Metabolism

What is metabolism?

The sum total of all ________________
__________________ in an organism.

Two main processes constitute metabolism:

Catabolism - breakdown of ____________
__________________
- oxidative processes: ________
- releases _________________

Anabolism - production of ________________
__________________
- reductive process: _________
- requires/uses _______________

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Metabolism
What is metabolism?

Catabolism
Nutrient (large molecules) intake is broken down to ___________________________
__________________________________
__________________________________

Oxidative
Fats
Polysaccharides
Proteins
Fatty acids
Glucose and other monosaccharides
Amino acids
Small molecules

Excretion
To anabolism

Anabolism
Some catabolism products and nutrients used to make _____
__________________________________
__________________________________

Reductive
Requires reducing agents and energy

Energy-requiring
Products of anabolism, including proteins and nucleic acids

To catabolism
Some excretion
Catabolism
- breakdown of larger molecules into smaller ones.
- oxidative processes: loss of $e^-$
- releases energy.

Anabolism
- production of larger molecules out of smaller ones.
- reductive process: gain of $e^-$
- requires/uses energy

- Oxidation/reduction reactions or redox reactions (electron-transfer reactions)

Reduced form of a compound has full _________________________

Oxidized form of a compound has __________________________

Example: the oxidation of Zn by Cu

$$Zn + Cu^{+2} \rightleftharpoons Zn^{+2} + Cu$$
Redox reaction example: oxidation (loss of $e^{-}$) of ethanol to acetaldehyde

- $e^{-}$ must have somewhere to go
- transferred to $e^{-}$ acceptor (oxidizing agent)
Reducing agent
- at start of reaction has full complement of $e^-$
- substance that __________
- $e^-$ __________
- becomes oxidized once it loses $e^-$

Oxidizing agent
- has less $e^-$
- substance that __________
- $e^-$ __________
- becomes reduced once it gains $e^-$
Metabolism
Redox Reactions - $e^-$ acceptors

NADH and NADPH
- Nicotinamide adenine dinucleotide
  NAD$^+$, oxidizing agent, _________________________
  NADH, reducing agent, _________________________

Oxidation of NADH to NAD$^+$ involves loss of $e^-$ in form of Hydride ion (H and 2 $e^-$)

-Nicotinamide adenine dinucleotide phosphate
  NADP$^+$, ____________
  NADPH, ____________

- act as coenzymes, a non protein substance that takes part in enzymatic reactions
  _________________________
  ________________________.

NADP$^+$ contains a $\text{P}$ on this 2'-hydroxyl
Metabolism
Redox Reactions

NADH as a coenzyme

Can **NADH** act as an oxidizing agent (e\textsuperscript{-} acceptor) to oxidize ethanol to acetaldehyde? ___________

This reaction requires that the e\textsuperscript{-} be moved to an e\textsuperscript{-} acceptor (oxidizing agent)
NADH as a coenzyme

Can **NAD**\(^+\) act as an oxidizing agent (e\(^-\) acceptor) to oxidize ethanol to acetaldehyde? _______________

This reaction requires that the e\(^-\) be moved to an e\(^-\) acceptor (oxidizing agent)

Oxidation of EtOH ________________________________

\[
\text{ethanol} \quad \xrightarrow{\text{oxidation}} \quad \text{acetaldehyde} \quad + \quad 2\text{H}^+ + 2e^- \\
\]

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NADH as a coenzyme

Can NADH act as a reducing agent (e⁻ donor) to reduce acetaldehyde to ethanol? ____________

This reaction requires that the e⁻ be donated by an e⁻ donor (reducing agent) ________________________

- Reaction also ________________
- Thus, NADH ________________
Metabolism
Redox Reactions

FAD - electron acceptor

FAD, oxidizing agent, _____________________________
FADH$_2$, reducing agent, ___________________________

rest of molecule similar to NADH
NADH and FADH$_2$ are used in metabolism to ________

Oxidation of nutrients (catabolism) to provide energy can not take place without

- NADH and FADH$_2$ are recycled
  __________
- not used and then lost
- cyclic

In anabolism NADH used as reducing agent ($e^-$ donor) to ____________
Metabolism

ATP

What is the connection between ATP production and ATP use

The main purpose of catabolism is to release the ____________
_____________________________________________________

The energy stored in ATP is then used in anabolism to _________
_____________________________________________________

The ADP produced from ATP is then rephosphorylated ________
_____________________________________________________

ATP/ADP cycling shunts energy from production to its uses

Why not use the energy from nutrients directly to power anabolism?
Metabolism

ATP

While the carbon-carbon bonds in nutrients (carbohydrates) are high energy, they are not ______________________

Phosphate ester bonds can be ______________________________

ATP has high amount of energy in its phosphate ester bonds
Metabolism

ATP

Other phosphate containing compounds have higher free energies than ATP and can be used in metabolism to produce ATP from ADP.

### Table 15.1

<table>
<thead>
<tr>
<th>Compound</th>
<th>$\Delta G^\circ$ kJ mol$^{-1}$</th>
<th>$\Delta G^\circ$ kcal mol$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphoenolpyruvate</td>
<td>$-61.9$</td>
<td>$-14.8$</td>
</tr>
<tr>
<td>Carbamoyl phosphate</td>
<td>$-51.4$</td>
<td>$-12.3$</td>
</tr>
<tr>
<td>Creatine phosphate</td>
<td>$-43.1$</td>
<td>$-10.3$</td>
</tr>
<tr>
<td>Acetyl phosphate</td>
<td>$-42.2$</td>
<td>$-10.1$</td>
</tr>
<tr>
<td>ATP (to ADP)</td>
<td>$-30.5$</td>
<td>$-7.3$</td>
</tr>
<tr>
<td>Glucose-1-phosphate</td>
<td>$-20.9$</td>
<td>$-5.0$</td>
</tr>
<tr>
<td>Glucose-6-phosphate</td>
<td>$-12.5$</td>
<td>$-3.0$</td>
</tr>
<tr>
<td>Glycerol-3-phosphate</td>
<td>$-9.7$</td>
<td>$-2.3$</td>
</tr>
</tbody>
</table>
The complete oxidation of glucose to CO$_2$ and H$_2$O yields 32 ATP

Glucose + 6 O$_2$ + 32 ADP + 32 P$_i$ $\rightarrow$ 6 CO$_2$ + 6H$_2$O + 32 ATP

$\Delta G = -1891$ kJ/mol

Requires ______________________________________

__________________________________________

__________________________________________

__________________________________________
Some enzymatic reactions in metabolism are not thermodynamically favorable. Thus, these reactions use the process called Activation.

**Activation** - a metabolite (metabolic intermediate) is bound to Coenzyme A (CoA) - is a common activator
- metabolite is bonded to S of sulfhydryl group

- this new bond formation has a \( \Delta G \)
- the next reaction in the pathway
- becomes thermodynamically

Coenzyme A (CoA) - is a common activator

Thioethanolamine  From pantothenic acid  3'-P-5'-ADP

Functional sulfhydryl group

Coenzyme A (CoA-SH)
Metabolism
Coenzyme A

Some enzymatic reactions in metabolism are not thermodynamically favorable. Thus, these reactions use the process called **Activation**.
We are next going to put all this together in relation to catabolism (glucose Oxidation):
- use of ______________
- use of CoA
- how is it all linked ________

Three steps involved in complete oxidation of glucose to produce ATP

- **Glycolysis**: break down of glucose into __________
- **Citric Acid Cycle**: oxidation of 3 carbon intermediates

- **oxidative phosphorylation**: use of NADH and FADH2 generated from citric acid cycle to __________________________