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Subject:	**Bioenergetics**
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Bioenergetics

-**reversible reactions** are the reactions which can go in both directions (forward and backward), and can achieve a state called **equilibrium**.

What do we mean by equilibrium?

Rate of the forward reaction is equal to the rate of the backward reaction. In other words, the rate of converting reactants into products is equal to the rate of converting products into reactants.

-be careful, when you achieve equilibrium you have equal rates of conversion not equal concentrations! You may also have equal concentrations but it is not a must!

-equilibrium is a dynamic state (there is a conversion but constant, No net energy of consumption or production (ΔG=0), No favorable for the forward or the backward direction.)

- **equilibrium constant K** = [products] at equilibrium / [reactant] at equilibrium

If we say that K = "number", **what should we understand from this number???**

-this number could be (the options of any ratio):

1-**(K= 1):** means we have equal concentrations at equilibrium.

Application about this value:

(in the lab if we start a reaction with equal concentrations of reactants and products, what's going to happen? the reaction goes to the forward and backward directions at equal rates "it's at equilibrium", "no favoring to any direction ", ΔG=0).

2- **(K>1)**. more products at equilibrium.

ex. K = 5, this mean that at <u>equilibrium</u> there is 5 particles of products compared to 1 particle of reactants (more products).

so if you started a reaction with equal concentrations of reactants and products with k > 1, this reaction will try to reach equilibrium by favoring the forward direction (giving more products than reactants)

3- **(K<1)**. at equilibrium you have more reactants compared to products. the reaction favors the backward direction.

** if K= 10000 (much more than 1), at equilibrium you have 10000 particles of products compared to 1 particle of reactants which means the reaction is completely finished (you almost got products at equilibrium). (spontaneous reaction)

** if K=0.0001 (much less than 1), at equilibrium you have 1 particle of products compared to 10000 particles of reactants which means the reaction is hardly going in the forward direction (you almost got reactants at equilibrium).

*0 – 11 min

There is a relation between ΔG & K:

For a reaction A + B ↔ C + D

$$\Delta G = \Delta G^\circ + RT \ln \left(\frac{[C][D]}{[A][B]} \right)$$

$\left(\frac{[C][D]}{[A][B]} \right) = K$ when ΔG equal 0 (when the reaction is at equilibrium)

ΔG° is the free energy difference at STD which is always constant.

ΔG is variable, and because ΔG° & R are constants, it's determined by the concentration factor$\left(\frac{[C][D]}{[A][B]}\right)$ and temperature (T).

How ΔG is changed with concentration??

- as you know ln (1) = 0, ln(x>1) is positive, ln(x<1) is negative. So following up ΔG equation:

* if you have a ratio $\left(\frac{[C][D]}{[A][B]}\right)$less than 1(the products have lower concentration than the reactant), this make ln$\left(\frac{[C][D]}{[A][B]}\right)$ negative and, $RT \ln\left(\frac{[C][D]}{[A][B]}\right)$ also become negative, accordingly ΔG decrease so if $RT \ln\left(\frac{[C][D]}{[A][B]}\right)$ is a bigger value than ΔG° (we suppose in this example ΔG° is positive value and that's mean the reaction is originally non spontaneous at standard condition), ΔG will become negative value (spontaneous)

<u>Negative ΔG means the reaction is spontaneous</u>

What is important to understand about this term is: if you start a reaction at STD with ΔG = 10 (positive value means this reaction is non spontaneous). **So can we make this reaction occur spontaneously??**

yes! , by making the ratio$\left(\frac{[C][D]}{[A][B]}\right)$ less than 1 and making the ln the ratio has big value it can make ΔG having negative value , and this achieved by increasing reactants concentration much more than products , that what our body does in many metabolic pathways by consuming the products directly after they produced by an endergonic reaction , making very low concentration of products compared to reactants , accordingly the reaction tend to occur spontaneously even though it's not .

Any reaction which is endergonic at STD conditions, can be converted into exergonic reaction at our body conditions.

How products and reactants concentrations affect the equilibrium state?

-if you put more reactants the equilibrium will shift forward to produce more products, and vice versa if you put more products it will shift backward to produce reactants.

What if we increase the temperature (heat content of the system)??

-this depends on the reaction if it's endothermic or exothermic.

*endothermic reaction absorbs heat, so heat is considered as a reactant that why by increasing the temperature the reaction will shift to make more products.

*exothermic reaction produce heat, so it's considered as a product, the reaction will shift back to make more reactants.

What about the effect of catalyst??

It has NO effect on the equilibrium state (no change in ΔG), but on the other hand they reduce the time needed to reach equilibrium. Enzymes only reduce the activation energy; they have nothing to do with potential energy.

(check slides 8-10), * 11-22 min

Energy and metabolic pathways

It's rare in the body to find single reaction instead you find pathways (series of reactions), as in glycolysis which needs 10 steps to convert

glucose into pyruvate. the body deals with a pathway as a single reaction (free energy difference between glucose and pyruvate) which means that the different steps within the pathway are additive to each other. pathways in the body are:

1-Catabolic pathways (exergonic), releasing energy by breaking down complex molecules into simpler compounds.

2-Anabolic pathways (endergonic), building compounds.

These pathways are interdependent(interconnected) on each other for better regulation and energy saving. they are connected by allosteric enzymes **why?** Because they have regulatory subunits which have many binding sites.

Metabolic pathways have many shapes:

1-linear pathway is a series of biochemical reactions where every reaction is leading to the other until we achieve the final product, and every step is catalyzed by different enzyme.

2-cyclic pathway same as linear but at the end we regenerate the first material that we started with.ex. crebs cycle.

3- spiral pathway same as cyclic or linear but all steps are catalyzed by the same enzyme.

*22- 30 min

Energy producing process

Sites of producing energy: 90% within mitochondria, cytosol.

Mitochondria is an organelle which has outer and inner membranes with enter membranous space where most energy production reactions

occur. Its number variable between different tissues depends on the activity of each tissue, **is this variability designed from the start or goes by need ??** it goes by need! increasing the activity of any tissue will increase the number of mitochondria.

Mitochondria replication occurs by binary fission during G1 phase of mitosis (binary fission is a division mechanism for prokaryotic cells and it is more simple than mitosis) with no regulation on daughter cells. it has its own DNA which could have mutations that could be expressed in all cells, so you may end up with a cell having the mutated mitochondria or normal cell (if this happened at early embryogenesis, you may have effected CNS while the muscular tissue has no problems!! different from nuclear mutations which affect all tissues). mitochondria are maternal inheritance because organelles are come from the ovum, that why maternal diseases are transmitted to children.

<u>Stages of energy production:</u>

1-digestion

2-Acetyl-coenzyme A (produced by the degradation of lipids, proteins, and carbohydrate)

3-cetric acid cycle (extracting electrons)

4- electron transfer chain & oxidative phosphorylation

When we talk about energy, we always remember ATP, which is considered as energy currency of the cell. **But why ATP not another molecule?** it's not the only molecule which produces energy but:

*it has intermediate energy value, (it's not easy to deal with high amount of currency or low), (easy to break down and rebuilt).

*it's not a long-term energy storage because you need very high amount of energy per day (90mol and that equal 50 kg of ATP per day), it's in a constant formation all time and breaks down all the time

*30-48 min

"always laugh when you can, it is cheap medicine "

sorry for any mistakes, Good Luck! ☺