



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ
الَّذِي عَلَّمَ بِالْقَلَمِ ۖ عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ

⚙ METABOLISM

MID | Lecture 1

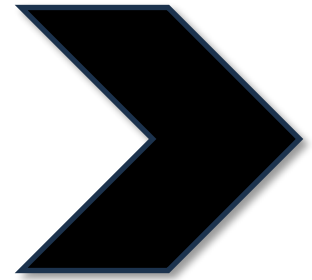
Bioenergetics & Thermodynamics

Written by : Ahmad Mohy

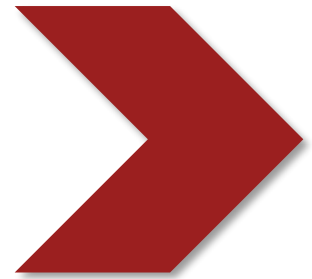
Reviewed by: Joud Alsafadi
Lamar Khorma



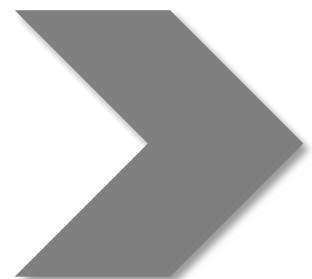
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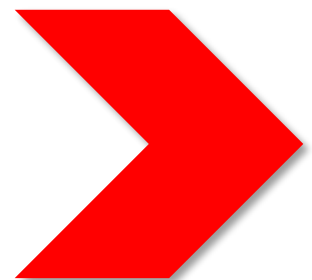
Black: the original slides



Maroon: the doctor's explanation/words



Gray: additional information and explanation



Red: important information

Energy and human life

PRINCIPLES OF BIOENERGETICS

1- Bioenergetics and Thermodynamics

Chemical energy

- Carbohydrates
- Fats
- Others

Chemical waste

- Carbon dioxide
- Water

Heat

ATP

- body's "energy currency"

DEFINITION

- The quantitative study of the energy transductions that occur in living cells and of the nature and function of the chemical processes underlying these transductions.

Why Do We Need Energy ?

We need energy for building up, Energy is required to build lipids ,proteins ,etc.

Anabolism: Building up molecules requires energy (endergonic) . ▲

Catabolism: Breaking down molecules releases energy (exergonic) . ▼

All reactions are designed for the sake of energy either production or consumption. So, when we lose the ability of making useful energy we die. We cannot make energy when our body is at equilibrium so whenever we reach equilibrium we will die.

▪ Bioenergetic Science:-

The branch of science that studies biochemical reactions from a thermodynamic perspective. It predicts how energy flows in living systems.

Studying Biochemical Processes:-

We can study biochemical reactions in our body from two different perspectives:

(a) Kinetic Theory

- Focuses on reaction rates and how fast reactions occur (the pathway itself) .
- Involves enzymes, which lower the activation energy
- Example: Enzymes speed up biochemical reactions without being consumed.

(b) Thermodynamic Theory

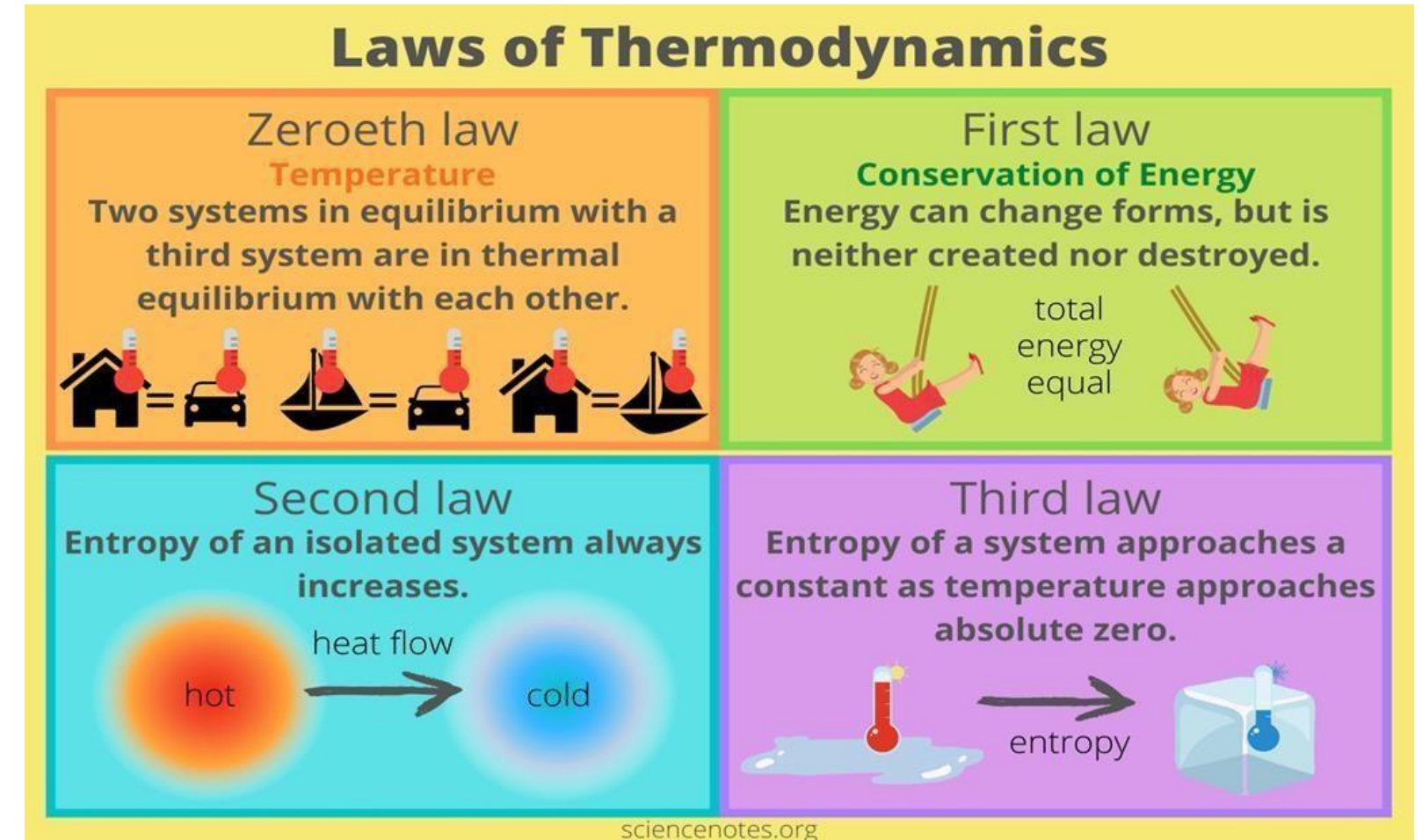
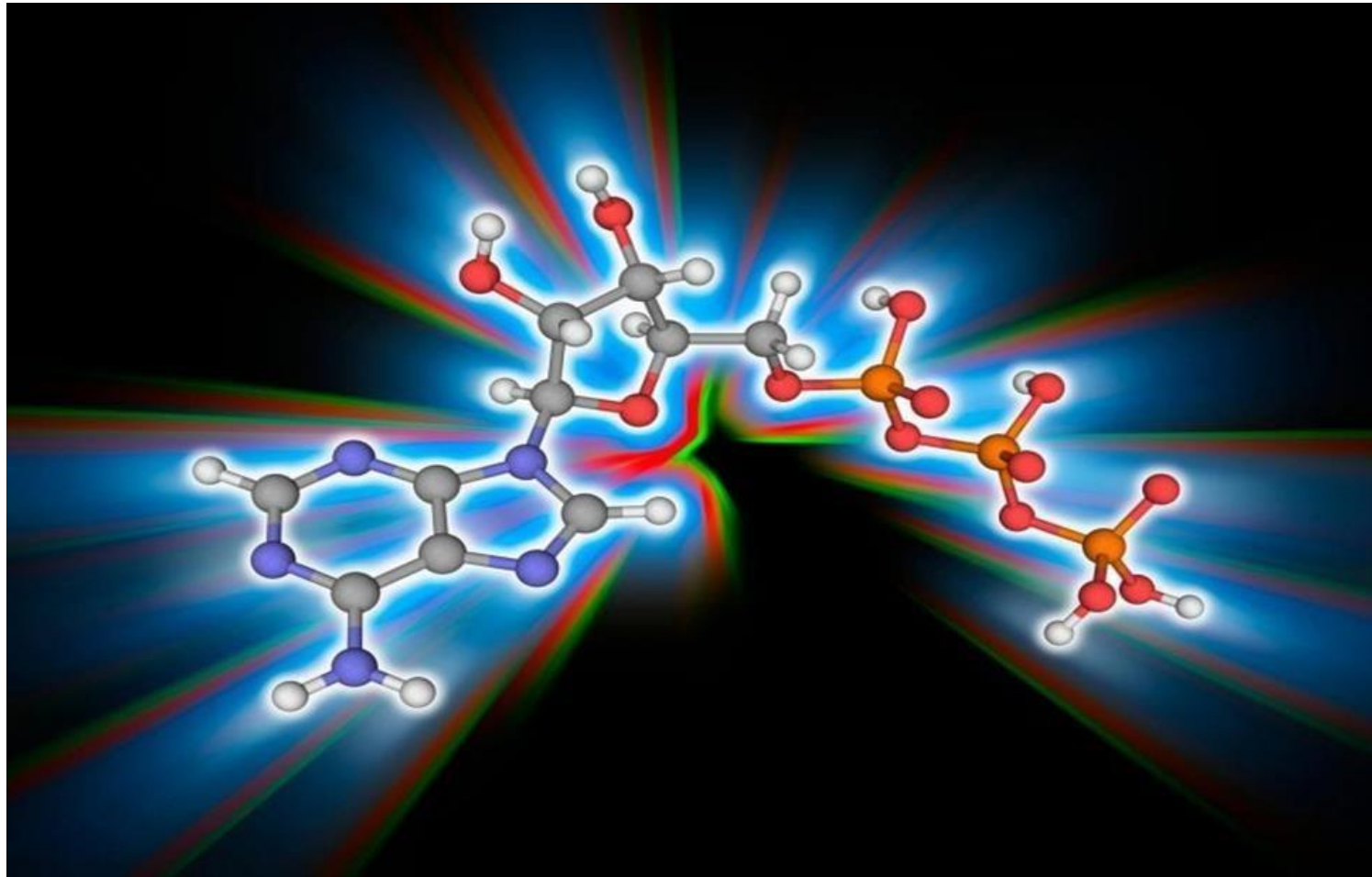
- Concerned with the start and end points of reactions.
- It doesn't care about the path! only about energy changes between the start and finish.
- Studies whether a reaction can occur **spontaneously or not**.

Generally, reactions happen to reach high degree of stability. Keep in mind that stability is inversely related to energy. For example when glucose is converted into pyruvate, we went from higher energy state (less stable)to a lower energy state (more stable) . But not all reactions behave in that way as there are reactions (anabolism) needs energy .

Pay attention that **all reactions need energy to occur "activation energy"** that provides a barrier to prevent exergonic reaction from happening uncontrollably . However, do not be missed by the word ‘spontaneously;’ in biochemistry , it doesn’t mean the reaction happens instantly or on its own without trigger. Instead, it means the reaction is thermodynamicly favorable".

- Our body is a natural system that follows the all rules that are applied to the natural systems like the rules of thermodynamics. For example, our body never creates energy which follows the first law of thermodynamics .
- The second law about increasing entropy and entropy is disorder or randomness , all though the body is perfectly organized so we spending energy to keep it organized.

LECTURE 1: THE LAWS OF ENERGY AND CELLULAR CURRENCY



THE CLINICAL STAGE: A CASE OF LETHARGY

Poor feeding → less nutrient intake → less ATP produced.

This leads to lethargy

Hypoglycaemia: Low blood sugar lack of glucose for energy.

Metabolic crisis: Failure of energy production

■ Clinical Presentation

- A 2-month-old infant presents with lethargy, poor feeding, and hypoglycemia indicating a metabolic crisis.

■ Laboratory Findings

- Initial labs reveal low blood glucose and mild metabolic acidosis, signaling disrupted metabolism.

■ Biochemical Diagnostic Question

- The clinical challenge is differentiating fuel deficiency from impaired energy utilization in the patient.

■ Importance of Bioenergetics

- Understanding bioenergetics is critical for diagnosing and managing metabolic crises in pediatric patients.



If the baby is actually eating well, we rule out bad feeding as the reason for his condition, which makes it easier to diagnose

BIOLOGICAL ENERGY TRANSFORMATIONS OBEY THE LAWS OF THERMODYNAMICS



The **1st** law
(**conservation of energy**): for any change, the total amount of energy in the universe remains constant;



The **2nd** law of thermodynamics: the universe always tends toward increasing disorder (or); in all natural processes, the **entropy of the universe increases**.



Signs for spontaneous systems...

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

"Biological energy transformations strictly obey the laws of thermodynamics. According to the first law, energy is conserved and remains constant in the universe. However, the second law dictates that the entropy of the universe is always increasing. In fact, it is impossible for entropy to decrease within an isolated system. Because of this natural drive toward maximum disorder, living organisms and cells must constantly expend energy to maintain their highly organized structures and actively fight against spontaneous decay

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

Gibbs Free Energy Equation

$\Delta G \rightarrow$ Change in free energy . It also represents the driving force in the reaction and is considered if the reaction is favorable or not.

$\Delta H \rightarrow$ Change in enthalpy (total energy).

$T\Delta S \rightarrow$ Effect of temperature(in Kelvin) $\times$ entropy change.

The equation tells us whether a reaction will occur spontaneously or not.

If $\Delta G < 0$, the reaction is spontaneous (occurs naturally, releases energy).

If $\Delta G > 0$, the reaction is non-spontaneous (needs energy input).

If $\Delta G = 0$, the system is at equilibrium.

The doctor indicated this in his explanation
but not explicitly :

For any natural system or molecule, we use Gibbs equation as follows :

$G = H - TS$ (without the delta)

G → energy stored in the bonds within the same molecule or system.

H → Enthalpy (total energy).

S → entropy .

➤ We only use delta when comparing two different states and the doctor mentioned these two examples :

1) When a glucose molecule is converted into pyruvate (notice two states so we used delta)
 ΔG here is the difference in the energy stored in bonds in glucose and pyruvate and that's called free energy.

2) When the physical state of water changes from liquid to gas. In this case as the chemical formula remains the same (H_2O) but the entropy increases(entropy here is how molecules are close or away from each other or how molecule is organized around another molecule , (interactions between molecules).

Solid to liquid to gas

Ordered → less ordered → less less ordered

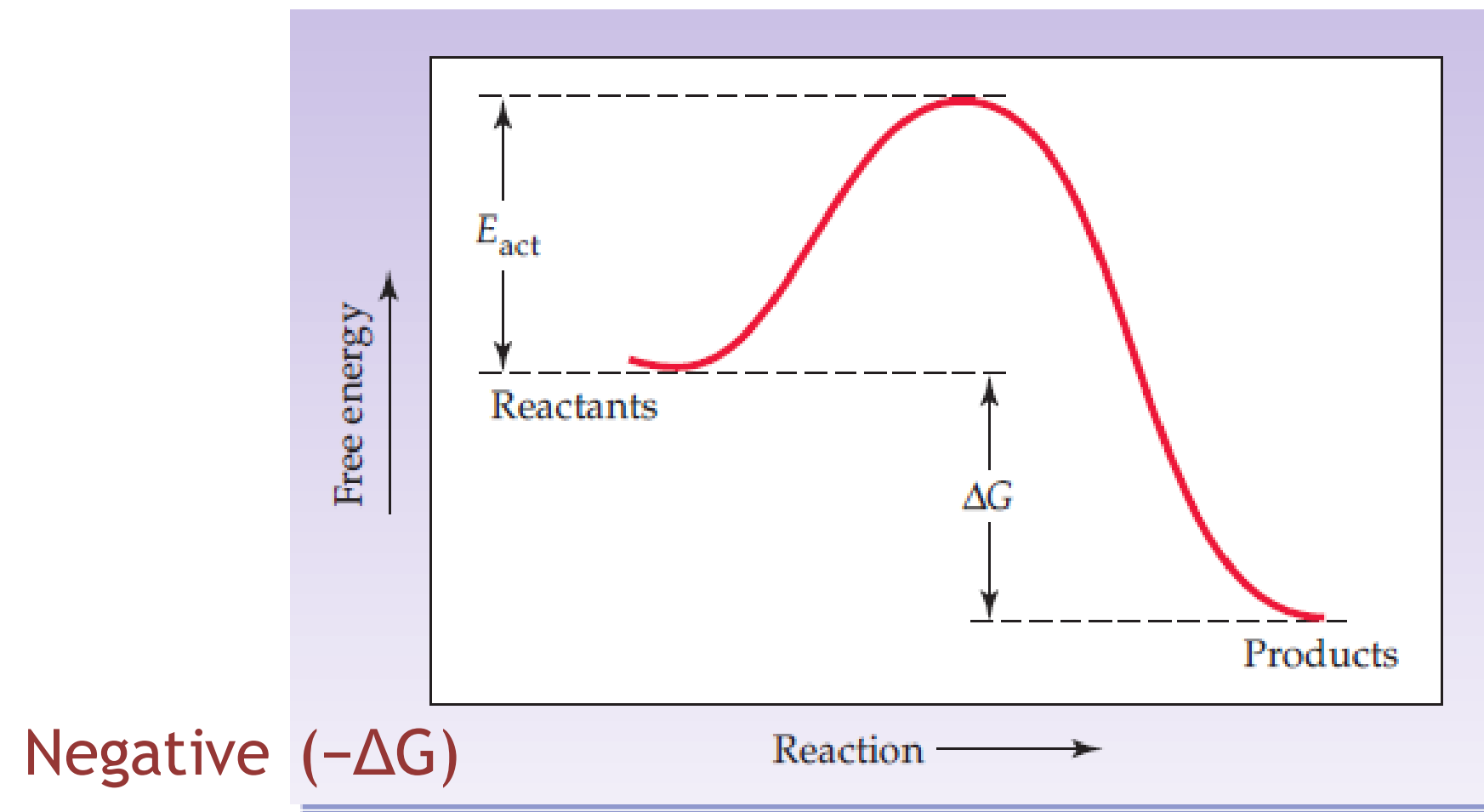
WHY DO CHEMICAL REACTIONS OCCUR?

- The concept of activation energy
- ΔG and ΔG°

Activation Energy (E_a)

Every chemical reaction needs some activation energy to get started.

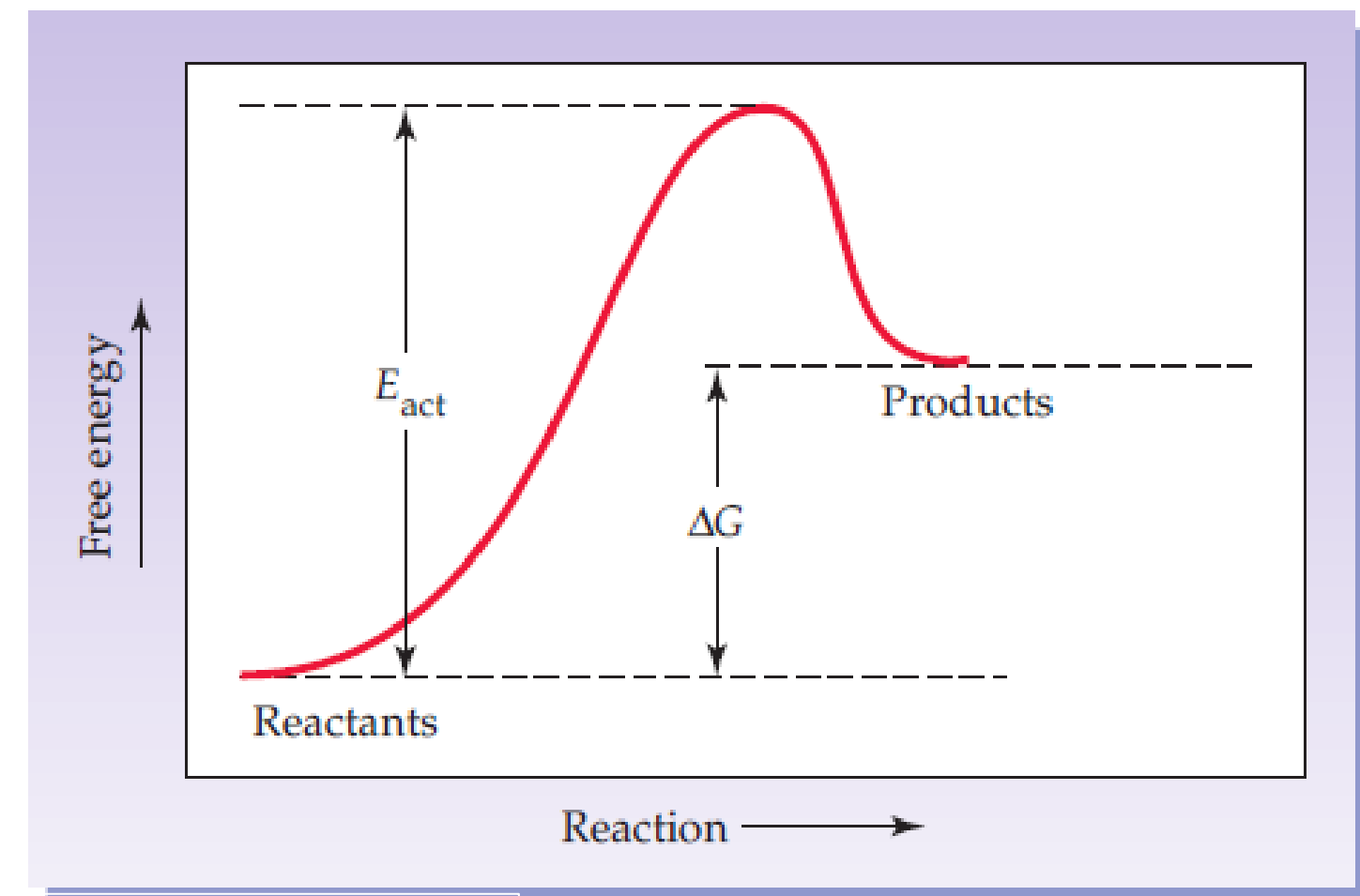
This is the energy barrier that must be overcome for reactants to turn into products.



Negative ($-\Delta G$)

Releases energy
Spontaneous

(a) An exergonic reaction

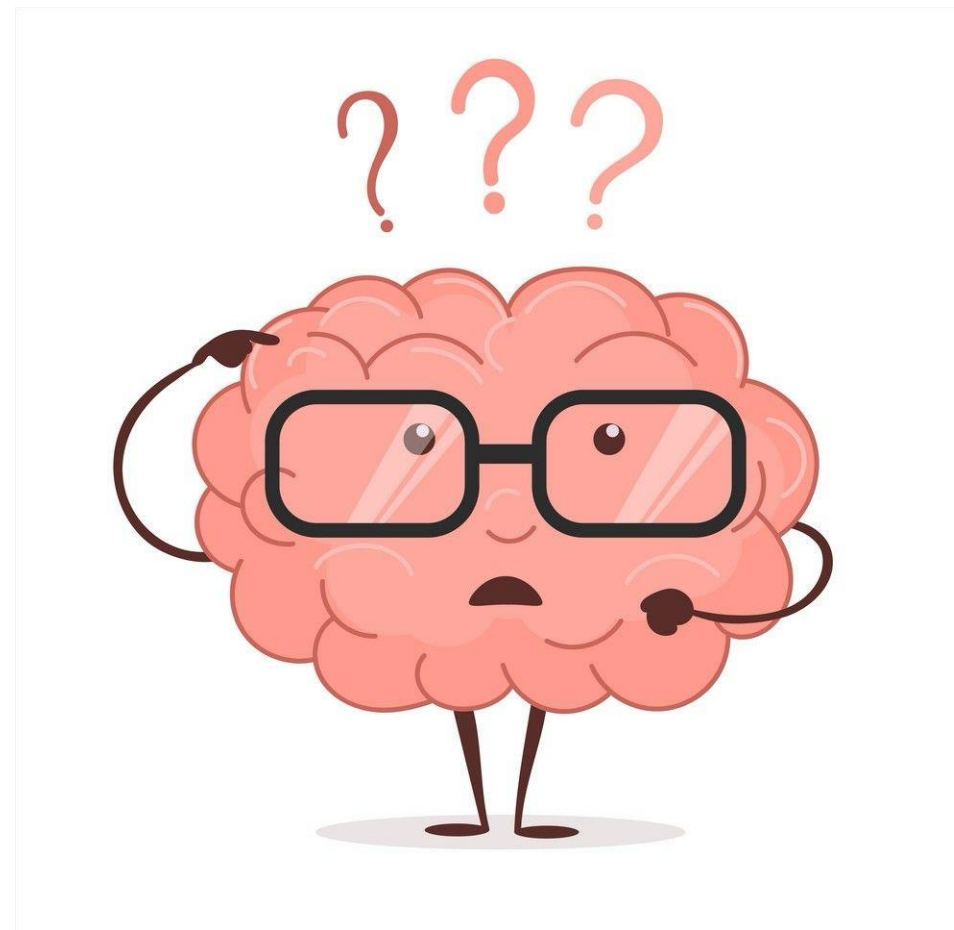


Positive ($+\Delta G$)

Absorbs energy
Non-spontaneous

(b) An endergonic reaction

Quiz



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



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

Additional resources:

References Used:

Dr. Nafez Abutarboush's Lecture

قال : عن شداد بن أوس رضي الله عنه قال
إذا رأيتَ النَّاسَ : رسولُ الله صلى الله عليه وسلم
قد اُكْتَنَزُوا الذهبَ وَالْفِضَّةَ، فَاكْنِزُوا هَؤُلَاءِ
اللَّهُمَّ إِنِّي أَسْأَلُكَ الثَّبَاتَ فِي الْأَمْرِ ، :الْكَلِمَاتِ
وَالْعَزِيمَةَ عَلَى الرُّشْدِ، وَأَسْأَلُكَ مُوجِبَاتِ
رَحْمَتِكَ، وَعَزَائِمَ مَغْفِرَتِكَ، وَأَسْأَلُكَ شُكْرَ
نِعْمَتِكَ، وَحُسْنَ عِبَادَتِكَ، وَأَسْأَلُكَ قَلْبًا سَلِيمًا،
وَلِسَانًا صَادِقًا، وَأَسْأَلُكَ مِنْ خَيْرِ مَا تَعْلَمُ، وَأَعُوذُ
بِكَ مِنْ شَرِّ مَا تَعْلَمُ، وَأَسْتَغْفِرُكَ لِمَا تَعْلَمُ؛ إِنَّكَ
أَنْتَ عَلَّامُ الْغُيُوبِ

رسالة من الفريق العلمي: