بسم الله الرحمن الرحيم

METABOLISM
MID – Lecture 3
Bioenergetics (pt.3)

﴿ وَإِن تَتَوَلَّوْاْ يَسْتَبْدِلْ قَوْمًا غَيْرَكُمْ ثُمَّ لَا يَكُونُوٓاْ أَمْثَٰلَكُم ﴾

اللهم استعملنا ولا تستبدلنا

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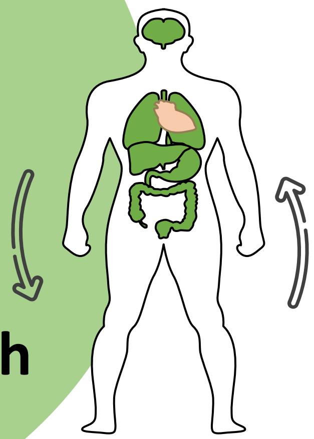


This slide will be explained in V1 after the Dr explains it.

Thermogenesis

- **Heat production is a natural consequence of "burning fuels"**
- **Thermogenesis refers to energy expended for generating heat (37ºC) in addition to that expended for ATP production**
- **Shivering thermogenesis (ATP utilization): activation of exothermic reactions by responding to sudden cold with asynchronous muscle contractions**
- **Non-shivering thermogenesis (ATP production efficiency)**
  - **In the first 6 months of life**
  - **It is associated with brown adipose tissue**

Oxidation reduction reactions (Redox)

- **Oxidation:**
  - ✓ Gain of Oxygen
  - ✓ Loss of Hydrogen
  - ✓ Loss of electrons
- ***Reduction:***
  - ✓ Gain of Hydrogen
  - ✓ Gain of electron
  - ✓ Loss of Oxygen
- ***E*= redox Potential: it is a POTENTIAL ENERGY that measures the tendency of oxidant/reductant to gain/lose electrons, to become reduced/oxidized**

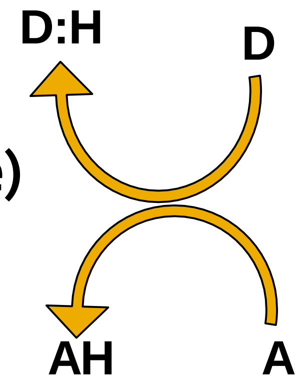
For a whole reaction, we can determine which substrate is going to be oxidized and which one is going to be reduced by comparing the reactants' redox potentials with each other.

- **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).



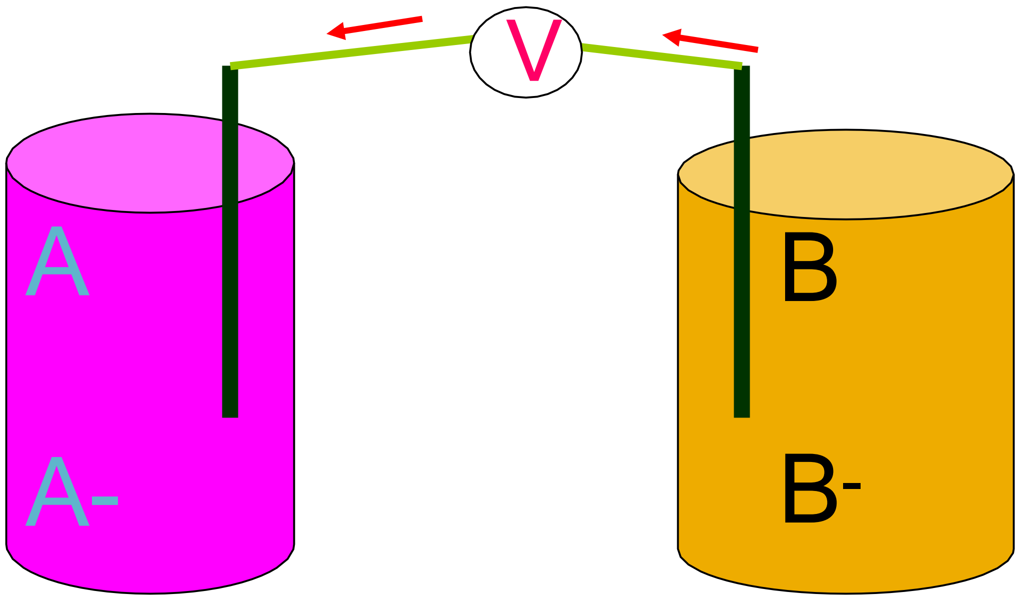
Reduction Potential and the direction of reaction

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

B oxidized form
B^- reduced form

Redox couple

Notice that the reaction has a negative $\Delta G°$, 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

$$H^+ + X^- \longrightarrow H_2 + X \quad \Delta G^o = \text{-ve}$$

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+.**

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.

Oxidized + e^-	→ Reduced	*ΔEº (V)*
Succinate	α ketoglutarate	- 0.67
Acetate	Acetaldehyde	- 0.60
NAD^+	**NADH**	**- 0.32**
Acetaldehyde	Ethanol	- 0.20
Pyruvate	Lactate	- 0.19
Fumarate	Succinate	+ 0.03
$Cytochrome^{+3}$	$Cytochrome^{+2}$	+ 0.22
oxygen	**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.

Calculation of ΔG^o and ΔE^o

- $\Delta G^o = - nf\Delta E^o$
  - F = Farady constant = 23.06 kcal/*Volt*
  - n is the number of moles of electrons transferred in the redox reaction
- Calculate ΔG^o of the following reaction
- $NADH + 1/2O_2 \rightarrow NAD^+ + H_2O$

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

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

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

Oxidation reduction reactions (Redox)

- 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.

- $\Delta G^o = -nf\Delta E^o$

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

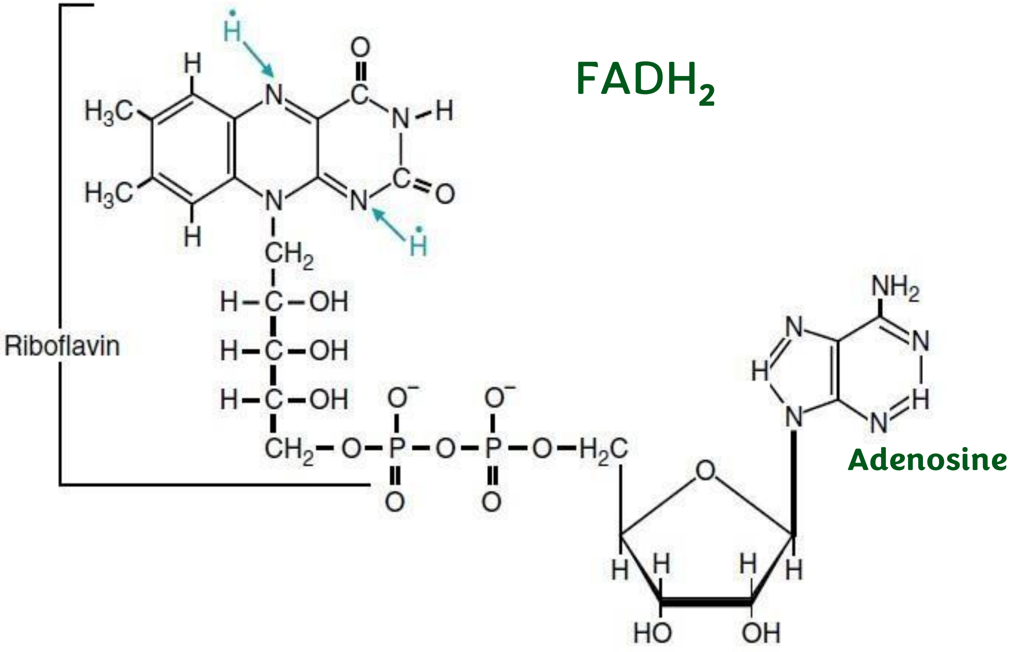
Why do we correlate the redox potential with ΔG?
The energy obtained from the transfer of electrons between compounds can be used to synthesize ATP during metabolic pathways, producing the energy currency for the cell.

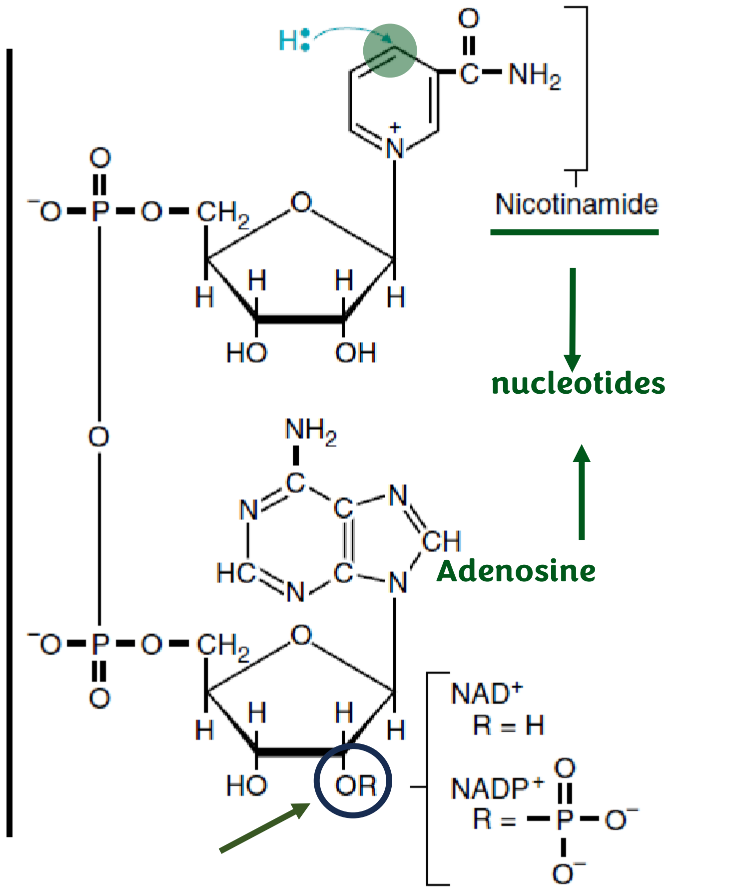
Oxidation reduction reactions (Redox)

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.

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

- Always involve <u>a pair</u> 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)



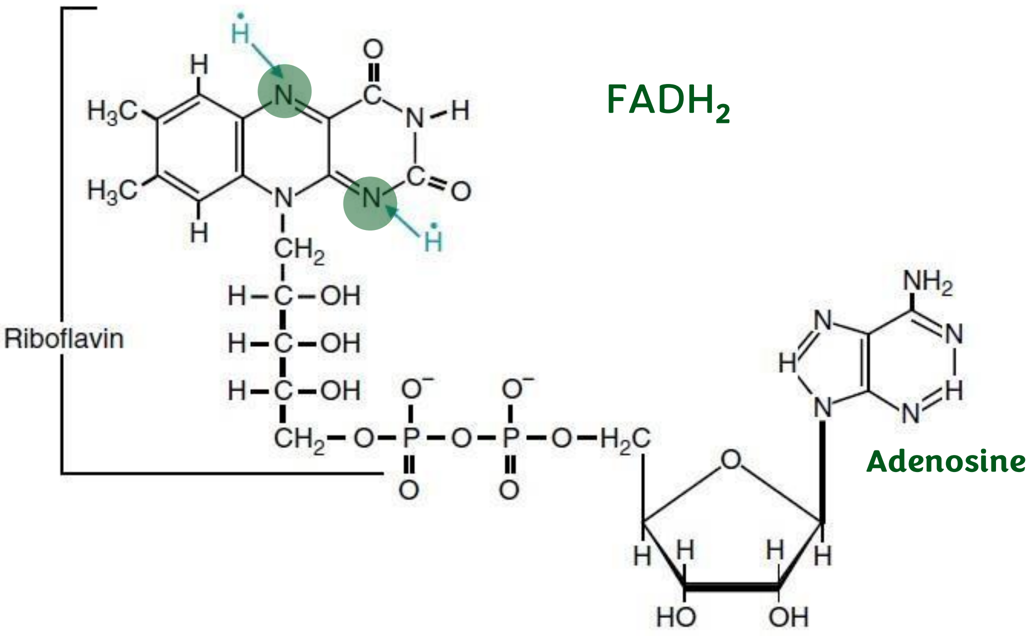


Notice the difference between NADP+ and NAD+, enzymes could distinguish between the two coenzymes by this difference.

Oxidation reduction reactions (Redox)

Further notes regarding the previous slide.

- 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.



Summary

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.
- NAD+: Primarily in degradative pathways.
- NADPH: Mainly in anabolic and synthetic pathways.

Reduction Potential and Reaction Direction [4][5]

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

Calculation of $\Delta G°$ and $\Delta E°$ [8]

- $\Delta G° = -nf\Delta E°$.
- 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)

ردّدوا دوماً اللّهم لكَ الحمد: فبالشُّكر تدومُ النِّعم

1. Lippincott’s Illustrated Reviews:Biochemistry