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The AP Biology Study Platform That Guarantees Success

AP Bio Semester 1 Review, Part 2

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Tonight's Focus: Units 3 and 4

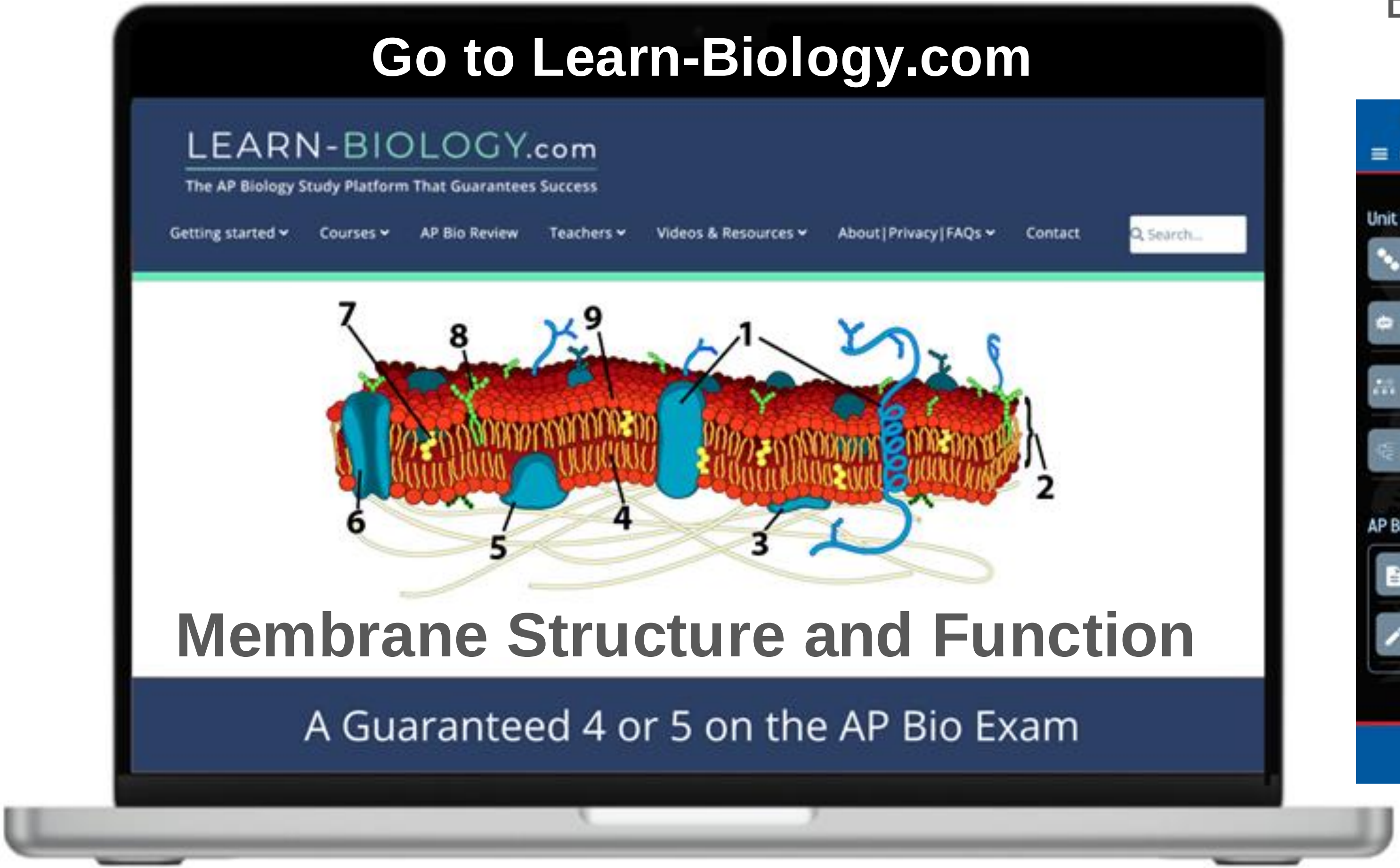
(more review Saturday): apbiosuccess.com/sem1review)

1. Resources for Semester 1 review
2. Your Questions
3. A few practice FRQs

AP Bio Semester 1 Review on ZOOM

- Saturday, 12/7/24, 10am PST (1pm EST)
- 20 participant limit
- Answering Questions, Content Review, FRQs, Study tips
- Sign up at apbiosuccess.com/sem1review

Ace AP Bio. Start with a free trial



Biomania AP BIO App

To help you study study for your semester final and the AP Bio exam…

Download this checklist at

apbiosuccess.com/checklist

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Topics 2.4 – 2.9: Membrane Structure and Function; Osmosis

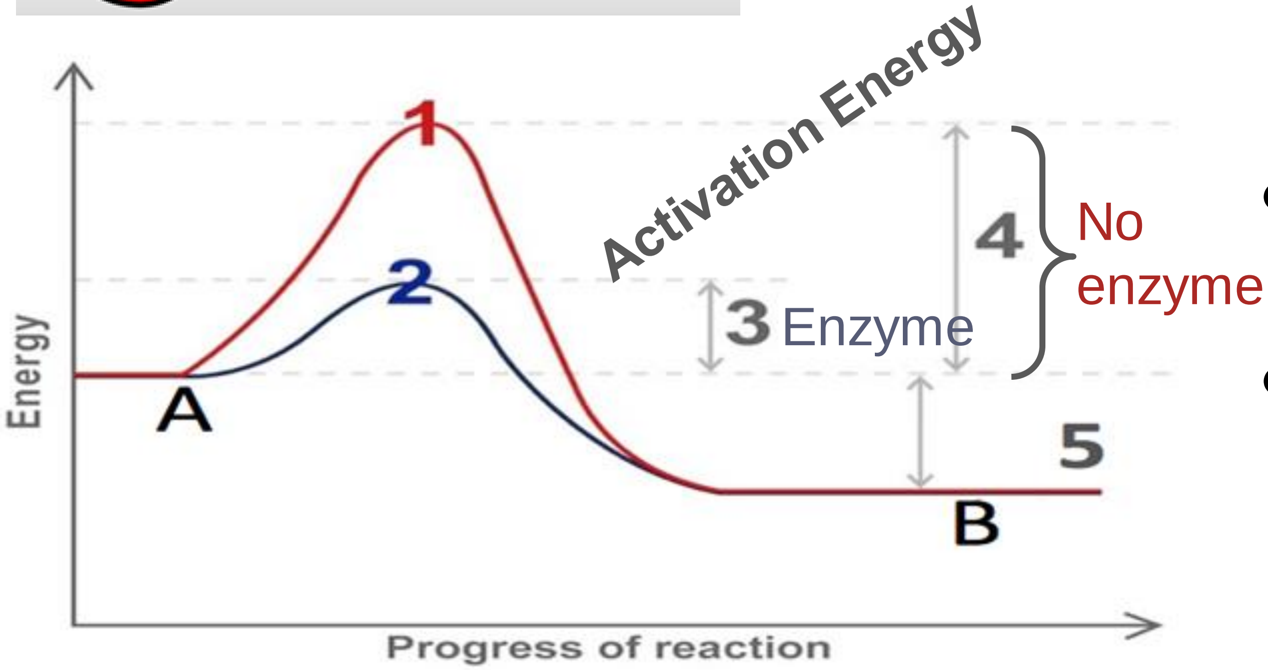
- ☐ Describe the fluid mosaic model of the cell membrane. Include
  - ☐ The overall function of the membrane
  - ☐ The role of phospholipids
  - ☐ The role of embedded proteins (how they fit into the bilayer, and their var
  - ☐ The functions of cholesterol, glycolipids, and glycoproteins.
- ☐ Define selective permeability.
- ☐ Explain how selective permeability arises from the fluid mosaic structure of the memb
  - ☐ How small, nonpolar molecules like N_2, CO_2, and O_2 can pass across the
  - ☐ How ions and large polar molecules move across the membrane
  - ☐ How small polar molecules (like water) pass through the membrane
- ☐ Compare and contrast passive transport, active transport, and facilitated diffusion. Co process to membrane structure.
- ☐ Compare and contrast endocytosis and exocytosis.
- ☐ Explain membrane potential
- ☐ Connect membrane potential to processes such as ATP synthesis.
- ☐ Define the term osmosis, and be able to predict and explain the flow of water into or hypotonic, hypertonic, and isotonic environments.

What are your ?s

1. Enzyme structure & function
2. Enzymes & their environment
3. Enzyme regulation
4. ATP and Cell Energy
5. Cellular Respiration: Big Picture (NADH, etc.)
6. Glycolysis
7. Link reaction and Krebs
8. Electron Transport Chain
9. Thermogenesis
10. Anaerobic respiration/fermentation
11. Photosynthesis overview
12. Light Reactions
13. The Calvin Cycle
14. Cell Signaling Overview
15. G-Protein Receptor Systems
16. Homeostasis
17. Feedback Loops
18. Blood Glucose Regulation & Diabetes
19. Positive Feedback
20. Cell Cycle/Mitosis
21. Cell Cycle Regulation
22. Cancer and Apoptosis

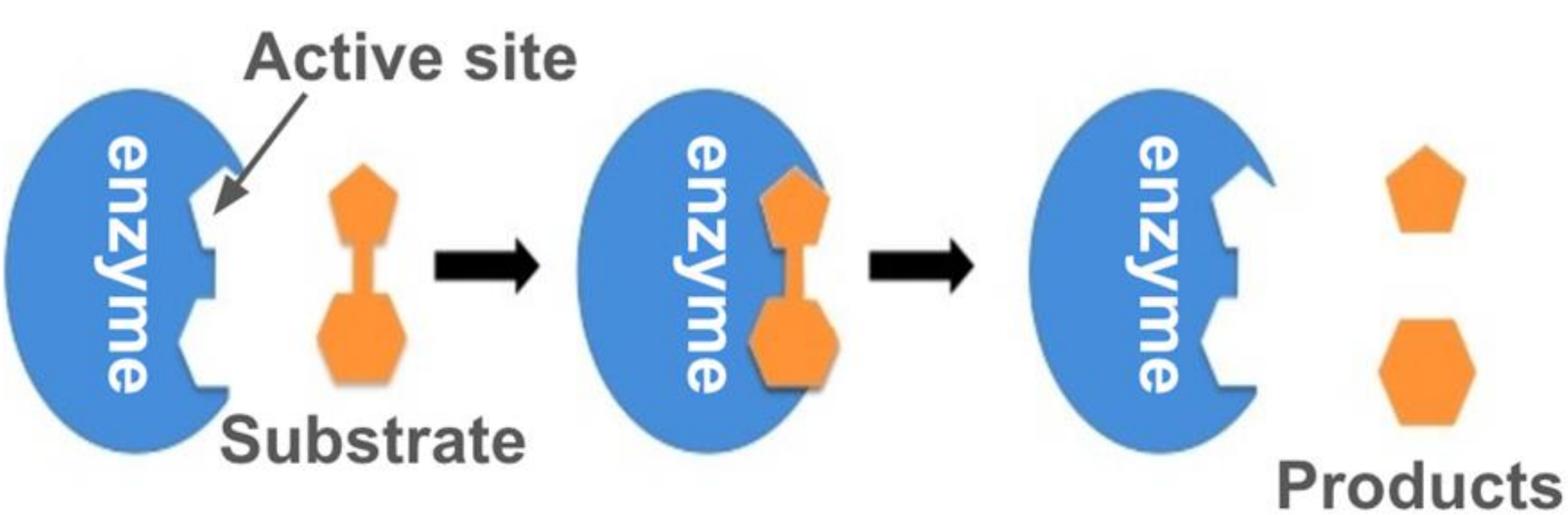
Topic 3.1: Enzyme Structure and Function

Describe the key properties of enzymes.



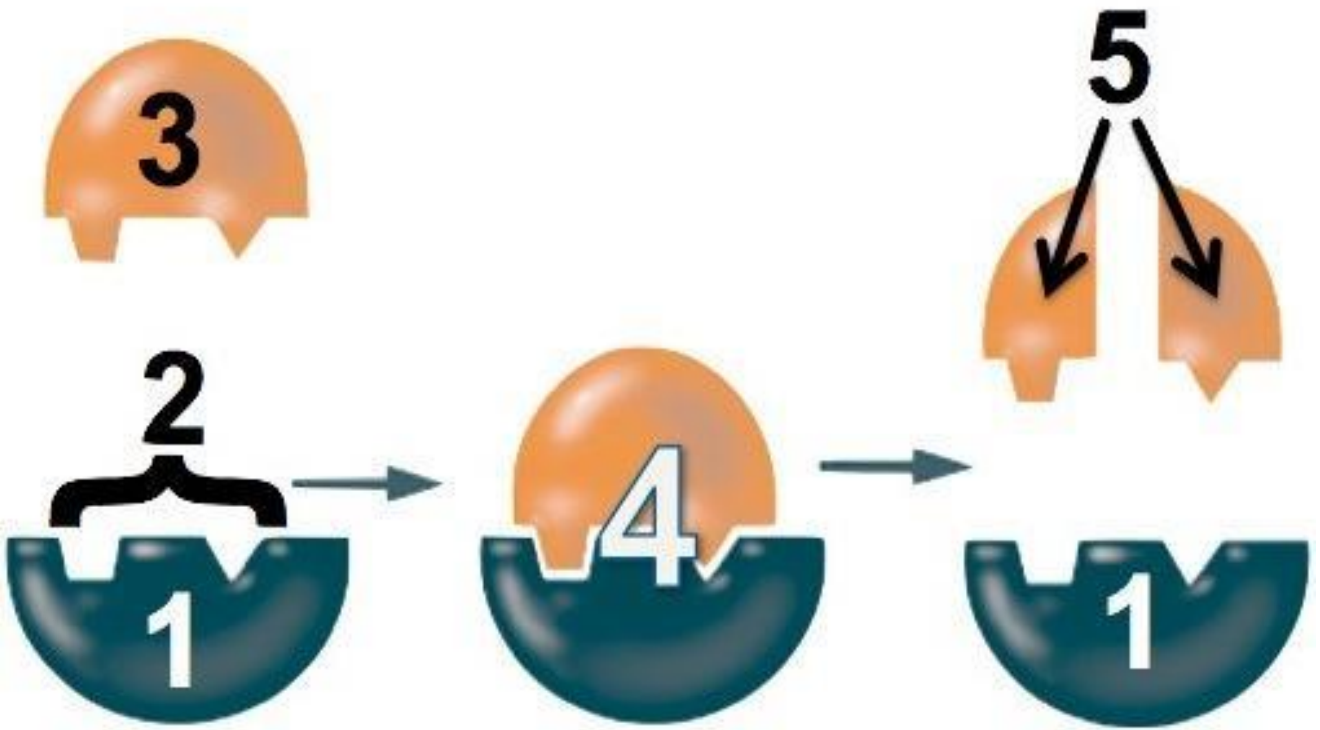
- Proteins (sometimes RNAs) that catalyze reactions in cells.
- Lower activation energy
- Increase the rate of reactions

Enzymes interact with specific substrates



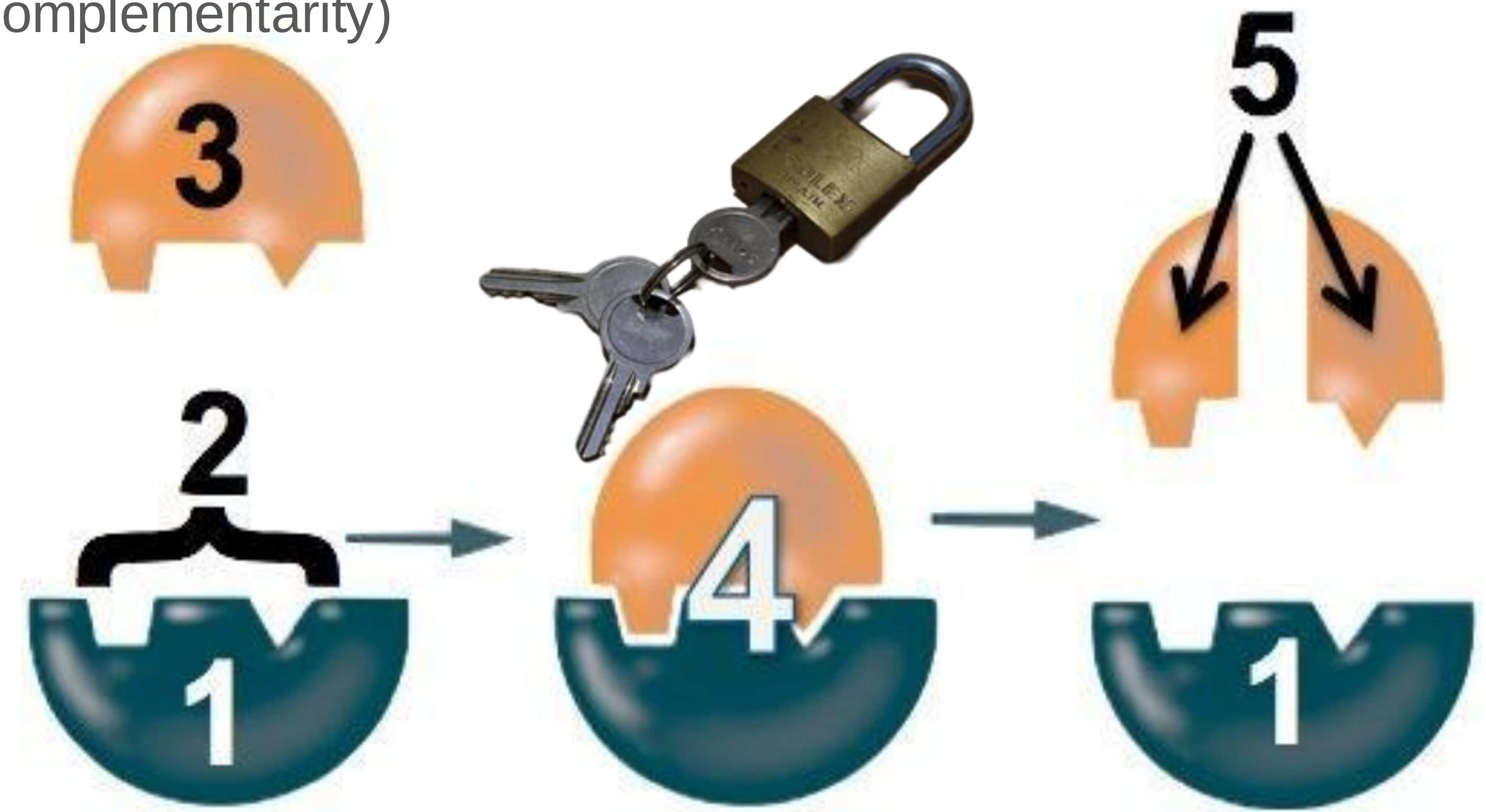
Their active site complements the *shape* and *charge* of their substrate (the substance that an enzyme acts upon).

Enzyme-substrate interaction

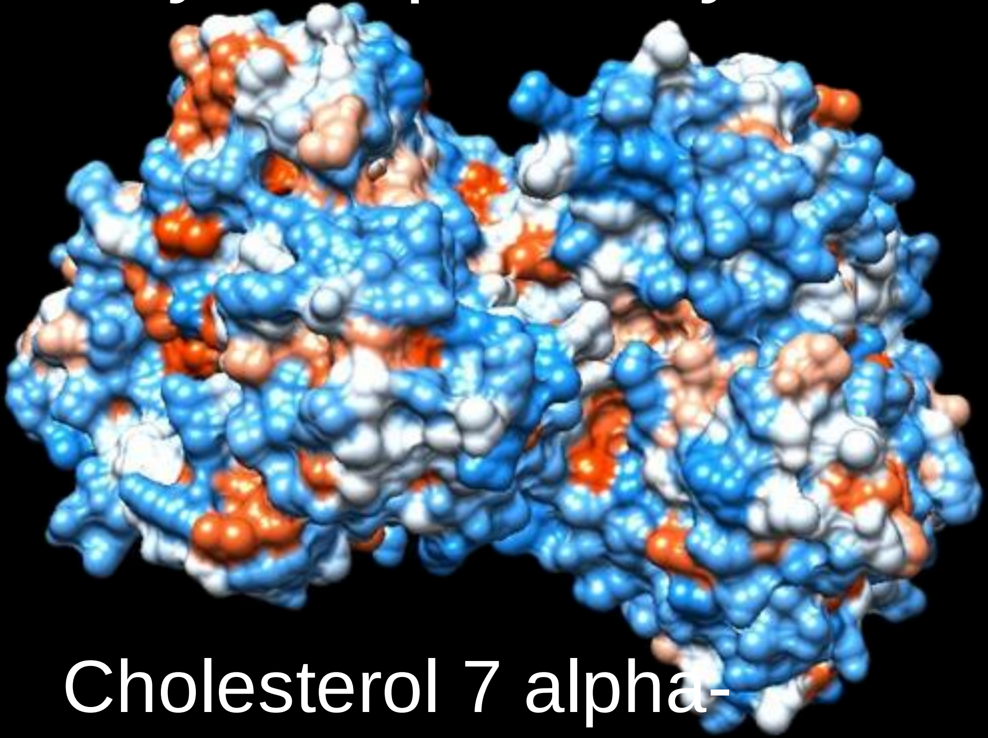


1. Enzyme
2. Active site
3. Substrate
4. Enzyme-substrate complex
5. Product

Enzyme substrate specificity is like a key and a lock (complementarity)



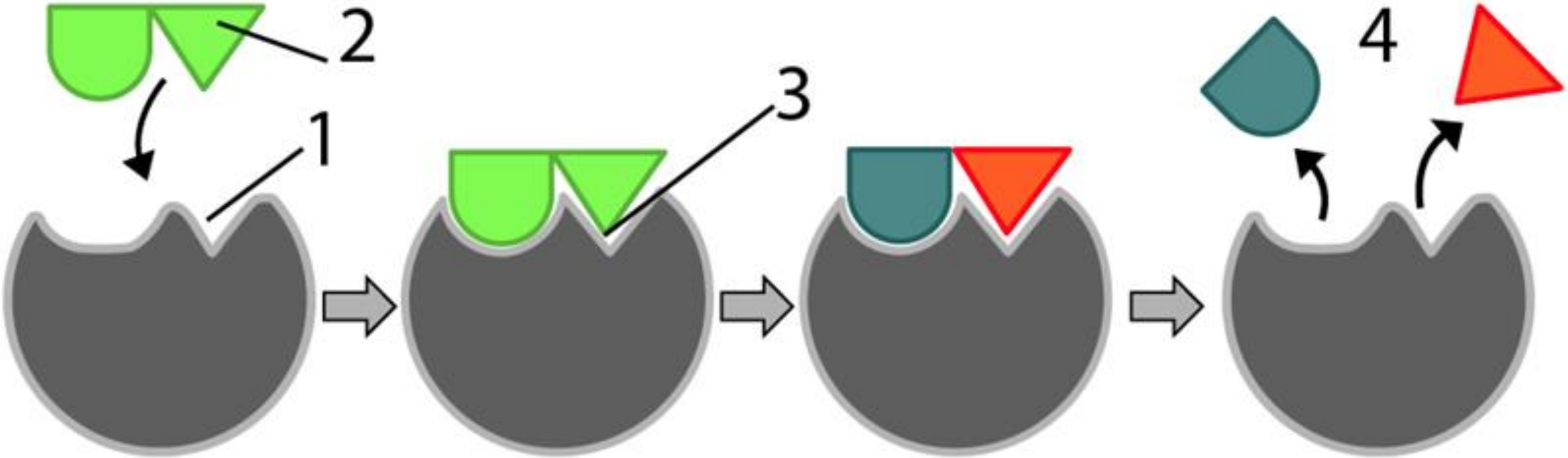
Enzyme specificity looks like this



Cholesterol 7 alpha-hydroxylase

- 491 amino acids
- 23 alpha helices
- 26 beta sheets

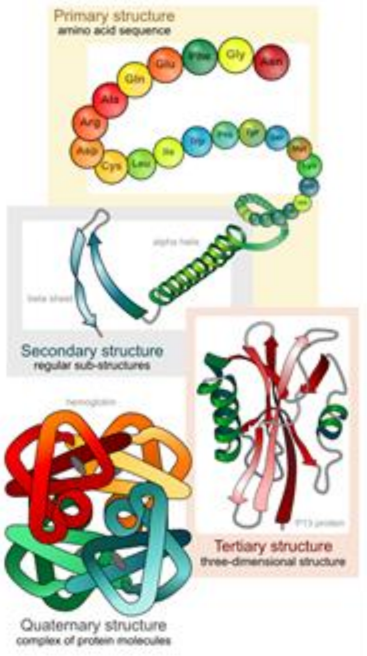
Induced-fit model of enzyme action

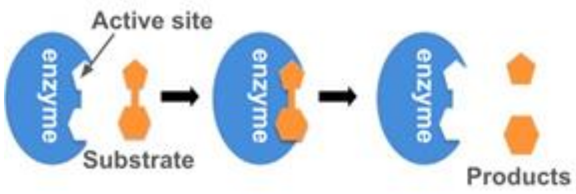


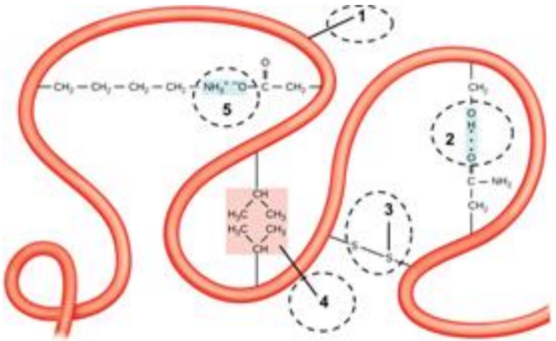
1. Active site before binding with substrate (2)
3. Active site with altered shape (induced fit)
4. Product

Topic 3.2: Enzymes and their Environment

Enzymes have a narrow set of conditions where they can function at or near their optimum.

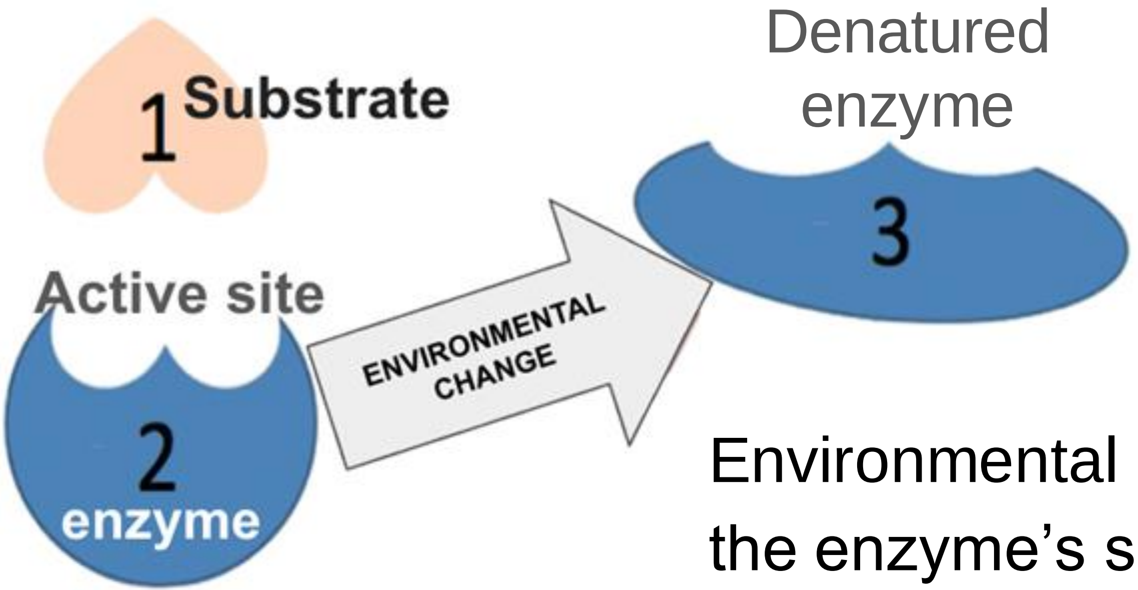






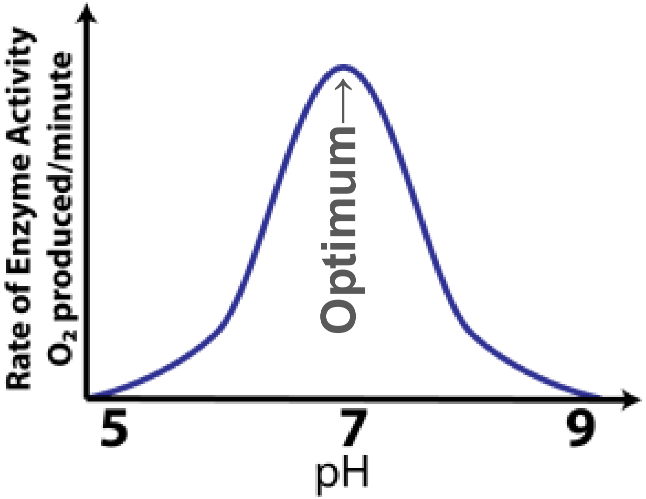
- Enzymes are proteins
- Their secondary, tertiary, and quaternary level structures involve, hydrogen bonds, ionic bonds, and hydrophobic clustering.
- Changing pH, temperature, or ion concentration interferes with these bonds, changing the shape of the active site, keeping the enzyme from binding with its substrate.

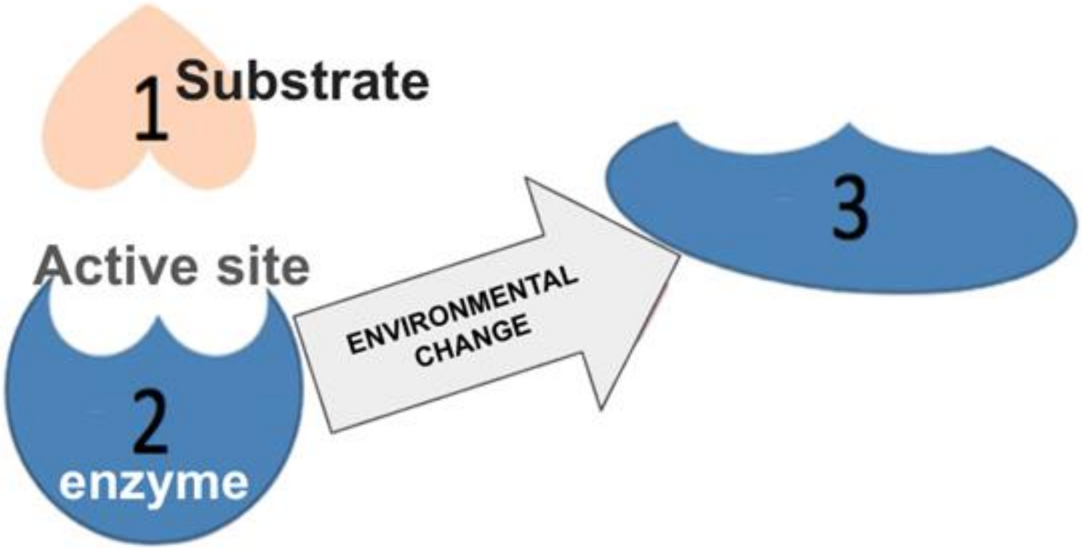
What is denaturation?



Environmental change that changes the enzyme’s shape in a way that lowers (or completely negates) enzyme function.

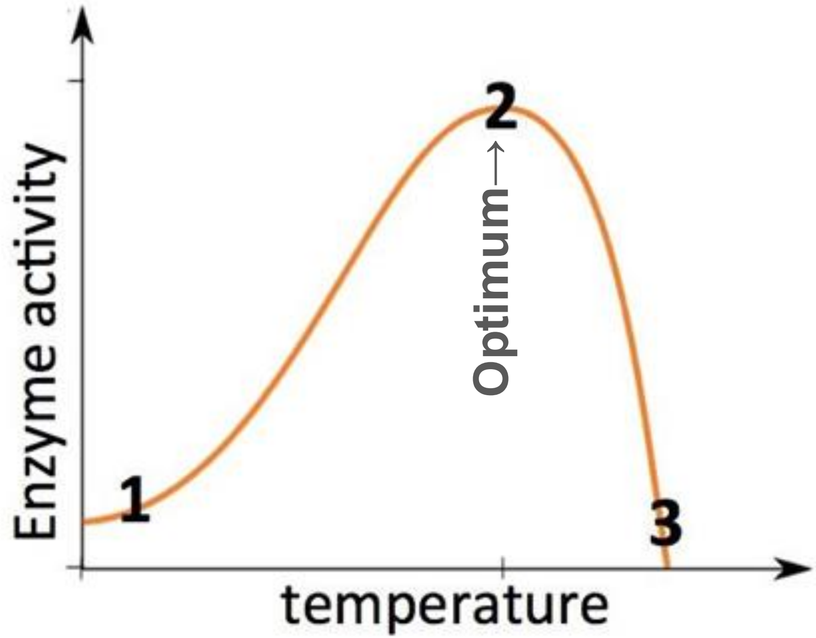
How is enzyme activity affected by changes in the pH of its environment?

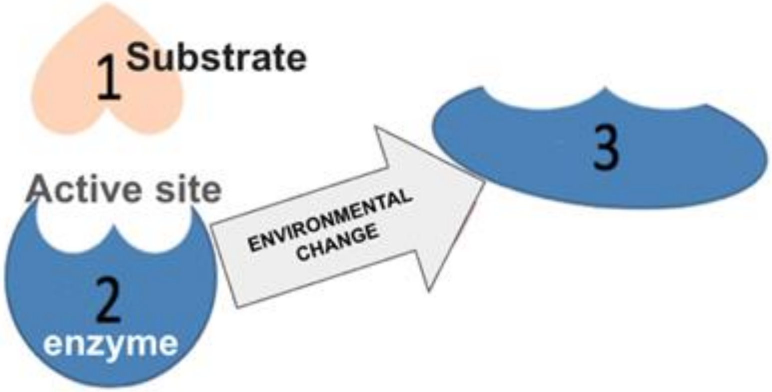




- Most enzymes have a **pH optimum** where they operate at peak efficiency.
- As the pH moves above or below the optimum, the enzyme denatures, and enzyme performance drops.

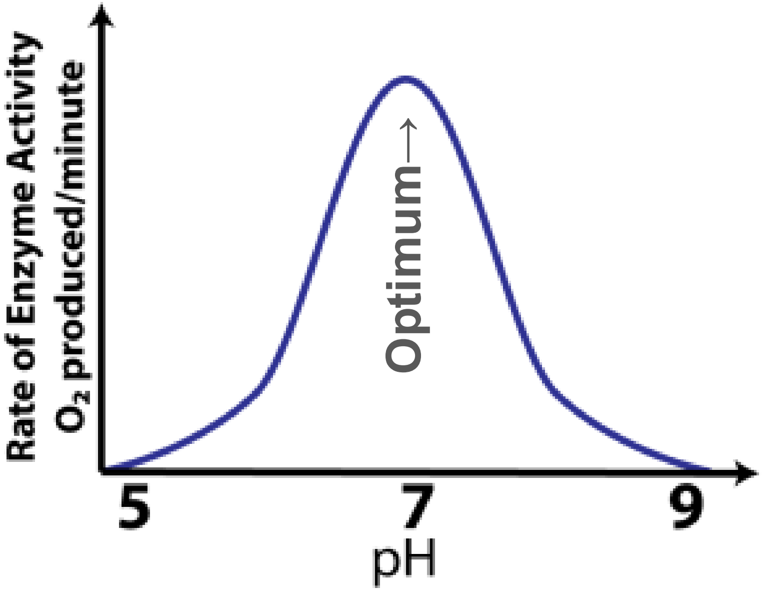
Describe how enzyme activity is affected by changes in the temperature of the enzyme's environment

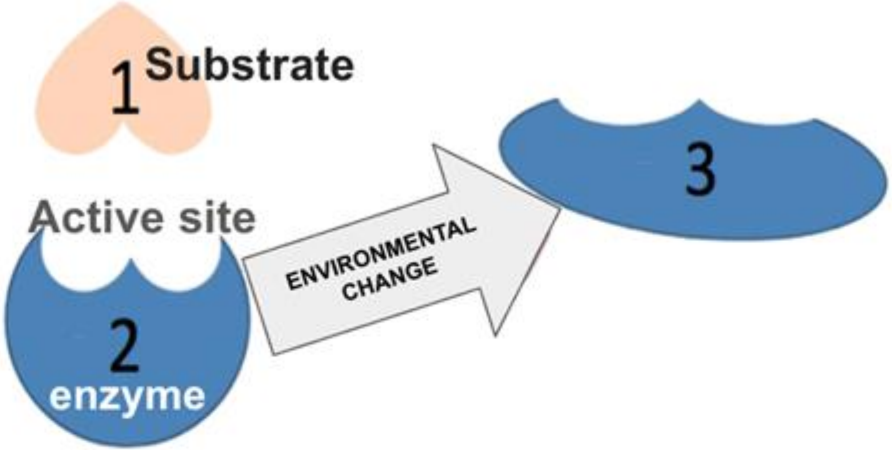




- Up to a certain point, enzyme activity increases with temperature: more kinetic energy increases molecular motion and increases the chance that the enzyme will bind with its substrate.
- At a certain temperature (beyond 2 in the graph), the enzyme denatures, reducing the enzyme’s catalytic abilities.

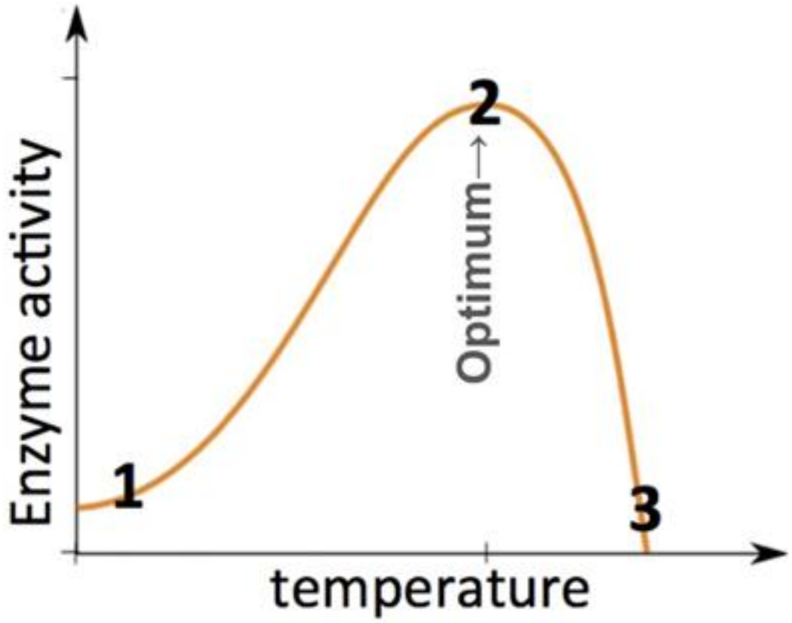
What's the difference between reversible and irreversible denaturation?

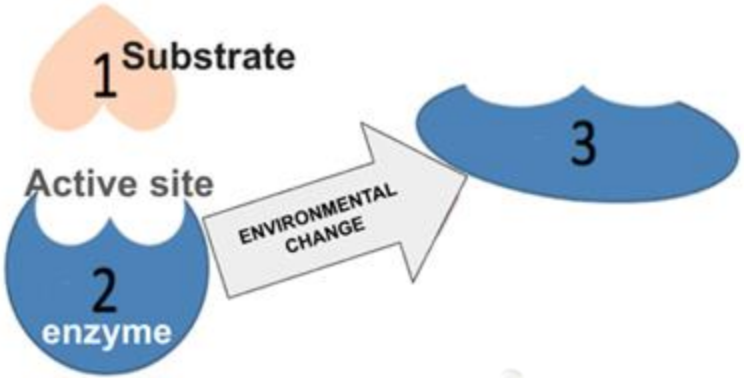


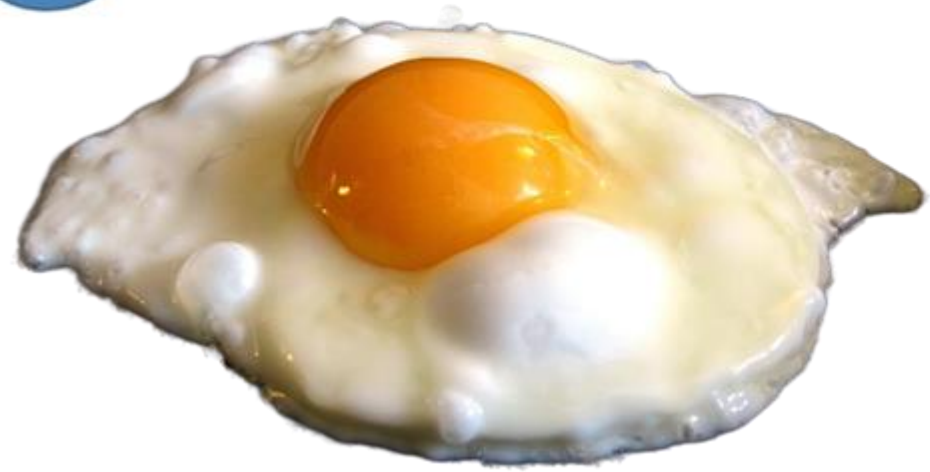


- **Reversible denaturation:** restoration of optimal conditions restores the enzyme’s function as it regains its optimal shape.
- **Irreversible denaturation:** enzyme’s shape is permanently changed, and its catalytic ability is destroyed.

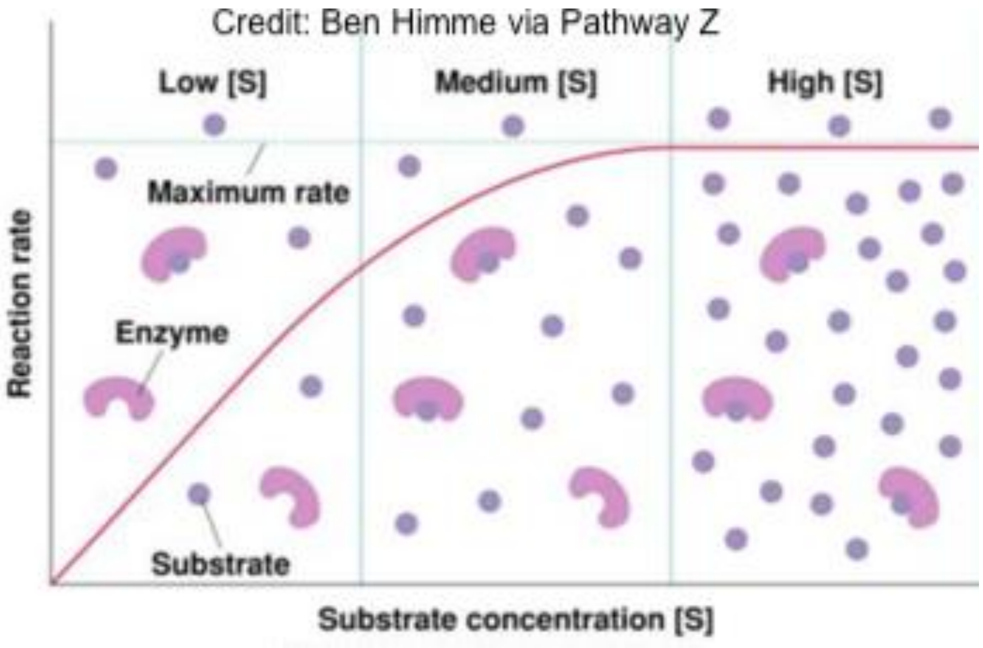
Example: irreversible denaturation of a egg white protein (albumin)





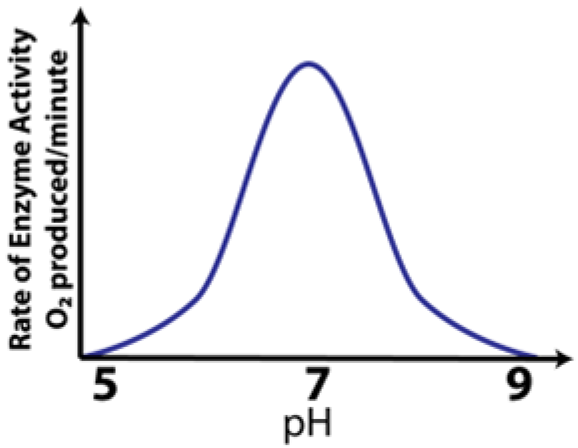


Explain how enzyme activity is affected by substrate concentration.

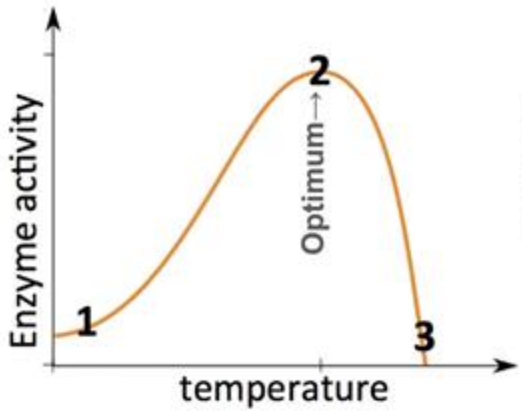


- *Low substrate concentrations:*
    - Probability of the enzyme meeting the substrate is low
    - Product will be produced at a low rate.
- *Medium substrate concentration*
    - Collision and the reaction rate increase.
- *High Substrate Concentration*
    - Saturation point
    - All active sites are interacting with substrates.
    - Rate peaks (and curve flattens)

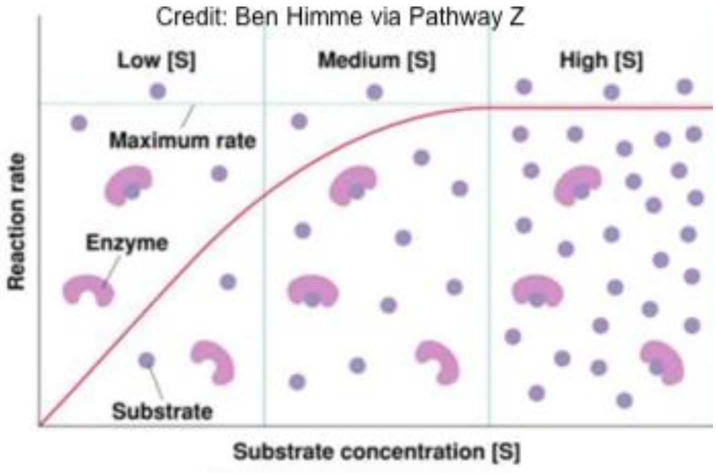
You can easily experiment with these variables



Change the pH

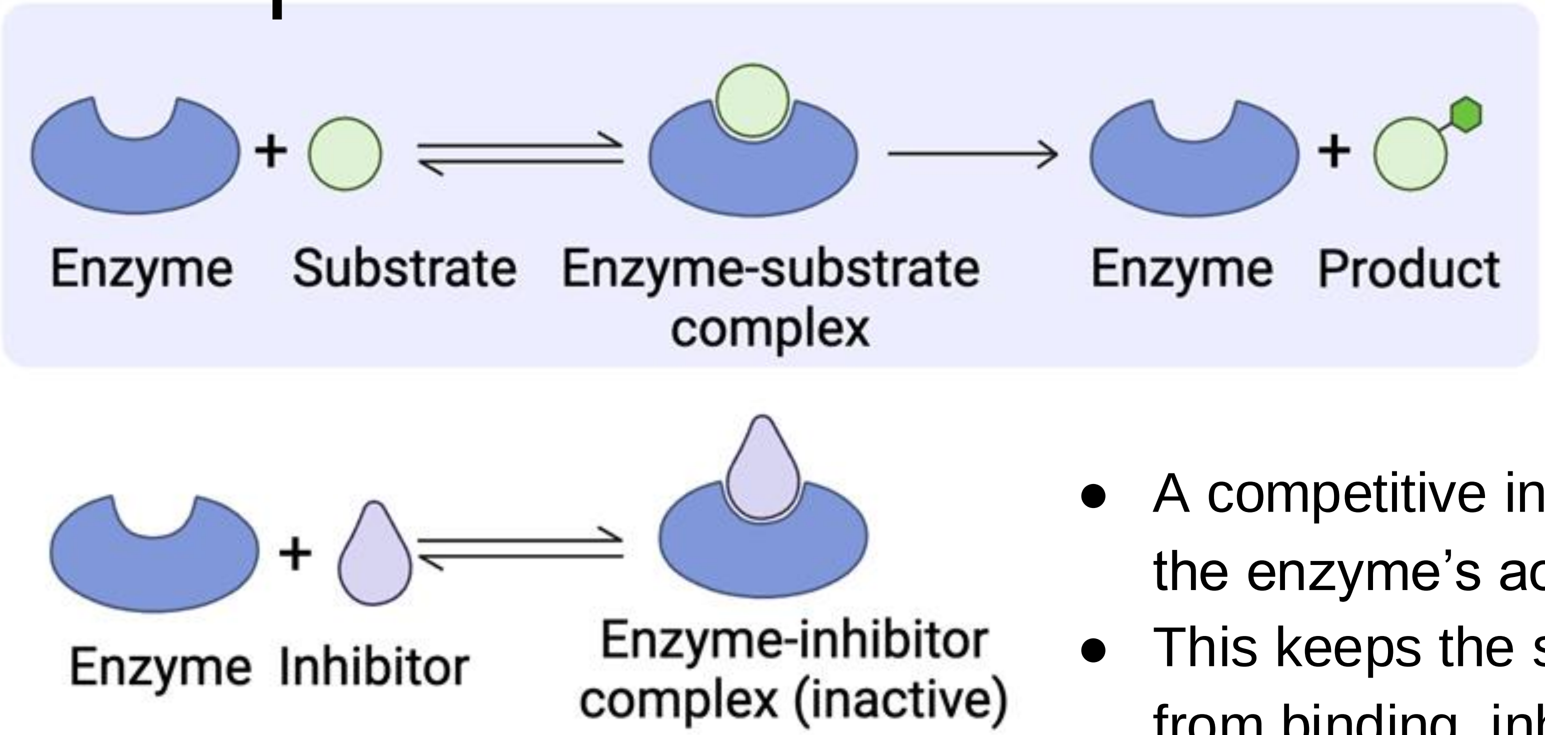


Change the temperature



Change the substrate concentration

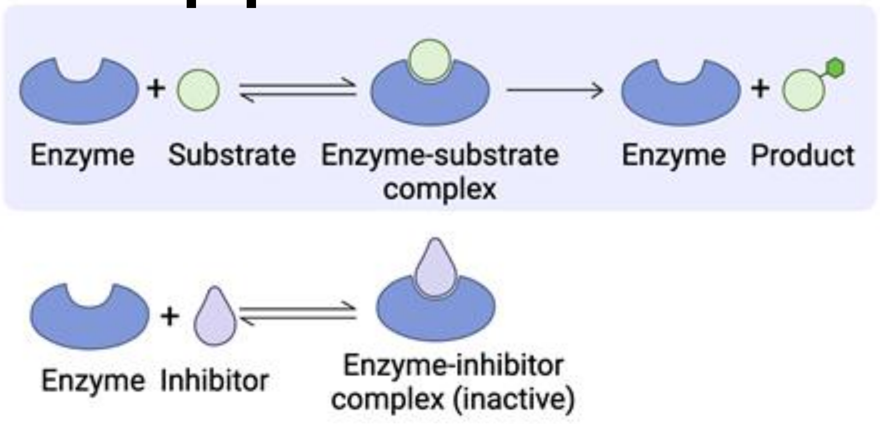
Competitive Inhibition

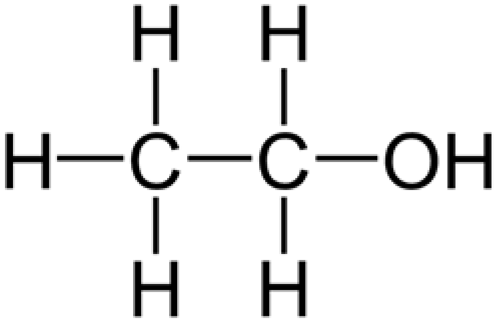


- A competitive inhibitor blocks the enzyme's active site
- This keeps the substrate from binding, inhibiting the rate of the reaction.

Competitive Inhibition Application

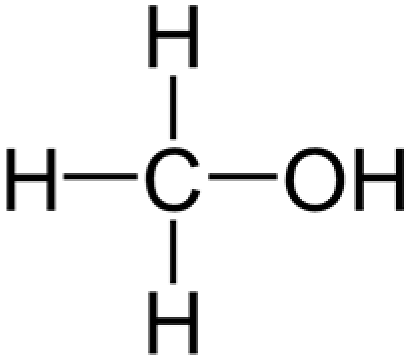
Treating methanol poisoning with ethanol blocks an enzyme that creates formaldehyde





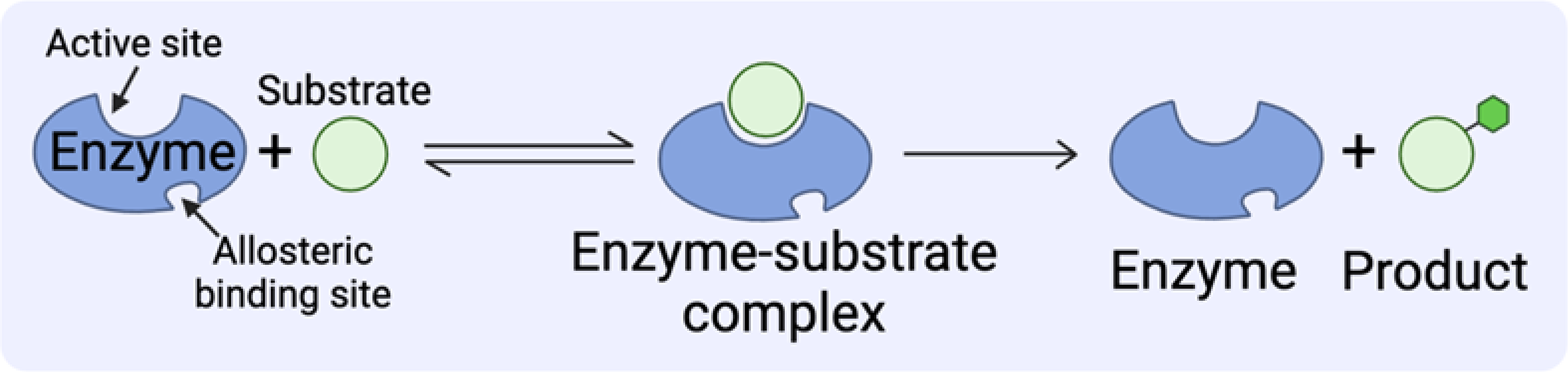
Ethanol

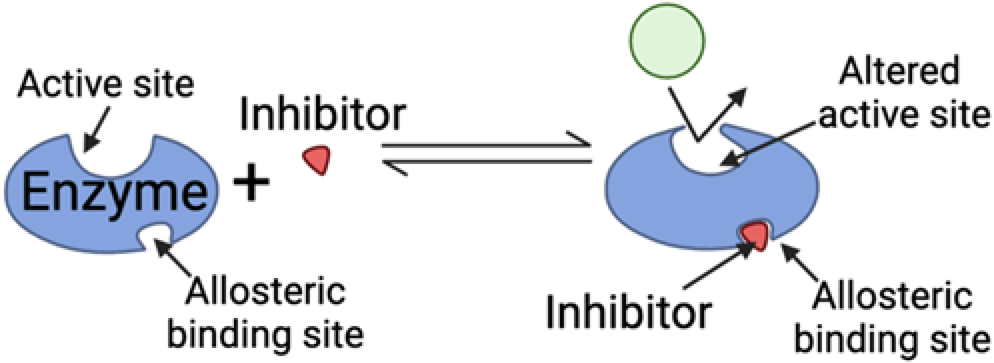
inhibits



Methanol

Noncompetitive Inhibition

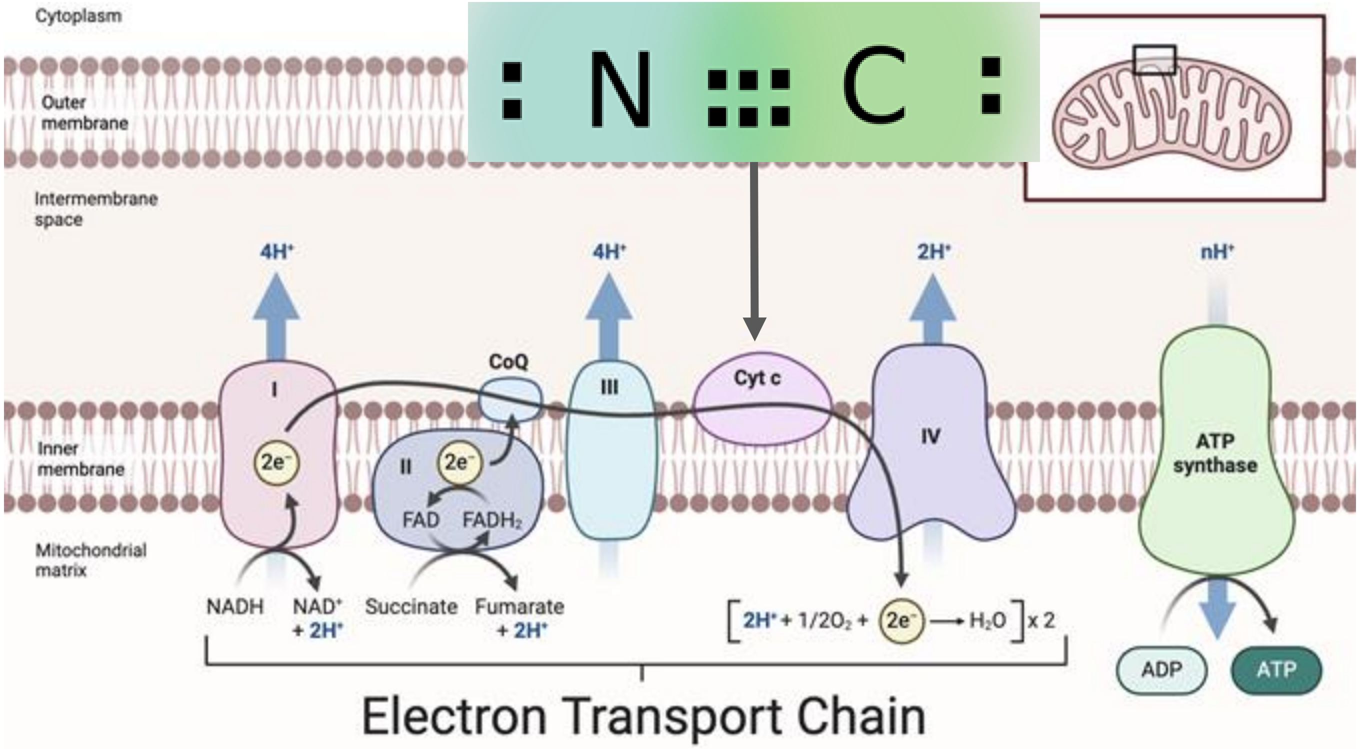




- Noncompetitive inhibitor binds away from the active site at an **allosteric** site.
- Binding at the allosteric site has a ripple effect throughout the protein
- Change in the shape of the active site diminishes or blocks enzyme activity.

Noncompetitive Inhibition Example

Cyanide inhibits Cytochrome *c*



- Blocks aerobic respiration
- Prevents ATP formation

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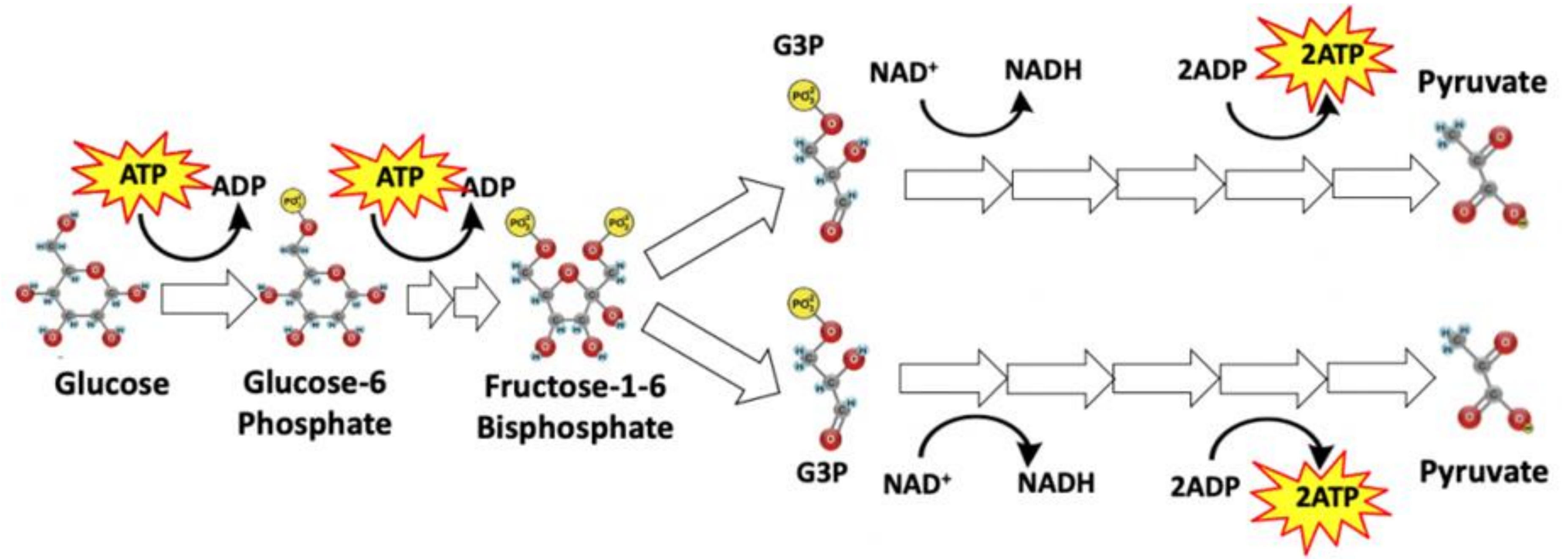
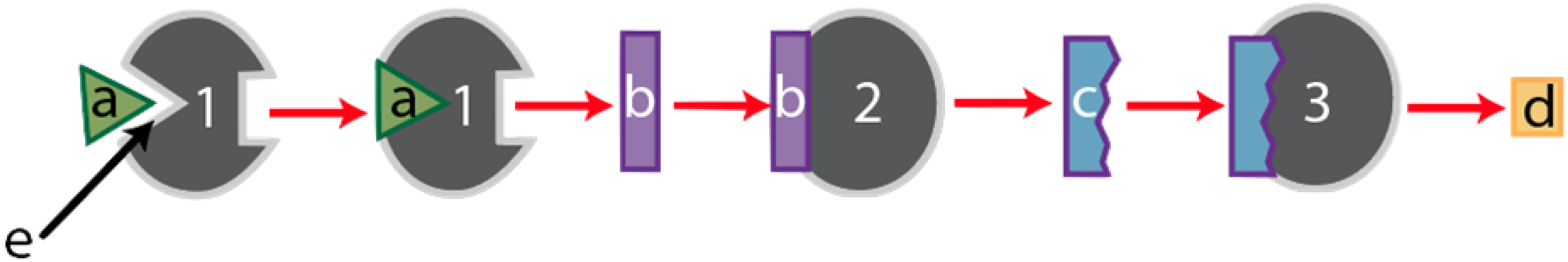
Topic 3.3: Enzyme Regulation

Many enzymes are parts of metabolic pathways



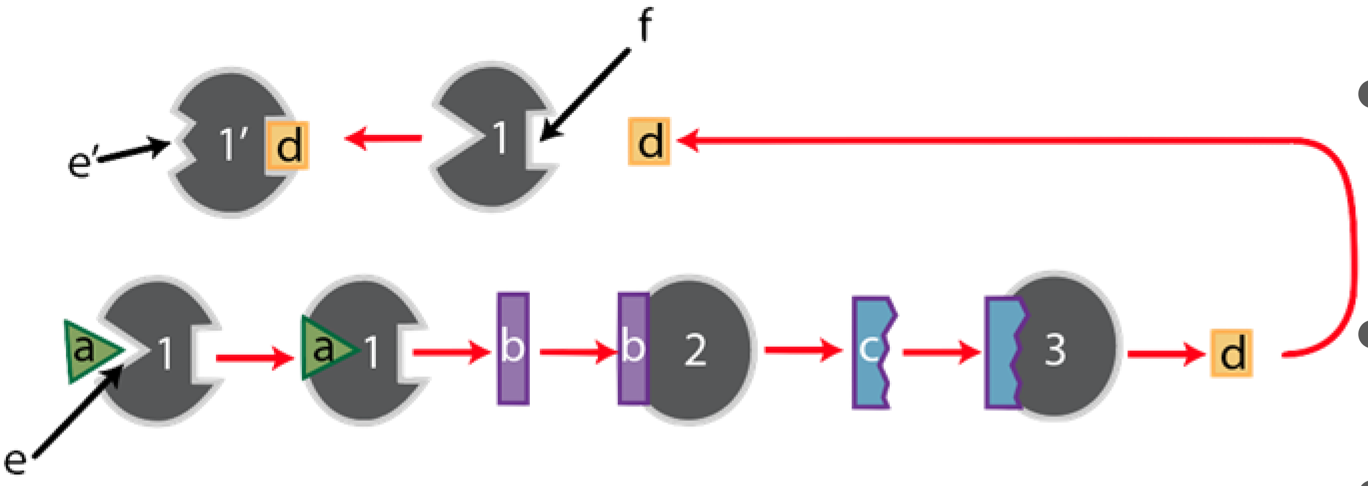
Each arrow is a different enzyme.

Metabolic pathways



- A: 1st reactant/substrate
- 1, 2 and 3 are enzymes
- B and C: intermediates
- D: final product

Metabolic pathways can be controlled by feedback

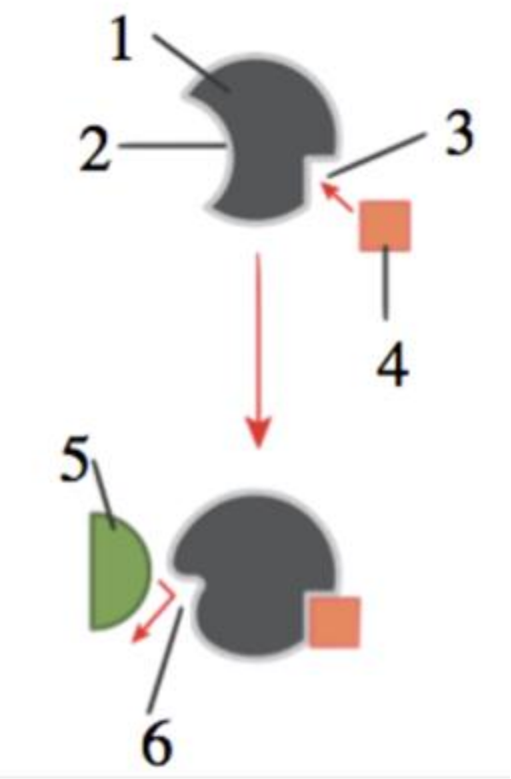


- F: allosteric site on enzyme 1
- e: initial active site
- e': altered active site

Adaptive rule: When the concentration of “d” is sufficient, then shut down the pathway that makes “d.”

Feedback can inhibit

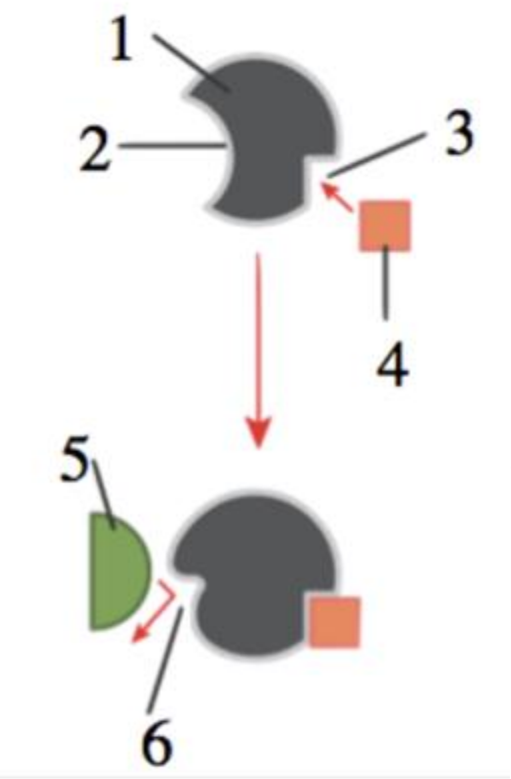
Allosteric Inhibition



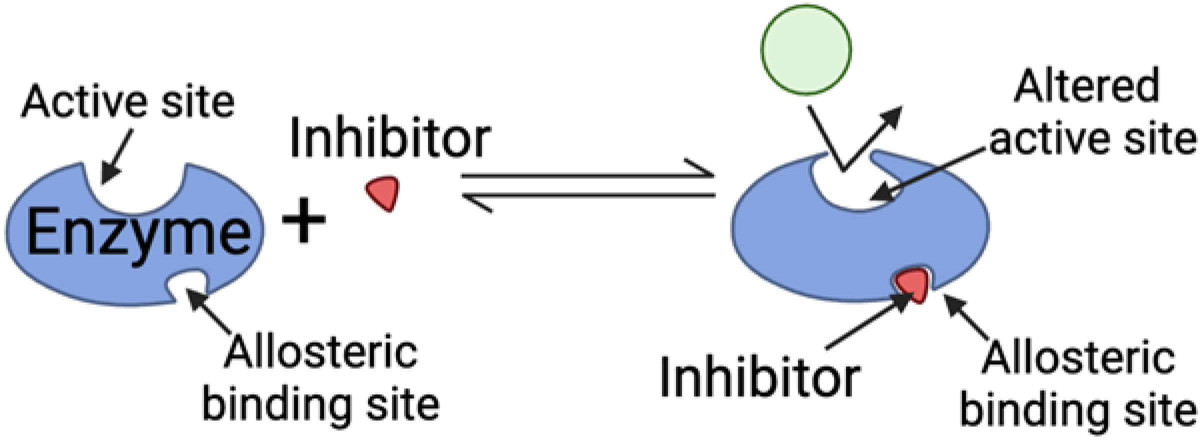
- 1: enzyme
- 2: active site
- 3: Allosteric site
- 4: Allosteric inhibitor
- 5: Substrate
- 6: modified active site (no longer binds the substrate)

Feedback inhibition looks like noncompetitive inhibition

Allosteric Inhibition



Noncompetitive Inhibition

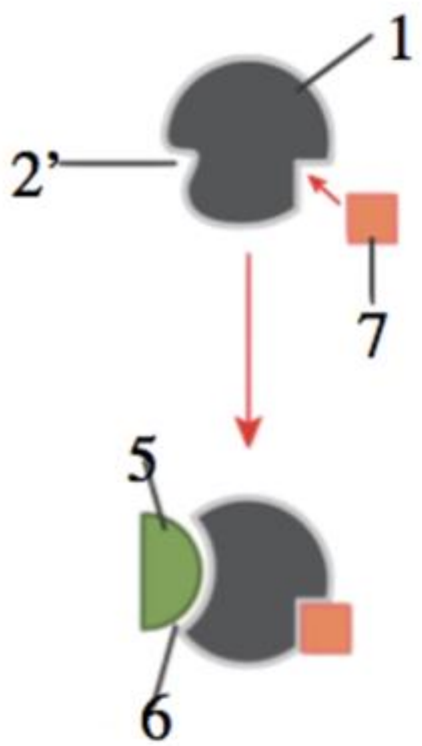


The difference is the context.

- Allosteric inhibition is a form of regulation
- Non-competitive inhibition is about an enzyme's molecular environment.

Feedback can activate

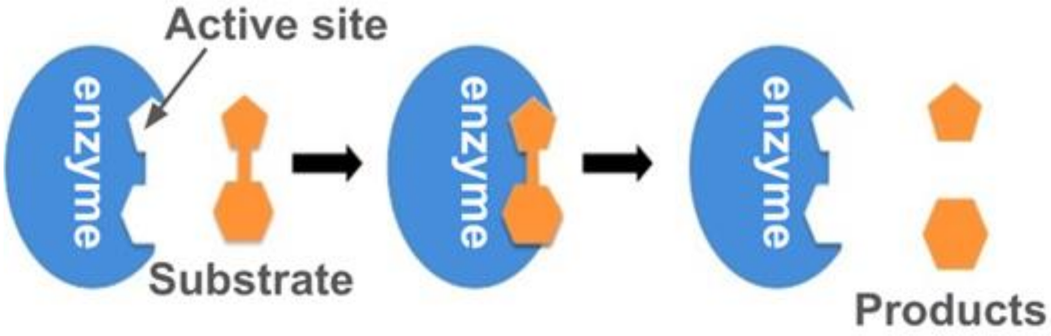
Allosteric Activation



- 1: enzyme
- 2': active site (can't bind substrate)
- 7: Allosteric activator
- 5: Substrate
- 6: modified active site (can bind with the substrate)

Want to learn more?

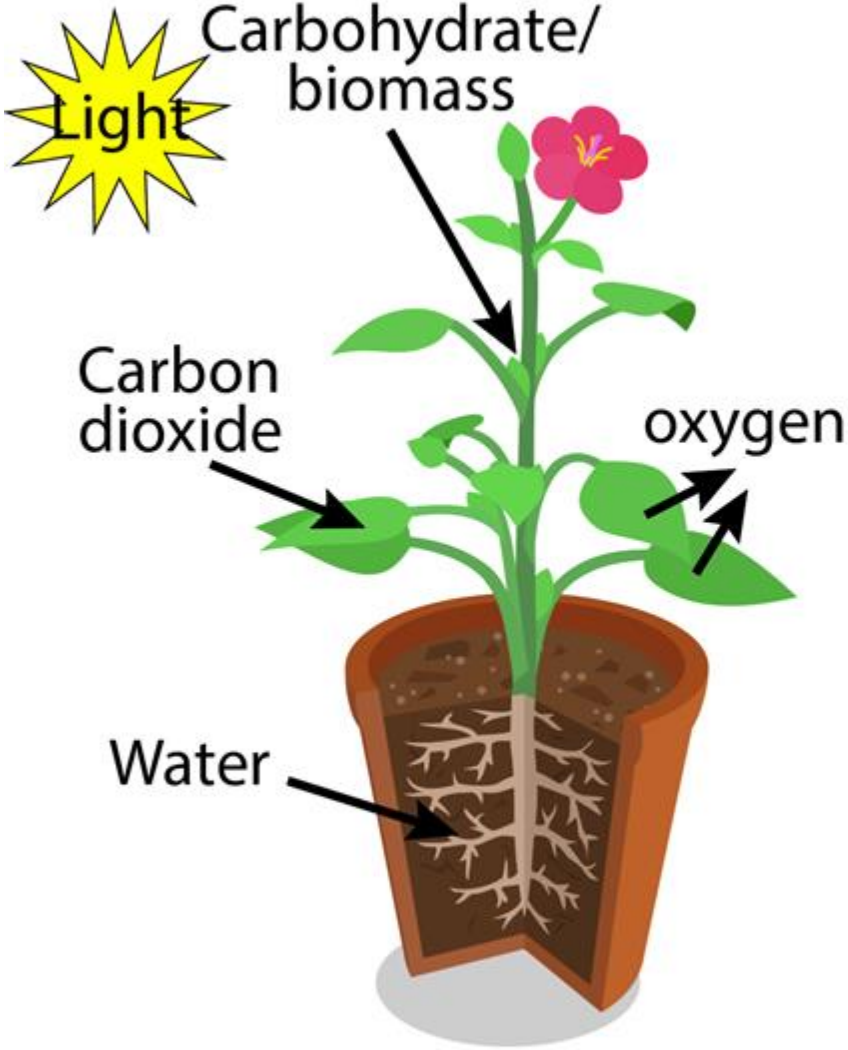
Complete the tutorials about enzymes on Learn-Biology.com



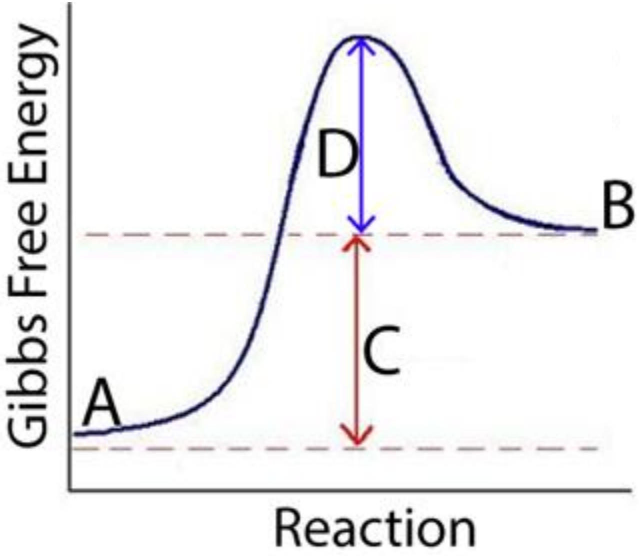
Topic 3.4: ATP and Cell Energy

All living things require energy

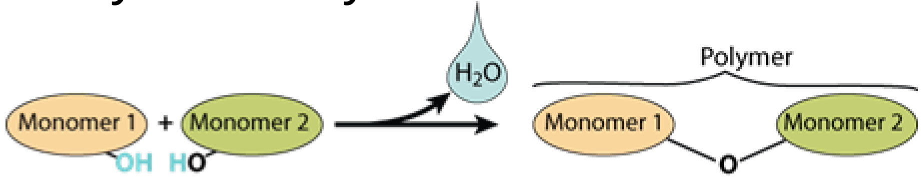
Almost all energy pathways start with photosynthesis



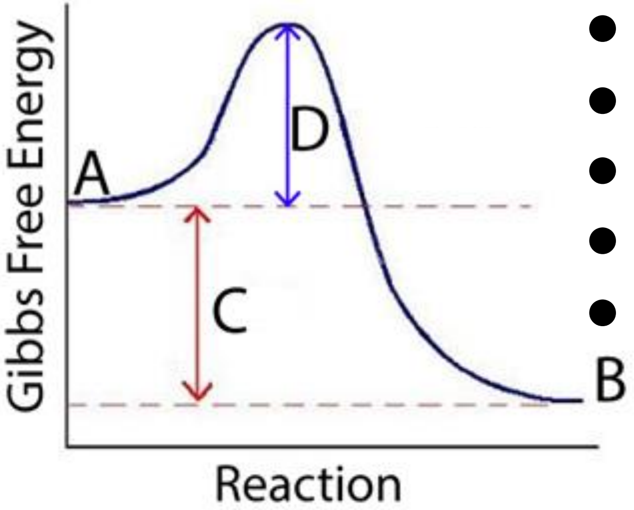
Photosynthesis is an endergonic reaction



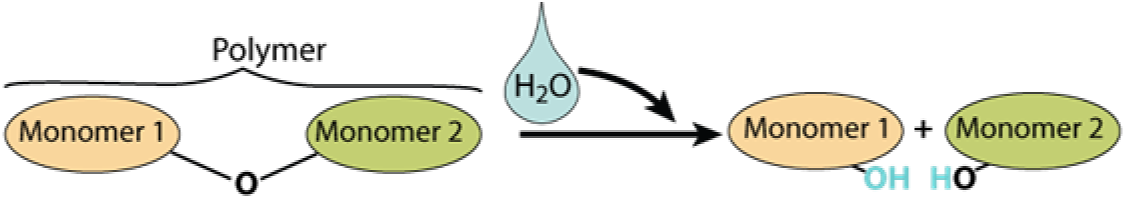
- Requires energy and decreases entropy.
  - A: reactants
  - B: products
  - C: energy difference
  - D: activation energy
- Examples
  - Photosynthesis
    - $6CO_2 + 6H_2O$ + light energy –> $C_6H_{12}O_6 + 6O_2$
  - Dehydration synthesis reactions



Cellular respiration is exergonic

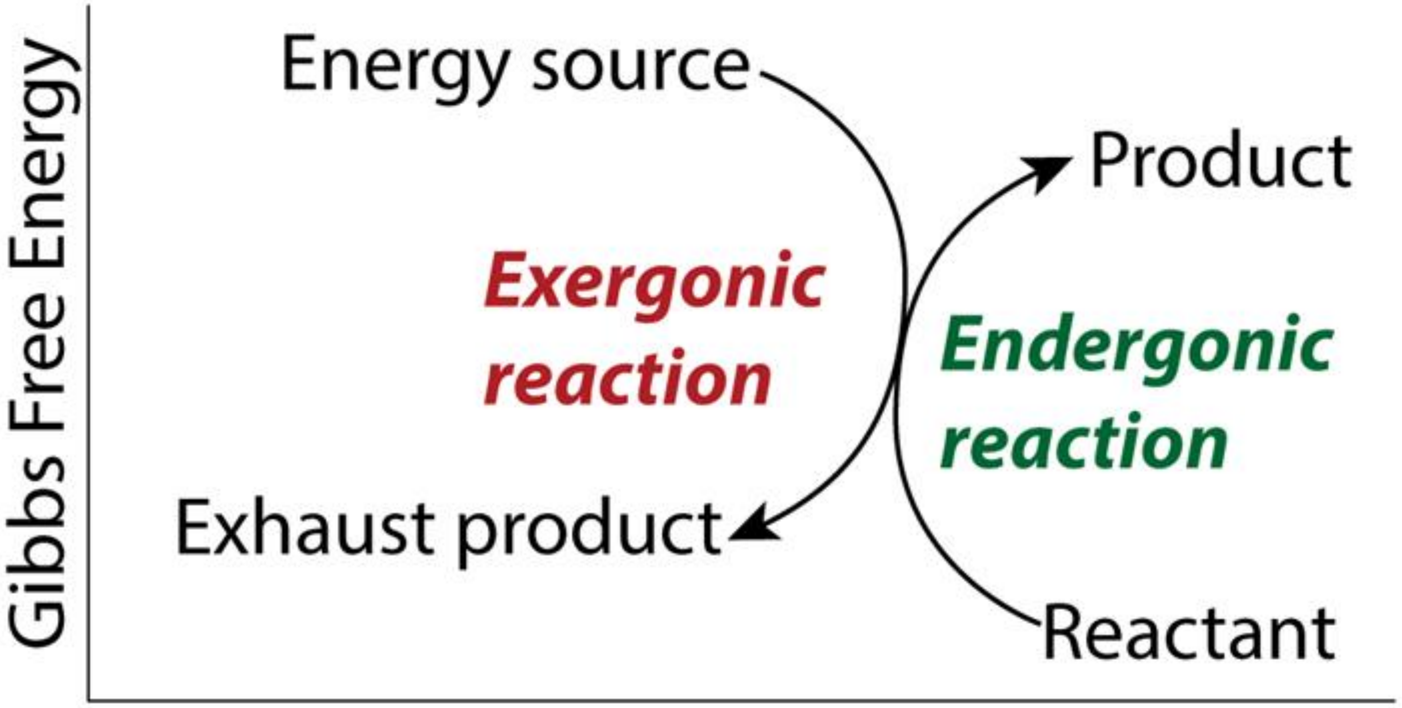


- A: energy of the reactants
- B: energy of the products
- C: energy difference
- D: Activation energy
- Examples
  - Combustion
  - Cellular respiration
    - $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy/ATP
  - Most hydrolysis reactions



Exergonic reactions release energy and increase entropy

A key process in living things is *energy coupling.*



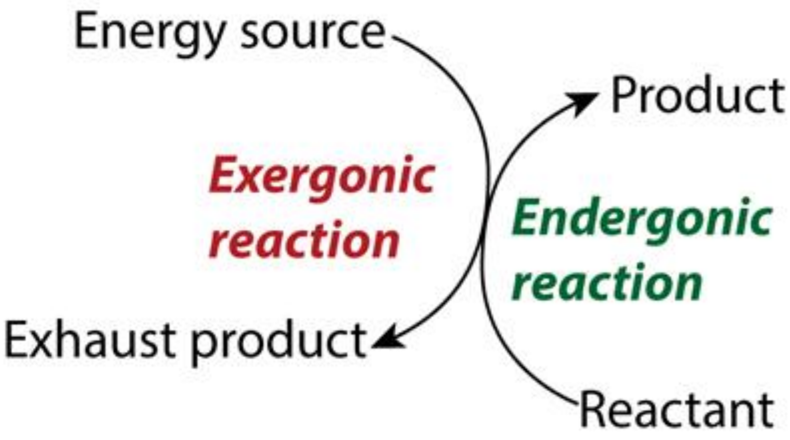
- Linking an exergonic reaction to an endergonic one
- The exergonic reaction provides the energy to drive the endergonic reaction forward

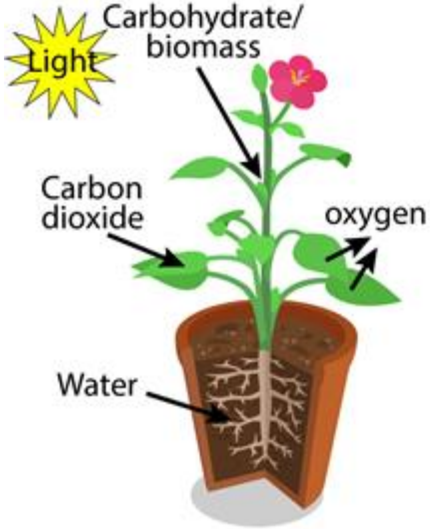
Exergonic nuclear fusion powers photosynthesis

$4(^1H)$

$^2He + 2(e+) + 2(v)$

Nuclear fusion





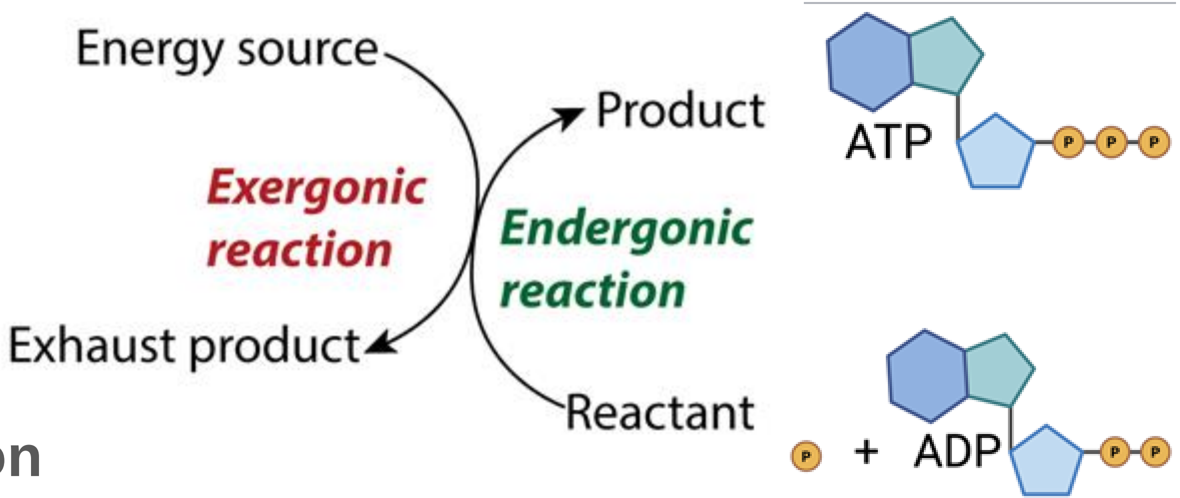
Photosynthesis

Exergonic cellular respiration powers ATP formation

$C_6H_{12}O_6 + 6O_2 \rightarrow$

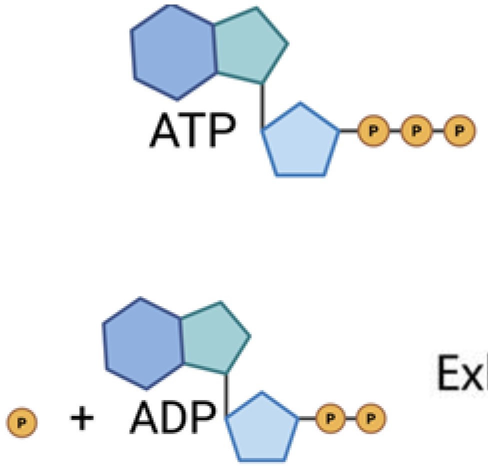
$6CO_2 + 6H_2O$

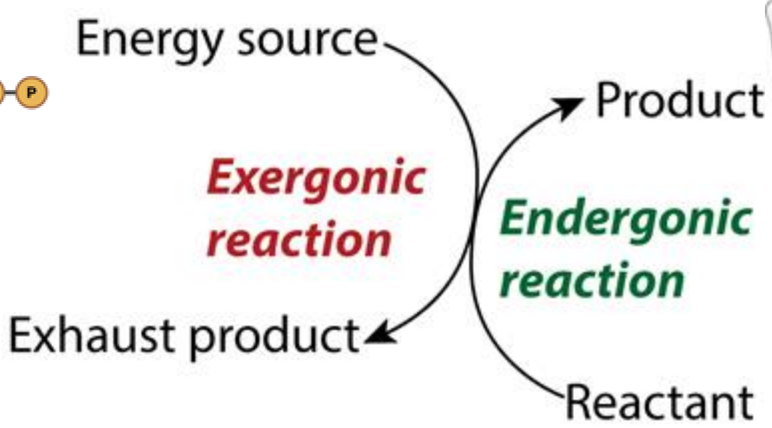
Cellular respiration

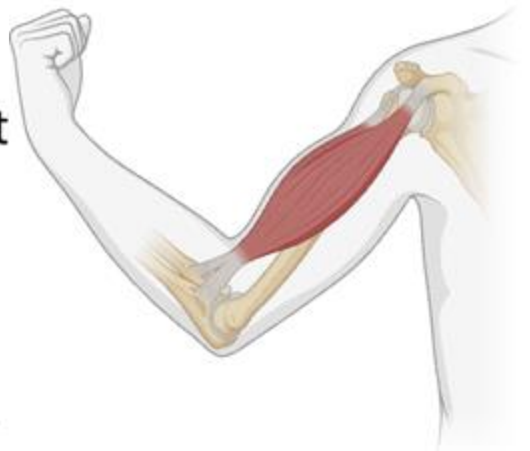


ATP formation

Exergonic breakdown of ATP to ADP and P_i powers muscle contraction…



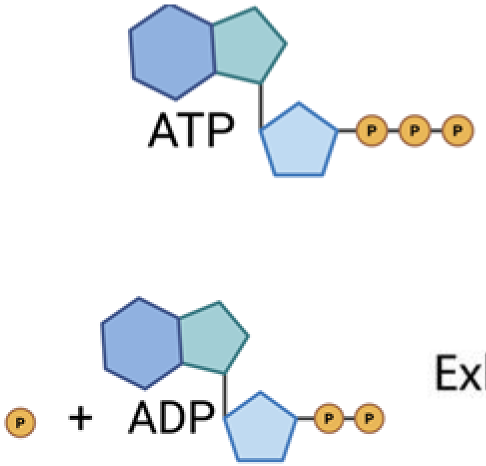


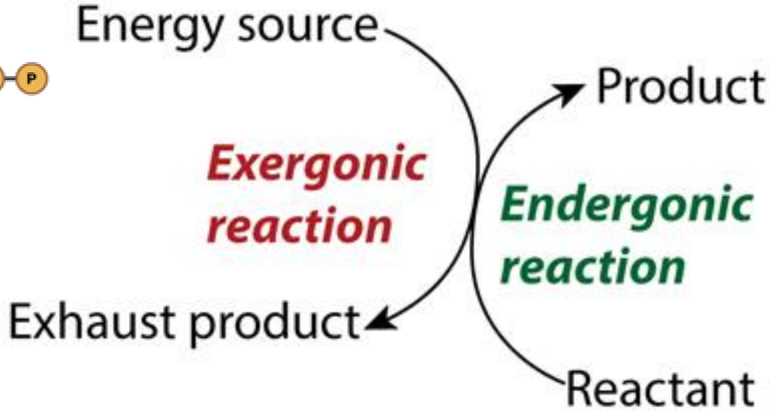


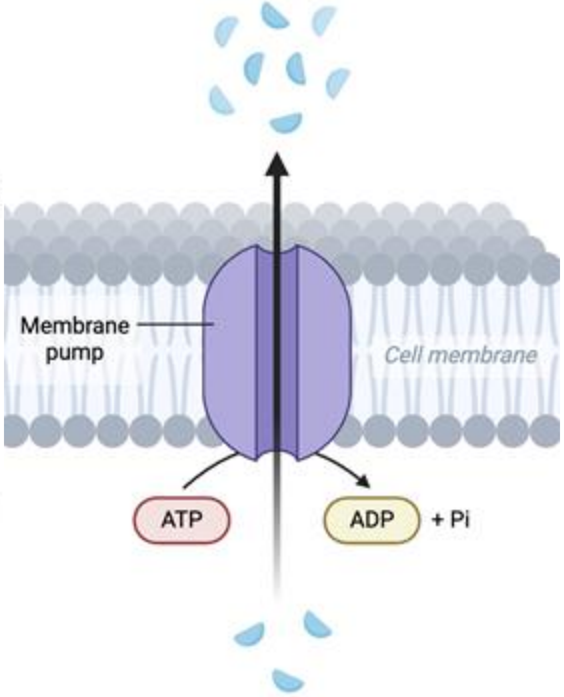
$ATP \rightarrow ADP + P_i$

Muscle Contraction

… and active transport



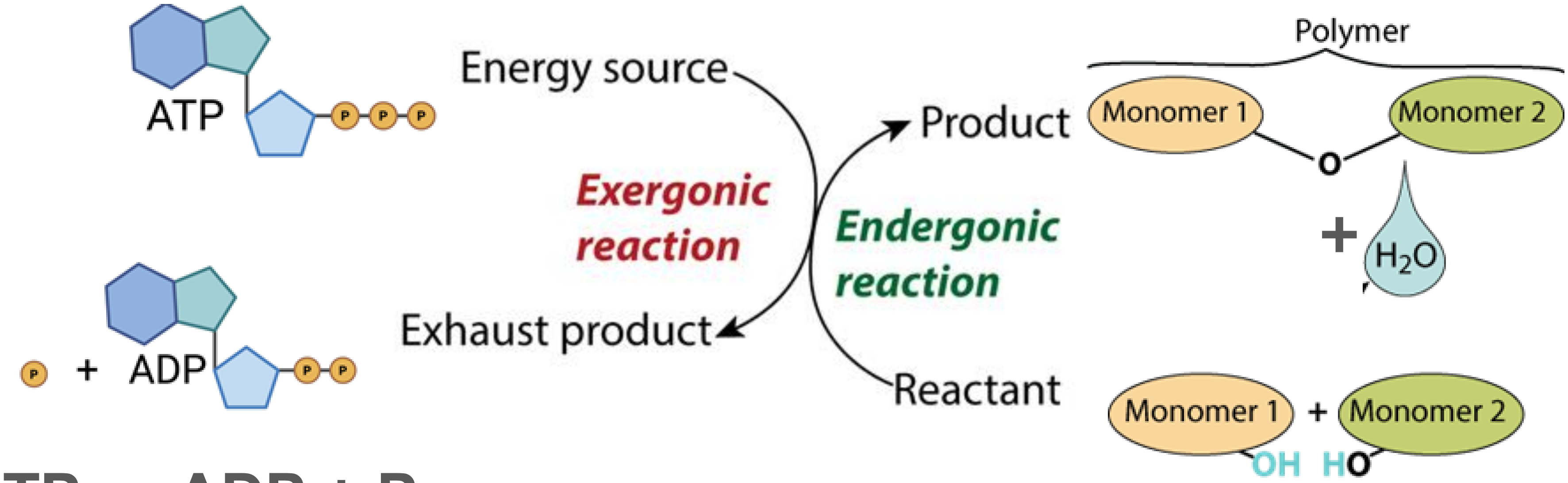




$$ATP \rightarrow ADP + P_i$$

Active Transport

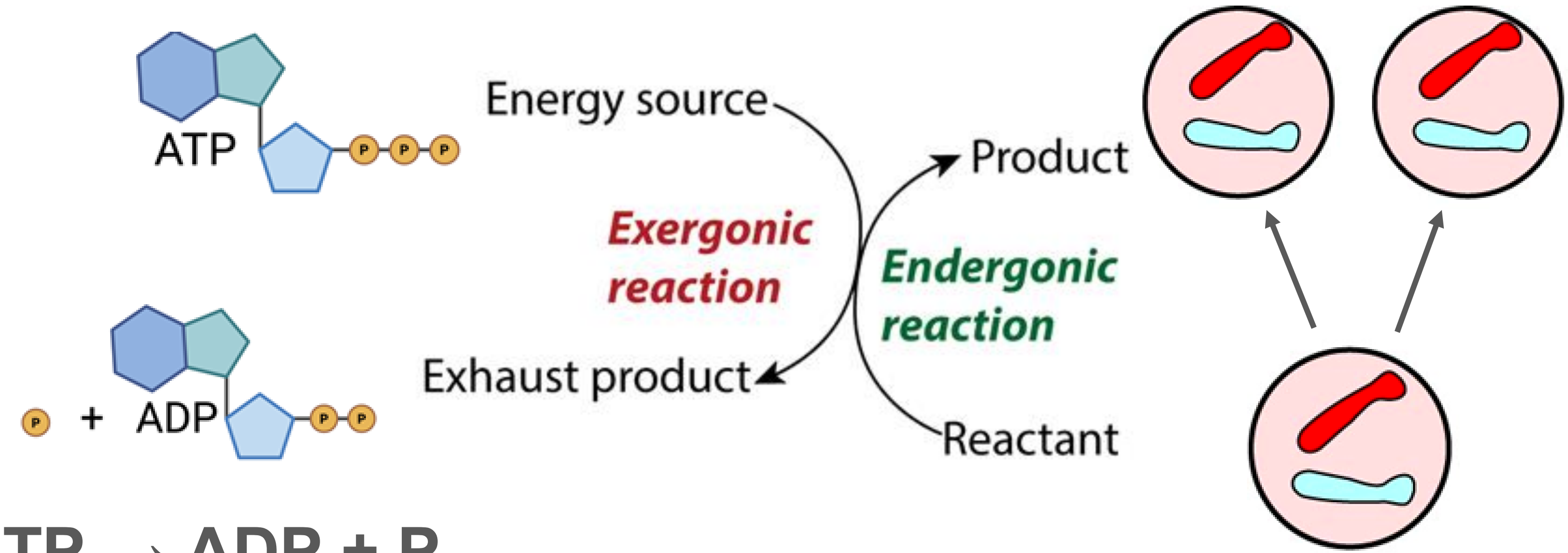
…Dehydration synthesis



$$ATP \rightarrow ADP + P_i$$

Dehydration Synthesis

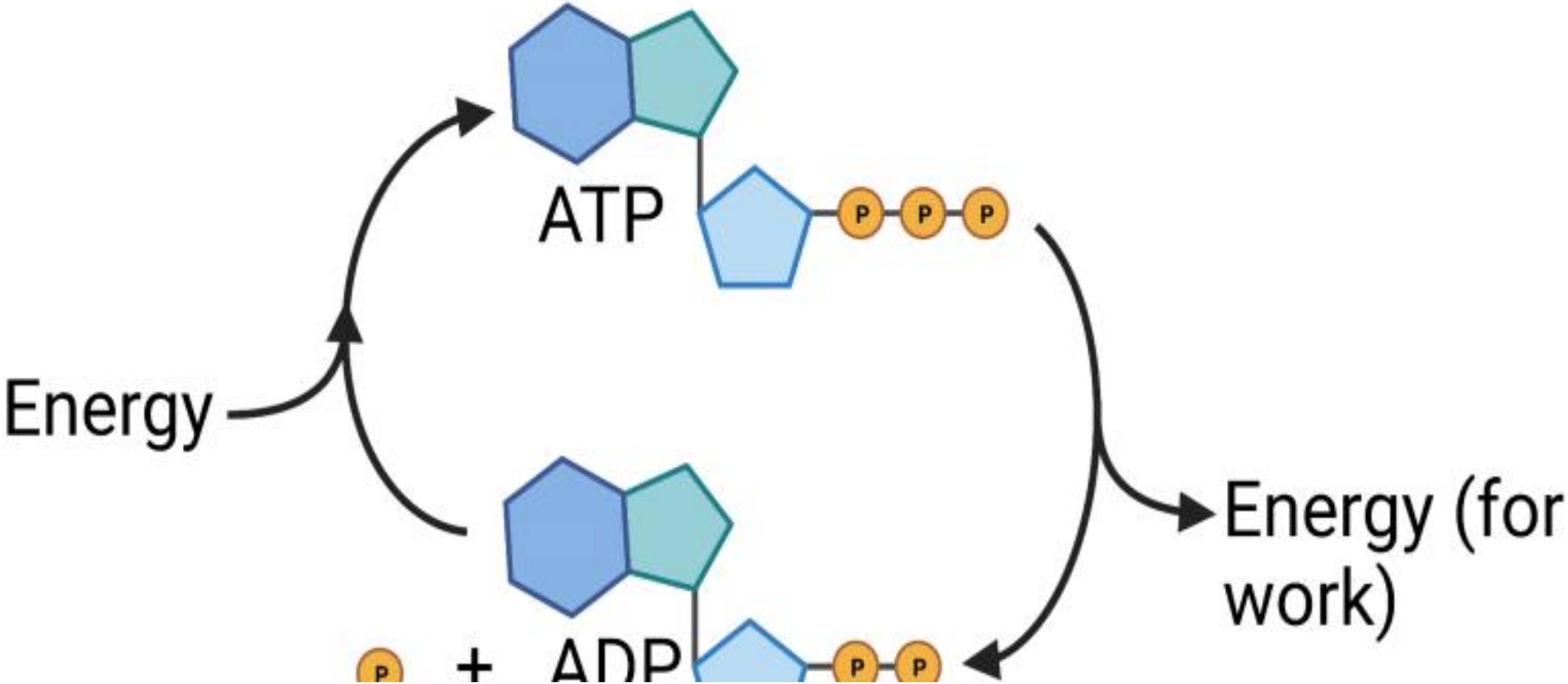
…Cell division



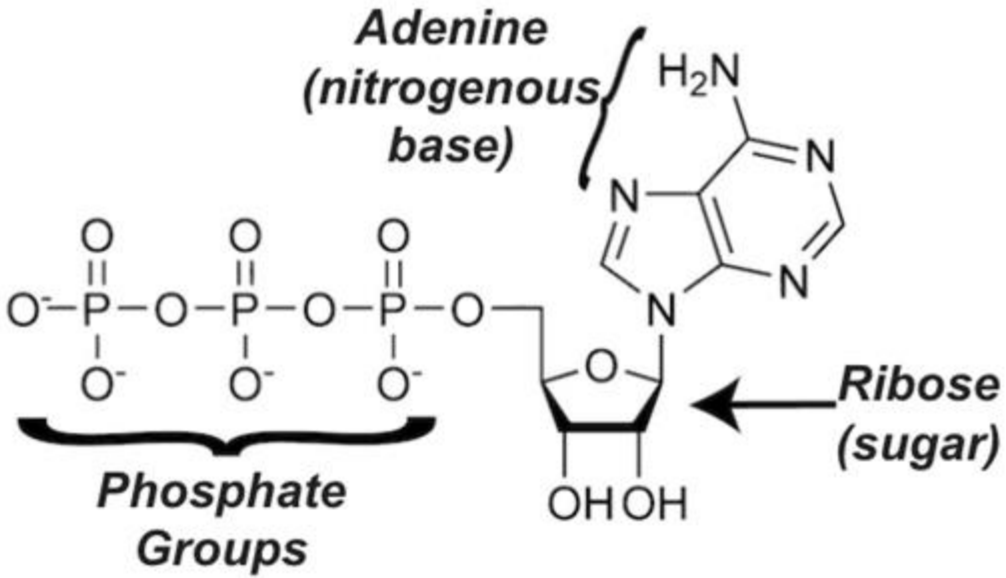
$$ATP \rightarrow ADP + P_i$$

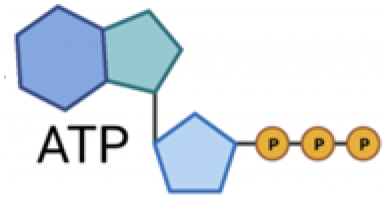
Cell division, Growth

ATP is how living things get work done



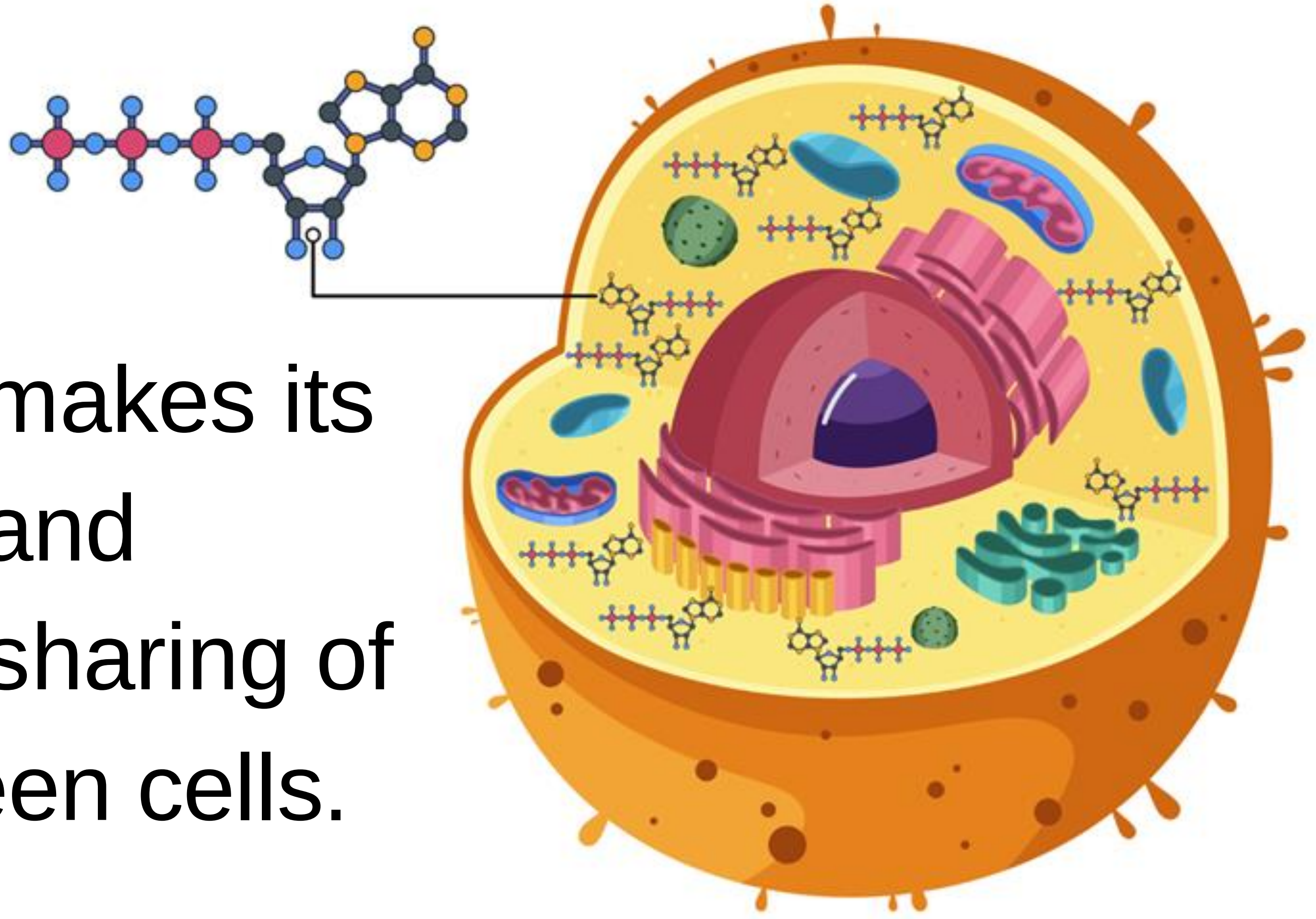
Describe the structure and function of ATP.



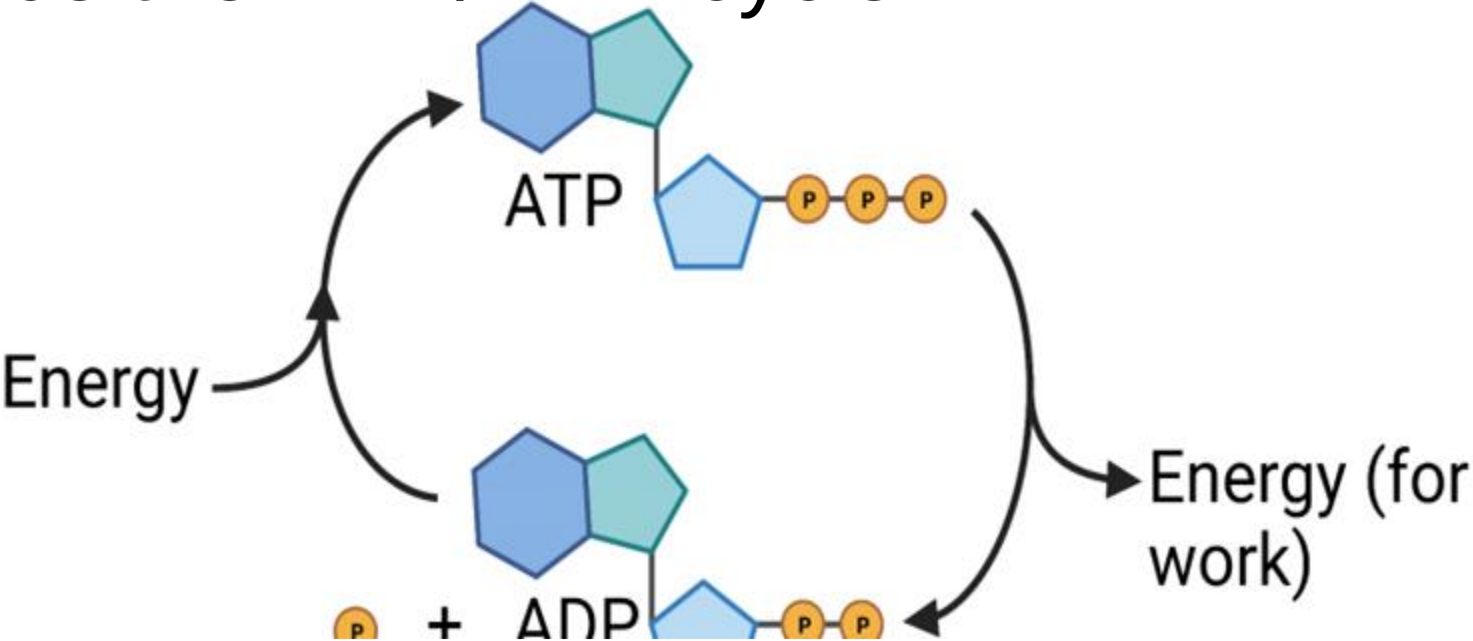


- **STRUCTURE**:
  - 5-carbon sugar **ribose**
  - the nitrogenous base **adenine**, and
  - 3 **phosphate groups**.
- **FUNCTION:** ATP is used to power work within cells.

Every cell makes its own ATP, and there's no sharing of ATP between cells.



Describe the ATP/ADP cycle



- **TO STORE ENERGY:** cells take energy from food (during cellular respiration) or light (during photosynthesis) and use it to make ATP from ADP and P_i.
- **TO RELEASE ENERGY FOR WORK**: cells remove a phosphate group from ATP, creating ADP and $P_{i.}$

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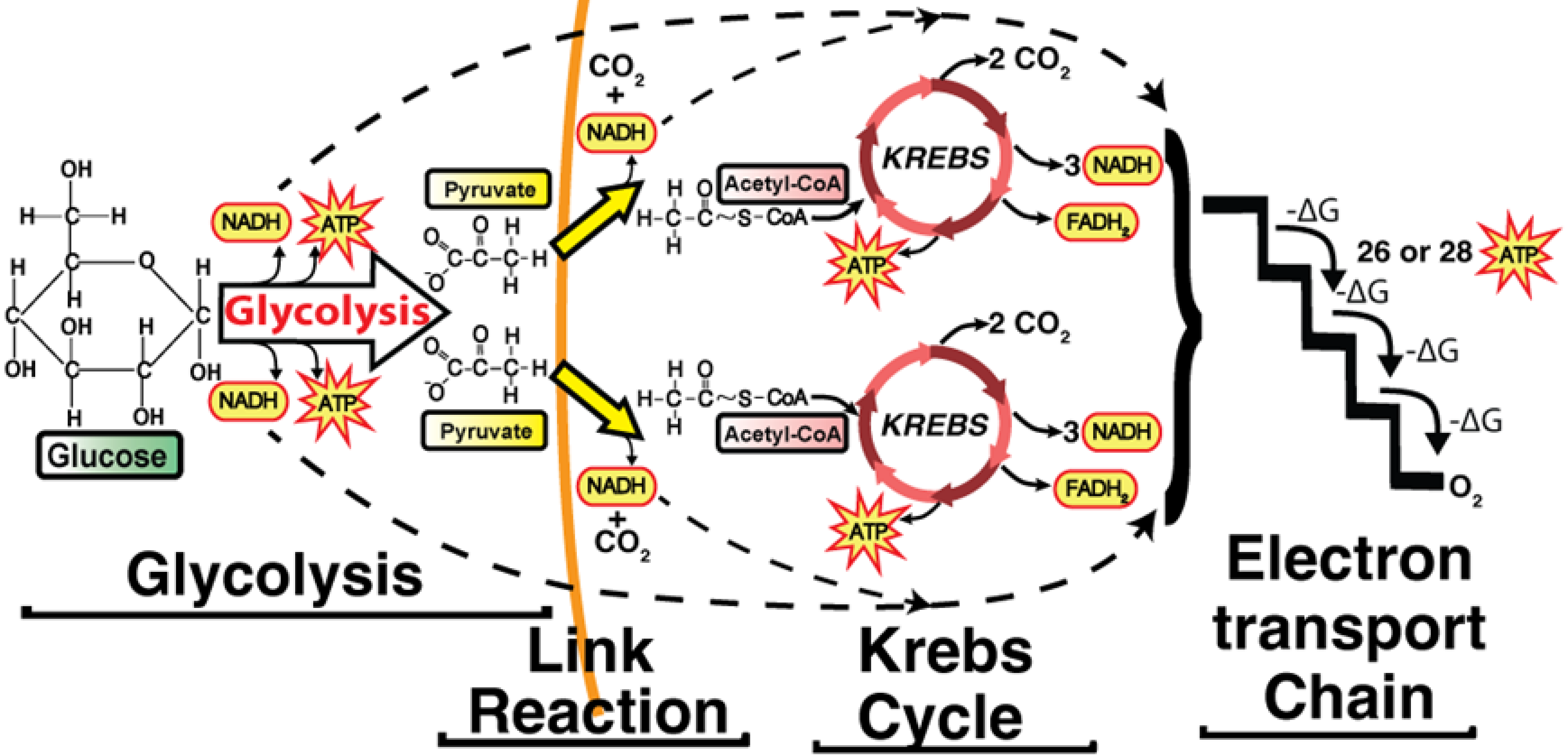
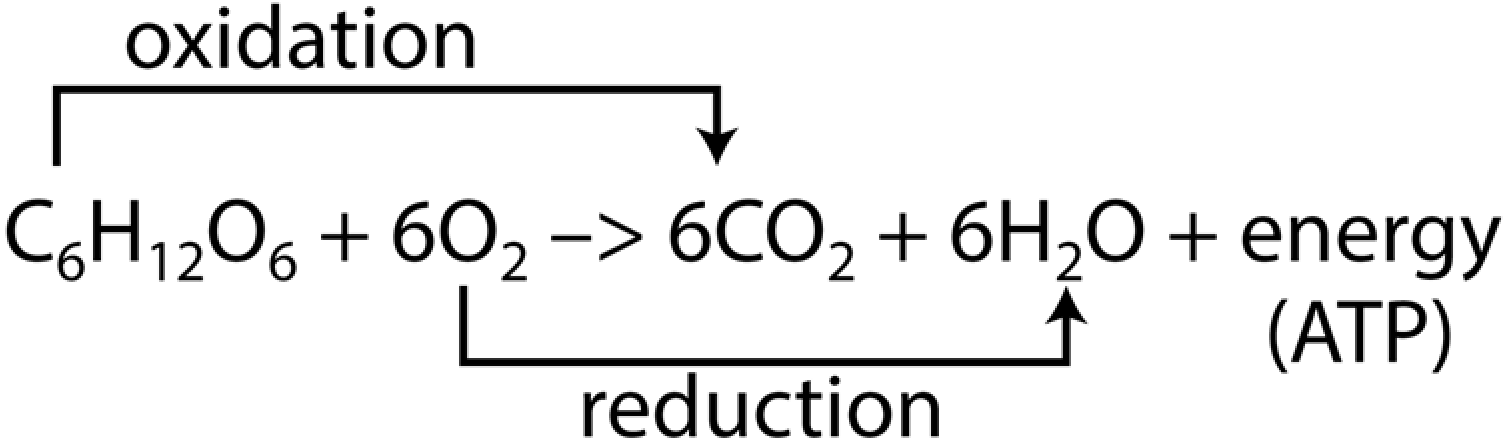
Cellular Respiration: the Big Picture and Glycolysis

Cellular respiration is how living things make ATP



Cellular respiration is a REDOX reaction:

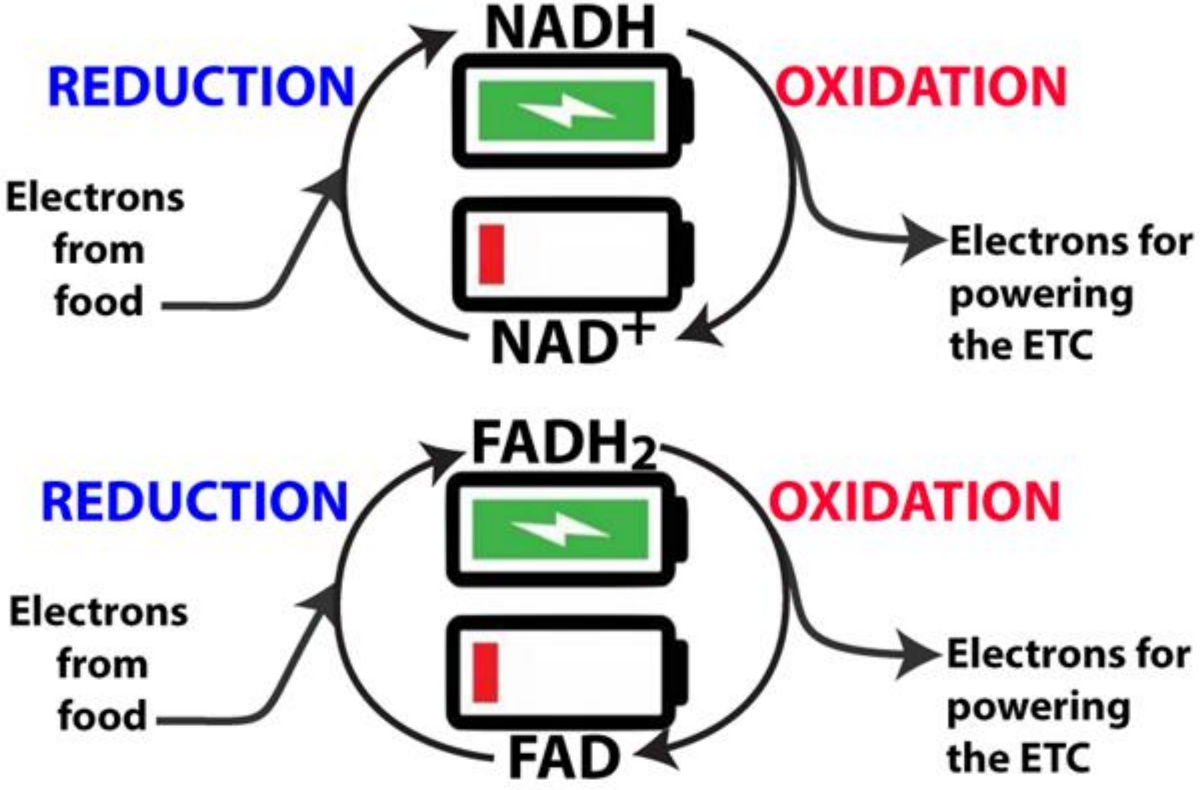
Glucose ($C_6H_{12}O_6$) is oxidized to CO_2, and oxygen is reduced to water



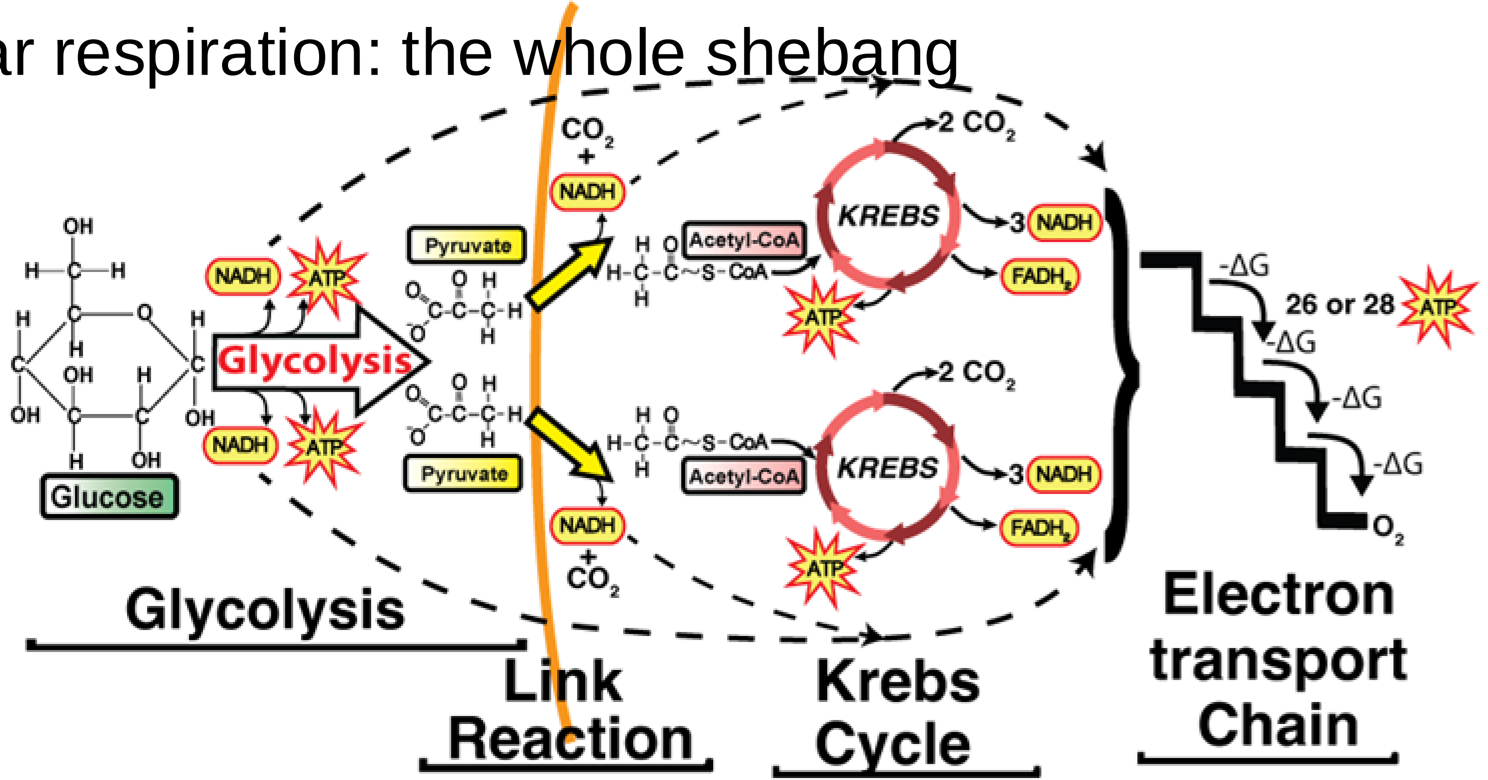
- Oxidation: loss of electrons (and hydrogen atoms)
- Reduction: gain of electrons (and hydrogens)

Along the way, there are intermediate REDOX reactions that reduce mobile electron carriers: NAD^+ and FAD

- NAD^+ is reduced to NADH
- FAD is reduced to $FADH_2$

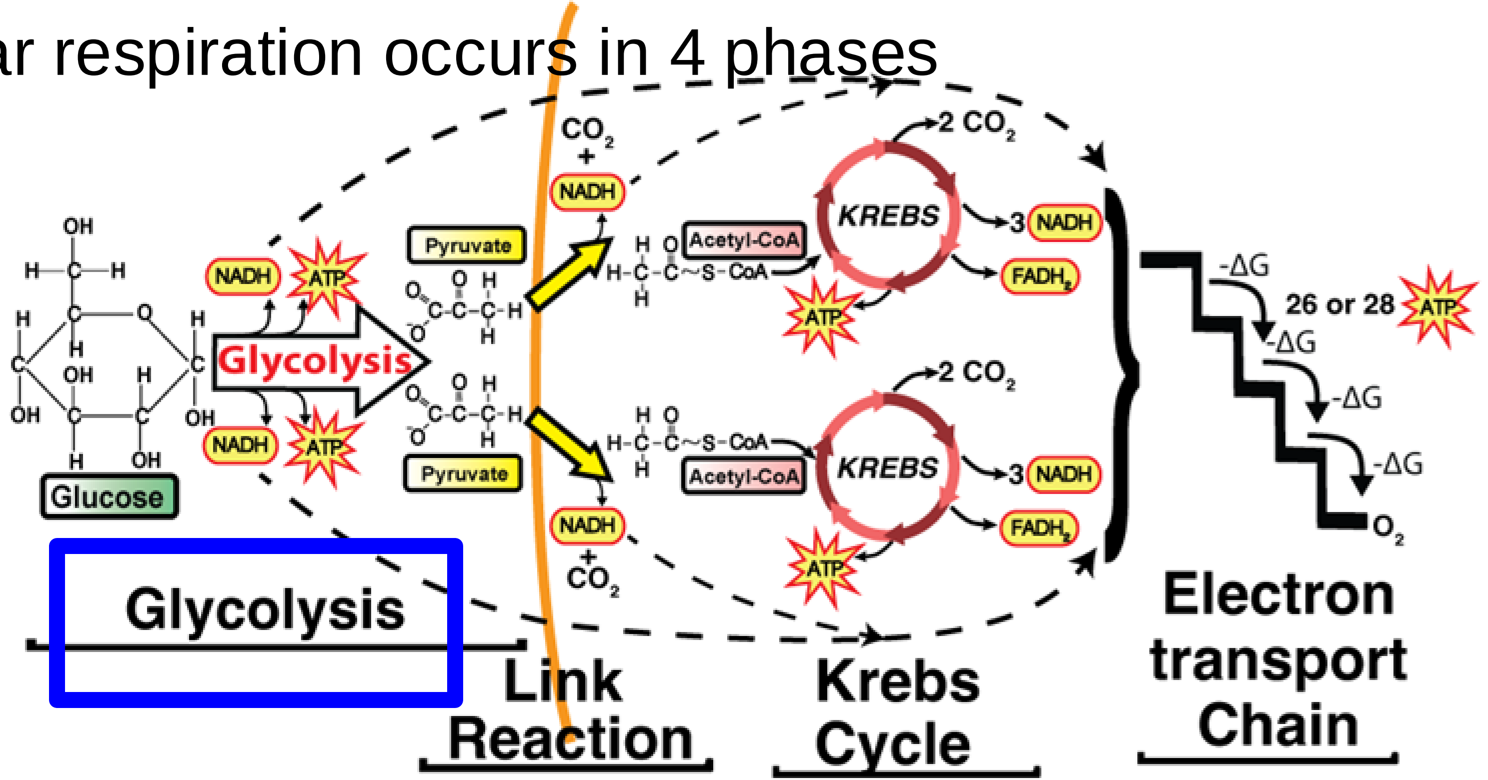


Cellular respiration: the whole shebang



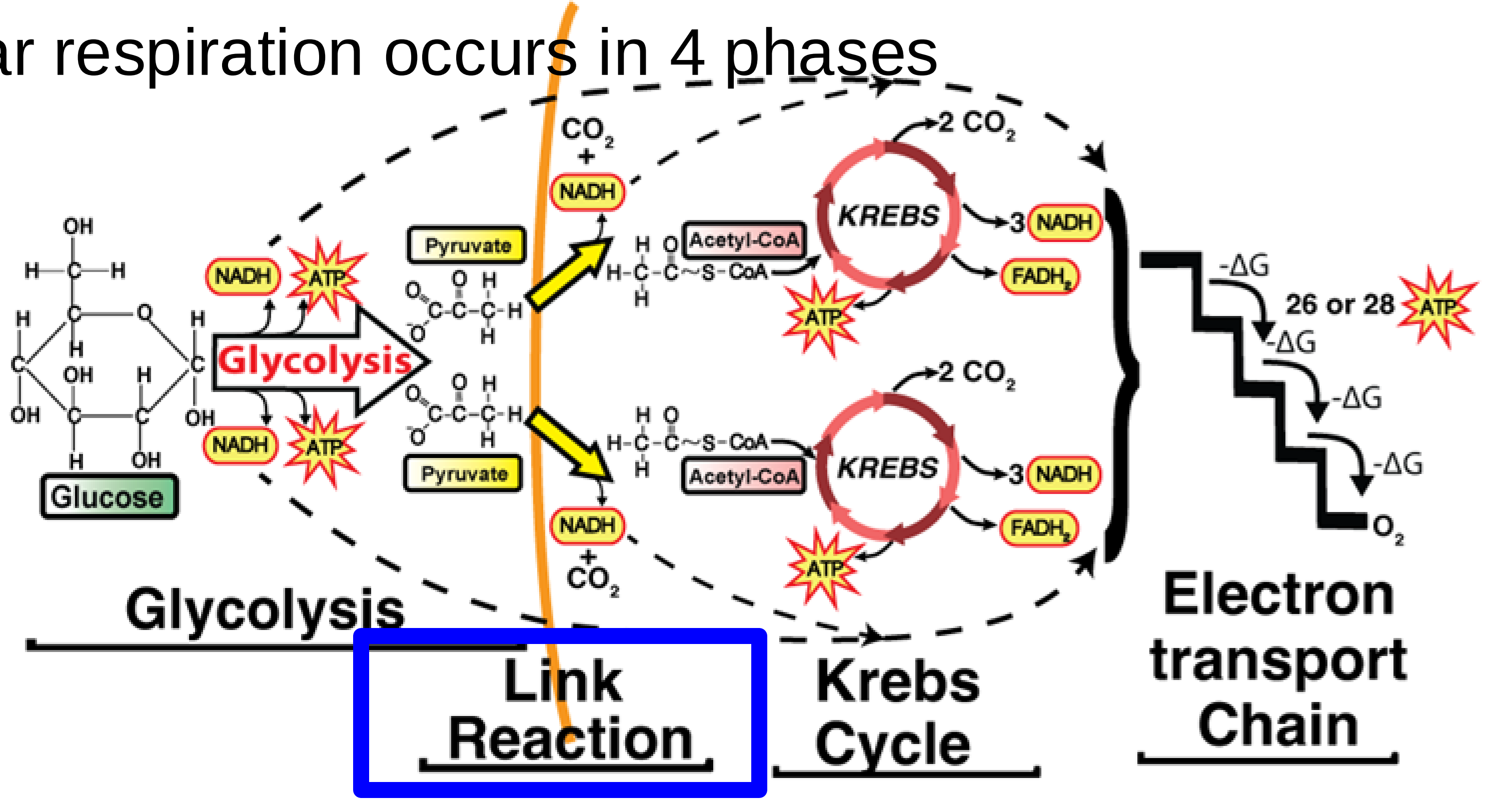
- Glucose and its byproducts are progressively oxidized as NAD^+ and FAD are reduced to NADH and $FADH_2$
- In the last phase, oxidation of NADH and $FADH_2$ powers ATP creation

Cellular respiration occurs in 4 phases



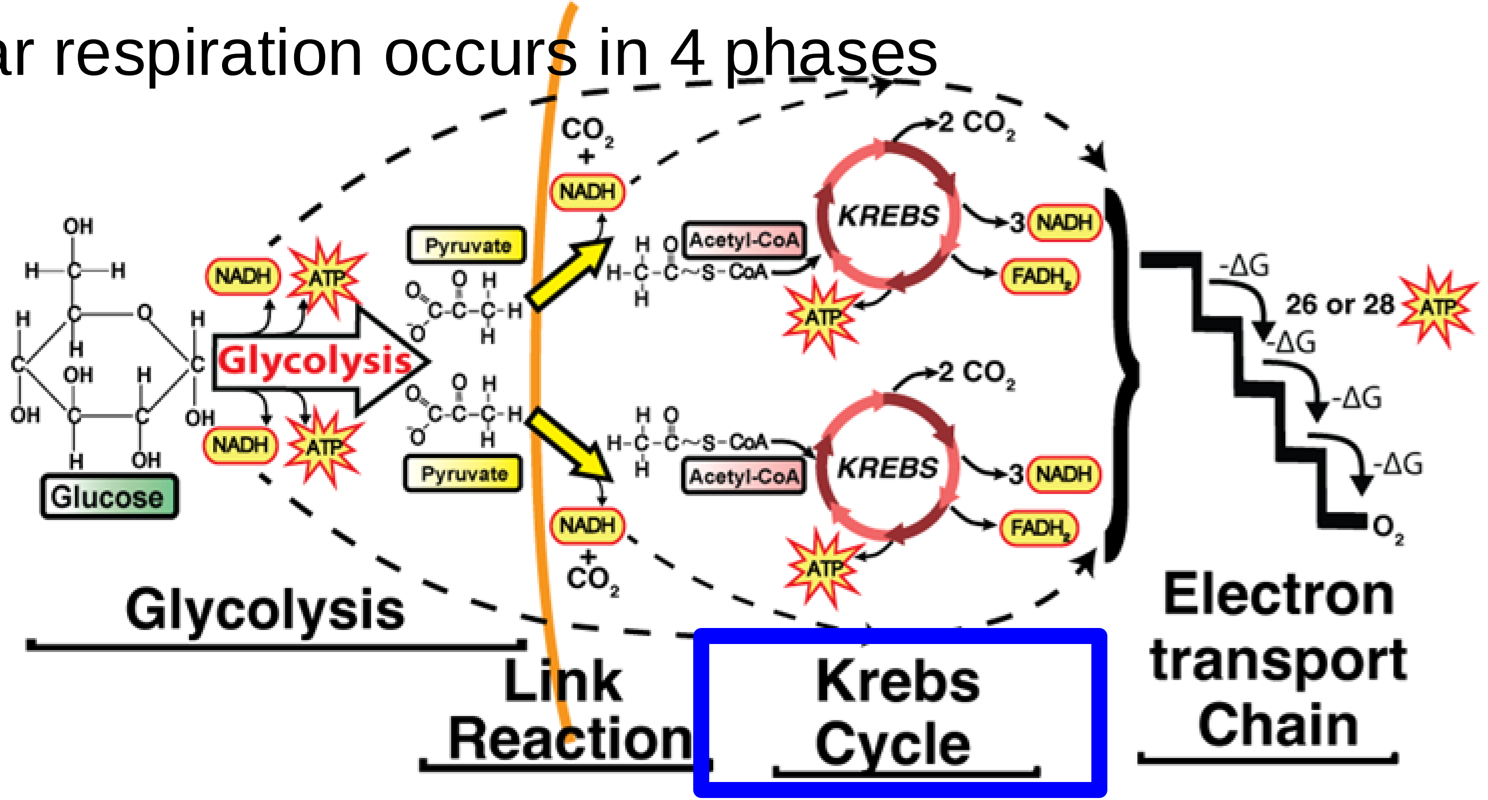
Glycolysis: Energy in glucose generates ATP and NADH. End product: 3-carbon pyruvate (AKA pyruvic acid)

Cellular respiration occurs in 4 phases



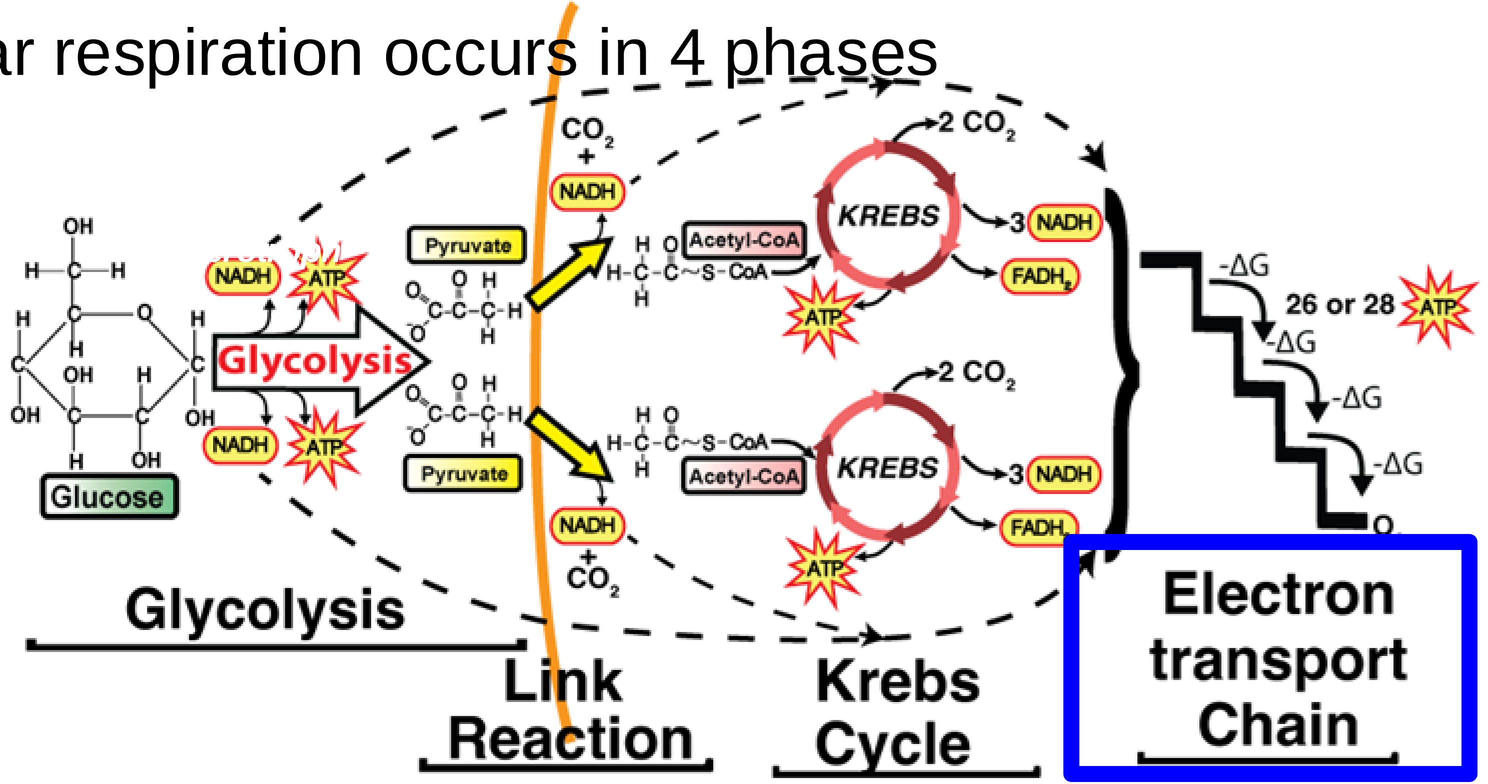
Link reaction: brings pyruvic acid into the mitochondria; converts it to Acetyl CoA; generates NADH, releases one CO_2.

Cellular respiration occurs in 4 phases



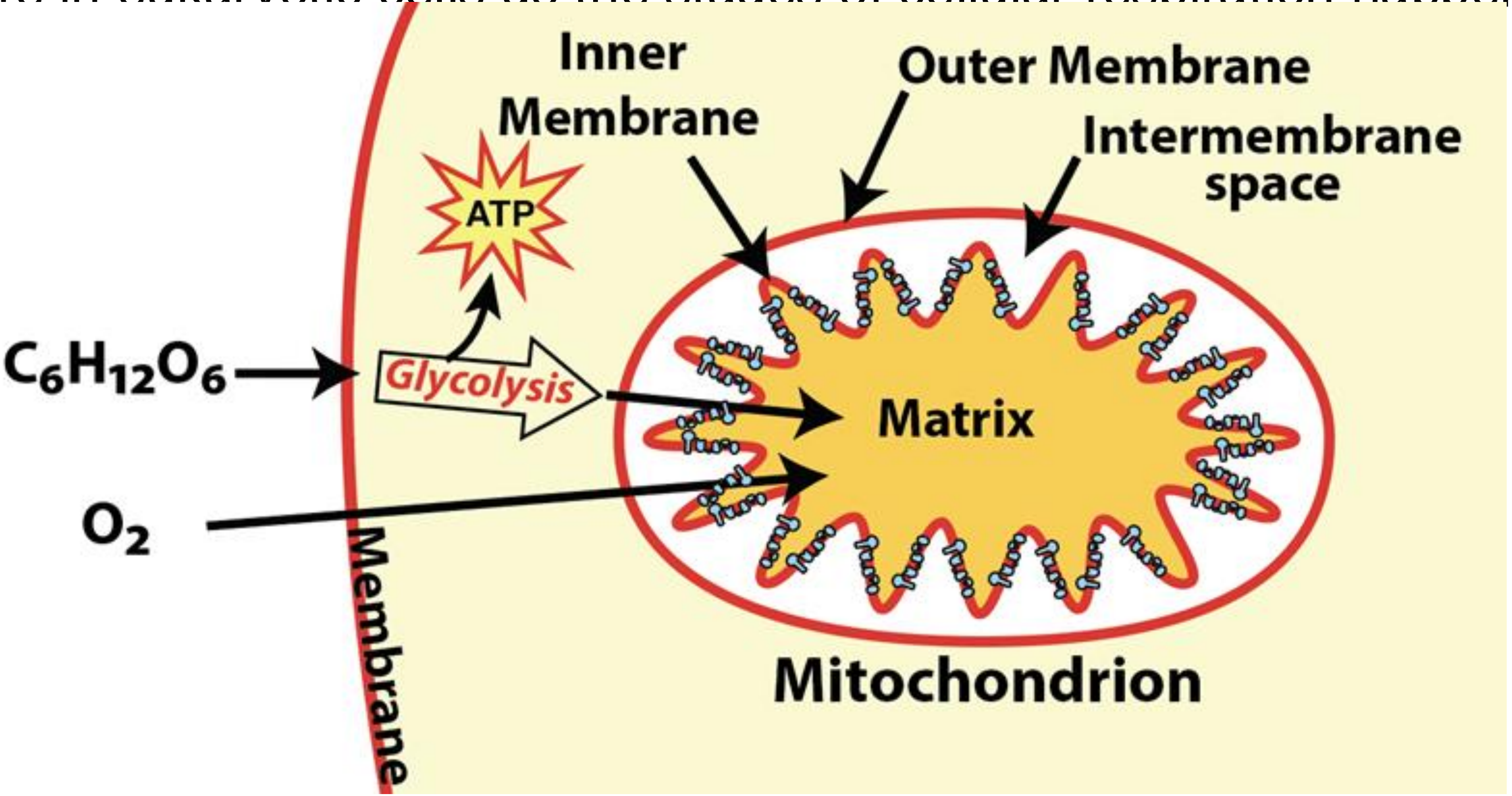
Krebs cycle: oxidizes Acetyl CoA to produce 3 NADH, 1 ATP, and 1 $FADH_2$; releases two CO_2s.

Cellular respiration occurs in 4 phases



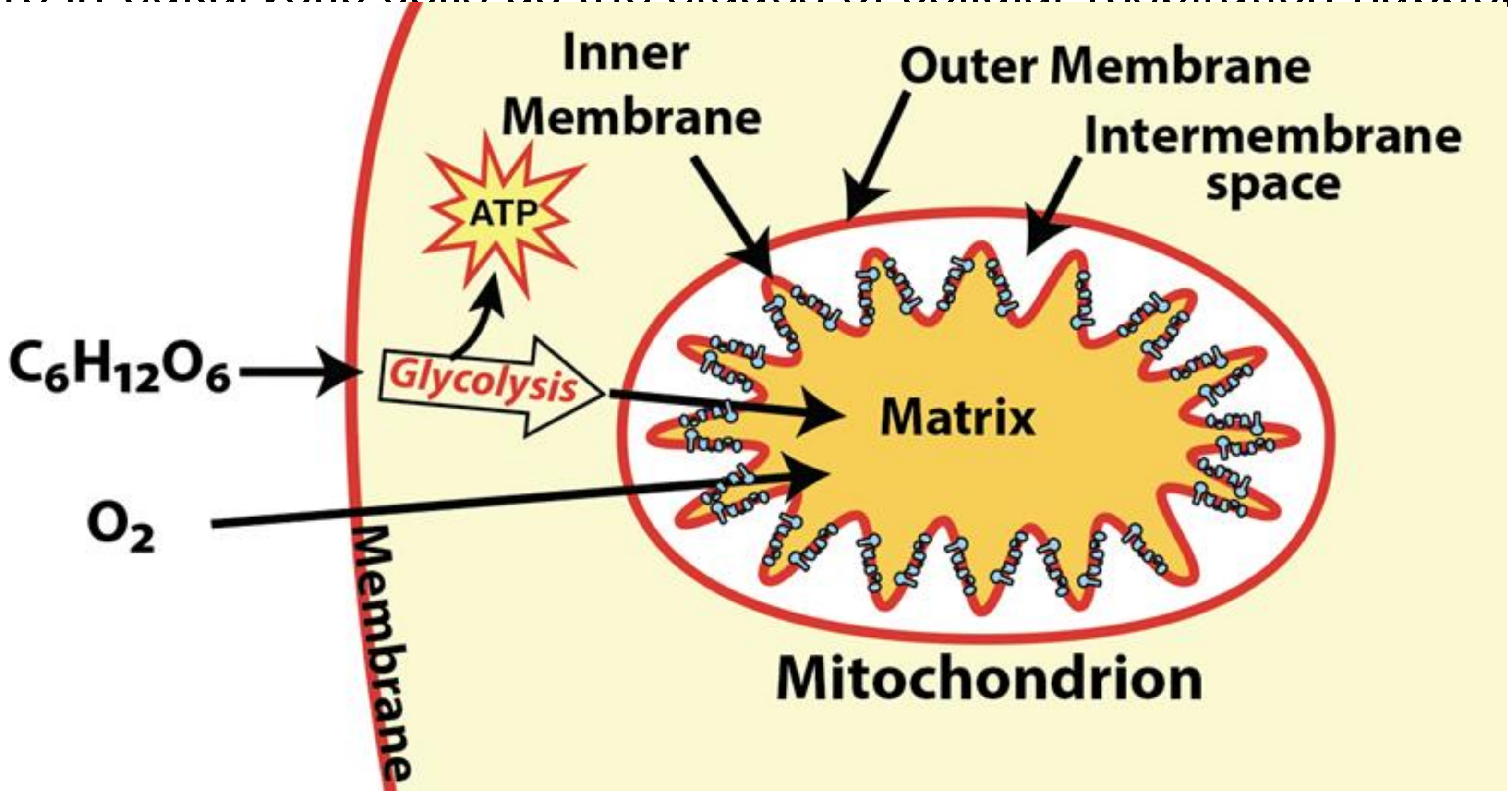
Electron transport chain (ETC): NADH and $FADH_2$ are oxidized to create electron flow which powers phosphorylation of ADP to ATP

Where in eukaryotic cells do the stages of cellular respiration happen?



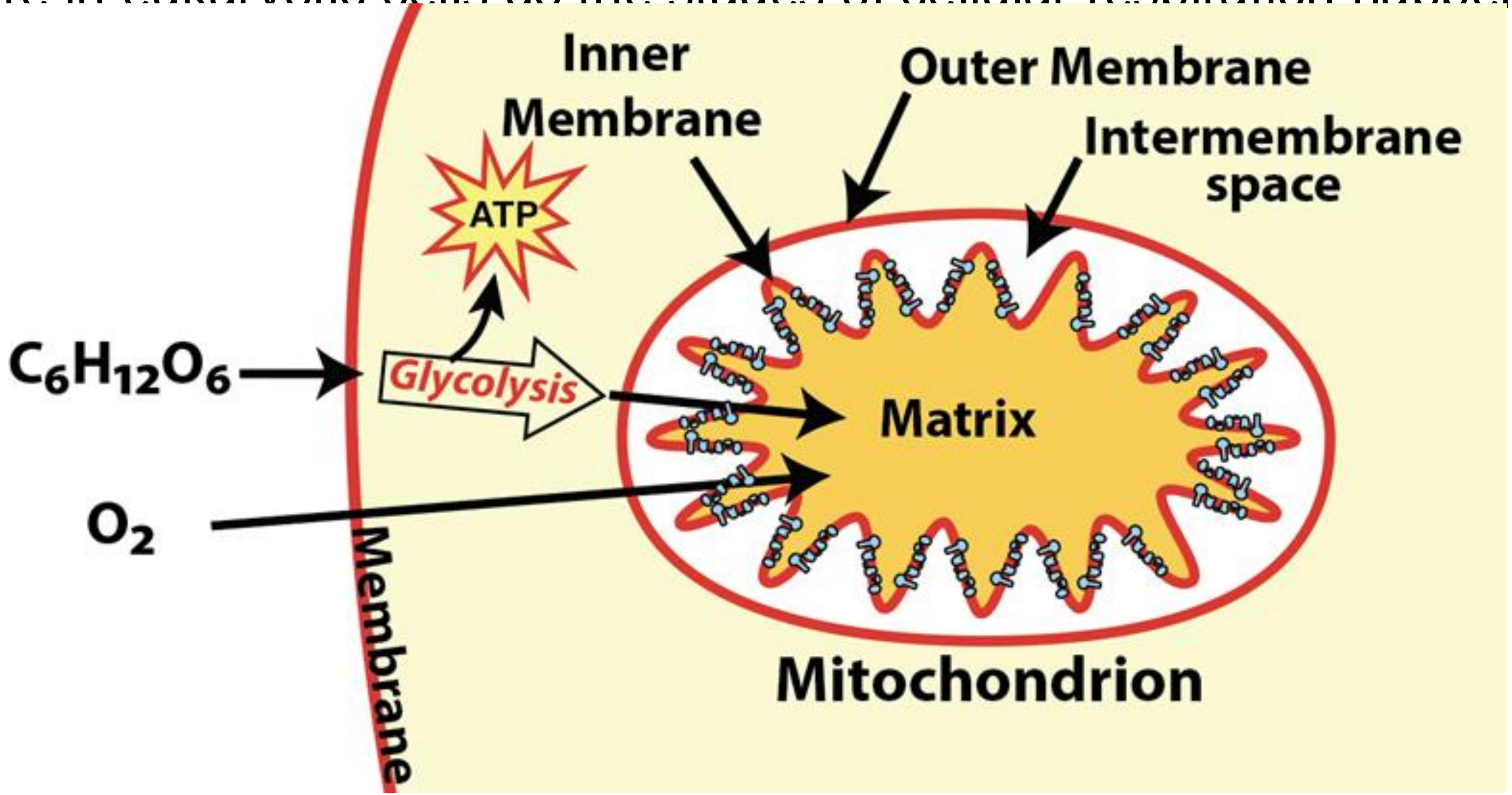
Glycolysis: cytoplasm

Where in eukaryotic cells do the stages of cellular respiration happen?



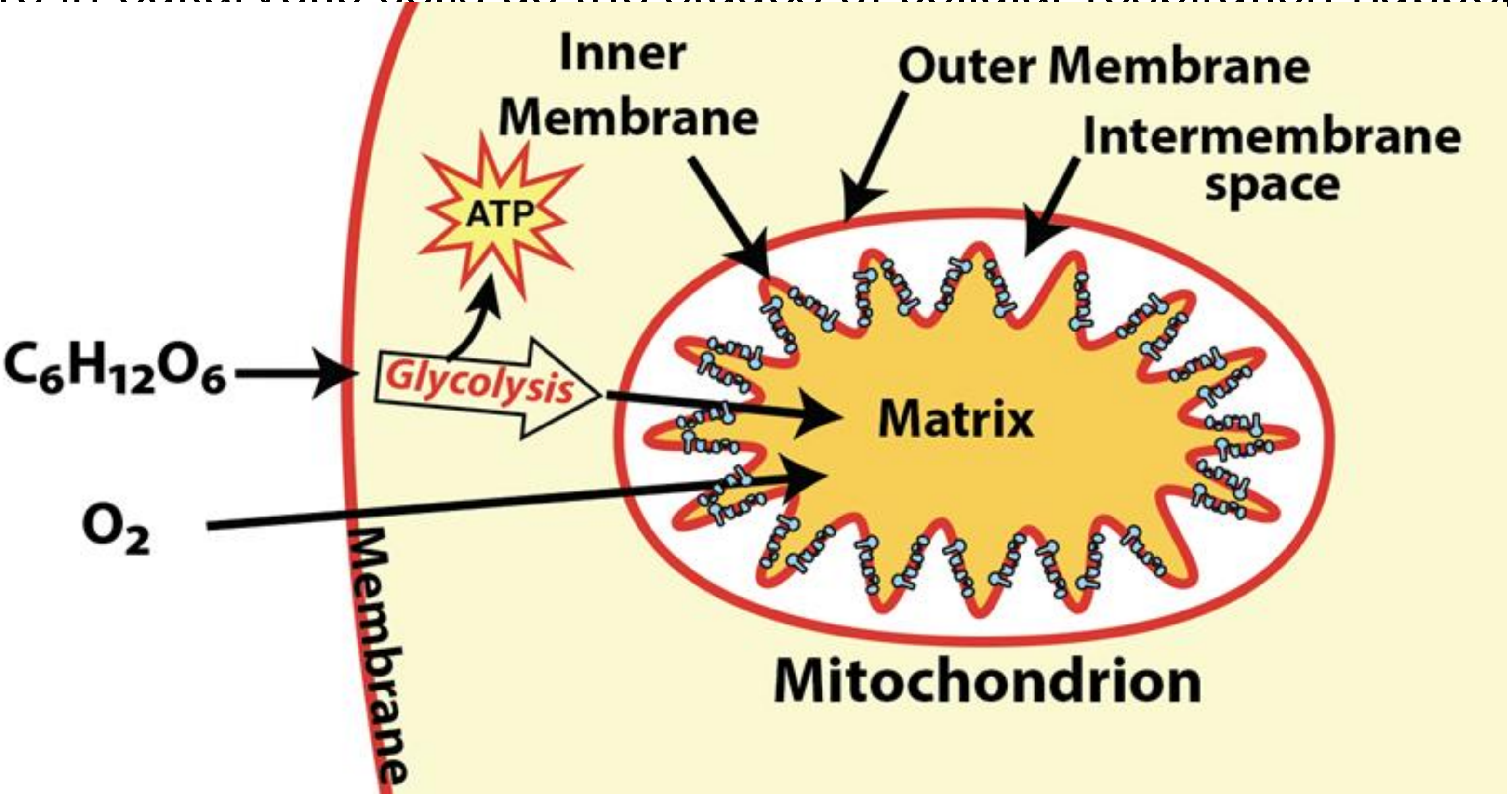
Link Reaction: as pyruvate crosses the mitochondrial membranes and enters the mitochondrial matrix

Where in eukaryotic cells do the stages of cellular respiration happen?



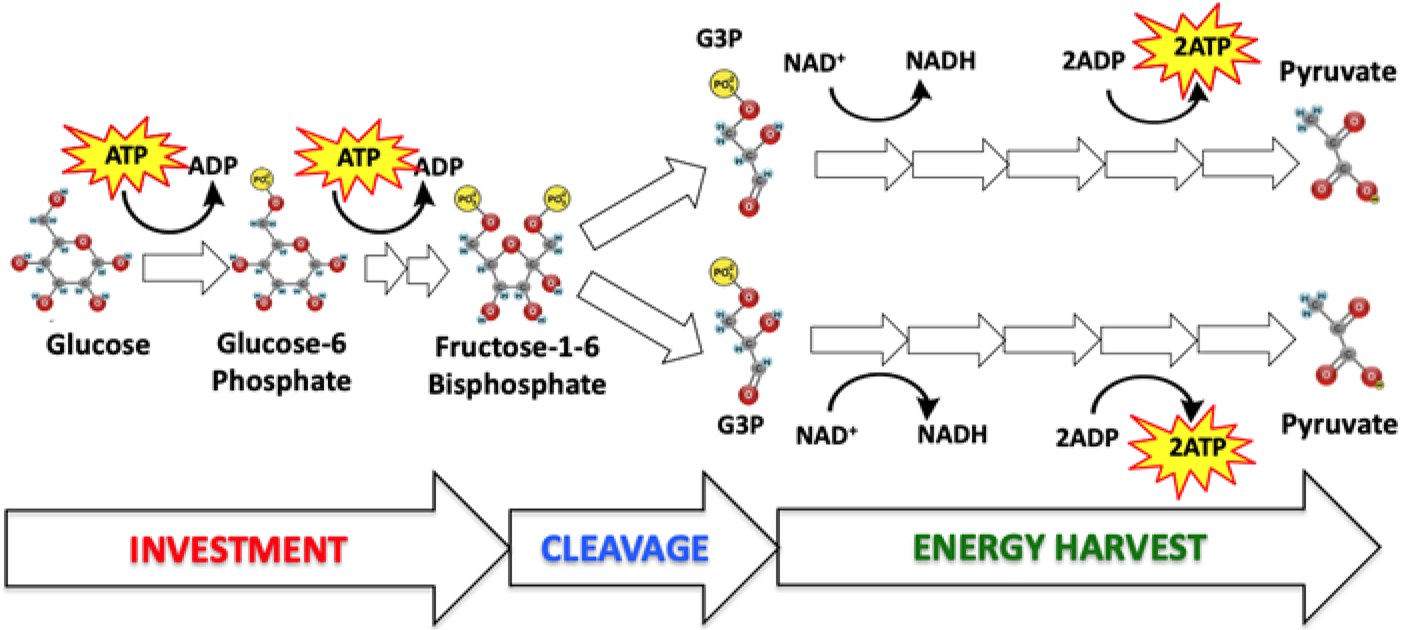
Krebs cycle: mitochondrial matrix

Where in eukaryotic cells do the stages of cellular respiration happen?

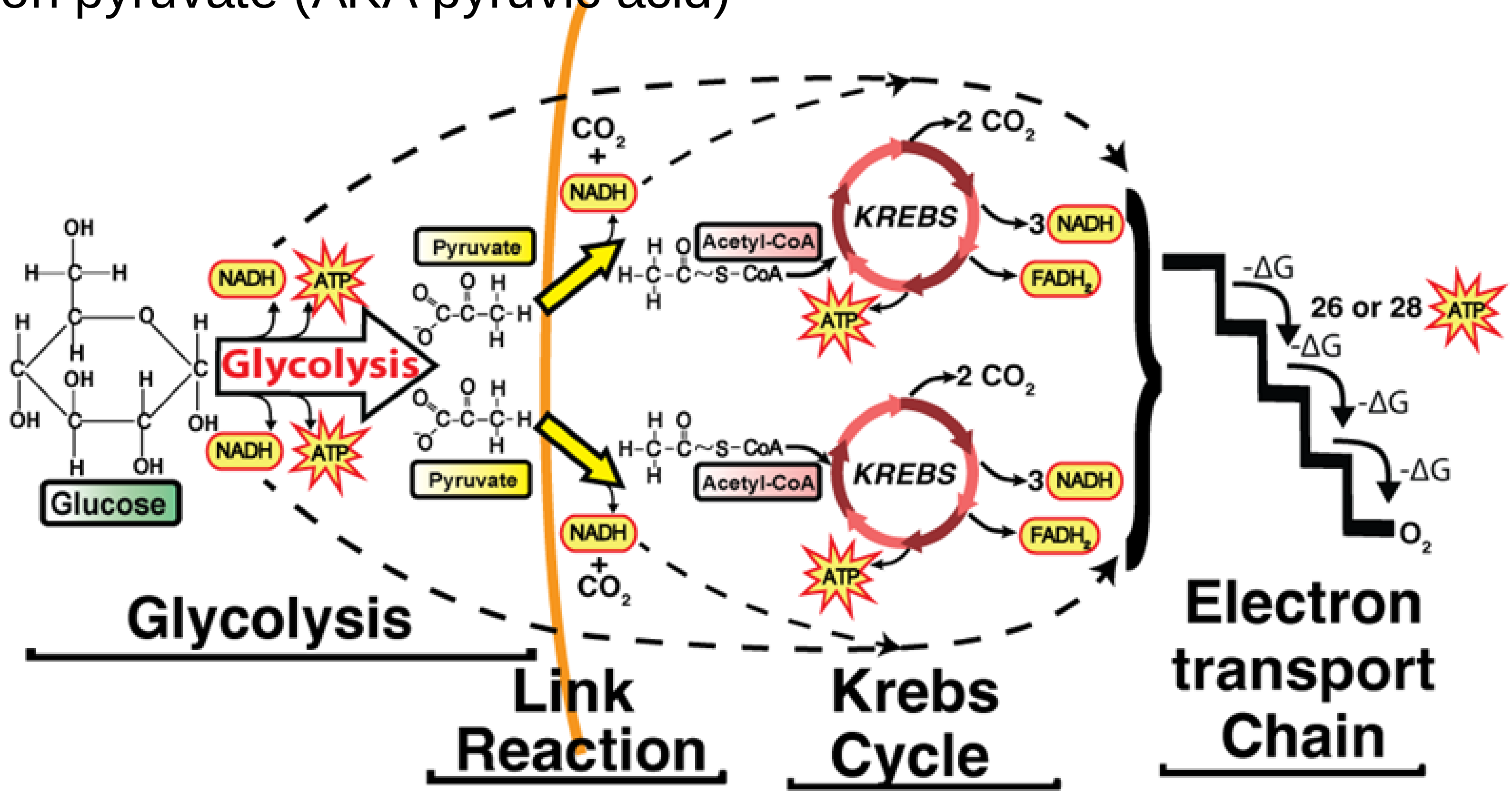


ETC and oxidative phosphorylation: inner mitochondrial membrane and intermembrane space

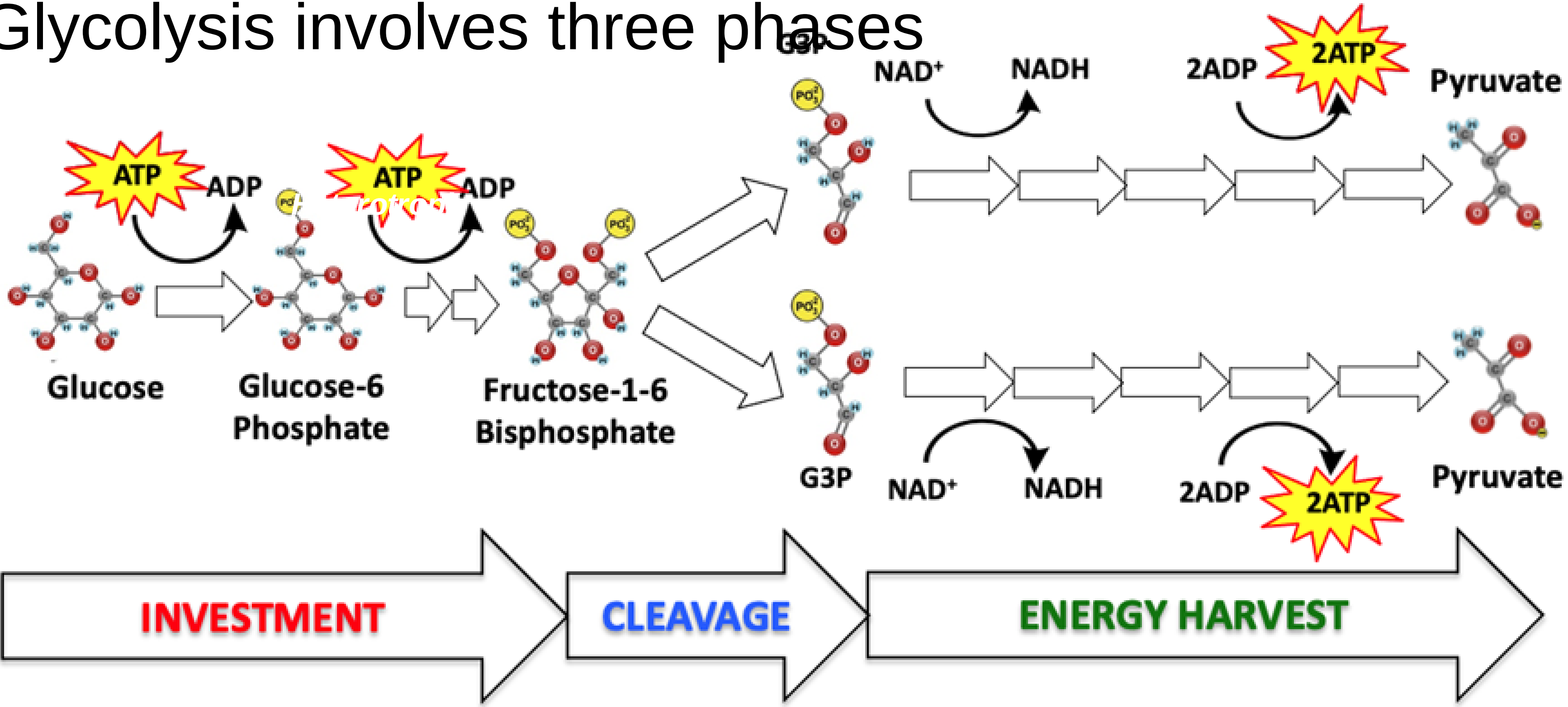
Topic 3.6, part 1.
GLYCOLYSIS



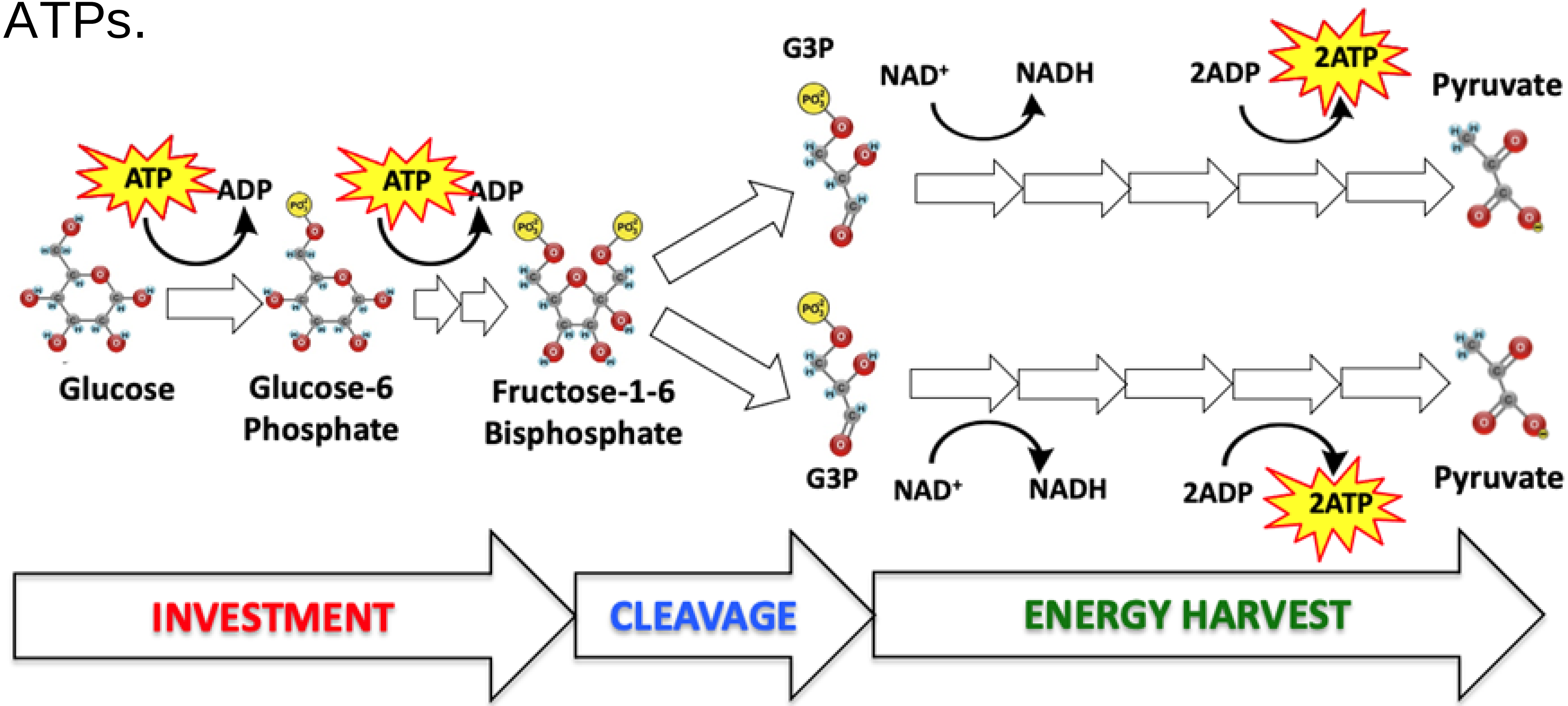
Glycolysis: Energy in glucose generates ATP and NADH. End product: 3-carbon pyruvate (AKA pyruvic acid)



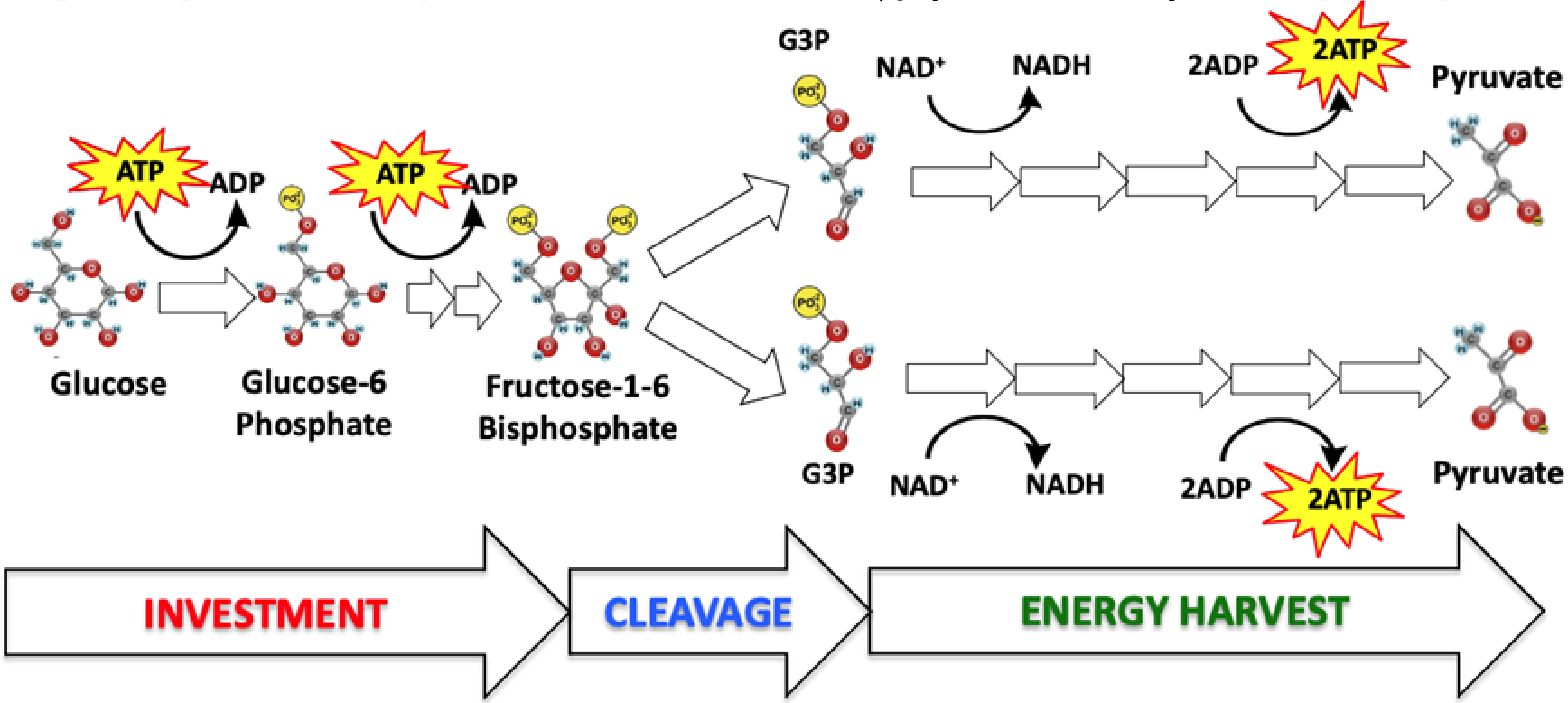
Glycolysis involves three phases



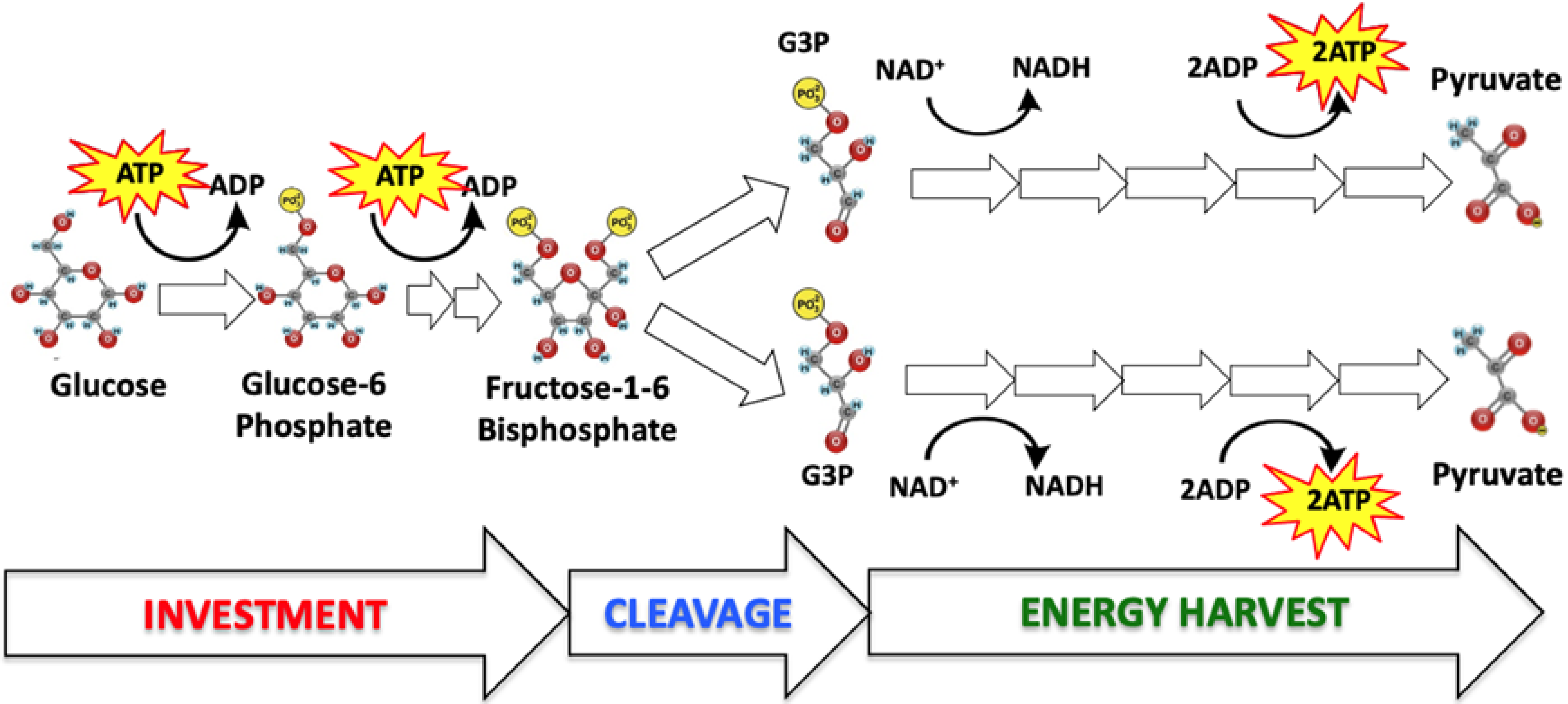
INVESTMENT: Enzymes phosphorylate glucose. This costs 2 ATPs.



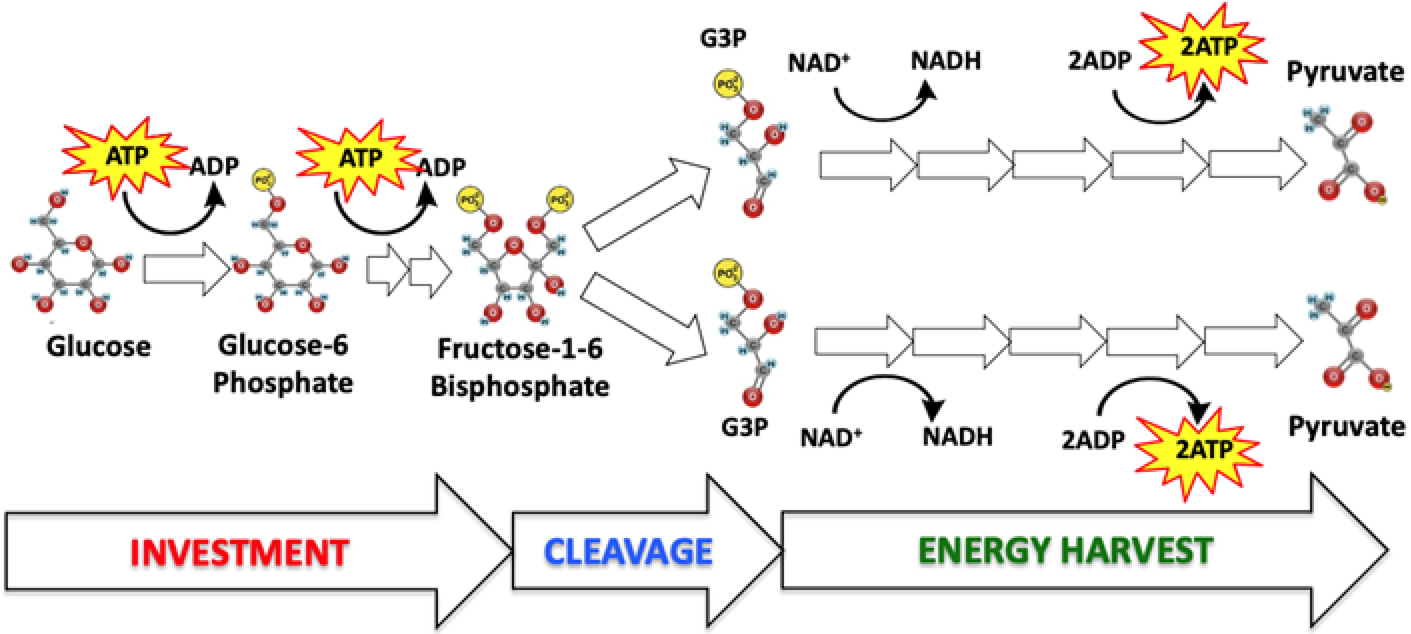
CLEAVAGE: the intermediate compound **fructose-1-6 bisphosphate** is split into two G3Ps (glyceraldehyde-3-phosphate).



HARVEST: In *parallel* (happens *twice*) G3P is oxidized as NAD^+ is reduced to NADH. Enzymes phosphorylate two ADPs to create 2 ATPs



Gross and net yield of glycolysis

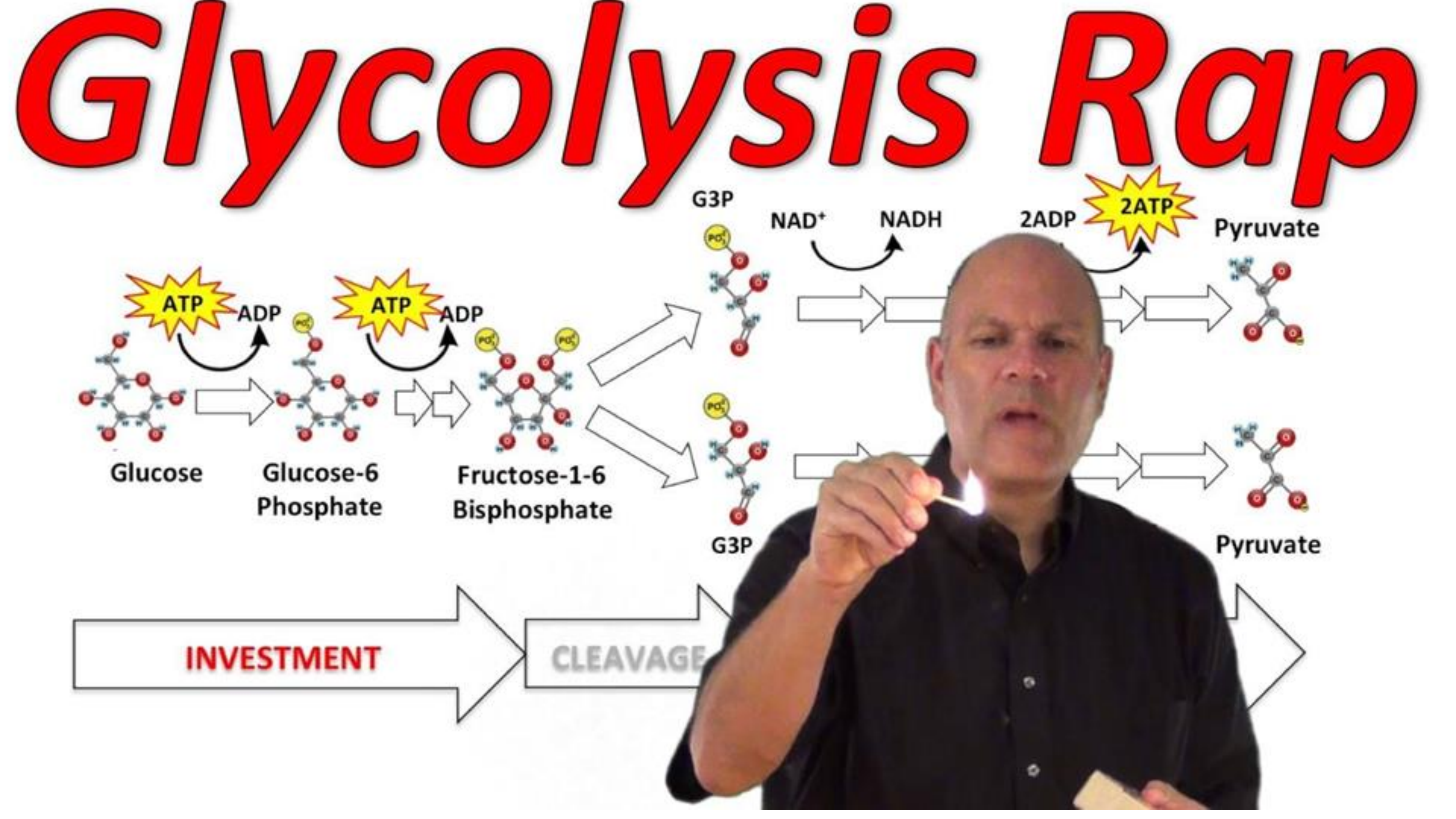


Gross Yield of Glycolysis

- 4 ATPs
- 2 NADHs
- Two pyruvates

Net yield of Glycolysis

- 2 ATPs
- 2 NADHs
- Two pyruvates


Glycolysis Rap
G3P
NAD+
NADH
2ADP
2ATP
Pyruvate
ATP
ADP
ATP
ADP
Glucose
Glucose-6 Phosphate
Fructose-1-6 Bisphosphate
G3P
Pyruvate
INVESTMENT
CLEAVAGE

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Want to learn more?

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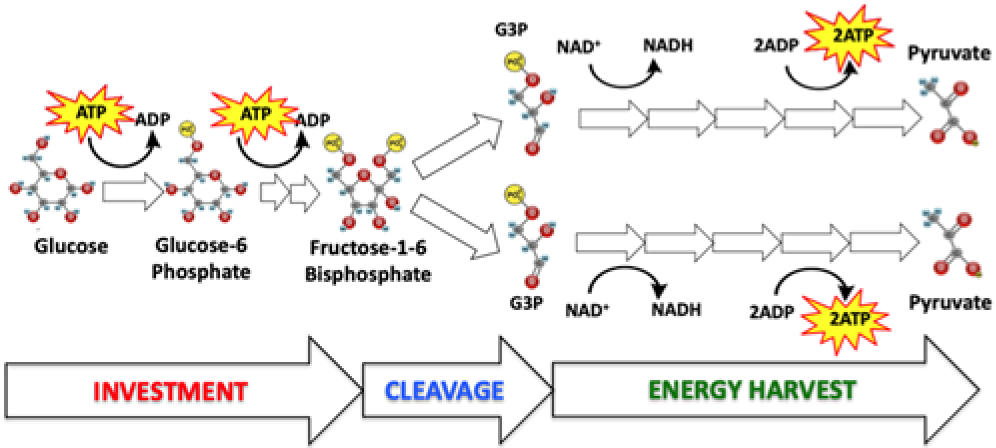
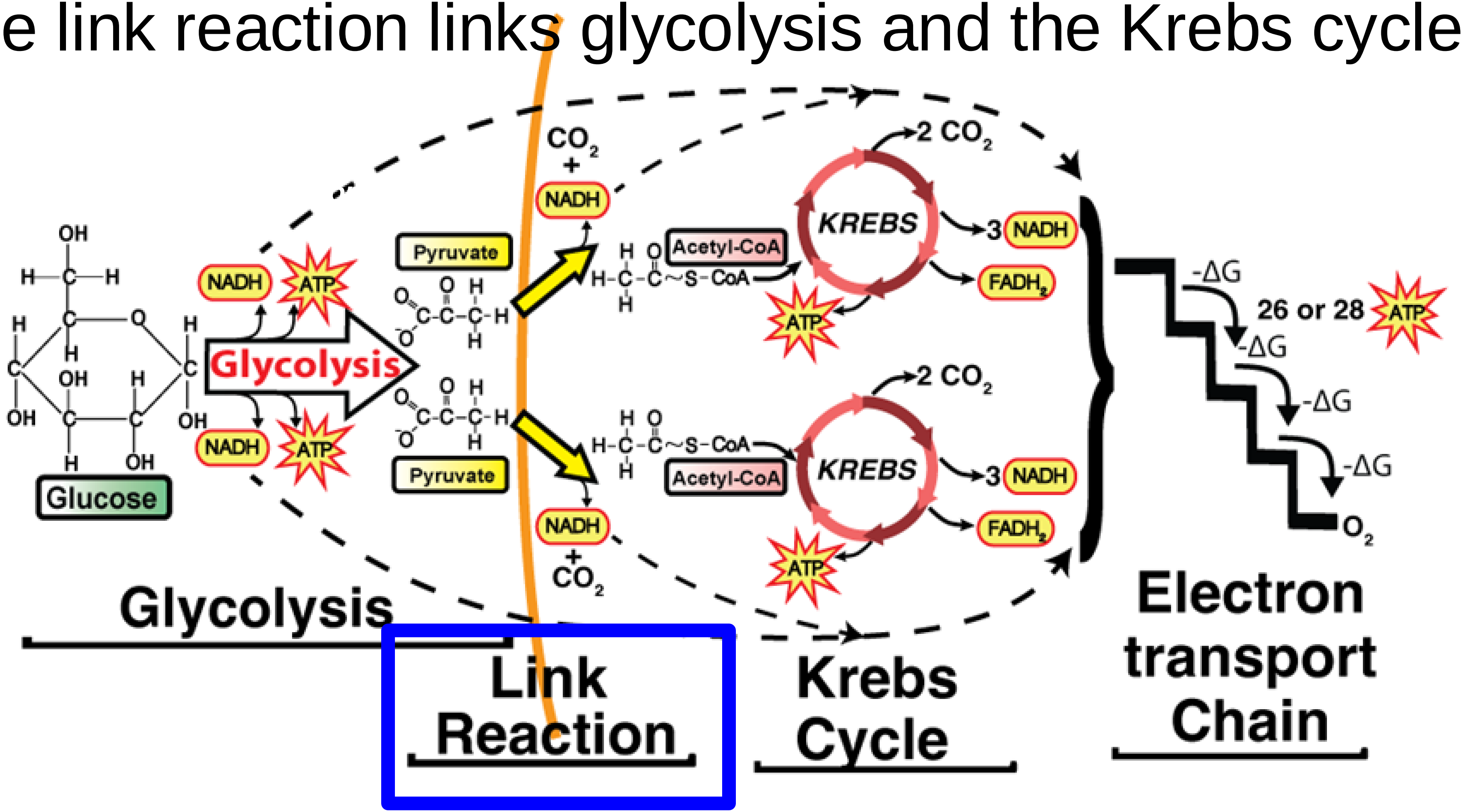
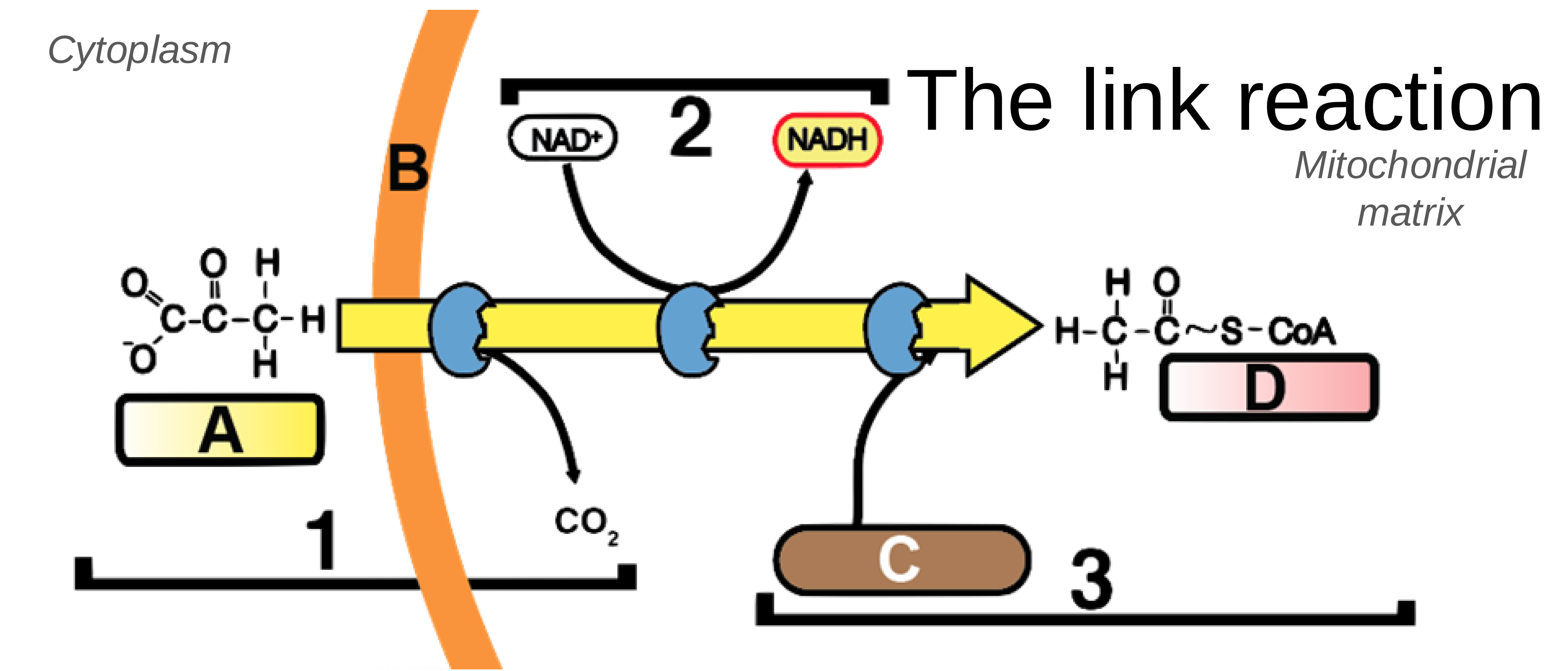


Topic 3.6: The Link Reaction and the Krebs Cycle

The link reaction links glycolysis and the Krebs cycle

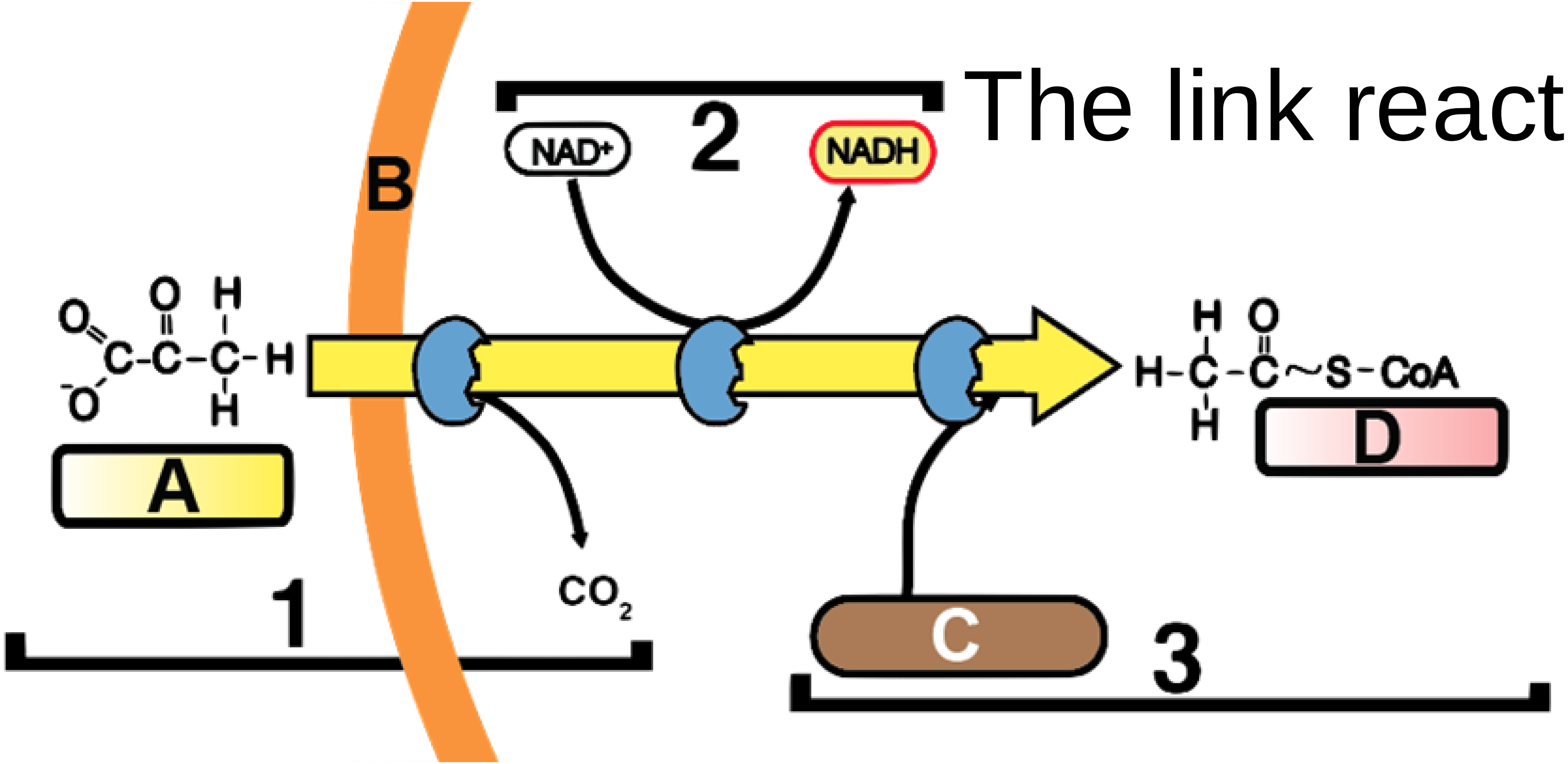


The link reaction



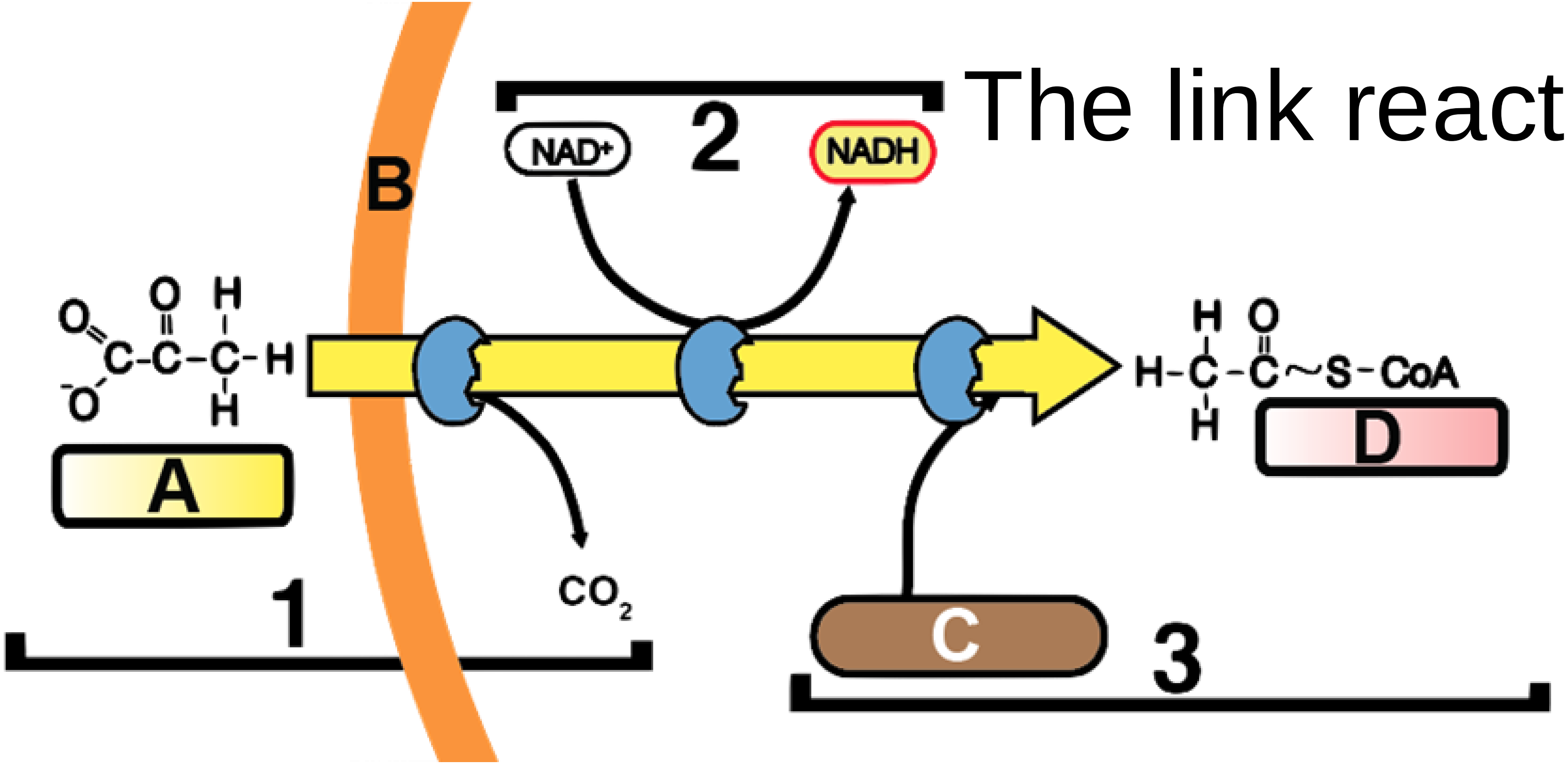
STEP 1: Pyruvic acid (from glycolysis, at A) is transported from the cytoplasm across the outer and inner mitochondrial membranes (B) into the mitochondrial matrix. Enzymes remove a CO_2

The link reaction



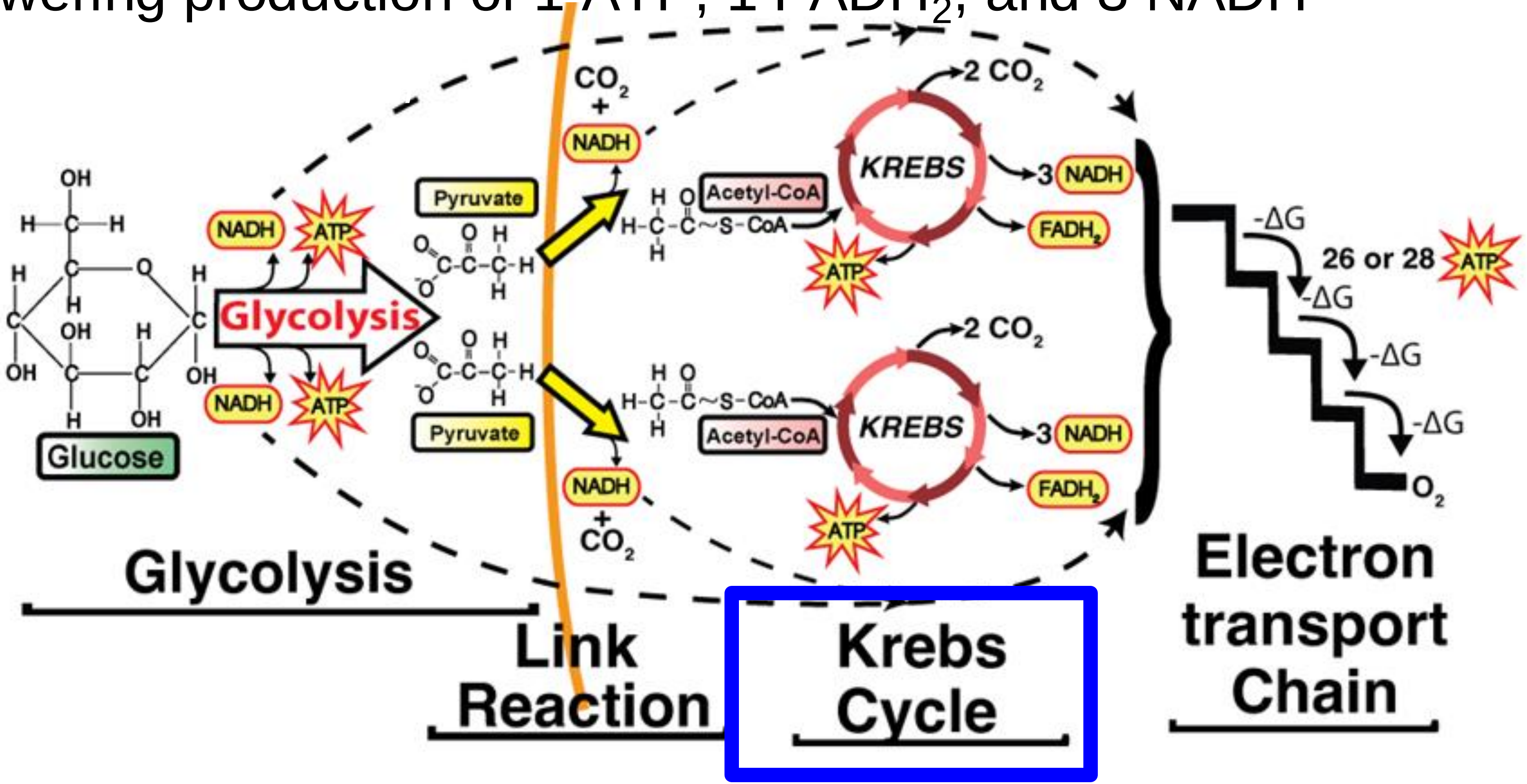
STEP 2: Other enzymes oxidize the resulting two-carbon molecule (an acetyl group), powering the reduction of NAD^+ to NADH (2).

The link reaction



STEP 3: Enzymes attach the two-carbon acetyl group to coenzyme A, generating Acetyl-CoA (at "D"), the starting point for the Krebs cycle.

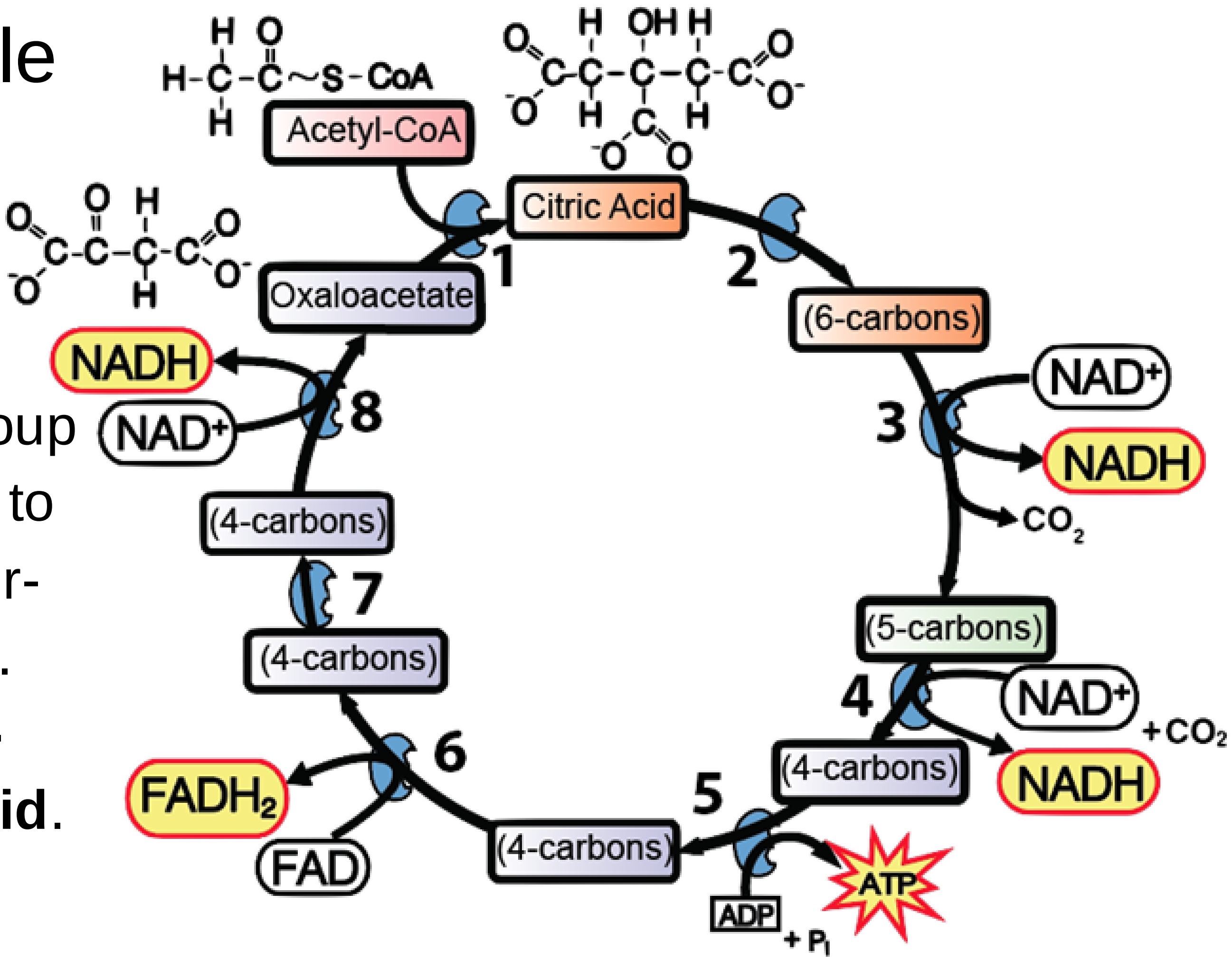
The Krebs cycle completes the oxidation of glucose byproducts, powering production of 1 ATP, 1 $FADH_2$, and 3 NADH



The Krebs Cycle

START:

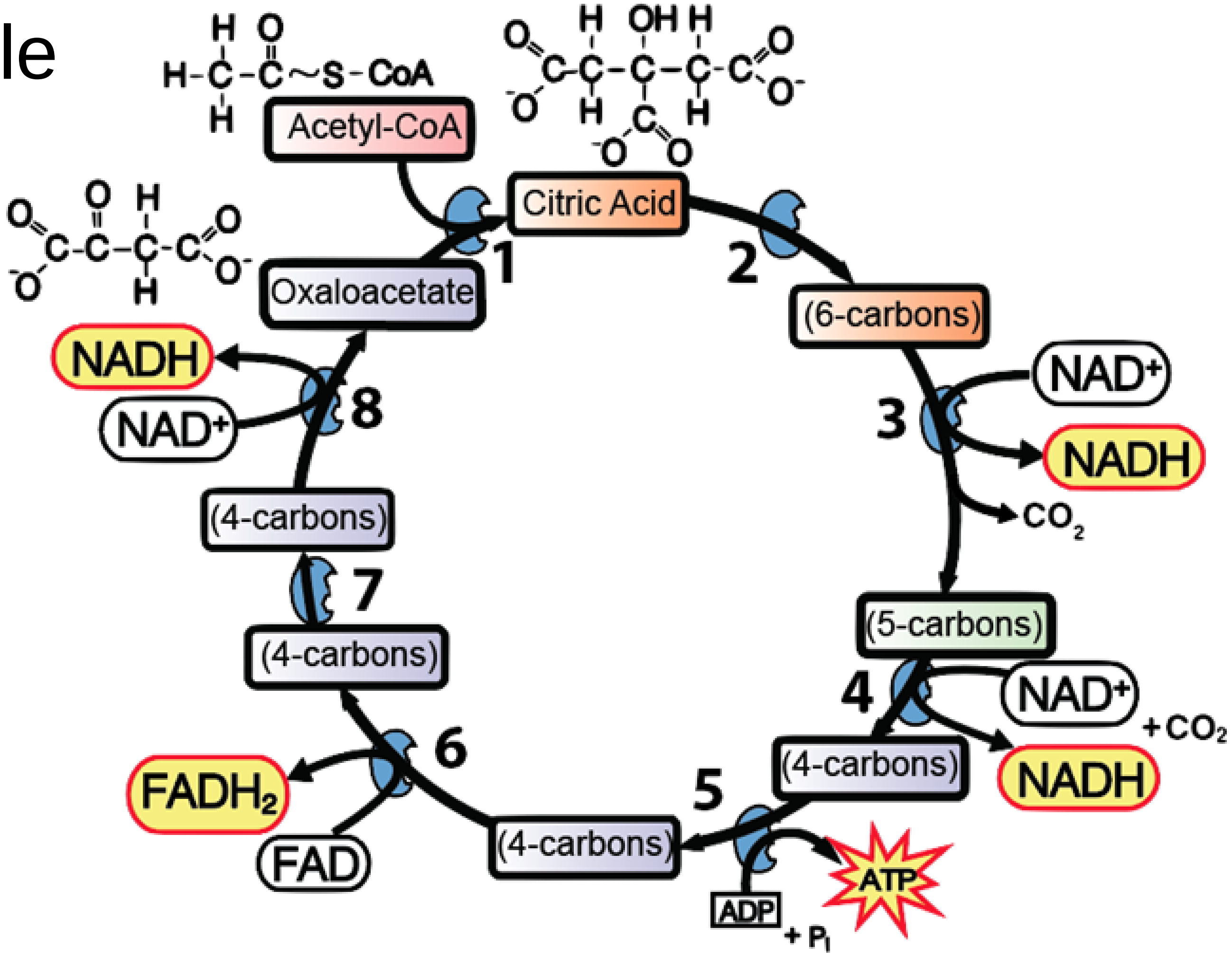
- Enzymes (at 1) transfer the two-carbon acetyl group from Acetyl-CoA to oxalic acid, a four-carbon molecule.
- This creates **six-carbon citric acid**.



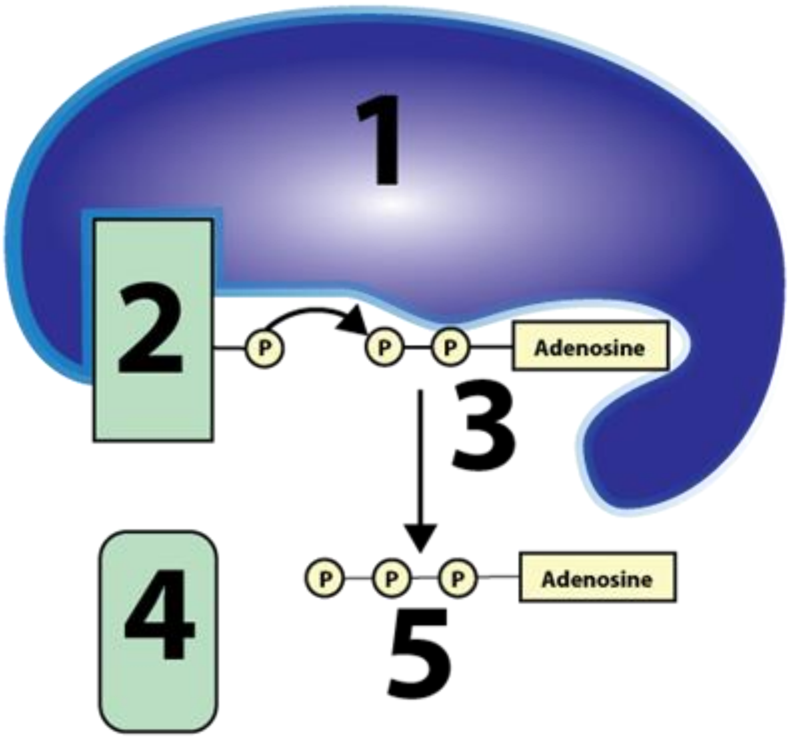
The Krebs Cycle

MIDDLE

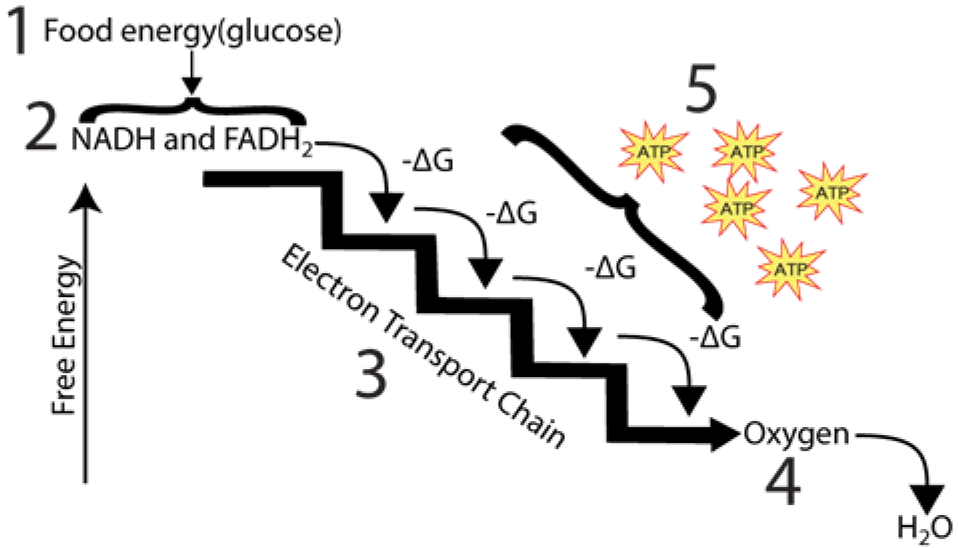
- Enzymes (2-8) oxidize citric acid and its byproducts.
- Its electrons are used to reduce NAD^+ to NADH and FAD to and $FADH_2$.
- Other enzymes power a substrate-level phosphorylation of ADP and P_i into ATP.



Substrate level phosphorylation



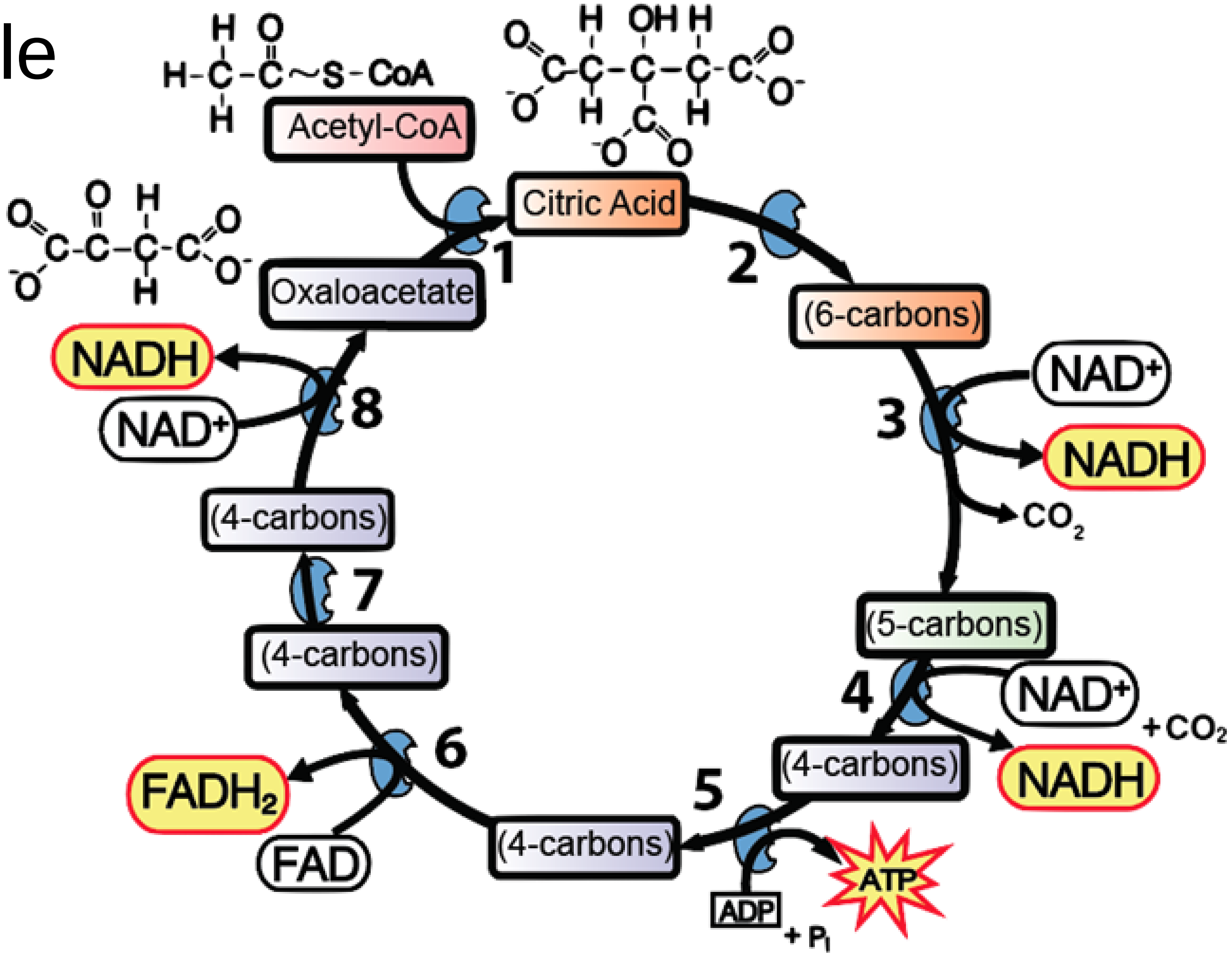
Oxidative phosphorylation

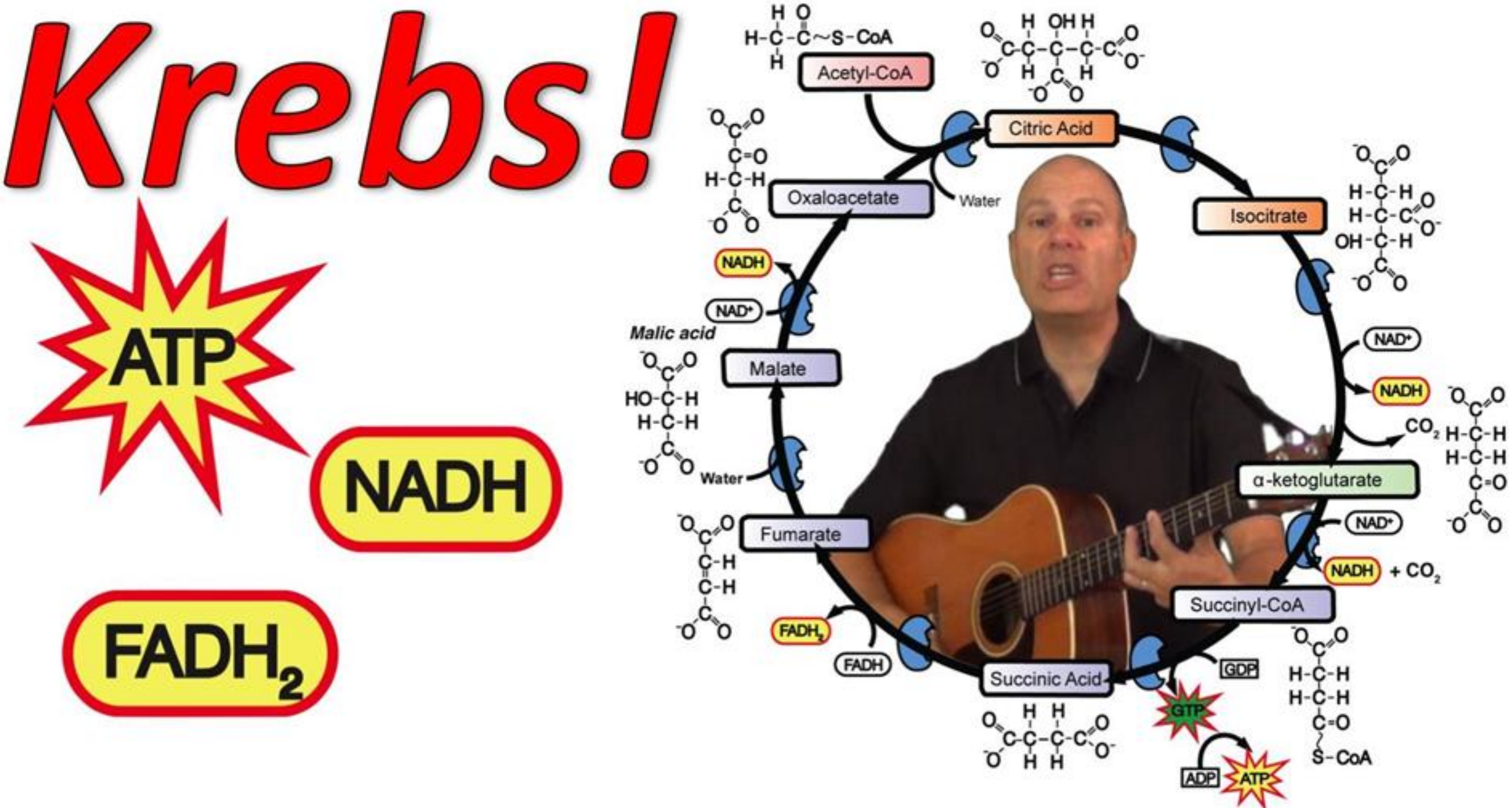


The Krebs Cycle

PRODUCTS

- For each acetyl-CoA that enters the cycle, one ATP, one $FADH_2$, and three NADHs are generated.
- 2 CO_2s are released as a waste product
- **Oxaloacetate** is the starting and ending compound

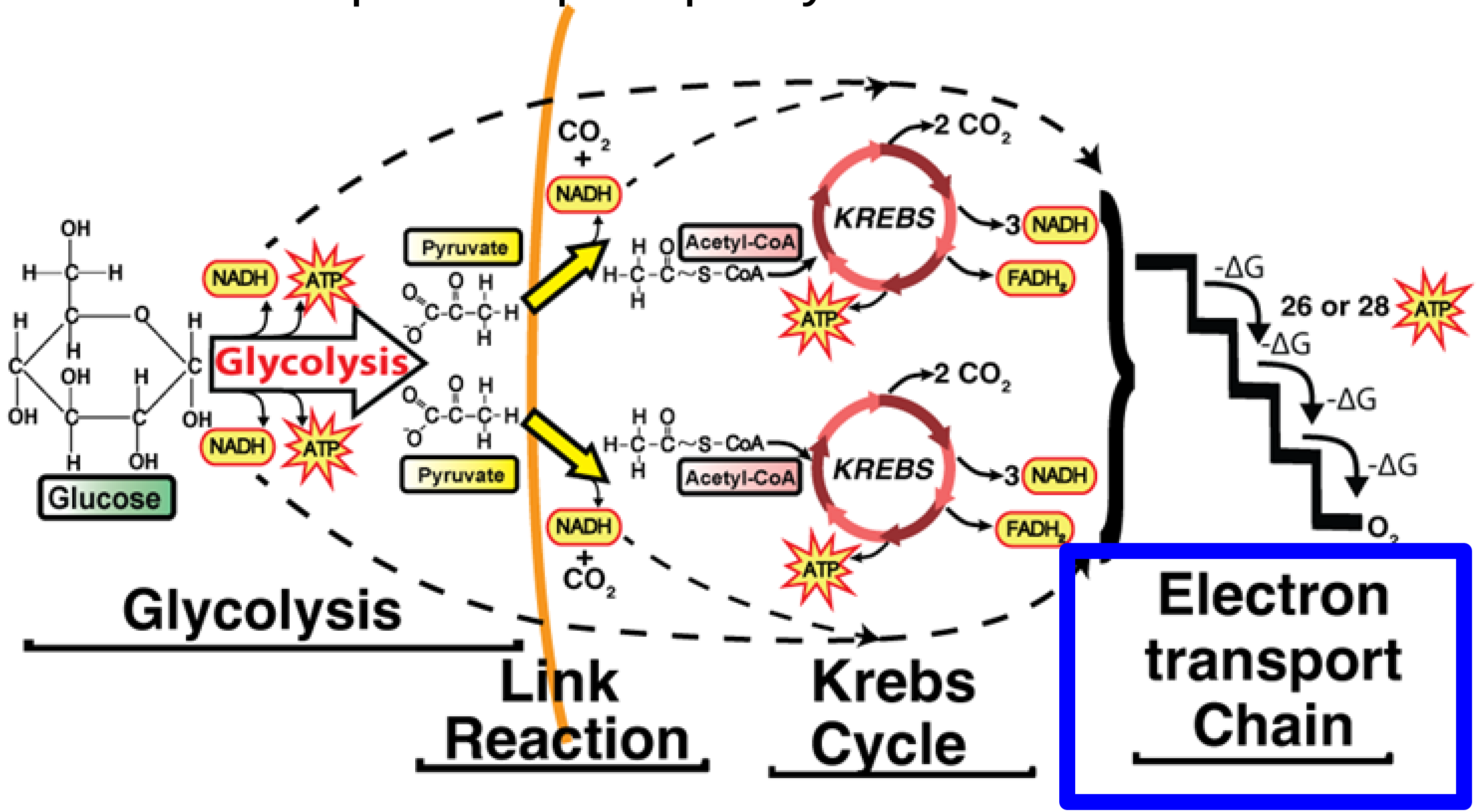




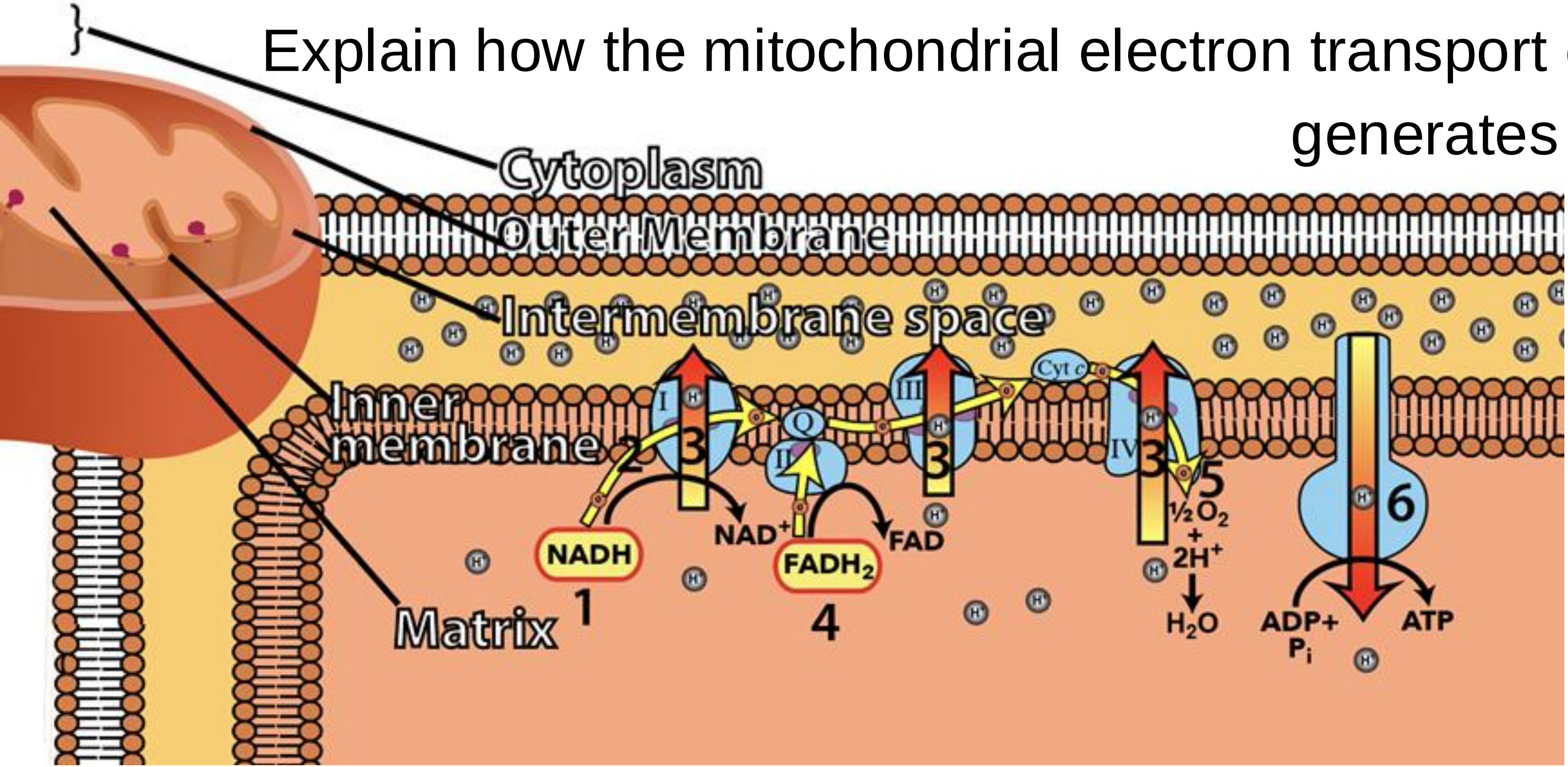
Krebs!
ATP
NADH
FADH2
Acetyl-CoA
Citric Acid
Water
Isocitrate
NAD+
NADH
CO2
α-ketoglutarate
NAD+
NADH + CO2
Succinyl-CoA
GDP
GTP
ADP
ATP
Succinic Acid
FADH
FADH2
Fumarate
Water
Malic acid
Malate
NAD+
NADH
Oxaloacetate

Topic 3.6: The Electron Transport Chain

Electron transport chain (ETC): oxidizes NADH and $FADH_2$ to create electron flow which powers phosphorylation of ADP to ATP

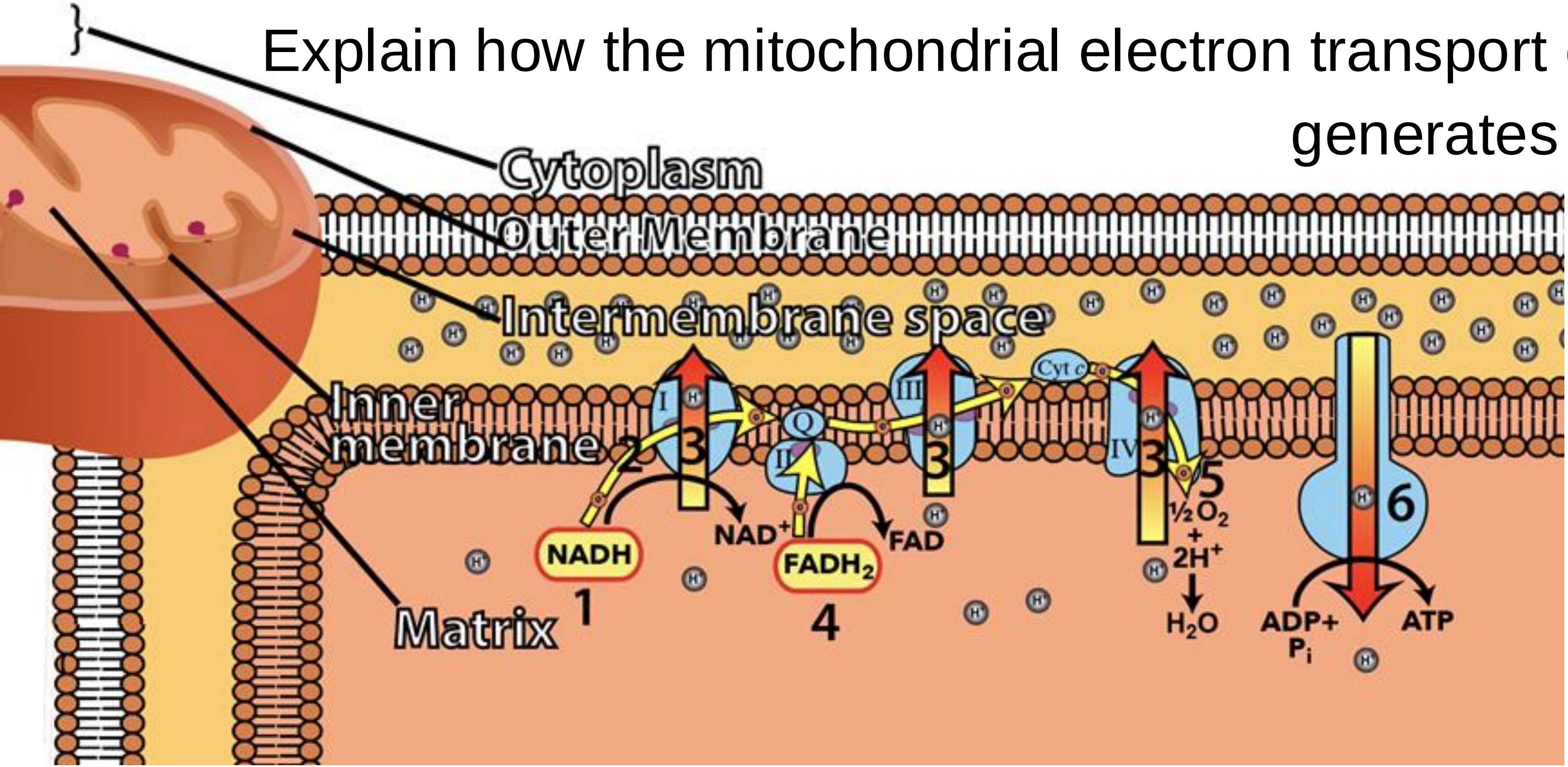


Explain how the mitochondrial electron transport chain generates ATP.



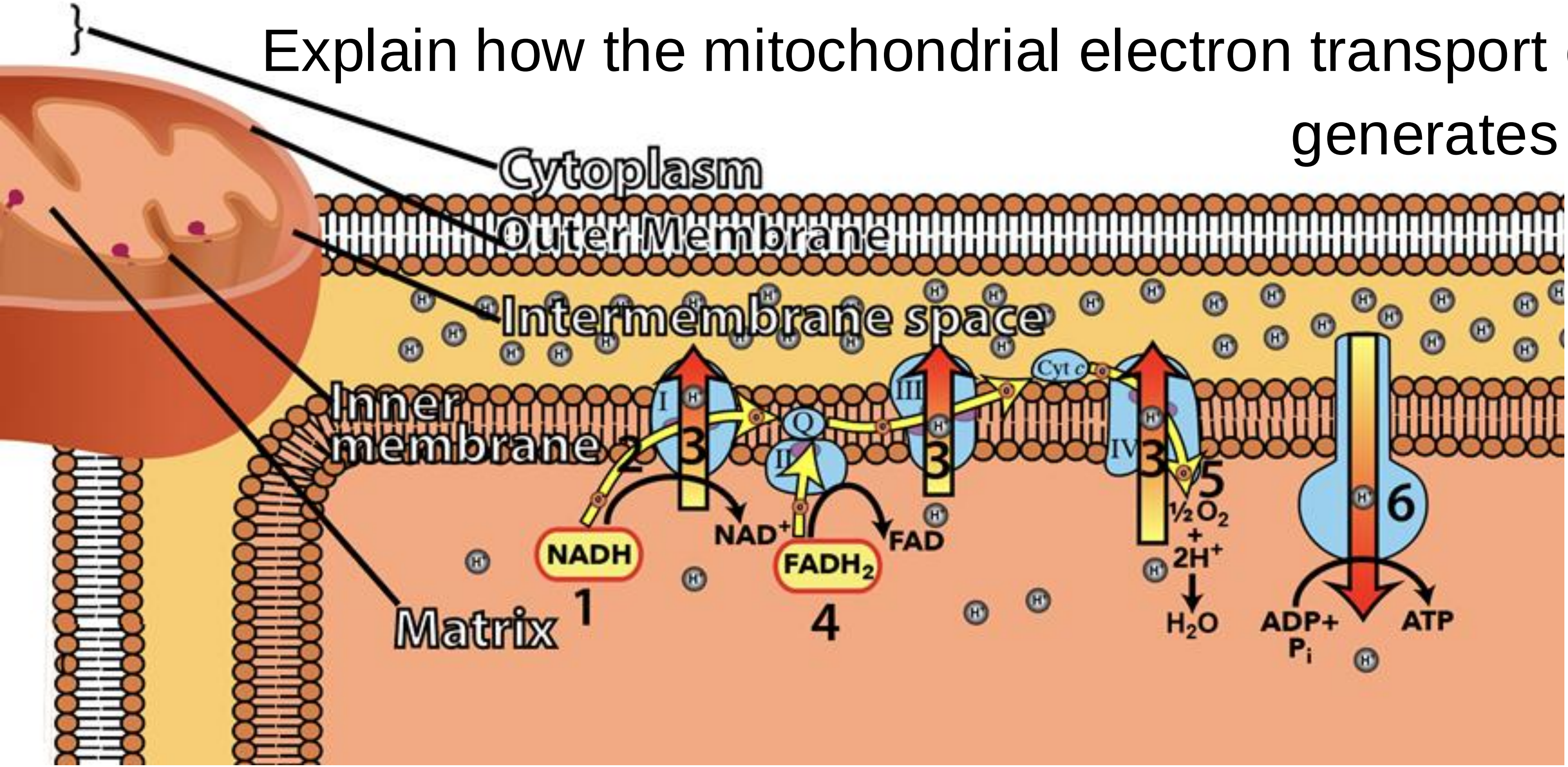
- Electrons from NADH and FADH$_2$ (1 and 4) are oxidized by proteins within the electron transport chain

Explain how the mitochondrial electron transport chain generates ATP.



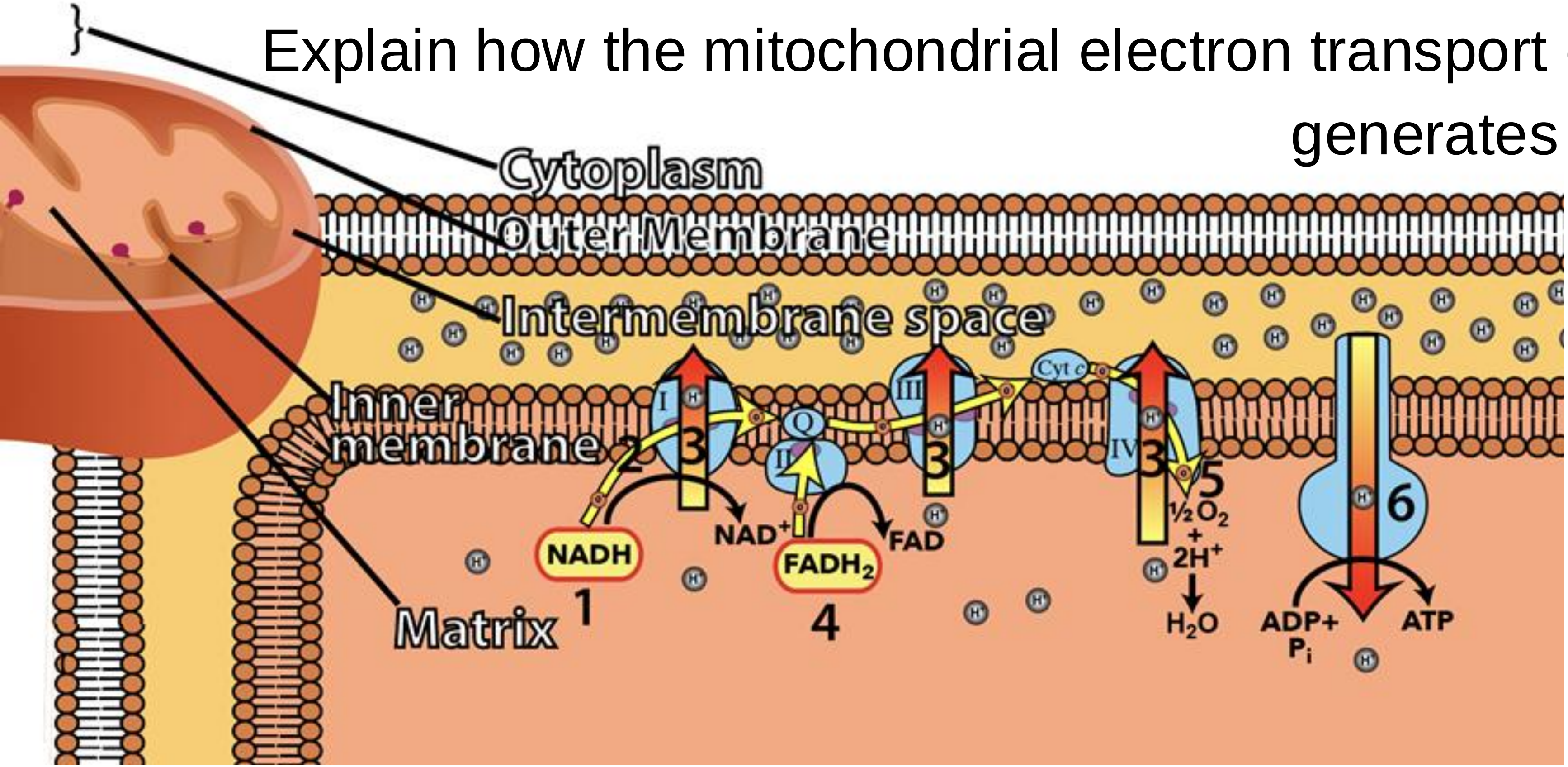
- The electron transport chain (2) is a series of membrane-embedded proteins in the mitochondrial inner membrane.

Explain how the mitochondrial electron transport chain generates ATP.

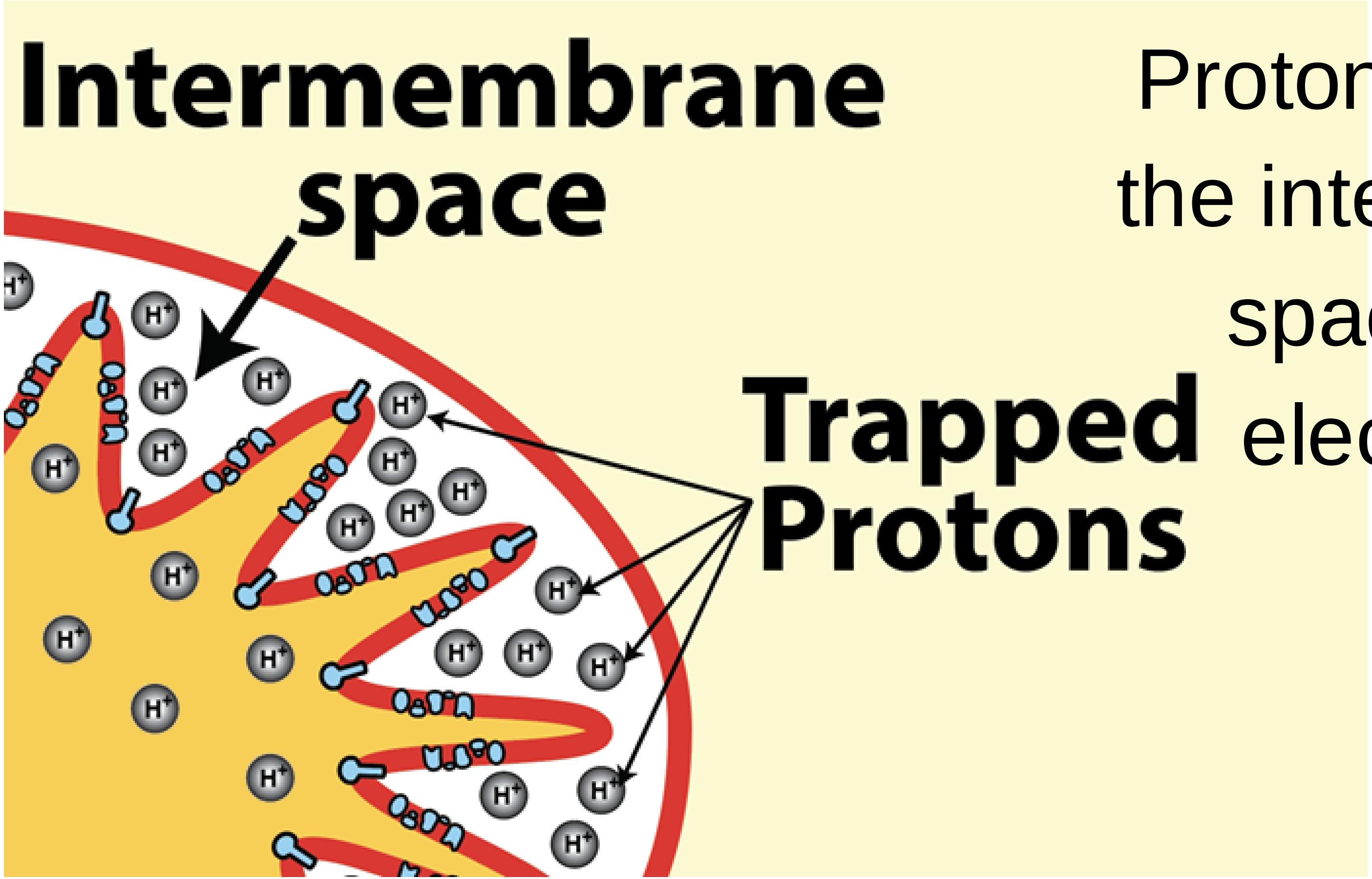


- Some ETC proteins are **proton pumps** (3) that pump protons from the matrix to the intermembrane space, creating an electrochemical gradient.

Explain how the mitochondrial electron transport chain generates ATP.

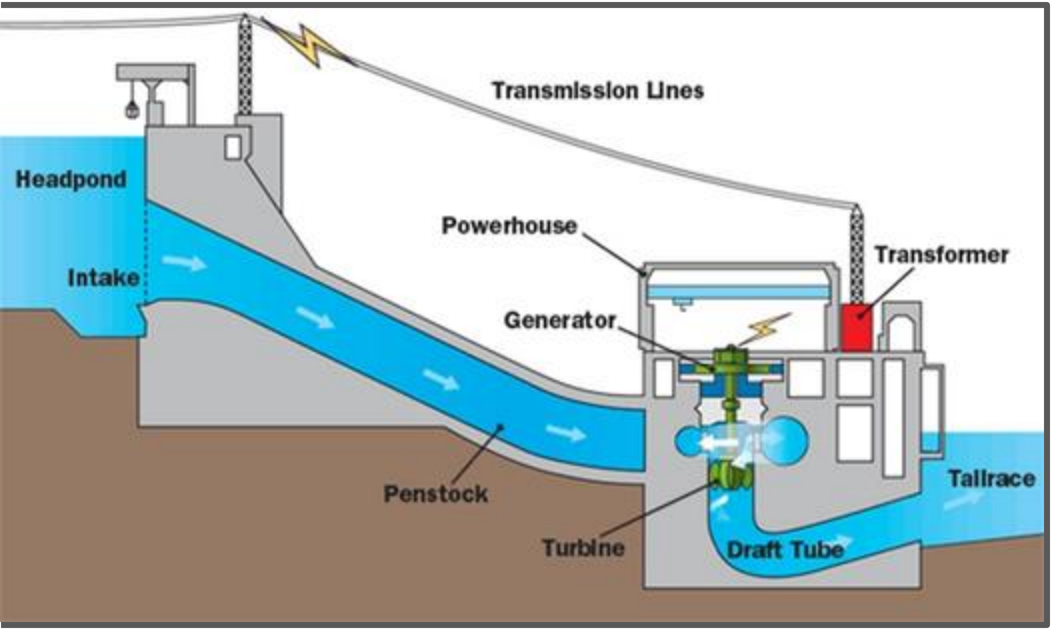


- O_2 (5) acts as the final electron acceptor, “pulling” electrons down ETC, increasing the proton gradient between the matrix and intermembrane space.

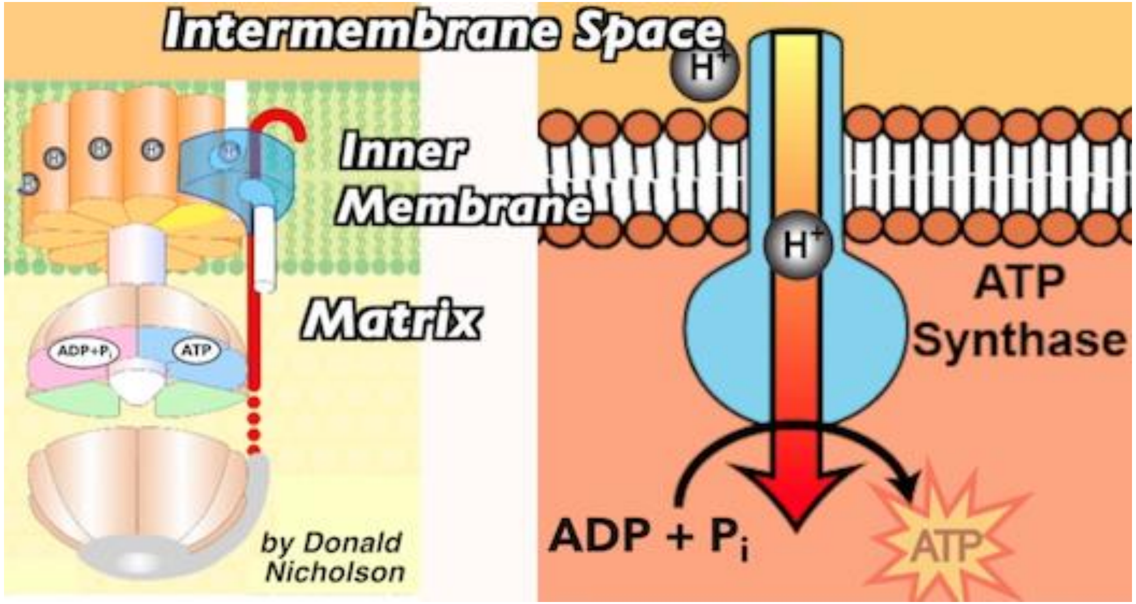


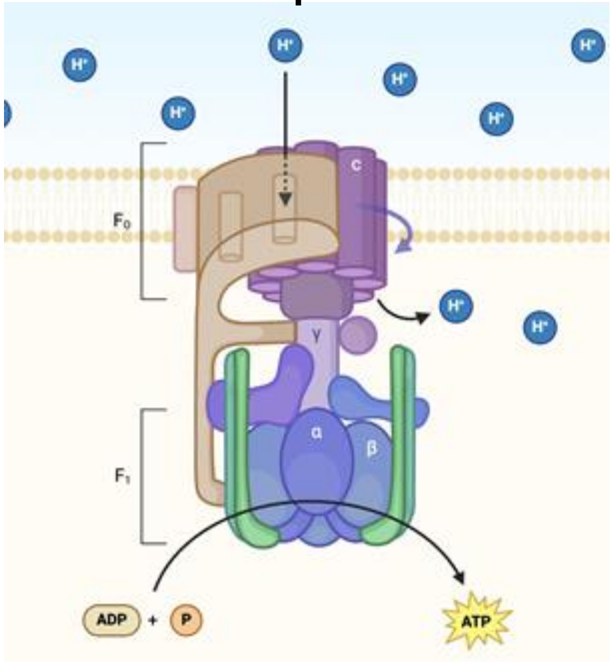
Protons trapped in the intermembrane space create an electrochemical gradient.

The trapped protons are potential energy, like water trapped behind a dam



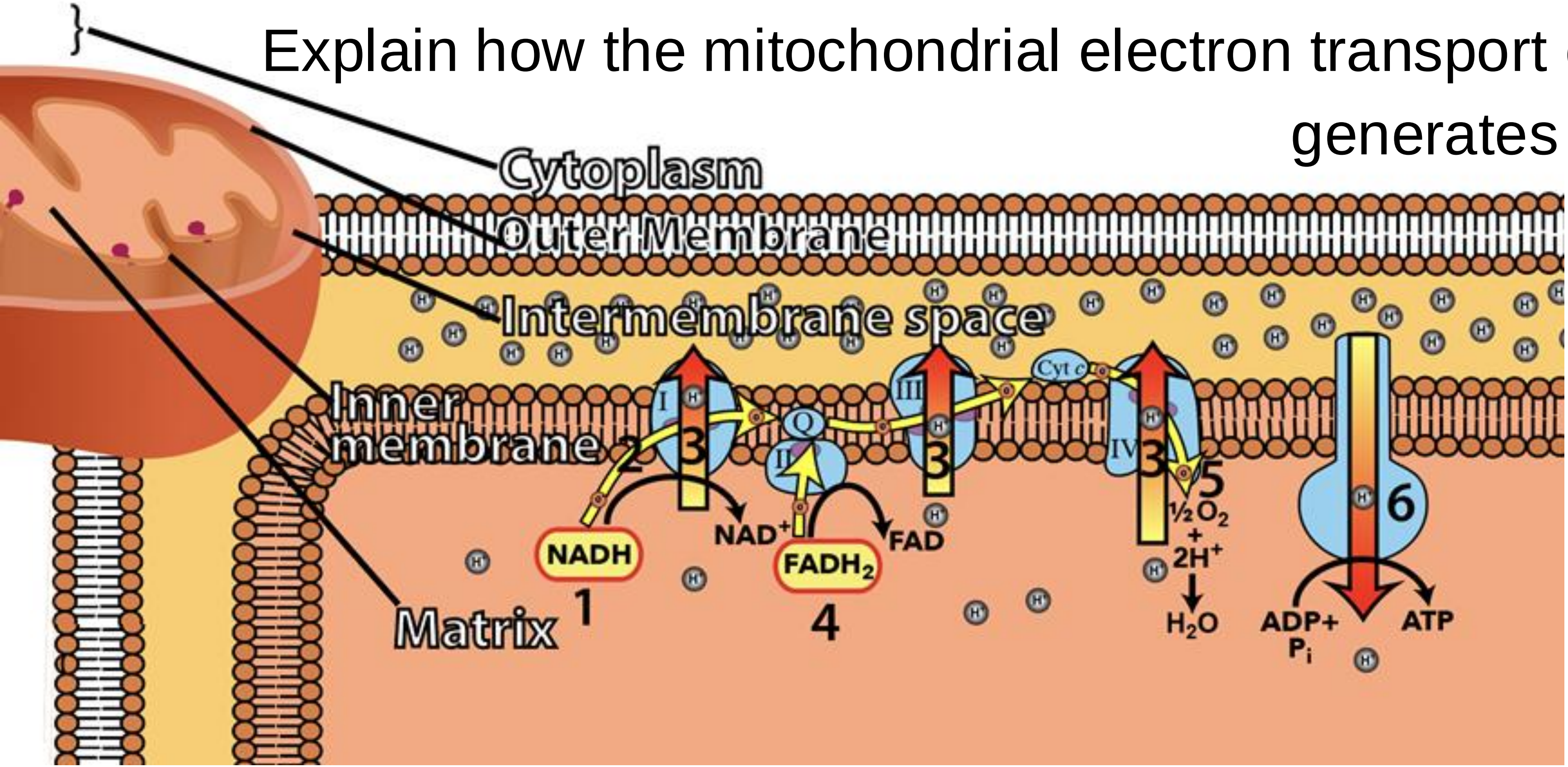
ATP synthase converts ADP and P_i into ATP





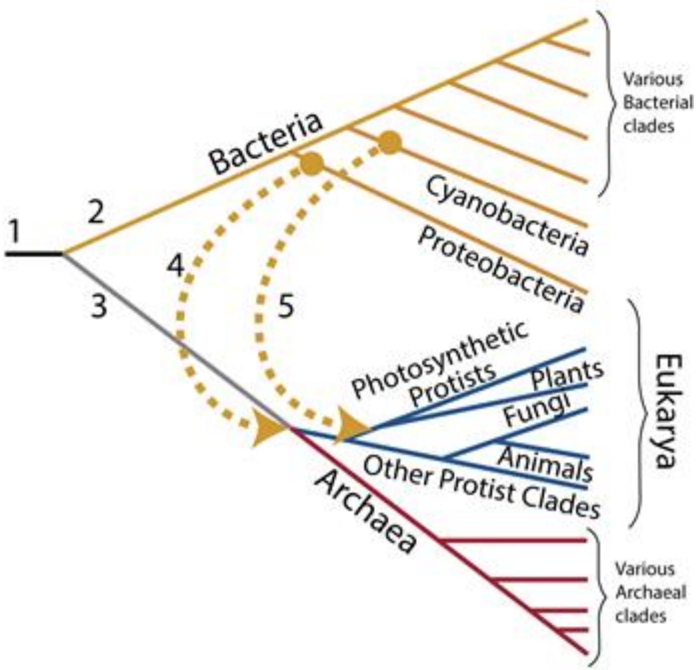
- A channel
- An ATP-synthesizing enzyme
- The only way for protons to leave the intermembrane space

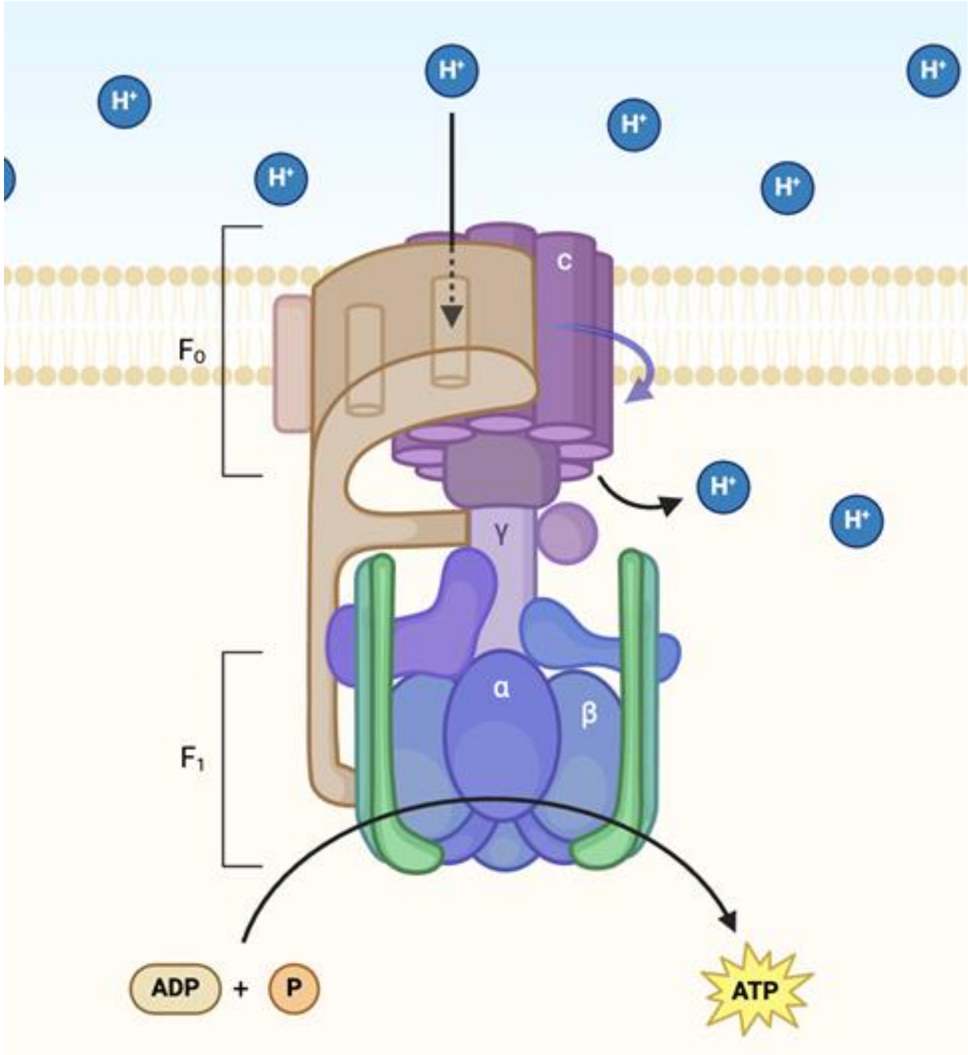
Explain how the mitochondrial electron transport chain generates ATP.



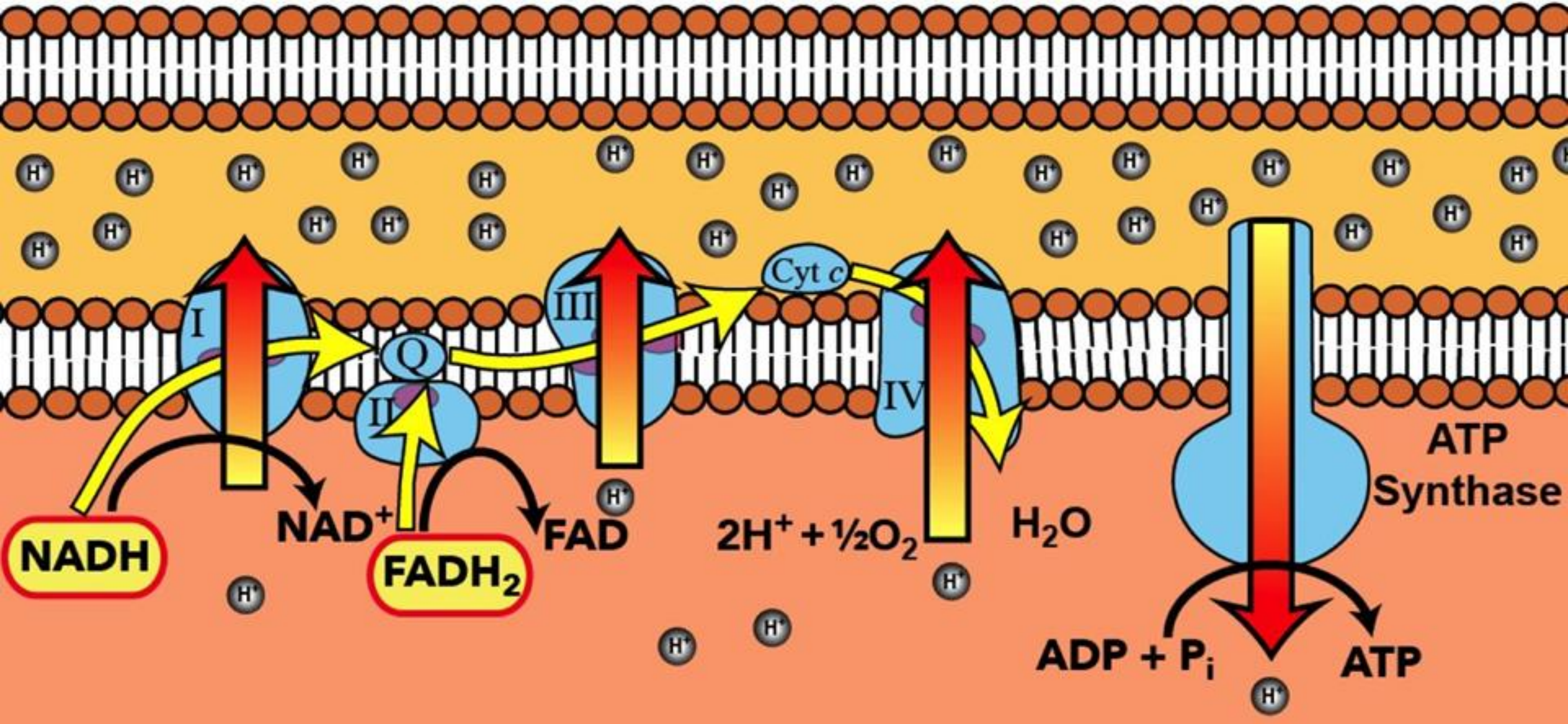
Facilitated diffusion through the ATP synthase channel (6) back to the the matrix powers formation of ATP from ADP and P_i.

ATP synthase is basic to life



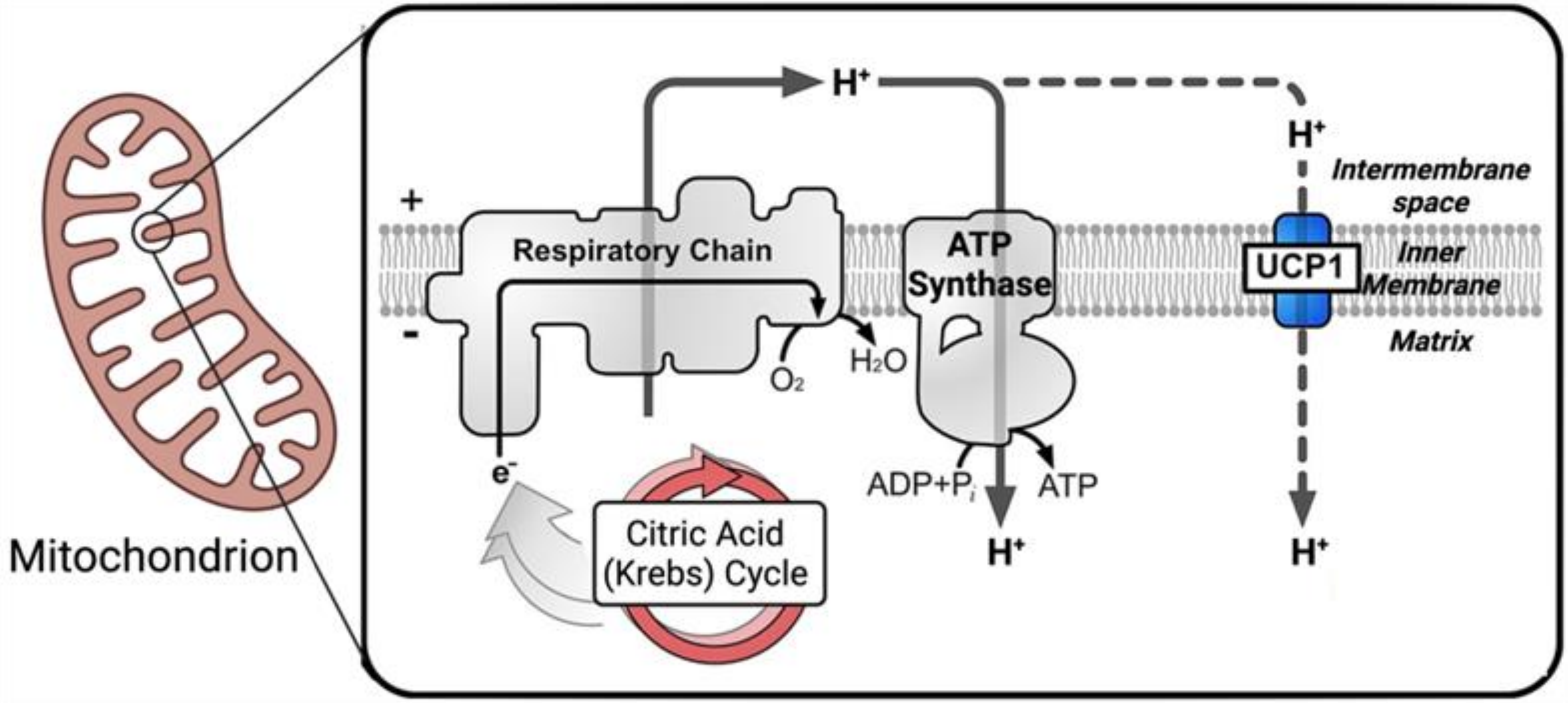


Electron Transport Chain



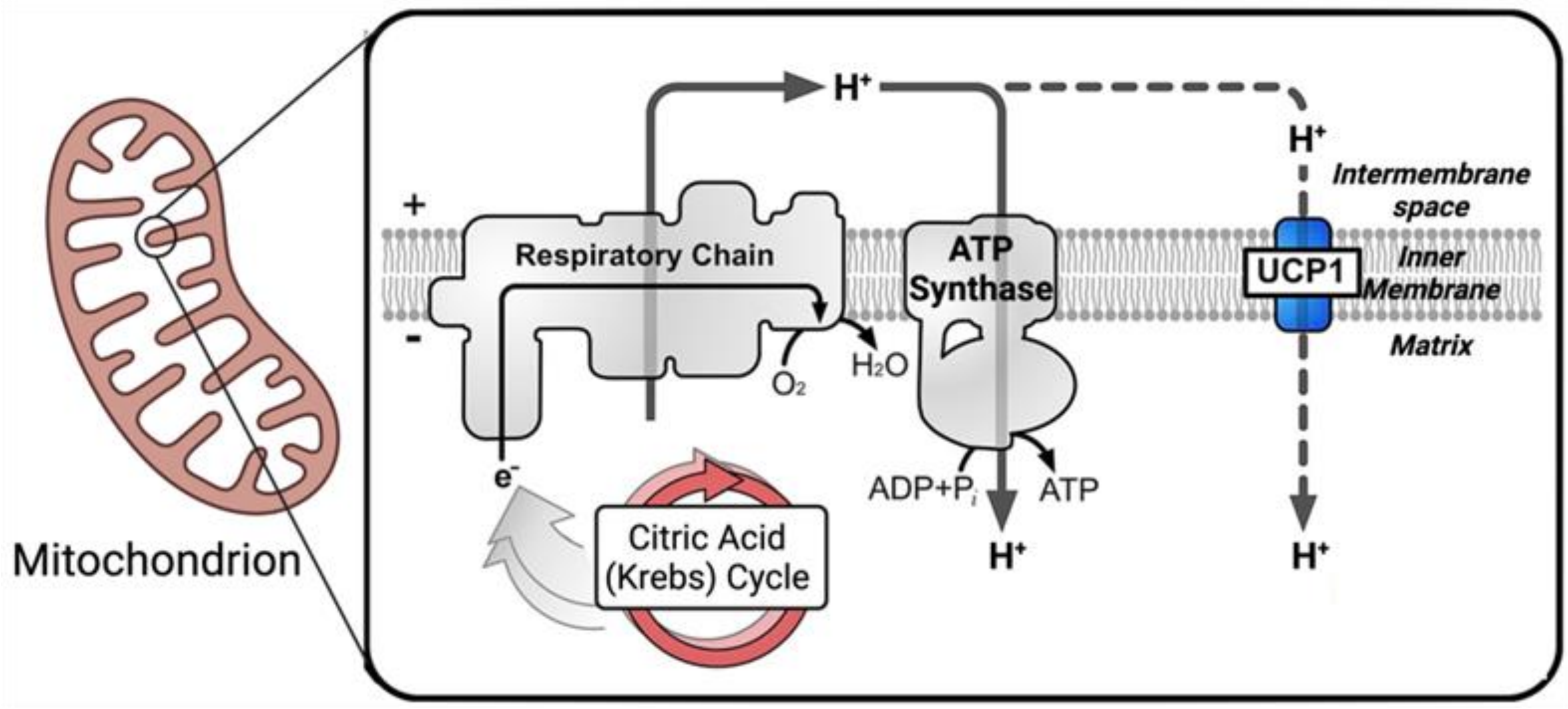
Now all these protons in the intermembrane space
Are trapped they can't get out of that place

Topic 3.6: Thermogeneisis: Cellular respiration can be used to generate heat instead of ATP. Explain.



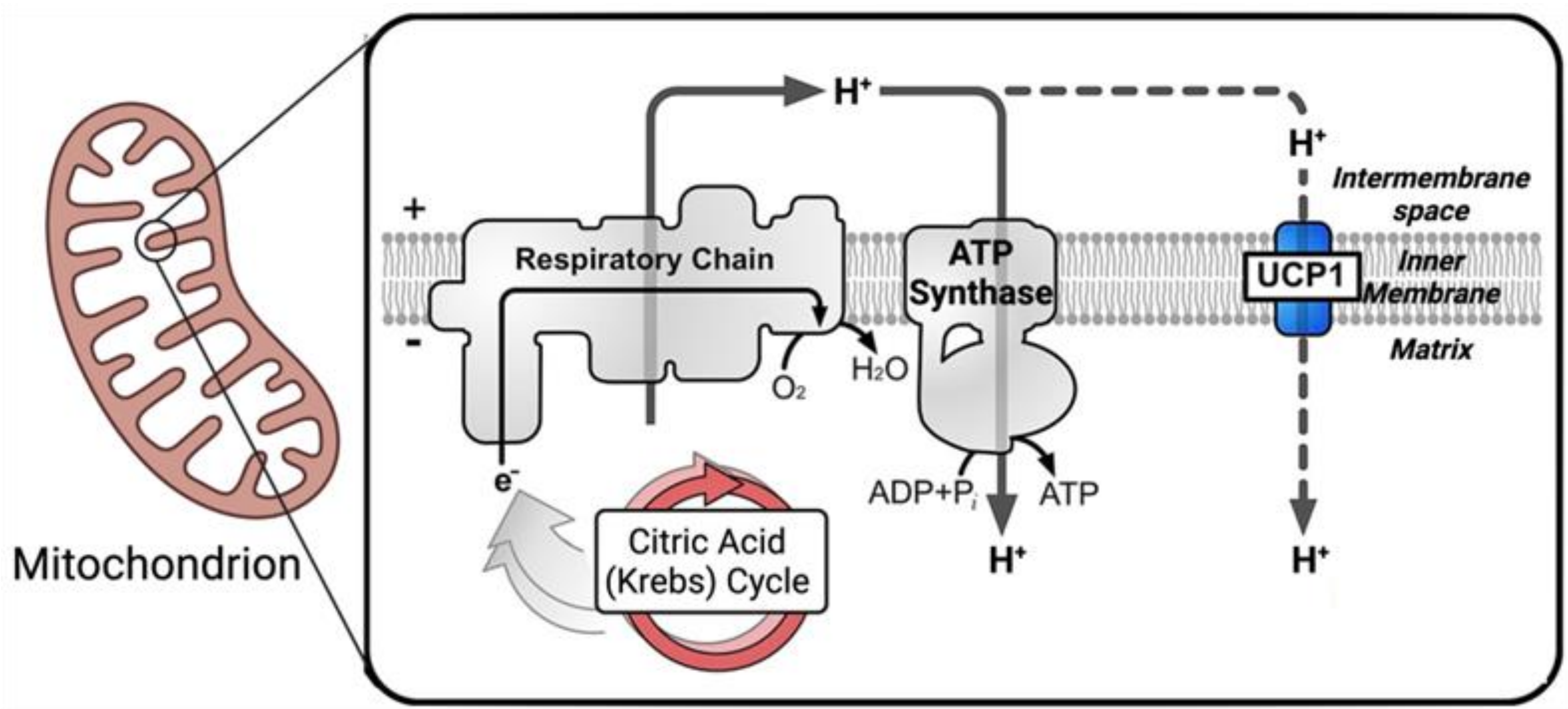
1. Newborn and hibernating mammals have brown fat cells, which are dense with mitochondria

Cellular respiration can be used to generate heat instead of ATP. Explain.



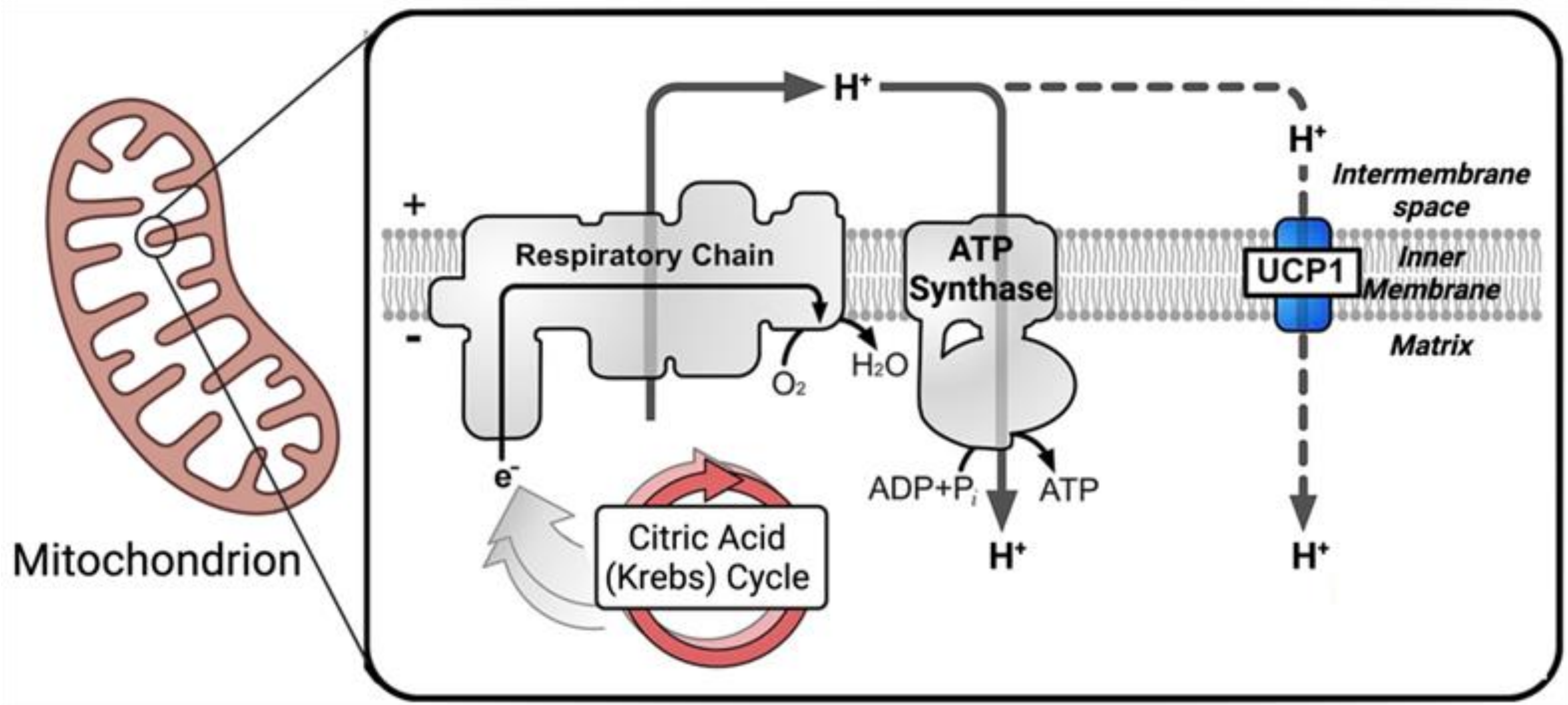
2. When body heat is needed, hormones induce a proton channel called *thermogenin or UCP* (for *uncoupling channel)* to form in the inner mitochondrial membrane.

Cellular respiration can be used to generate heat instead of ATP. Explain.



3. Protons diffuse back to the matrix from the intermembrane space through the UCP, without passing through ATP synthase.

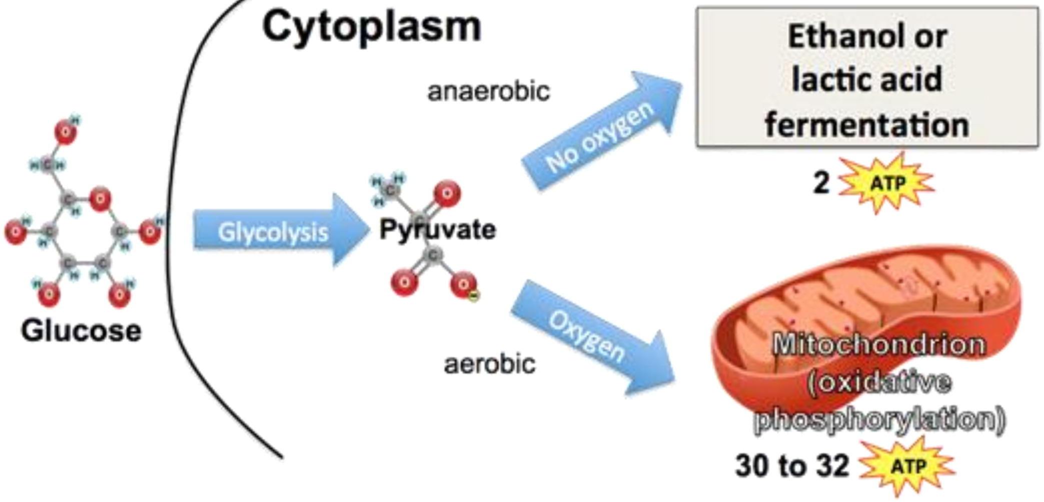
Cellular respiration can be used to generate heat instead of ATP. Explain.



4. Electron flow along the ETC generates heat (but not ATP).

Topic 3.6, part 5: Anaerobic respiration and fermentation

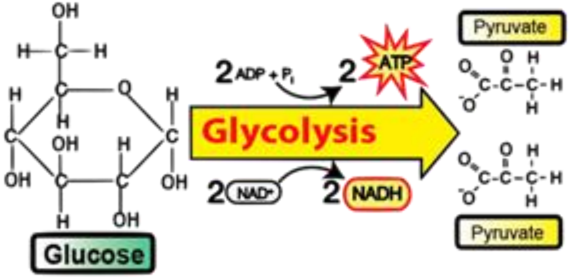
Compare aerobic and anaerobic respiration.

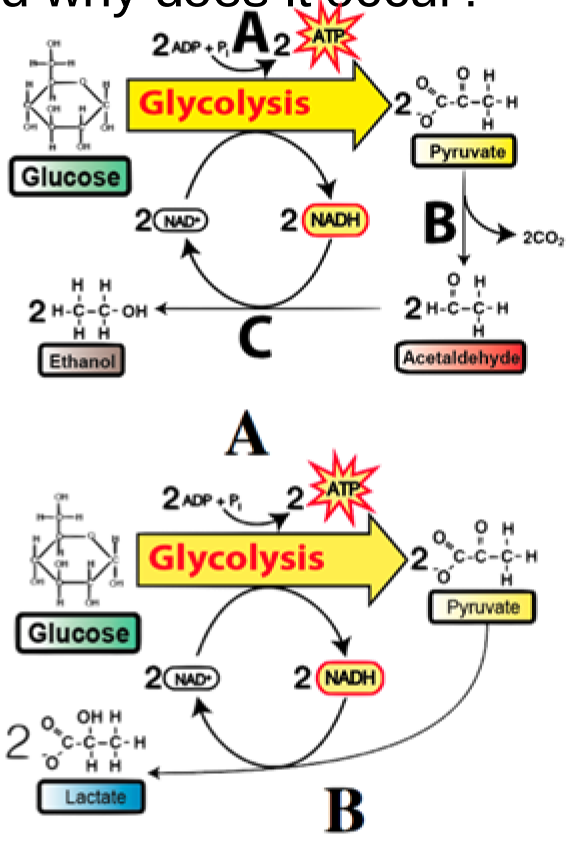


1. Aerobic respiration:
   a. Oxygen is required
   b. Glycolysis + Link + Krebs + ETC generate about 32 ATPs
   c. Most ATP is created in the mitochondria

2. Anaerobic respiration
   a. Occurs when oxygen is lacking or insufficient.
   b. Glycolysis followed by fermentation: generates 2 ATPs.
   c. Occurs in the cytoplasm

What is fermentation, and why does it occur?

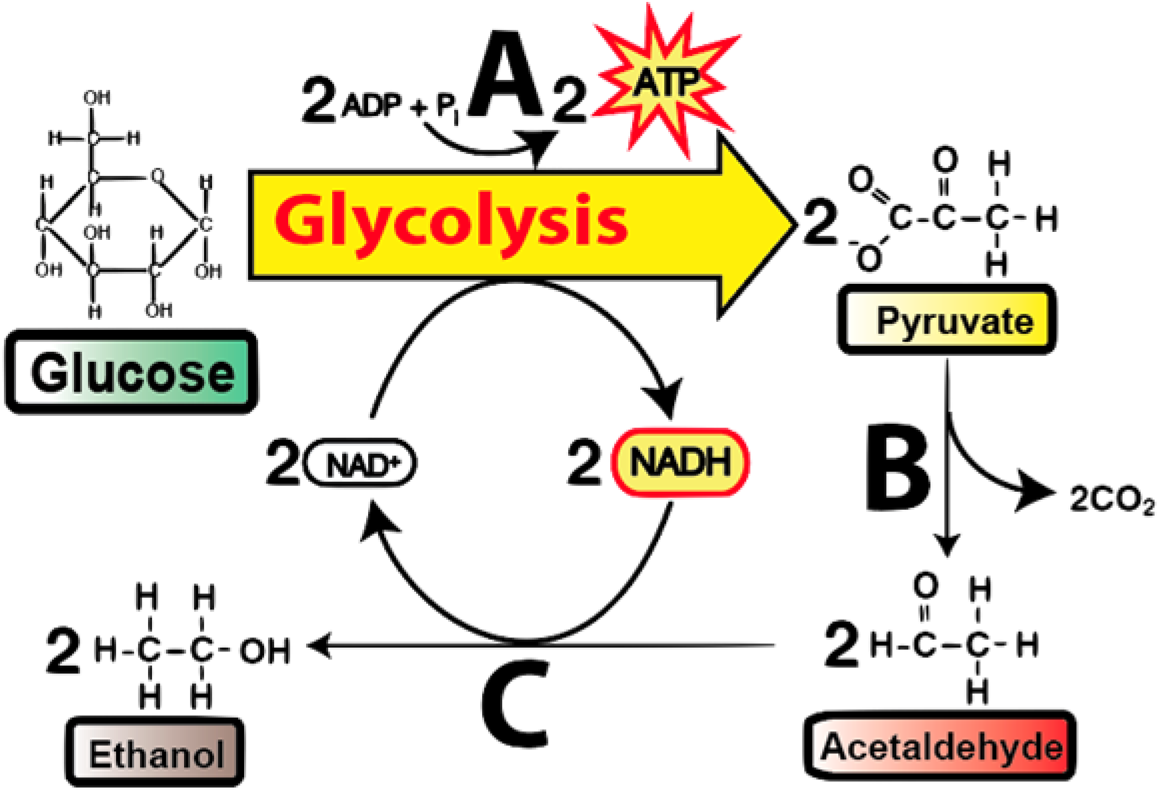




- Fermentation: glycolysis followed by reactions that regenerate NAD^+
- WHY:
  - Glycolysis requires NAD+
  - 2 ATP are better than none!

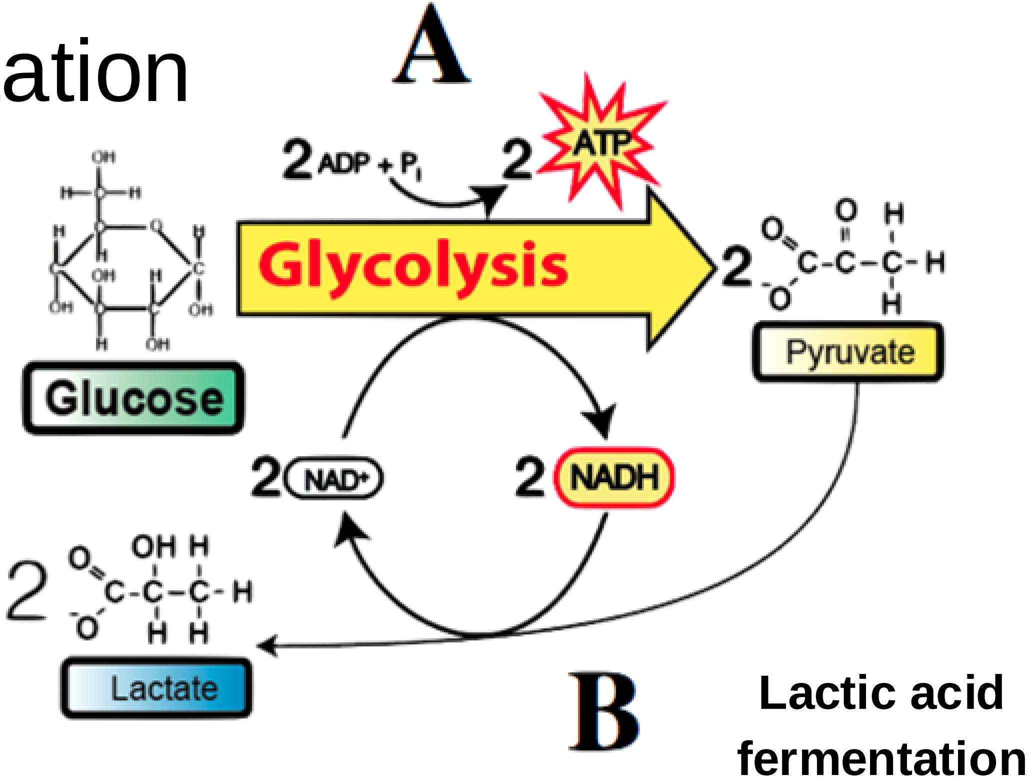
Alcohol fermentation

Alcohol fermentation (ethanol fermentation)



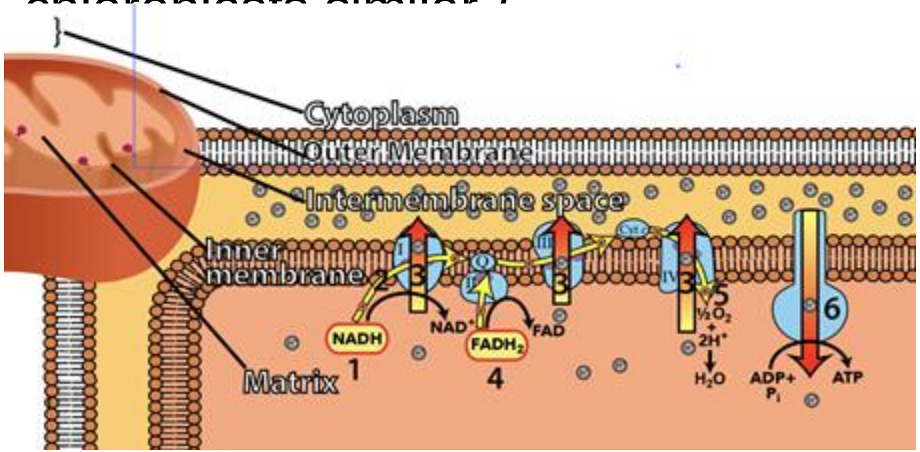
- Occurs in yeast
- Enzymes remove a CO_2 from pyruvate.
- Acetaldehyde is reduced to ethanol as NADH is oxidized to NAD^+

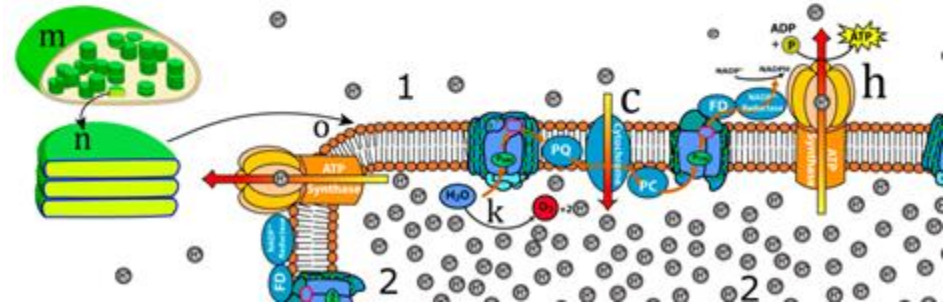
Lactic acid fermentation



- Occurs in muscle tissue under anaerobic conditions.
- Pyruvate is reduced to lactic acid as NADH is oxidized to NAD^+

How is ATP generation in mitochondria and chloroplasts similar?





- Both use an ETC to pump protons to an enclosed space, creating an H^+ gradient
  - PSN: thylakoid space
  - CR: intermembrane space
- Both use chemiosmosis and ATP synthase to generate ATP
- Unit 7 Preview: The similarities indicate that these processes evolved in a common ancestor

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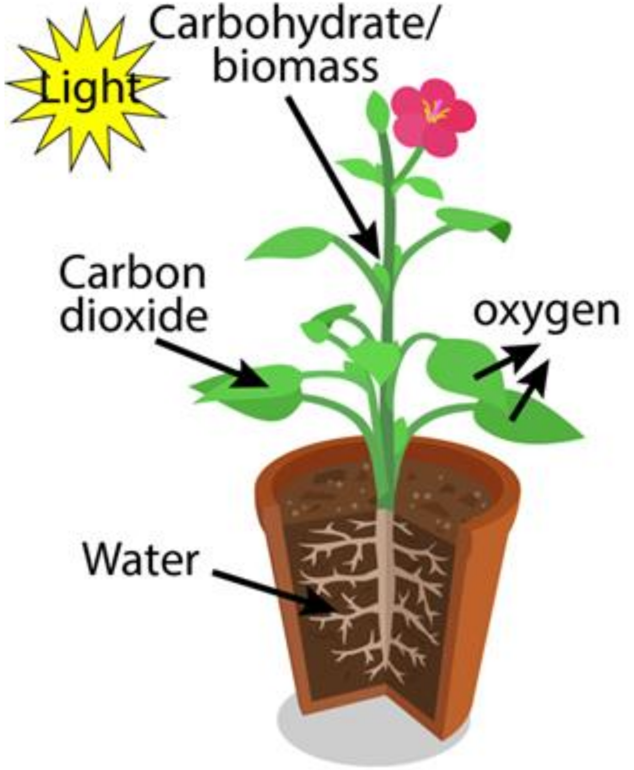
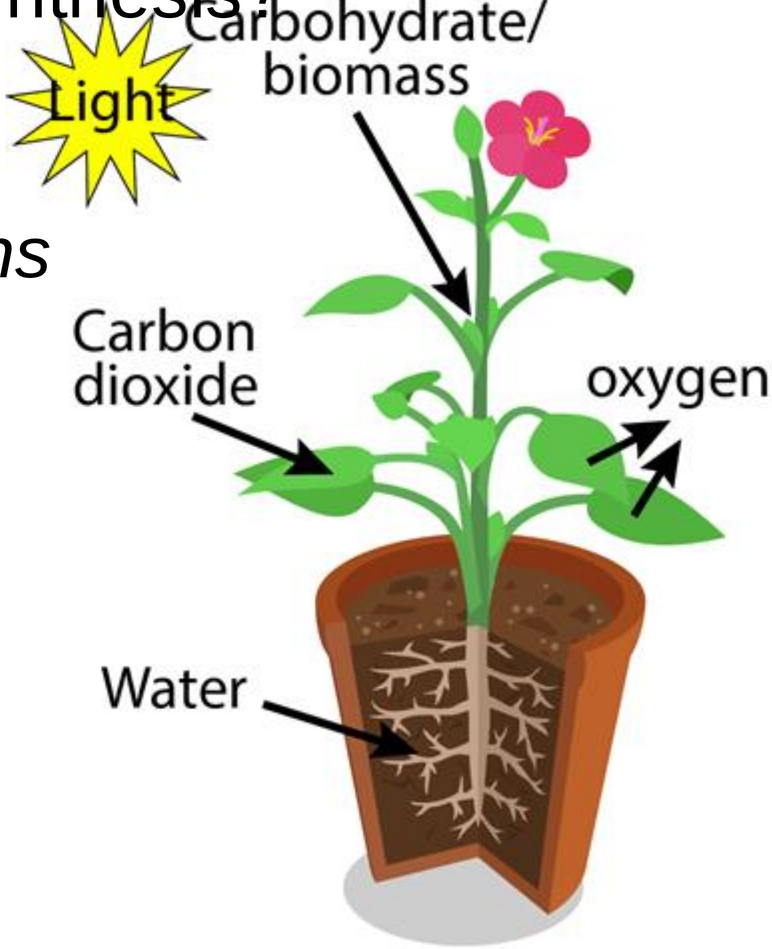
AP Bio Topic 3.5, part 1: Photosynthesis, the Big Picture



What happens during photosynthesis?

- Powered by light
- Performed by *photoautotrophs (self-feeders using light)*
- Inputs: carbon dioxide and water
- Outputs
  - Carbohydrates
  - Oxygen (waste product)

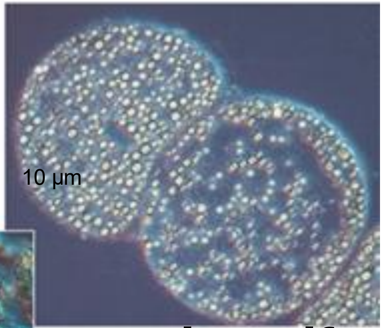


Photoautotrophs

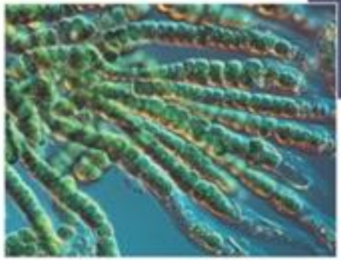
Plants

Multicellular algae

protists



Purple sulfur bacteria



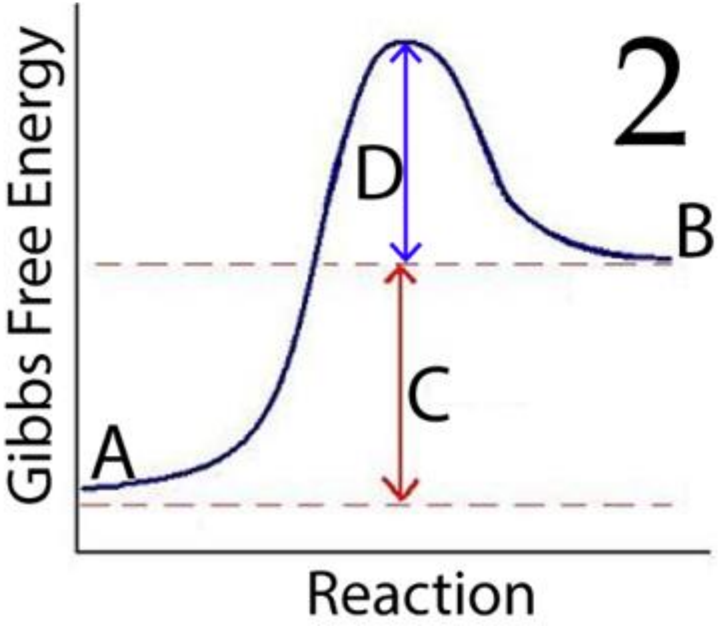
Cyanobacteria

What's the chemical equation for photosynthesis? Is it endergonic or exergonic?

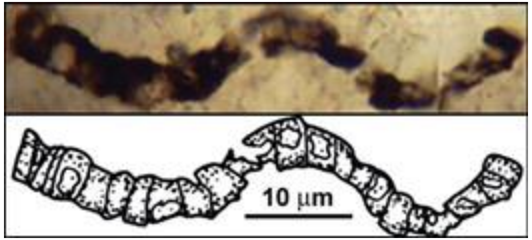
Equation: $6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$

It's **endergonic**.

- Two low-energy inputs (CO_2 and H_2O) are converted into a high-energy product (glucose, $C_6H_{12}O_6$).
- Reduces entropy:
  - 12 reactant molecules → 7 product molecules
  - Highly diffuse, unorganized CO_2 is organized into carbohydrates

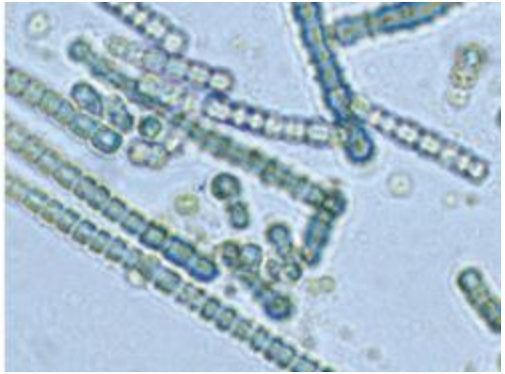


When did photosynthesis first evolve?



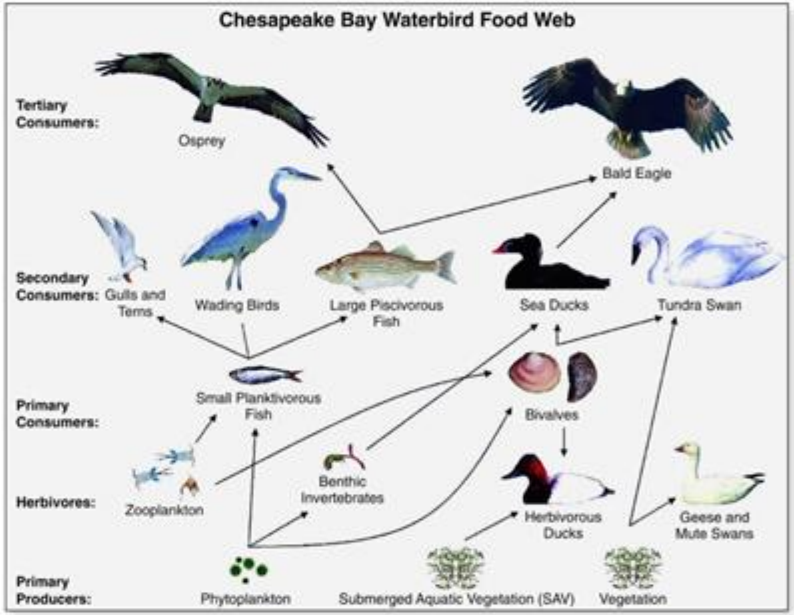
3.5 bya microfossils of photosynthetic bacteria

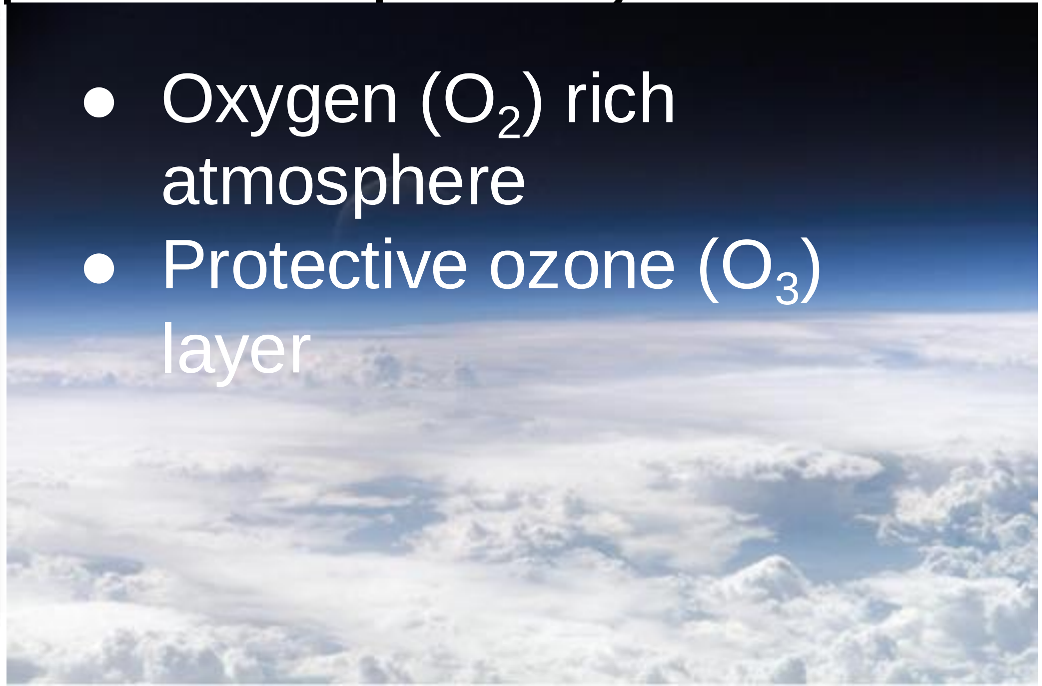
- Based on fossil and chemical evidence, about 3.5 bya (relatively close to the emergence of life 3.8 bya)
- Early photosynthesizers included **cyanobacteria**, which performed oxygen-producing photosynthesis.



Modern cyanobacteria

What are some consequences of photosynthesis?

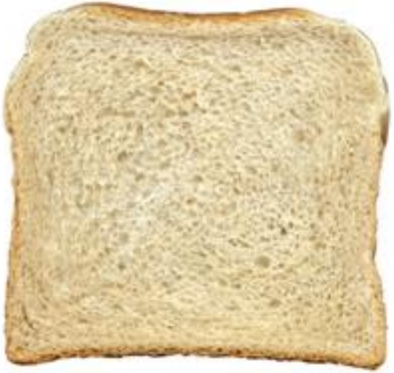




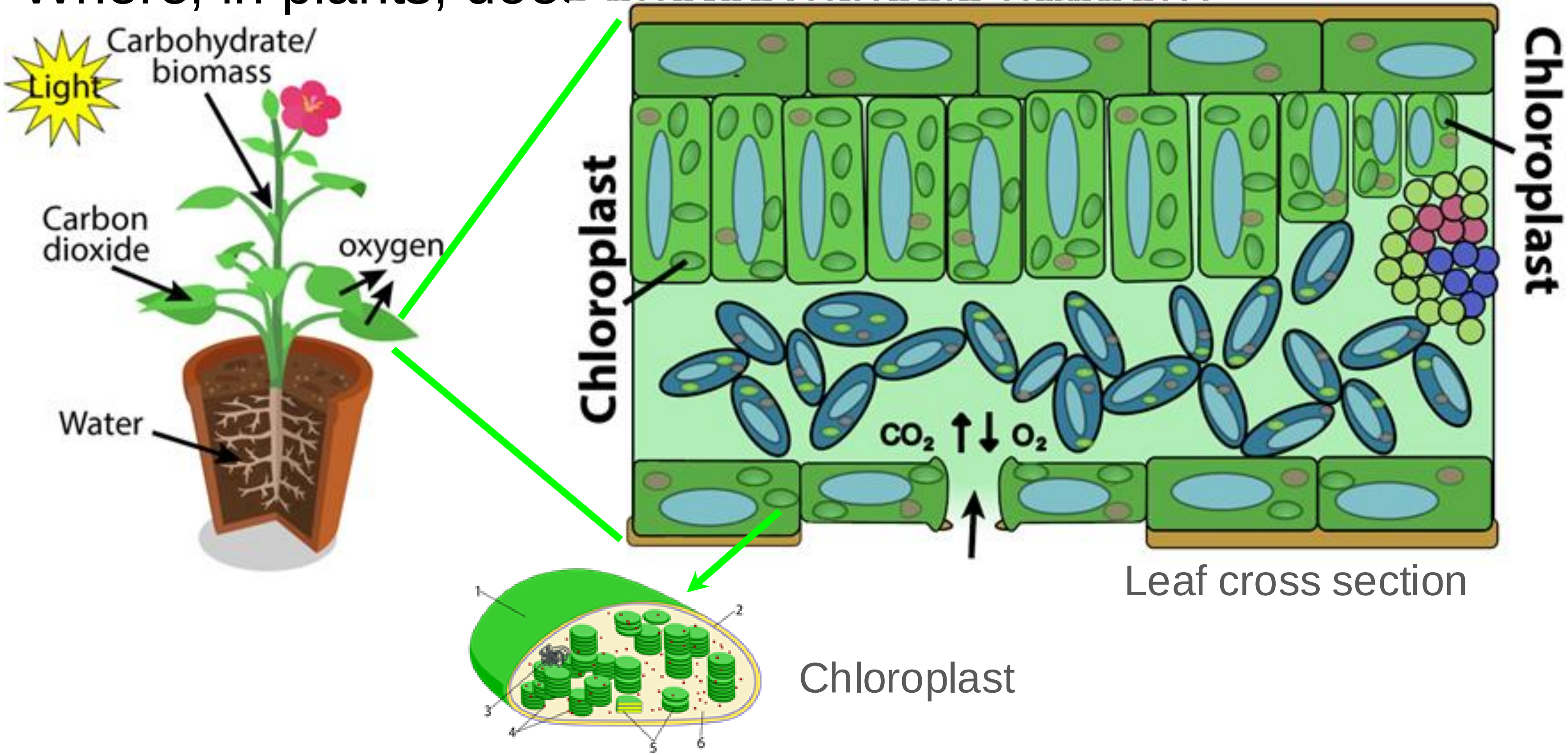
- Oxygen (O_2) rich atmosphere
- Protective ozone (O_3) layer

- Food webs: Photoautotrophs are ecological producers

All food can be traced to photosynthesis

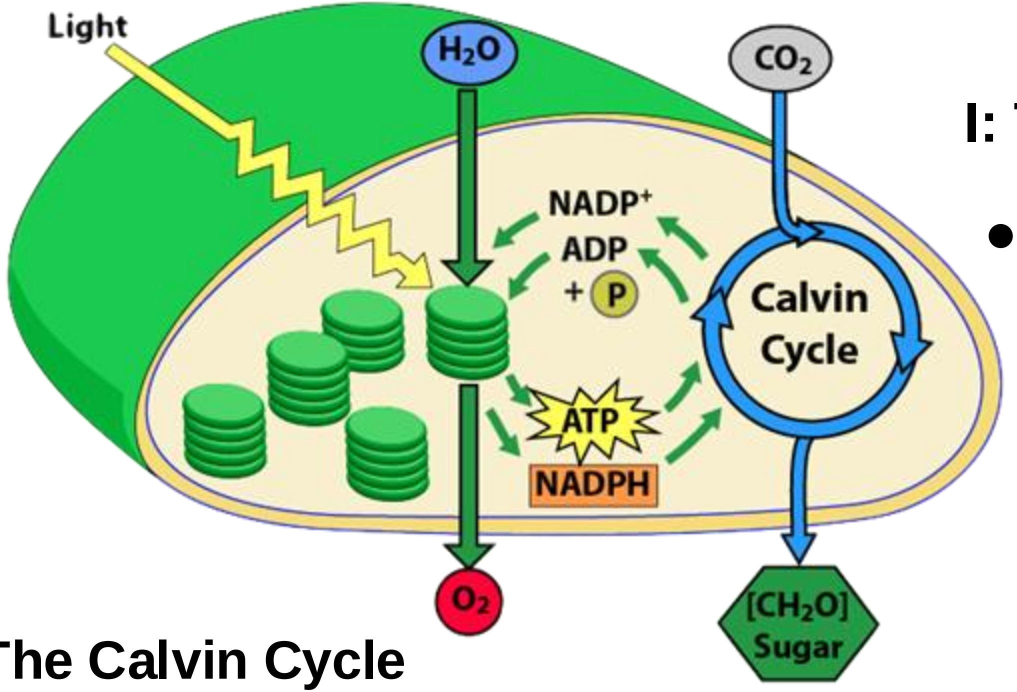


Where, in plants, does photosynthesis happen?



- Mostly in photosynthetic cells in leaves, in chloroplasts

What are the two phases of photosynthesis?



I: The Light Reactions

- Converts light energy into chemical energy
  - ATP
  - NADPH (electron carrier)

II. The Calvin Cycle

- Converts the chemical energy in NADPH and ATP into carbohydrate.
- “Fixes” carbon dioxide, converting it from a low energy gas into high energy sugars.

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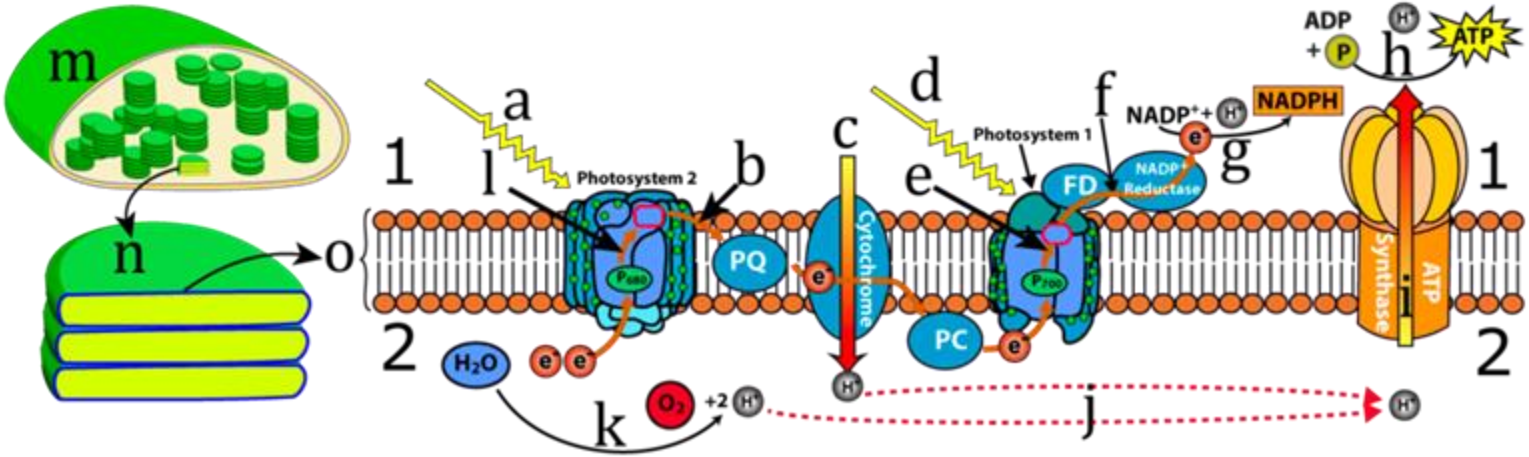
AP Bio Topic 3.5, part 2: The Light Reactions



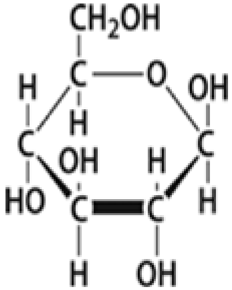
Four energy transformations occur during photosynthesis

1. Light energy

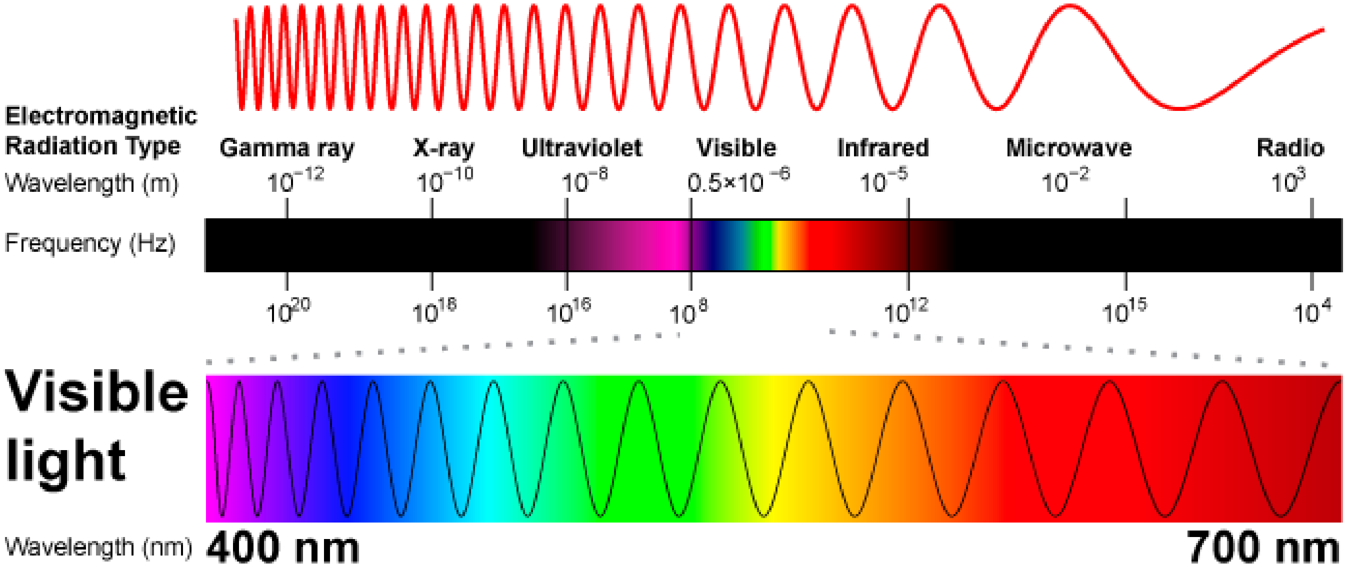
2. Electricity

3. Short term chemical energy
  - ATP
  - NADPH

4. Long term chemical energy

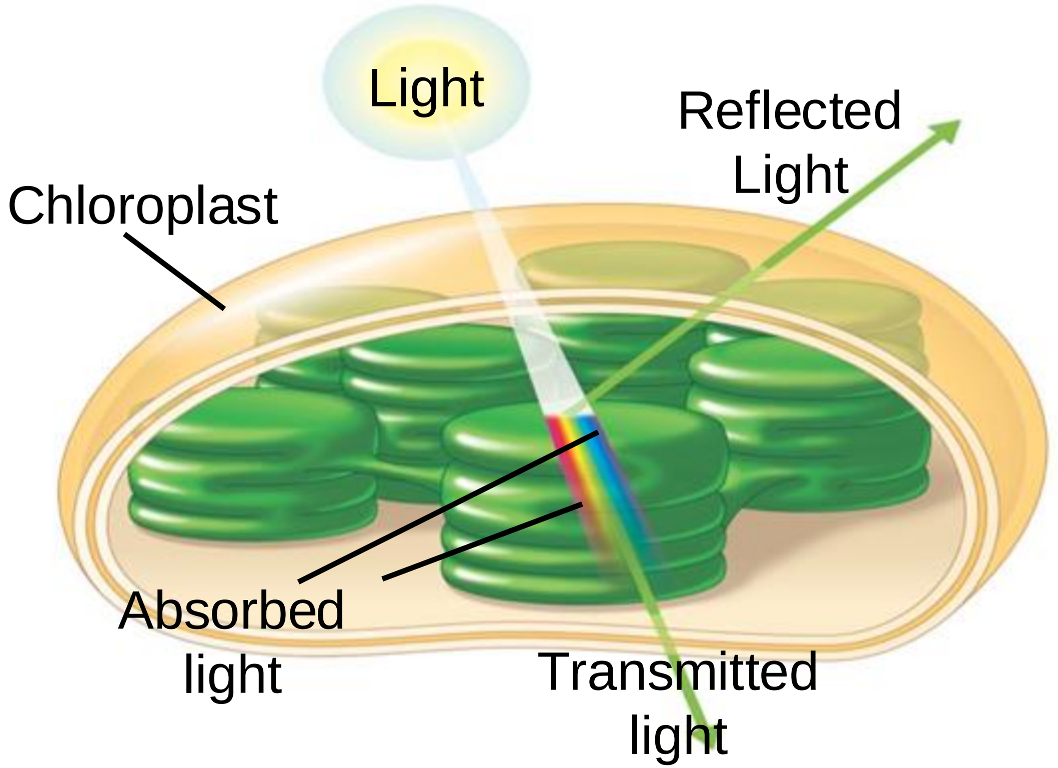


Light is electromagnetic energy



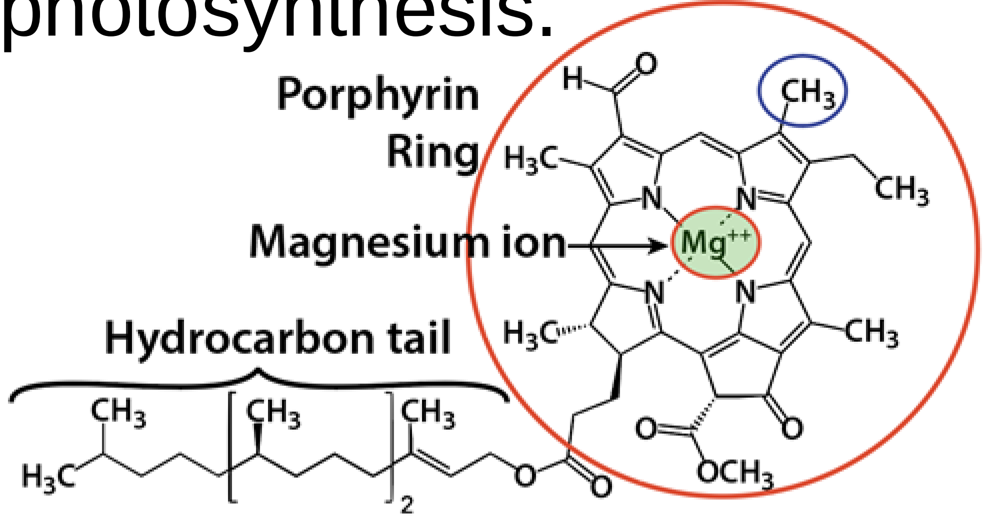
- Made of *photons*
- Blue light: shorter waves (more energy)
- Red: longer waves (less energy)

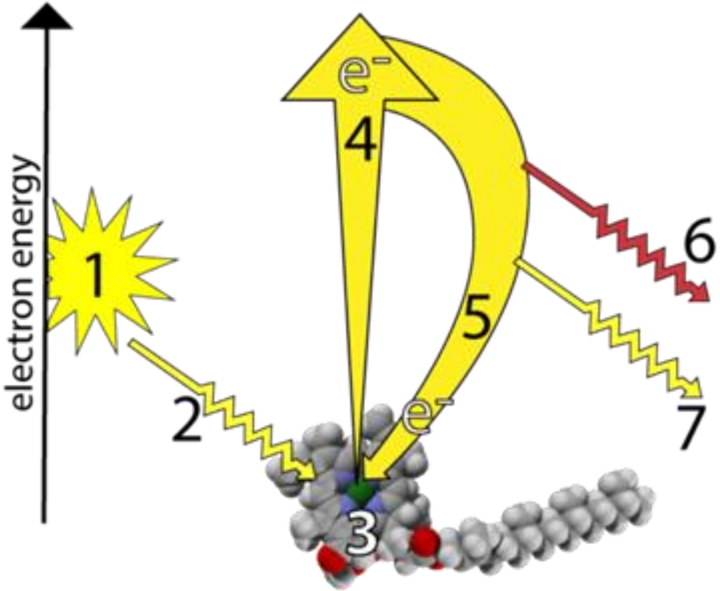
Pigments absorb certain wavelengths of light (and reflect others)



- Green leaf:
  - Absorbs red and blue light
  - Reflects green

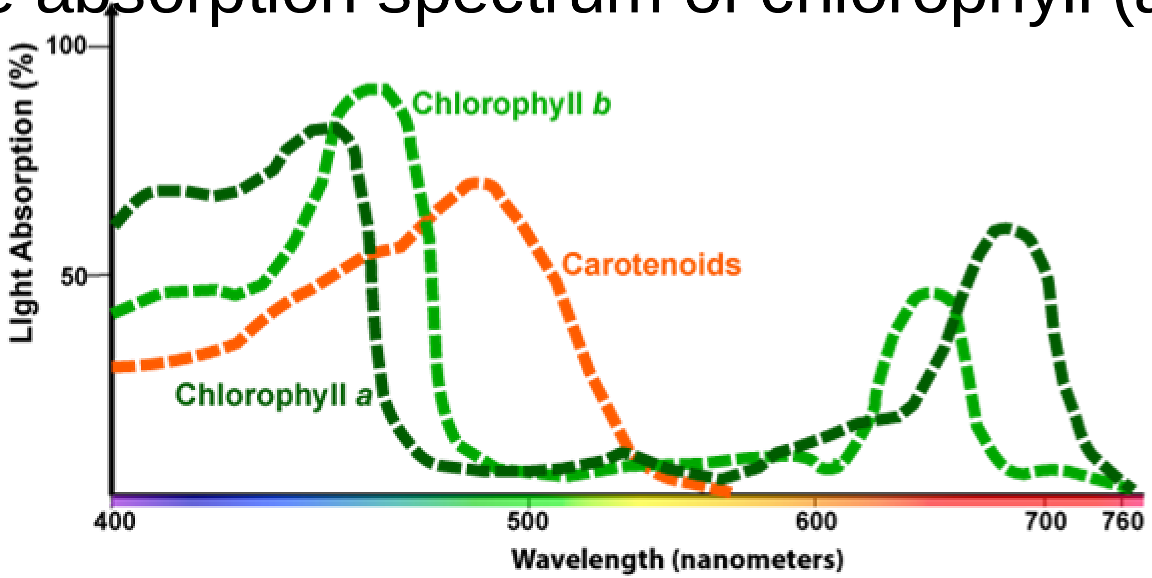
Chlorophyll is the key light-capturing pigment in photosynthesis.





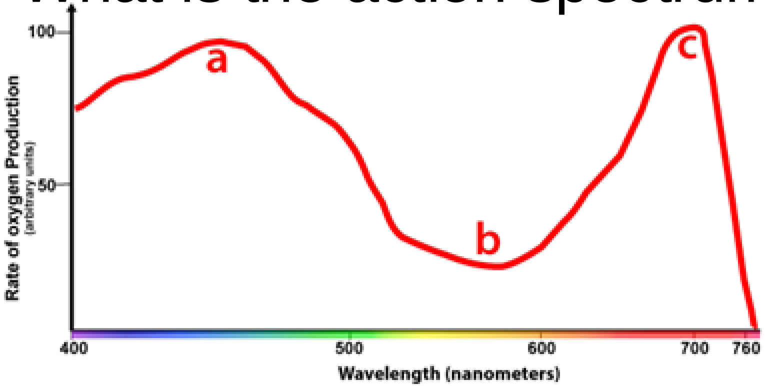
- Light energy boosts electron energy (photoexcitation)
- Two forms: *a* and *b* that differ by one functional group.
- Hydrocarbon tail embeds chlorophyll in the P-L bilayer.

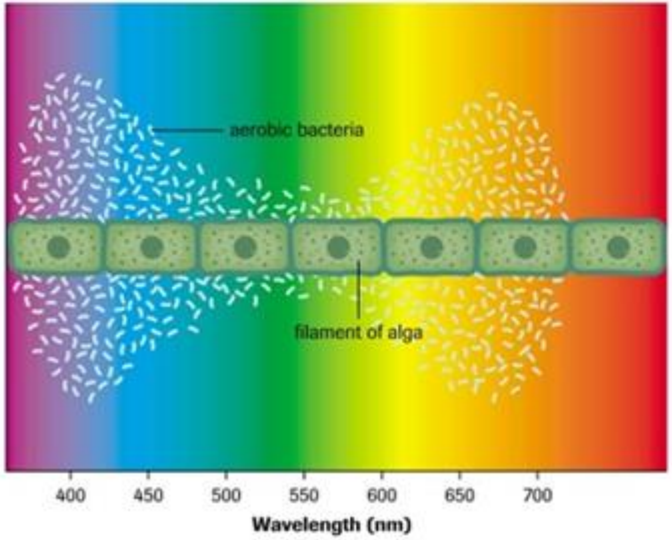
Explain the absorption spectrum of chlorophyll (and other pigments)



- **Absorption spectrum:** the amount of light absorbed at different light wavelengths.
  - Chlorophyll has two forms (a and b) that absorb most in blue and red, least in green.
  - Other pigments (e.g. carotenoids) absorb other wavelengths.

What is the action spectrum of photosynthesis?

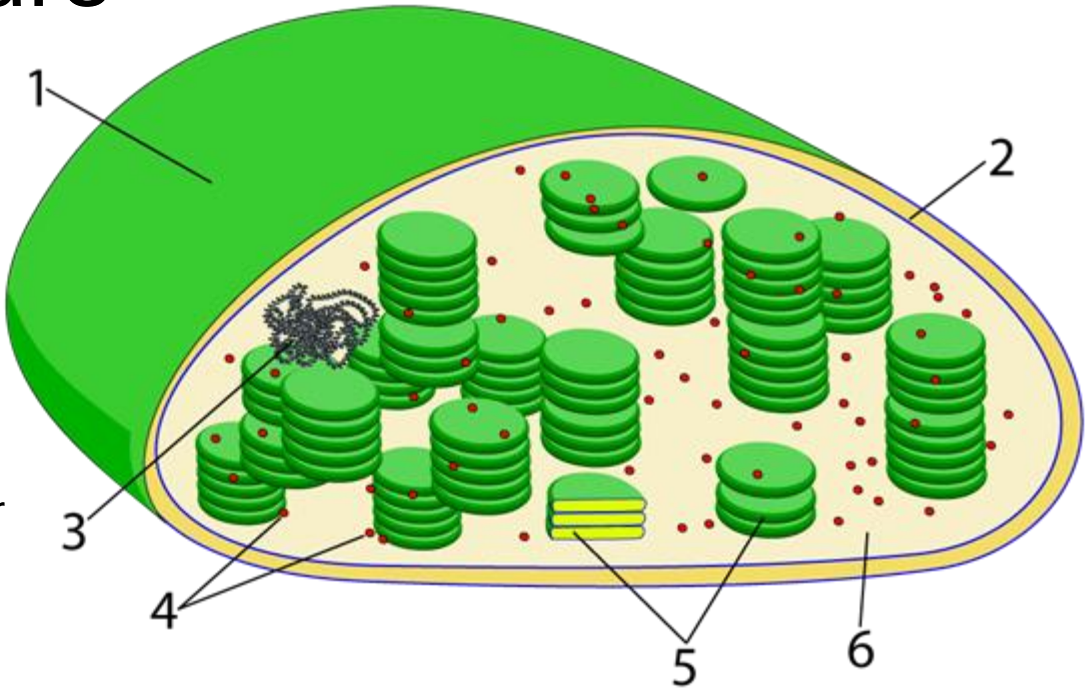




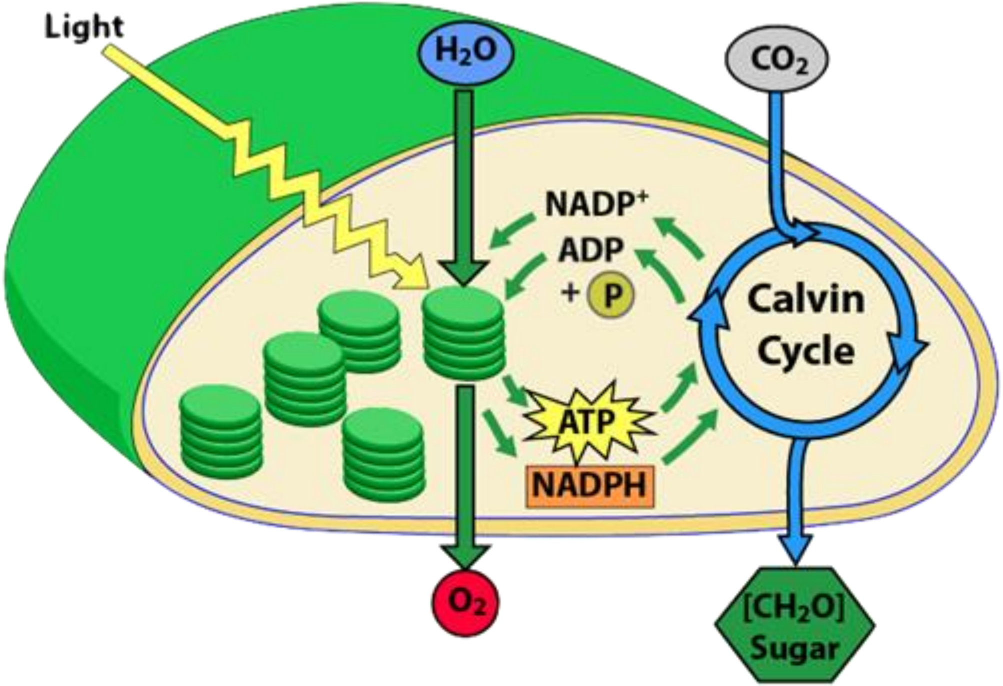
- **Action spectrum:** Shows how various light wavelengths drive photosynthesis
- **Engelmann experiment:**
  - Grew algae under light from a prism
  - Aerobic bacteria grew best in blue and red part of the spectrum.

Chloroplast structure

- 1. Outer membrane
- 2. Inner membrane
- 3. DNA
- 4. Ribosomes
- 5. Thylakoids:
  - Membrane-bound sacs.
  - Contain the membrane-bound photosystems and chlorophyll for light reactions of photosynthesis.
  - Organized into stacks called grana.
- 6.Stroma (the cytoplasm of the chloroplast):
  - Contains DNA, ribosomes
  - Where Calvin cycle occurs.

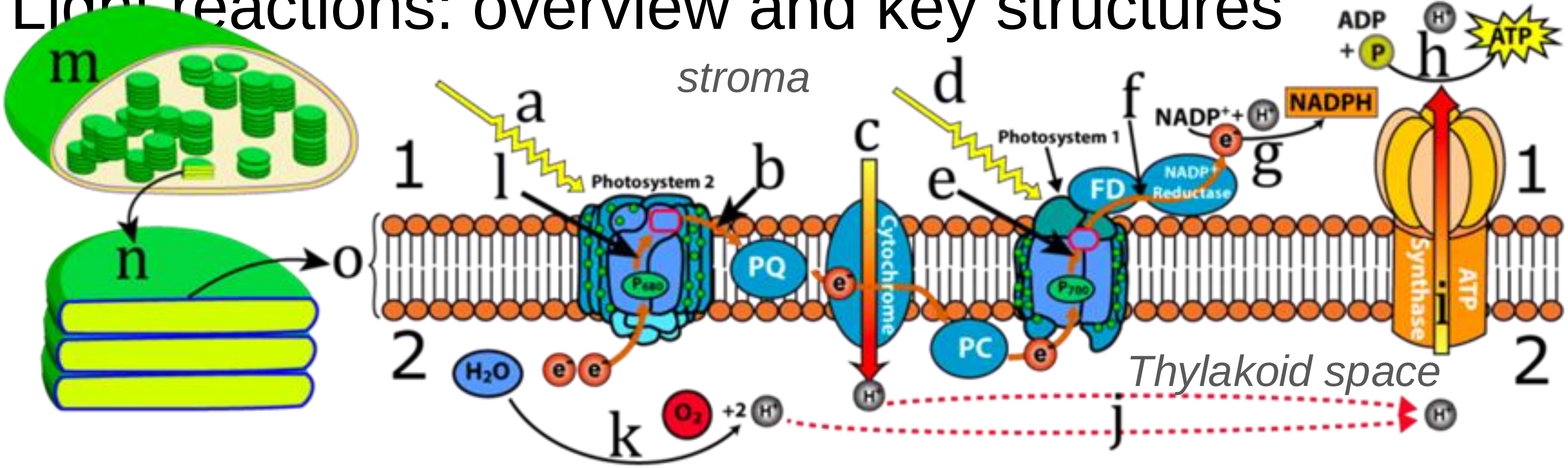


What do the light reactions produce? Where do these reactions occur? What are the inputs and outputs?



- **Light reactions:** convert the energy in light into the chemical energy of NADPH and ATP.
- **WHERE**: Occurs in the thylakoids
- **Outputs**:
  - NADPH
  - ATP
  - O_2 (waste product),
- **Inputs**:
  - Light and water
  - $NADP^+$, ADP + P_i (from the Calvin Cycle)

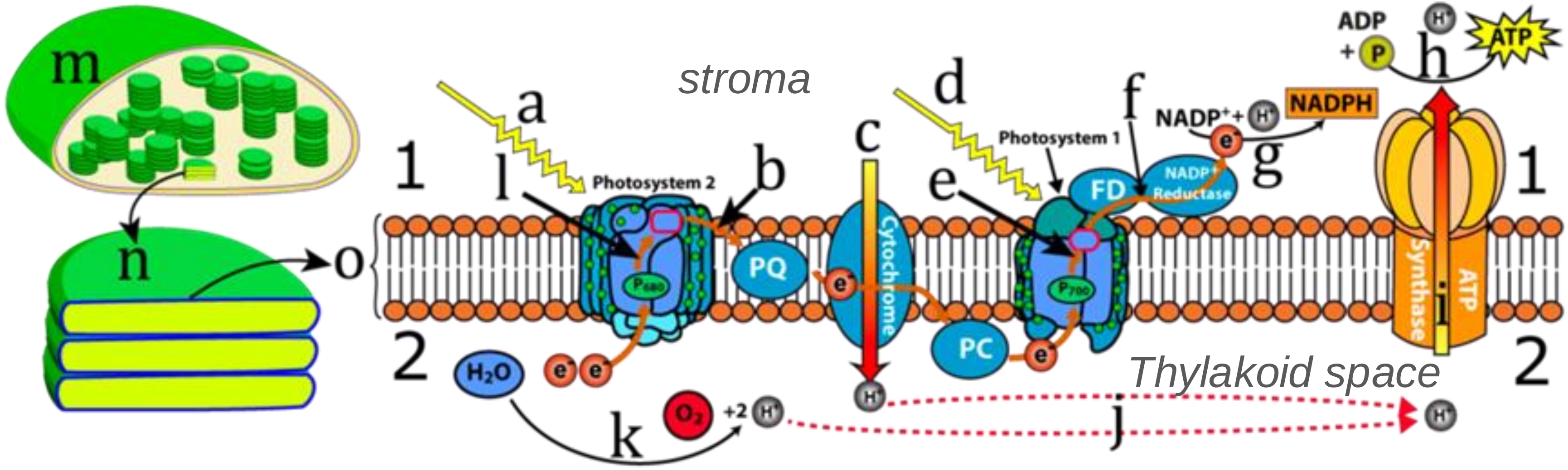
Light reactions: overview and key structures



- “m:” chloroplast
- “n” and “o:” grana and thylakoid membrane
- Photosystems: proteins with embedded chlorophyll molecules
  - Convert light energy (“a” and “d”) into a flow of electrons
  - Split water molecules (Photosystem 2 only)

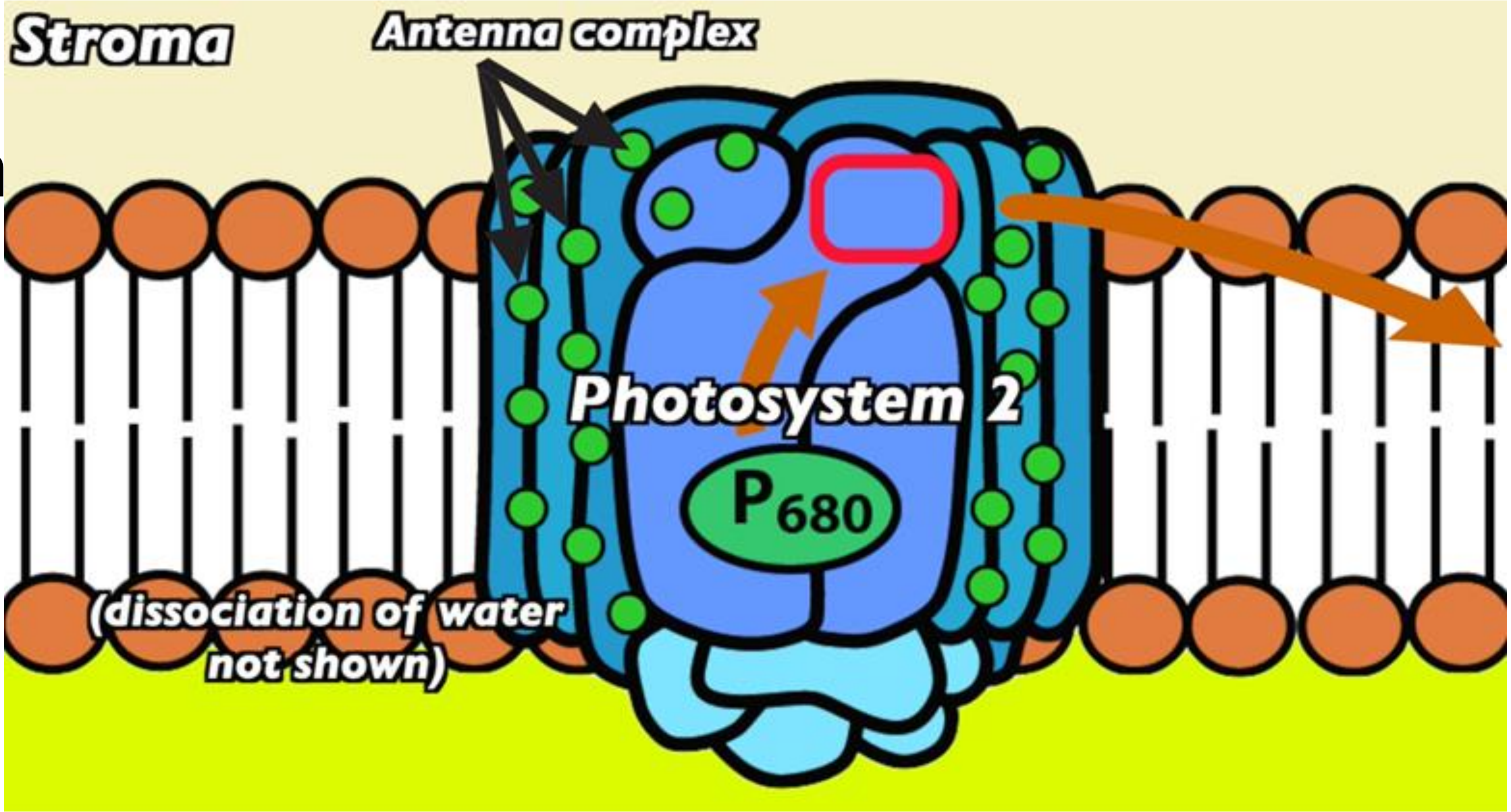
- Electron pathway (“l”, “b,” “e,” “f.”)
- Proton pumps (“c”)
- ATP Synthase

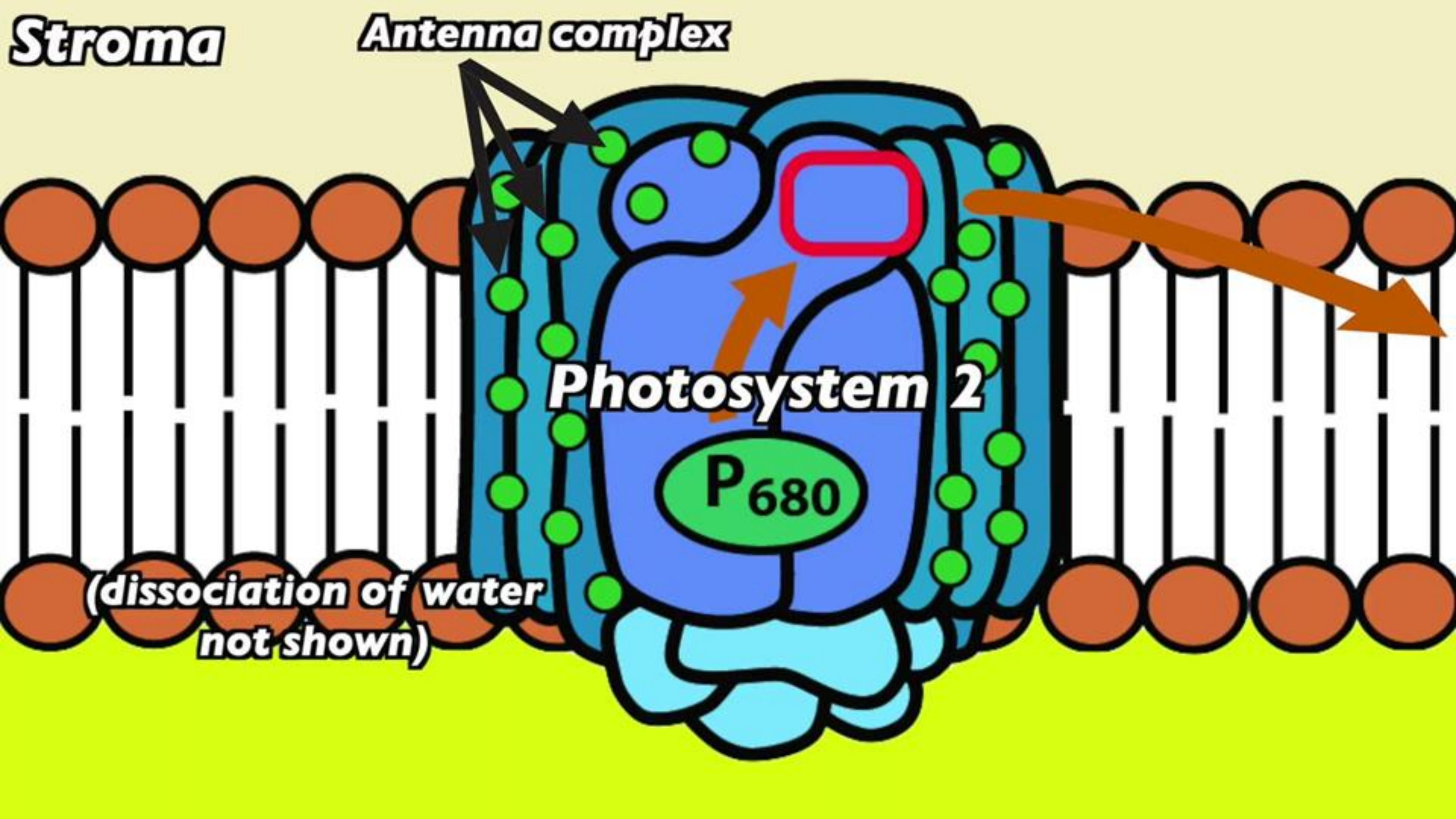
Photosystem 2 comes *before* Photosystem 1!



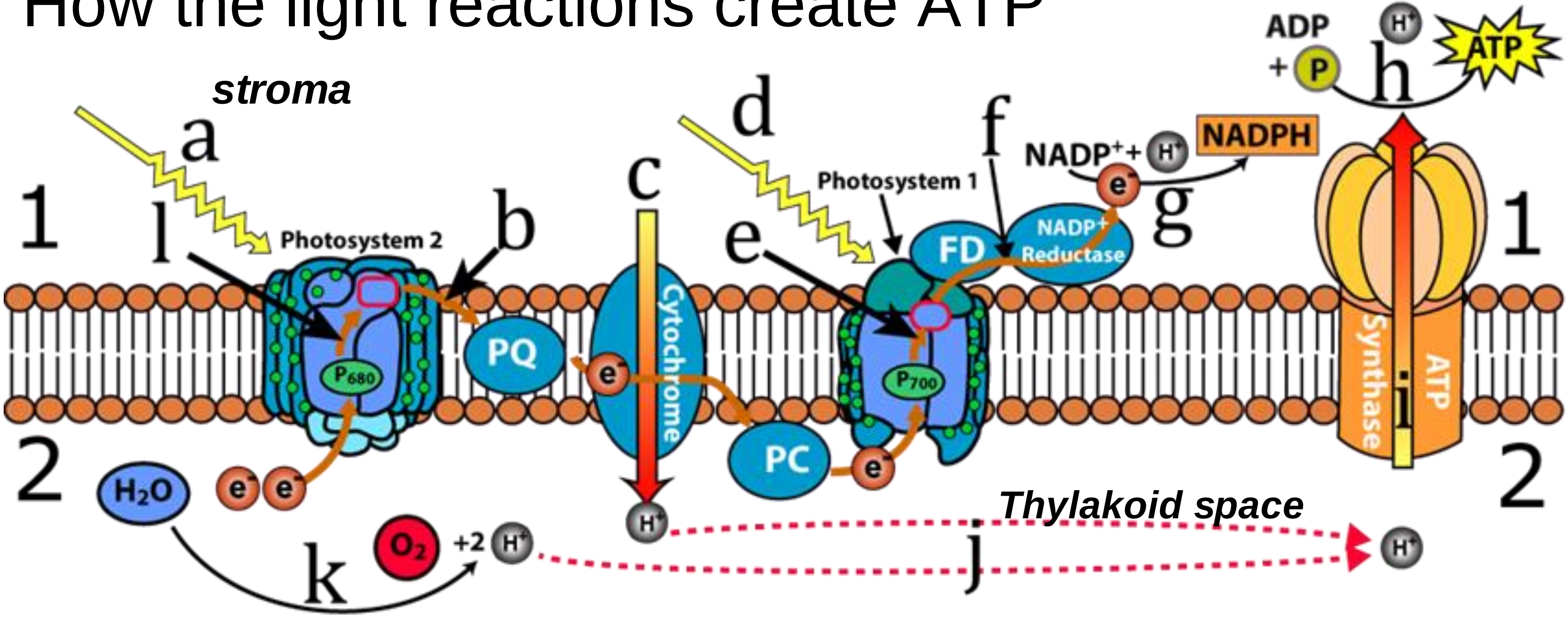
It's a fact to memorize, just get it done!

The light reactions begin by converting light energy into electron flow

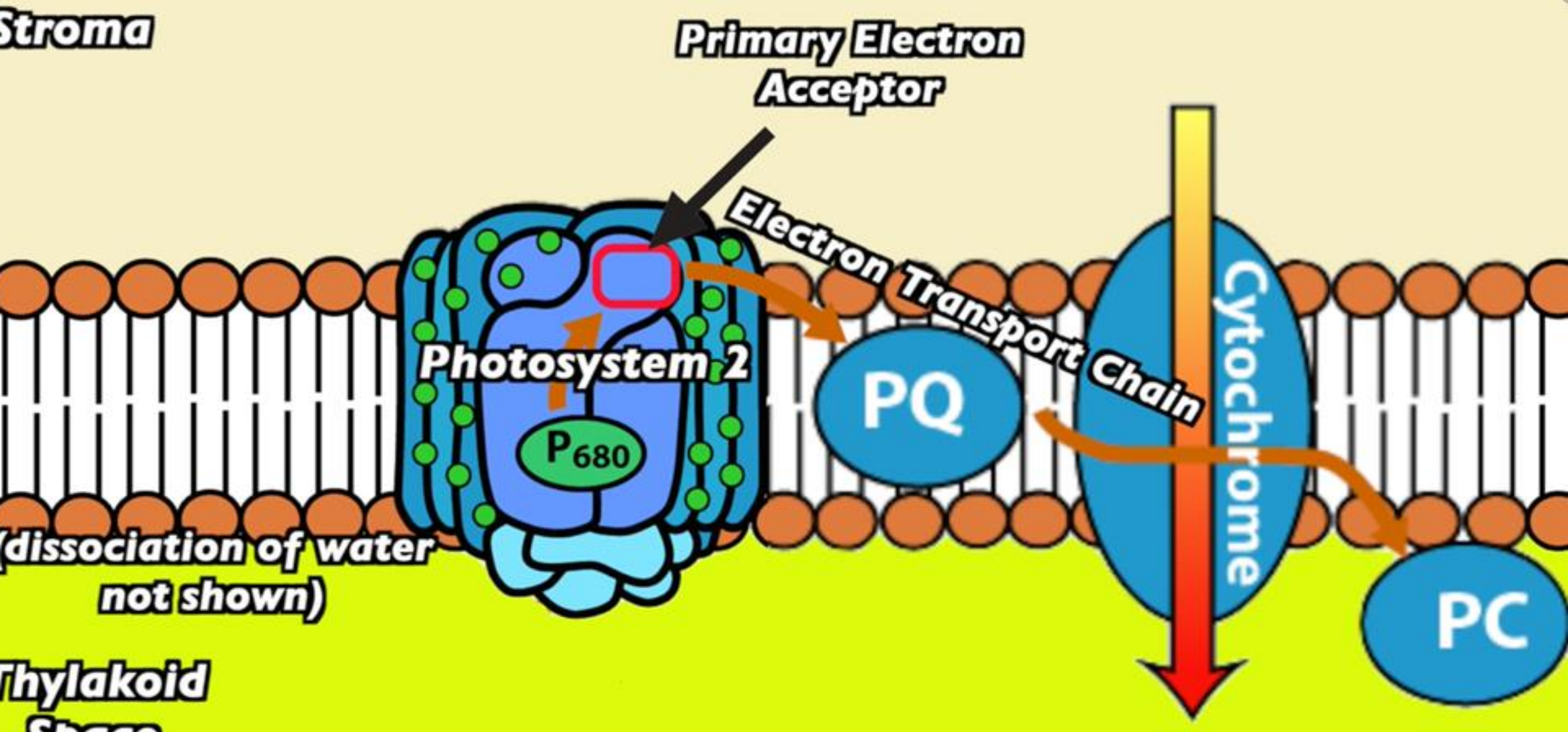



Stroma
Antenna complex
Photosystem 2
P680
(dissociation of water
not shown)

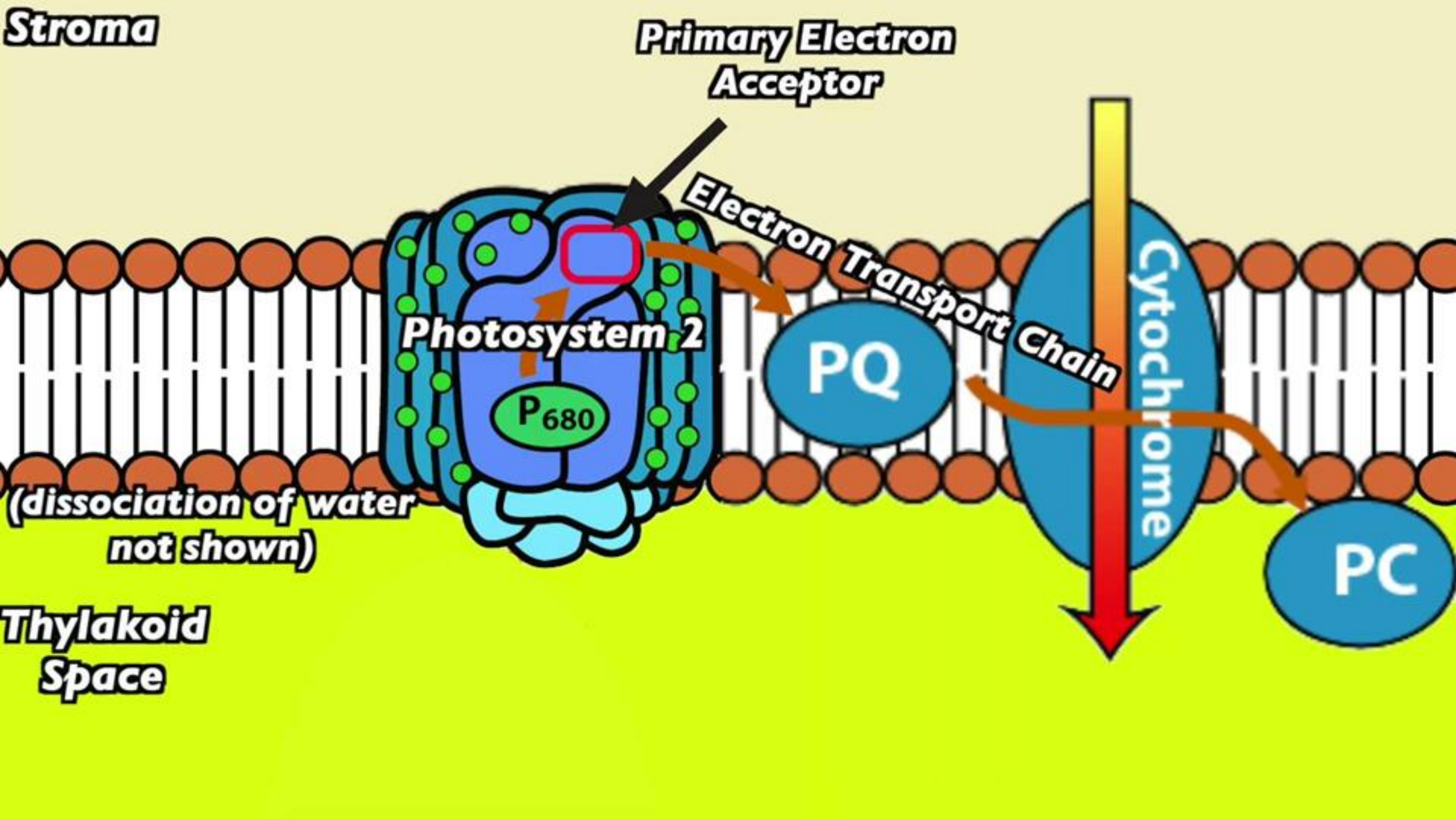
How the light reactions create ATP

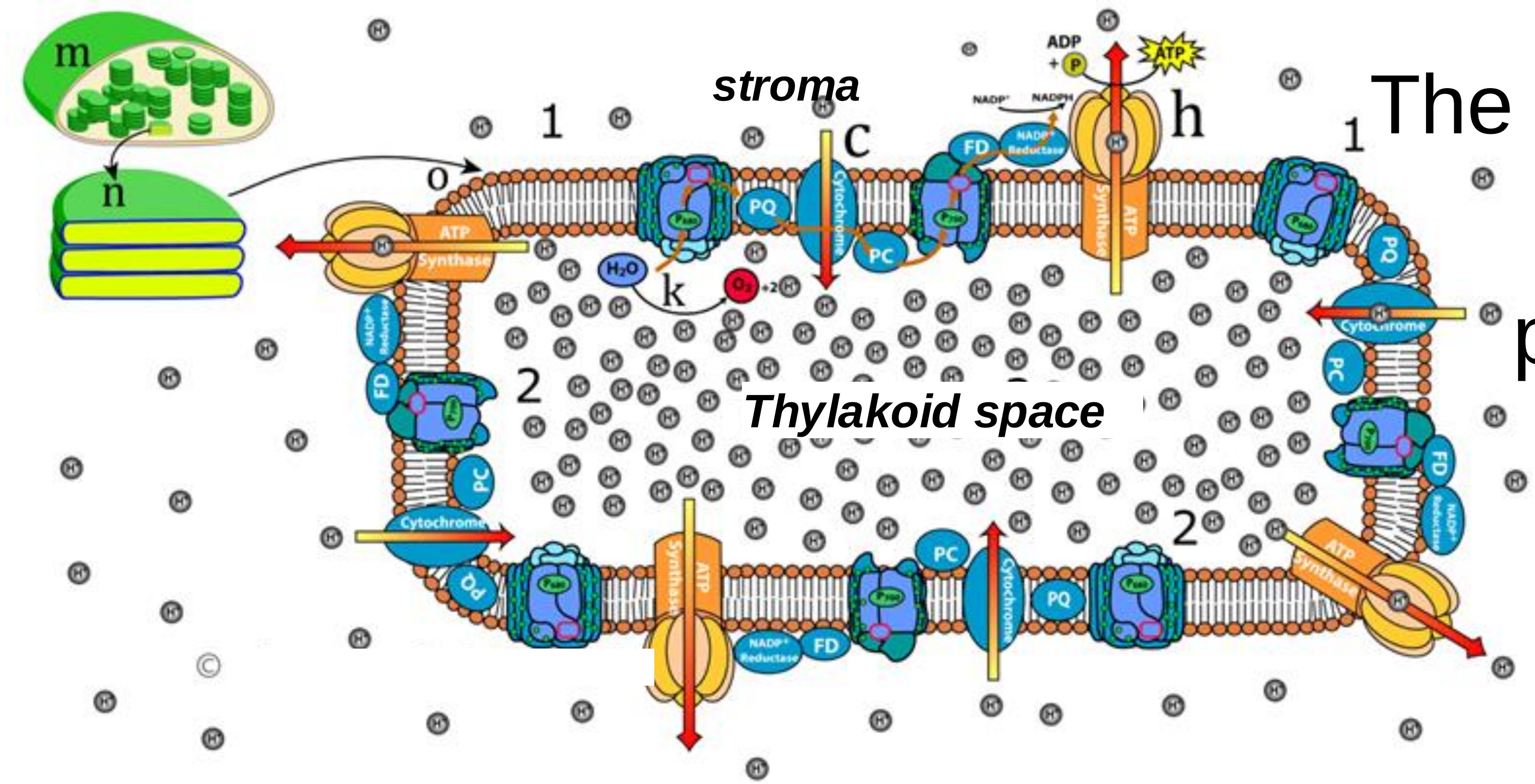


- Photoexcitation of chlorophyll in PS II → flow of electrons (b) along an electron transport chain in the thylakoid membrane.
- ETC powers proton pumping from the stroma (1) to the thylakoid space (2)



Proton Pumping

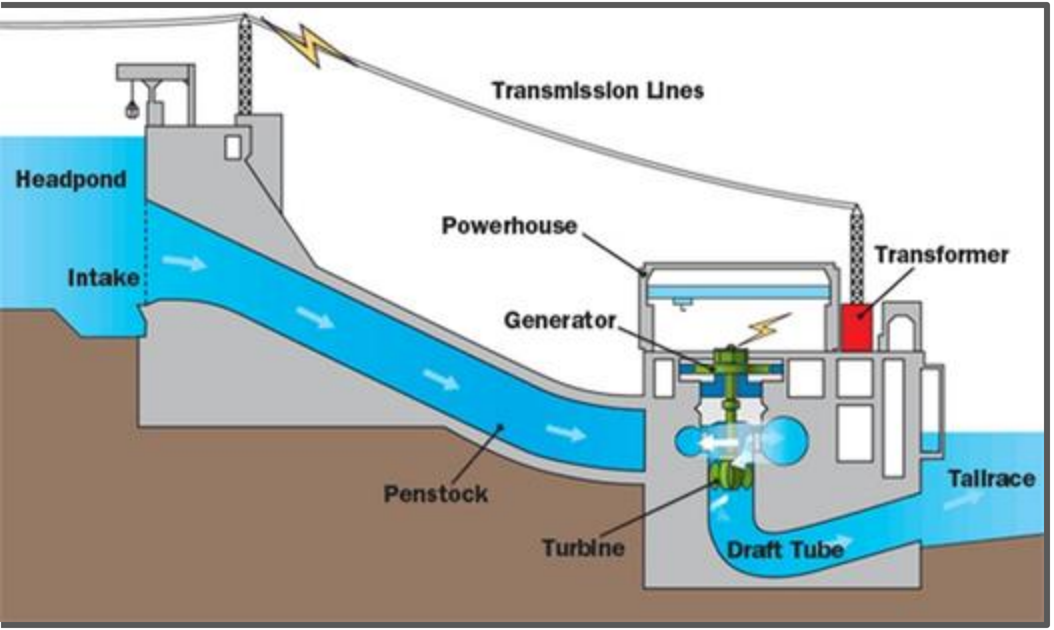

Stroma
Primary Electron
Acceptor
Electron Transport Chain
Photosystem 2
P680
PQ
Cytochrome
PC
(dissociation of water
not shown)
Thylakoid
Space



The result of proton pumping

- Protons are trapped in the thylakoid space
- Protons “want” to diffuse back to the stroma
- Water splitting (“k”) enhances the proton gradient

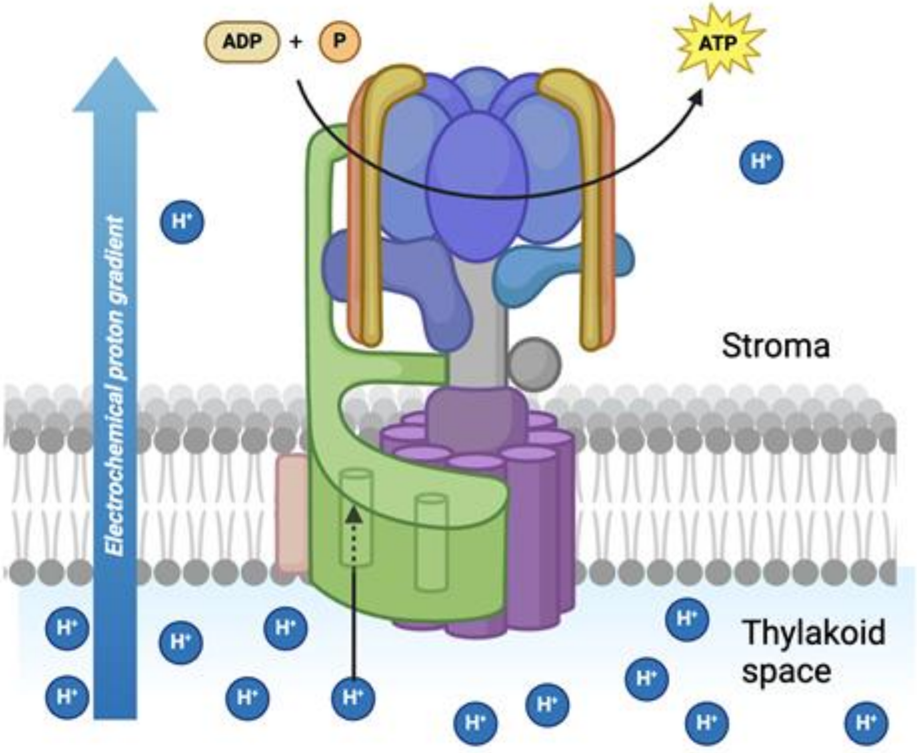
The trapped protons in the thylakoid space are potential energy, like water trapped behind a dam

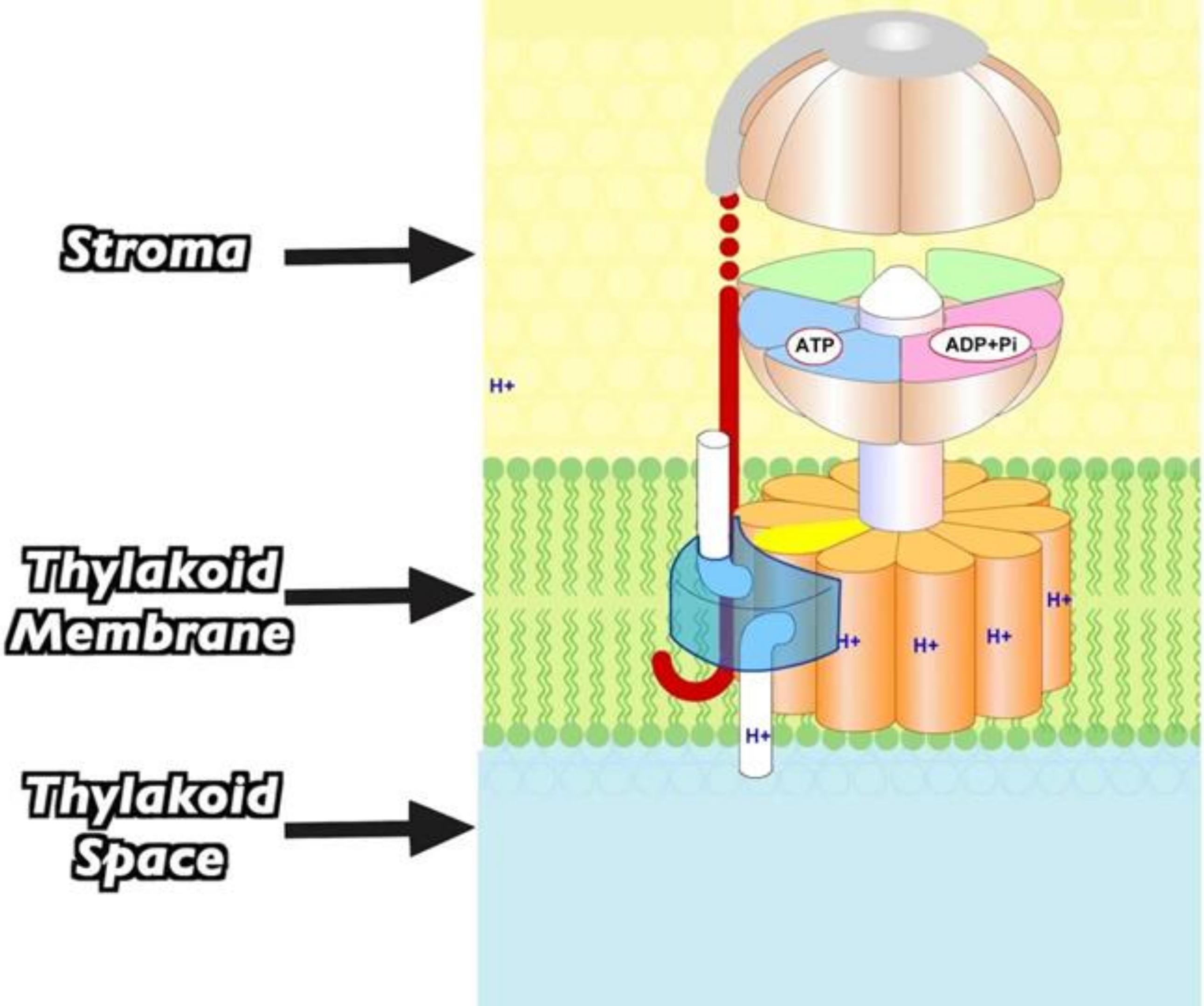


Proton diffusion through ATP synthase creates ATP

ATP synthase

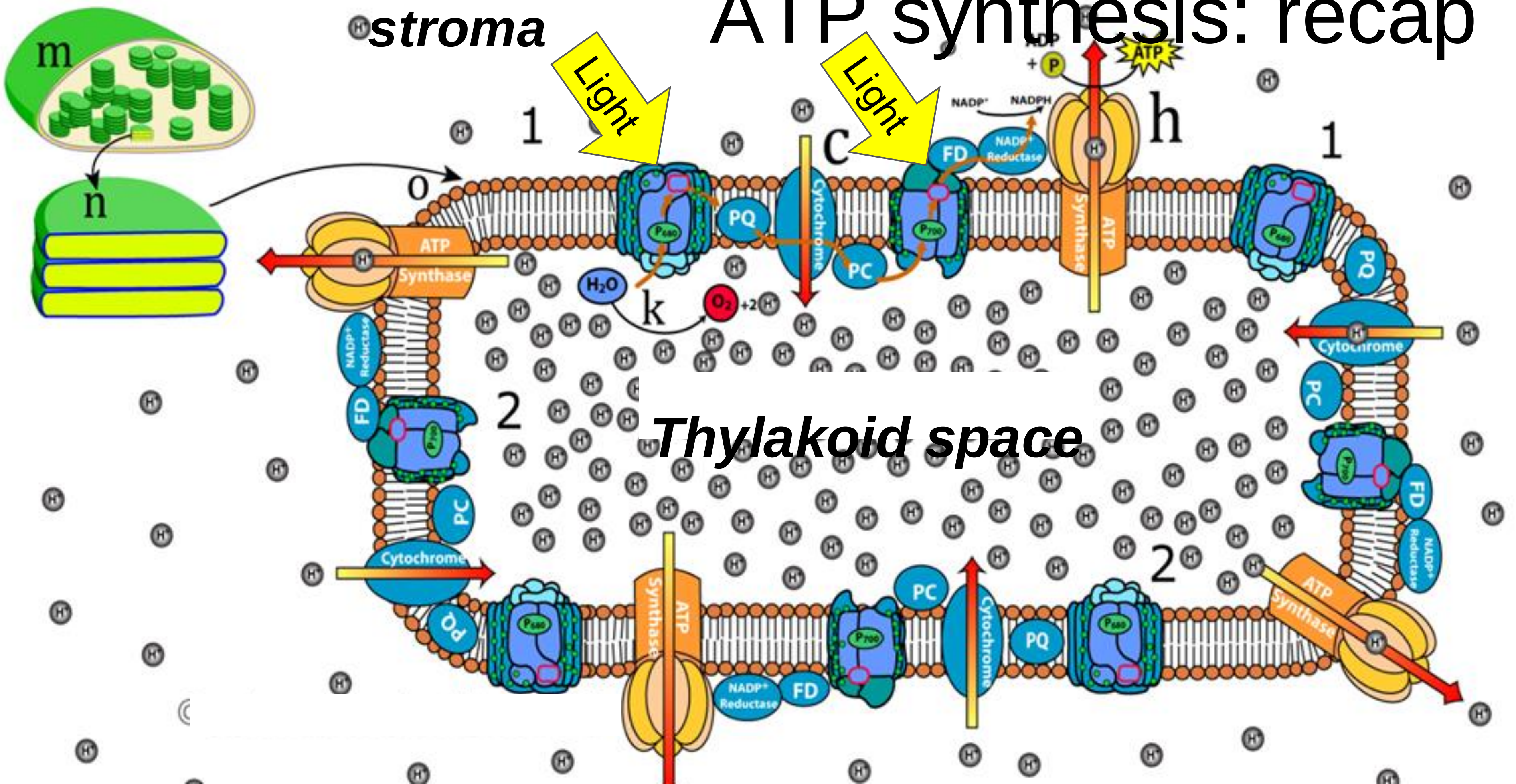
- A proton channel
- An enzyme
- The only way for protons to diffuse back to the stroma



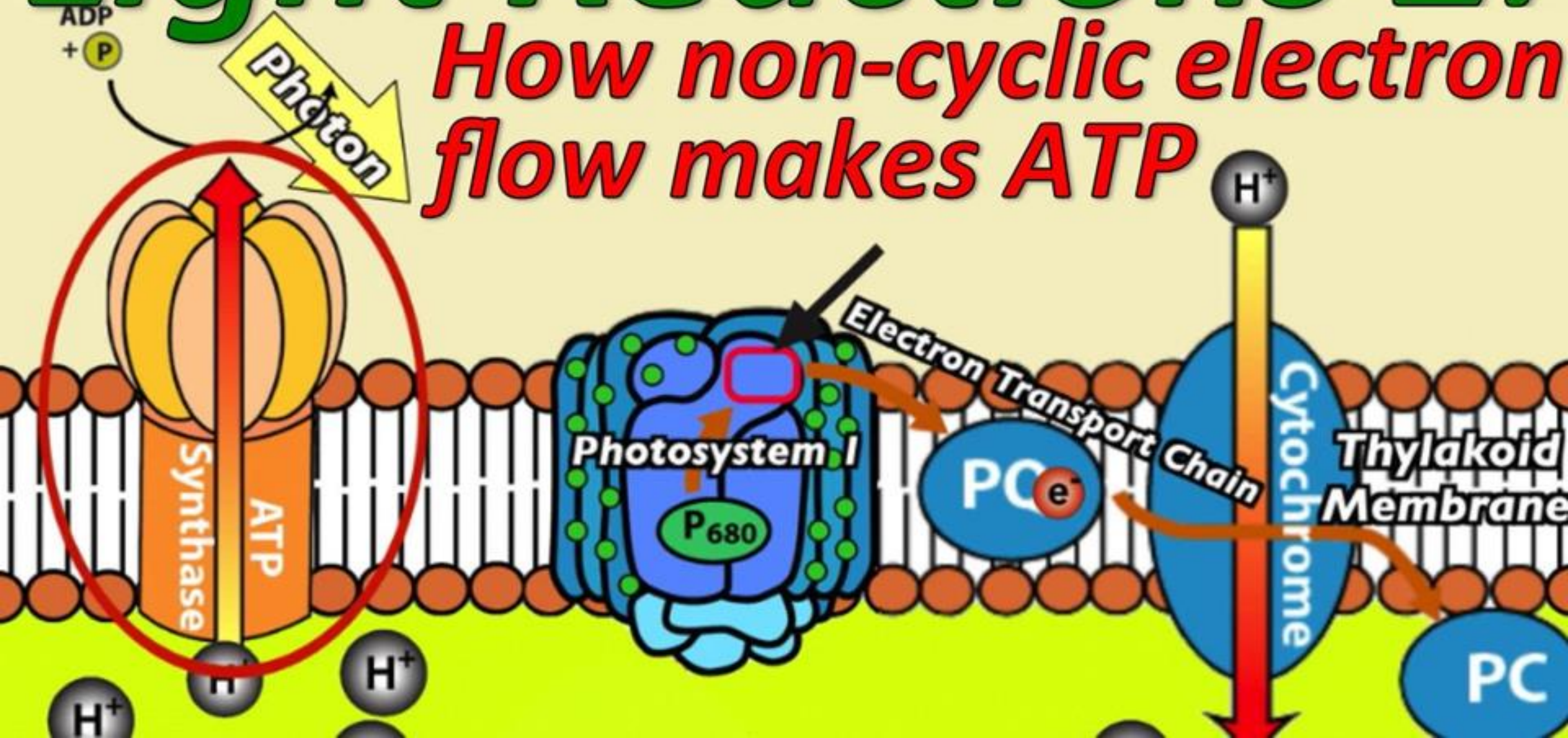


ATP Synthase:
Animation by Donald Nicholson

ATP synthesis: recap



Light Reactions 2:
How non-cyclic electron flow makes ATP



Light Reactions, Part 2

(How Non-Cyclic Electron Flow Makes ATP)

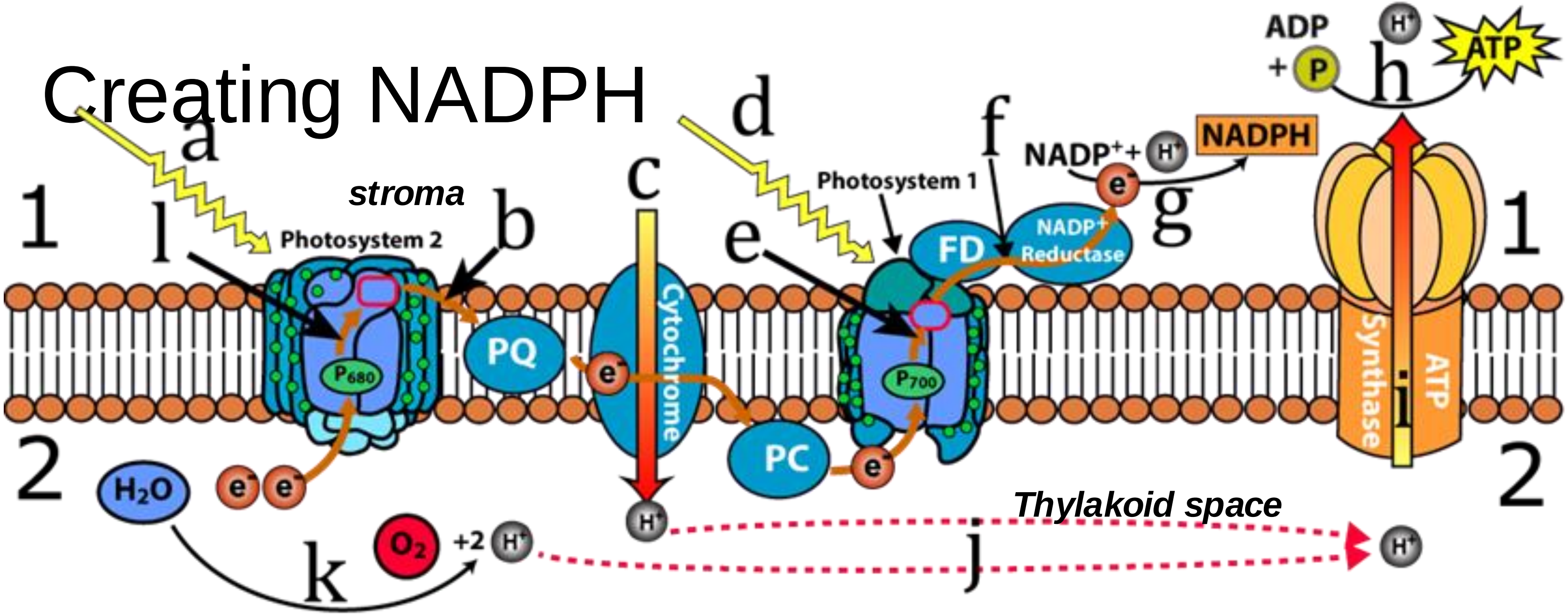
A musical lecture

by

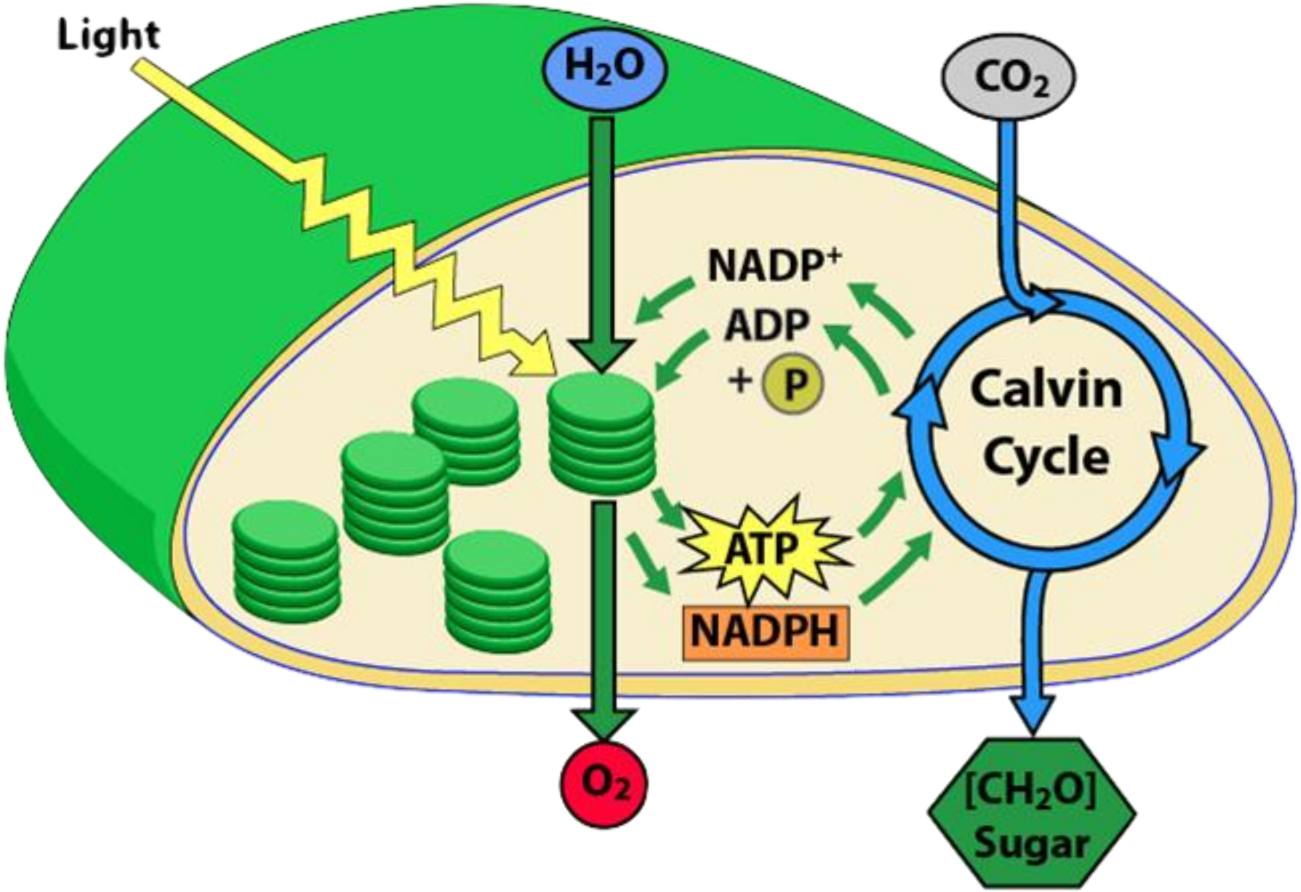
Glenn Wolkenfeld

www.sciencemusicvideos.com

Creating NADPH

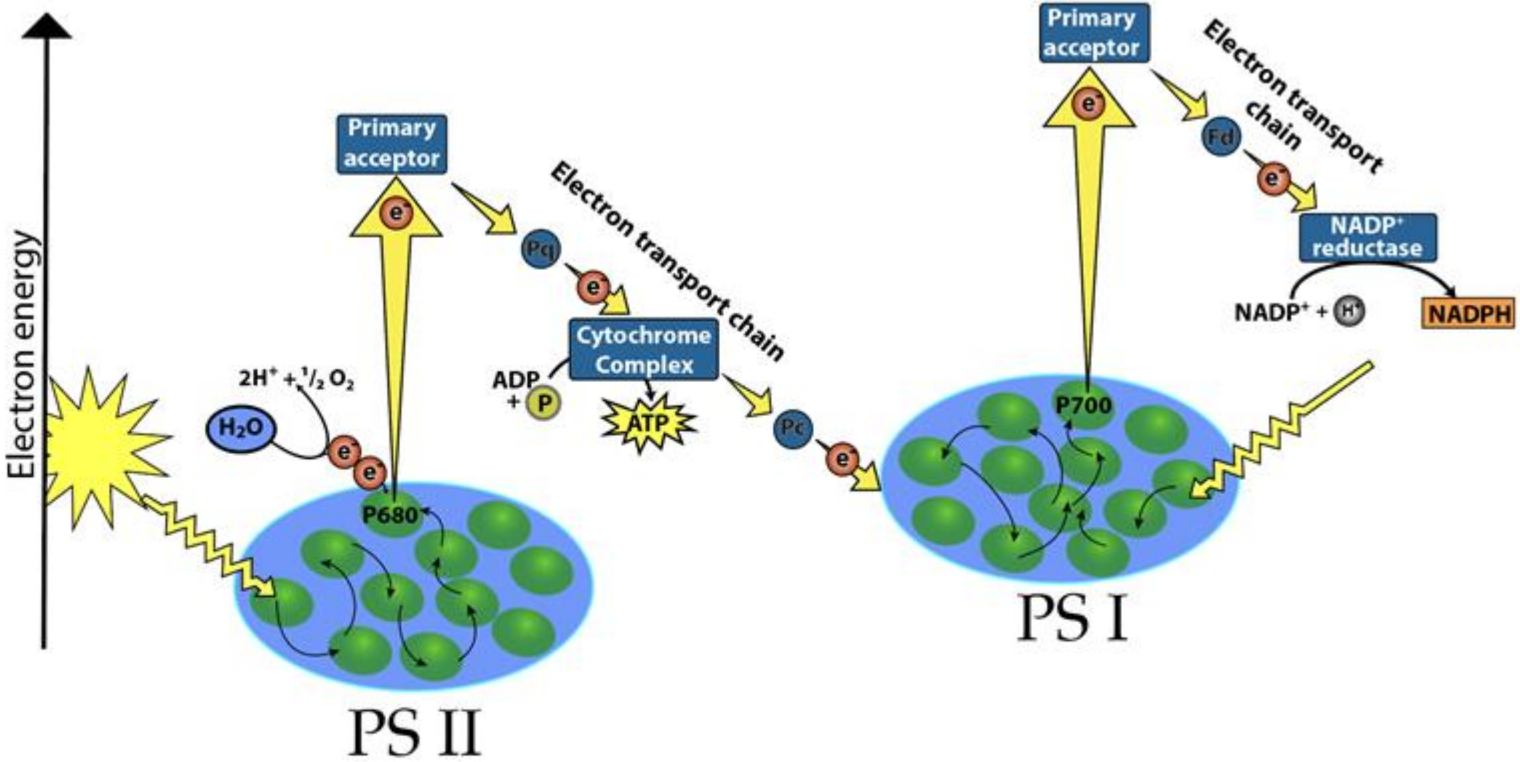


- “e:” Photoexcitation of chlorophylls in Photosystem I (which follows Photosystem II)
- “f:” Electron flow along the electron transport chain of PS I
- “g:” Electrons flow to the enzyme $NADP^+$ reductase, which reduces $NADP^+$ into NADPH



NADPH provides reducing power for the Calvin cycle

The Z-scheme



- Light drives electron boosting from PS II; water gets split into O_2, H^+, and electrons.
- e^- flow powers proton pumping → ATP Synthesis
- Light boosts electrons in PSI.
- e^- flow powers $NADP^+$ reduction to NADPH

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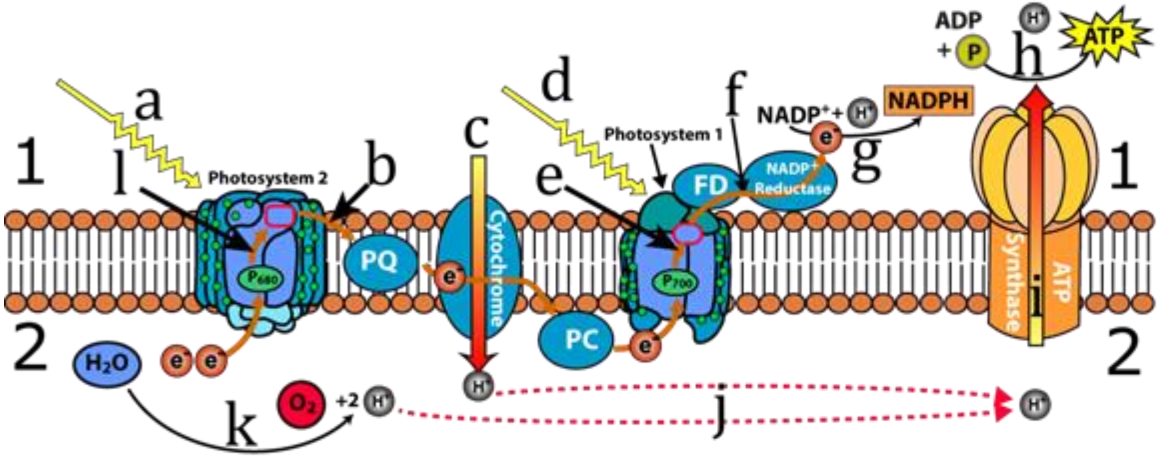
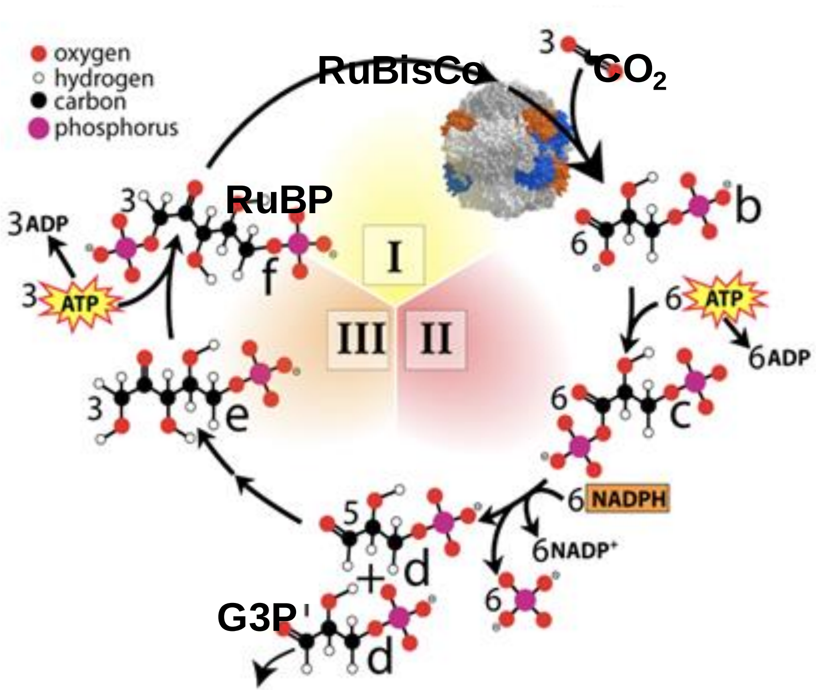
Need more support?

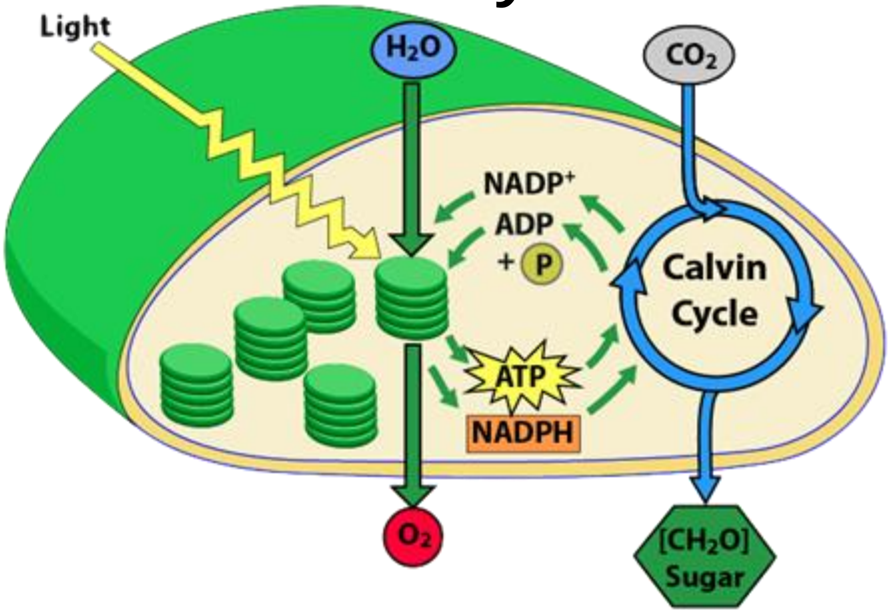


Complete the tutorials about the Light Reactions on Learn-Biology.com

TOPIC 3.5: Photosynthesis, Part 3: The Calvin Cycle



The Calvin Cycle follows the light reactions



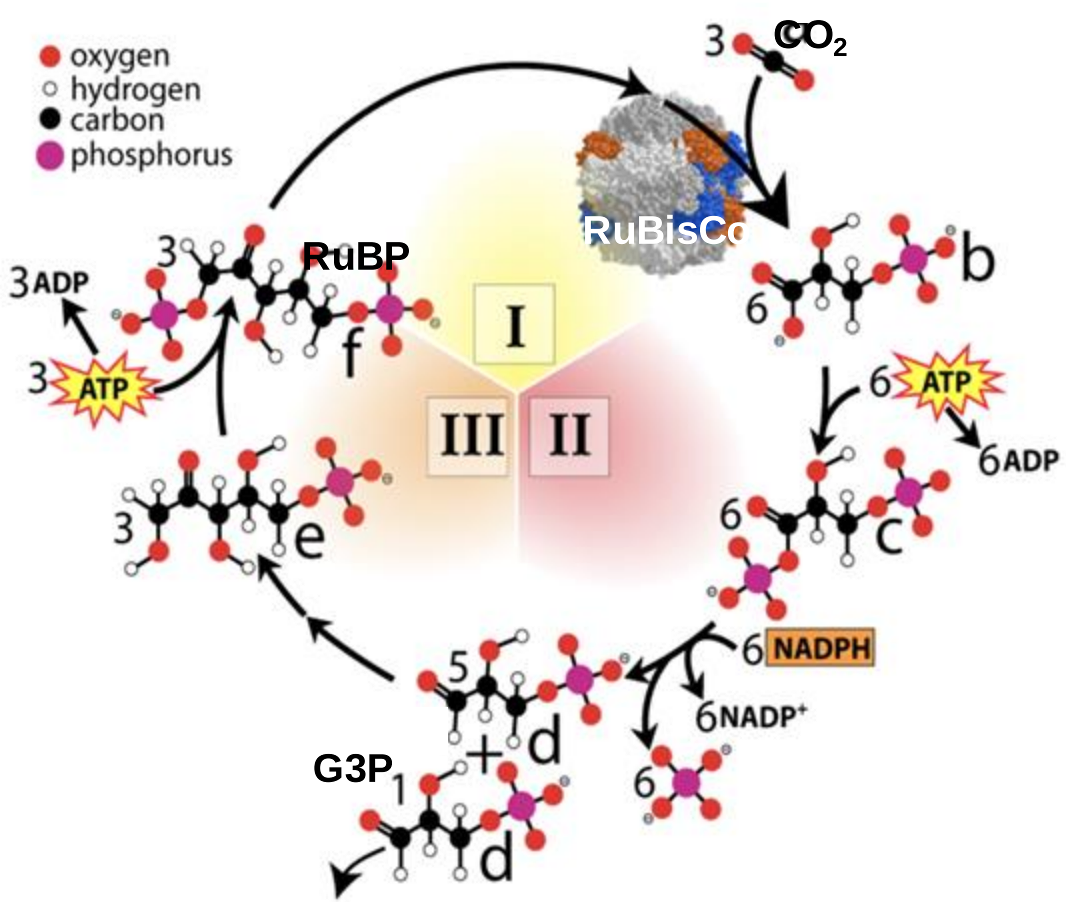
I: The Light Reactions

- Converts light energy into chemical energy
  - ATP
  - NADPH

II. The Calvin Cycle

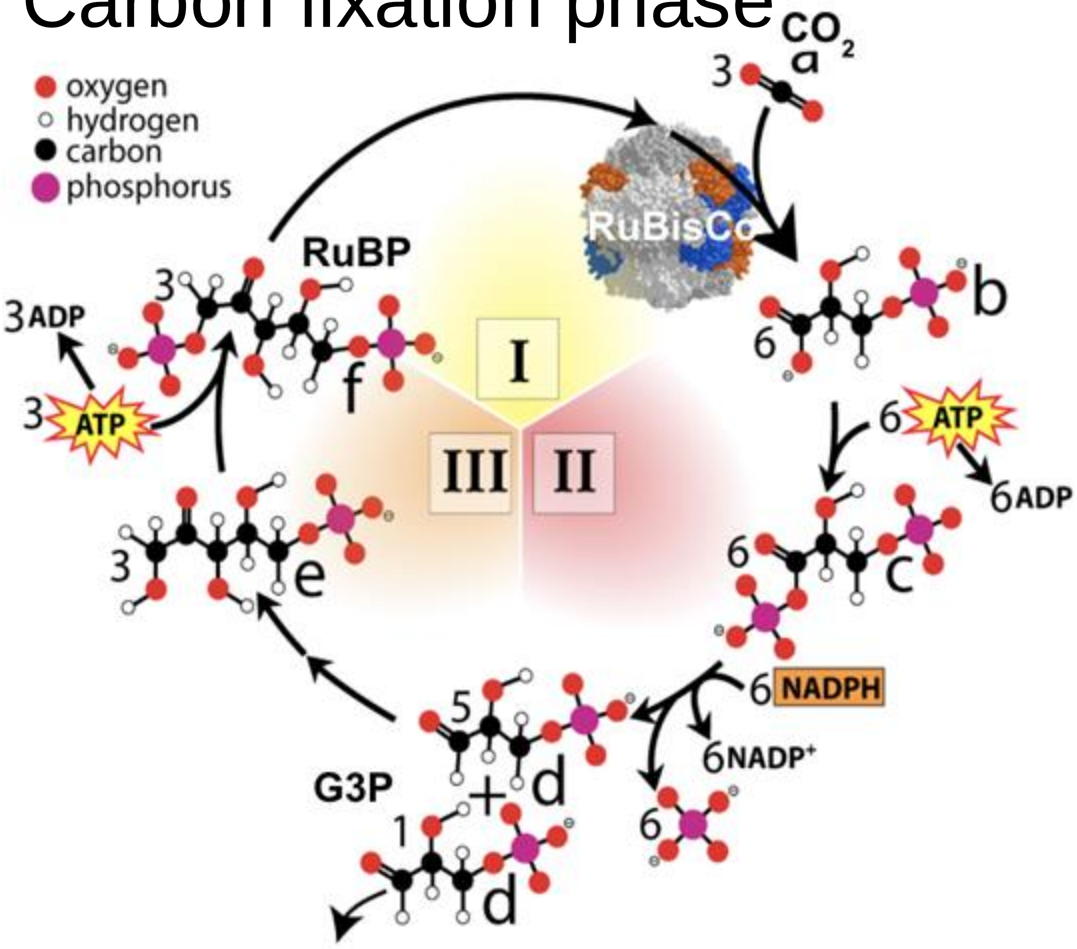
- Converts the chemical energy in NADPH and ATP into carbohydrate.
- “Fixes” carbon dioxide, converting it from a low energy gas into high energy sugars.

What are the three phases of the Calvin Cycle?



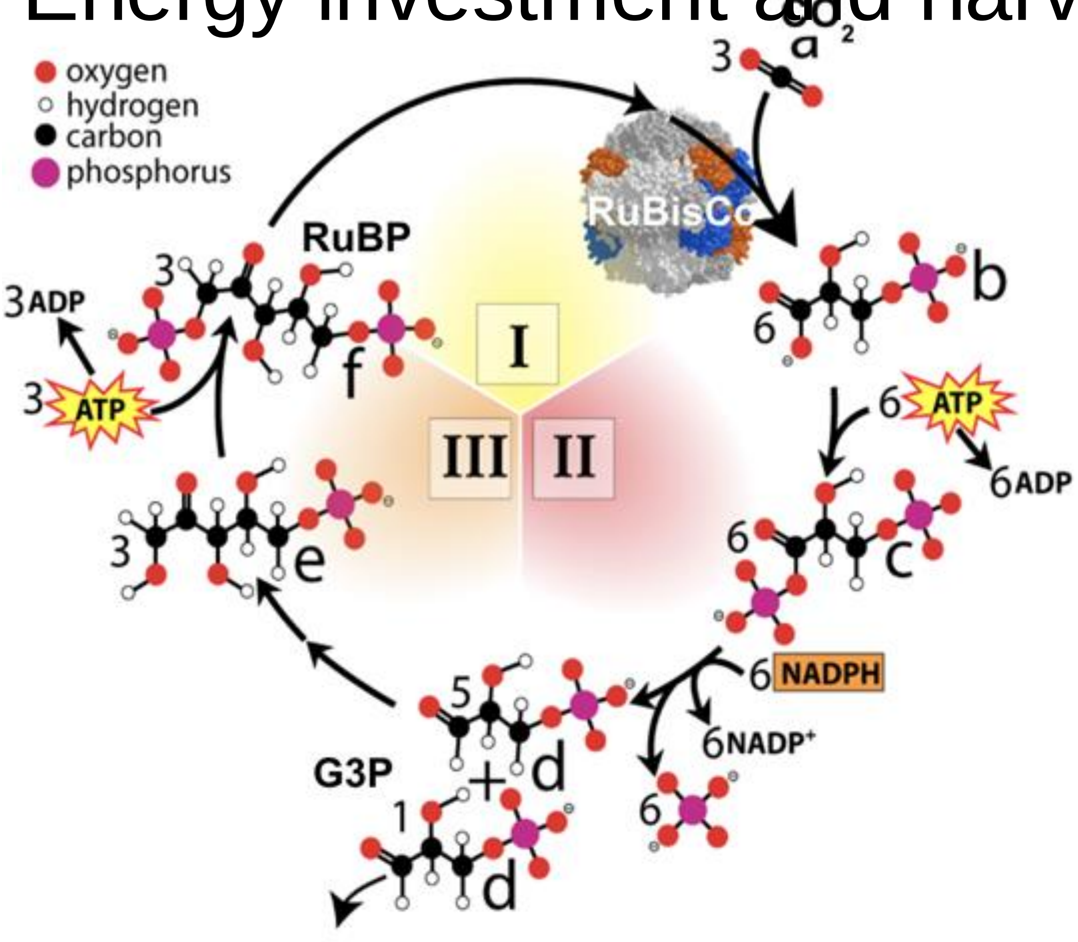
- Carbon fixation
- Energy investment and harvest
- Regeneration of RuBP (starting compound)

Carbon fixation phase



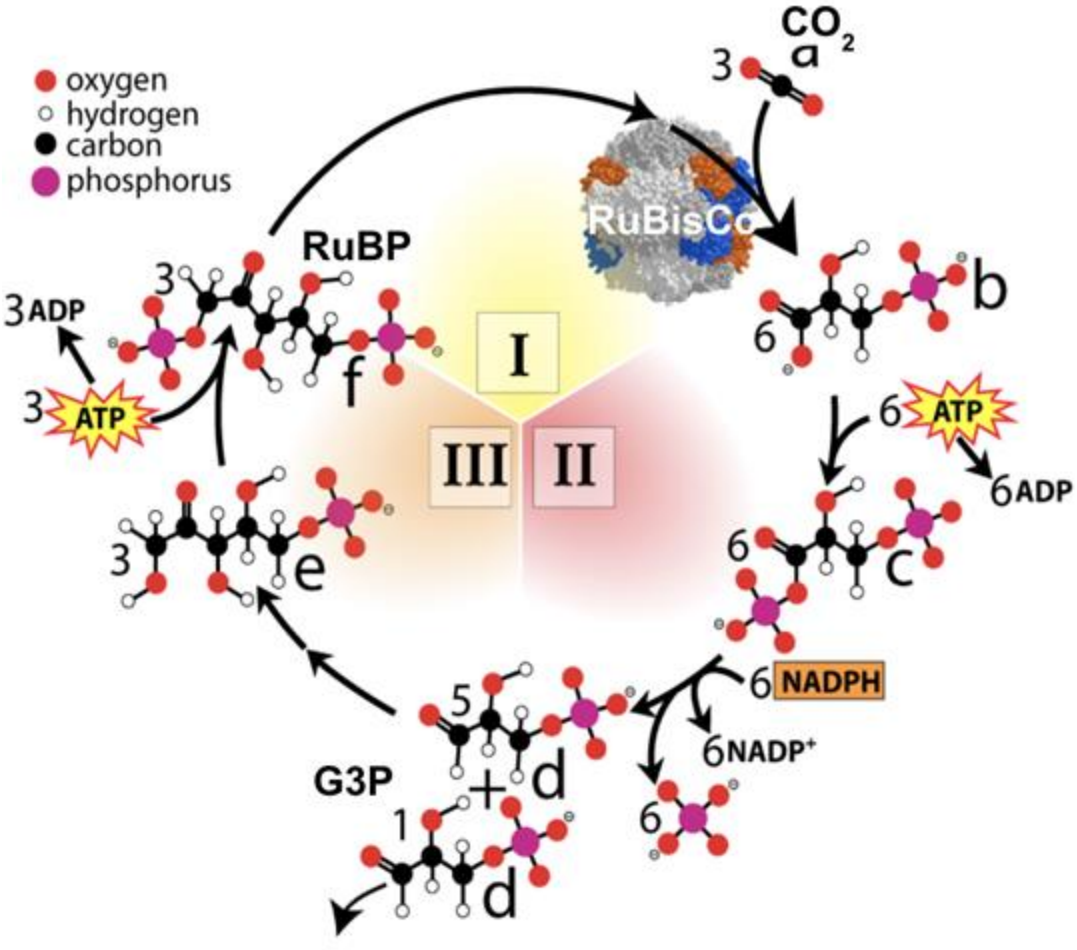
- CO_2 is combined with RuBP.
- Reaction is catalyzed by the enzyme RuBisCo.
- Six-carbon product immediately dissociates into two 3 carbon molecules.

Energy investment and harvest phase

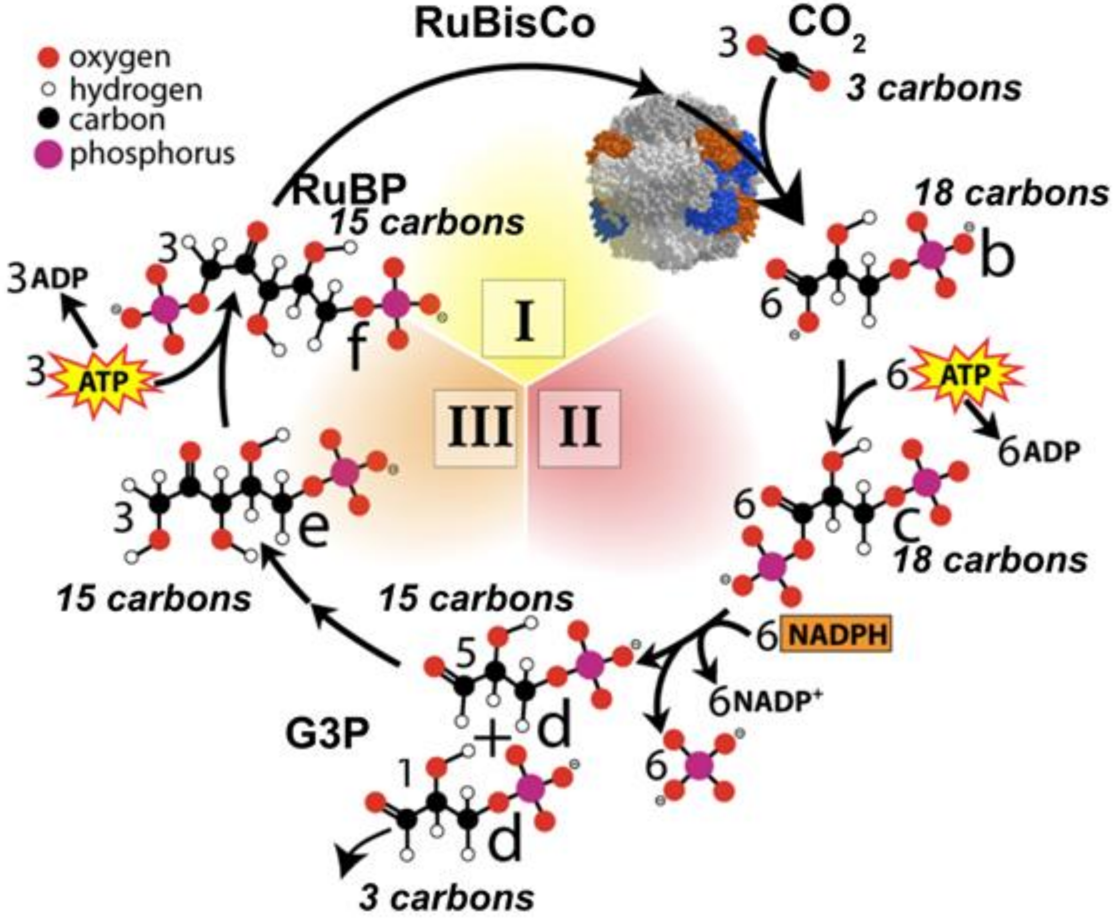


- The three-carbon products (b) of carbon fixation are reduced and phosphorylated into glyceraldehyde-3-phosphate (d): AKA G3P or PGAL).
- The energy comes from the ATP and NADPH from the light reactions.
- One G3P is harvested (to become glucose, other molecules)

Last phase: regeneration of RuBP



- The remaining five G3Ps are rearranged into three 5-carbon RuBPs
- A phosphorylation also occurs
- RuBP is one of the substrates during carbon fixation (the other one is CO_2).



Calvin Cycle recap with carbon accounting

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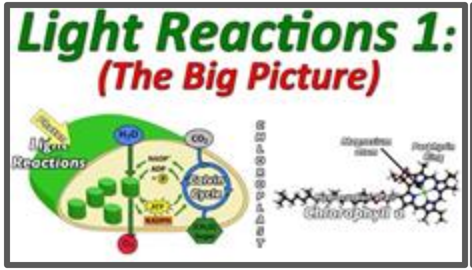
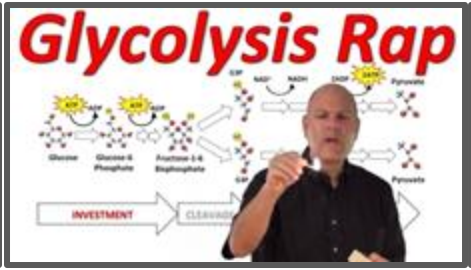
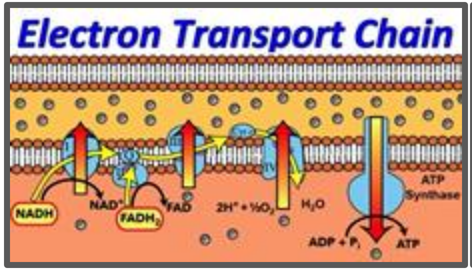
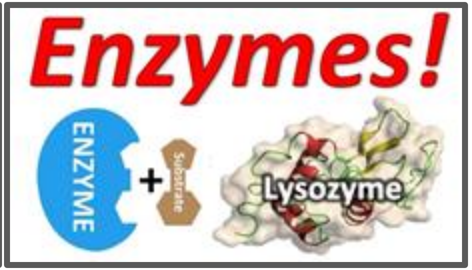
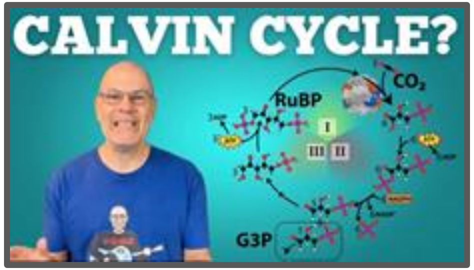
Lots of opportunities for musical learning





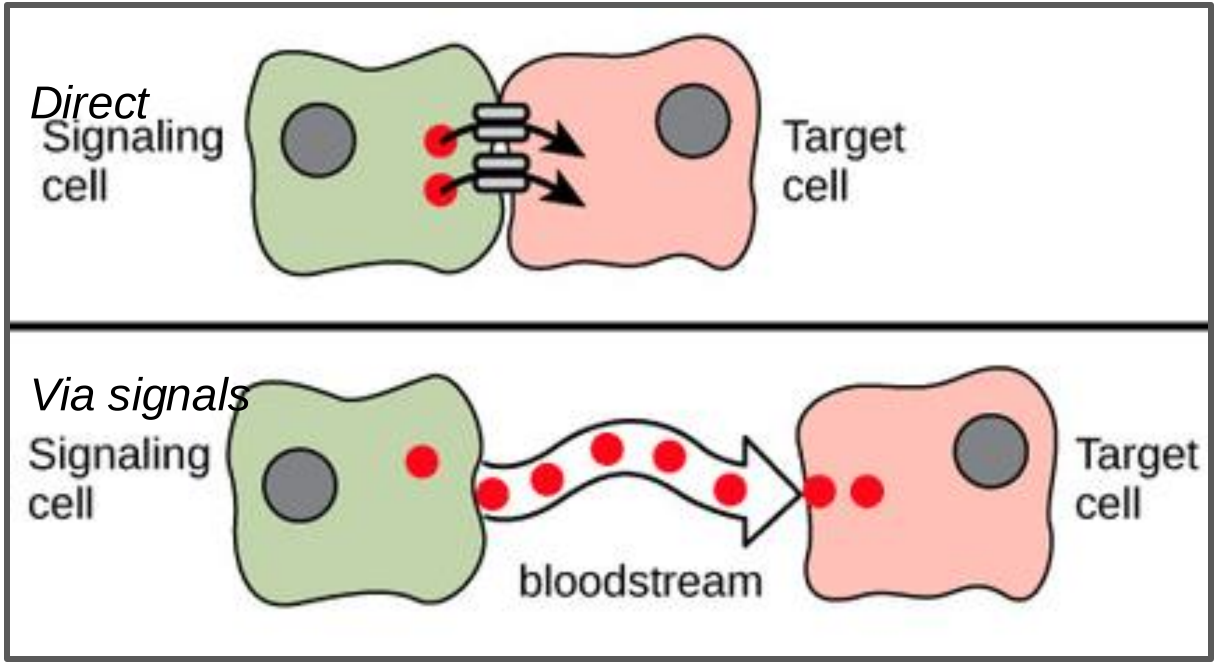






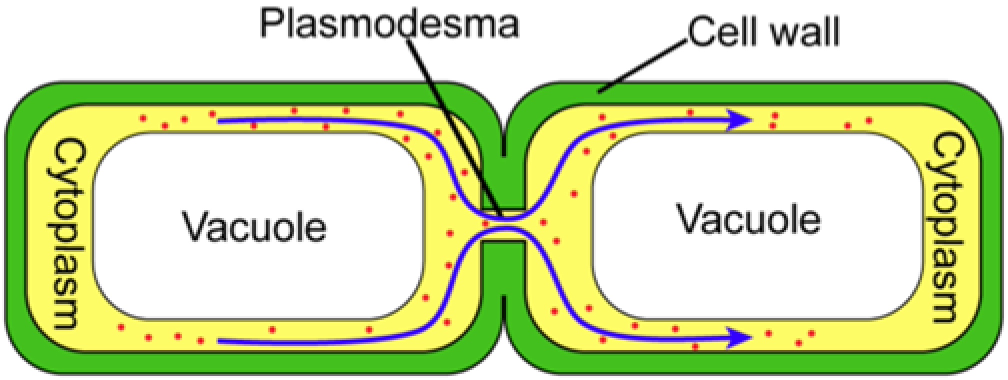
Topics 4.1 - 4.4, Part 1:
Cell Signaling:
The Big Picture

Cells are constantly communicating with one another



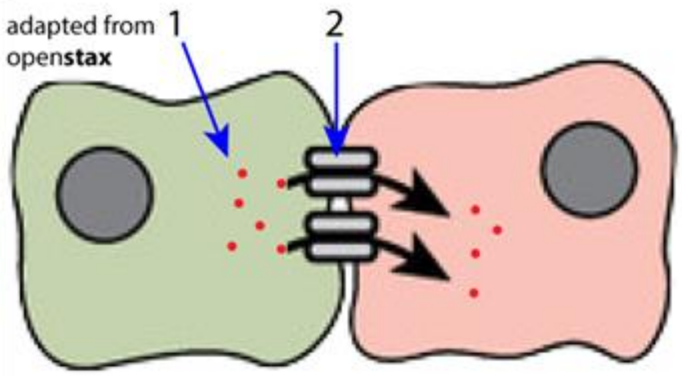
- Direct, cell to cell communication
- Communication via signals (ligands)
    - Hormones (long distance)
    - Local regulators (short distance)

Direct contact communication in plants and animals



Plants have **plasmodesmata**

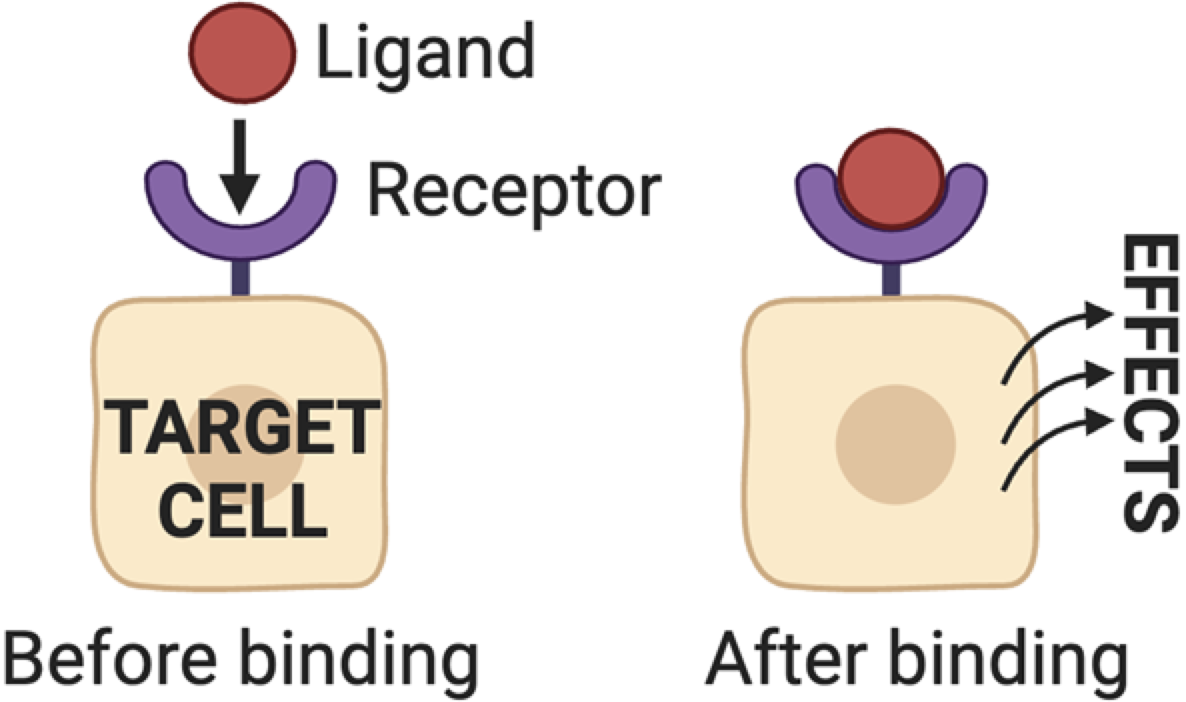
- Bridges involving the cell wall and membrane.
- Allow signaling molecules, water and other substances to diffuse from cell to cell.



Animals have **gap junctions**

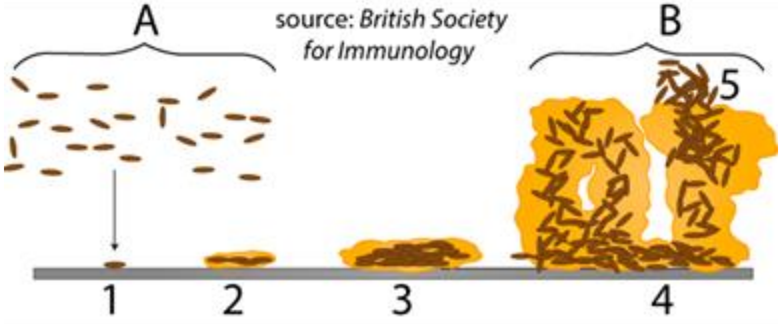
- Built from protein channels (2)
- Allow substances — including signaling molecules (1) —to move from the cytoplasm of one cell to the next.

Ligands are signaling molecules

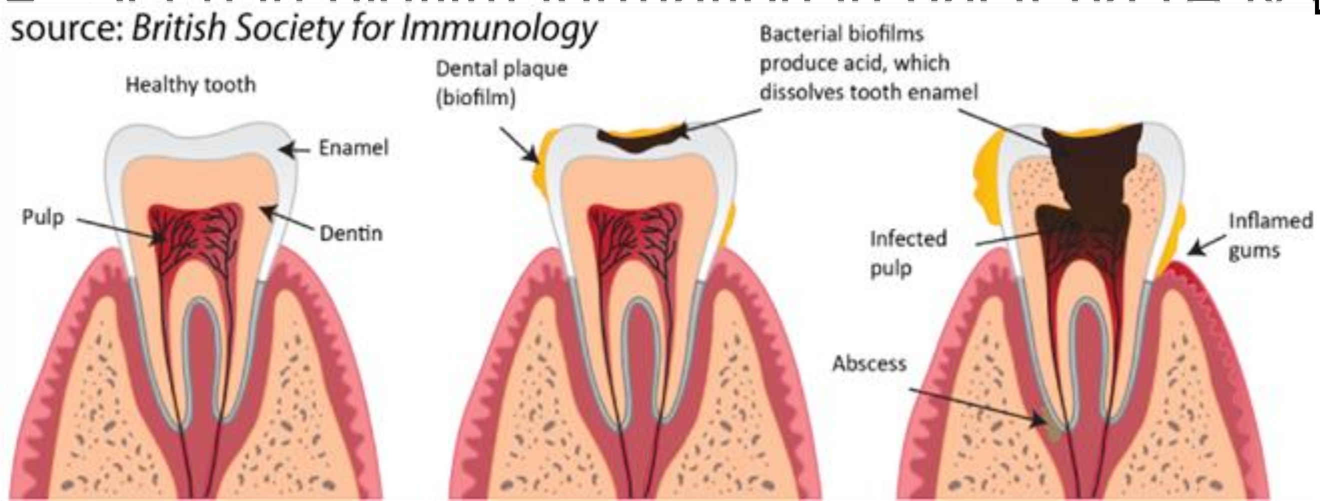


- Many ligands are hormones
- Bind with receptors based on complementary shape
- Binding → cellular response

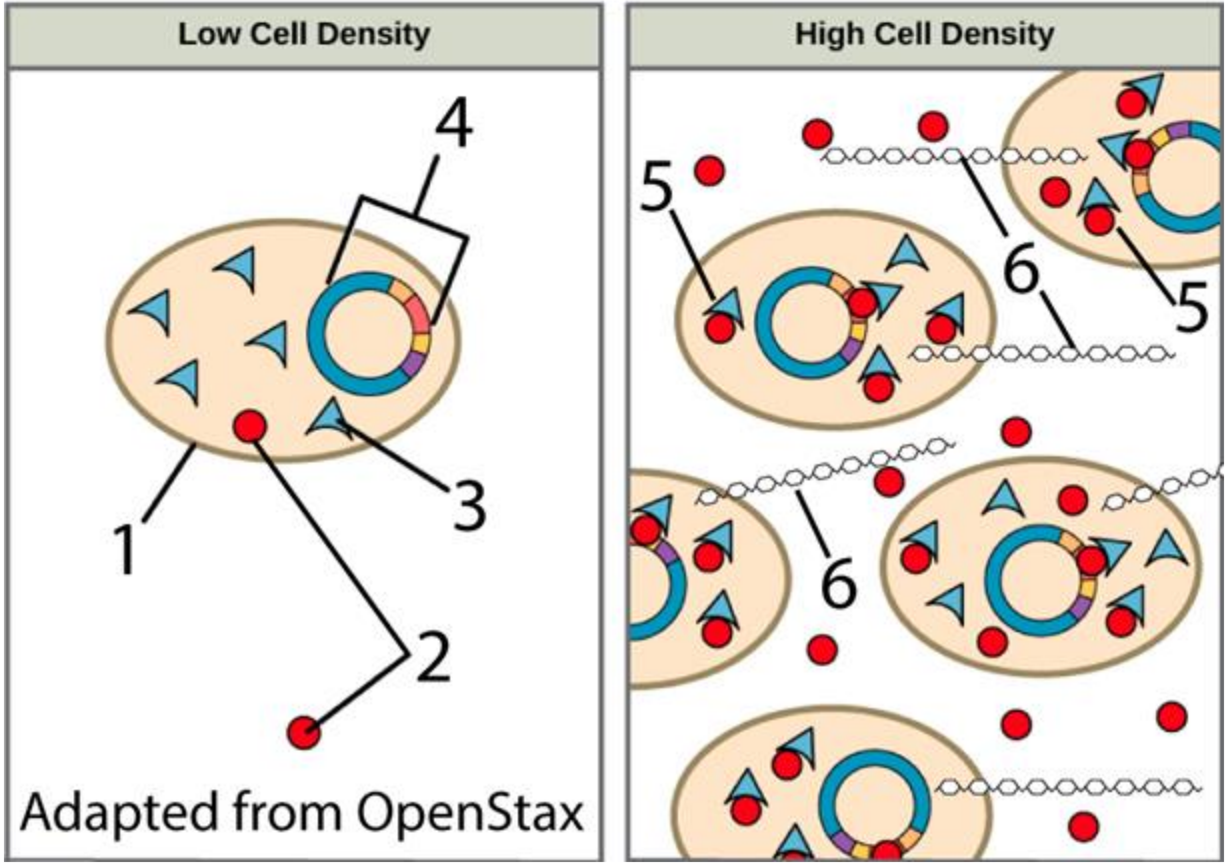
Explain quorum sensing in bacteria



- Bacteria change their behavior based on their density.
- Seen in biofilm formation in bacteria (A & B)



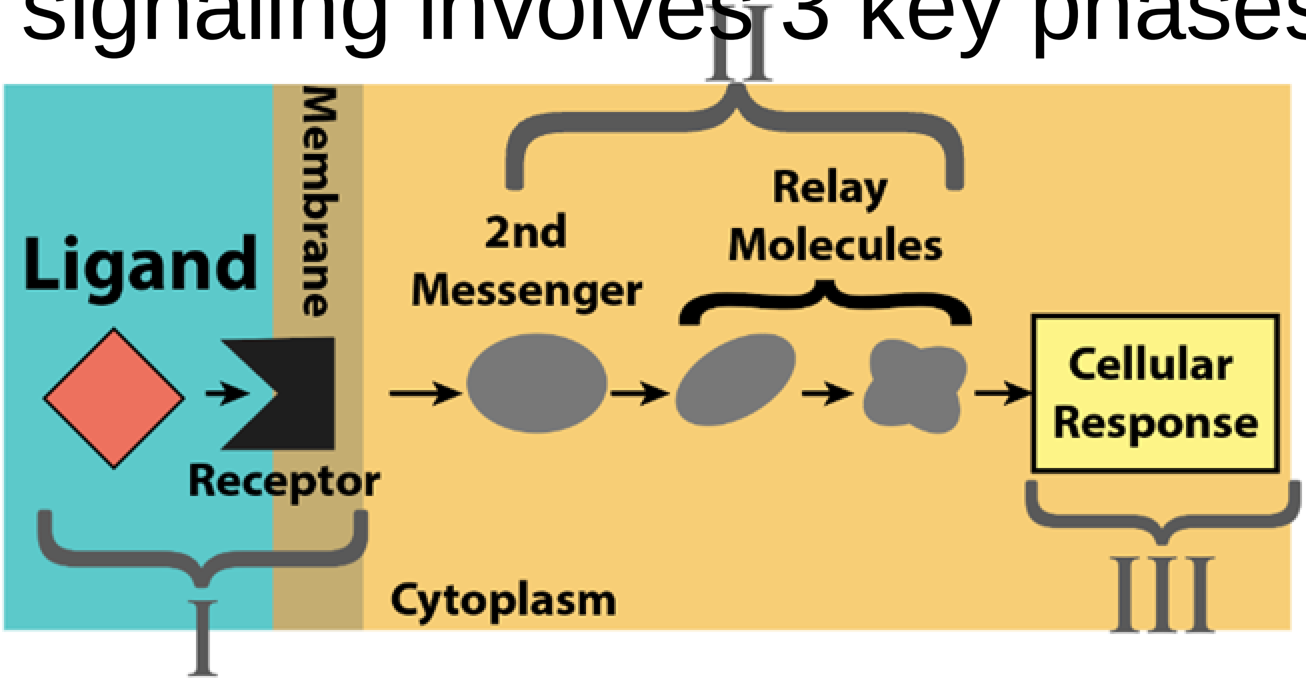
Explain quorum sensing



- Bacteria release signaling molecules (2), that bind to cytoplasmic receptors (3 and 5)
- At a certain signal density (a quorum), genes (4) are activated that lead to biofilm formation (6).

TAKEAWAY: all cells communicate (even bacteria)

Cell signaling involves 3 key phases.

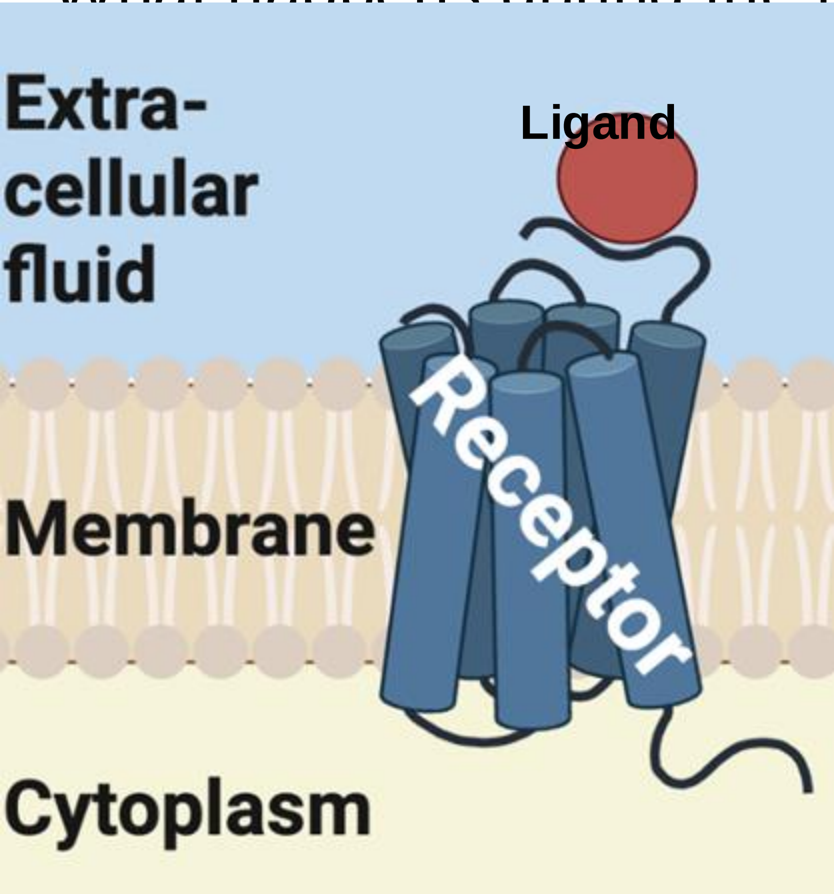


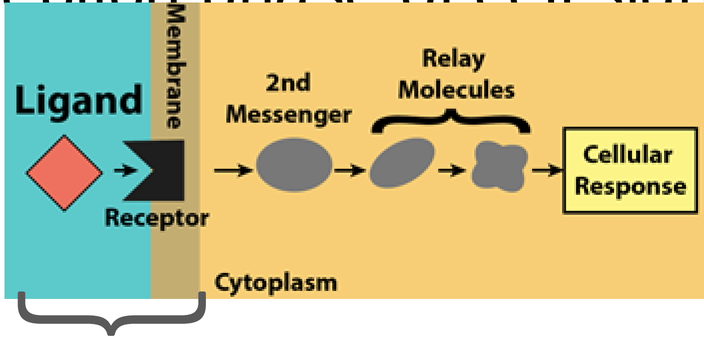
I) Reception of a ligand

II) Signal transduction (often with signal amplification)

III) Cellular response

What happens during the reception phase of cell signaling?

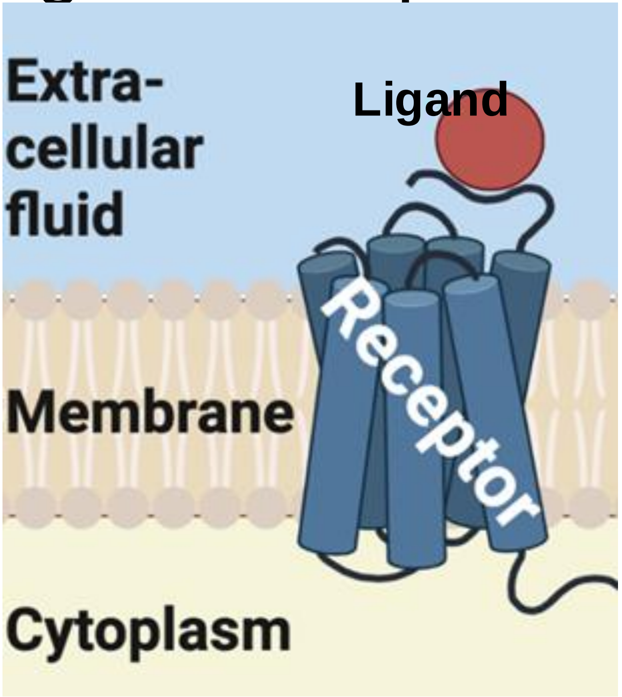


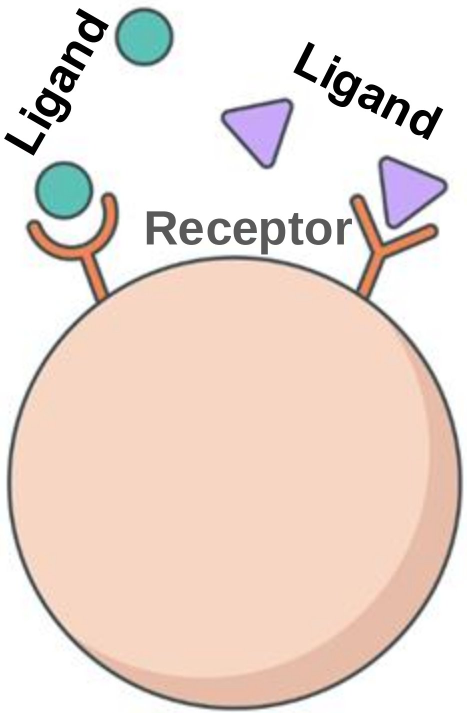


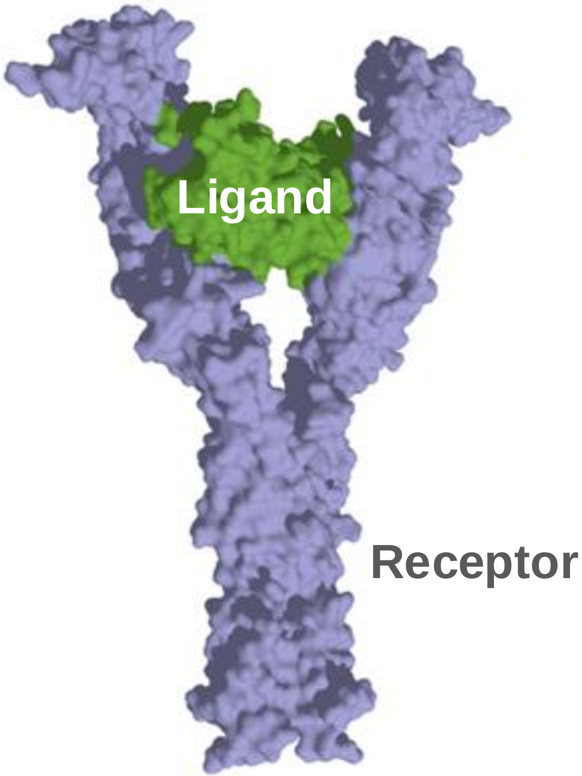
- Signal molecule (the *ligand*), binds with a receptor molecule embedded in the cell membrane

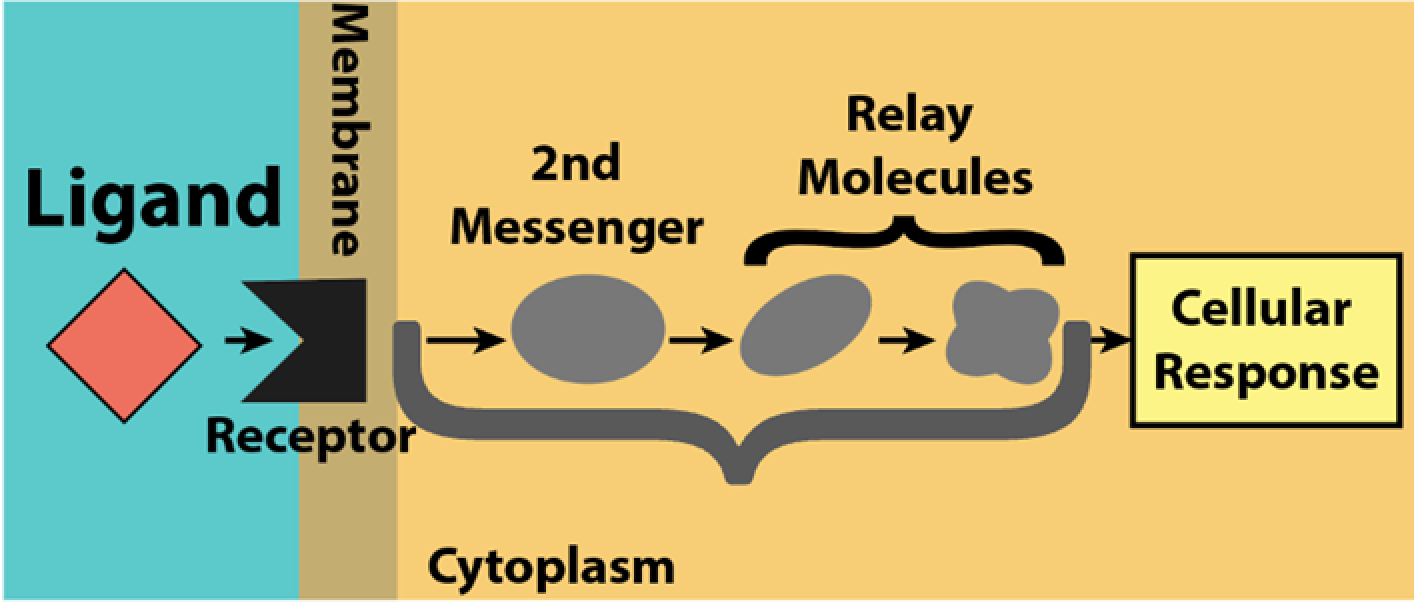
This binding is based on complementary shape.

Ligand-receptor binding is **specific**, and based on **complementary shape**





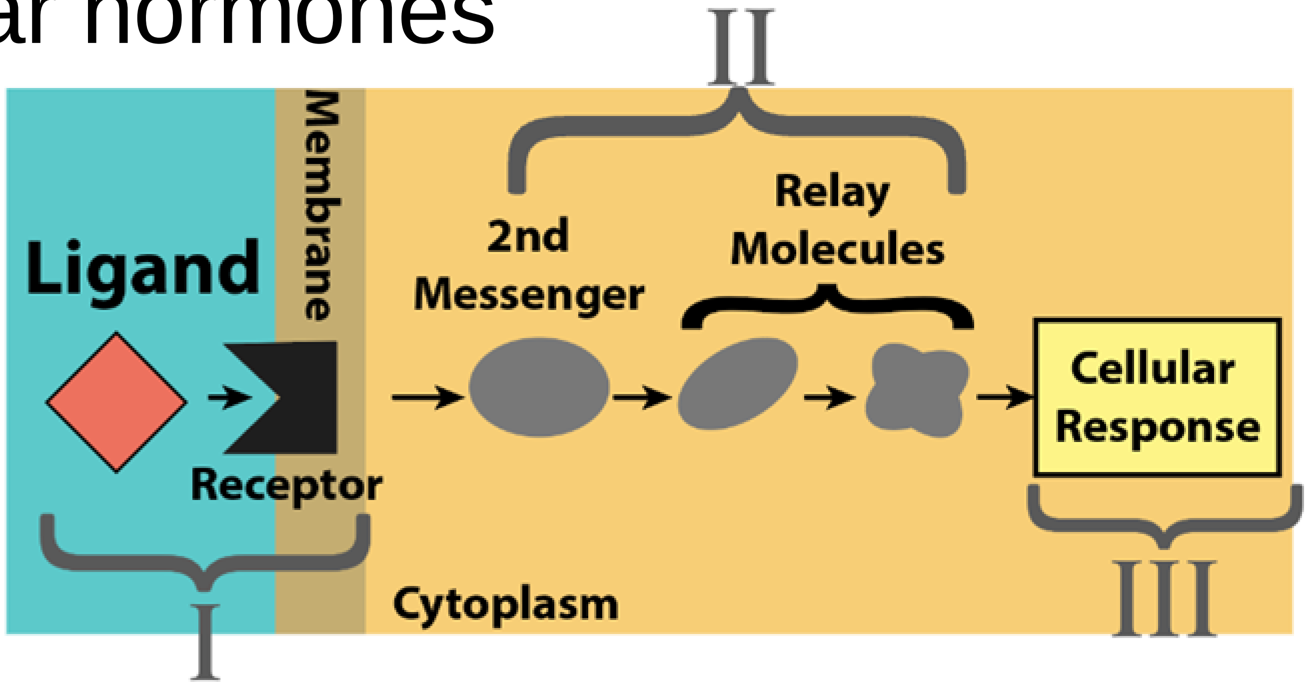




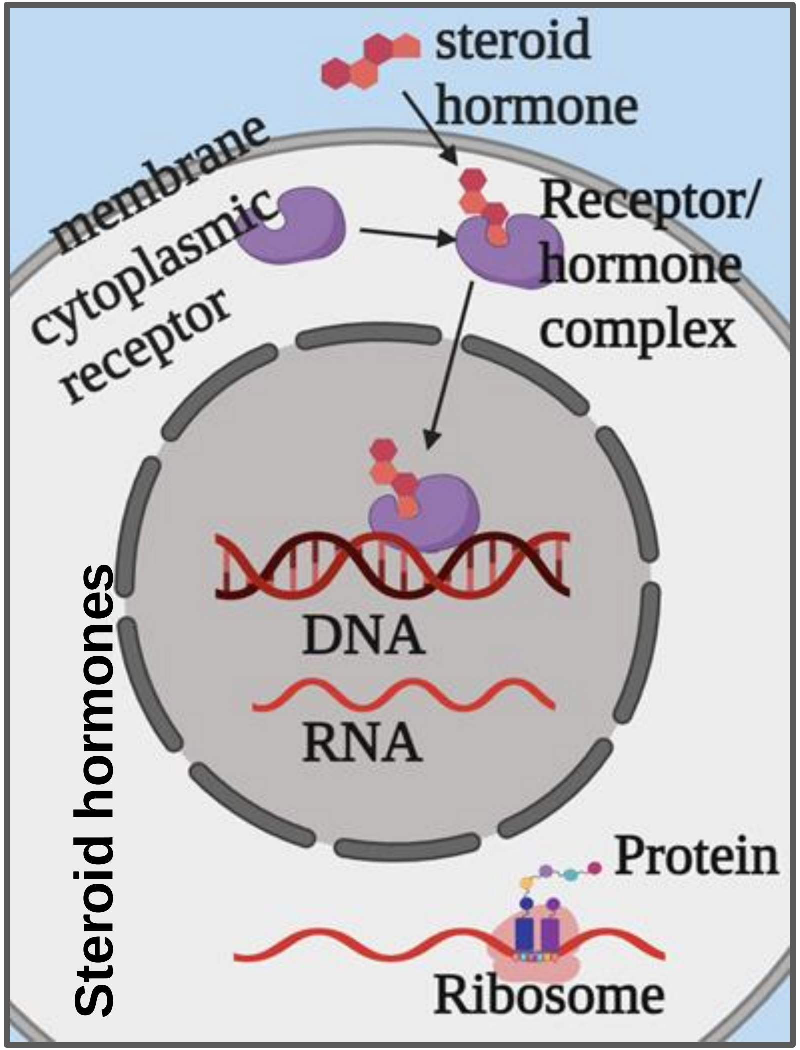
What happens during the **transduction** and **response** phases of cell signaling?

- Receptor interacts with membrane proteins to produce a **second messenger**
- Second messenger (and other relay molecules) brings the message to
  - The cytoplasm (activating enzymes)
  - The nucleus (activating genes)

Polar hormones



- Bind at the membrane
- Activate 2nd messengers



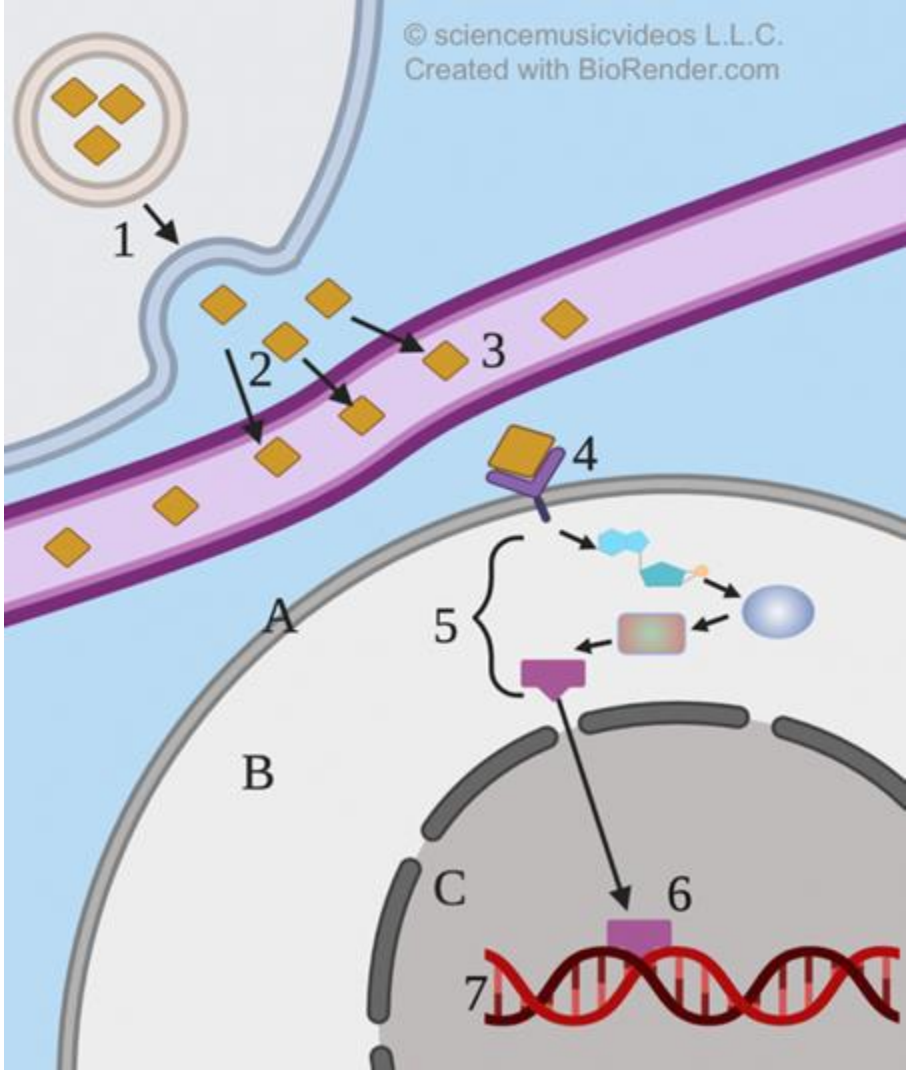
Steroid hormones

- Diffuse through lipid bilayer
- Bind with cytoplasmic receptors
- Diffuse into nucleus
- Activate genes

Polar hormones can also activate genes

Example: Growth Hormone

1. Gland
2. Hormone
3. Bloodstream
4. Receptor
5. Signal transduction pathway
6. Transcription factor
7. DNA/Genes



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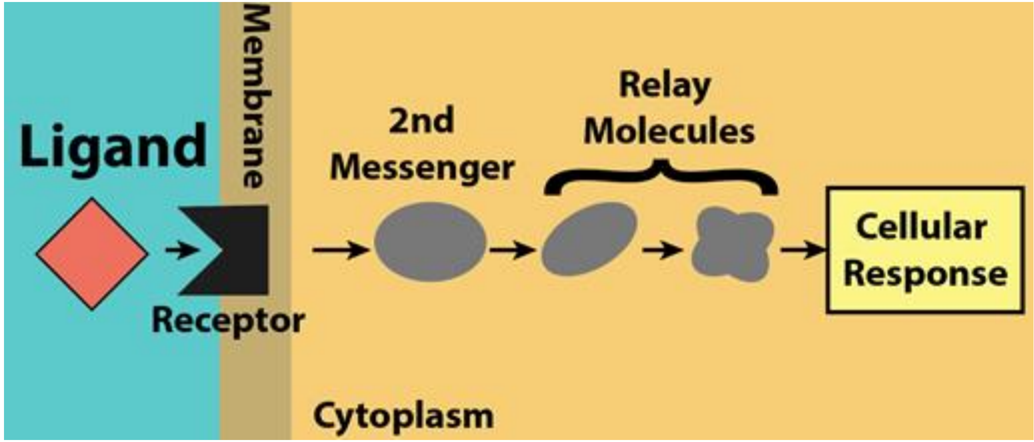


Complete the tutorials about Cellular communication on Learn-Biology.com

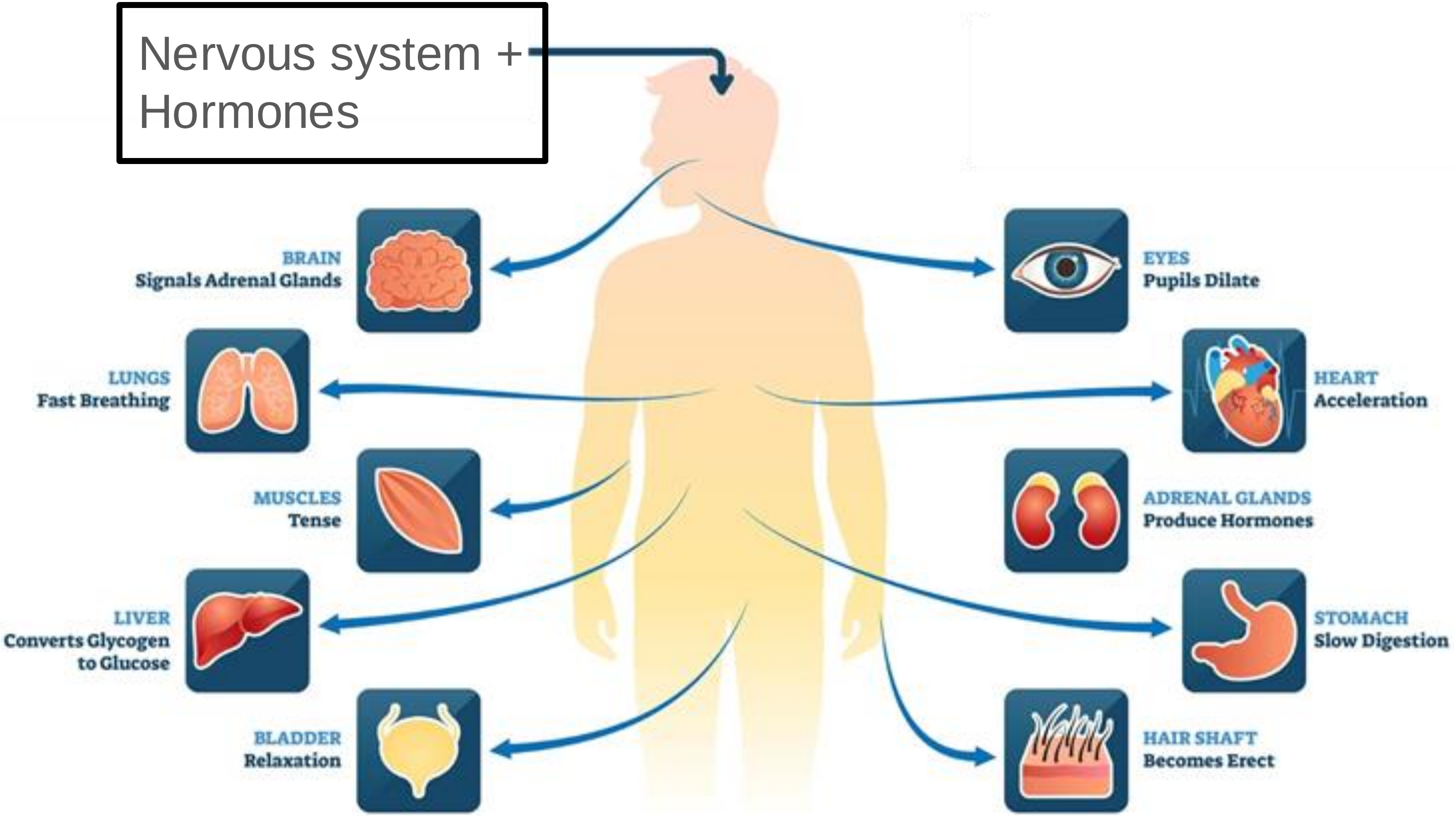
TOPICS 4.1 - 4.4, Part 2:

Epinephrine and G-protein Coupled Receptor systems

Illustrative Example

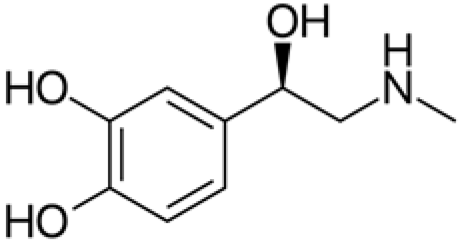
Context: The Fight or Flight Response

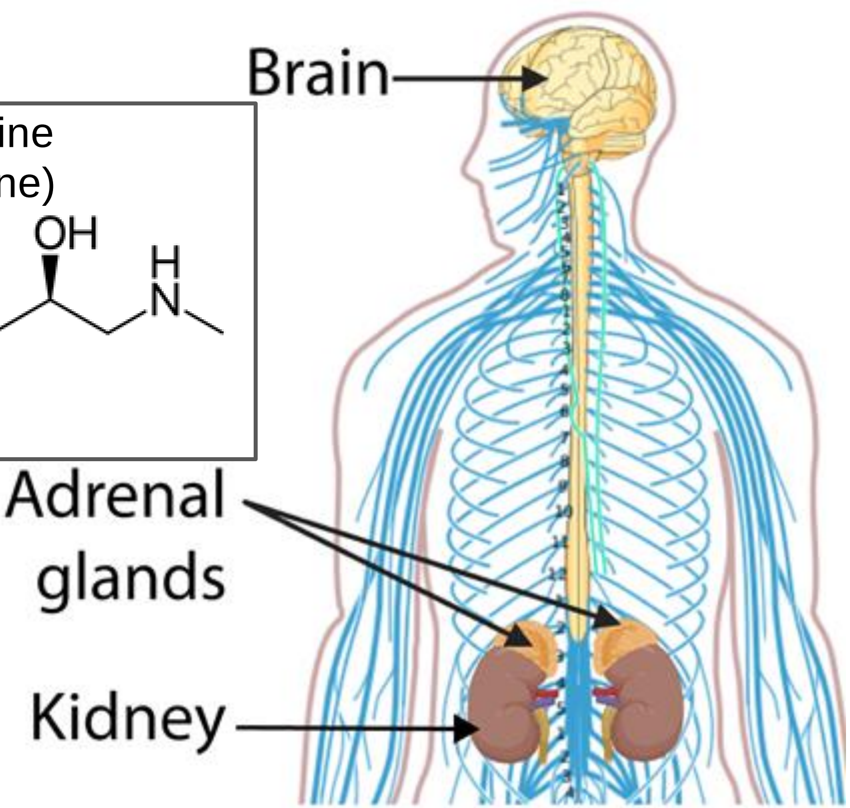
Nervous system + Hormones



Epinephrine: a key hormone in the fight or flight response

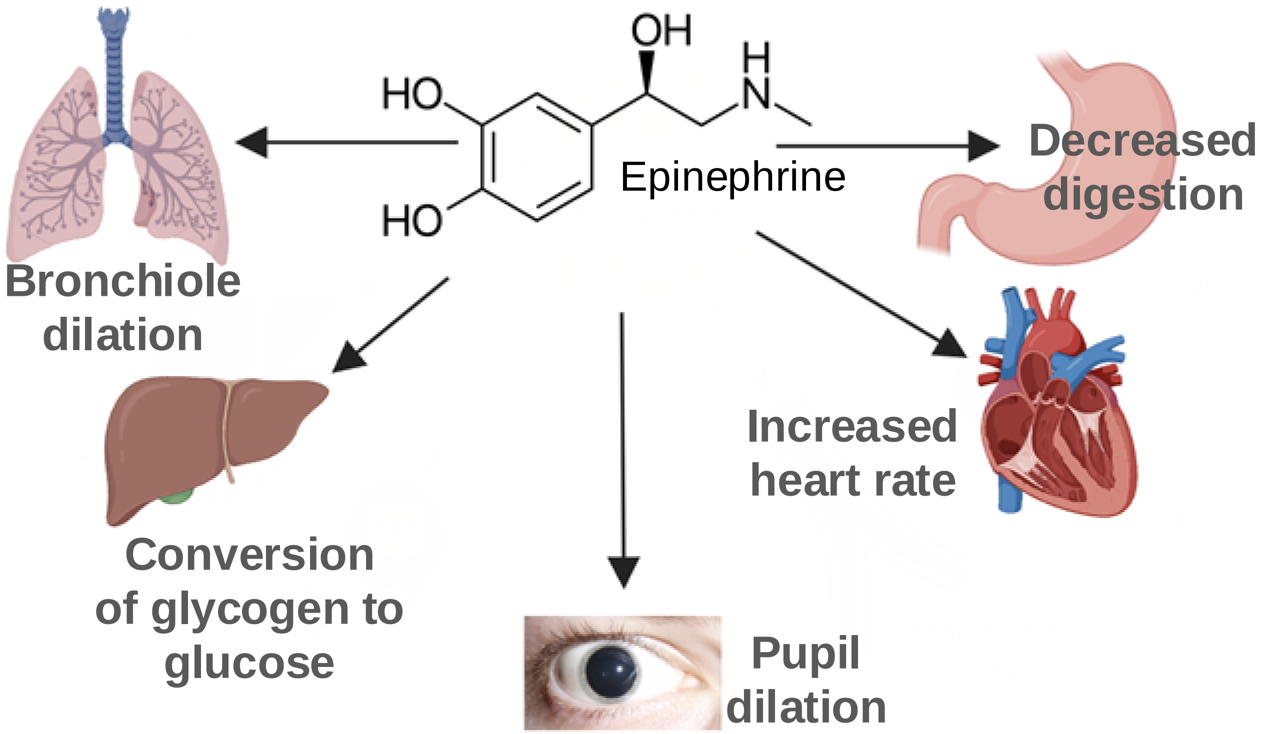
Epinephrine
(Adrenaline)





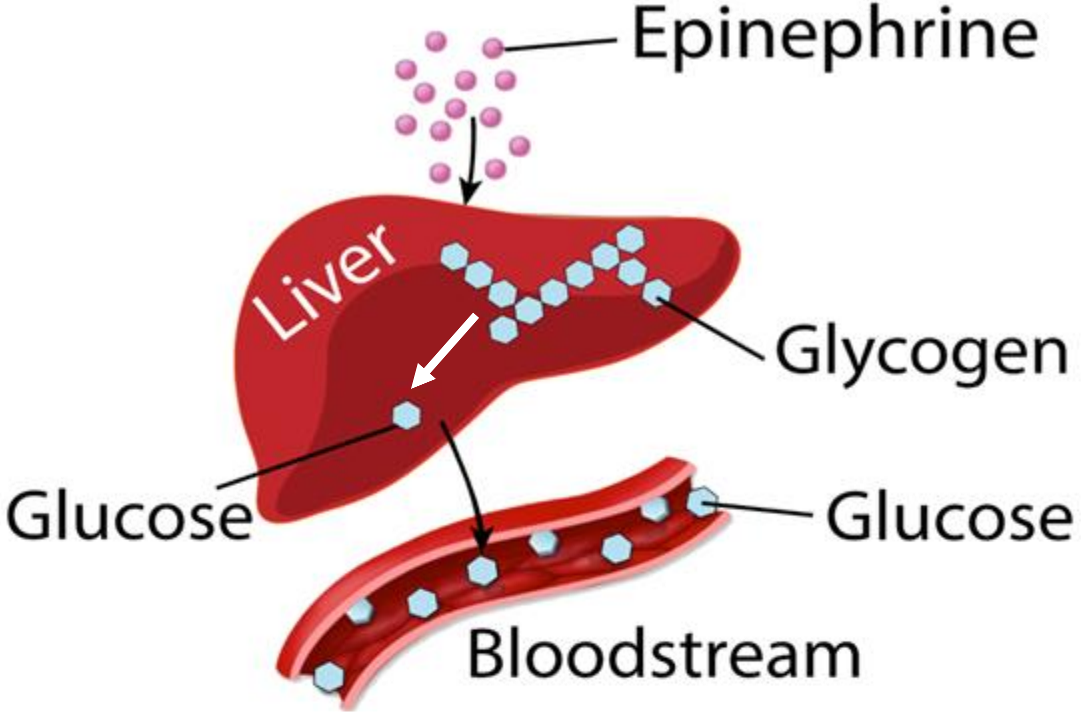
- Epinephrine: AKA adrenaline
- Polar/water soluble
- Released from adrenal glands

Epinephrine's effects are widespread, but *tissue-specific.*

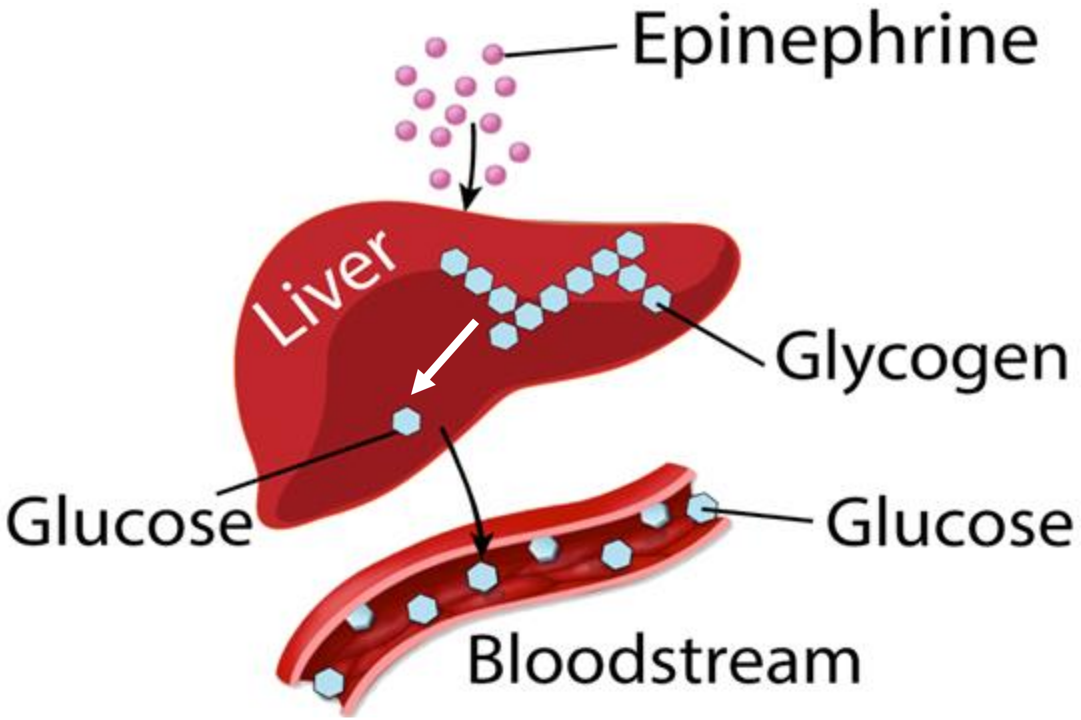


- Through the blood, epinephrine goes everywhere
- Only tissues with receptors respond.
- Response differs based on tissue-type

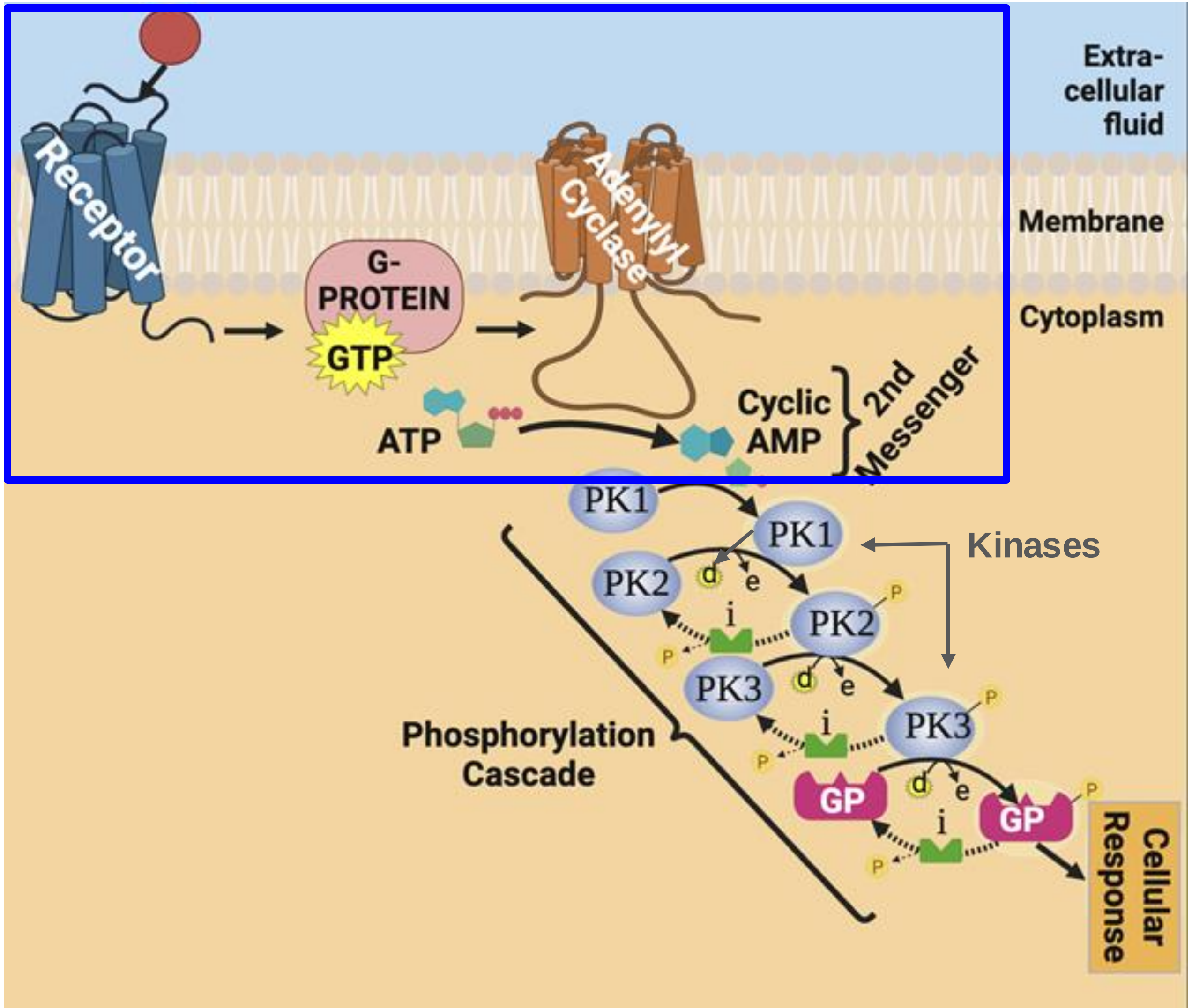
Epinephrine’s effect on the liver



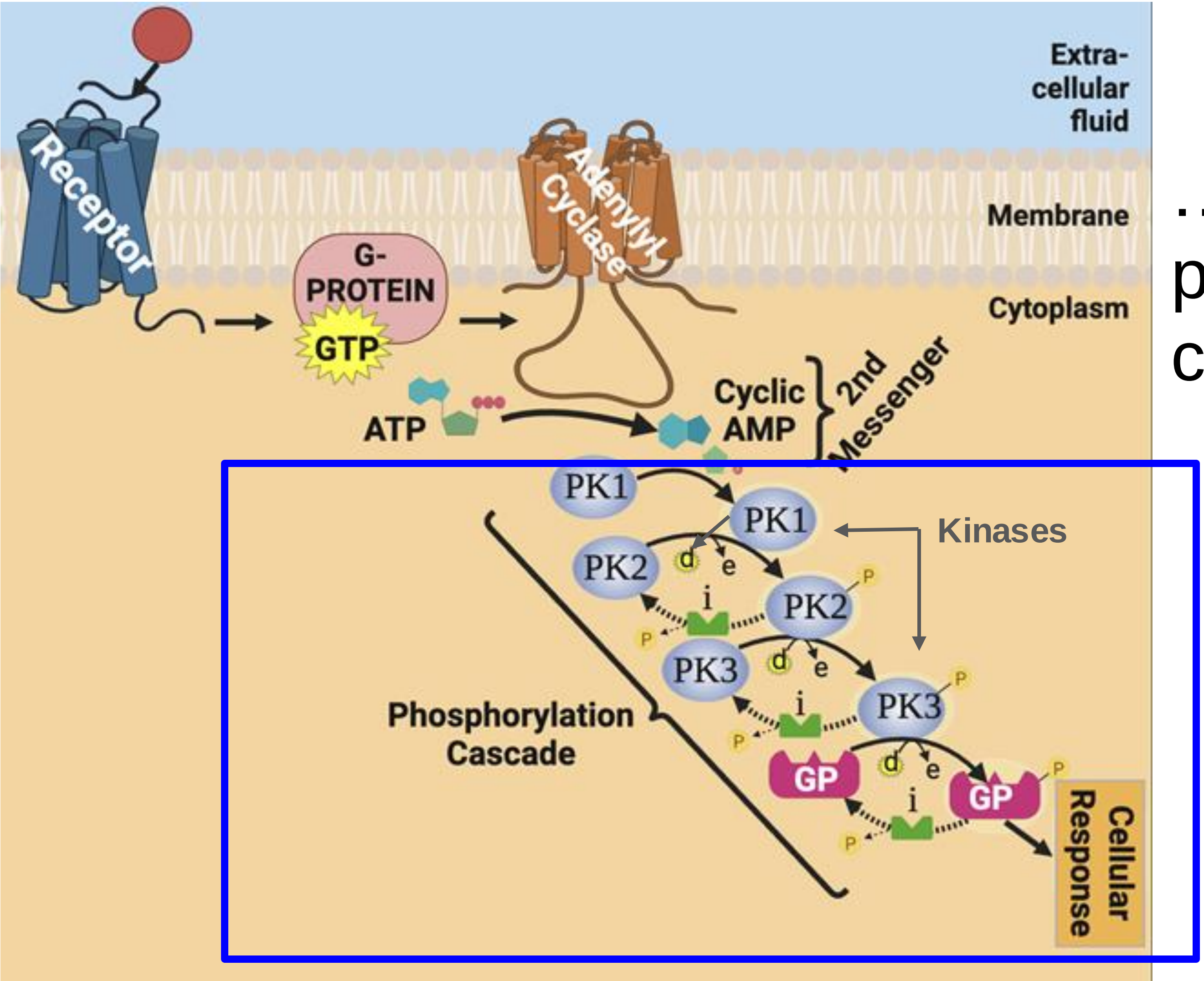
- Induces liver cells to hydrolyze glycogen (a polysaccharide) into glucose
- Glucose diffuses into blood
- Provides energy to fight or flee



HOW *does* epinephrine induce the glycogen-to-glucose conversion?

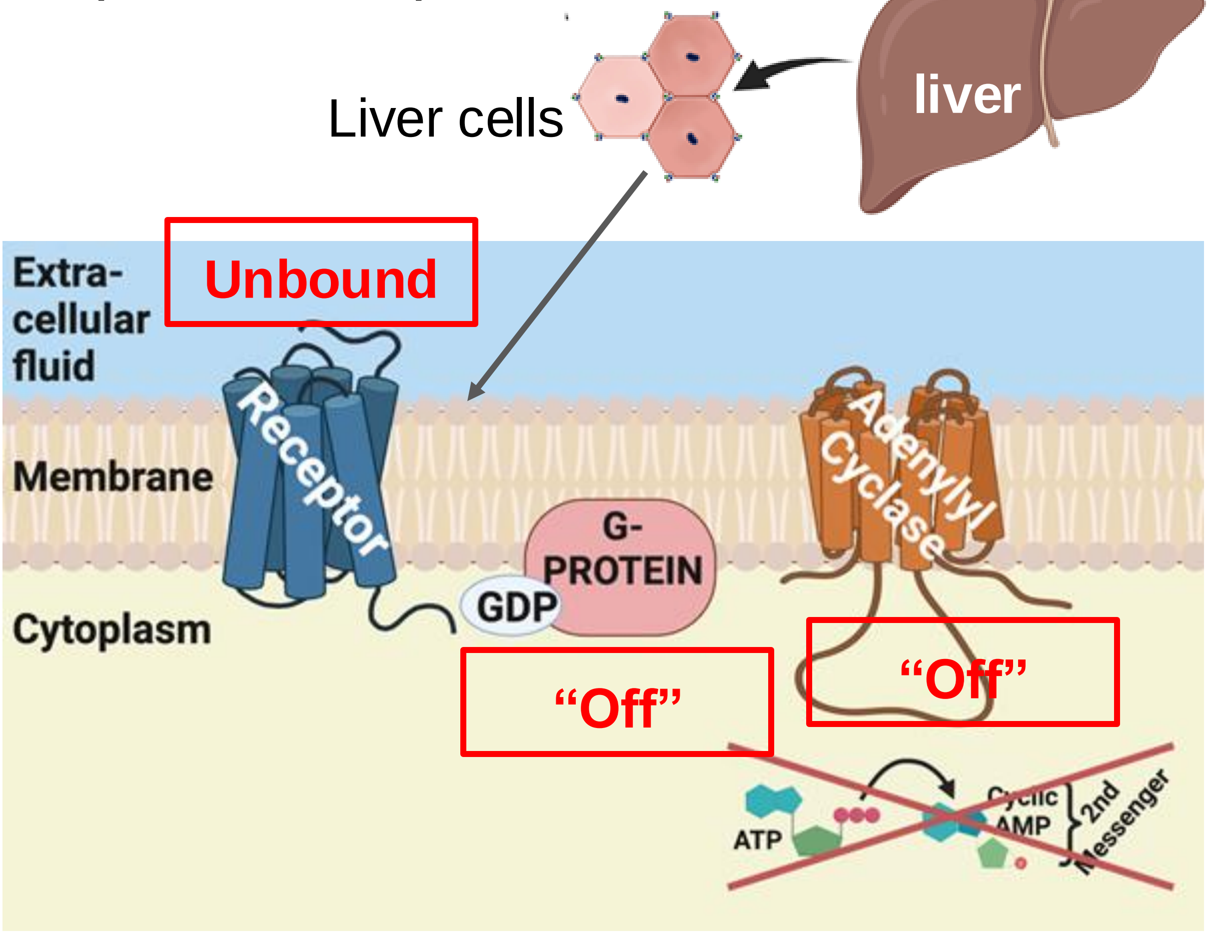


Through a G-protein coupled receptor system…



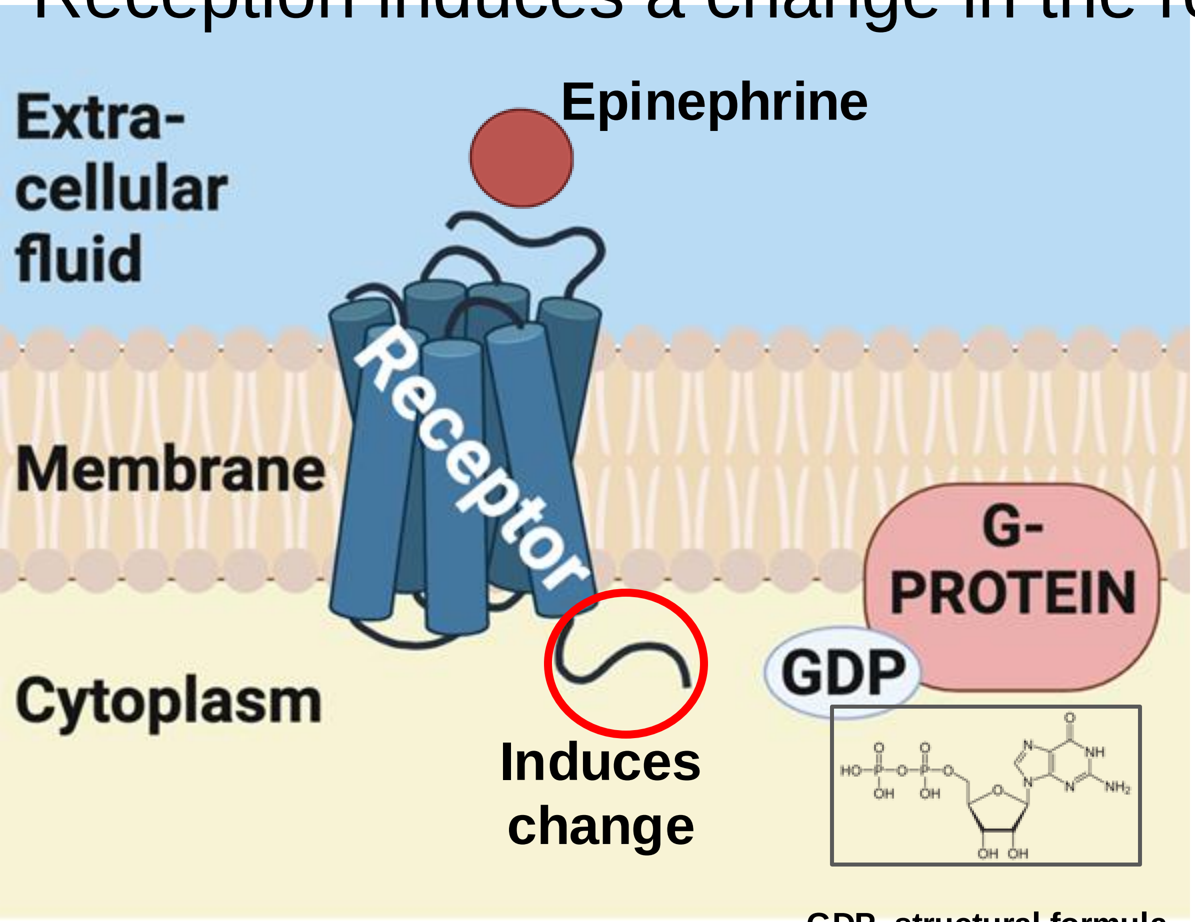
…That induces a phosphorylation cascade

G-protein coupled receptor system in liver cells: “resting state”



- Receptor is unbound
- Nearby G-protein is “off”
- Nearby Adenylyl cyclase (a membrane embedded enzyme) is “off”
- 2nd messenger is *not* activated

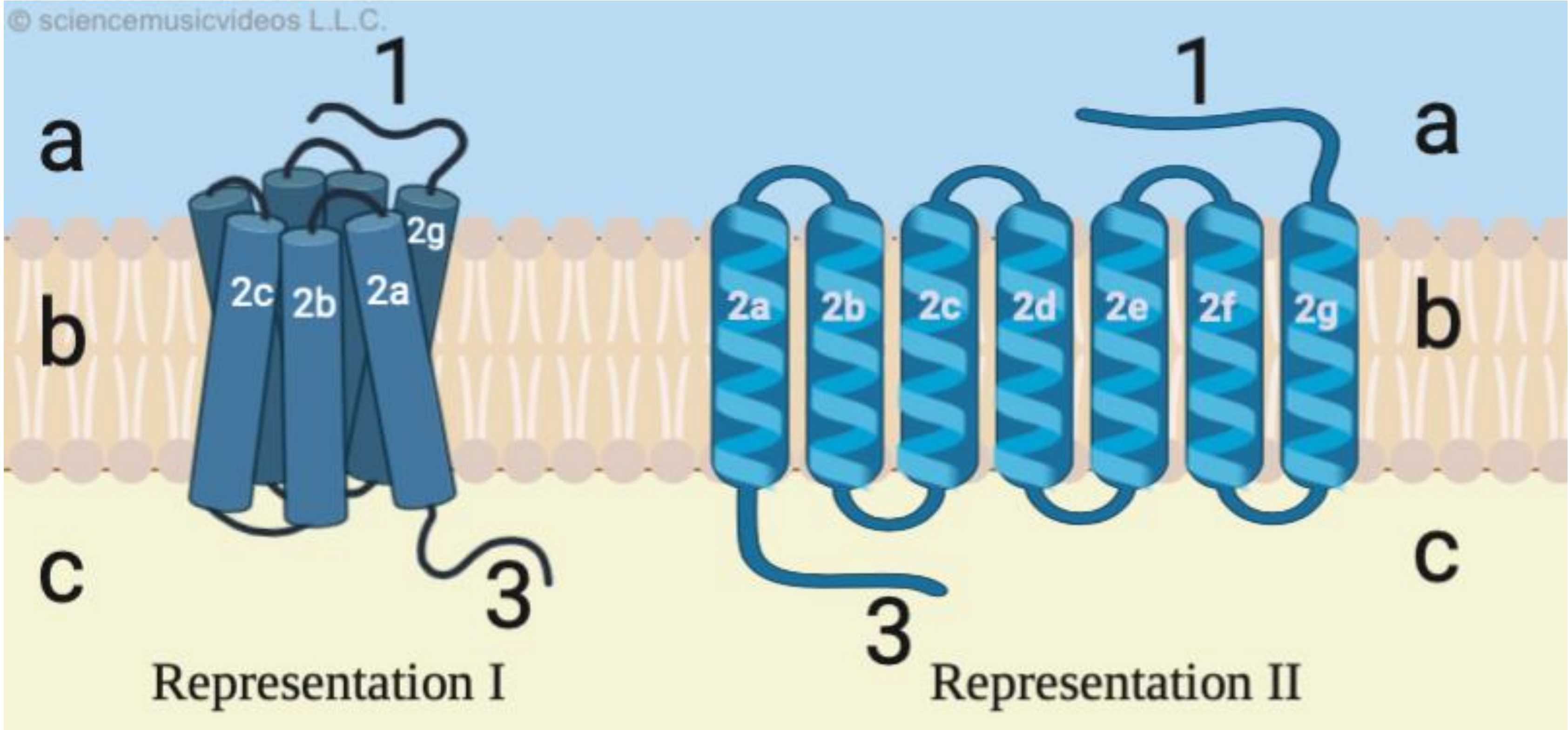
Reception induces a change in the receptor



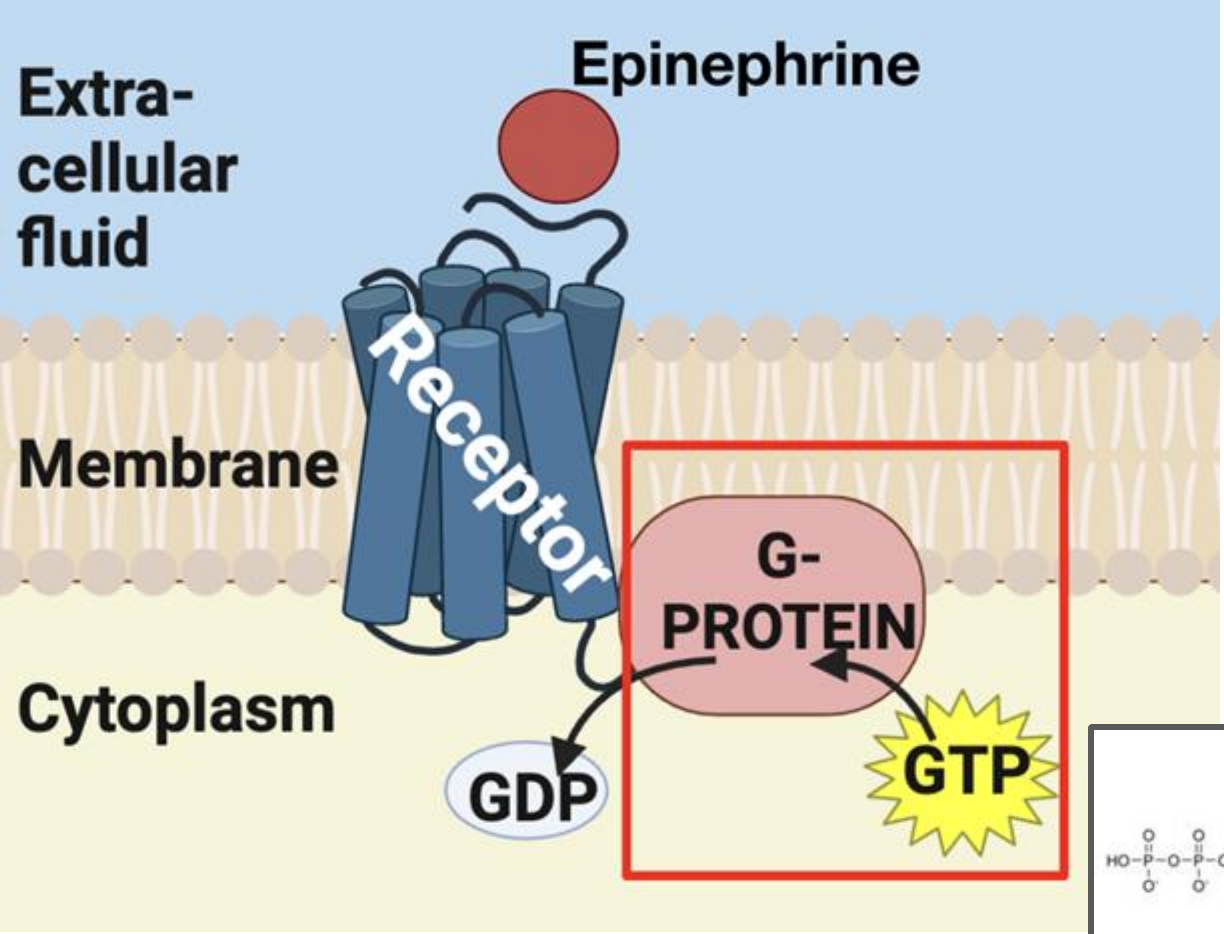
GDP, structural formula

- Epinephrine binds with G-protein coupled receptor
- The receptor changes shape on its cytoplasmic side
- The nearby G-protein is still dormant (bound to GDP)

G-Protein coupled receptor: detailed structure



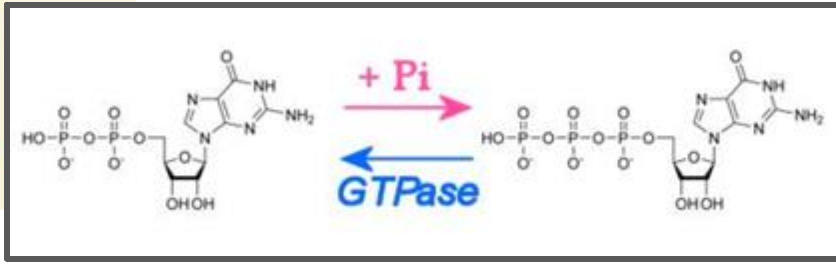
1. Ligand-binding site   2a-2g: Alpha helices (7)   3. Extension into cytoplasm

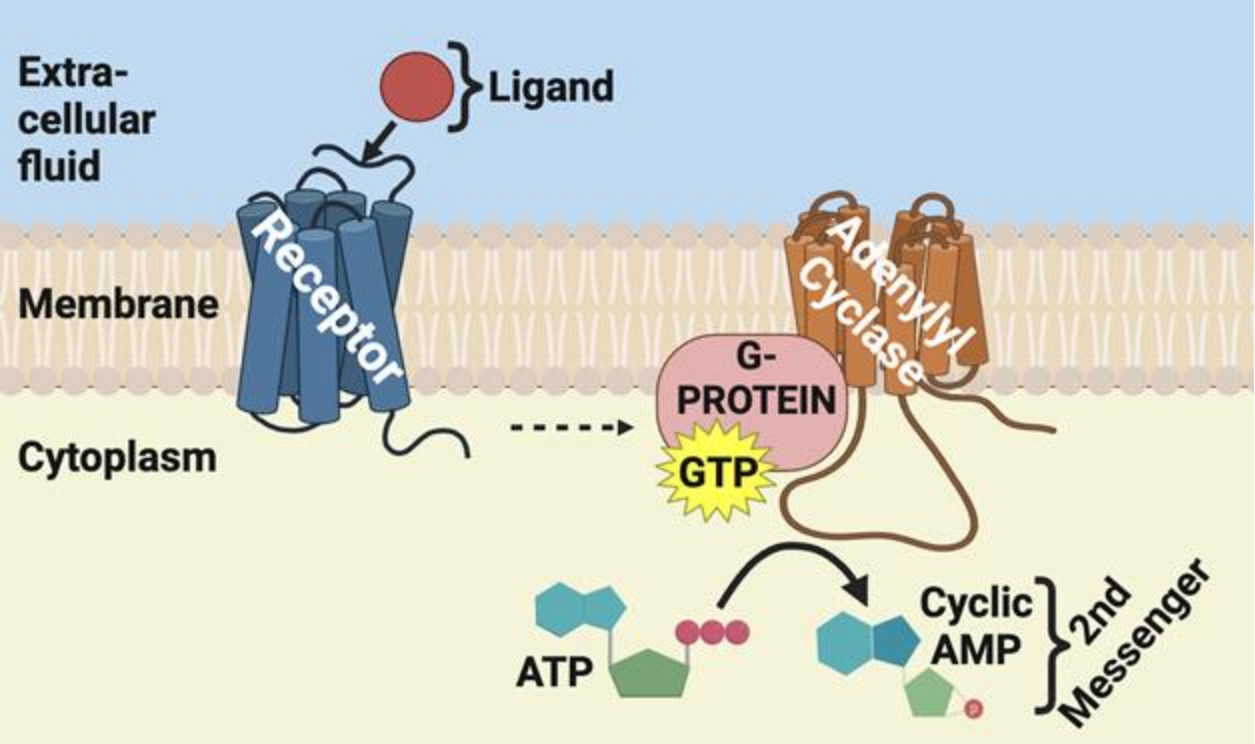


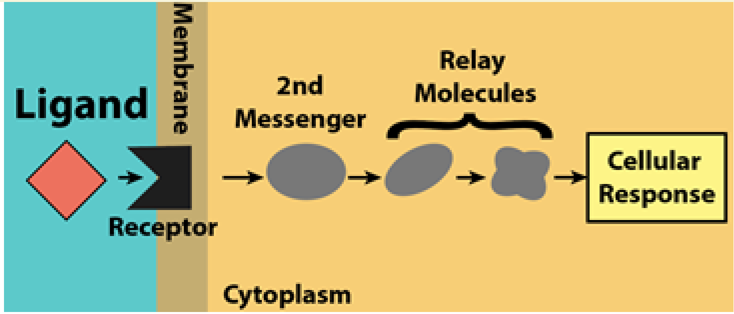
After epinephrine binds, changes in the receptor activate the G-Protein

The G-protein

- Interacts with receptor
- Discharges GDP and binds with GTP
- Becomes activated



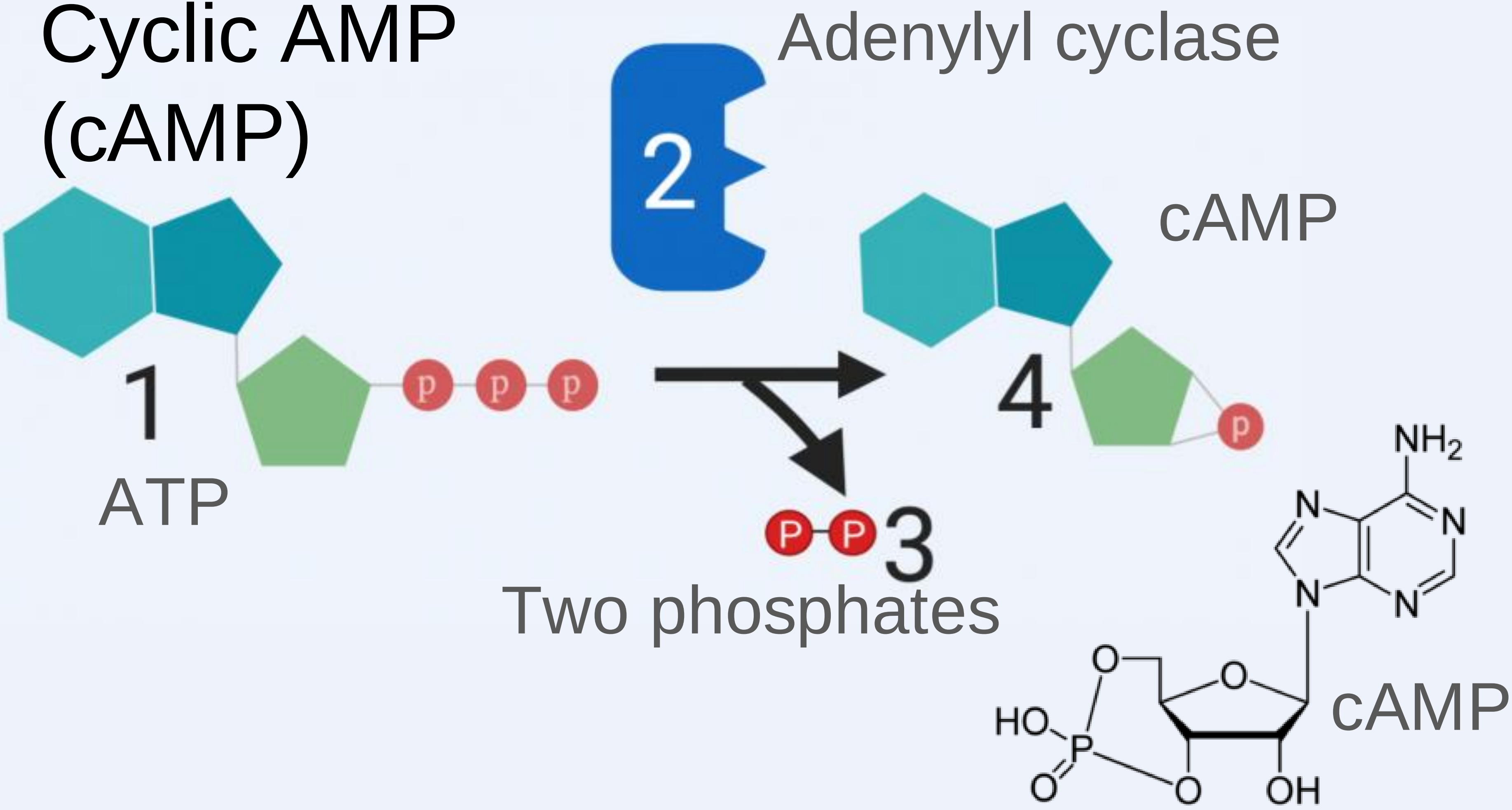




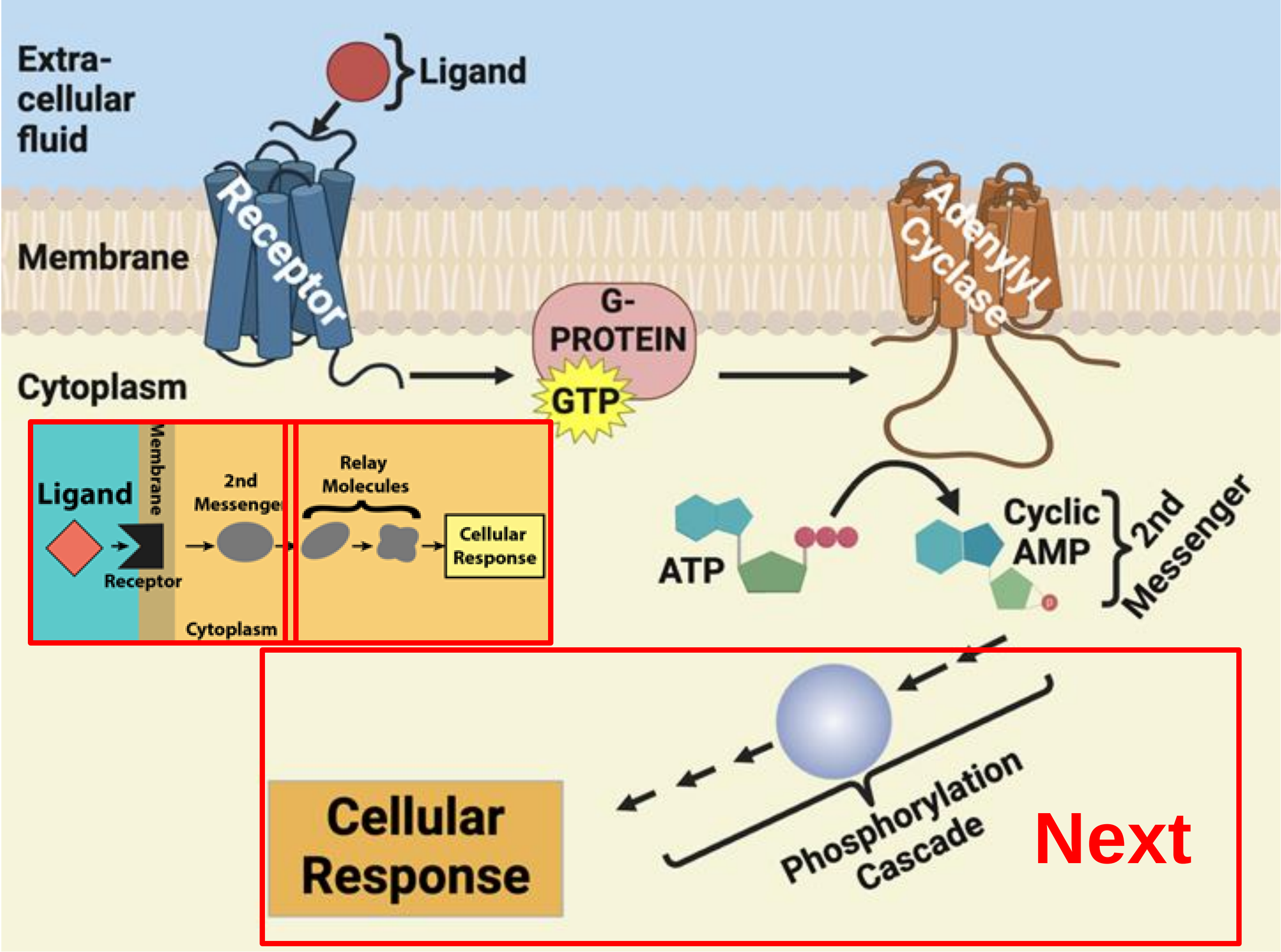
Activated G-protein

- Drifts in the membrane
- Binds with Adenylyl cyclase
- Adenylyl cyclase converts ATP → cyclic AMP
- Cyclic AMP is the **2nd messenger**

Cyclic AMP (cAMP)



REVIEW



Extra-cellular fluid
Ligand
Membrane
Receptor
Cytoplasm
G-PROTEIN
GTP
Adenylyl Cyclase
Ligand
Membrane
Receptor
2nd Messenger
Cytoplasm
Relay Molecules
Cellular Response
ATP
Cyclic AMP
2nd Messenger
Cellular Response
Phosphorylation Cascade
Next

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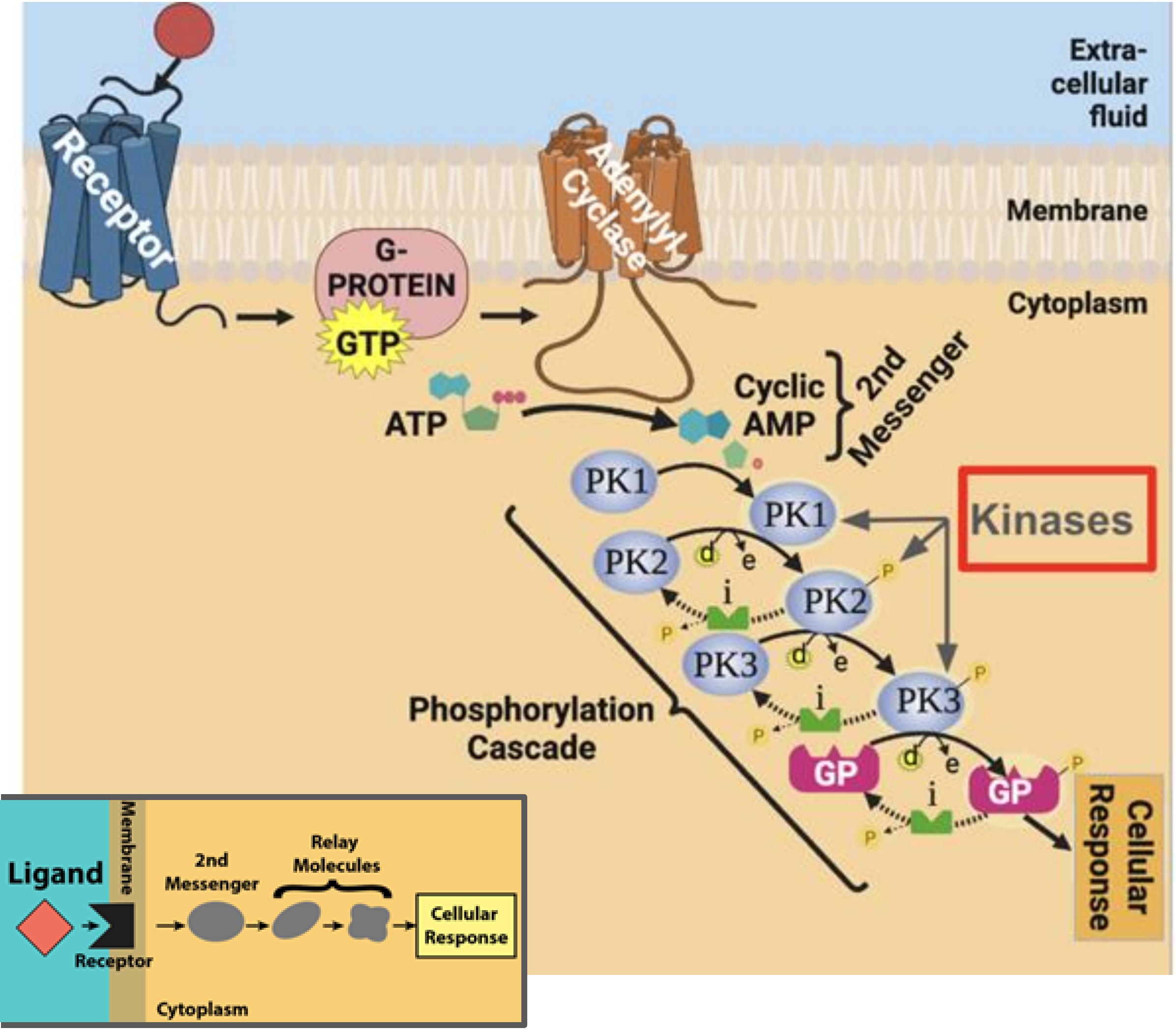
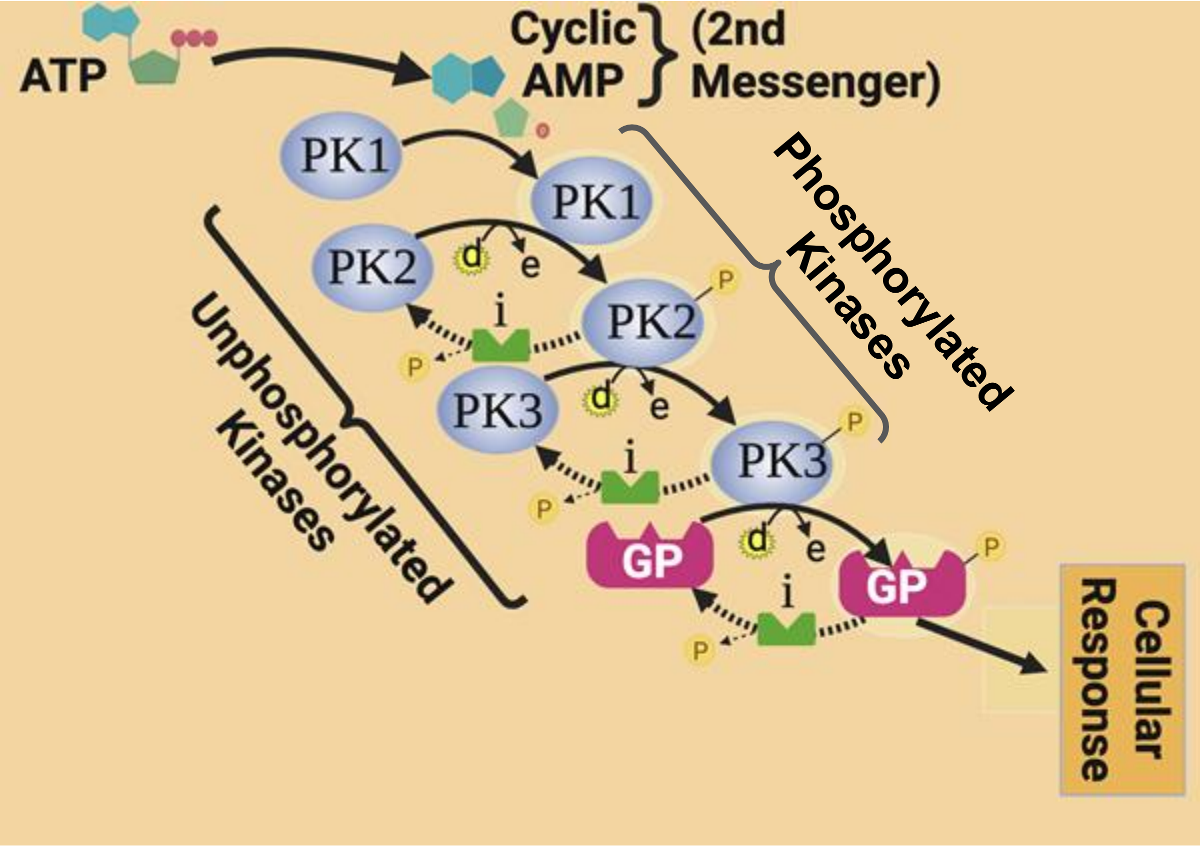
QUESTIONS (and comments)

?s



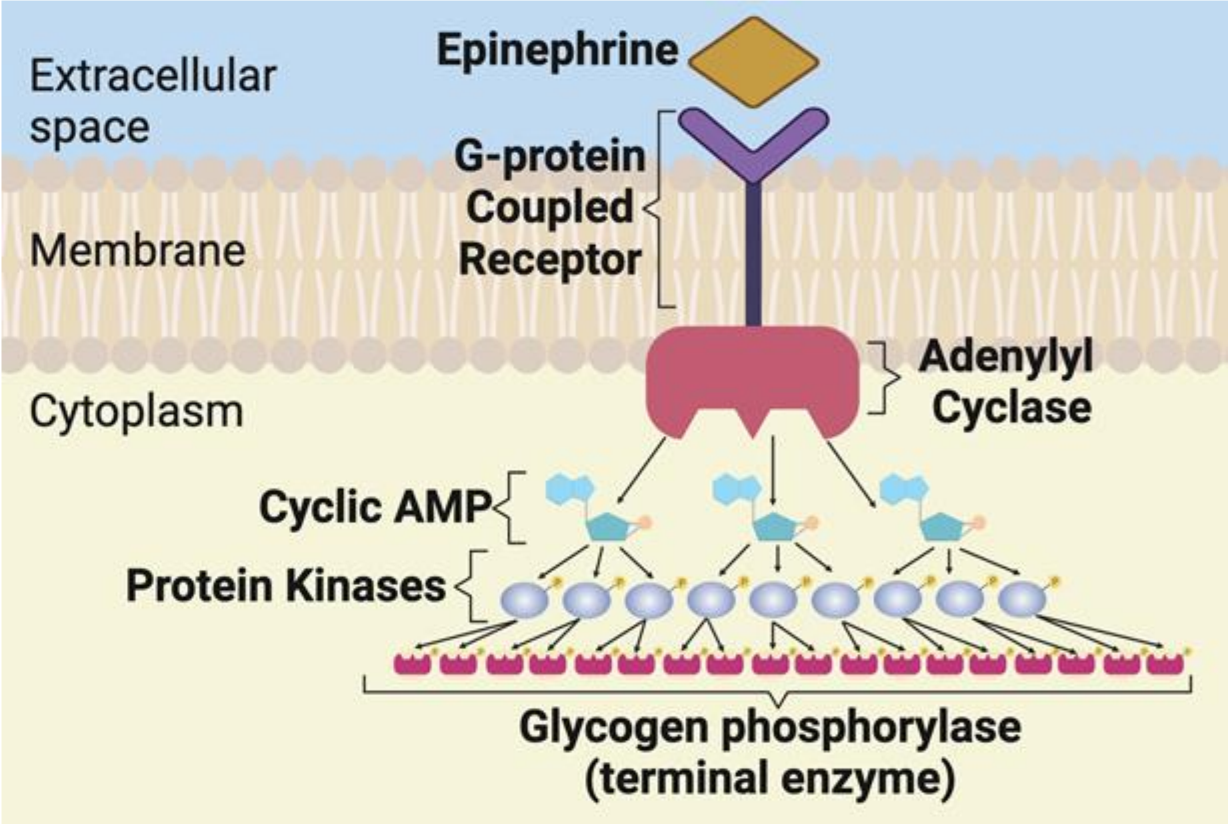
Transduction and amplification

- cAMP (2nd messenger) activates a chain of relay molecules
- These are **kinases**
- Activation involves a **phosphorylation cascade**



Transduction and amplification

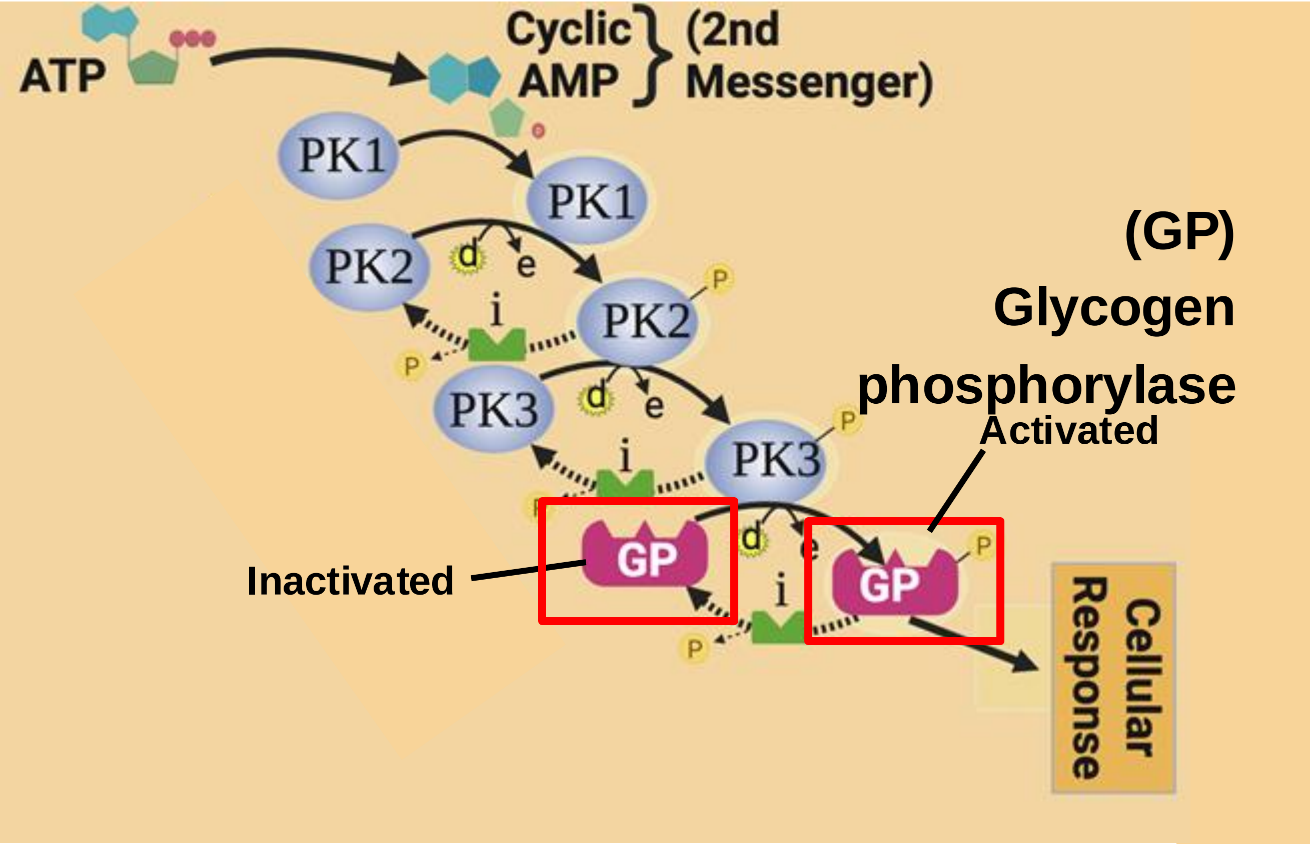
- **Kinases** are activated by phosphorylation (gaining a phosphate)
- Activated kinases phosphorylate the next kinase in the chain → **phosphorylation cascade**



Transduction and amplification

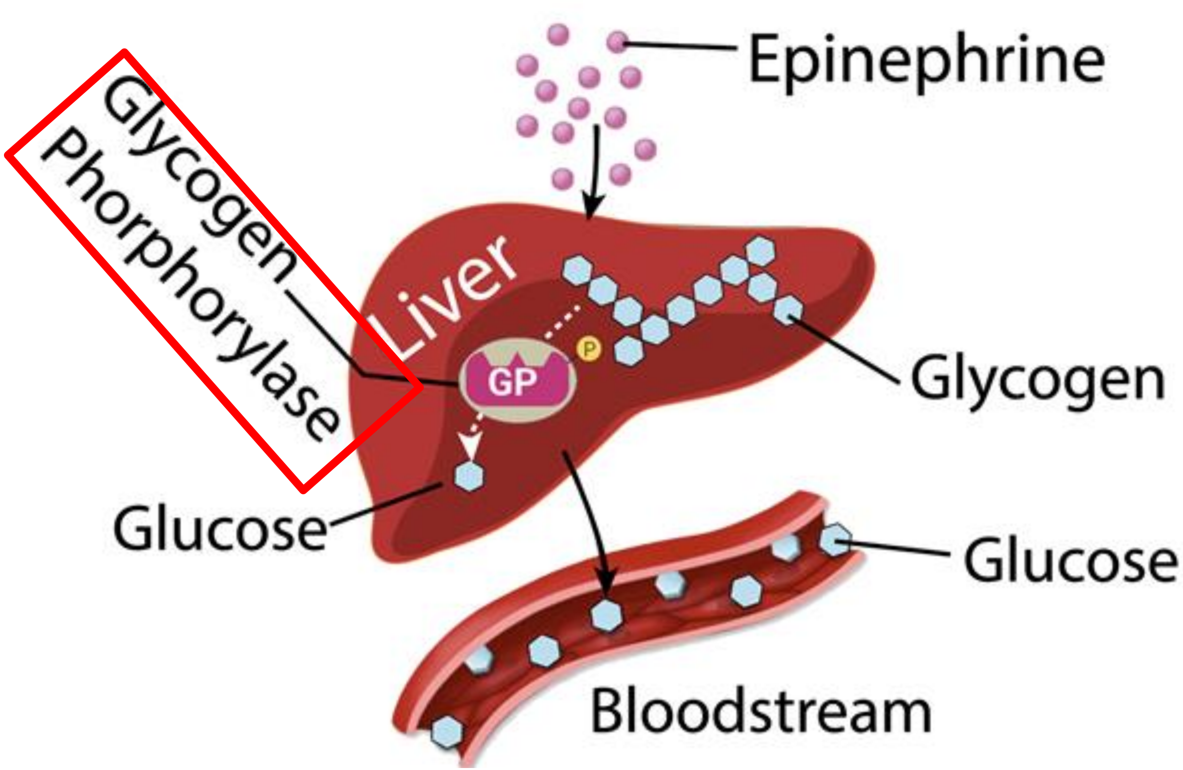
- Each step involves multiple activations
- Result: **SIGNAL AMPLIFICATION**
- One epinephrine activates millions of enzymes

Response: Molecular view

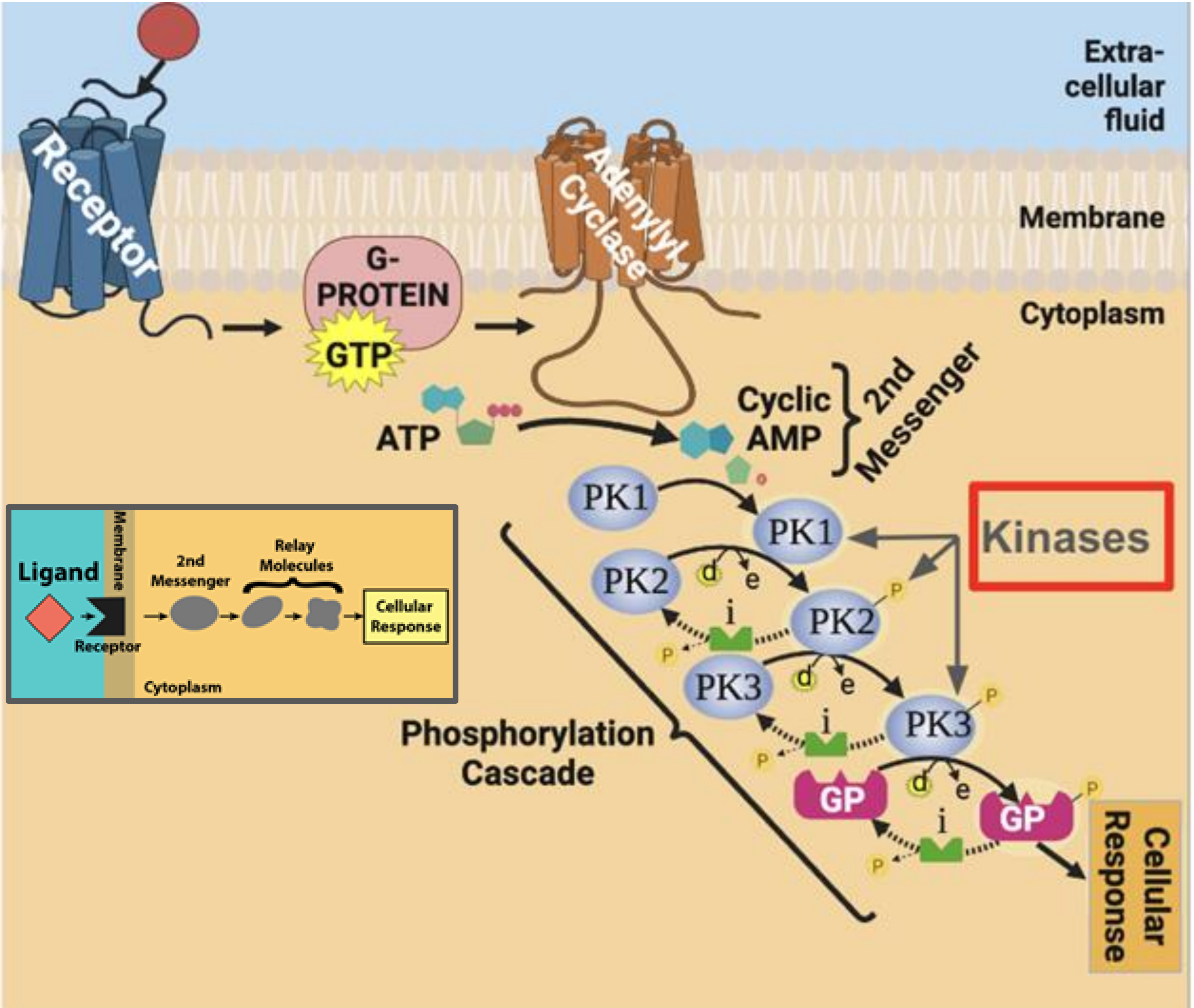


- Activation of terminal enzyme (glycogen phosphorylase)

Response (2)



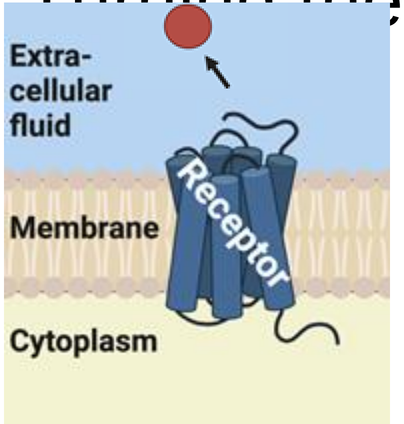
- Glycogen phosphorylase converts glycogen into glucose



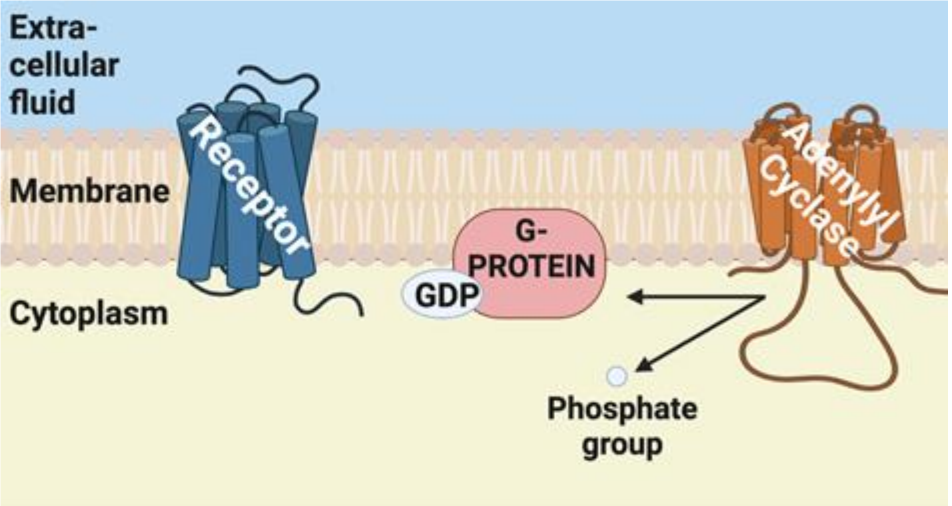
Extra-cellular fluid
Membrane
Cytoplasm
Receptor
G-PROTEIN
GTP
Adenylyl Cyclase
ATP
Cyclic AMP
2nd Messenger
PK1
PK2
PK3
Kinases
d
e
i
P
GP
Phosphorylation Cascade
Cellular Response
Ligand
Membrane
2nd Messenger
Relay Molecules
Receptor
Cellular Response
Cytoplasm

?s

Turning the response off (1)

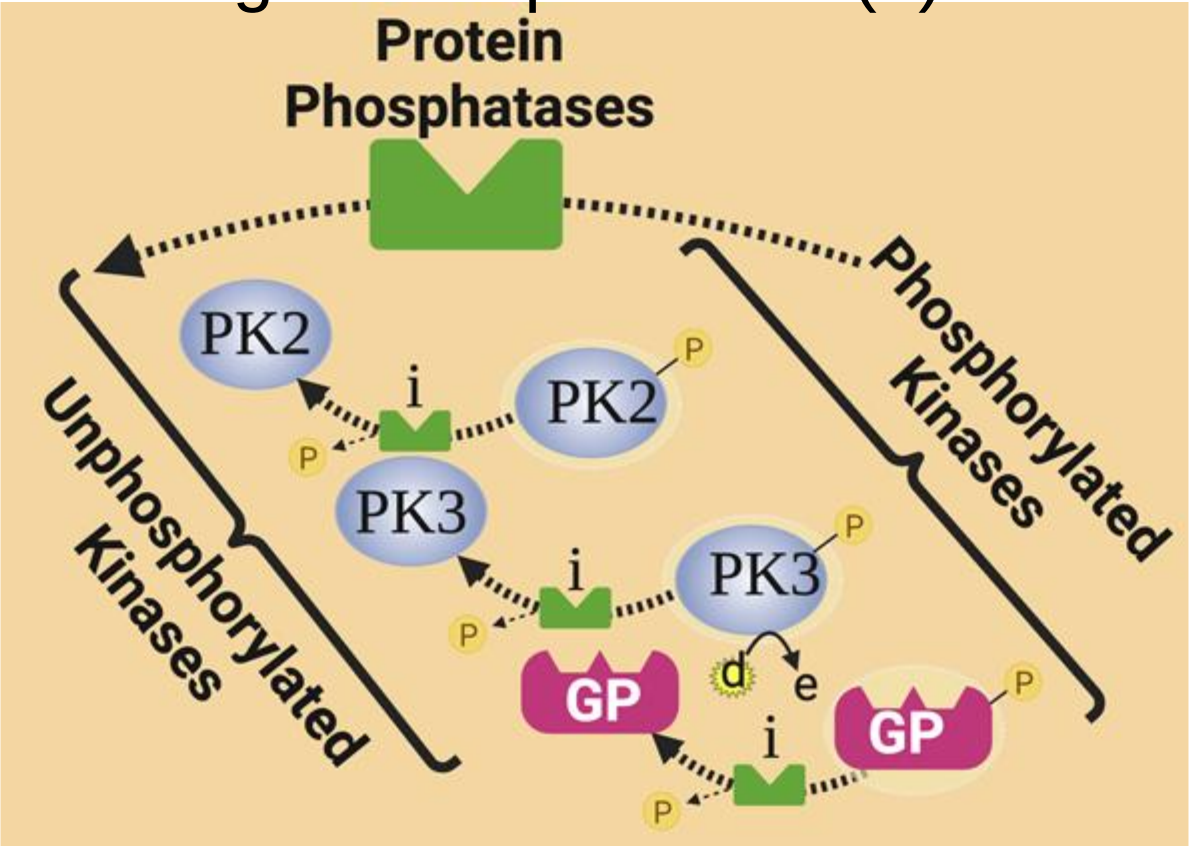


- End of threat → end of epinephrine secretion
- Epinephrine diffuses away from receptor.



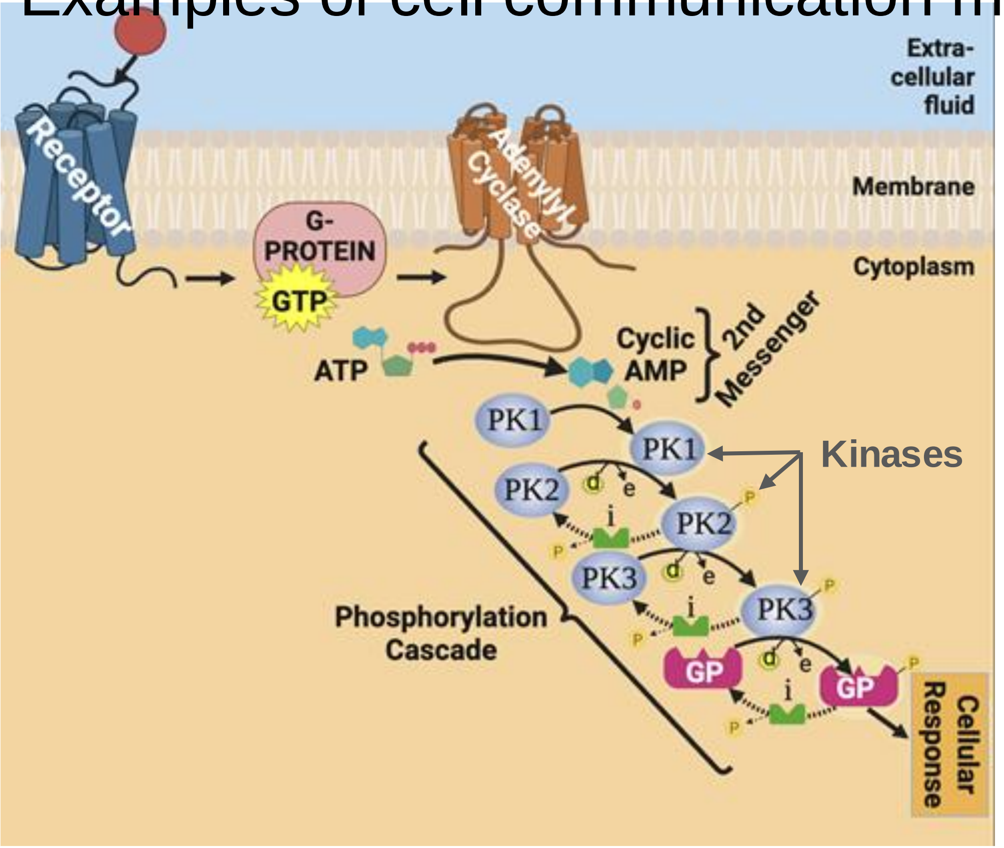
- G protein converts GTP to GDP and deactivates.
- Adenylyl cyclase deactivates
- Conversion of ATP to cAMP ceases
- RESULT: no more 2nd

Turning the response off (2)

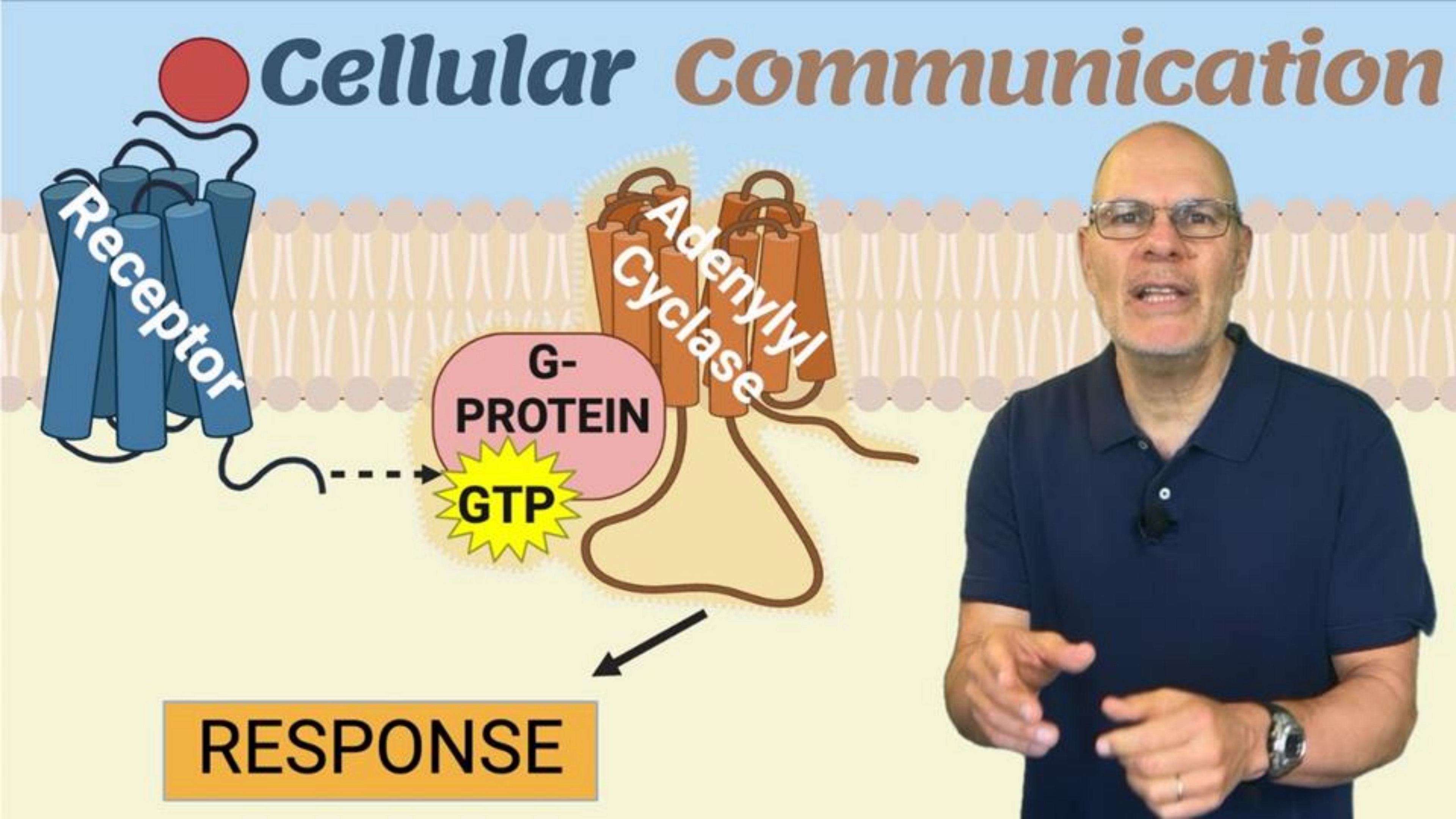


- Protein phosphatases deactivate kinases
- Cytoplasmic signal transmission ends
- Glycogen hydrolysis ends

Examples of cell communication malfunction



- Cancer
- Metabolic disorders
  - Type I diabetes
  - Type II diabetes
  - Graves disease (hyperthyroidism)
- Cholera


Cellular Communication
Receptor
Adenylyl Cyclase
G-PROTEIN
GTP
RESPONSE

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TOPIC 4.5, part 1:
HOMEOSTASIS
(Conformers and Regulators)

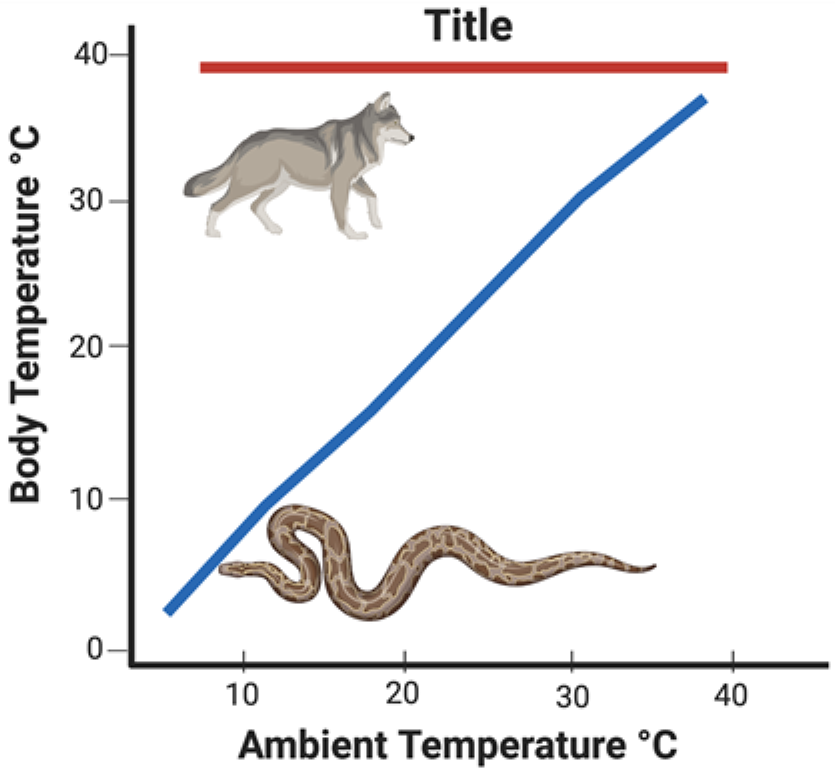
What is homeostasis?

- **Homeostasis**: the ability of a living system to maintain its internal conditions at a relatively constant, optimal level.

A few homeostatic variables

- Body temperature
- Blood glucose level
- Blood pH
- Blood pressure
- Blood calcium level
- Oxygen and carbon dioxide levels
- Water and electrolyte balance

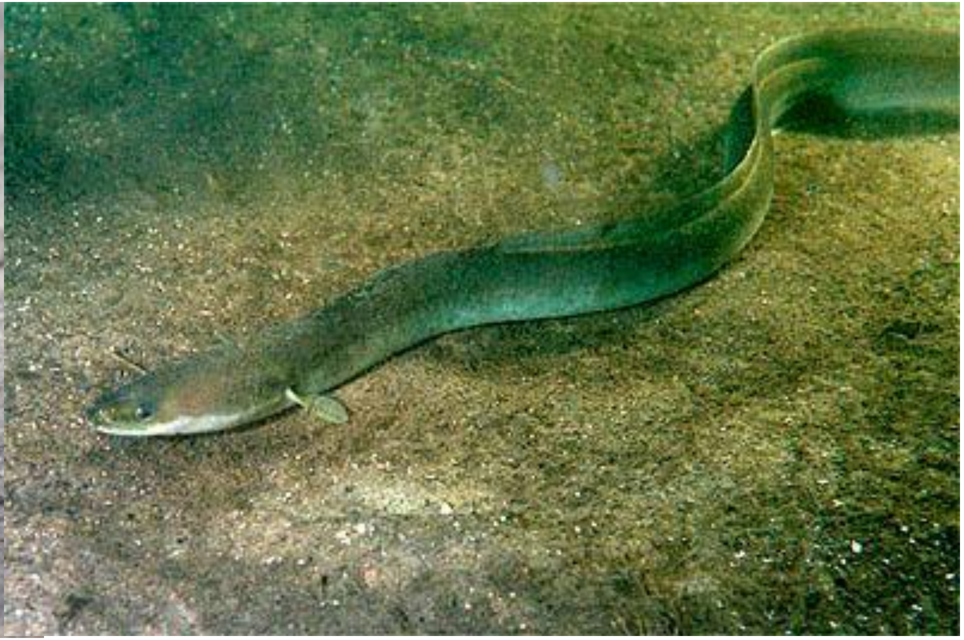
Regulators and Conformers



- Mammals and birds are body temperature **regulators**
- Regulators are **endotherms** *(warm-blooded)*
- Reptiles, amphibians, fish, most invertebrates, plants, fungi, protists, bacteria, archaea are body temperature **conformers**
- Conformers are **ectotherms** *(cold-blooded)*

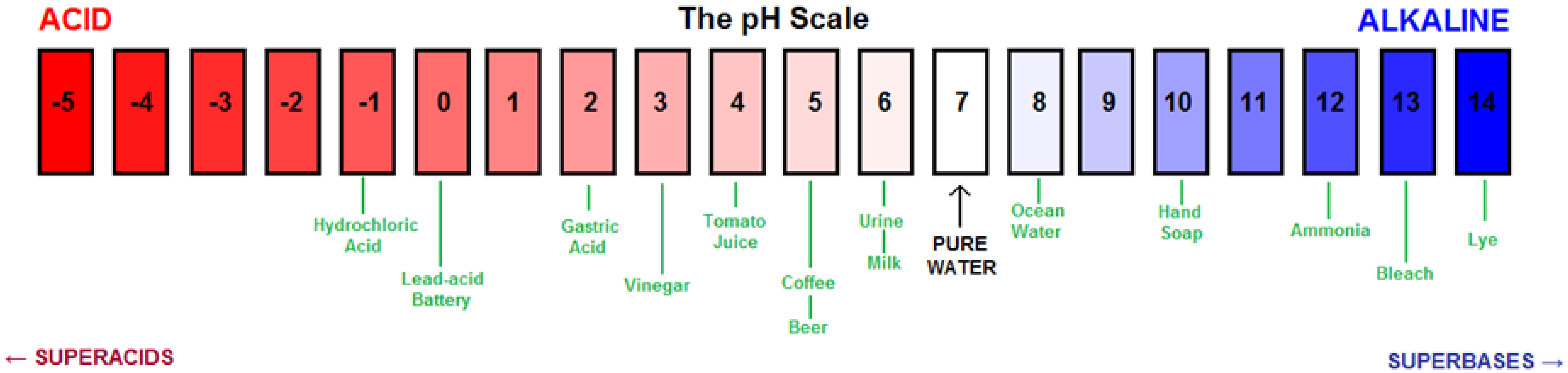
Jellyfish and Mussels are conformers for osmolarity

Crabs and eels are conformers for oxygen levels



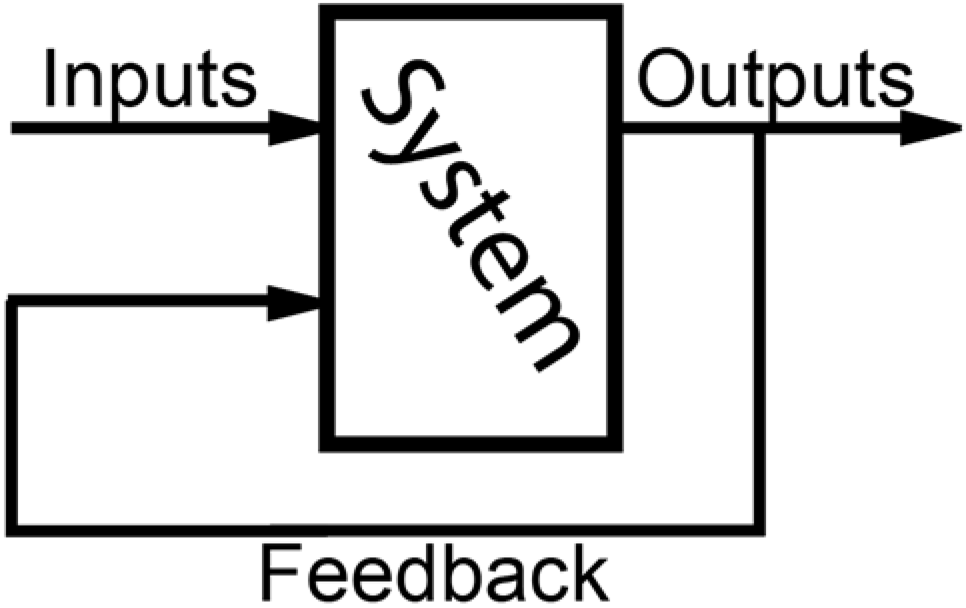
Other environmental variables for conformers

- pH
- Ion concentration
- Nitrogenous waste levels



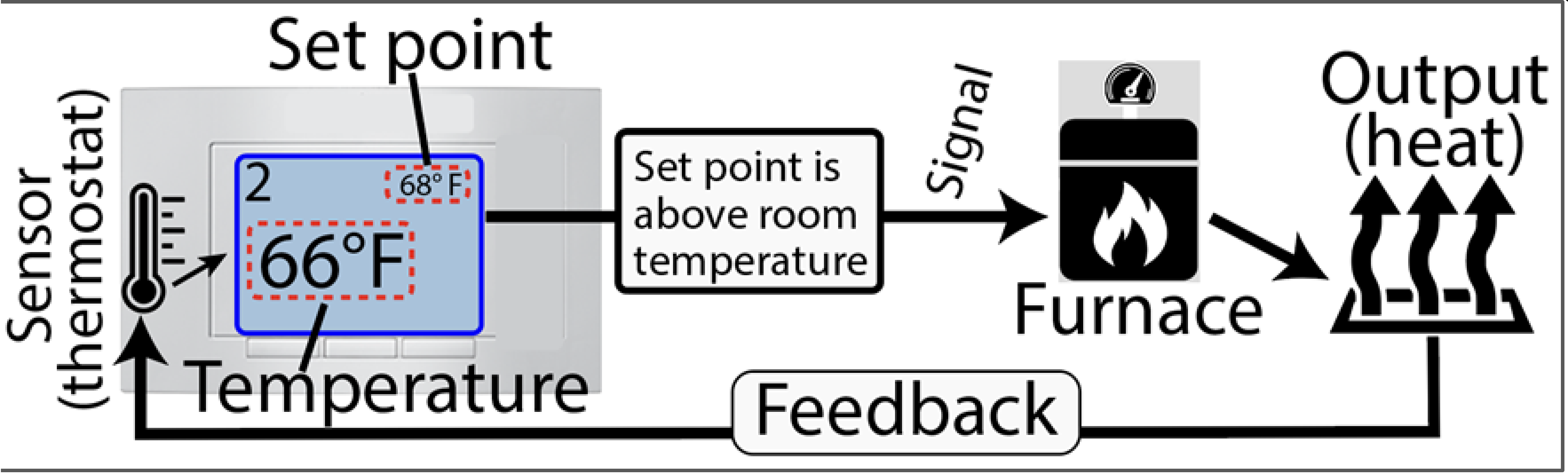
Topic 4.5, part 2: FEEDBACK

What are feedback mechanisms, and how do they connect to homeostasis?



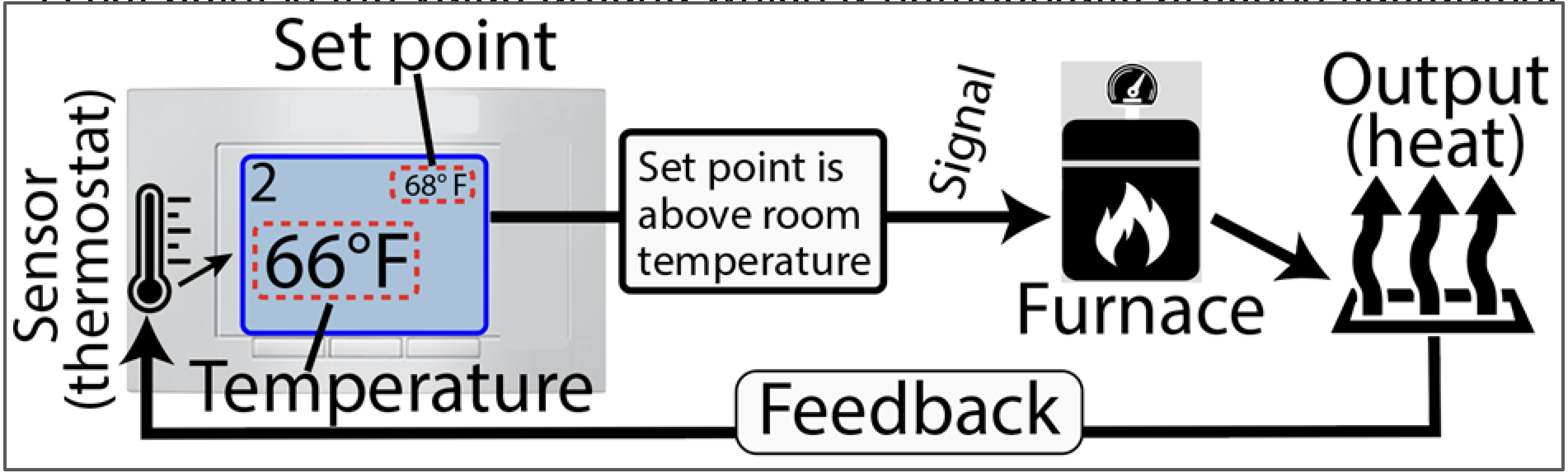
- **FEEDBACK**: when the output of a system is also an input.
- **Negative feedback:** Allows organisms to maintain homeostasis as they respond to internal and external changes (negative feedback)
- **Positive feedback:** can accelerate internal changes and drive a process forward

Set points and negative feedback in home heating systems



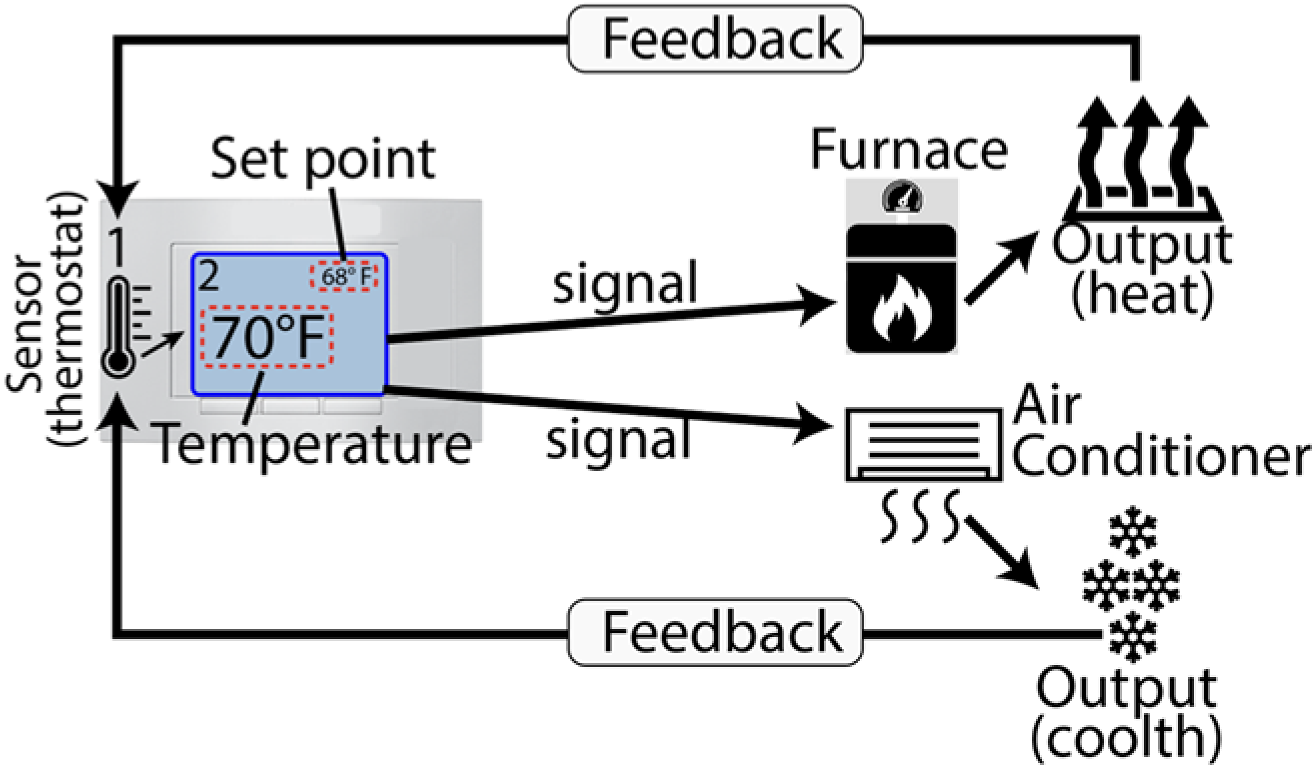
- Above: the set point for the thermostat is 68°F
- **Negative feedback:**
  - Output feeds back to the system in a way that decreases the system's output.
  - Promotes homeostasis, returning a system to its set point.

A set point is the value around which a homeostatic process fluctuates.



- Biological examples
  - Body temperature in humans: 37℃
  - Blood glucose: 70 to 100 mg/dL
  - Blood CO_2 partial pressure: 35–45 mmHg

Homeostasis is often controlled by paired antagonistic negative feedback loops



- One negative feedback system responds when conditions are above the set point.
- A second system responds when conditions are below the set point.

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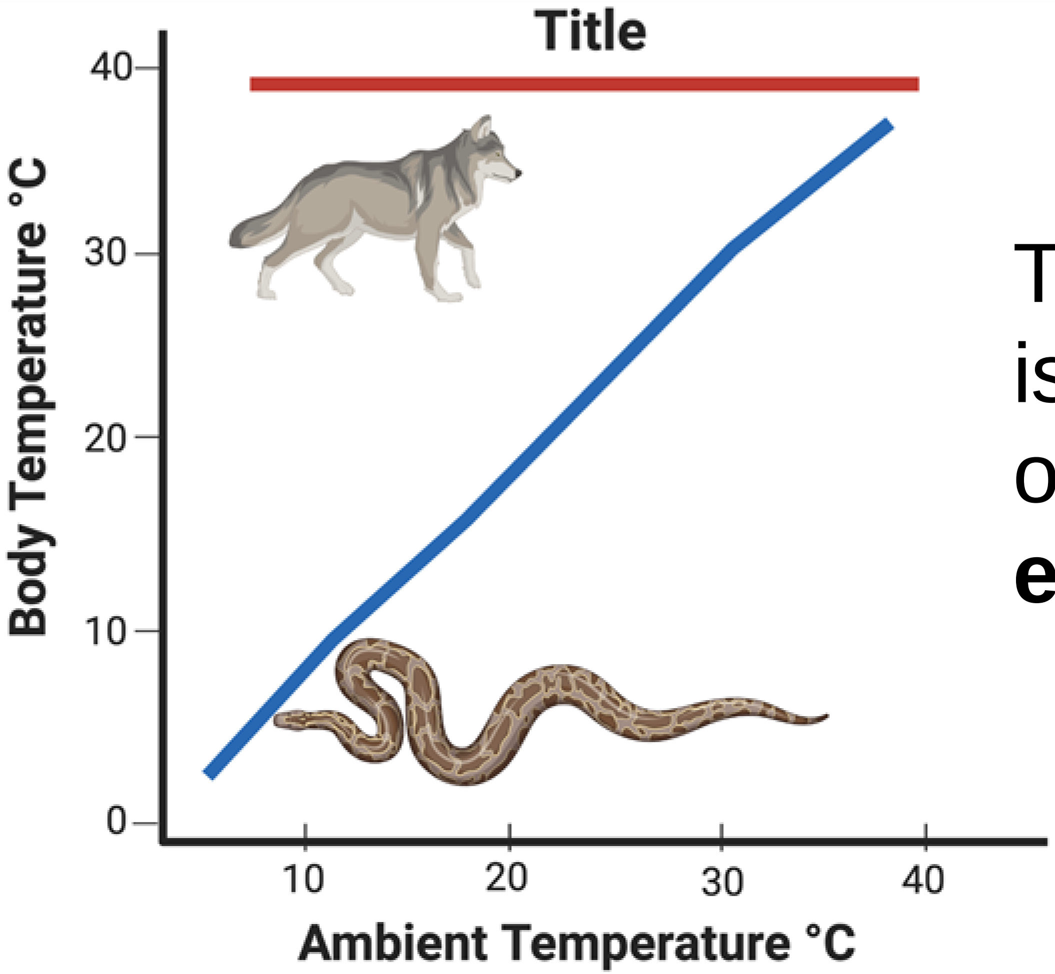
TOPIC 4.5, part 3:

Thermoregulation



Thermoregulation is mostly carried out by **endotherms**

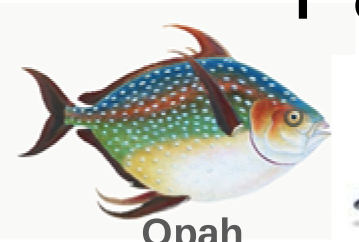
Endotherms

Complete

Mammals

Birds

Partial



Opah

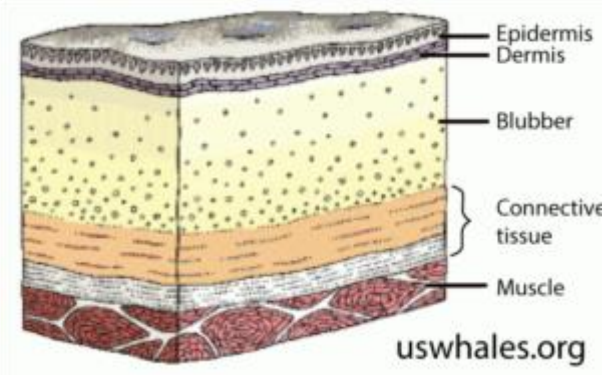
Tuna

Leatherback sea turtle

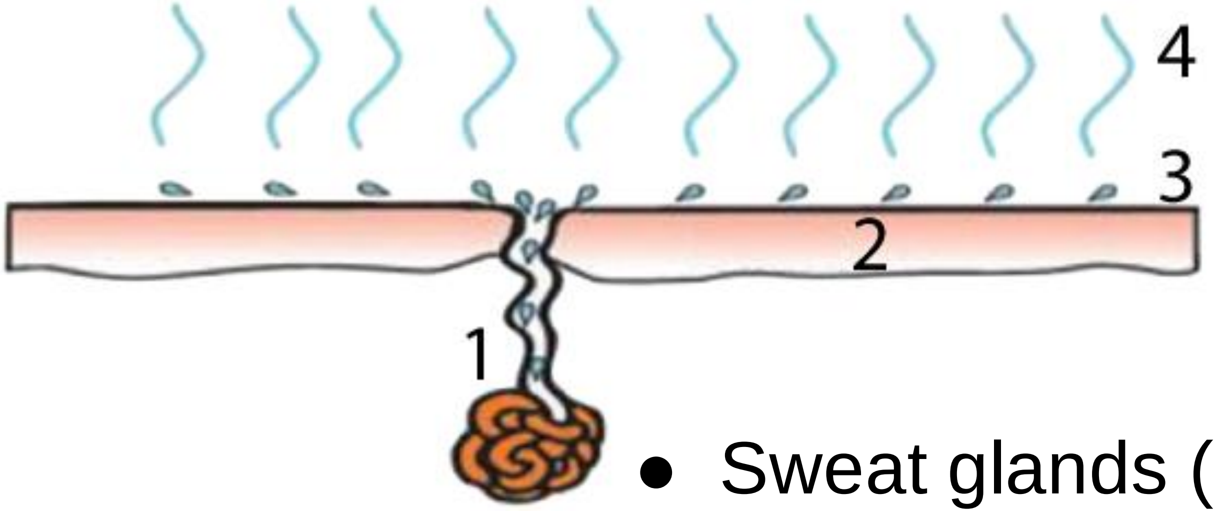
Bees

Dinosaurs: probably endothermic!

Insulation: Fur and fat

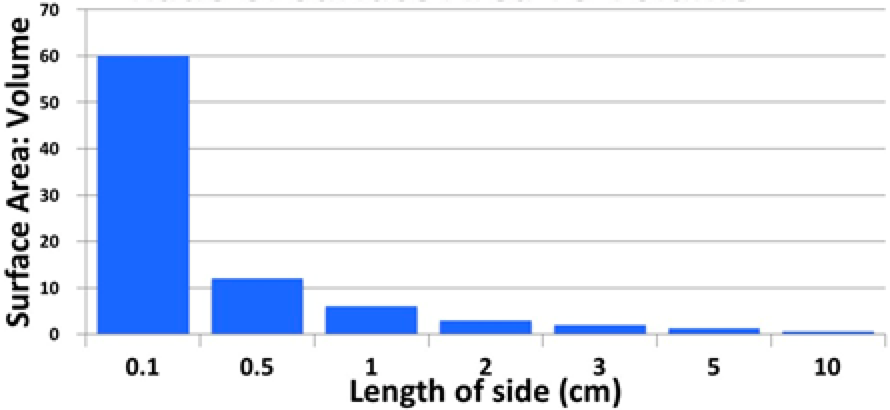


Evaporative Cooling



- Sweat glands (1) release
- Sweat (3) onto the
- Skin (2)
- Evaporation lowers temperature

Surface area evolutionary modifications

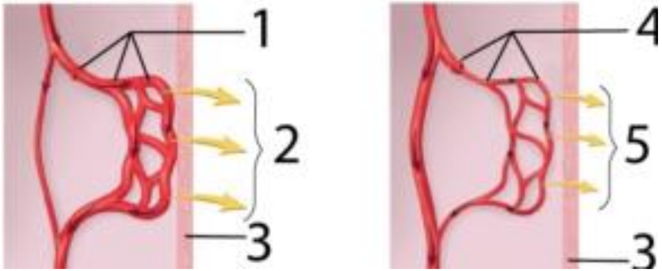


With cold stress, selection against small size:
lots of surface area: volume

With cold stress, evolve large size:
relatively little surface area: volume

With heat stress, evolve appendages like huge ears:
increase surface area for radiation

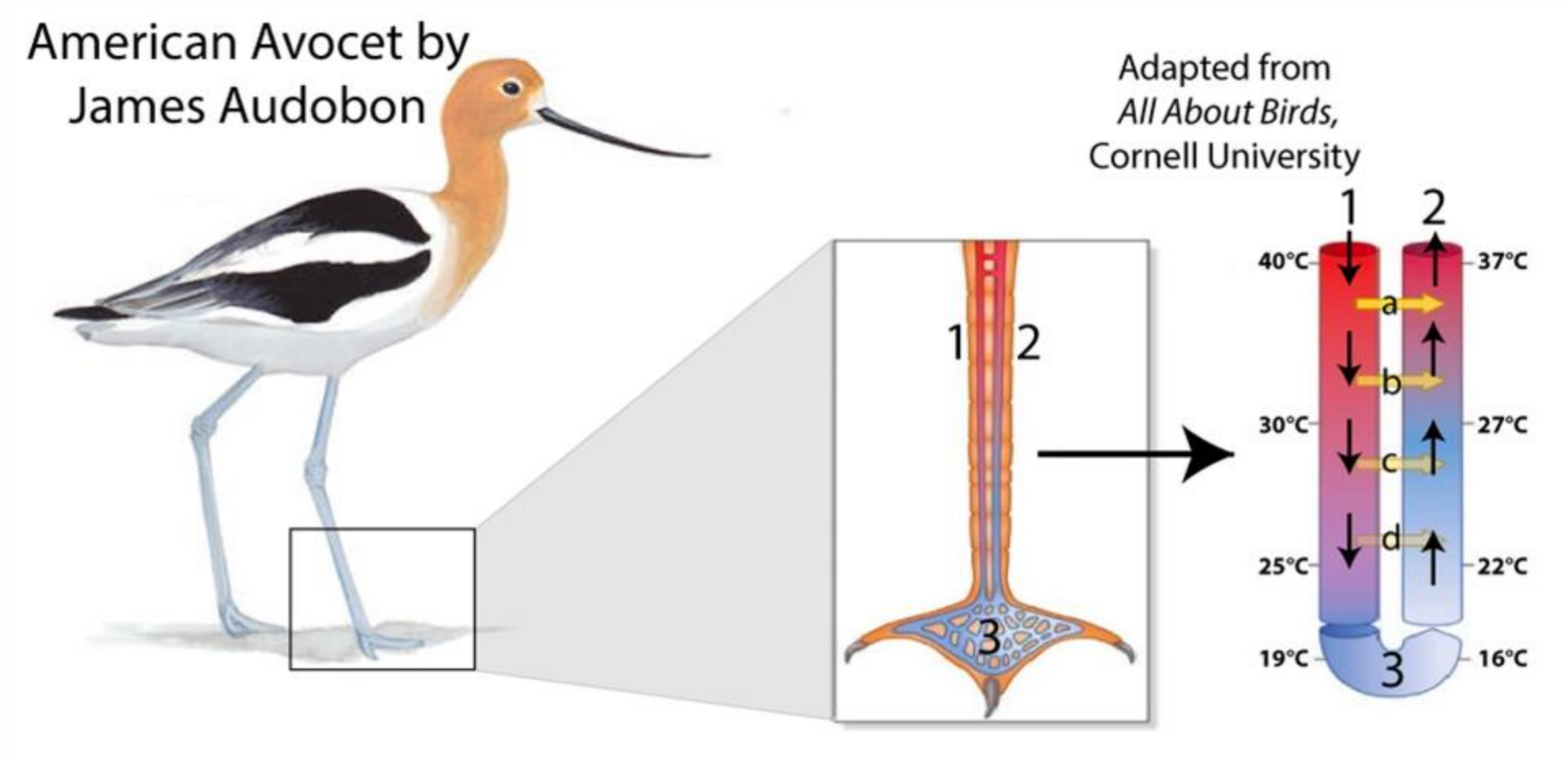
Vasodilation releases heat; vasoconstriction reduces heat loss



1. Dilated capillaries
2. More heat released
3. Skin

4. Constricted capillaries
5. Less heat released

Countercurrent exchange minimizes heat loss



Thermoregulatory behaviors in ectotherms…

Basking in the sun

Seeking shade

Thermoregulatory behaviors in endotherms

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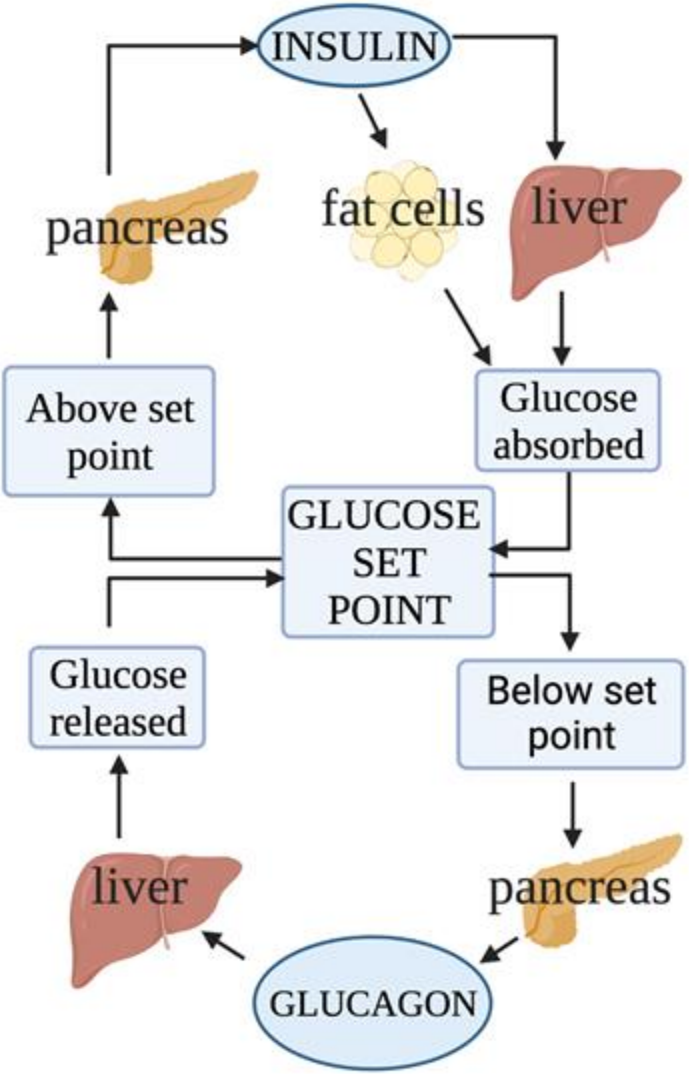
QUESTIONS (and comments)

?s

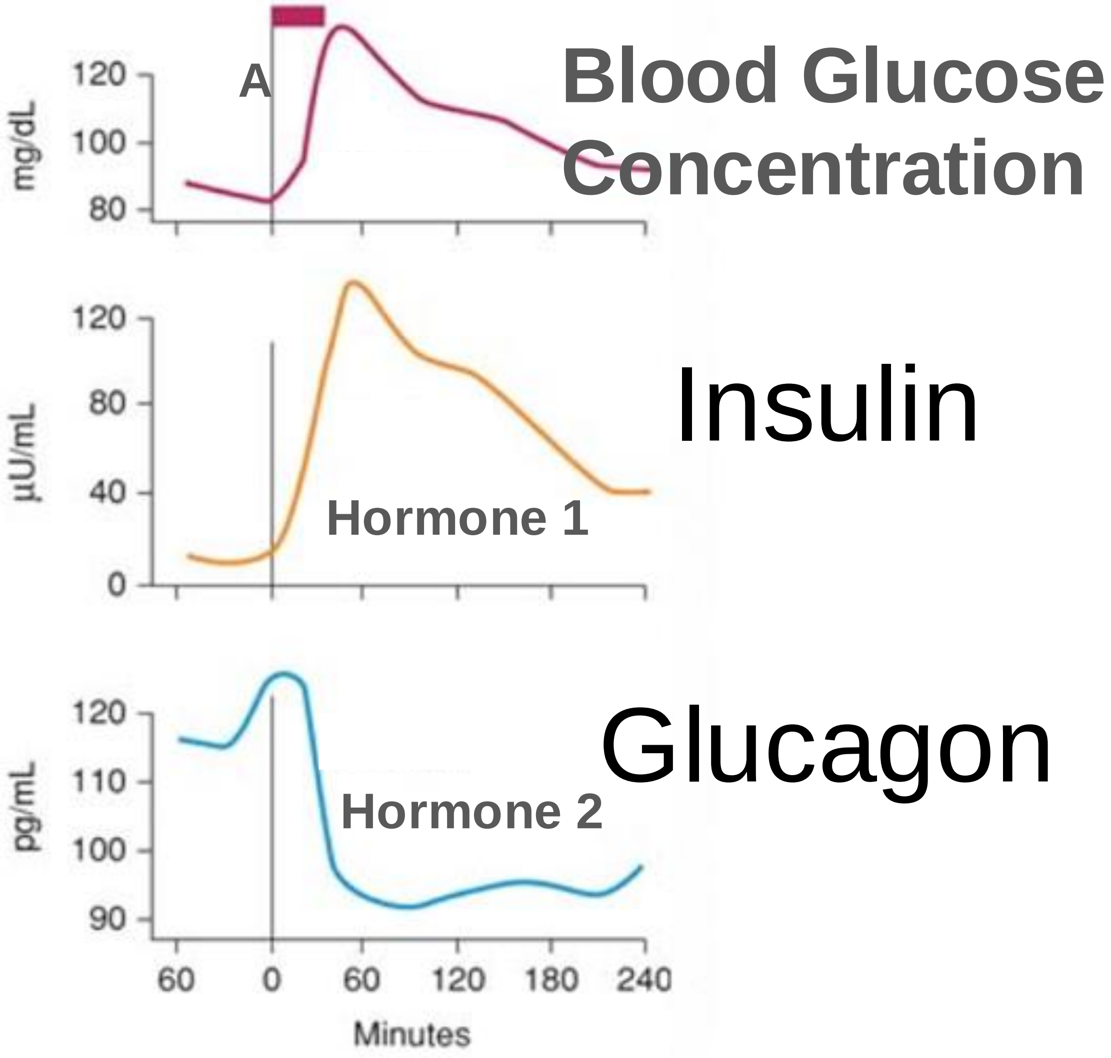
TOPIC 4.5, part 4: Blood Glucose Regulation



Insulin and glucagon maintain blood glucose homeostasis

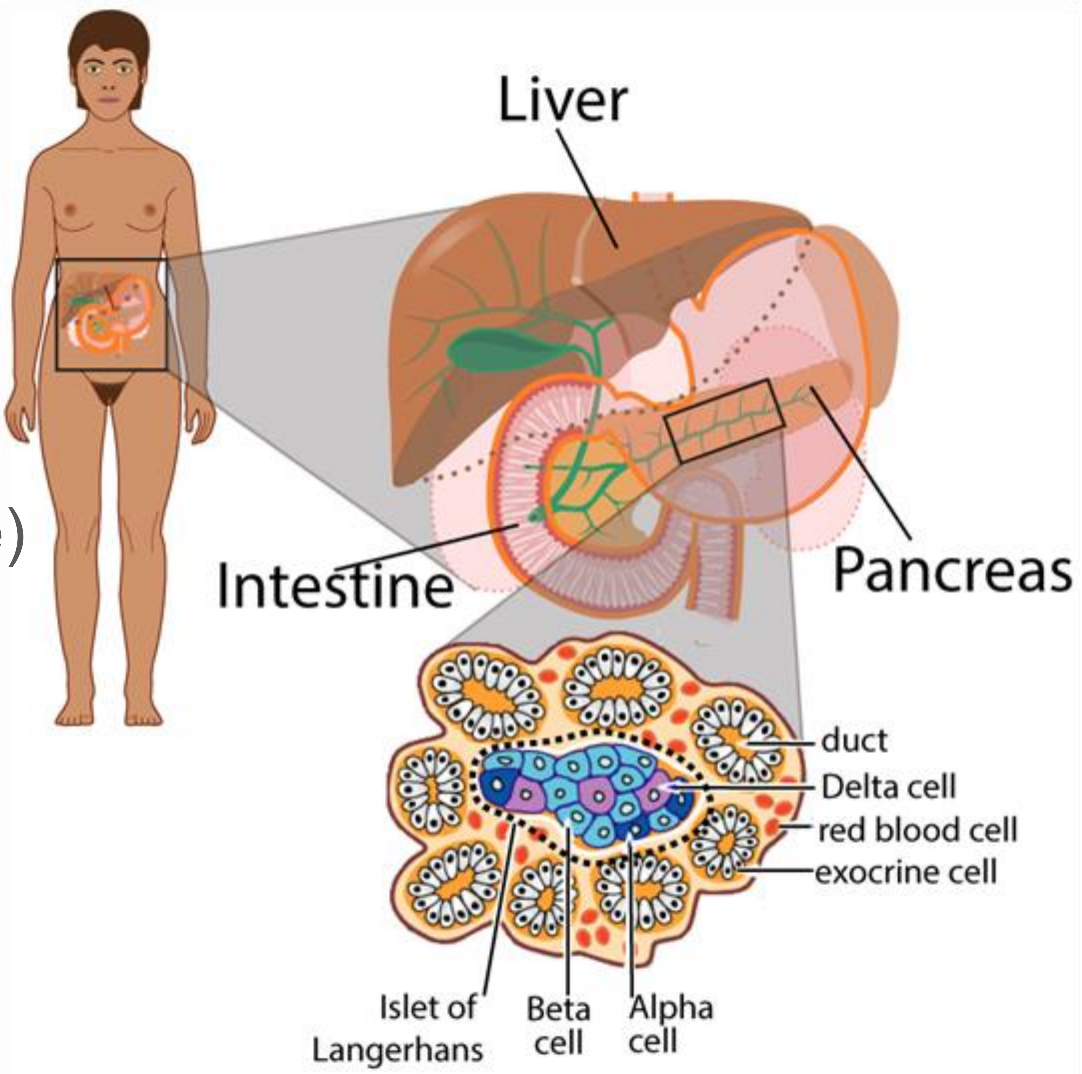
- Blood glucose set point : about 90 mg/dL
- Above set point
  - Pancreas releases insulin
  - Liver, fat (and muscle) cells absorb glucose
- Below set point
  - Pancreas releases glucagon
  - Liver converts glycogen to glucose

Which hormone is glucagon? Which is insulin?

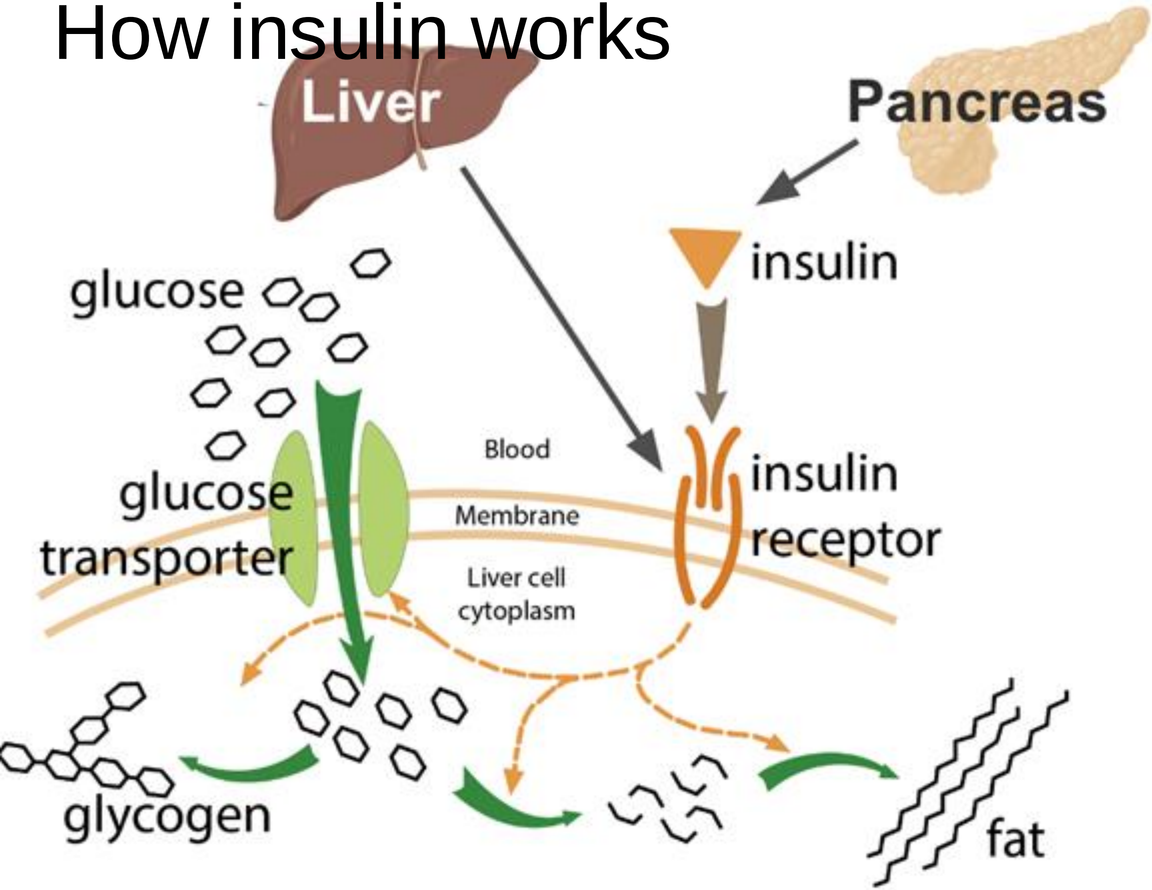


The underlying anatomy

- Cells in the **pancreas** control blood glucose
- **Beta cells** secrete insulin (↓ blood glucose)
- **Alpha cells** secrete glucagon (↑ blood glucose)

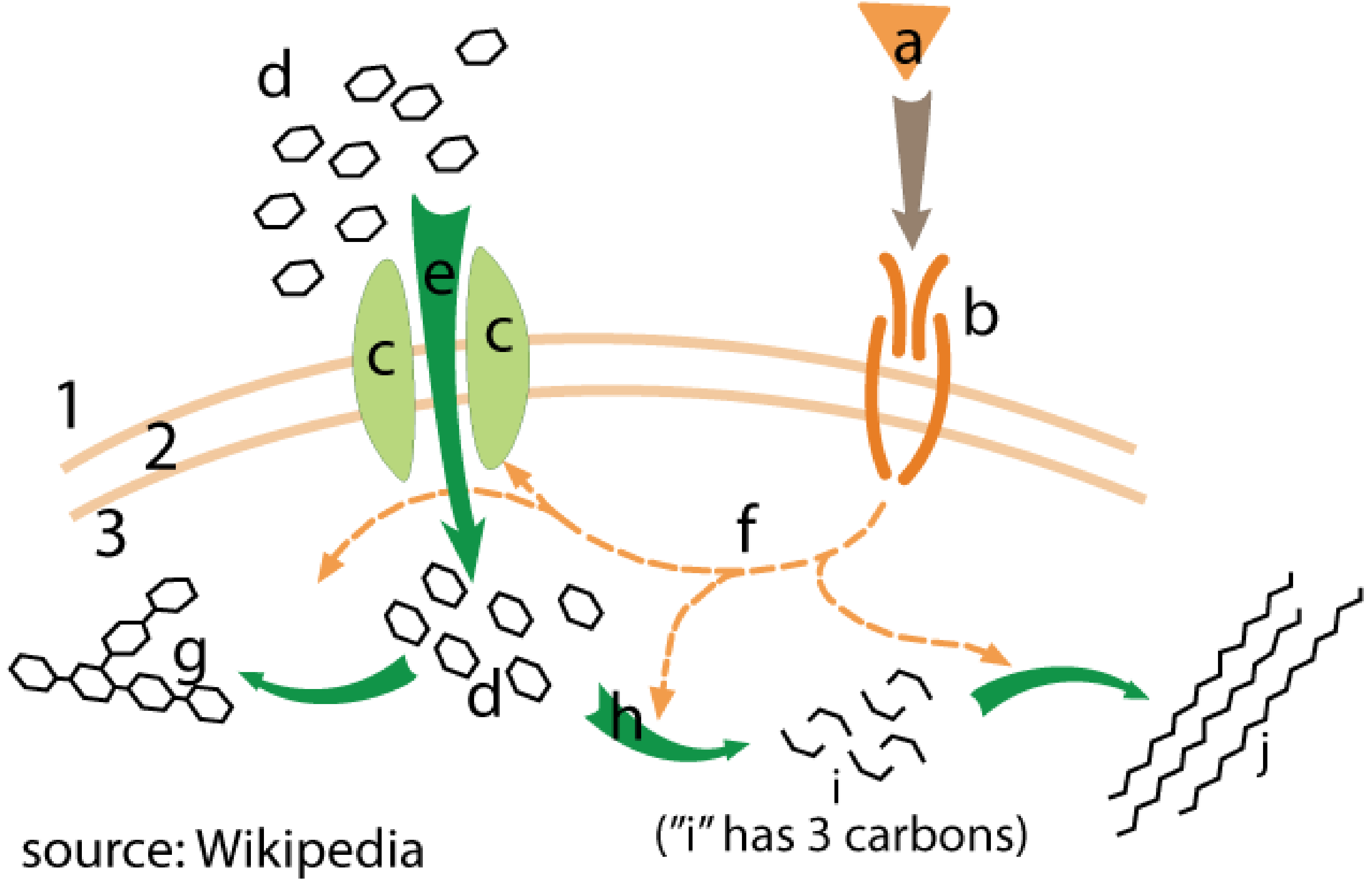


How insulin works

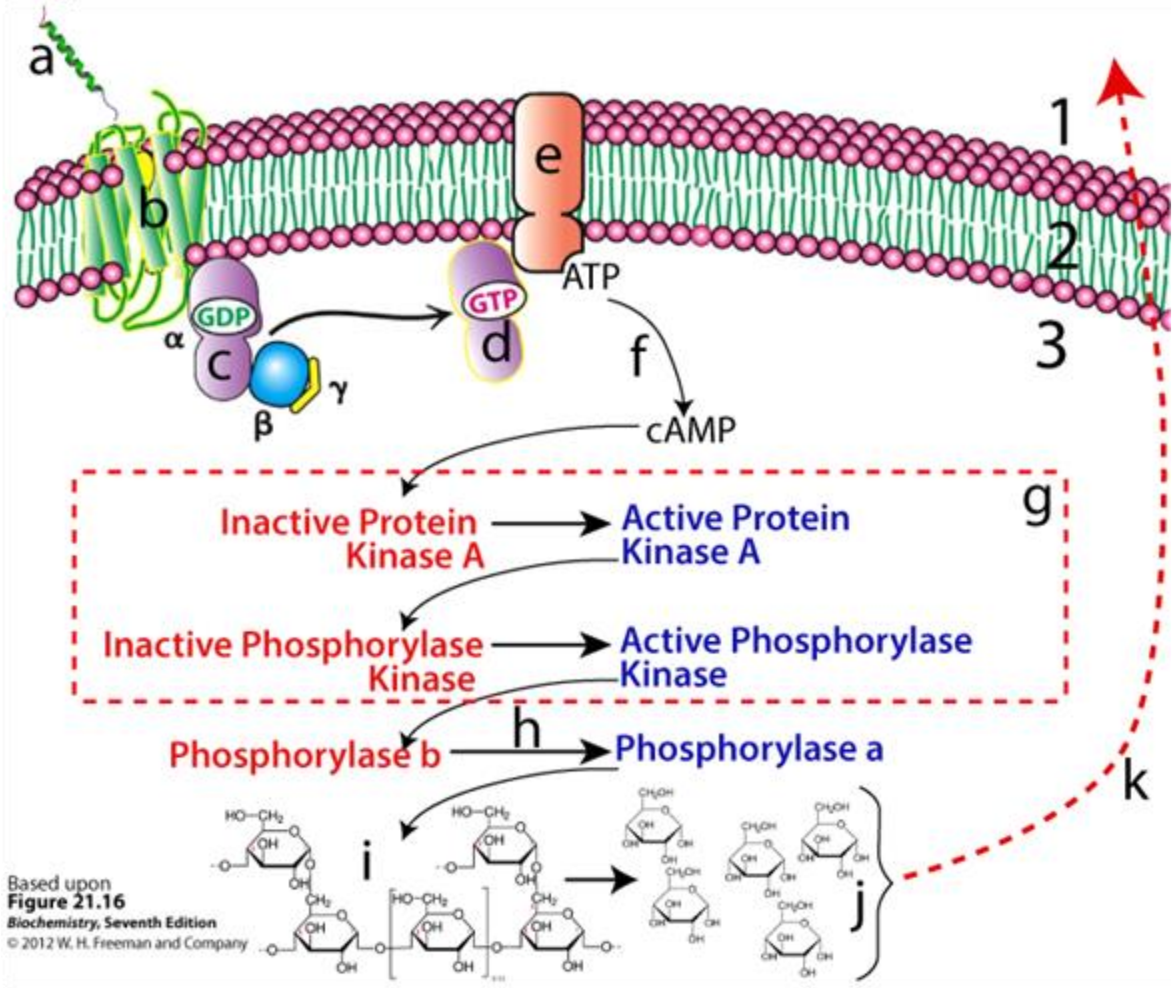


- NEGATIVE FEEDBACK SYSTEM
- High blood glucose levels → pancreas releases insulin.
- Insulin binds at receptors in liver cells
- Signaling cascade → glucose transport channel to open
- Glucose
  - Diffuses into liver cells
  - Gets converted to glycogen and fat for storage.

Insulin Action: Checking Understanding



Glucagon Action



G-protein coupled receptor system

A: Glucagon

B: Receptor

C: G-protein (inactive)

D: G-protein (activated)

E: Adenylyl cyclase

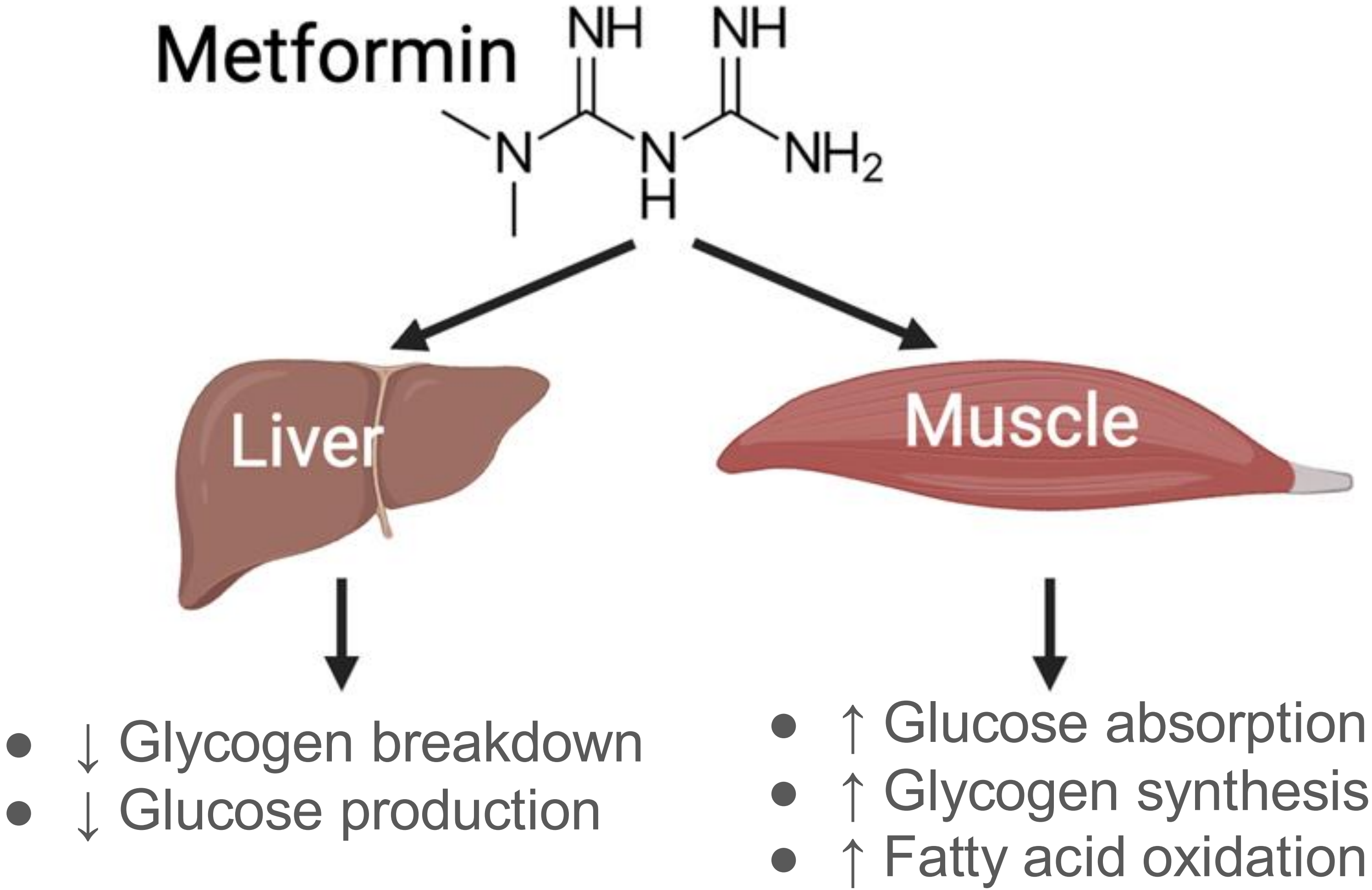
F: 2nd Messenger (cAMP)

G: Phosphorylation cascade

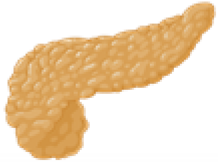
H: Terminal enzyme

I-J: Glycogen → Glucose

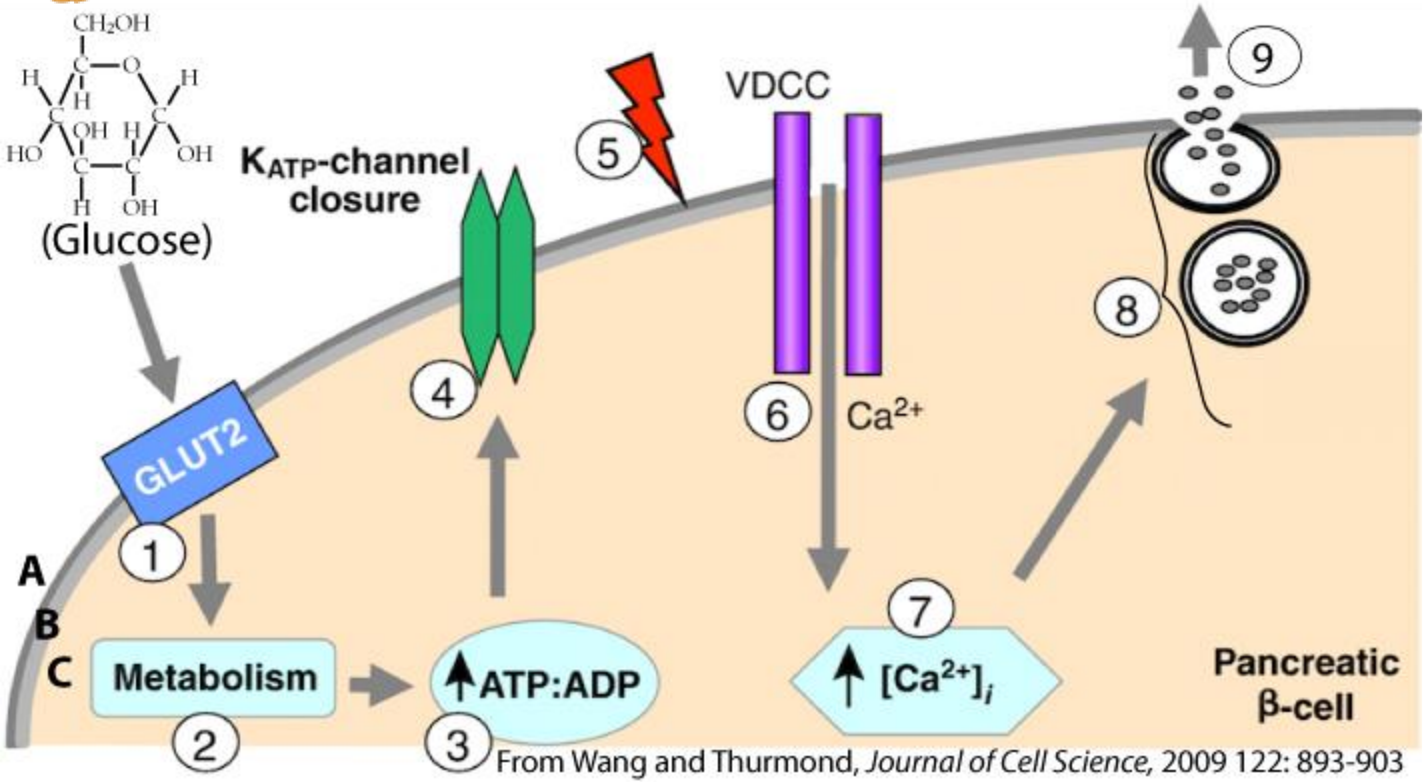
K: Glucose secretion



Metformin
NH
NH
N
N
H
NH_2
Liver
Muscle
• ↓ Glycogen breakdown
• ↓ Glucose production
• ↑ Glucose absorption
• ↑ Glycogen synthesis
• ↑ Fatty acid oxidation



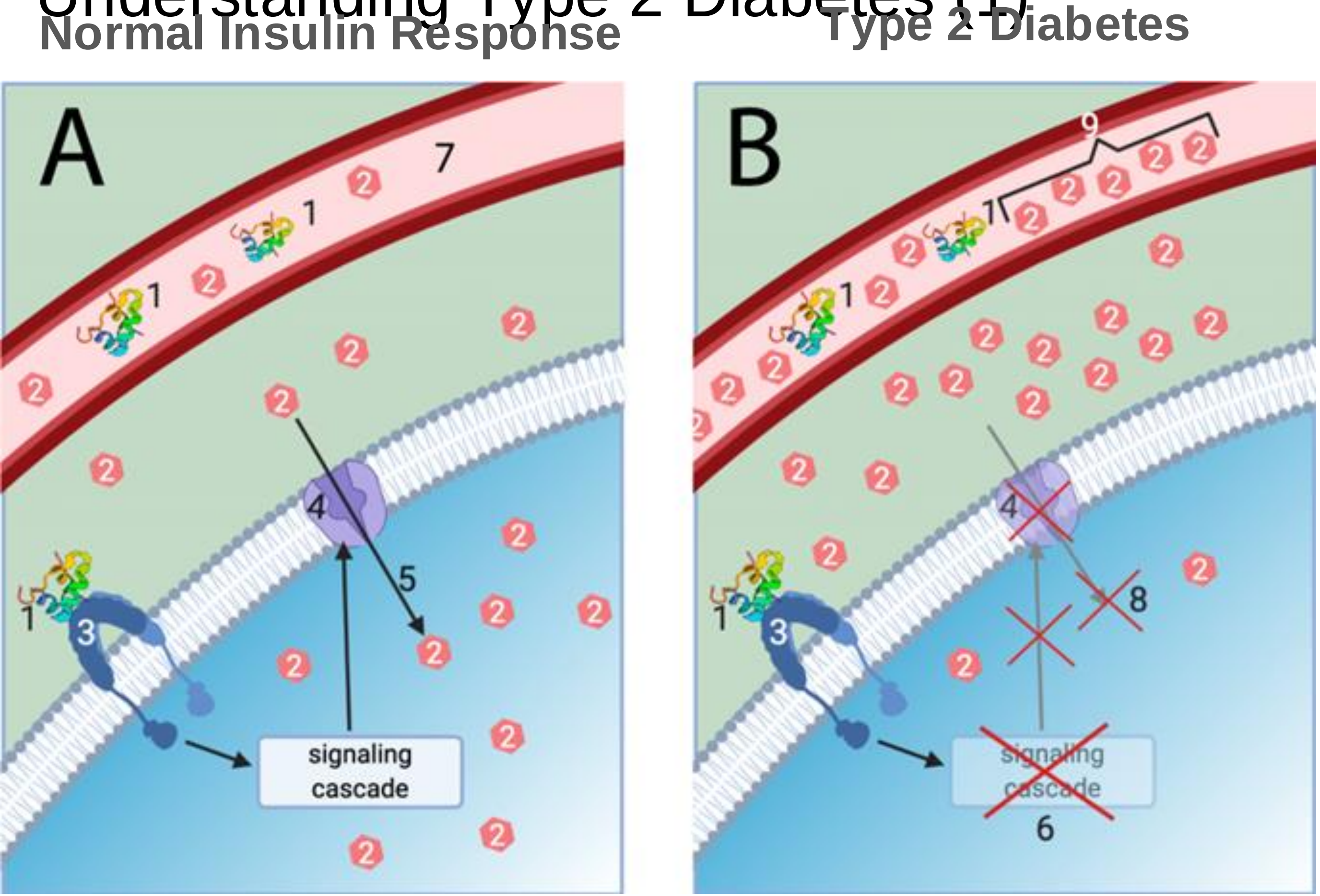
Control of Insulin Action in the Pancreas



From Wang and Thurmond, *Journal of Cell Science*, 2009 122: 893-903

- ↑ Glucose →
- ↑ ATP →
- Closing a K^+ channel →
- Depolarization (5)→
- Opening a Ca^{++} Channel
- ↑ Ca^{++} →
- Vesicles releasing insulin

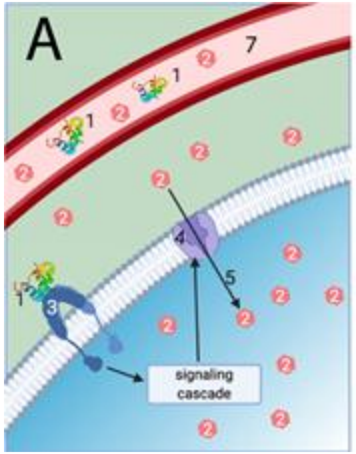
Understanding Type 2 Diabetes (1)



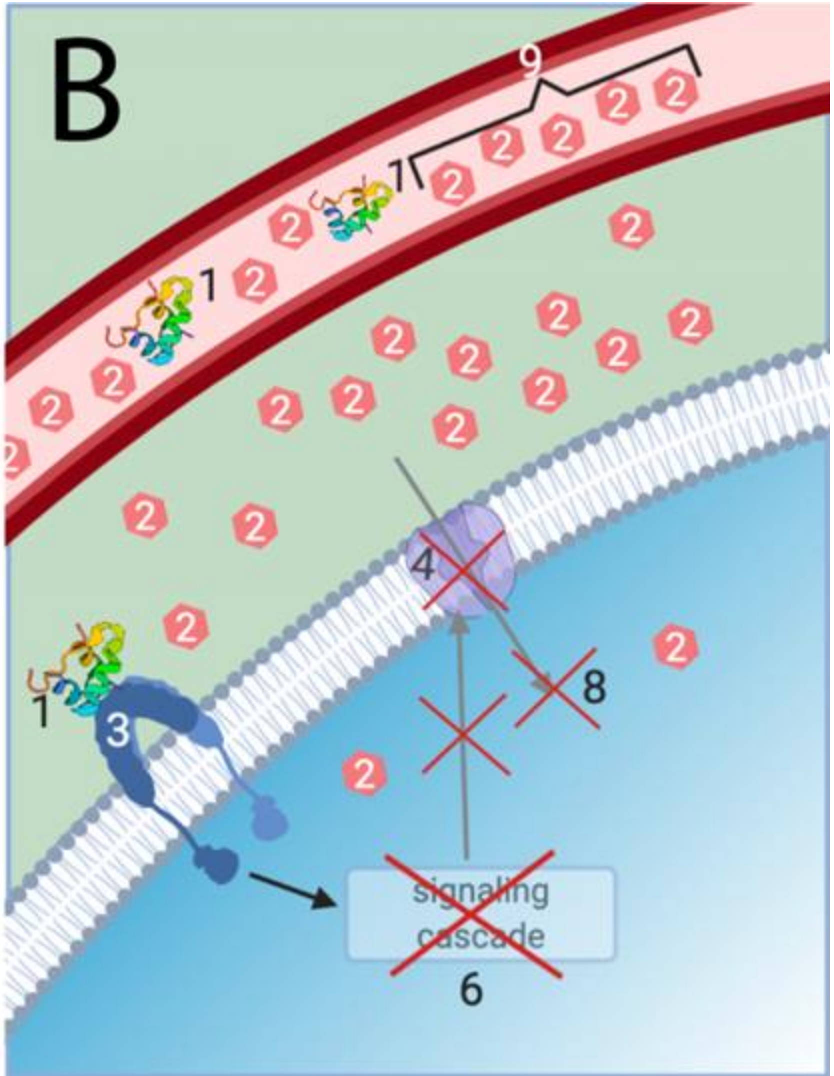
Normal metabolism

- Insulin (1) binds with insulin receptor
- Signal cascade
- Glucose channel opens
- Glucose absorbed into cells
- Blood glucose falls.

Type 2 Diabetes (2)

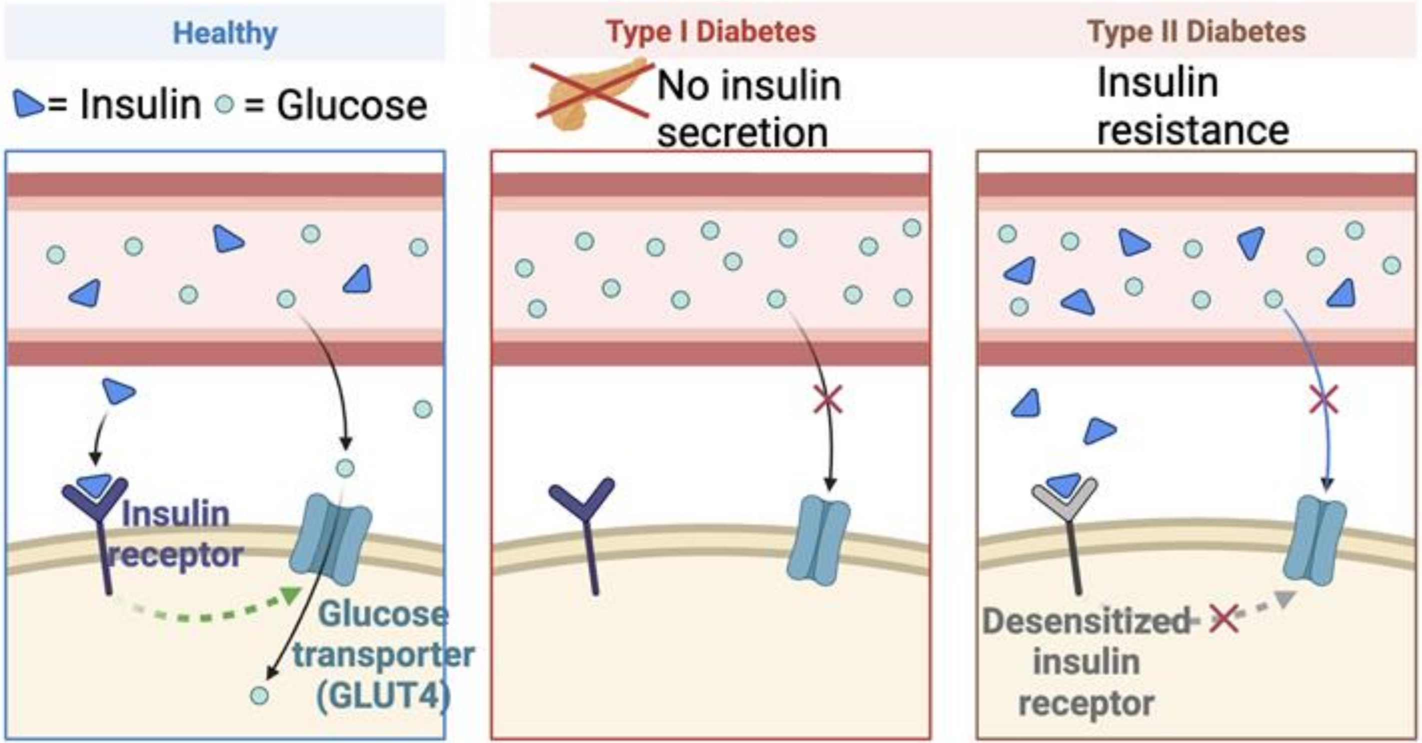


Normal Insulin Response



- Cells become insulin resistant.
- Insulin binding DOES NOT lead to signaling cascade
- Glucose channel remains closed
- Blood glucose stays high
- High blood glucose damages organs and tissues

Compare and contrast Type 1 and Type 2 Diabetes



Type 1 (AKA "Juvenile"

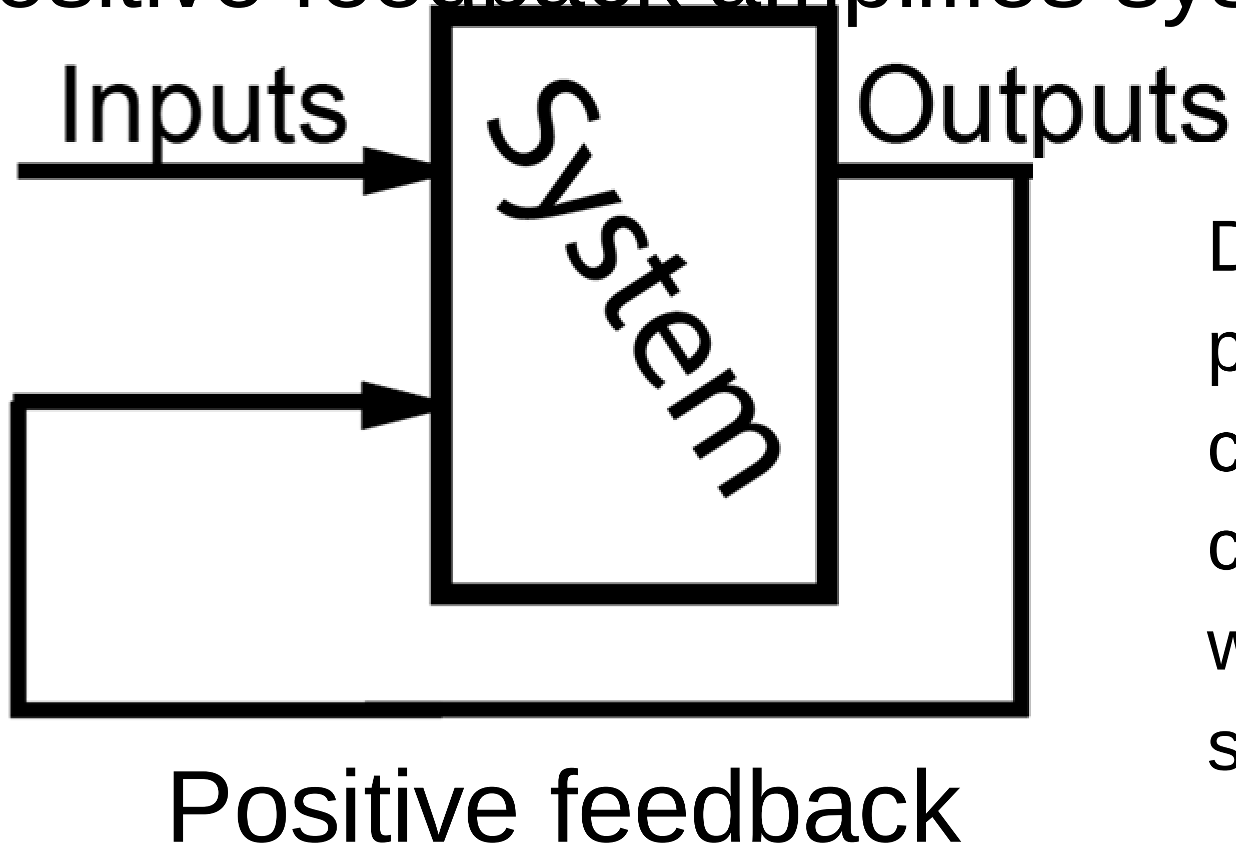
- Autoimmune disorder
- Pancreas doesn't produce insulin

Type 2 (AKA Adult Onset)

- Insulin resistance

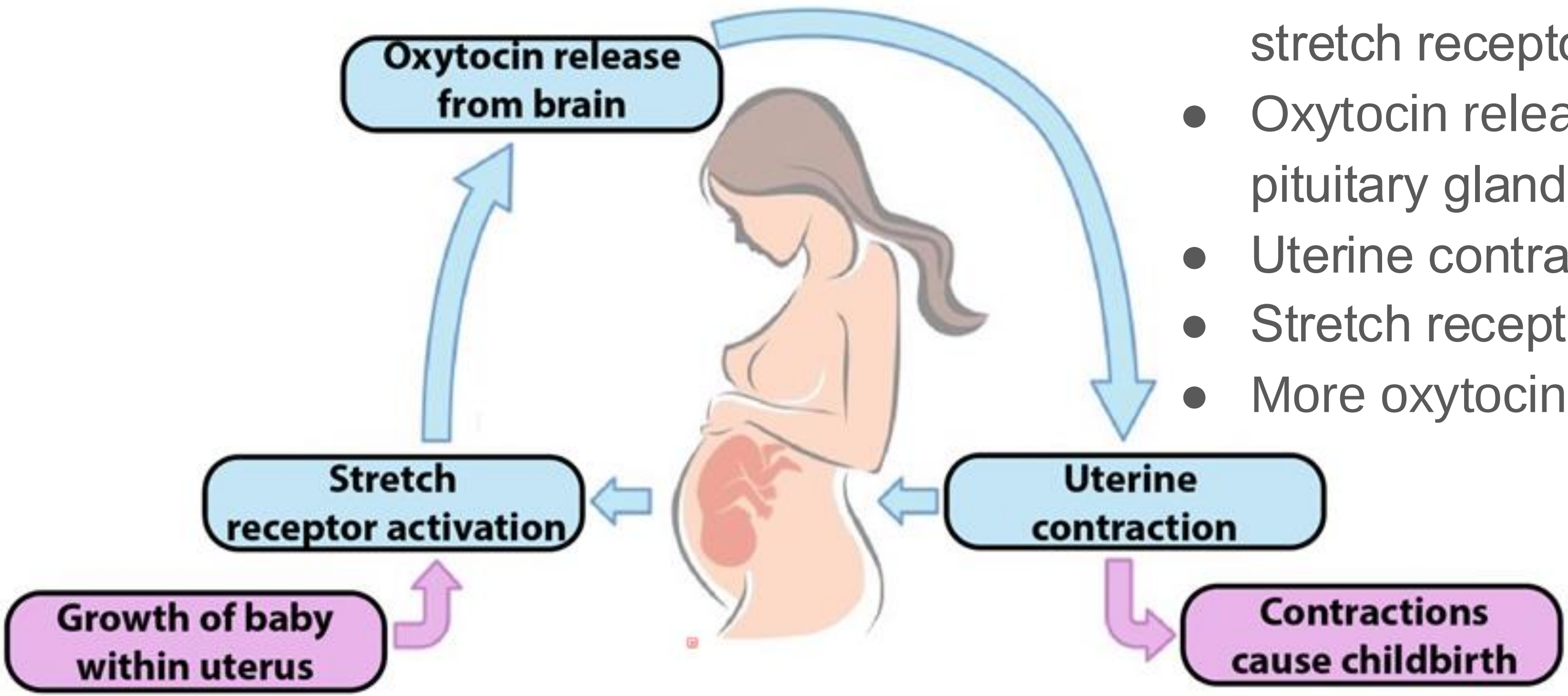
TOPIC 4.5, part 5: Positive Feedback

Positive feedback amplifies system activity



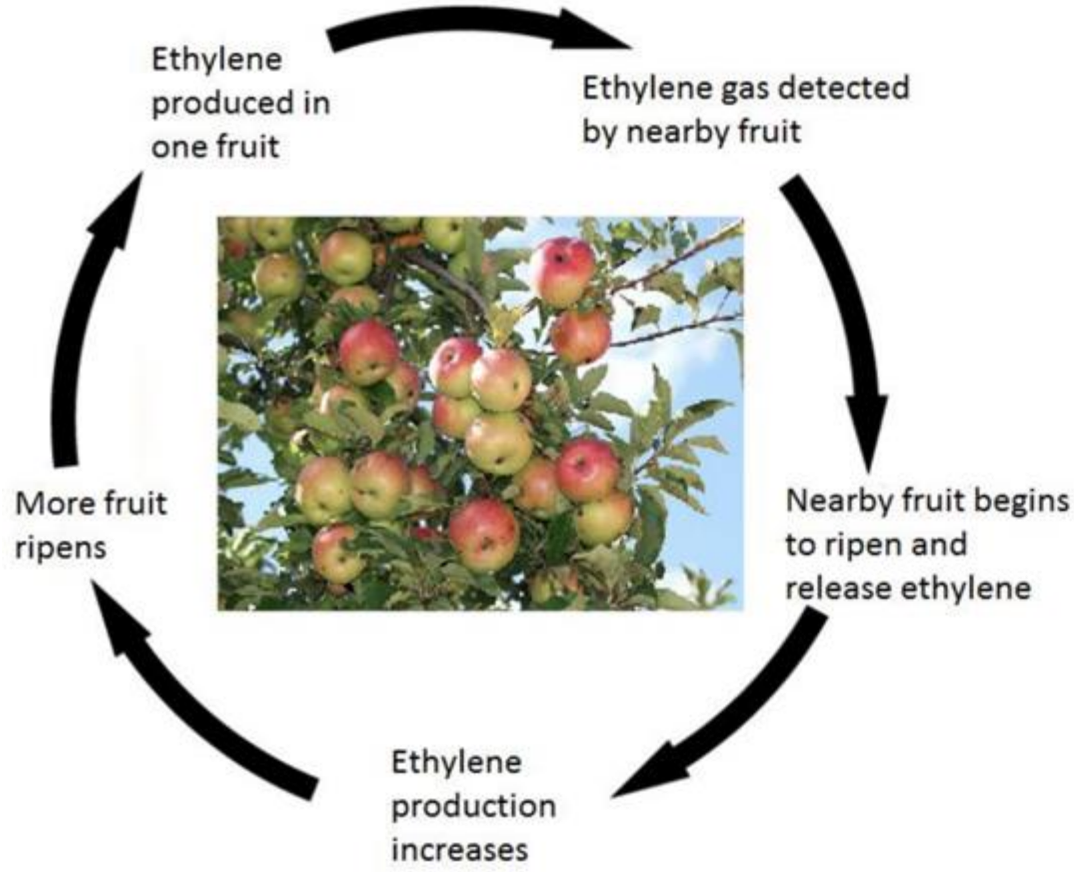
Drives a biological process (such as childbirth) to a conclusion, after which the system shuts down.

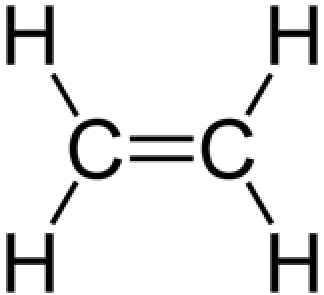
Positive feedback works during childbirth



- Growth of baby activates uterine stretch receptors →
- Oxytocin release from pituitary gland →
- Uterine contraction →
- Stretch receptors→
- More oxytocin release

Positive feedback in fruit ripening.





Ethylene

- Fruit ripening → release of ethylene gas (a hormone)
- Ethylene receptors in nearby fruit bind with the ethylene, inducing ripening and ethylene production.
- Increased concentration of ethylene accelerates the ripening process in all fruit →
- More ethylene

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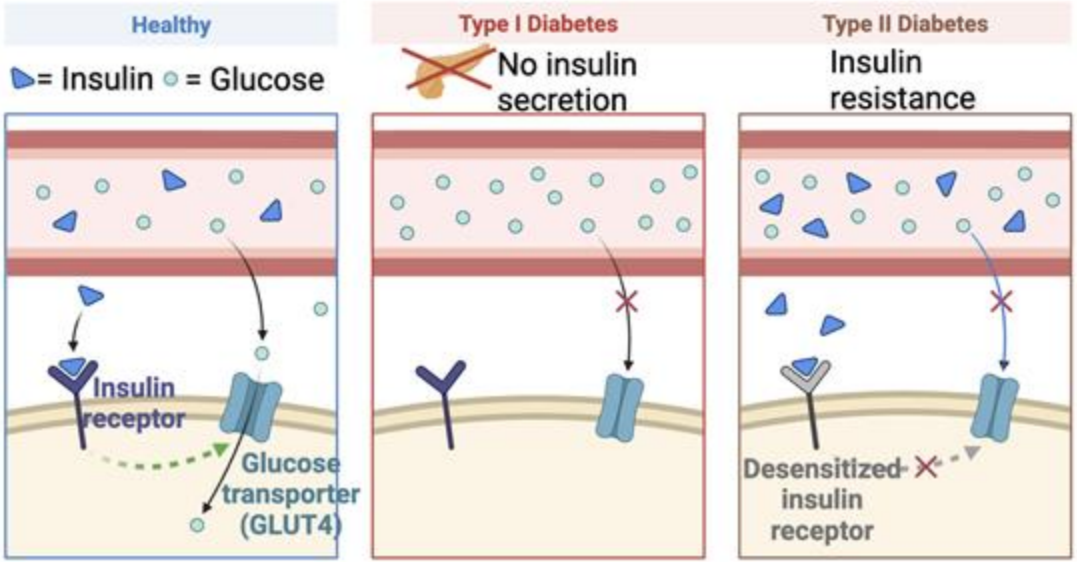
Need more support?



Complete the tutorials about Feedback and Homeostasis on Learn-Biology.com

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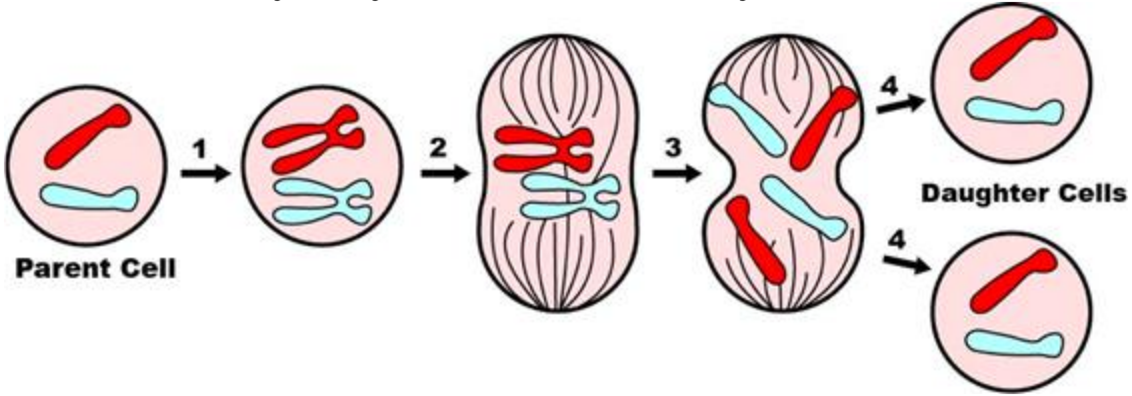
TOPIC 4.6: The Cell Cycle

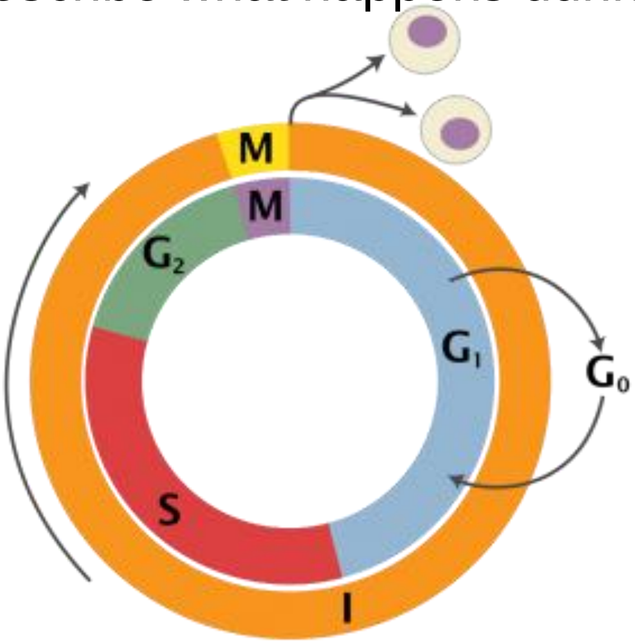
On a big picture level, what does mitosis do? List three of its key functions in living things. *For this question, “mitosis” is synonymous with “eukaryotic cell division."*



- Mitosis duplicates the chromosomes of a eukaryotic cell, transmitting that cell’s entire genome to its daughter cells.

- In multicellular organisms, mitosis is how an organism grows and repairs itself.
- In unicellular eukaryotes, mitosis is how reproduction occurs.

Describe what happens during the cell cycle?



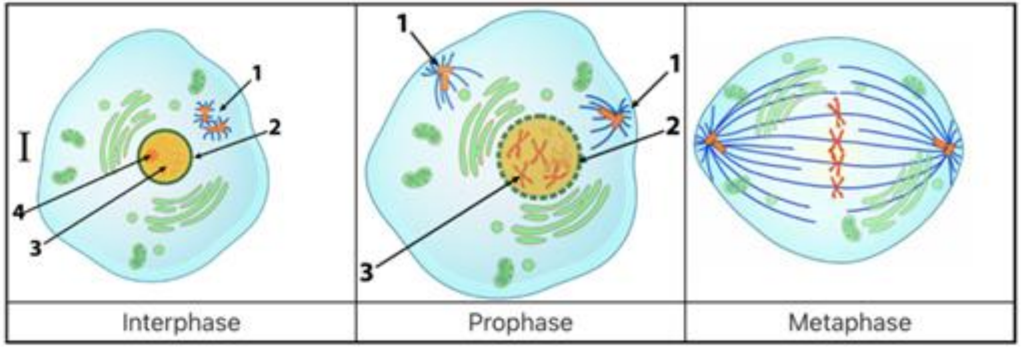
- **Interphase (I)**
- **Mitosis (M phase: M)**

Interphase

- G_1 (growth phase 1): the cell increases in size.
- S: (synthesis): DNA replication/chromosome duplication
- G_2 (growth phase 2): growth of structures for cell division

M: Phase

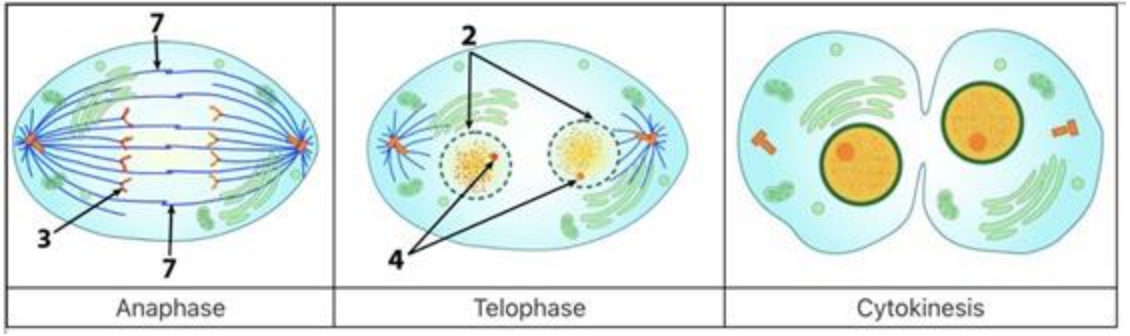
- Mitosis: separation of chromosomes
- Cytokinesis: Division of the cell



- **Interphase:** cell grows and replicates its DNA
- **Prophase:** chromosomes (3) condense, the nuclear membrane (2) disintegrates, and a spindle apparatus begins to grow from each centrosome (1).

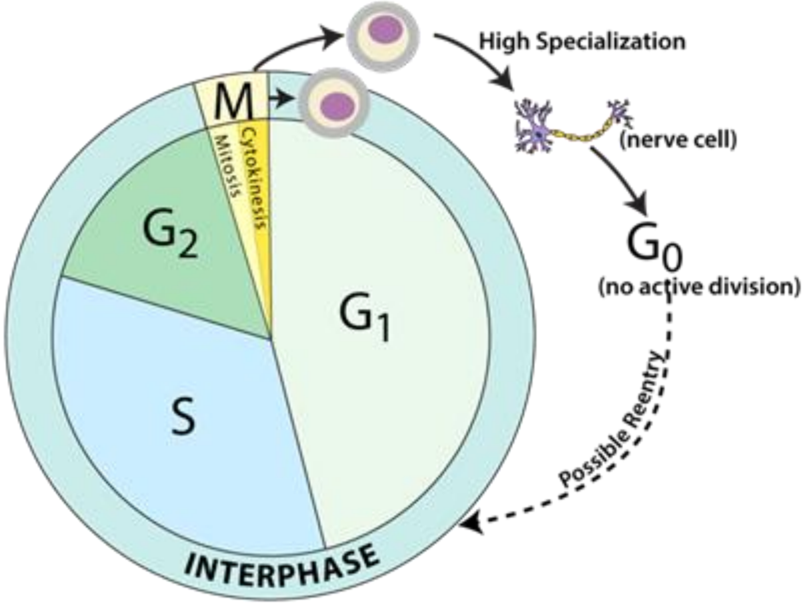
- During **metaphase**, the spindle fibers pull each chromosome to the cell equator. Each chromosome is doubled, consisting of two sister chromatids.

Describe the phases of mitosis (2 of 2)



- **Anaphase**: sister chromatids are pulled apart (3), and dragged to opposite ends of the cell. Non-kinetochore microtubules cause the cell to elongate.
- **Telophase**: a new nuclear membrane (2) forms around each set of chromosomes. The chromosomes spread out, and a nucleolus (4) appears in each nucleus.
- **Cytokinesis**: cell splits apart into two daughter cells.

Explain the importance of the G_0 phase of the cell cycle.



- Not all cells go through the entire cell cycle.
- Specialized cells (muscle cells and nerve cells, for example) leave the cell cycle and enters into **G_0.**
- Cells in G_0 no longer divide.
- Certain stimuli, however, can induce a cell in G_0 to reenter the cell cycle.

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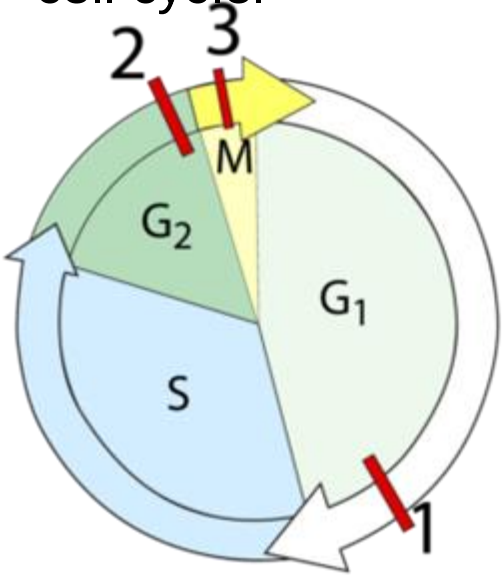
TOPIC 4.7: Regulation of the Cell Cycle

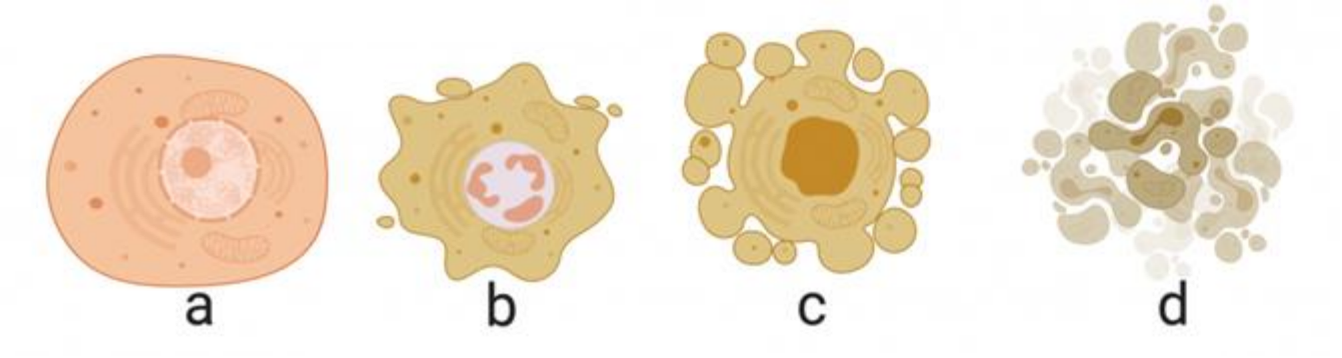
Describe the role that checkpoints play in regulating the cell cycle.



- Cell cycle checkpoints: moments when the cell "checks" its internal conditions and "decides" whether to progress to the next phase of the cell cycle.

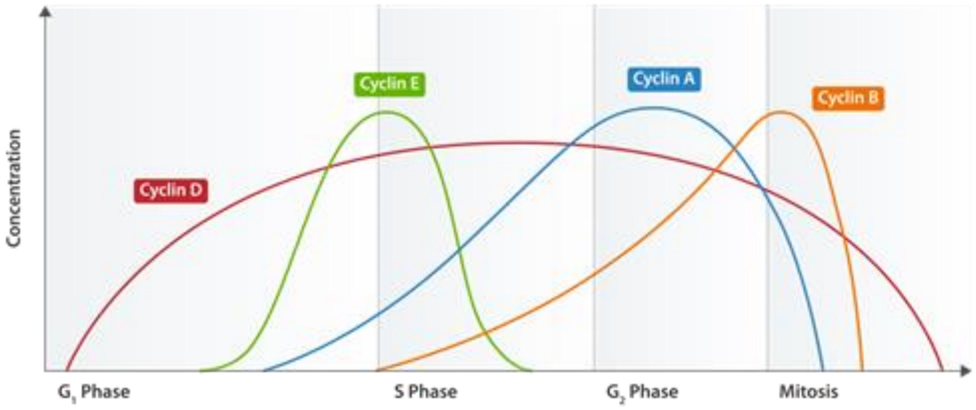
- If certain molecules are in the right concentration: cell continues through the cell cycle.
- If not: cell moves into G_0 or might initiate *apoptosis* (programmed cell death).
- The primary checkpoints occur during G_1, G_2, and M. (“1,” “2,” and “3”).

What is apoptosis?



- Apoptosis is **programmed cell death.**
- It’s highly regulated (unlike cell death which results from traumatic injury)
- Cells are broken down into cytoplasmic fragments called **blebs** (at "b" and "c")
- Blebs are consumed by cells of the immune system, preventing cellular debris and enzymes from damaging nearby cells.

What are cyclins and cyclin-dependent kinases?

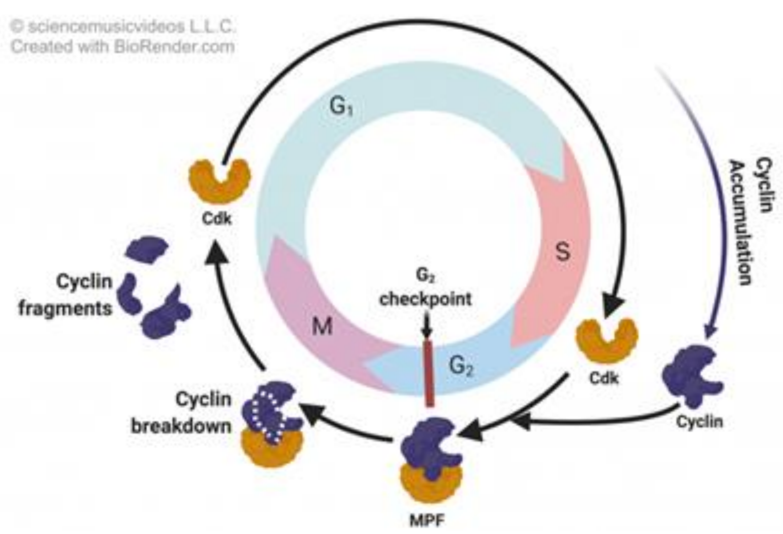


Cyclins and cyclin-dependent kinases are important internal regulators of the cell cycle

- **Cyclins**: molecules whose concentration rises and falls throughout the cell cycle.

- **Kinases**: molecules that activate other molecules, often by phosphorylating them.
- **Cyclin-dependent kinases**, or CDKs, are kinases that respond to rising and falling cyclin levels.

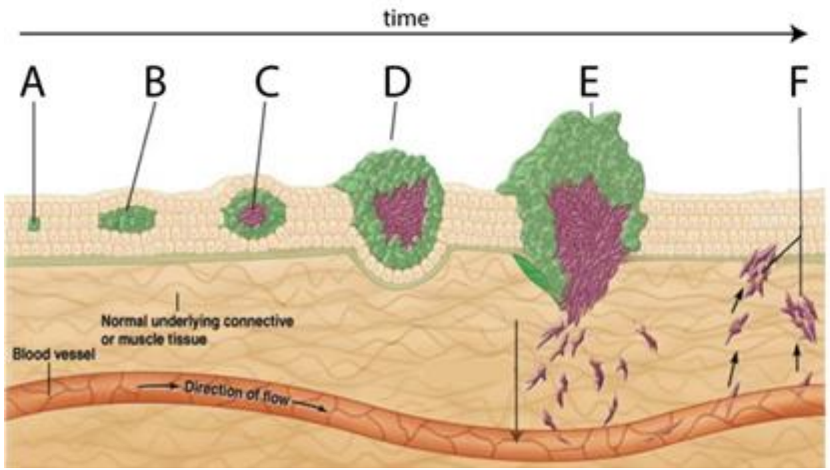
Explain how interactions between cyclins and cyclin-dependent kinases (CDKs) control the cell cycle.



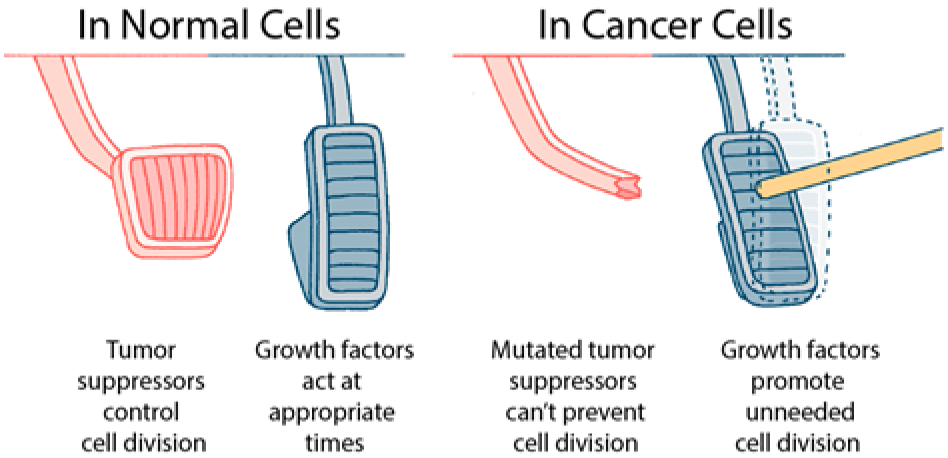
- CDKs are present at a constant level throughout the cell cycle.
- By contrast, the level of cyclins (of which there are several) rises and falls.
- When cyclin levels are high, cyclin binds with CDK to form a complex called MPF (maturation promoting factor).
- MPF allows the cell to pass through the G_2 checkpoint and divide.
- During M phase, cyclin is broken down, allowing the process to repeat in each daughter cell.

What’s the connection between cell division and cancer?

What are the two types of genetic mutations that are connected to cancer?

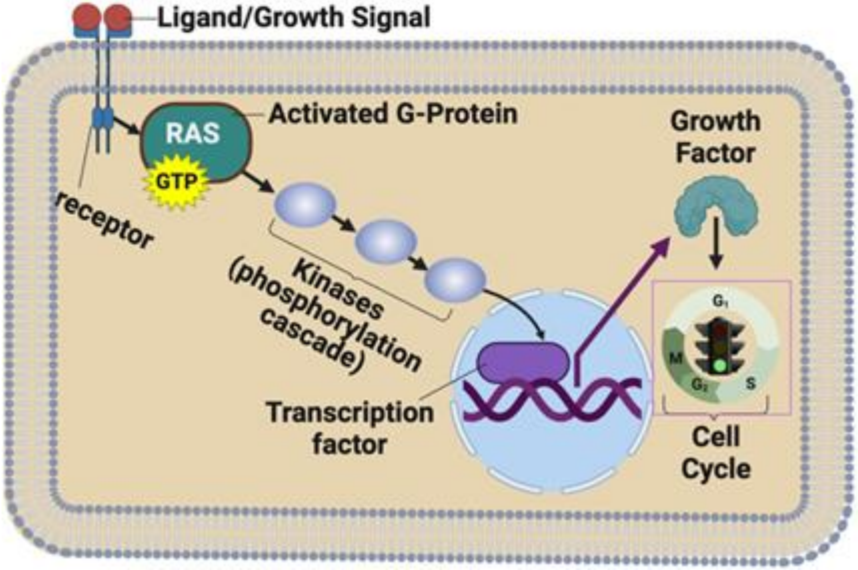


- Mutations in proto-oncogenes increase cell division by creating too many growth factors.
- Mutations in tumor suppressor genes remove cell division inhibitors



- Cancer is caused by unregulated cell division.

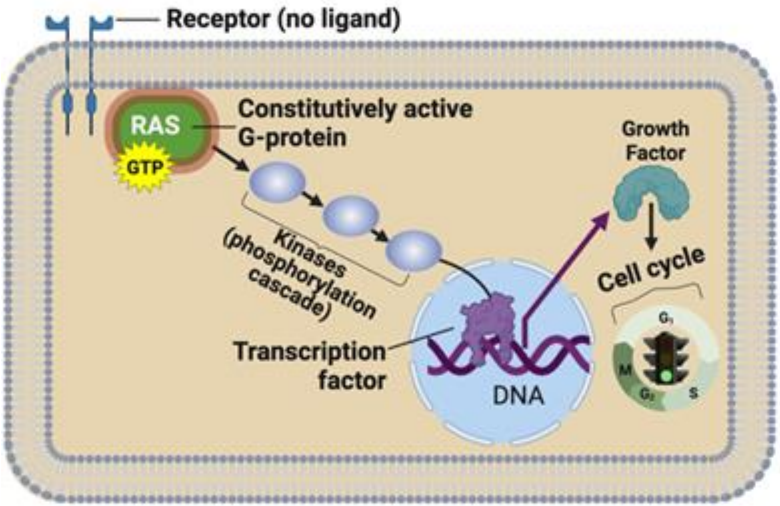
Describe how a mutation in the RAS proto-oncogene can induce a noncancerous cell to become cancerous (1).



- This causes RAS to bind with GTP → signaling cascade → transcription factor that results in a growth factor that promotes cell division

- RAS is a G protein.
- As a proto-oncogene (above), RAS only becomes active when an outside growth-factor ligand binds with RAS's coupled receptor.

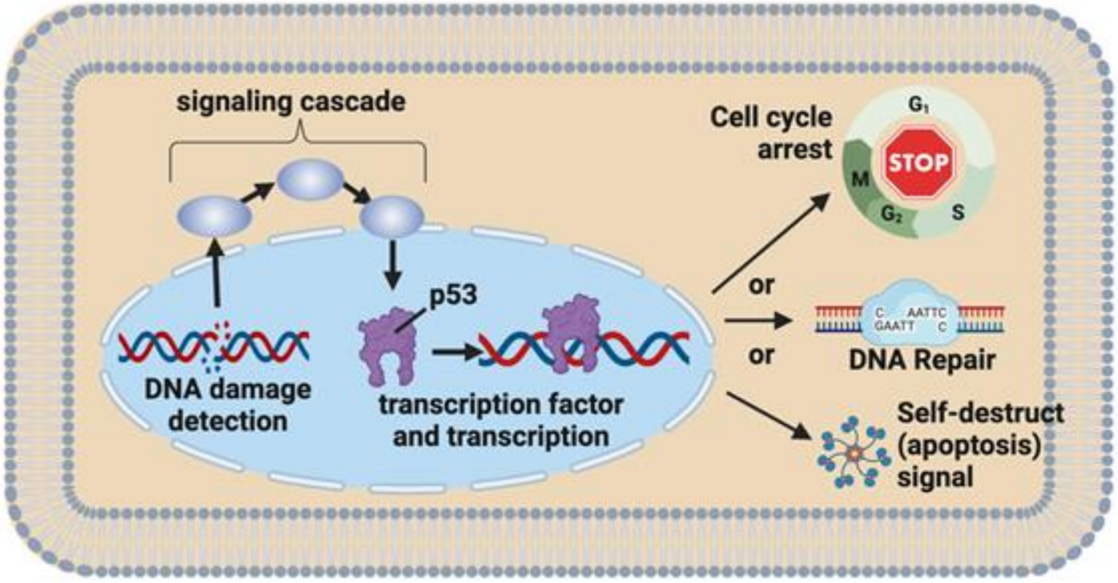
Describe how a mutation in the RAS proto-oncogene can induce a noncancerous cell to become cancerous (2).



- Because RAS is always active, the growth factor is overproduced, resulting in too much cell division.

- When RAS mutates into an oncogene (Image II), it becomes **constitutively active**.
- Mutant RAS binds GTP even in the absence of a growth signal

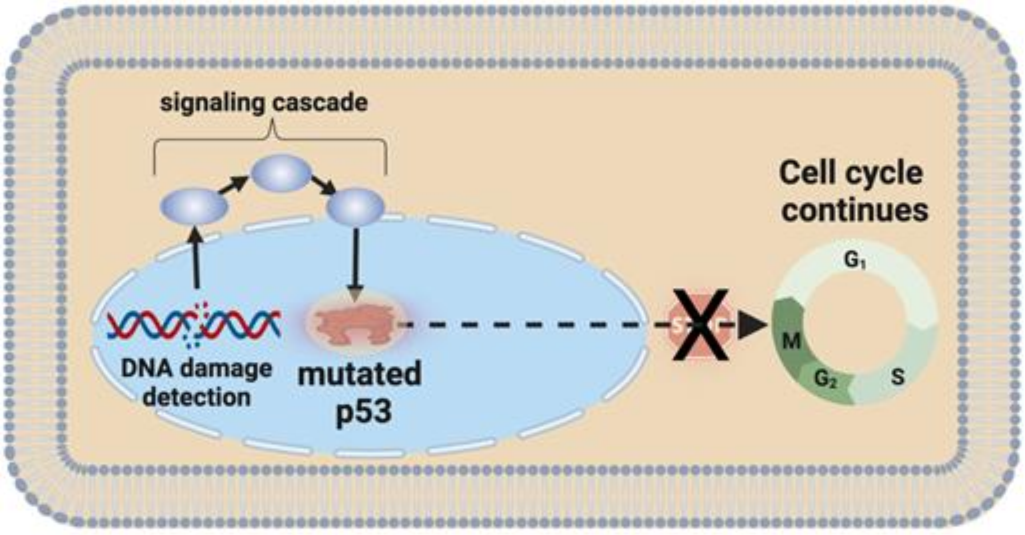
Describe how a mutation in a tumor suppressor gene such as the p53 gene can contribute to the development of cancer. (1)



- If the DNA can be repaired, p53 halts the cell cycle while DNA repair enzymes fix the damage
- If the damage is too great, p53 will signal the cell to initiate apoptosis.

- p53 is a tumor suppressor gene.
- When cells experience DNA damage, a signaling cascade activates p53.

Describe how a mutation in in a tumor suppressor gene such as the p53 gene can contribute to the development of cancer. (2)



- That will increase the chance of the cell acquiring further mutations that can lead it to become cancerous.

- If mutations lead p53 to become non-functional then the cell will continue to divide, even with damaged DNA.