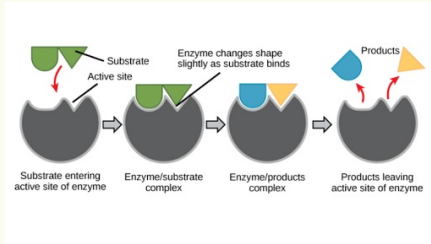


### Enzymes



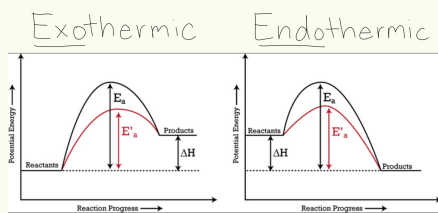
- **enzyme:** macromolecule that acts as a biological catalyst to speed up reactions by lowering  $E_A$
- **substrate:** molecule that can interact with an enzyme
- **active site:** spot to specially interact with the substrate
- **cofactor:** non-protein bound to the active site to allow for the substrate to properly bind
- **coenzyme:** organic molecule serving as a cofactor
- \*enzymes are reusable\*

### Enzyme Lowers Activation Energy

- Proper Alignment~** active site allows place for reactants (substrates) to come together
- Pulls Reactants~** breaks chemical bonds before reaction
- More Conducive~** chemical/physical properties better than those in surrounding environment
- Form Temporary Bonds~** amino acids in active site bond with the substrate molecule

- catalyze either the forward or reverse reaction --- depends on the concentration of reactants/products

### Enzyme Reaction Graphs



### Enzyme Structure

- same as structure of proteins: primary, secondary, tertiary, & quaternary
- shape denatures at...
  - high temperature~ (thermal agitation) bonds disrupted
    - ideal at: 35-40 degrees
    - graph: wide parabola
  - low pH~ (too acidic) hydrogen bonds disrupted
    - ideal at: pH 6-8
    - graph: steep parabola (log scale)
- (3.) substrate concentration~ determine rate of collision
  - ideal at: below saturation level
  - graph: logistic growth (levels off)

### Enzyme Activity

- **competitive inhibitors:** enter the active site in place of the substrate
- **noncompetitive inhibitors:** bind to a location that isn't the active site (allosteric site), change enzyme shape, & block substrate
- **allosteric regulation:** binding of a regulatory molecule at a site that affects the function at a different site
  - ex) allosteric deactivation & allosteric activation
- **feedback inhibition:** end product of metabolic pathway acts as an inhibitor of an enzyme within the pathway



### ATP Background

<i>main 3 kinds of work performed:</i>	1. chemical work- start reactions
	2. transport work- moving substances
	3. mechanical work- movement of cilia, contract muscles, etc.
<i>ATP synthesis 2 ways:</i>	1. substrate level phosphorylation
	↳ phosphate group removed from substrate & added to ADP to form ATP
	2. chemiosmosis (electron transport chain)
	↳ H <sup>+</sup> ions move across membrane moving e <sup>-</sup> & uses that energy for ATP synthesis
<b>- uncouplers:</b>	chemical in liquid membrane that moves H <sup>+</sup> across the membrane (blocks ATP synthesis)

### Energy

<b>- metabolic pathway:</b>	series of chemical reactions that has a starting molecule and results in a product
<b>- catabolic pathway:</b>	pathway that breaks down complex molecules/polymers into simpler molecules/monomers (releases energy)
<b>- anabolic pathway:</b>	pathway that uses simple molecules/monomers to form complex molecules/polymers (consumes energy)

### Energy (cont)

<b>- 1st Law of Thermodynamics~</b>	conservation of energy
	↳ energy can be transferred/transformed, but can't be created or destroyed
<b>2nd Law of Thermodynamics~</b>	increases entropy/disorder (heat)
	↳ usable forms of energy are changed to useless forms

### Free Energy

<b>- free energy (<math>\Delta G</math>):</b>	portion of a system's energy that can perform work		
	↳ must be <i>negative</i> for reaction to be spontaneous		
	<b>gravitational position</b>	<b>solutes in solvent</b>	<b>molecules (size &amp; #)</b>
<b>higher <math>\Delta G</math></b>	high altitude	clustered	large, few
<b>lower <math>\Delta G</math></b>	low altitude	dispersed	small, many
	<b>define</b>	<b>how <math>\Delta G</math> changes</b>	<b>example</b>



### Free Energy (cont)

<b>exergonic reaction:</b>	spontaneous reaction with a net release of free energy	- $\Delta G$	cellular respiration
<b>endergonic reaction:</b>	nonspontaneous reaction with free energy absorbed	+ $\Delta G$	photosynthesis

### Photosynthesis Background

equation:  $6\text{CO}_2 + 6\text{H}_2\text{O} (+\text{energy}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$

two processes:

1. light dependent reaction (light reaction)
2. light independent reaction (dark reaction)

#### light reaction

- pigments trap light energy to transform into chemical energy

- breaks down  $\text{H}_2\text{O}$  to release  $\text{O}_2$  ( $2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4\text{e}^-$ )

- produces ATP from ADP

- unites  $\text{H}^+$  with  $\text{NADPH}^+$

#### dark reaction

- forms glucose from  $\text{CO}_2$ , ATP, &  $\text{NADPH}^+$

- light energy stored in bonds of glucose

### Chloroplast Structure

- light & dark reactions occur in chloroplasts  
 - inner membrane organized into structures that photosynthesis reactions are located

↳ *light* reactions occur in the *thylakoid*

↳ *dark* reactions occur in the *stroma*

### Pigments

pigments absorb certain light wavelengths and reflect others

↳ *blue/violet*: shortest & more energy

↳ *red*: longest & less energy

- chlorophyll appears green due to reflecting green and absorbing red/blue

- chlorophyll has at least 5 forms that vary:

*Chlorophyll type~*

*Found in~*

1. Chl. A	all plants & algae
2. Chl B	all plants & green algae
3. Chl. C	brown algae
4. Chl. D	red algae
5. bacteriochlorophyll	some bacteria

- accessory pigments trap light wavelengths different from chlorophyll (increase the amount of light used)

*carotenoids~*

*phycobillin~*

↳ carotene & xanthophylls

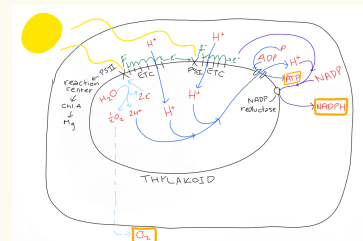
↳ in red algae & blue-green bacteria

↳ yellow, brown, orange colors

↳ absorb violet, blue, and green light

↳ allow red algae to live deeper than other types

### Light Dependent Reaction



- scaffolds to reaction center → chlorophyll molecules → excited element e- (higher energy level) → e- out of photosystem II

-  $\text{H}_2\text{O}$  breakdown only PS II

-  $2\text{e}^-$  replaces lost e- in PS II

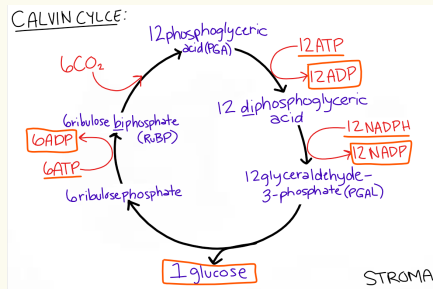
- e- lost by PS I is replaced by e- from PS II

- ETC taking steps to keep releasing energy for  $\text{H}^+$  to pass through

- **products:**  $\text{O}_2$ ,  $\text{NADPH}$ , &  $\text{ATP}$



### Light Independent Reaction



- RuBP carboxylase.\*

- ↳ a.k.a. rubisco
- ↳ enzyme changes inorganic to organic
- ↳ 6 diphosphate (6C) -- split in half -- 12 phosphate (3C)

- ATP equivalents:

- ↳ 18 ATP (total) = 18 (1 each)
- ↳ 12 NADPH = 36 (3 each)
- ↳ TOTAL = 54 ATP used

- ADP & NADPH used from light dependent reaction

- **products:** ADP, NADP, & glucose

### Cellular Respiration Background

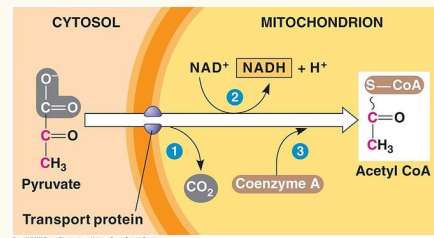
equation:  $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$  (+energy)

- three stages (w/ O<sub>2</sub>):
1. glycolysis
  - (pyruvate processing)
  2. krebs cycle
  3. electron transport chain

- two stages (w/o O<sub>2</sub>):
1. glycolysis
  2. fermentation

### Glycolysis

### Pyruvate Processing



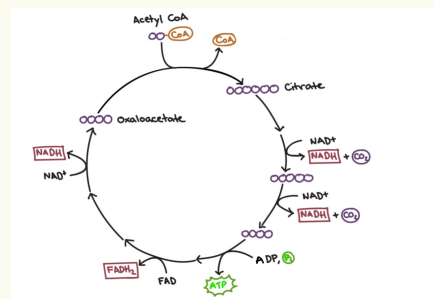
\* occurs twice (once per pyruvate)

- **location:** mitochondria

- **reactants:** pyruvic acid, NAD<sup>+</sup>, & coenzyme A

- **products:** CO<sub>2</sub>, NADH, & acetyl CoA

### Krebs Cycle



\* occurs twice

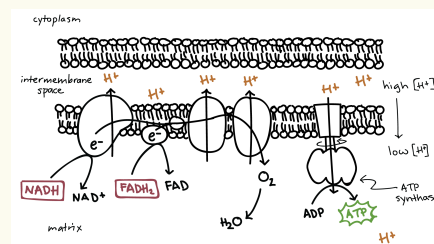
\* a.k.a. citric acid cycle

- **location:** mitochondria

\*\* - **reactants:** pyruvic acid, FAD, NAD<sup>+</sup>, & ADP

- **products:** CO<sub>2</sub>, NADH, FADH<sub>2</sub>, & ATP

### Electron Transport Chain



\* occurs constantly

\* a.k.a. oxidative phosphorylation

- e<sup>-</sup> from NADH & FADH<sub>2</sub> passed along chain = release energy every step

- H<sup>+</sup> moves through channel (energy released)

↳ ADP + P → ATP

- e<sup>-</sup> combine with O = O<sub>2</sub>

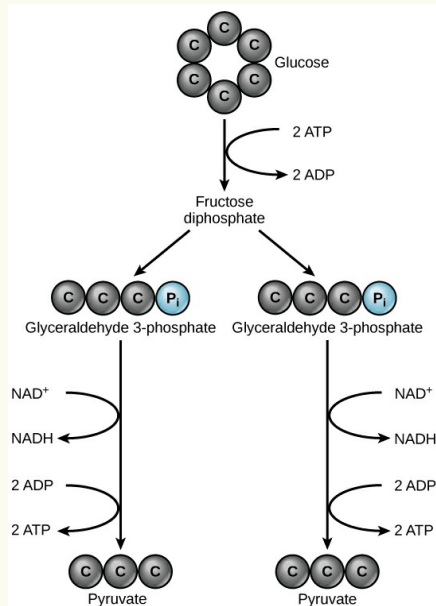
↳ O<sub>2</sub> + 2H<sup>+</sup> → 2H<sub>2</sub>O

- makes 32 ATP from 1 glucose

- **location:** inner membrane of mitochondria

- **reactants:** NADH, FADH<sub>2</sub>, O<sub>2</sub>, & ADP

- **products:** ATP, H<sub>2</sub>O, NAD, & FAD



\* occurs once

\* all cells do this

\* does NOT require O<sub>2</sub>

- **location:** cytoplasm

- **reactants:** glucose, 2 ATP, 2 NAD<sup>+</sup>, & 4 ADP

- **products:** 2 pyruvic acids, 2 NADH, & 4 ATP (*net gain 2*)



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Last updated 11th April, 2022.

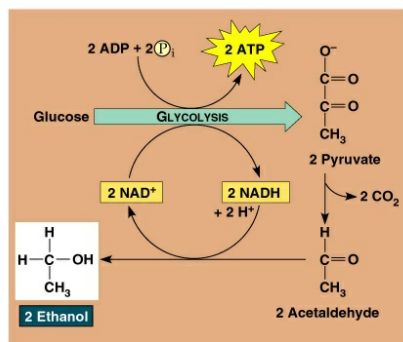
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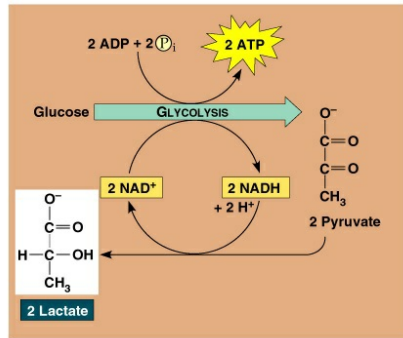
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### Fermentation



(a) Alcohol fermentation



(b) Lactic acid fermentation

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\* NO O<sub>2</sub>

\* a.k.a. anaerobic cellular respiration

\* no ATP production

\* recycles NAD for glycolysis

- location: cytoplasm

**Alcoholic Fermentation**

- reaction: pyruvic acid + NADH → ethanol + CO<sub>2</sub> + NAD

**Lactic Acid Fermentation**

- reaction: pyruvic acid + NADH → lactic acid + NAD



By kmz\_2022

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