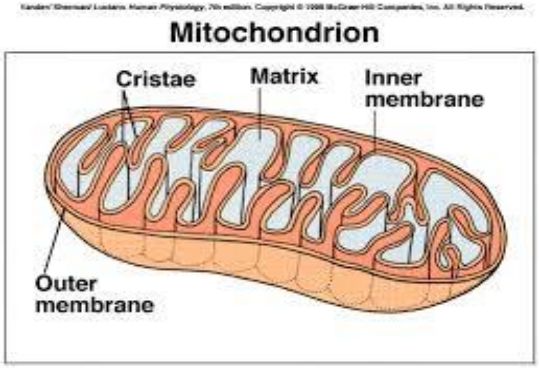
are not photosynthetic . The bacterial cell has

outer membrane , inner membrane ,

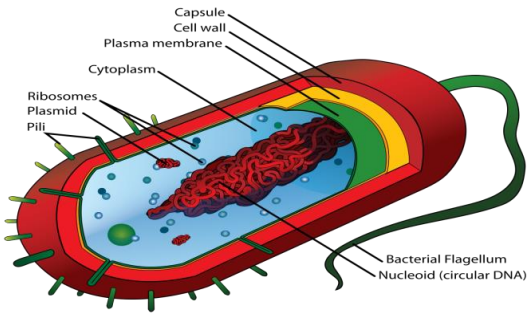
intermembrane space and cytoplasm. Mitochondria also have outer, inner membranes, intermembrane space and cytoplasm (Matrix).

The difference between prokaryotic and eukaryotic cells is the presence of organelles in eukaryotic cells .

The energy formation in both of them (Mitochondria, bacteria) occur on the membrane.



Mitochondria



Bacteria

According to the theory of evolution ,the mitochondrion is a bacterial cell that infected the eukaryotic cell to produce energy , they live together in a symbiotic releationship (the materials are supplied by the cell and the energy is supplied by mitochondrion) .

Now the question is : **how do mitochondria reproduce ?**

Mitochondria reproduce by binary fission (they have their own DNA) , it is different from the machinery of reproduction of the cell it self (mitosis), but similar to bacteria ! And that is considered as a clue on the evolution theory .

There is no link between mitochondrial reproduction and cellular reproduction, if you have 10 mitochondria within a cell which wants to divide, how will they divide ?? How will they be segregated(separated) to the daughter cells ?

There will be 2 daughter cells out of the mother cell , nothing controls the number of mitochondria that'll go to each daughter cell (there is no link between the mitochondrial division and the cellular division) . so, you can end up with cells without mitochondria (it's rare but can happen) or you can find 8 mitochondria in one cell and 2 in the other one and so on .

The mitochondrion has its own **DNA** , so it can be mutated through life ,you have 10 mitochondria (this is an example) , 5 of them are mutated with time and 5 of them are not , then the cell will divide ; how the mitochondria will segregate ? Again there is nothing to control the segregation , so you may have a daughter cell with 5 mutated mitochondria , and the other cell to be normal . If this occurs early in embryogenesis you can have a normal tissue , and a tissue that has a disease due

to the mutated mitochondria , and this is called “heteroplasmy” >>> to have different tissues ; some of them are affected and the others are normal .

#Note: mitochondrion is singular (plural mitochondria)

☺ The number of mitochondria varies according to the tissue ; a tissue with high need of energy >>> will have high number of mitochondria , and vice versa.

✍. **What controls this ?** Is it genetically determined or is it aquired ? if you are doing an exercise ,will the amount of your mitochondria within muscles increase ? or if you are thinking will the amount of mitochondria increase within your brain ?

Mitochondria divide according to the need of oxygen / energy within the tissues , so if you are doing exercise regularly the amount of mitochondria within your skeletal muscle tissue will increase .

The amount of mitochondria is greatest in the highest energy demand tissues like : (eye , brain , heart ,muscle) , if you are thinking all the time the amount of mitochondria in your brain will increase .

☺ large amount of mitochondria in fat tissue, converts it from white to brown fat . The tissues which have more mitochondria appeare more reddish in color , more mitochondria means more Myoglobin within tissues to store oxygen to give it to mitochondria.

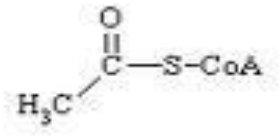
Mitochodria have a maternal inheritance , which means : we take mitochondria from the mother (because the sperm only gives the nucleus in fertilization) , so the source of all energy in our bodies is females ☺ .

As we mentioned , mitochondrial DNA can be mutated , there are huge numbers of diseases due to these mutations , so If the mother has a mitochondrial disease , then it can be inherited to the children (boys or girls) , but males don't transmit such kinds of diseases to their children .

☺ stages of energy production :

Stage 1 : Ingestion , digestion , absorbtion of materials to the blood reaching cells .

Stage 2 : The use of materials from the first stage , when these materials reach the cells , different molecules (lipids , carbohydrates , proteins) will be degraded and converted to a molecule called (Acetyl-coenzyme A) .



Stage 3 : how we use acetyl coA to get energy >> citric acid cycle .

we need citric acid cycle (krebs cycle) to (extract / remove) electrons from molecules (breaking down bonds) , then these electrons will be carried by electron carriers (NAD+ and FAD) so the result of this cycle is the production of electron carrier molecules (NADH and FADH2) which will be used in stage 4 of energy production .

Stage 4 : oxidative phosphorelation , oxidation reduction reactions in the electron transport chain which will result in phosphorylation of the ADP molecules to be ATP by ATP synthase .

☺ ATP is the energy currency of the cell (you are dealing with ATP as a currency) .

Through ATP content we can determine which cell has higher amount of energy so ATP is important in comparison.

✍. **Why ATP is considered as the currency of the cell ?**

ATP can phophorylate other molecules , but any molecule that has a phosphate group can do that too !

Also, We have other energy carrier molecules like :

Compound $+H_2O$	Product + phosphate	$\Delta G°$
Phosphoenol pyruvate	Pyruvate	-14.8
1,3 bisphosphoglycerate	3 phosphoglycerate	-11.8
Creatine phosphate	Creatine	- 10.3
ATP	**ADP**	**- 7.3**
Glucose 1- phosphate	Glucose	-5.0
Glucose 6- phosphate	Glucose	-3.3

*Phosphoenol pyruvate gives pyruvate in the last step of glycolysis , it has alarge amount of energy .

The question was : Why ATP is considered as a currency in the cell ,and not any other energy molecule ?

ATP has an (intermediate/ average) energy value ;

If you are using phosphoenol pyruveta as the energy currency of the cell , then you should have a high amount of this molecule , and you should regenerate it all the time (a high amount of energy is needed to regenerate it), reactions in our bodies don't produce very high energy to produce the high energy

molecule (in this case the phosphoenol pyruvate, so it is not easy to regenerate it).

Huge number of reactions within the body, when they occur result in around 7 kcal/mole, so if you put ADP in any of them you'll result in ATP formation and then you can use ATP again . So it is much easier to regenerate ATP because it has an intermediate energy value , and this is why ATP is used ☺ .

Why don't we use a much lower energy molecule value ? Because we'll need a much higher concentration of that molecule to make energy processes .

(The same as if you are using a currency :P
شلووون or قروووش)

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with some patience ,Insistence and faith.....everything is possible; Little drops of water ...little grains af sand ...make the mighty ocean and the pleasant land .

(فلا تقنع بما دون النجوم)

Your colleague : Afnan Ahmad Abu Qadoum .

Corrected by : Mohammed Nawaiseh .