

Enzymes

proteins (and RNA)

organic catalysts that lower the required activation energy to get reactants to products

facilitate chemical reactions:

~ increase rate of reaction without being consumed

~ reduce activation energy

~ do not change free energy released or required

substrate:

~ reactant which binds to enzyme

~ enzyme-substrate complex: temporary association

product:

~ end result of reaction

active site:

~ enzyme's catalytic site: substrate fits into active site

pH

changes in pH:

~ adds or removes H⁺

~ disrupts bond, disrupts 3D shape

~ disrupts attractions between charged amino acids

~ affects 2' and 3' structure

~ denatures protein

Activators

cofactors:

small, inorganic compounds and ions

binds with enzyme

Mg, K, Ca, Zn, Fe

coenzymes:

organic compounds

bind to enzymes near active site

vitamins (NAD, FAD, Coenzyme A)

Allosteric Regulation

conformational changes by regulatory molecules

inhibitors: keeps enzyme in inactive form

activators: keeps enzyme in active form

Metabolic Pathways

catabolic pathways: metabolic pathways:

release energy

consume energy

cellular respiration

photosynthesis

Transformation of Energy

sunlight → chemical bonds during photosynthesis

Exergonic vs. Endergonic Reactions

	exergonic:	endergonic:
positive / negative G free energy:	negative	positive
released / absorbed	released	absorbed
cellular respiration / photosynthesis	cellular respiration	photosynthesis
uphill / downhill	downhill	uphill
spontaneous	spontaneous	not spontaneous

Endotherms

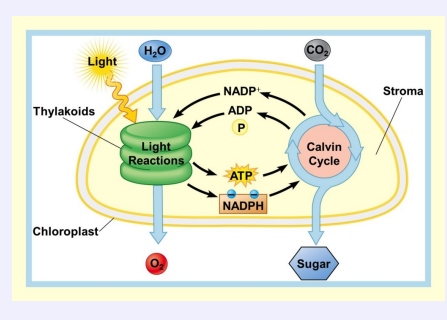
regulate internal body temperatures through metabolism

balancing heat loss and gain

five adaptations help animals thermoregulate:

- 1) insulation
- 2) circulating adaptations
- 3) cooling by evaporative heat loss
- 4) behavioral responses
- 5) adjusting metabolic heat production

Overview of Photosynthesis



Glycolysis

location: cytoplasm

reactants: ~ glucose

~ 2 ADP + 2 Pi

~ 2 NAD⁺

products: ~ 2 pyruvate

~ 2 ATP

~ 2 NADH

~ 2 H₂O

transfer of energy: NADH (electrons and Hydrogen) → C₆H₁₂O₆ → ATP

purpose: ~ convert glucose to pyruvate

~ initial breakdown of sugar

~ generating ATP

~ shuttling e⁻ and H⁺ to ETC

Steps of Light Reactions

1) H₂O splits

~ H⁺: pump into thylakoid out of ATP synthase

~ e⁻: 2 ETCs

~ O₂: released out of stomata

2) light excites e⁻ in Photosystem II

3) e⁻ to primary electron acceptor (PEA)



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Steps of Light Reactions (cont)

4) the e⁻ travels down the ETC and replaces the e⁻ from Photosystem I

5) the e⁻ travels down another ETC and combines with NADP⁺

meanwhile...

~ energy from 1st ETC is used to pump H⁺ into the thylakoid space

~ a proton gradient forms and H⁺ leave through ATP synthase

~ H⁺ combines with e⁻ and NADP⁺ to form NADPH

~ ATP synthase generates ATP

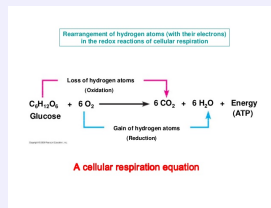
REDOX Reactions

molecular exchange of an electron

oxidation: lose electrons

reduction: gain electrons

REDOX reactions image



Photosynthesis

transformation of solar light energy trapped by chloroplasts into chemical bond energy stored in sugar and other organic molecules

1) synthesizes energy rich molecules

2) uses CO₂ as carbon source

3) directly or indirectly supplies energy

CO₂ + H₂O + sunlight -> C₆H₁₂O₆ + O₂

Properties of Enzymes

reaction specific:

~ each enzyme works with a specific substrate chemical fit between active site and substrate

~ H bonds and ionic bonds

not consumed in reaction:

~ single enzyme molecule can catalyze thousands or more reactions per second

~ enzymes are unaffected by the reaction

affected by cellular conditions

~ ex: temperature, pH, salinity, etc.

Substrate Concentration

as substrates increase, reaction rate increases and levels off

more substrate = more frequently collide with enzyme

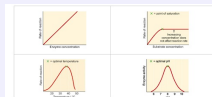
the reaction levels off because...

~ all enzymes have active site engaged

~ enzyme is saturated

~ maximum rate of reaction

Factors that Affect Enzyme Structure



Competitive Inhibitors

inhibitor competes with active site

substrate cannot bond

can overcome with substrate saturation

penicillin (competes with bacterial enzyme that builds cell wall)

directly blocks active site

Energy

the ability to do work

kinetic

potential energy:

energy:

energy of motion

energy of position

heat

water behind a dam

light energy

chemical energy stored in cells

Free Energy and Equilibrium

free energy: energy available to do work

free energy decreases when reactions proceed toward equilibrium

Biosynthesis

building complex molecules out of simple molecules

amino acids -> proteins

glucose -> glycogen

Ectotherms

do not regulate internal body temperature

rely on environmental heat sources

less respiration/food

Cellular Respiration

catabolic

C₆H₁₂O₆ + O₂ -> CO₂ + H₂O + energy

steps:

1) glycolysis

2) intermediate step

3) citric acid cycle

4) oxidative phosphorylation



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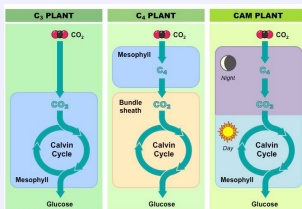
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Intermediate Step

location:	mitochondrial matrix
reactants:	2 pyruvate
products:	~ acetyl CoA ~ 2 NADH ~ 2 CO ₂
transfer of energy:	pyruvate (sugar) -> NADH (e- and H+)
purpose:	convert pyruvate into more reactive Acetyl CoA

C3 vs. C4 vs. CAM plants



Oxidative Phosphorylation

location:	~ inner membrane of mitochondria (ETC) ~ inner membrane space (chemiosmosis)
reactants:	~ NADH ~ FADH ₂ ~ ADP+P ~ O ₂
products:	~ NAD+H ~ FAD+H ~ ATP ~ H ₂ O
transfer of energy:	NADH/FADH ₂ -> proton gradient -> ATP synthase -> ATP
purpose:	use REDOX reactions to make a large amount of ATP (34)

producers

autotrophic nutritional: nutritional made of synthesizing organic molecules from inorganic raw materials
photoautotrophs: uses light energy
chemoautotrophs: oxidation of inorganics for energy

Chloroplast

site of photosynthesis
double membrane system
thylakoids: flattened photocenters
granum: stacks of thylakoids
stroma: fluid outside thylakoid

Calvin Cycle

location: stomata
production of sugar
recognition of RUBP
reactants: CO ₂ , NADPH, ATP
products: C ₆ H ₁₂ O ₆ , NADP+, ADP+Pi, G3P

Pathways of Photosynthesis

noncyclic photophosphorylation produces ATP and NADPH
cyclic photophosphorylation is ATP production
calvin cycle consumes more ATP than NADPH

Induced Fit

"lock and key"
3-D structure of enzyme fits substrate
substrate binding cause enzyme to change shape leading to a tighter fit
"conformational change": slight change in shape
bring chemical groups in position to catalyze reactions

Enzyme Concentration

as enzymes increase, reaction rate increases
more enzymes = more frequently collide with substrates

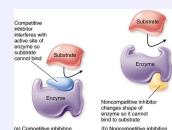
Temperature

optimum temperature:	~ as temp increases, reaction rate increases	~ greater number of molecular collisions
cold temperature:	~ molecules move slower	~ decrease collisions between enzymes and substrates
heat (beyond optimum)	~ increased energy level disrupts weak bond in 2' and 3' structure	~ denaturation: loses 3D shape

Noncompetitive Inhibitors

inhibitor binds to allosteric site (not active site) which changes the shape of the active site
ex: anti-cancer drugs, cyanide, poisoning, DDT

Competitive vs. Noncompetitive Inhibitors



Thermodynamics

study of energy transformation
first law: energy of the universe is constant
second law: every process increases the entropy of the universe
entropy: "quantity of energy in universe is constant, but quality is not"



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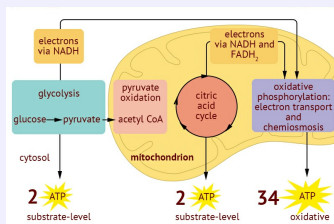
ATP Powers Cellular Work

- coupling endergonic/exergonic reactions
- energy coupling: phosphorylated intermediates; regeneration of ADP to ATP
- 3 main types of work
 - 1) mechanical work (motor protein)
 - 2) transport work (Na/K pump)
 - 3) chemical work

Size and Metabolic rate

- larger mammals have more body mass and require more chemical energy (higher BMR)
- smaller animals require more kcal/gram, have greater rate of O₂ delivery, higher breathing rate
- increase activity → increase metabolic rate → more ATP

Overview of Cellular Respiration



Citric Acid Cycle

- location: mitochondrial matrix
- reactants:
 - ~ acetyl CoA
 - ~ citric acid
 - ~ ADP + Pi
 - ~ NAD⁺ and FAD
- products:
 - ~ oxaloacetate
 - ~ ATP
 - ~ NADH and FADH₂
 - ~ CO₂
- transfer of energy: NADH and FADH₂ (e⁻ and H⁺)
- energy: <- citric acid → ATP

Citric Acid Cycle (cont)

- purpose:
 - ~ complete the oxidation of glucose
 - ~ producing NADH/FADH₂ (e⁻ and H⁺)
 - ~ ATP

Phosphorylation

- substrate-level: ATP is synthesized by enzymes
- oxidative: ATP is synthesized by an ETC and chemiosmosis

Fermentation

- anaerobic process (no O₂)
- produces small amounts of ATP
- regenerates NAD⁺/NADH
- alcoholic fermentation
 - ~ yeast/bacteria
 - ~ produces CO₂ and alcohol
- lactic acid
 - ~ human muscles
 - ~ yogurt
 - ~ produces lactic acid

Consumers

- heterotrophs: acquire organics to create energy from other creatures
- ~ consumers
- ~ decomposers

Light Reactions

- occurs in the thylakoid
- splitting of water
- generation of ATP and NADPH
- reactants: H₂O, NADP⁺, ADP+Pi
- products: O₂, NADPH, ATP

Steps of Calvin Cycle

- 1) carbon fixation
 - ~ ribulose biphosphate: RuBP
 - ~ rubisco: RuBP carboxylase: most abundant protein
- 2) reduction
 - ~ adding H⁺ and e⁻ from NADPH to CO₂ to make sugar
- 3) regeneration
 - ~ G3P → RuBP

Alternative Pathways of Carbon Fixation

- photorespiration: fixing oxygen rather than CO₂
- C3 plants:
 - ~ hot/dry days
 - ~ stomata close (prevents H₂O, inc CO₂, dec O₂)
- C4 plants:
 - ~ spatial separation of calvin cycle into bundle sheath cell
 - ~ PEP carboxylase initially captures CO₂
- CAM
 - ~ temporal separation
- pathways:
 - ~ takes in CO₂ at night



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