بسم الله الرحمن الرحيم

METABOLISM
MID – Lecture 3
Bioenergetics (pt.3)

﴿ وَإِن تَتَوَلَّوْا يَسْتَبْدِلْ قَوْمًا غَيْرَكُمْ ثُمَّ لَا يَكُونُوا أَمْثَالَكُم ﴾

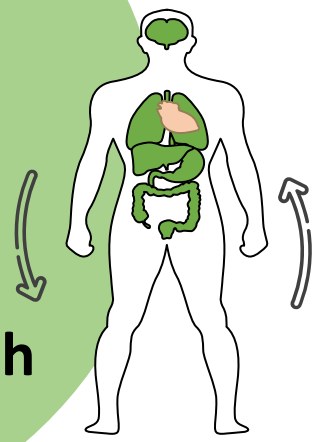
اللهم استعملنا ولا تستبدلنا

Written by:

- **Bashar khraisat**

Reviewed by:

- **Mohammad Almahasneh**



This slide will be explained in V1 after the Dr explains it.

Thermogenesis

Heat Production

- Heat production is a natural consequence of "burning fuels"

- **Thermogenesis** refers to energy expended for generating heat (37°C) in addition to that expended for ATP production

* لما يتكسر غلوكوز بيطلع: ١) حرارة للحفاظ على 37° ٢) ATP

1

- **Shivering thermogenesis (ATP utilization)**: activation of exothermic reactions by responding to sudden cold with asynchronous muscle contractions

طارد — نزلت حرارتك عن 37°

2

- **Non-shivering thermogenesis (ATP production efficiency)**
  - In the first 6 months of life
  - It is associated with brown adipose tissue

اللهم صل على سيدنا

Oxidation reduction reactions (Redox)

- **Oxidation:**
  - ✓ Gain of Oxygen
  - ✓ Loss of Hydrogen
  - ✓ Loss of electrons

اذا كانت المادة ميلانها للأكسدة عالٍ يعني ميولها للاختزال قليل

- ***Reduction:***
  - ✓ Gain of Hydrogen
  - ✓ Gain of electron
  - ✓ Loss of Oxygen

$A^{+} + \bar{e} \rightarrow A$ ← E = 10 — التفاعل الأول ميول A إنها تختزل أكبر من التفاعل الثاني

$B^{+} + \bar{e} \rightarrow B$ ← E = 4 — measure the tendency .... ← E بـ

- ***E*= redox Potential:** it is a **POTENTIAL ENERGY** that measures the tendency of oxidant/reductant to gain/lose electrons, to become reduced/oxidized

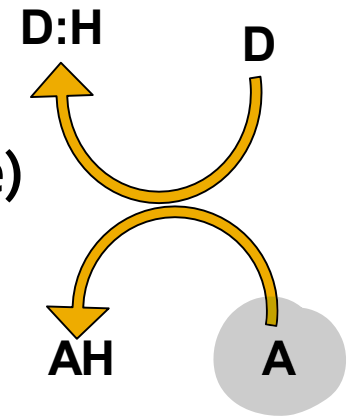
معطيك خفي تفاعلين بتشوف التفاعل اي بميل للا نتزال هو قيمة E الأكثر موجبة

For a whole reaction, we can determine which substrate is going to be oxidized and which one is going to be reduced by comparing the reactants' redox potentials with each other.

- Electrons move from compounds with lower reduction potential (more negative) to compounds with higher reduction potential (more positive)

When comparing the reduction potentials of two substrates, the one with the lower reduction potential will be oxidized

- Oxidation and reduction must occur simultaneously (no oxidation without reduction and vice versa).



Reduction Potential and the direction of reaction

$$A + B^- \longrightarrow A^- + B \quad \Delta G^\circ = -VE$$

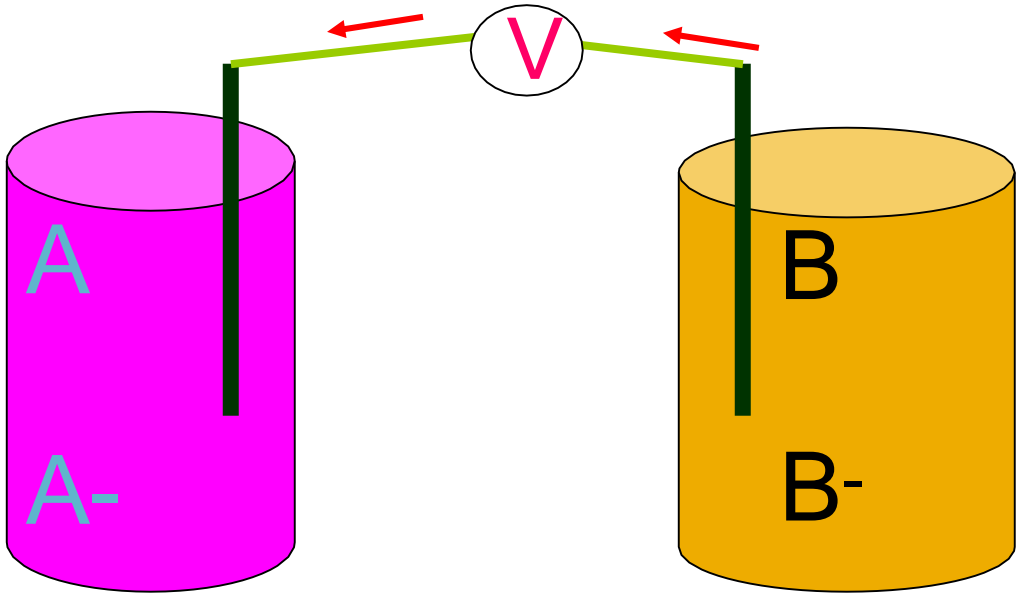
B oxidized form

B^- reduced form

Redox couple

حلت ΔG سالبة يعني التفاعل Favorable
لما تكون ΔE هو جبة و حلت ΔE موجبة
كأن الالكترونات انتقلت من الأقل E للأعلى E [أعلى حيل للانتزال].
وبناءً عليه من التفاعل بين انتقال e من B إلى A وكانت قيمة التفاعل سالبة (أي تم التفاعل دون الحاجة لطاقة) لذا هو Favorable.

Notice that the reaction has a negative ΔG°, this means that it's a favourable reaction moving in the forward direction so, **A** is more likely to be reduced than **B**, this means that **A** has a higher reduction potential than **B**.



Reduction Potential and the direction of reaction

Higher tendency to oxidize than reduce.

H^+ + X^- ⟶ H_2 + X ΔG° = -ve ⇝ favorable in forward direction at standard condition.

Positive reduction potential

negative reduction potential (loose electron)

at standard condition يعني كان التفاعل favorable ← forward ← (−) والتفاعل الأطرافي كان أكسدة X. لختزال H^+.

X oxidized form

X^- reduced form

Redox couple

X^- has higher tendency to lose electrons than H_2 does ➔ Negative reduction potential.

As we discussed in the previous slide, the reaction occurs spontaneously, **H+** tends to be reduced and **X-** tends to be oxidized.

The reduction potential for **X** Is less than the reduction potential for **H+**.

- E° represent standerd Reduction potential.
- The sign indicates a tendcy to undergo reduction/oxidation.

How? المرجع نبعتا ← zero = SHE يعني ميلان ذرة الهيدروجين للاختزال
بتساوي صفر لما يكون الرقم أصغر من صفر (سالب) يعني ما بيختزل
لاختزال ، لما يكون الرقم (E°) موجب يعني بميل للاختزال.

When E is negative, it suggests that the species is less likely to be reduced compared to the standard hydrogen electrode (SHE) اقل ميل للاختزال أي اعلى ميل للأكسدة

- If E° is **positive**, ΔG° will be **negative**. This means the reaction is spontaneous under standard conditions.
- If E° is **negative**, ΔG° will be **positive**, indicating that the reaction is non-spontaneous under standard conditions.

Summary:

The equation shows that the greater the positive value of E°, the more favorable the reaction is (more spontaneous), and conversely, a negative E° means the reaction is less favorable (non-spontaneous). This relationship is crucial for understanding thermodynamics in electrochemical reactions.

] → depends on

$\Delta G^\circ = -nF\,\Delta E^\circ$ (عكسية)

$* NAD^+ + \bar{e} \longrightarrow NADH \quad \Delta E^\circ = -0.32$

لعلامة السالبة يعني ما بميل إنه يختزل بميل إنه يتأكسد يكون NAD^+ ، لذلك NAD^+ موجود بكمية أكبر

Reduction Potential: the ability to accept electrons

NAD+ is more abundant in the cell than NADH with a concentration that is 1000 times greater than that of NADH.
because of reduction potential for this compound.

Oxidized + e^-	➔ Reduced	ΔE^o (V)
Succinate	α ketoglutarate	- 0.67
Acetate	Acetaldehyde	- 0.60
NAD^+	**NADH**	**- 0.32**
Acetaldehyde	Ethanol	- 0.20
Pyruvate	Lactate	- 0.19
Fumarate (tend to be reduced.)	Succinate	+ 0.03
$Cytochrome^{+3}$	$Cytochrome^{+2}$	+ 0.22
oxygen (during metabolism)	**water**	**+ 0.82**

The negative sign indicates that the reduction is not favourable so, oxidized form of these reactions are more abundant in the cell.

The positive sign here indicates that they tend to undergo reduction, so the reduced form of these reactions are more abundant in the cell.

لكن يحكيلنا خلص هم بس على التجربة وده وهاكا / اختزال

جدول أنصاف الإختزال

Calculation of ΔG^o and ΔE^o

Constant value for certain reaction.

- $\Delta G^o = -nF\Delta E^o$ ← بمعنى ΔG تكون موجبة عشان ΔE تكون سالبة ويكون التفاعل Favorable.
  - F = Farady constant = 23.06 kcal/*Volt*
  - n is the number of moles of electrons transferred in the redox reaction

بمثلك اتجاه انتقال الالكترونات و اكيد الأعلى ينتقل ج من المادة اللي ما بتميل للاختزال (قيمة E موجبة) إلى المادة اللي بتميل للاختزال (قيمة E كبيرة).

بنطلع ΔE موجبة

مثلاً:

ΔE = product (اللي انتقلة ج لكان بميل للاختزال أكثر (قيمة E عنده أكبر)) − reactant (اللي صنع ج (قيمة E أقل))

ΔE = 8 − 2 = +6

ΔG gonna be (−)

So, the reaction is spontaneous. لذلك متفقل تكون ΔE موجبة

- Calculate ΔG^o of the following reaction ← منطلع نصف التأكسد ثم منطلع نصف الاختزال.

- $NADH + 1/2O_2 \longrightarrow NAD^+ + H_2O$

$NADH \longrightarrow NAD+ + 2e^-$ $\Delta E^o = +0.32V$

$O + 2e^- \longrightarrow O^{2-}$ $\Delta E^o = +0.82V$

أخذت الأرقام من الجدول السابقة بس هون عندك أكسدة وليس اختزال فمنعكس الإشارة

Standard reduction potential.

Standard oxidation potential, notice the sign here is opposite to the sign in the previous table as the reaction is oxidation.

$\Delta G^o = -52.6$ kcal/mol

So, it's prefer forward direction

Oxidation reduction reactions (Redox)

difference of reduction potential in system

- **ΔE^o = Redox difference of a system in standard condition (25C° and 1 atmosphere pressure, pH = 7)**

- **Does ΔE^o determine the feasibility of a reaction?**

Reactions with higher positive ΔE° values are more likely to occur spontaneously, while those with negative values are not favoured.

السبب :
ΔE^o ← موجبة
و قيمتا كبيرة
بتعطيه ΔG أكبر بالسالب

more exorgonic ➤ $\Delta G^o = -nf\Delta E^o$

more spontinous.

- **In other words; energy (work) can be derived from the transfer of electrons Or**
- **Oxidation of food can be used to synthesize ATP**

Why do we correlate the redox potential with ΔG?
The energy obtained from the transfer of electrons between compounds can be used to synthesize ATP during metabolic pathways, producing the energy currency for the cell.

ATP

ΔE ← بحسب عن تفاعلات أكسدة واختزال (انتقال إلكترونات) وانتقال بعطيك طاقة ممكن نستغلها لعمل

تفاعل ADP + P → ATP لذلك ΔG لهذا التفاعل تتأثر بوجود طاقة عشان هيك نظرة ال ADP تعتبر endorgonic-

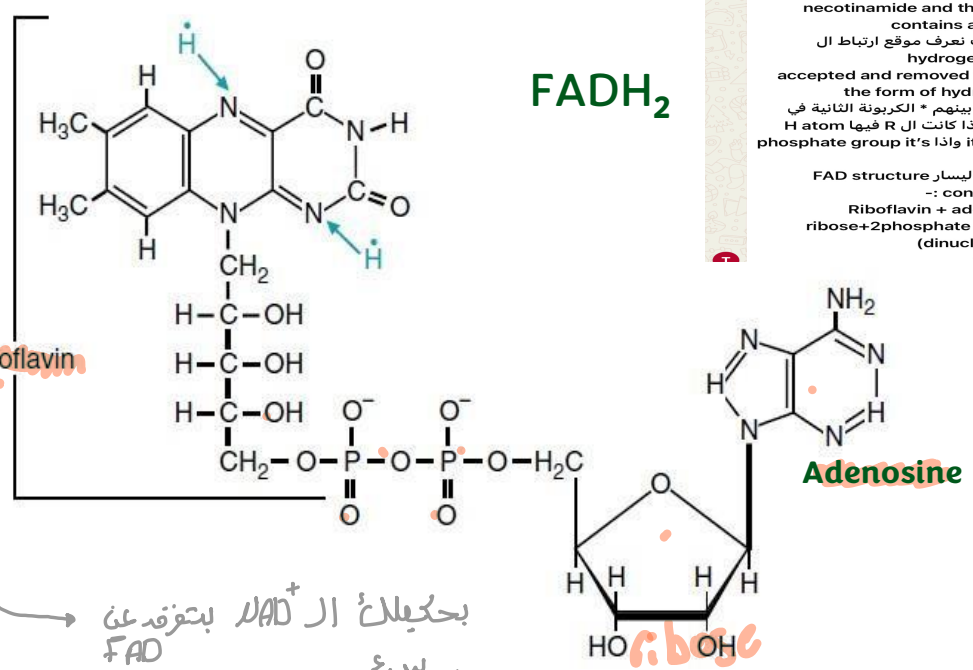
Oxidation reduction reactions (Redox)

The function of a coenzyme in a redox reaction is to undergo the opposite change that occurs on the main substrate so, if the substrate is oxidized the coenzyme will be reduced and vice versa.

- Always involve a pair of chemicals: an electron donor and an electron acceptor (Food vs. NAD+)
- NAD+ vs. FAD (hydride vs H-atom, number, energy)
- NAD+ vs. NADP+ (fatty acid synthesis and detoxification reactions)

NAD+ / NADP ---> serve different roles, particularly in fatty acid synthesis and detoxification reactions.

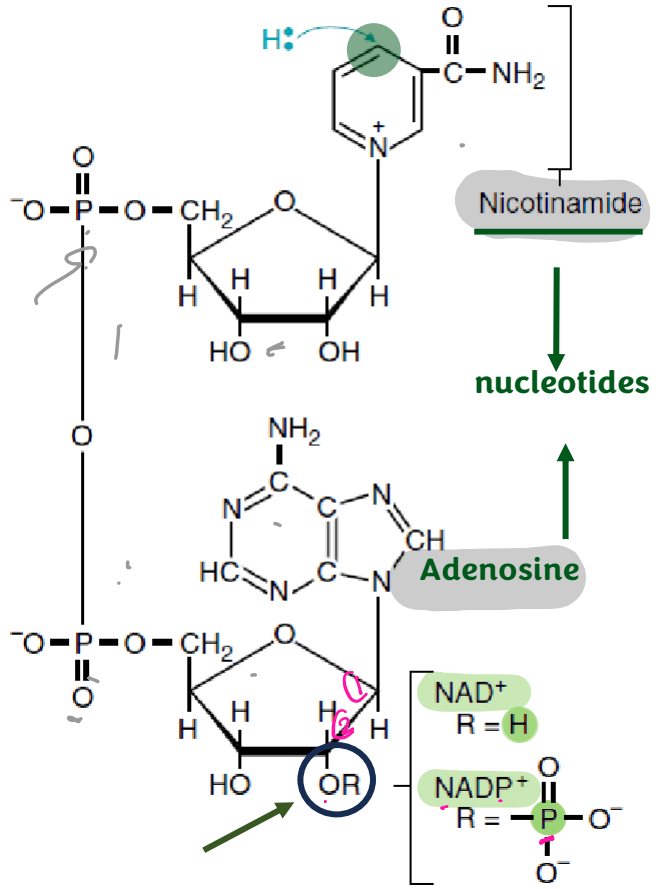
من اليمين مطلوب تعرف انه NAD+ & +NADP
Consist of 2 nucleotides(each nucleotide consists of :- phosphate +ribose+nitrogenous base)
Joined by their phosphate groups
One nucleotide consists of necotinamide and the other contains adenine
ومطلوب نعرف موقع ارتباط ال hydrogen atom
وأنهم accepted and removed in the form of hydride ion
*والفرق بينهم * الكربونة الثانية في الرايبوز إذا كانت ال R فيها H atom واذا it's NAD phosphate group it's NADP
الرسمة اليسار FAD structure :- consists of Riboflavin + adenine + ribose+2phosphate groups (dinucleotide)



بتحكيلك ال NAD+ بتتفرق عن FAD بـ ٣ أمور:

1) NAD+ → accept hydride (H^-).
   FAD → accept hydride ion or H-atom.
2) number of electron transferred.
3) NAD+ → high reduction energy.
   FAD → low reduction energy.

Here's the location where the electrons are accepted or donated.



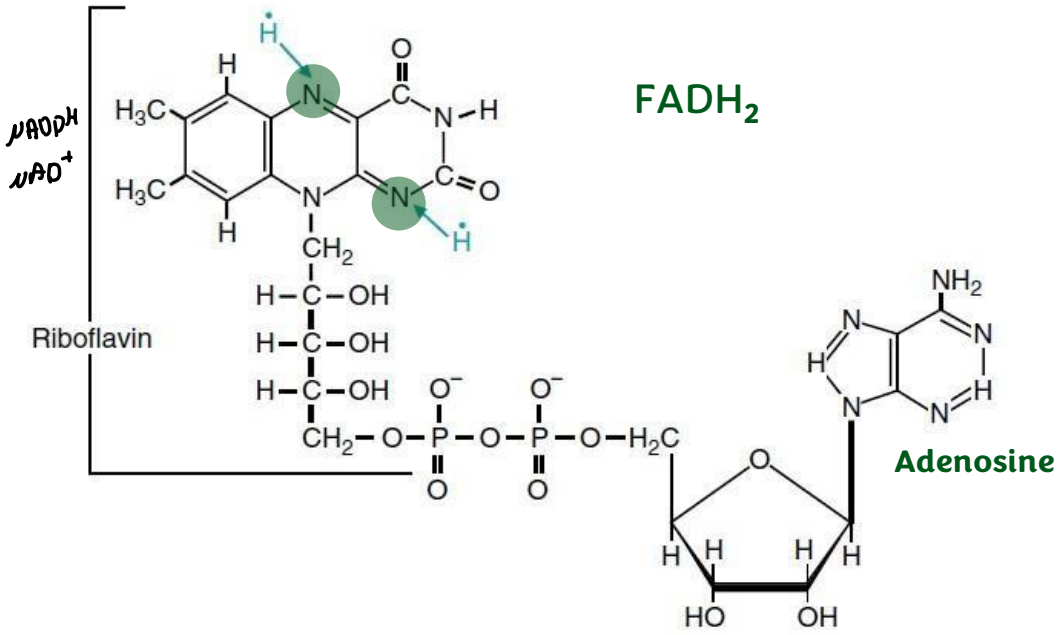
Notice the difference between NADP+ and NAD+, enzymes could distinguish between the two coenzymes by this difference.

Oxidation reduction reactions (Redox)

Further notes regarding the previous slide.

In summary, the distinct forms of NADPH and NADH and their roles in reduction and oxidation reactions ensure that cells can efficiently manage their metabolic needs without needing to constantly switch between forms.

- NADPH is found mainly in the reduced form (NADPH) ready to be oxidized, while NADH is found mainly in the oxidized form (NAD+) ready to be reduced so, we don't need to alternate between the two forms of each coenzyme, this ensures that coenzymes are ready for any reaction either a reduction or an oxidation reaction.
- FAD accepts electrons in the form of hydrogen atoms.
- NAD+ and NADP+ accepts electrons in the form of hydride ions.
- NAD+ is primarily involved in catabolic and degradative pathways, transferring energy stored in nutrients into a usable form of energy.
- NADPH is primarily involved in anabolic and synthetic pathways such as fatty acid synthesis and detoxification reactions.



$FADH_2$

Summary جدًا مهم.

Oxidation-Reduction (Redox) Reactions. [2][3]

- Oxidation: Loss of electrons, gain of oxygen, loss of hydrogen.
- Reduction: Gain of electrons, loss of oxygen, gain of hydrogen.
- Redox potential (E): Measures tendency to gain/lose electrons.
- Electrons move from lower to higher reduction potential.

Coenzymes in Redox Reactions [6][7]

- ·NAD+ vs. FAD: Different in electron acceptance mechanisms.
- NAD+ vs. NADPH: Used in different metabolic pathways. واحد Catabolic، واحد Anabolic
- NAD+: Primarily in degradative pathways.
- NADPH: Mainly in anabolic and synthetic pathways.

Reduction Potential and Reaction Direction [4][5]

- Spontaneous reactions have negative ΔG°.
- Compounds with higher reduction potential tend to be reduced.
- NAD+ more abundant than NADH in cells (1000:1 ratio).

Calculation of ΔG° and ΔE° [8]

- $\Delta G^\circ = -nf\Delta E^\circ$.
- f = Faraday constant (23.06 kcal/Volt).
- n = number of moles of electrons transferred.

Importance of Redox Reactions

- Producing energy from the electron transfer chain used to synthesize ATP.
- Critical for metabolic pathways and cellular energy production.

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			

Additional Resources:

رسالة من الفريق العلمي:

Reference Used:
(numbered in order as cited in the text)

1. Lippincott’s Illustrated Reviews:Biochemistry

ردّدوا دوماً اللّهم لكَ الحمد: فبالشُّكر تدومُ النِّعم