AP Biology Insta-Review

Big Idea 2: Energetics

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AP Biology students are penguins because they are Dressed for Success!
You are now an AP Bio Penguin!

Today's Plan:

Unit 1: Chemistry of Life

Topic 1.2: Elements of Life

Unit 2: Cell Structure & Function

Topic 2.3: Cell Size

Topic 2.4: Plasma Membrane

Topic 2.5: Membrane Permeability

Topic 2.6: Membrane Transport

Topic 2.7: Facilitated Diffusion

Topic 2.8: Tonicity & Osmoregulation

Topic 2.9: Mechanisms of Transport

Topic 2.10: Cell Compartmentalization

Today's Plan:

Unit 3: Cellular Energetics

Topic 3.1: Enzyme Structure

Topic 3.2: Enzyme Catalysis

Topic 3.3: Environmental Effects on Enzyme Function

Topic 3.4: Cellular Energy

Topic 3.5: Photosynthesis

Topic 3.6: Cellular Respiration

Unit 4: Cell Comm & Cell Cycle

Topic 4.5: Feedback

Unit 8: Ecology

Topic 8.1: Responses to the Environment

Topic 8.2: Energy Flow through an Ecosystem

Topic 8.5: Community Ecology

Carbohydrates

- Composed of CHO
- Used for energy storage (glycogen in liver or starch in plants)
- Used for structural support(chitin in exoskeletons or cellulose in plant cell walls)
- Monomer: monosaccharides

Proteins

- Composed of CHON(S)
- Used for enzymatic, defensive, storage, transport, hormonal, receptor, contractile/motor, or structural proteins
- Monomer: amino acids (amine group, carboxyl group, hydrogen, and central carbon)

1.2: Elements of Life

Nucleic Acids

- Composed of CHONP
- Used for genetic information storage
- Monomer: nucleotide (sugar, nitrogenous base, and phosphate)
- DNA/RNA

Lipids

- Composed of CHO
- Used for energy storage (fat), membrane structure (phospholipid), or signaling molecules (steroids)
- NO monomer
- Nonpolar group

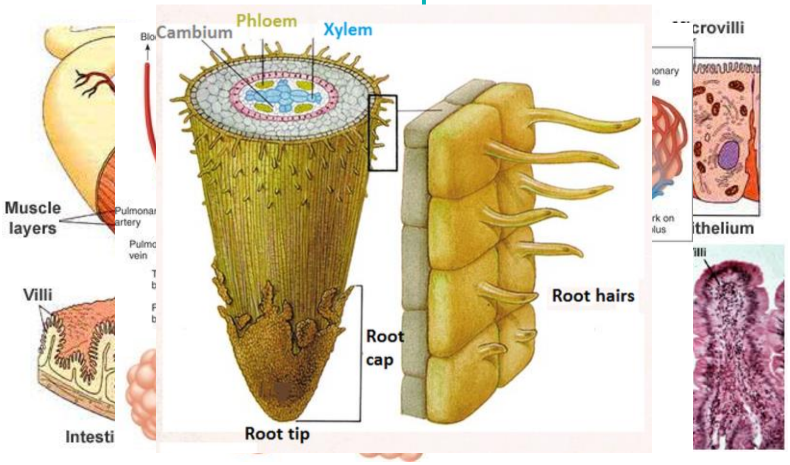
SA:V Ratios

- obtain necessary resources
- eliminate waste products
- acquire or dissipate thermal energy
- exchange chemicals and energy with the environment.

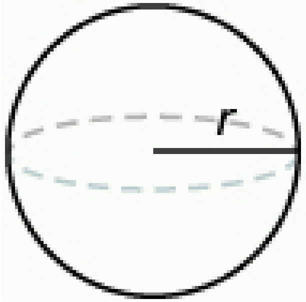
Growth Problems

- As volume ⇧, the surface area ⇩ and the demand for internal resources ⇧
- As organisms ⇧ in size, their SA:V ratio ⇩
- affects properties like rate of heat exchange with the environment.

Examples:

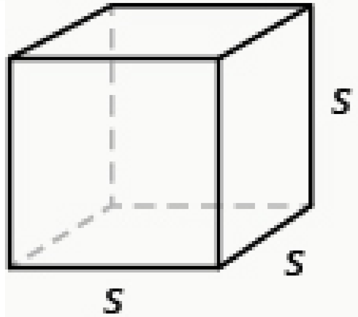


2.3: Cell Size



Volume: $V = \frac{4}{3}\pi r^3$

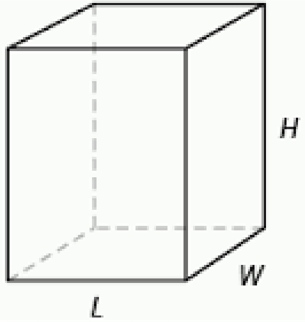
Surface Area: $S = 4\pi r^2$



Volume: $V = s^3$

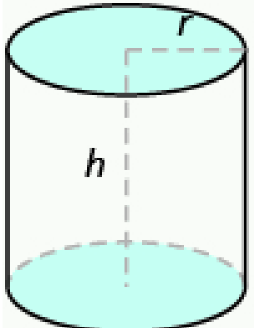
Surface Area: $S = 6s^2$

Smaller cells typically have a higher surface area-to-volume ratio and more efficient exchange of materials with the environment.



Volume: $V = LWH$

Surface Area: $S = 2LH + 2LW + 2WH$



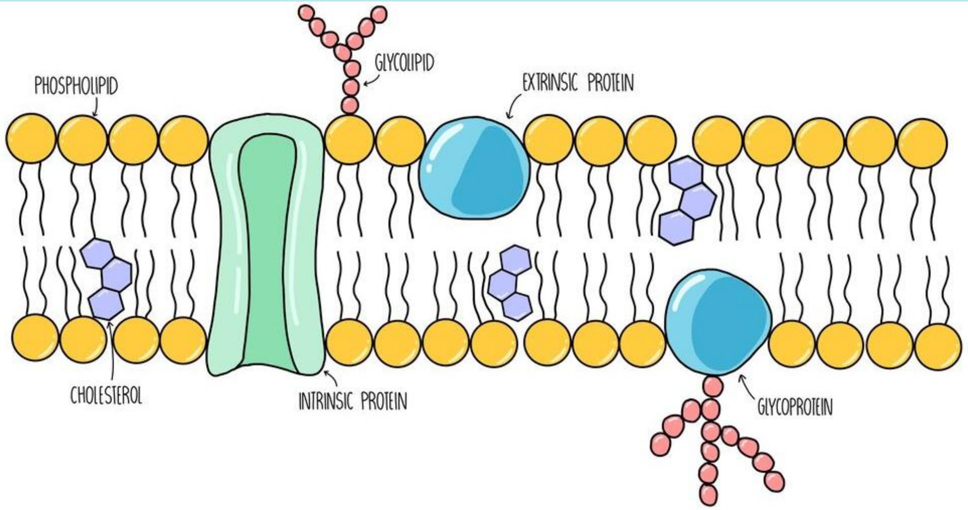
Volume: $V = \pi r^2 h$ or $V = Bh$

Surface Area: $S = 2\pi r^2 + 2\pi rh$

2.4 Plasma Membrane

Composition

- Phospholipids
- Membrane Proteins
- Glycolipids/Glycoproteins
- Cholesterol



Properties

- hydrophilic (phosphate) region: oriented toward the aqueous external or internal environments
- hydrophobic regions: fatty acid regions face each other within the interior of the membrane.

2.5 Membrane Permeability

Selective Permeability

FREELY PASS

- Small non-polar materials
  - Example: CO_2, O_2, N_2

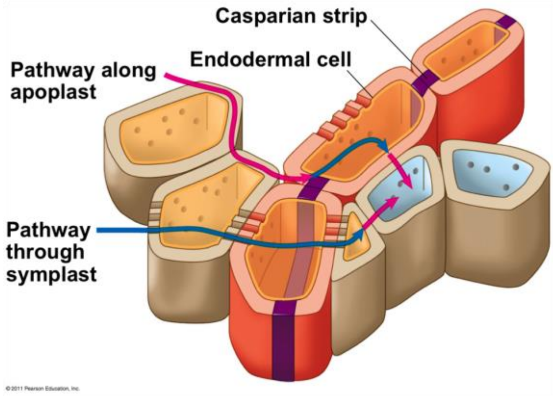
REQUIRE ASSISTANCE

- Hydrophilic substances
- Example: large polar molecules (glucose) or ions (Na^+)

DID YOU KNOW?

- Polar uncharged molecules, including H_2O, pass through the membrane in small amounts.

Cell Wall



Plants: Cellulose

Prokaryotes: Peptidoglycan

Fungi: Chitin

2.6 Membrane Transport

Passive Transport

- Movement across membrane from HIGH concentration to LOW concentration
- NO input of energy (ATP) needed

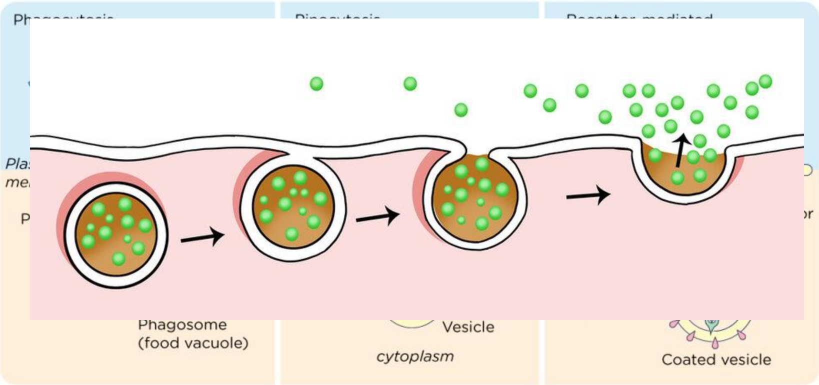
The selective permeability of membranes allows for the formation of concentration gradients of solutes across the membrane.

Active Transport

- Movement across membrane from LOW concentration to HIGH concentration
- Requires input of energy (ATP)

Endocytosis

- Import of materials
- Phagocytosis: Cellular Eating
- Pinocytosis: Cellular Drinking
- Receptor-Mediated: Endocytosis



Exocytosis

Export of materials
Rough ER (synthesize) → Golgi complex (package/modification) → Plasma Membrane

Transport Materials

- charged and large polar molecules through a membrane—
- large quantities of water pass through aquaporins.
- charged ions, including Na^+ and K^+, require channel proteins to move through the membrane.

Membrane Proteins

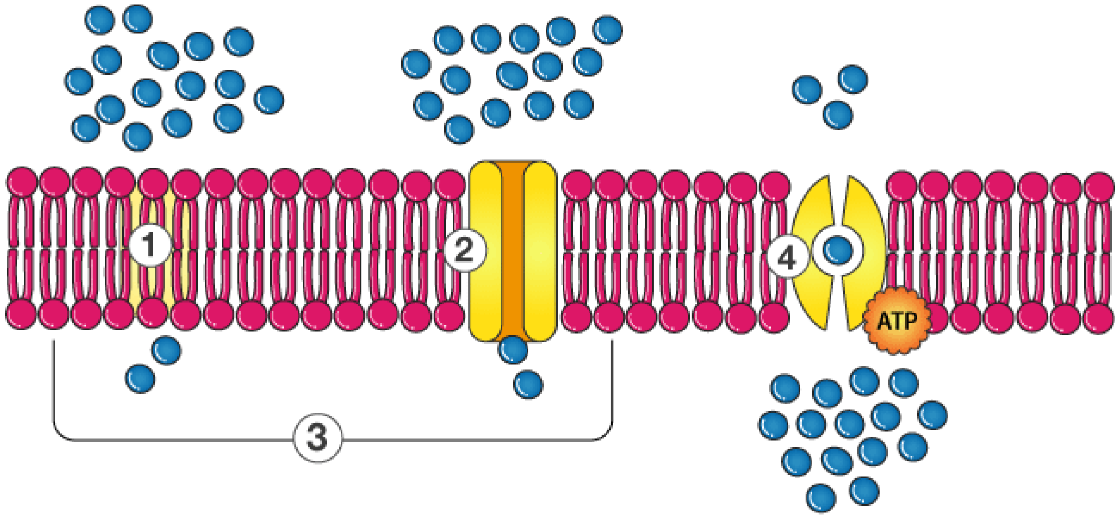
- Carrier: Binds & shape change to shuttle across membrane
- Channel: Passage for materials

Active Transport

- Establish concentration gradient
- Requires transport protein (carrier protein)
- Na^+/K^+ maintains membrane potential

2.7 Facilitated Diffusion

requires membrane proteins



1. Diffusion
2. Facilitated Diffusion
3. Passive Transport
4. Active Transport

Hypertonic Solution

- HIGH solute concentration
- LOW free water concentration
- GAINS water from hypotonic solution

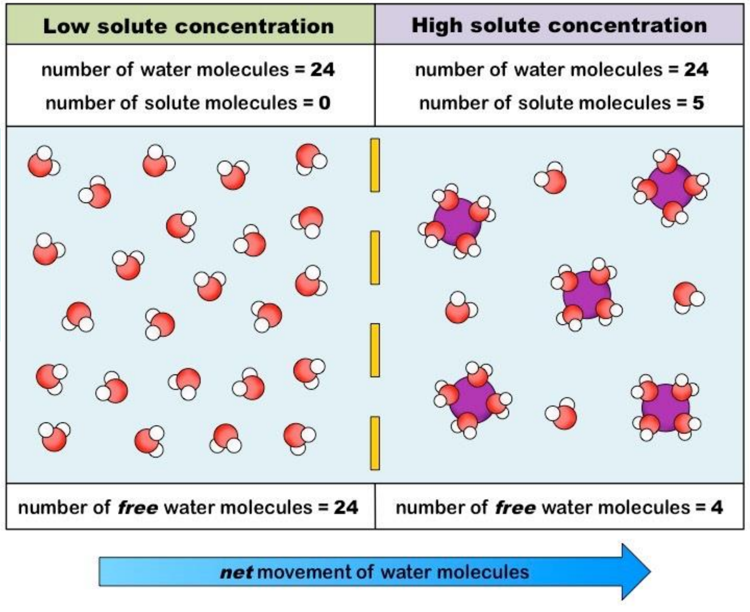
Isotonic Solution

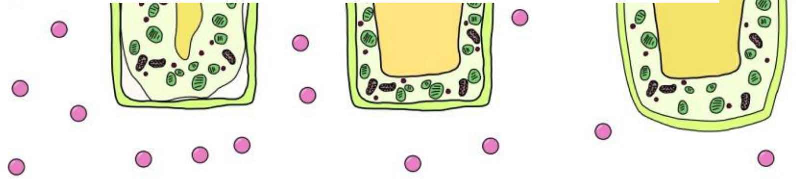
- EQUAL solute concentration (as other solution)
- EQUAL free water concentration (as other solution)
- Equal water movement into and out of solution

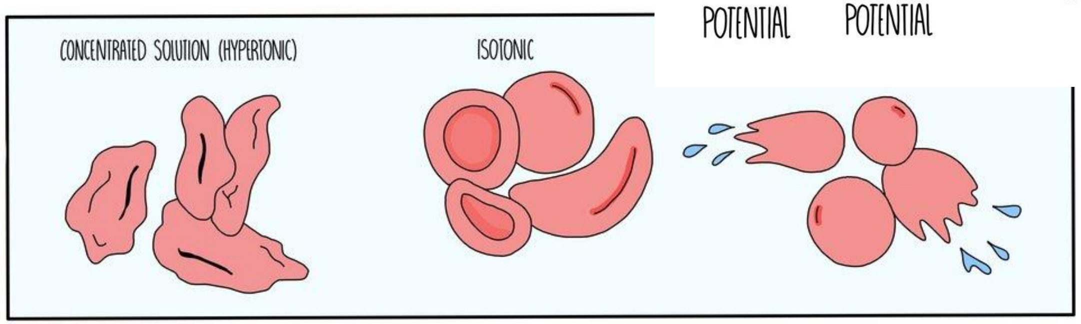
Hypotonic Solution

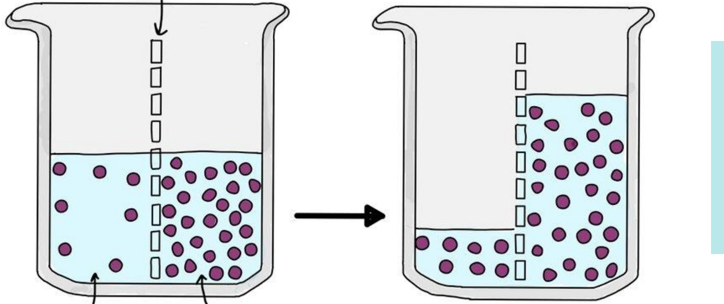
- LOW solute concentration
- HIGH free water concentration
- LOSES water to hypertonic solution

city & Osmoreg









Hypertonic Solution

- HIGH solute concentration
- LOW free water concentration
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Isotonic Solution

- EQUAL solute concentration (as other solution)
- EQUAL free water concentration (as other solution)
- Equal water movement into and out of solution

Hypotonic Solution

- LOW solute concentration
- HIGH free water concentration
- LOSES water to hypertonic solution

2.8 Tonicity & Osmoregulation

Water Potential:

$\Psi = \Psi_p + \Psi_s$

$\Psi_p =$ pressure potential

$\Psi_s =$ solute potential

Practice Problem

cell in 0.5M NaCl solution at 25°C

$$\varphi_s = -(2)(0.5M)\left(0.0831\,\frac{L\cdot bars}{mol\cdot K}\right)(25+273K)$$

$$\varphi_s = 24.8\ bars$$

$\Psi_s = -iCRT$

where:

$i =$ ionization constant

$C =$ molar concentration

$R =$ pressure constant

$\left(R = 0.0831\,\frac{L \bullet bars}{mol \bullet K}\right)$

$T =$ temperature in Kelvin (°C + 273)

HIGH water potential
LOW osmolarity
LOW solute concentration
HYPOtonic

water movement →

LOW water potential
HIGH osmolarity
HIGH solute concentration
HYPERtonic

2.9 Mechanisms of Transport

Simple Diffusion

- Passive Transport, No NRG
- Down concentration gradient
- Small, Nonpolar
- No transport protein needed
- Examples: CO_2, O_2, N_2, steroids
- Small amount of H_2O leak through membrane

Facilitated Diffusion

- Passive Transport, No NRG
- Down concentration gradient
- Small Molecules
- Requires transport protein Channel vs. Carrier protein
- Example: water, Na^+, K^+, Ca^+

Active Transport

- Requires input of NRG
- Against concentration gradient
- Requires transport protein (carrier protein)
- Example: Na^+, K^+, Ca^+, H^+

Bulk Transport

Endocytosis

- Import of materials
- Phagocytosis: Cellular Eating
- Pinocytosis: Cellular Drinking
- Receptor-Mediated: Endocytosis

Exocytosis

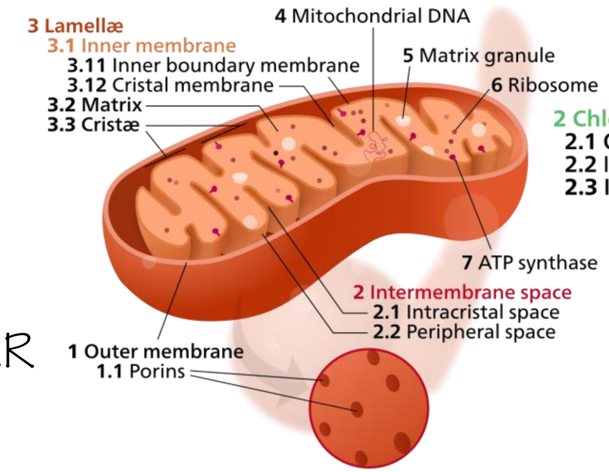
- Export of materials
- Rough ER (synthesize) → Golgi complex (package/modification) → Plasma Membrane

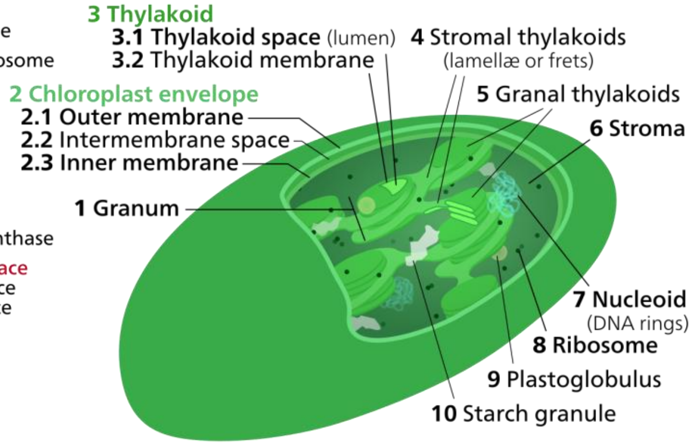
2.10 Compartmentalization

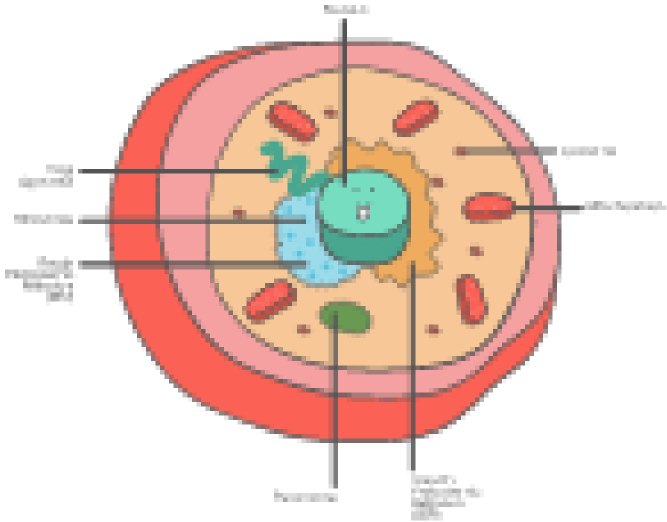
Membrane-Bound Structures

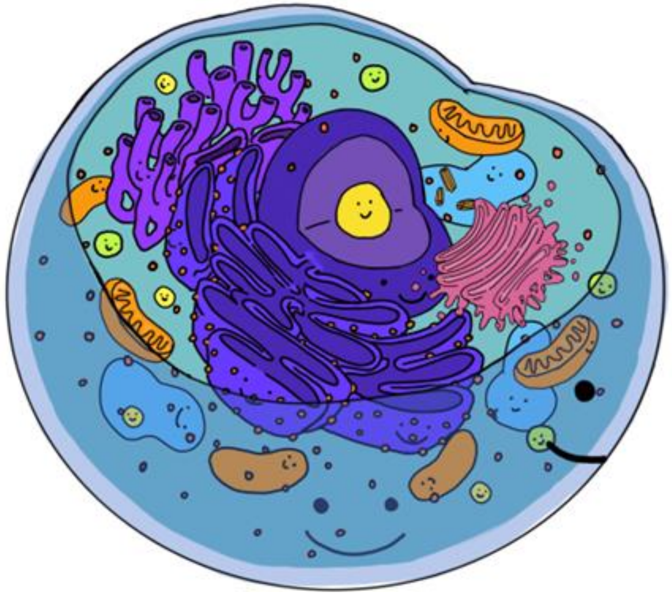
Membranes and membrane-bound organelles in eukaryotic cells compartmentalize intracellular metabolic processes and specific enzymatic reactions.

- Rough ER: Protein synthesis for membrane & secretion
- Golgi: Package & modify protein products from Rough ER
- Lysosome: Cellular digestion with hydrolytic enzymes
- Mitochondria: site of cellular respiration (Krebs cycle & oxidative phosphorylation)







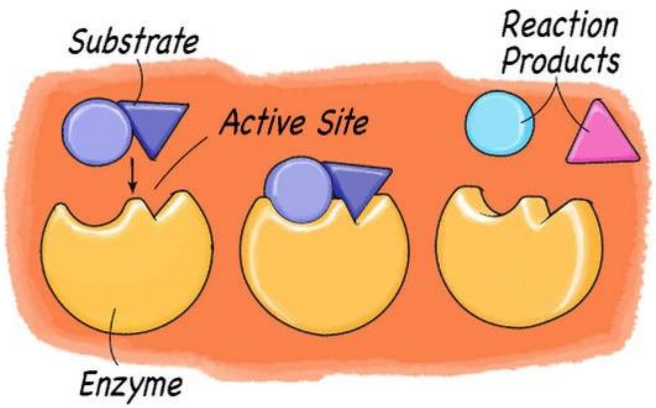


Internal Membrane

Internal membranes facilitate cellular processes by minimizing competing interactions and by increasing surface areas where reactions can occur.

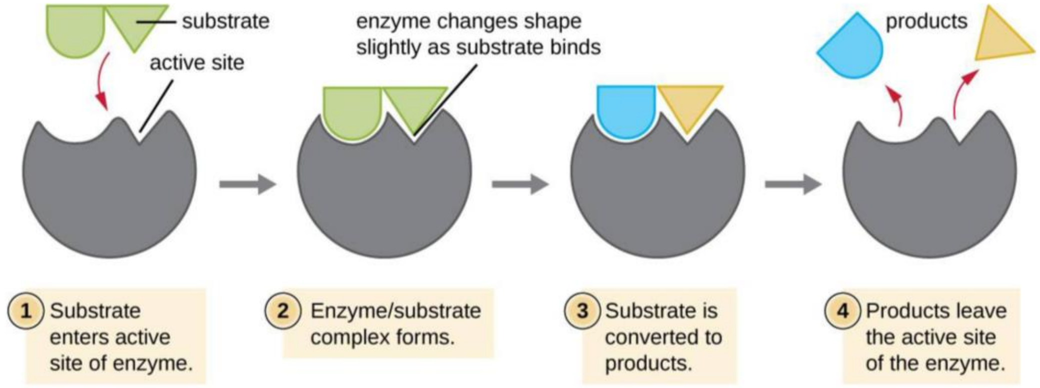
- Mitochondria: cristae increases SA for oxidative phosphorylation
- Chloroplast: thylakoid increases SA for light reactions

3.1 Enzyme Structure



Structure

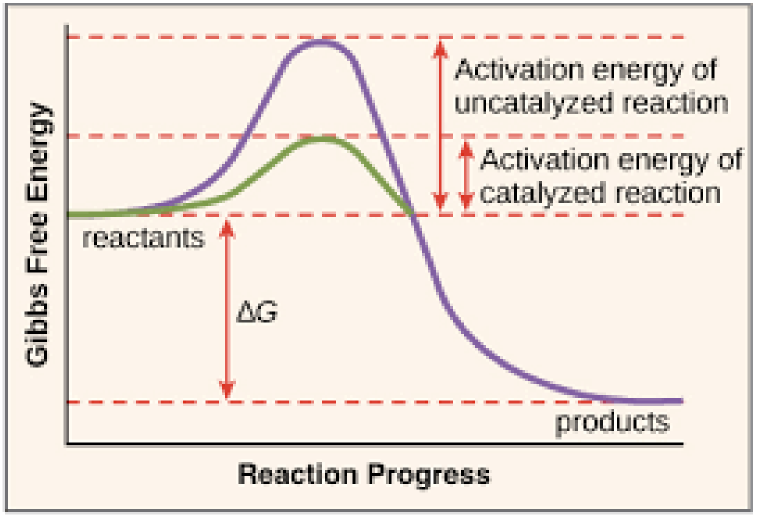
- Active Site: location for substrate to bind
- Allosteric Site: another binding location on the enzyme



3.2 Enzyme Catalysis

Important Notes:

- Enzymes are PROTEINS
- Are NOT consumed by the reaction
- Have no effect on the change in Gibbs Free Energy



Function

- Biological catalyst
- Speeds up chemical reactions
- Reduces the activation energy

Shape Changes

Change in structure could lead to change in function

Changes shape of active site due to bonds breaking/reforming

Denaturation

Denaturation of an enzyme occurs when the protein structure is disrupted, eliminating the ability to catalyze reactions

Cause of Denaturation

Environmental Temperatures (increase in kinetic energy)

pH changes outside of optimal range (changes bonding with R groups)

Salinity

3.3 Env. Impacts on Enzyme Function

RELEVANT EQUATION

$$pH = -\log[H^+]$$

- As concentration of hydrogen ions ⇧, the pH ⇩
- As concentration of hydrogen ions ⇩, the pH ⇧

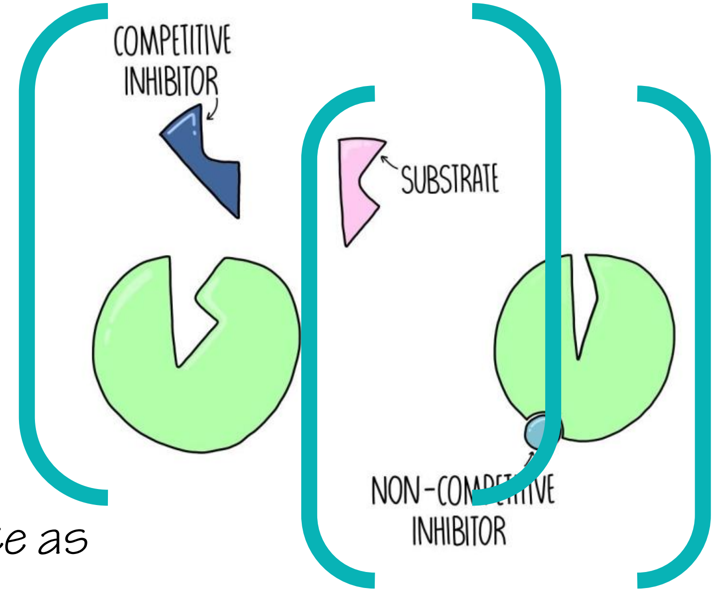
Inhibitors

Competitive:

- Binds to active site

Noncompetitive:

- Binds to allosteric site



What will happen?

Increased Temperature:

- Increase reaction rate as increased molecular collisions

Decreased Substrate:

- Decrease reaction rate as less reactant available

Increased Enzyme:

- Increase reaction rate as each enzyme decreases activation energy

First Law of Thermodynamics

Energy cannot be created or destroyed, it is transferred or transformed

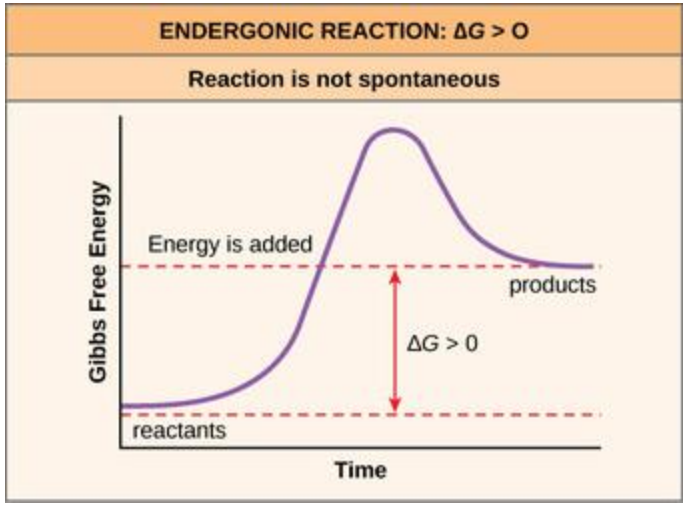
Second Law of Thermodynamics

Energy reaction increases the entropy (disorder) of the universe

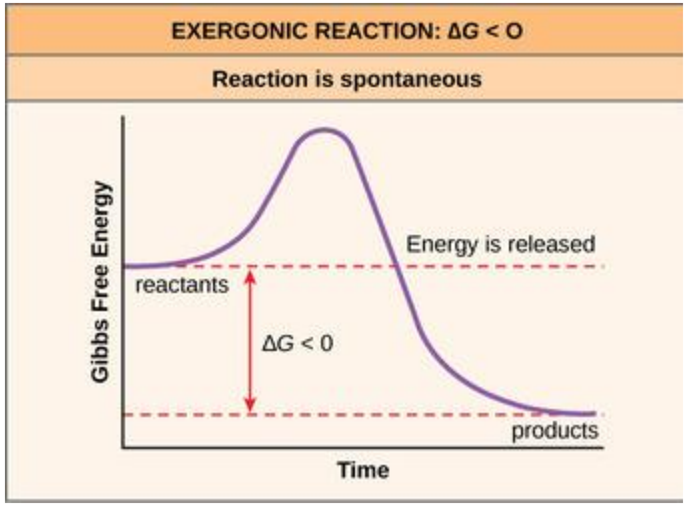
- energy input > energy loss (maintain order & power cell processes)
- energy coupling
- Loss of order or energy flow

3.4 Cellular Energy

Endergonic Reaction



- Not spontaneous
- ABSORB energy
- Example: ADP + P_i → ATP



- Spontaneous
- RELEASE energy
- Example: ATP → ADP + P_i

Exergonic Reaction

3.5 Photosynthesis

Light Reactions

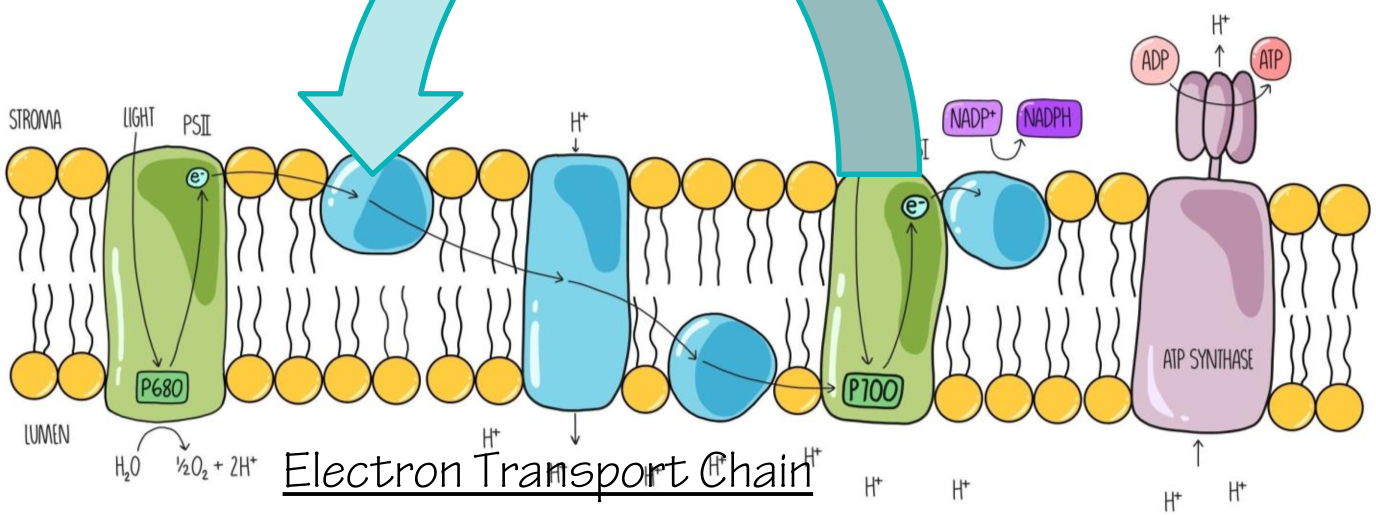
- Location: Thylakoid Membrane
- Starting Material:
  - Water (electrons)
  - Photons (energy)
- Products:
  - ATP
  - NADPH

Linear Electron Flow

- PS I & PS II
- Synthesizes ATP & NADPH

Cyclic Electron Flow

- PS I ONLY
- Synthesizes ATP ONLY

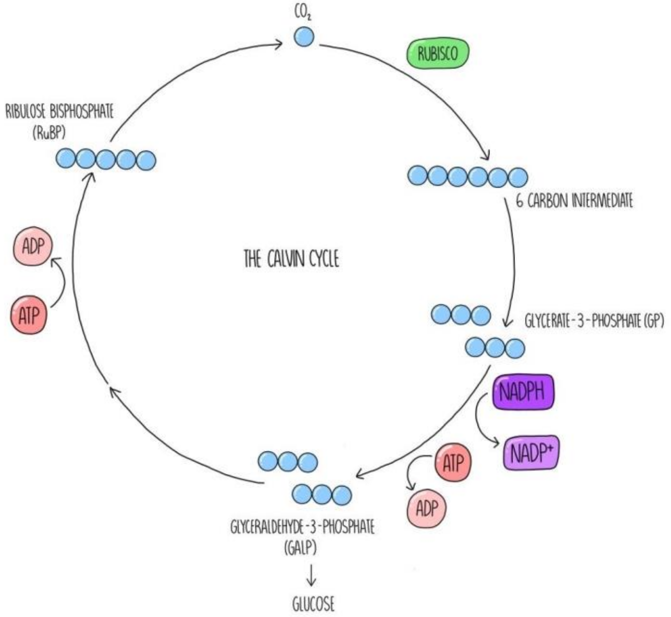


<u>Electron Transport Chain</u>

- Protons are pumped into the thylakoid space

Calvin Cycle

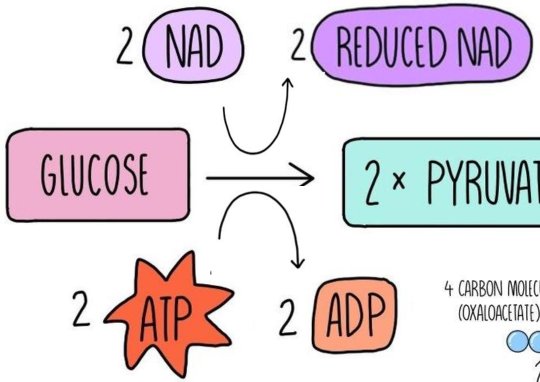
- Location: Stroma
- Starting Material:
  - 3 CO_2
  - 9 ATP
  - 6 NADPH
- Products:
  - G3P

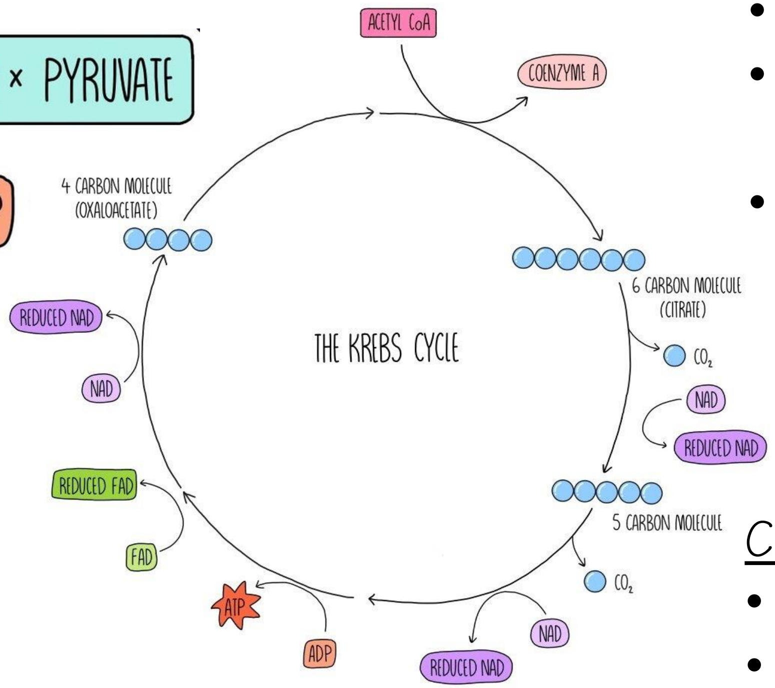


3.6 Cellular Respiration

Glycolysis

- Location: Cytosol
- Starting Material:
  Glucose
- Products:
  2 Pyruvate
  2 NADH
  2 ATP





Krebs Cycle

- Location: Mitochondrial Matrix
- Staring Material:
  Acetyl CoA
- Products:
  2 CO_2
  3 NADH
  1 $FADH_2$
  1 ATP

Oxidative Phosphorylation

- Location: Mitochondrial Cristae
- Starting Material:
  NADH/$FADH_2$ (electrons)
- Product:
  ATPs
- Two Parts:

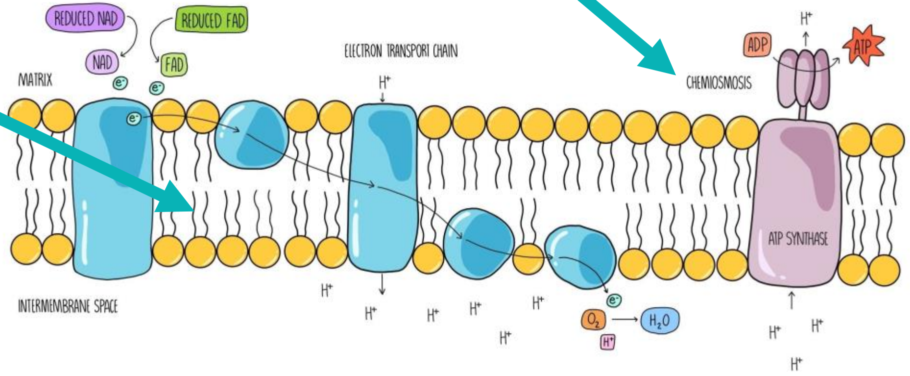
Electron Transport Chain & Chemiosmosis

<u>Electron Transport Chain</u>

- Protons pumped into IM space
- Generates proton gradient
- Final electron acceptor: OXYGEN

<u>Chemiosmosis</u>

- ATP Synthase uses proton gradient
- Synthesizes ATP



Cellular respiration includes the metabolic pathways of glycolysis, the Krebs cycle, and the electron transport chain, as represented in the figures. In cellular respiration, carbohydrates and other metabolites are oxidized, and the resulting energy-transfer reactions support the synthesis of ATP.

(a) Using the information above, describe ONE contribution of each of the following in ATP synthesis.

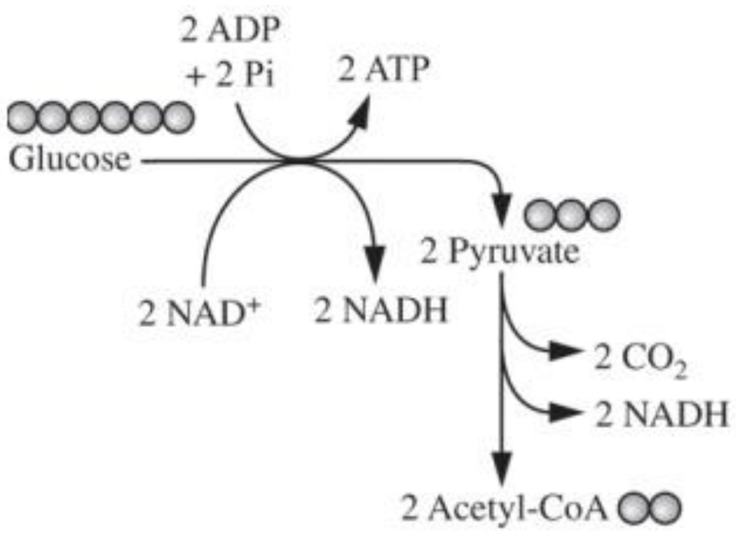


Figure 1. Glycolysis and pyruvate oxidation

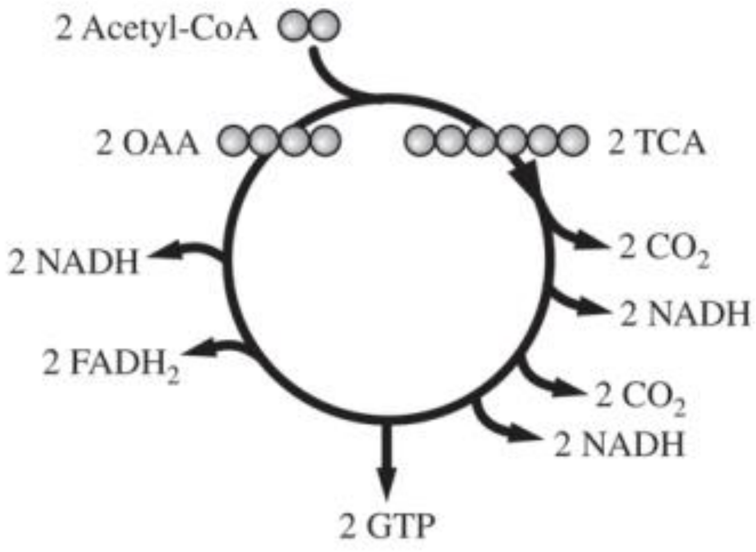


Figure 2. Krebs cycle

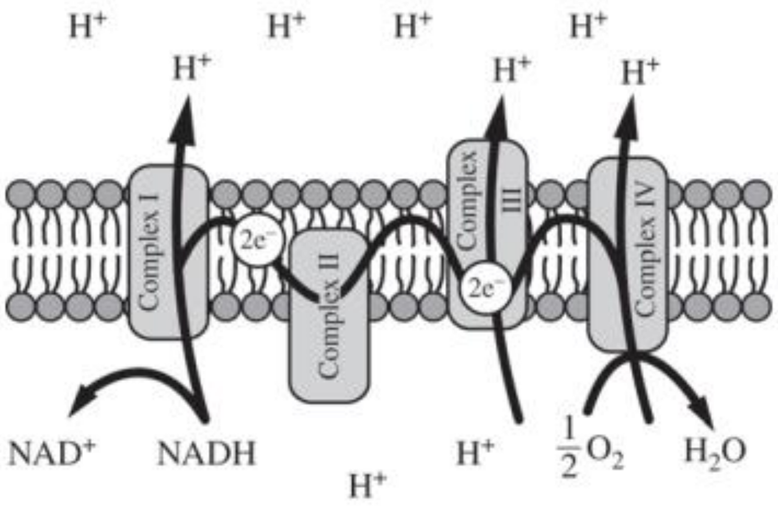


Figure 3. Electron transport chain

Catabolism of glucose in glycolysis and pyruvate oxidation

- Produces NADH for use in ETC
- Produces acetyl-CoA for entry into Krebs cycle
- Provides energy for (substrate level) phosphorylation of ADP

Oxidation of intermediates in the Krebs cycle

- Produces NADH or FADH2 for use in ETC
- Releases high energy electrons for use in ETC
- Provides energy to pump protons against their concentration gradient
- Produces GTP for (substrate level) phosphorylation of ADP

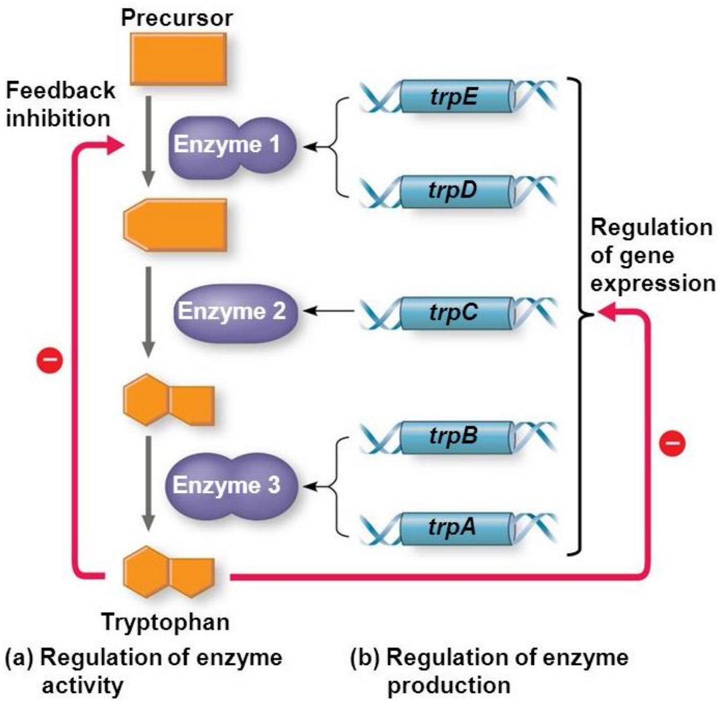
Formation of a proton gradient by the electron transport chain

- The flow of protons through membrane-bound ATP synthase generates ATP
- Provides energy for (oxidative) phosphorylation of ADP

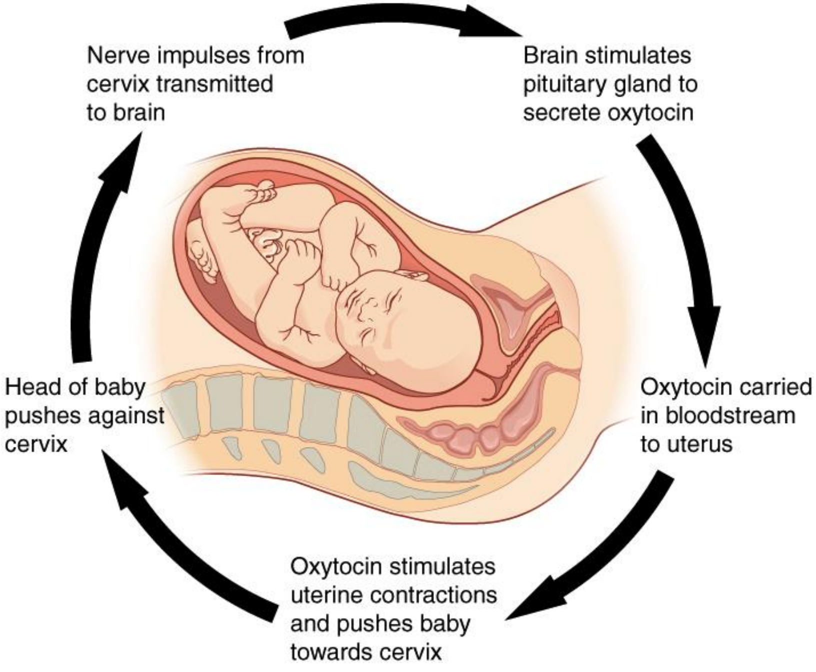
4.5 Feedback

Negative Feedback

- maintain homeostasis
- regulates processes
- return the system back to its target set point
- molecular and cellular levels



Organisms use feedback mechanisms to maintain their internal environments and respond to internal and external environmental changes.

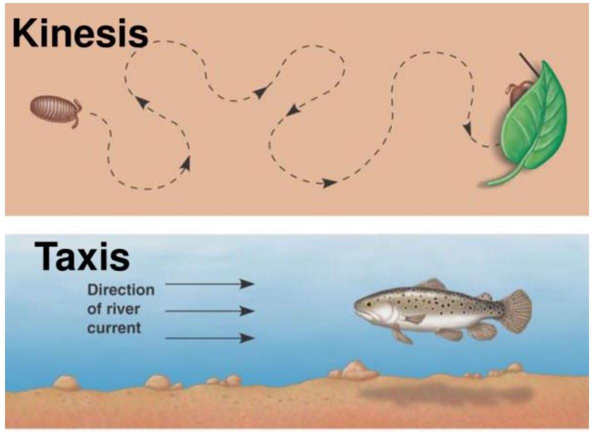


- amplify responses/processes
- variable initiating the response is moved farther away from the initial set point
- amplification occurs when the stimulus is further activated, which initiates additional response to produce system change.

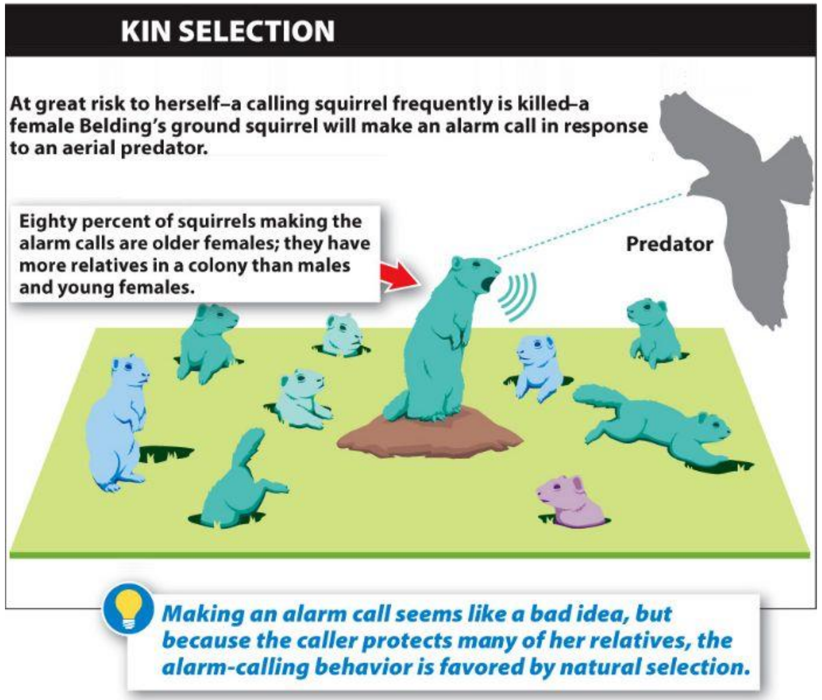
Positive Feedback

8.1 Responses to the Environment

Taxis and kinesis in animals

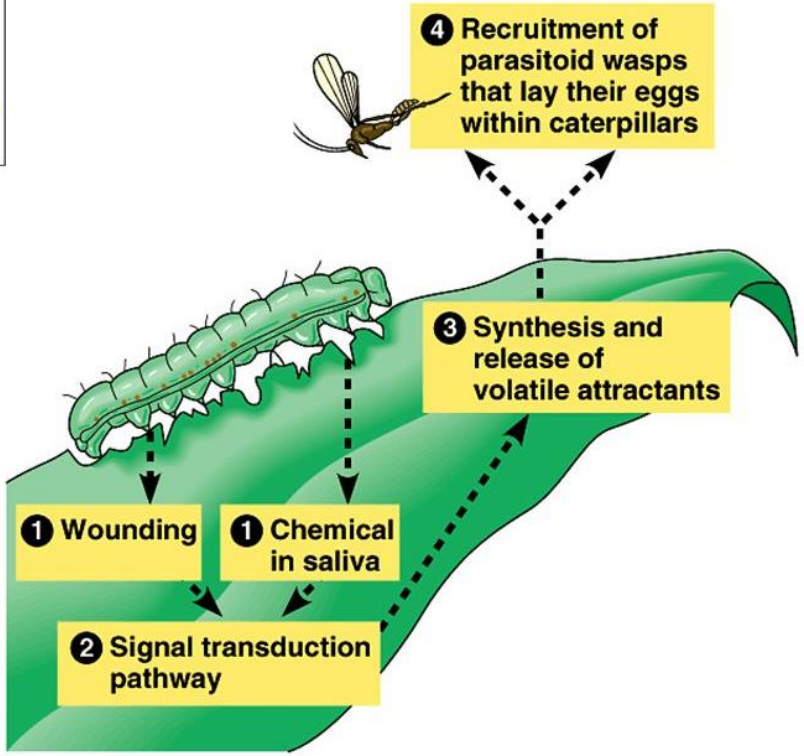


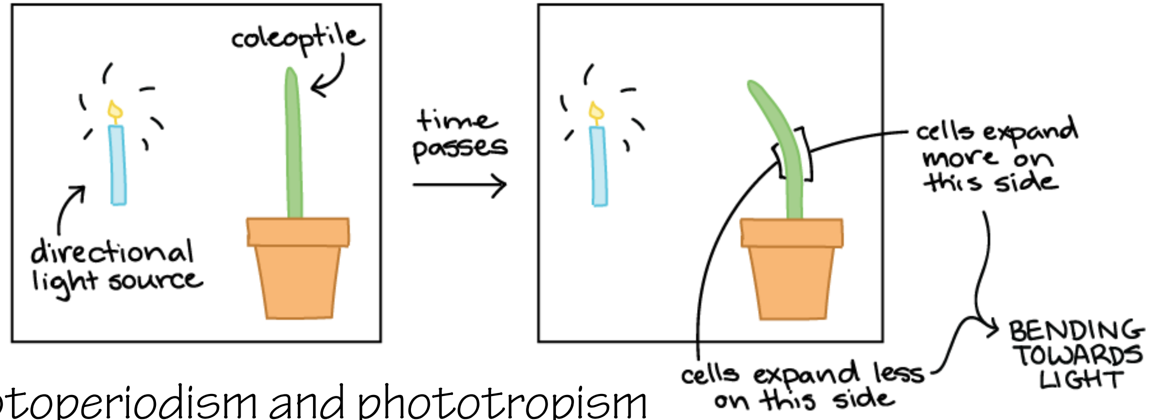
Organisms respond to changes in their environment through behavioral and physiological mechanisms



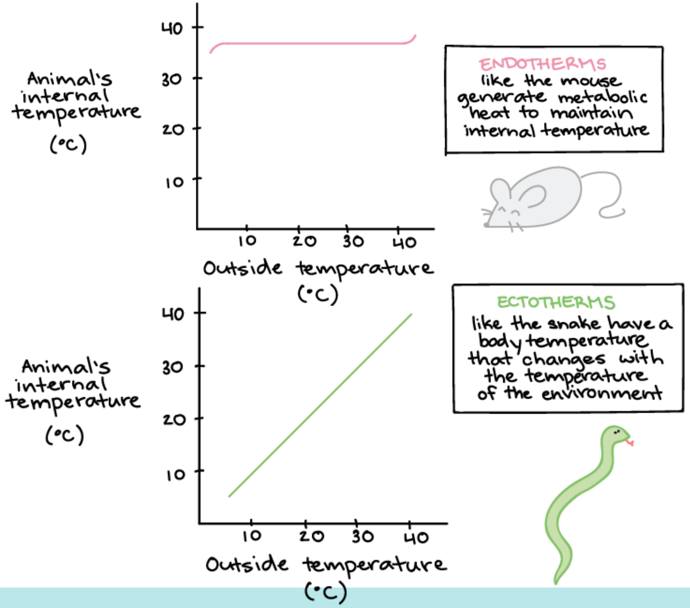
Organisms exchange information with one another in response to internal changes and external cues, which can change behavior

- Fight-or-flight response
- Predator warnings
- Plant responses to herbivory





Photoperiodism and phototropism



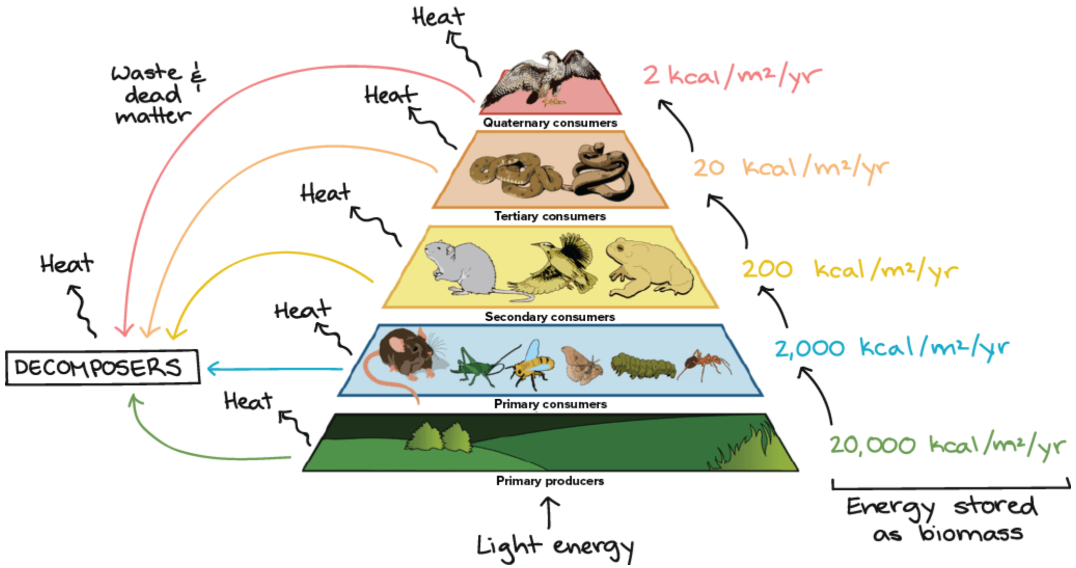
Body Temperature

Endotherm

Maintains body temperature through metabolism

Ectotherm

Maintains body temperature through behaviors (bask in sunlight, aggregation)



8.2 Energy Flow Through Ecosystems

Trophic Structure

Autotroph

Capture energy from physical or chemical source

- Photosynthetic
  - sunlight
- Chemosynthetic
  - small inorganic molecules in environment (sometimes without oxygen)

energy

Heterotroph

Capture energy present in carbon compounds produced by other organisms

Metabolize carbohydrates, lipids, and proteins (notice: not nucleic acids) for energy through hydrolysis

Organisms use energy to maintain, organize, grow and reproduce

Changes in Availability

Change in Energy Resource

Affects number and size of trophic levels

Change in Producer Level

Affects number and size of trophic levels

8.5 Community Ecology

Species Diversity

Simpson's Index: measures biodiversity (species composition and diversity)

$$Simpson\ Diversity = 1 - \sum \left(\frac{n}{N}\right)^2$$

n = total number of organisms of particular species

N = total of organisms of all species

Species	Number
Sloth	18
Penguin	13
Total	31

$$1 - \left(\left(\frac{18}{31}\right)^2 + \left(\frac{13}{31}\right)^2\right)$$

$$1 - ((0.58)^2 + (0.42)^2)$$

$$1 - (0.34 + 0.18)$$

$$1 - 0.52 = 0.48$$

Keystone Species

Organism with disproportionate to their abundance effect, and when they are removed from the ecosystem, the ecosystem often collapses.

Examples: Sea Otter

Interactions

Predator/Prey (+/-)

Herbivory (+/-)

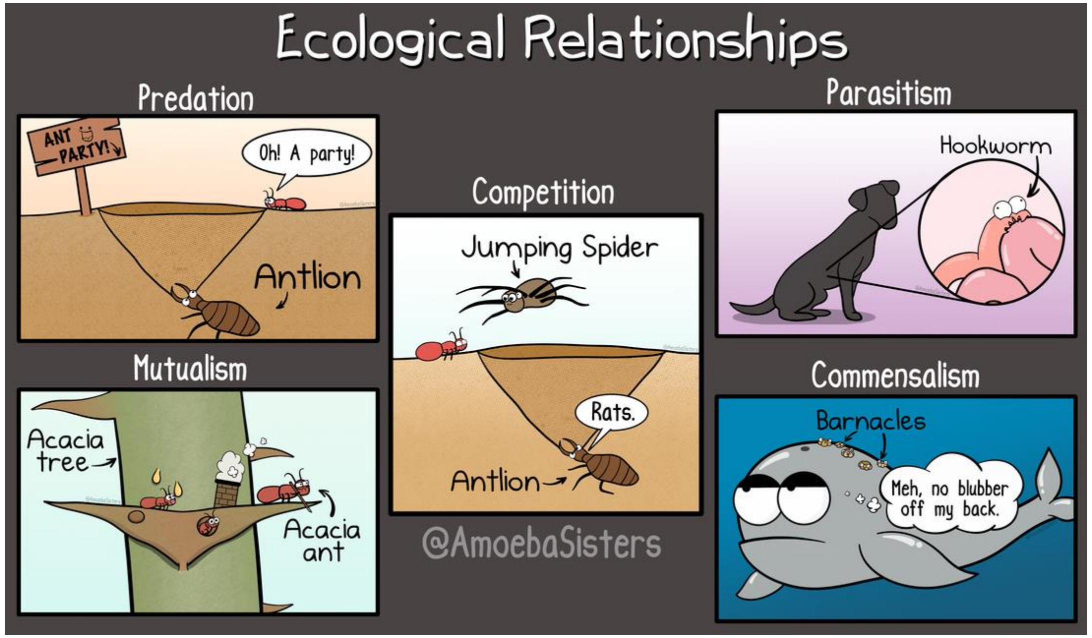
Competition (-/-)

Symbiosis

Parasitism (+/-)

Mutualism (+/+)

Commensalism (+/0)



Species Diversity

Species	Number

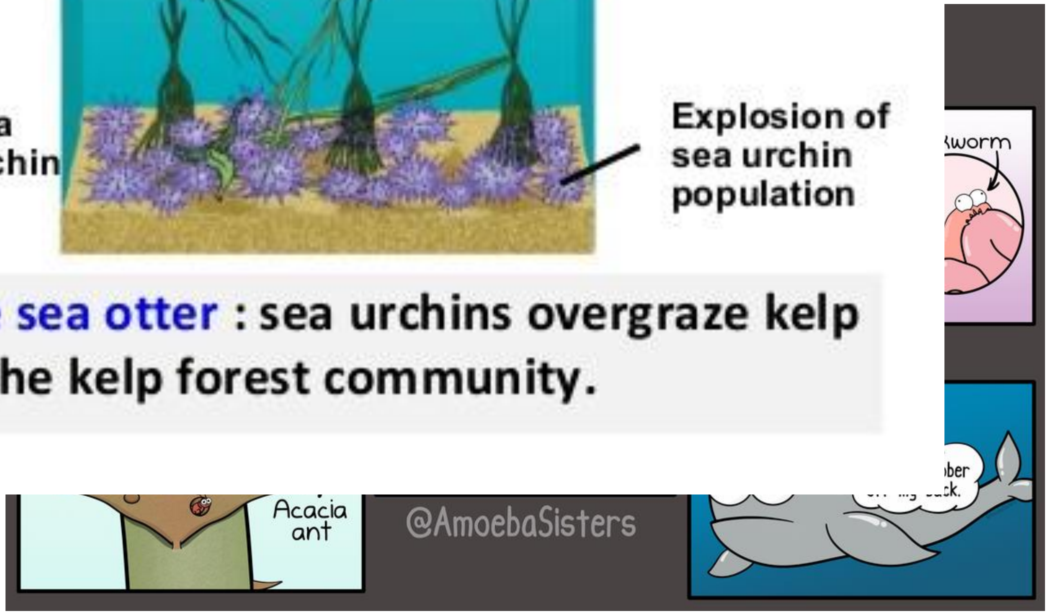
Keystone Species

Organism with disproportionate to their abundance effect, and when they are removed from the ecosystem, the ecosystem often collapses.

Examples: Sea Otter

Removal of the **keystone sea otter** : sea urchins overgraze kelp and destroy the kelp forest community.

ology



Mutualism (+/+)
Commensalism (+/O)

Species Diversity

Simpson's Index: measures biodiversity (species composition and diversity)

$$Simpson\ Diversity = 1 - \sum(\frac{n}{N})^2$$

n = total number of organisms of particular species

N = total of organisms of all species

Species	Number
Sloth	18
Penguin	13
Total	31

$$1 - ((\frac{18}{31})^2 + \left(\frac{13}{31}\right)^2)$$

$$1 - ((0.58)^2 + (0.42)^2)$$

$$1 - (0.34 + 0.18)$$

$$1 - 0.52 = 0.48$$

Keystone Species

Organism with disproportionate to their abundance effect, and when they are removed from the ecosystem, the ecosystem often collapses.

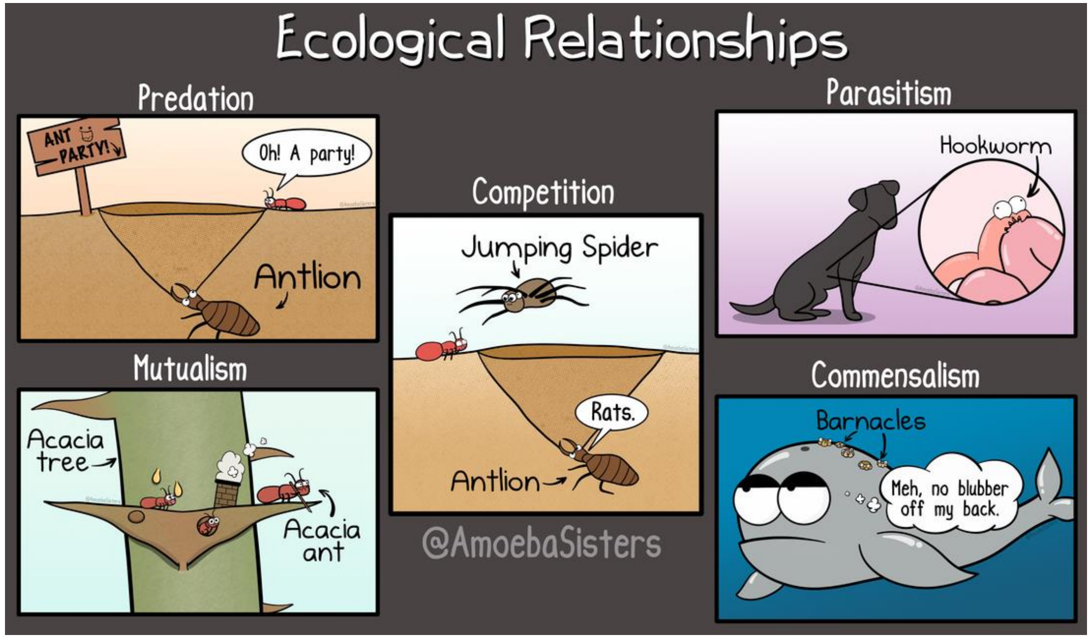
Examples: Sea Otter

8.5 Community Ecology

Interactions

Predator/Prey (+/-)
Herbivory (+/-)
Competition (-/-)

Symbiosis
Parasitism (+/-)
Mutualism (+/+)
Commensalism (+/0)



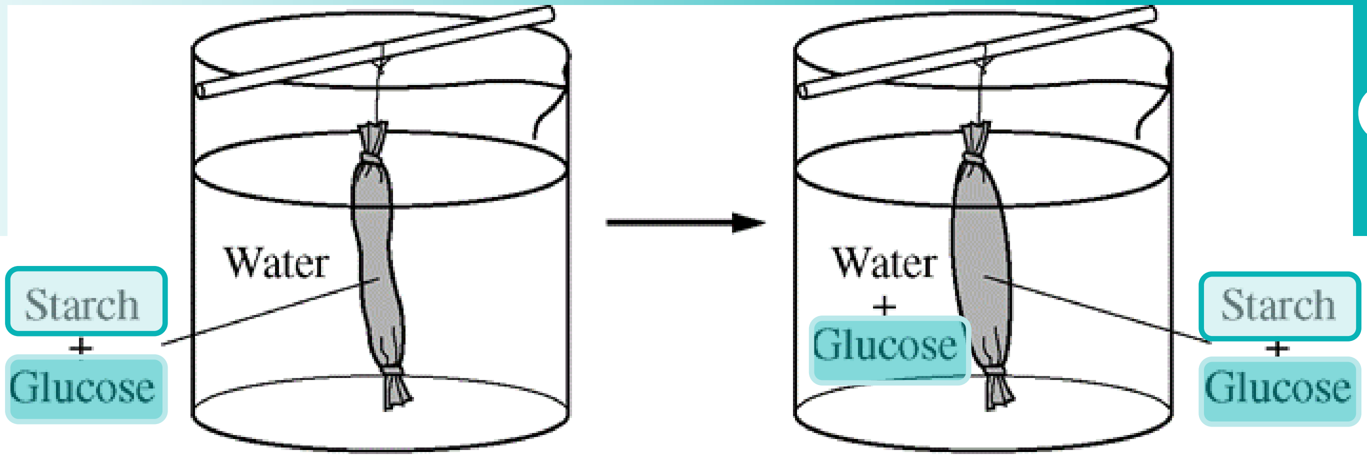
Invasive Species

Organism that is not indigenous, or native, to a particular area with no natural predators and unlimited resources

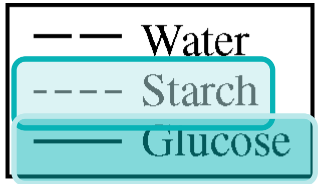
Examples:

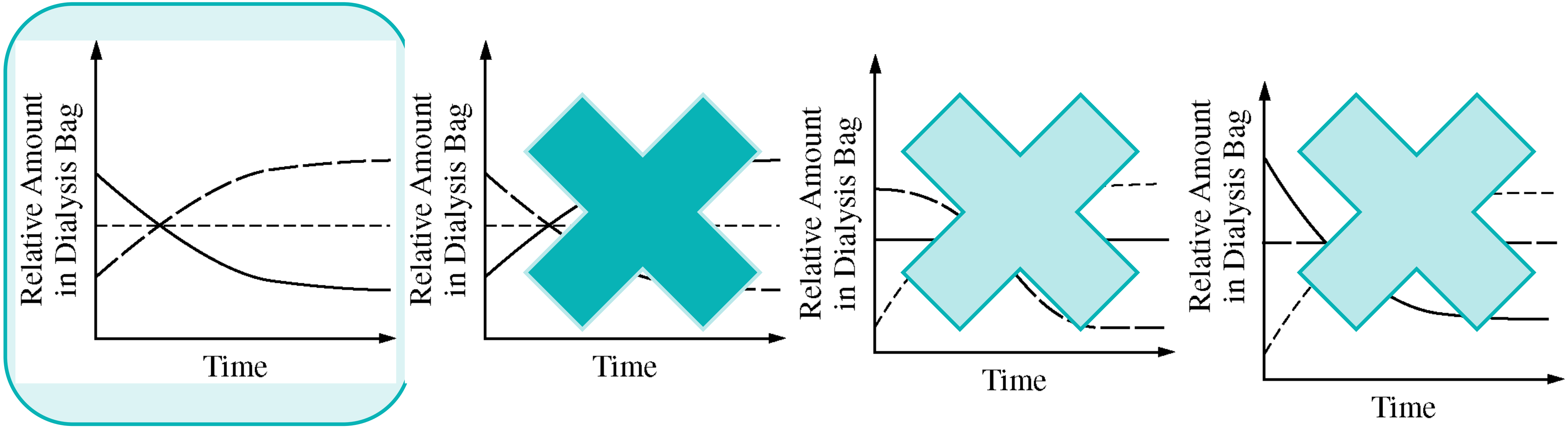
- Zebra Mussel: clogging water way
- Lionfish: venomous species

Choice Practice



A common laboratory investigation involves putting a solution of starch and glucose into a dialysis bag and suspending the bag in a beaker of water, as shown in the figure below. The investigation is aimed at understanding how molecular size affects movement through a membrane. Which of the following best represents the amount of starch, water, and glucose in the dialysis bag over the course of the investigation?





Multiple Choice Practice

The chemical reaction for photosynthesis is

$$6\,CO_2 + 12\,H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\,O_2 + 6\,H_2O$$

If the input water is labeled with a radioactive isotope of oxygen, ^{18}O, then the oxygen gas released as the reaction proceeds is also labeled with ^{18}O. Which of the following is the most likely explanation?

a. During the light reactions of photosynthesis, water is split, the hydrogen atoms combine with the CO_2, and oxygen gas is released.

b. During the light reactions of photosynthesis, water is split, removing electrons and protons, and oxygen gas is released.

c. During the Calvin cycle, water is split, regenerating NADPH from $NADP^+$, and oxygen gas is released.

d. During the Calvin cycle, water is split, the hydrogen atoms are added to intermediates of sugar synthesis, and oxygen gas is released.

Free Response Practice

Some birds, including great spotted cuckoos, lay their eggs in the nests of other birds, such as reed warblers. The warbler parents raise the unrelated chicks and provide them with food that would otherwise be given to their biological offspring. A researcher conducted an investigation to determine the type of relationship between warblers and cuckoos in an environment without predators. The researcher found that nests containing only warblers were more likely to be successful than nests containing warblers and cuckoos (data not shown). A successful nest is defined as a nest where at least one chick becomes an adult warbler.

In some geographic areas, several species of nest predators are present. Researchers h chicks, while in the nest, produce a smelly substance that deters nest predators. The s in the nest if cuckoo chicks are removed. Figure 1 shows the probability that nest conta containing both warblers and cuckoos will be successful in an environment with predato experiment, the researchers added cuckoos to a nest that contained only warblers (gro nest containing warblers and cuckoos (group 2).

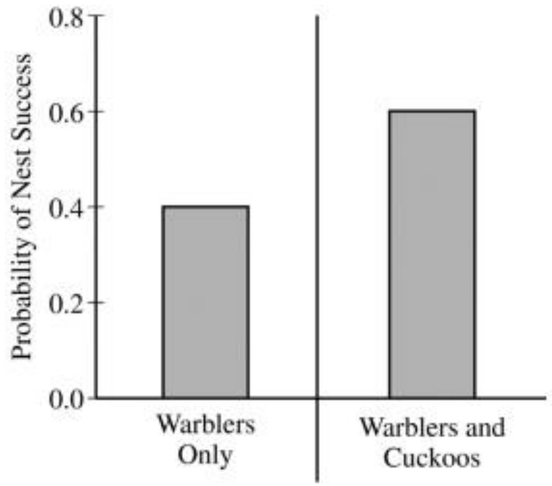


Figure 1. Probability of nest success in an environment with predators

Free Response Practice

(a) **Describe** the symbiotic relationship that exists between the cuckoo and warbler in an environment without predators.

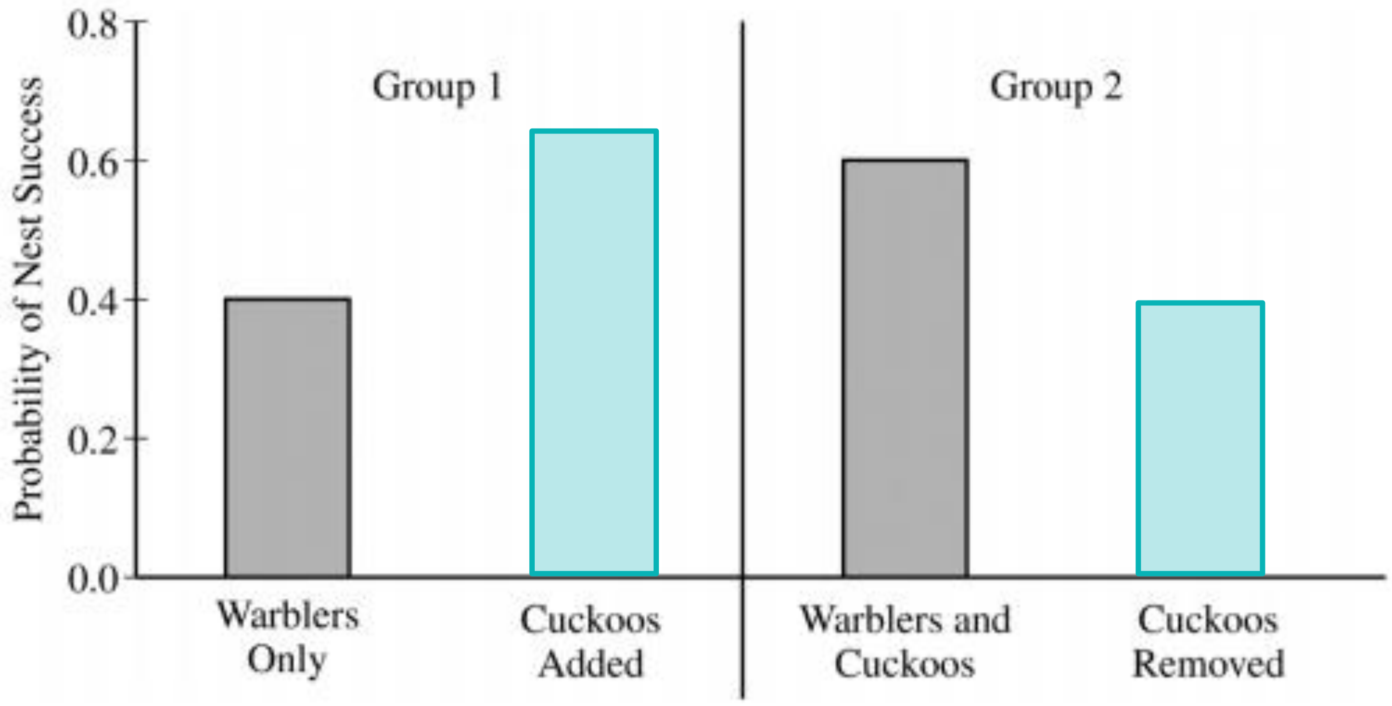
Cuckoo are parasites to the warblers because the cuckoo is benefited while the warbler is harmed in the relationship.

Recall: Cuckoos lay their eggs in the nests of warblers. The warbler parents raise the unrelated chicks and provide them with food that would otherwise be given to their biological offspring.

Free Response Practice

(b) On the template provided, draw bars in the appropriate locations to predict the relative probability of success for the nest in the presence of predators where:

* the cuckoos were added to the nest containing only warblers (group 1)
* the cuckoos were removed from the nest containing warblers and cuckoos (group 2)



Free Response Practice

(c) **Identify** the symbiotic relationship that exists between the cuckoo and the warbler in the presence of predators.

Cuckoo bird and the warbler are in a mutualistic relationship.

Recall: Researchers have found that cuckoo chicks, while in the nest, produce a smelly substance that deters nest predators. The substance does not remain in the nest if cuckoo chicks are removed.

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