

Cells at work

Cell Metabolism and ATP

- ATP is the energy molecule of the cell.
- Billions are used and reassembled every second!!
- Endergonic Rxn – Requires energy (ie. Photosynthesis)
- Exergonic Rxn – releases energy (ie. Cellular Respiration)
- Glucose = 1 dollar
- ATP = 1 penny

The diagram illustrates the synthesis of ATP from ADP and inorganic phosphate (Pi). It shows a central purple circle labeled 'Energy' with radiating lines representing energy input. Two green circles labeled 'A' (Adenosine) are shown; one is bound to a blue pentagon representing ribose, and the other is free. Three yellow circles labeled 'P' (Phosphate) are also shown. Arrows indicate the transfer of phosphate groups from inorganic phosphate to the adenosine, forming ADP, which then further reacts with another phosphate group to form ATP.

- Enzymes → key to biochemical reactions

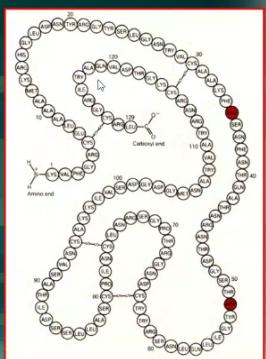
ENZYMES

- Proteins that accelerate chemical reactions
- Almost all processes in the cell need enzymes in order to occur – Cellular Respiration, Photosynthesis, food digestion etc.
- Are extremely selective – very specific to certain reactions



ENZYMES

- For Example:
Lysozyme digests bacterial cell walls, and is found in human tears, egg-white, etc



ENZYMES

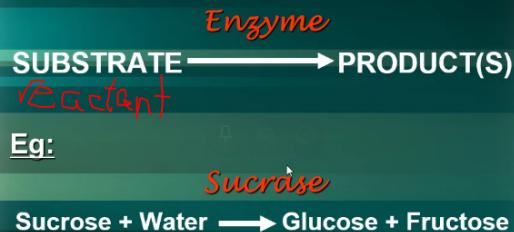
- Enzymes are known to catalyze about 4,000 reactions in the human body
- Remain unchanged after reactions
- Most are named after the reaction they catalyze and their names end in “-ase”
Ex: Lactase breaks down lactose



HOW ENZYMES WORK:

- By providing a lower activation energy for a reaction and dramatically accelerating its rate
- For example...
the reaction catalysed by orotidine-phosphate decarboxylase will consume half of its substrate in 78 million years if no enzyme is present. However, when the decarboxylase is added, the same process takes just 25 milliseconds

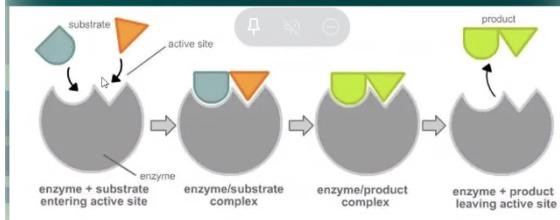
HOW ENZYMES WORK:

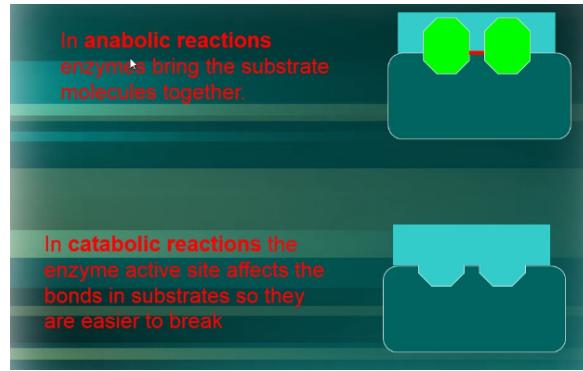


Enzymes help a reaction to occur ... without being directly involved!!!

Enzyme Structure

- The substrate must fit precisely in the active site in order for the reaction to proceed
- All enzymes are highly specific!

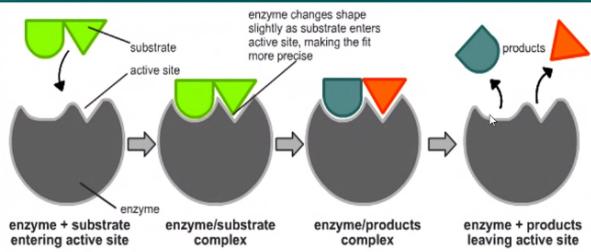




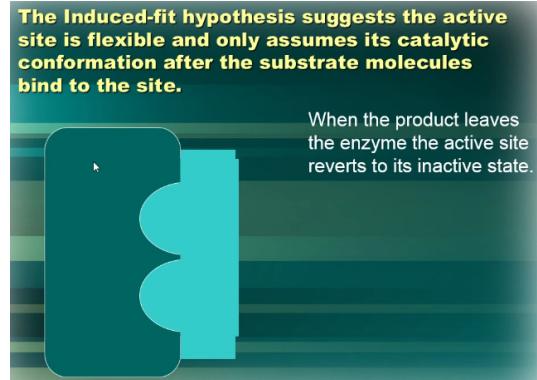
- A is like add, C is like cut

Enzyme Structure

- “Lock and Key” Model:



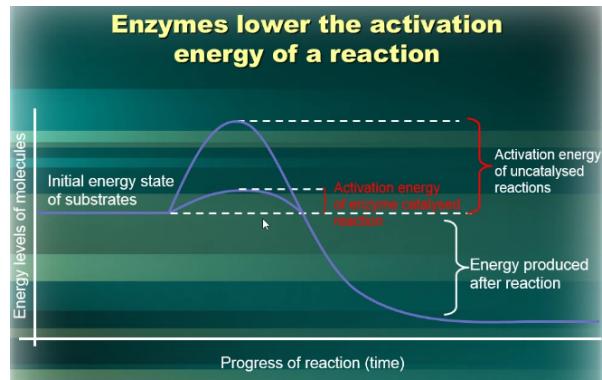
- Lock and key is prob wrong cuz proteins have been proven to be flexible



Induced Fit Model

- When the substrate and enzyme interact, it causes the enzyme to change its shape and better fit the substrate

https://www.youtube.com/watch?v=pVoytz_3H_s



Activation Energy

Normal circumstances:

- Obtain activation energy (usually thermal energy from surrounding)
- Absorption energy increases the speed of the molecules in reactants, colliding more often & forcefully

With enzymes:

- Lowers the energy barrier required for the reaction to occur → speeds up process

Activation Energy

Enzymes can lower the activation energy by:

- The R-group of the protein interferes with the molecule's bond in the substrate
- Transfer of electrons between the enzyme and substrate
- Add or remove hydrogen ions or from the substrate

- Factors affecting enzyme activity

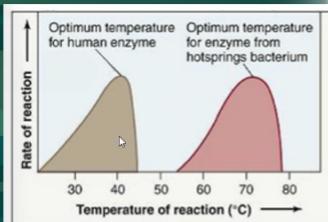
Rate of Enzymes

- Enzymes function in an optimal environment
- Factors affecting activity:
 - Temperature
 - pH
 - Enzyme concentration
 - Substrate concentration

Factors Affecting Enzyme Activity

1) Temperature

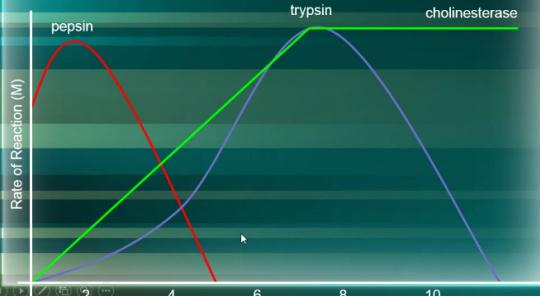
- Rate of reaction increase with temperature
- Enzymes denature at 60° C
- Some **thermophilic** bacteria have enzymes with optimum temperatures of 85°C



Factors Affecting Enzyme Activity

2) pH:

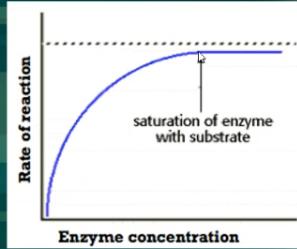
- Bonds between the functional groups that hold the protein together are sensitive to H⁺ concentration



Factors Affecting Enzyme Activity

3) Enzyme Concentration:

- The more enzymes in the solution, the more likely they are to collide with the substrate

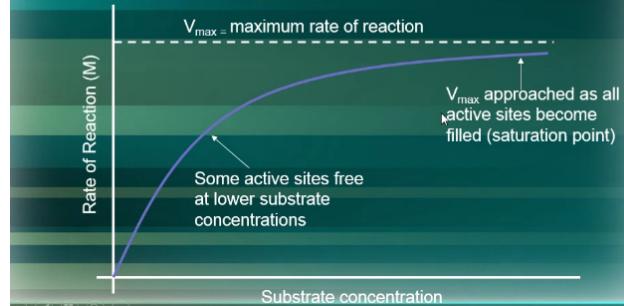


- The more seats u have in a movie theater, the more people that can sit

Factors Affecting Enzyme Activity

4) Substrate Concentration:

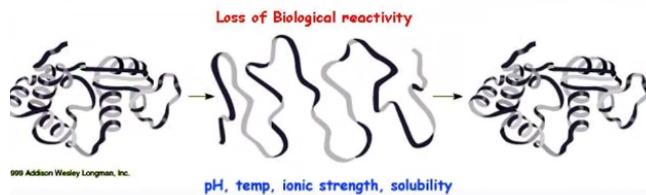
- Increase in substrate concentration increases the rate of reaction until it reaches saturation point



- Summary

In Summary...

- Work at optimal concentrations, temp. & pH
- If it is too hot, an enzyme can become DENATURED... and will no longer function properly



Define the following terms:

- Anabolic reactions: Reactions that build up molecules
- Catabolic reactions: Reactions that break down molecules
- Metabolism: Combination of anabolic and catabolic reactions
- Catalyst: A substance that speeds up reactions without changing the produced substances
- Metabolic pathway: Sequence of enzyme controlled reactions
- Specificity: Only able to catalyse specific reactions
- Substrate: The molecule(s) the enzyme works on
- Product: Molecule(s) produced by enzymes

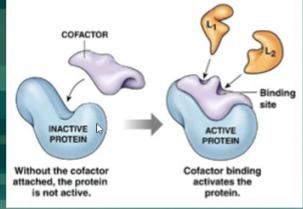
- Enzyme regulation

Enzyme Regulation

- Regulation mechanisms:
 - Cofactors/ Coenzymes
 - Competitive inhibitors
 - Non-Competitive inhibitors
 - Allosteric Changes
 - Feedback Inhibition
 - Precursor Activation

1. Cofactors/Coenzymes

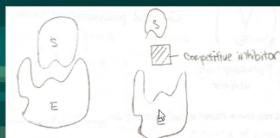
- Non-protein helper
- Enzymes can't speed up reaction without them



1. Cofactors/Coenzymes

- Example: Vitamin B₂ (riboflavin)
- Involved in energy metabolism (ie. metabolism of fat, carbohydrates and proteins)
- Deficiency: body will have problem metabolizing (fats, carbs, proteins)
- Often caused by dietary inadequacy
- Can be obtained from meat, nuts, cheese, eggs
- Diagnosis: measure activity of enzyme glutathione
- Symptoms: bloodshot eyes, mouth, inflammation, sores, burning tongue
- Not common because most countries fortify their breads and cereals with vitamin B₂

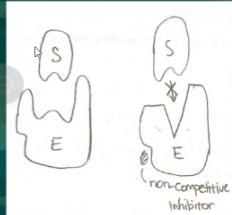
2. Competitive Inhibitors



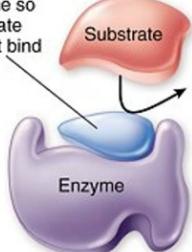
- Resembles the normal substrate and compete for admission into the active site
- Reduces the productivity of the enzyme by locking the active site from substrate
- If the inhibitor attaches to the enzyme by covalent bond, the inhibition is usually irreversible (ex. nerve gas, cyanide, arsenic)
- If the inhibitor binds to the enzyme by a weak bond, the inhibition is reversible; it can be overcome by increasing the concentration of substrate

3. Non-Competitive Inhibitors

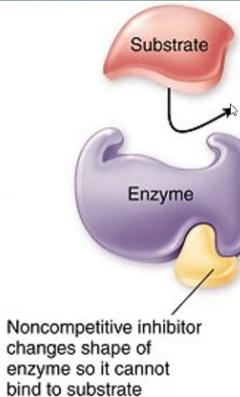
- Inhibits enzymatic reaction **without** actually entering the active site
- The inhibitor binds to a part of the enzyme separated from the active site, causing the enzyme to change its shape in such a way that the active site is no longer receptive to the substrate



Competitive inhibitor interferes with active site of enzyme so substrate cannot bind



(a) Competitive inhibition



(b) Noncompetitive inhibition

- Inhibitors r there to either poison or to save energy

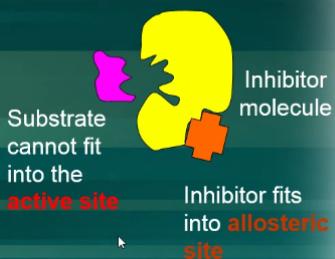
4. Allosteric Regulation

- Process where a regulator molecule will influence an enzyme's activity by combining with the enzyme to change its shape
- Regulator molecule may Inhibit or stimulate enzyme activity
- The activator/inhibitor binds to the allosteric site

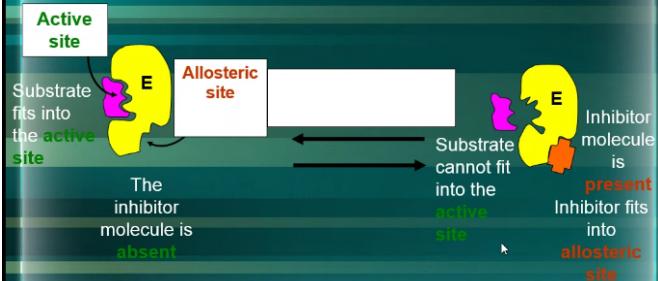
- This one can also start the reaction
- Missed one

Switching off

- These enzymes have two receptor sites
- One site fits the substrate like other enzymes
- The other site fits an inhibitor molecule

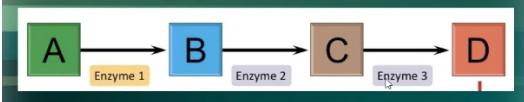


The allosteric site the enzyme “on-off” switch



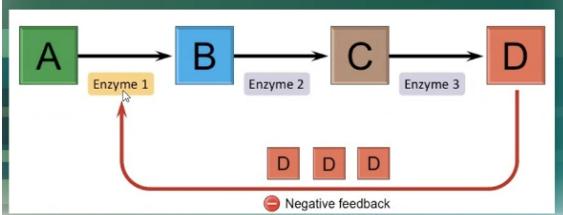
5. Feedback Inhibition

- The product of one reaction becomes the substrate of another reaction
- The product formed in the last step of the pathway can become an inhibitor



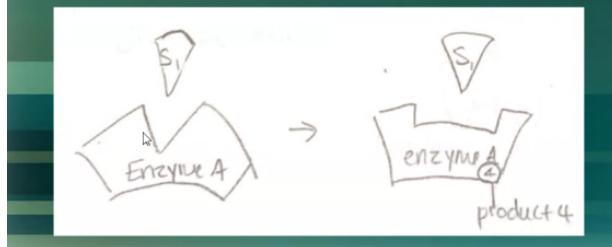
5. Feedback Inhibition

- Accumulation of product inhibit the activity of enzyme 1
- If enzyme 1 is inhibited, everything will slow down



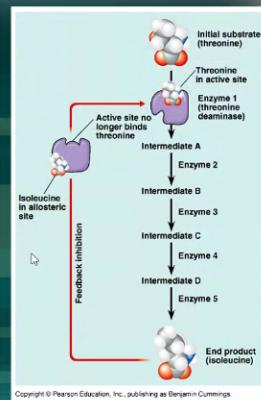
5. Feedback Inhibition

- Product 4 binds to allosteric site of enzyme 1, changing its shape



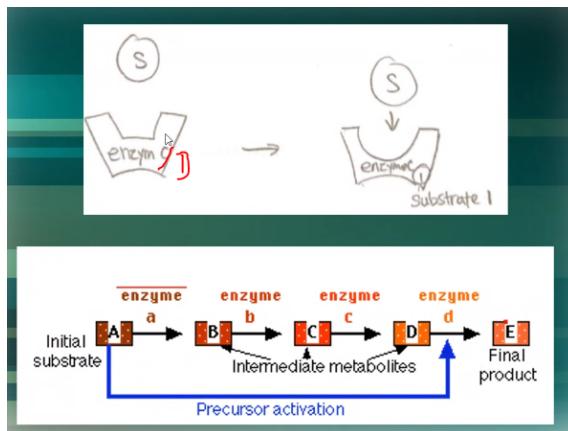
This example demonstrates how an end product can inhibit the first step in its production.

1. Isoleucine binds to the allosteric site of threonine deaminase and prevents threonine from binding to the active site because the shape of the active site is altered.
2. When the level of isoleucine drops in the cell's cytoplasm, the isoleucine is removed from the allosteric site on the enzyme, the active site resumes the activated shape and the pathway is "cut back on" and isoleucine begins to be produced.



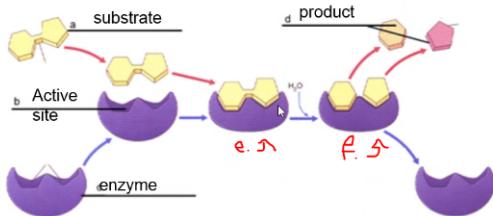
6. Precursor Activation

- Requires a reactant to activate enzyme further along a reaction series
- It may combine with the enzyme, changing its shape, so that the active site fits with its substrate
- Substrate 1 activates enzyme C



Check your Understanding

Label the following diagram



- E. substrate-enzyme complex
- F. product-enzyme complex

Check your Understanding

Determine whether the following statements are true or false:

- A) Enzymes interact with specific substrates *t*
- B) enzymes change shape after a reaction occurs *f*
- C) Enzymes speed up reactions *t*
- D) Adding more enzyme will decrease the rate of reaction. *f*
- E) Enzyme reactions can be slowed or halted using inhibitors. *t*
- F) All enzymes have an optimal pH of 8. *f*

Homework

- 50 - 56 textbook
- Optional enzyme worksheet
- Enzyme gizmo lab → for marks

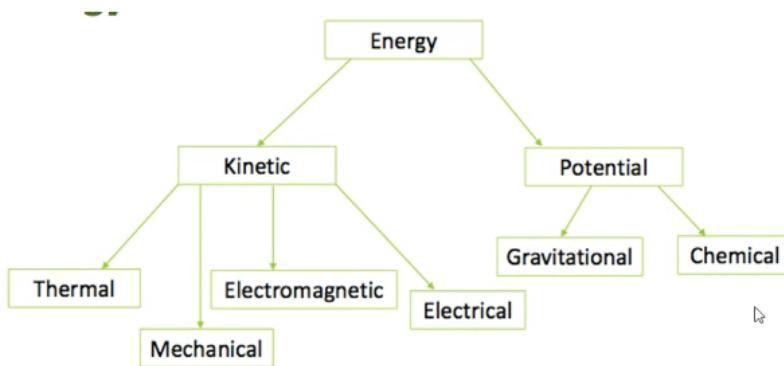
Nomenclature Functional Group Priority for Bio

- Carboxylic Acid + derivatives like ester
- Amino
- Aldehyde
- Ketone
- Alcohol
- Alkyne
- Alkene
- /33, 10 marks for MC, 3 naming diagrams,
- Acetone is the common name for 2-propanone
- Prioritize triple over double bonds

Metabolism

Energy

- Ability to do work
- Must continuously capture, store and use energy
- Organisms do majority of work on a cellular level
- Must manage amount of energy used w amount produced
- Anabolic reactions:
 - Energy + small molecules → larger molecules
- Catabolic reactions:
 - Large molecules → energy + smaller molecules
- Kinetic energy (Ek) has to do with movement, potential energy (Ep) is stored



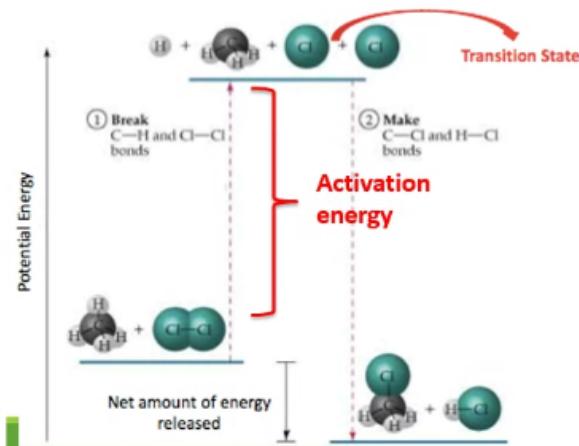
Laws of Thermodynamics

- Looks at physical rules of organisms and how energy is transferred between them
1. Total amount of energy in any closed system is constant. Energy cannot be created or destroyed, only converted from one form to another
 - Bond energy
 - Measured in kJ/mol
 - Farther the electrons away from nucleus the more potential energy
 - Energy is released when bonds break and is absorbed when they form new bonds
 - Enthalpy: sum of internal energy (heat content) of a system
 - $H = U + P(v)$
 - Energy is absorbed when reactant bonds break and energy is released when product bonds form

Enthalpy

A few terms...

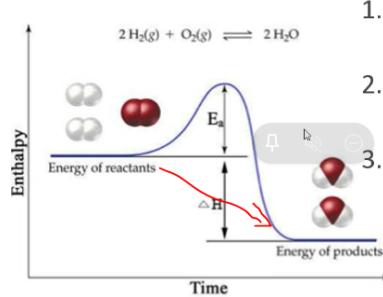
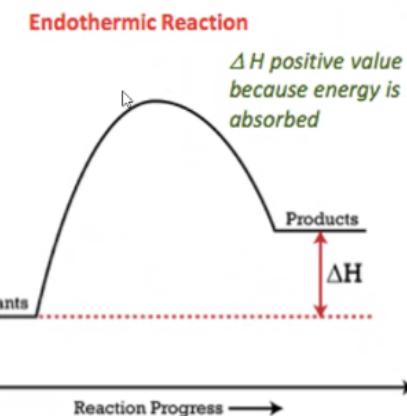
- Activation energy (E_a) – the minimum amount of energy that reactants must absorb to start a reaction
- Transition state – a temporary condition during a chemical reaction in which the bonds in the reactants are breaking and the bonds in the products are forming
- Change in potential energy (ΔH)



- Exothermic reactions

Endothermic Reaction

- energy absorbed, products have higher E_p than reactant
- Positive ΔH



- What does E_a stand for?
- What does ΔH stand for?
- Is this endothermic or exothermic? Why?

2. In every transfer or conversion, some of the useful energy in the system becomes unusable and increases the entropy
- Energy transformation is never 100% efficient
 - Entropy is a measure of disorder in a system
 - Think of a room and how it always gets messier
 - Entropy: in chemical reactions, entropy will increase in following circumstances
 - Solid becomes liquid
 - Liquid becomes gas
 - Complex molecule becomes simpler
 -
 - Catabolic reaction → energy released, entropy increases
 - exothermic reaction and spontaneous process
 - Anabolic reactions → cells trying to become less messy as their building things
 - While it seems this way, its prob not cuz anabolic reactions require energy which they most likely get from catabolic reactions
 - There is order within the disorder
 - Look at cells and ATP using entropy tomorrow
 - Gibbs free energy
 - Gibbs discovered relationship between energy change and temperature of reaction n how relationship could help determine...

- The free energy change can be calculated:

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

Where

ΔG = change in free energy

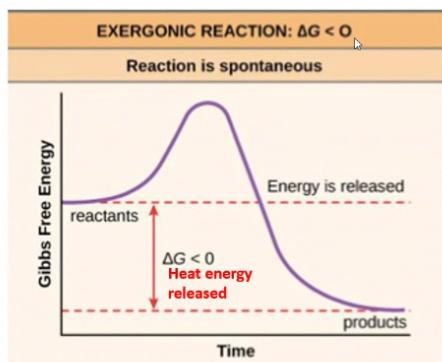
ΔH = change in enthalpy

T = Temperature in Kelvin

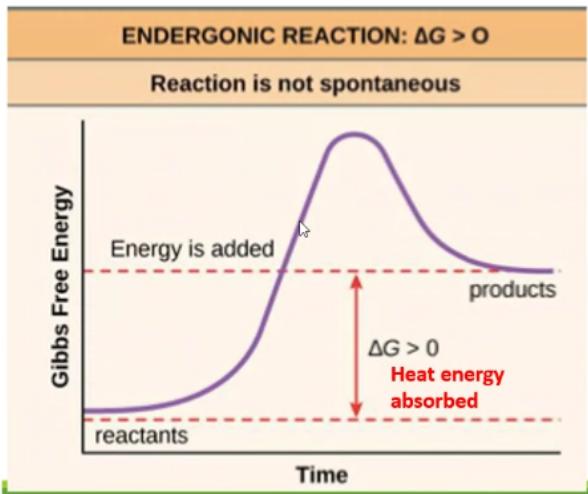
ΔS = change in entropy

$$\text{Gibb's Free Energy} \quad \Delta G = \Delta H - T\Delta S$$

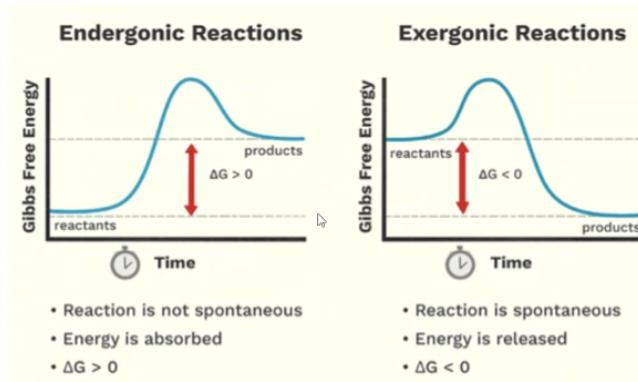
	$\Delta H < 0$	$\Delta H > 0$
$\Delta S > 0$	$\Delta G < 0$ $\Delta G < 0$ at higher temp $\Delta G > 0$ at lower temp	
$\Delta S < 0$	$\Delta G < 0$ at lower temp $\Delta G > 0$ at higher temp	$\Delta G > 0$



- Ex: $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$
- Exergonic means like if there's free energy



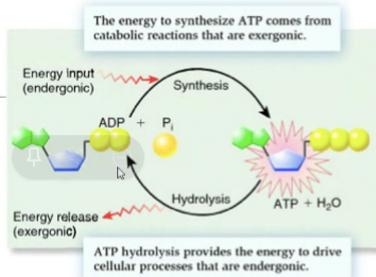
- So many words starting with E → review lol



- Delta G not affected by enzyme
- Coupled reactions

Cells are able to make endergonic reactions from the energy supplied by the exergonic reactions.

Energy coupling is the transfer of energy from one reaction to another in order to drive the second reaction.

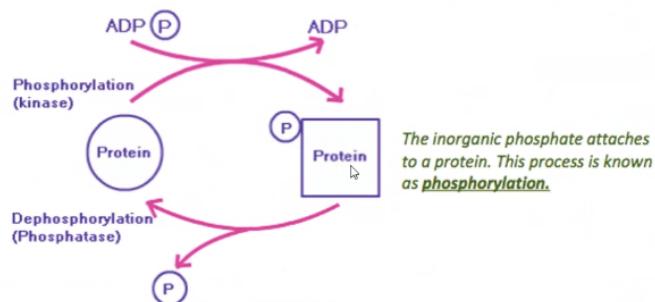


ADP and Inorganic Phosphate

The inorganic phosphate can participate in a wide range of chemical reactions:

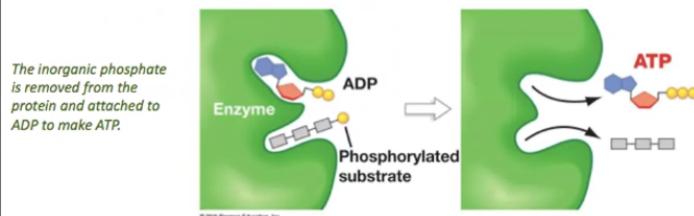
1. Phosphorylation
2. Substrate level Phosphorylation
3. Oxidative phosphorylation

1. Phosphorylation



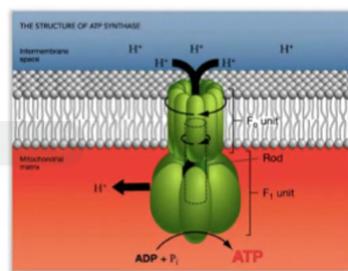
2. Substrate Level Phosphorylation

Used to form ATP directly in an enzyme-catalyzed reaction.



3. Oxidative Phosphorylation

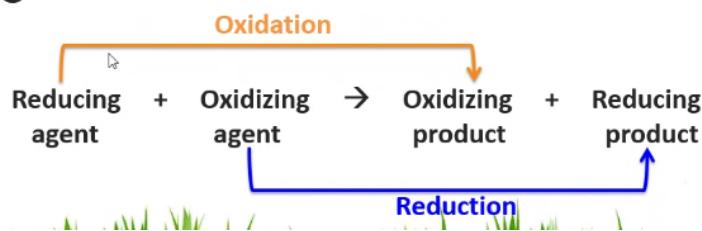
- Used in cellular respiration within mitochondria to produce ATP
- Channel opens when there is a high concentration of H⁺ in the intermembrane space
- H⁺ are pumped back in to create ATP



- Redox omni LEO says GER
- Oxidation or "Ox"
 - Energy metabolism in cells involves oxidation reactions
 - Oxidation involves the transfer of an electron from a molecule which is said to be oxidized to another molecule which is said to be reduced
 - .
- Reduction
 - Overall charge is reduced i.e. gains electrons

Oxidation	Reduction
Addition of Oxygen	Removal of Oxygen
Removal of Hydrogen	Additional of Hydrogen
Loss of electron	Gain of electron

In general:



Redox Reactions & Coenzymes

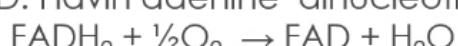
The redox reactions of cellular respiration commonly involve the following coenzymes:

1) NAD: Nicotinamide adenine dinucleotide



Oxidative phosphorylation

2) FAD: Flavin adenine dinucleotide



LEO the lion says GER

- Lose
 - Electrons
 - Oxidized!
- SAYS...
- Gain
 - Electrons
 - Reduced!

OIL RIG

- Oxidation
 - Is
 - Loss of electron
- Reduction
 - Is
 - Gain of electron

-
-
-
3. a

Glycolysis

- The breakdown of glucose to produce: 1 NADH, 4 ATP - 2 ATP,