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AP BIOLOGY

Big Idea 2
Part B

November 2012

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Big Idea 2: Part B

Click on the topic to go to that section

- Photons & Electrons
- ATP& Photosystems
- Photosynthesis
- Cellular Respiration
- Bioenergetics

Photons & Electrons

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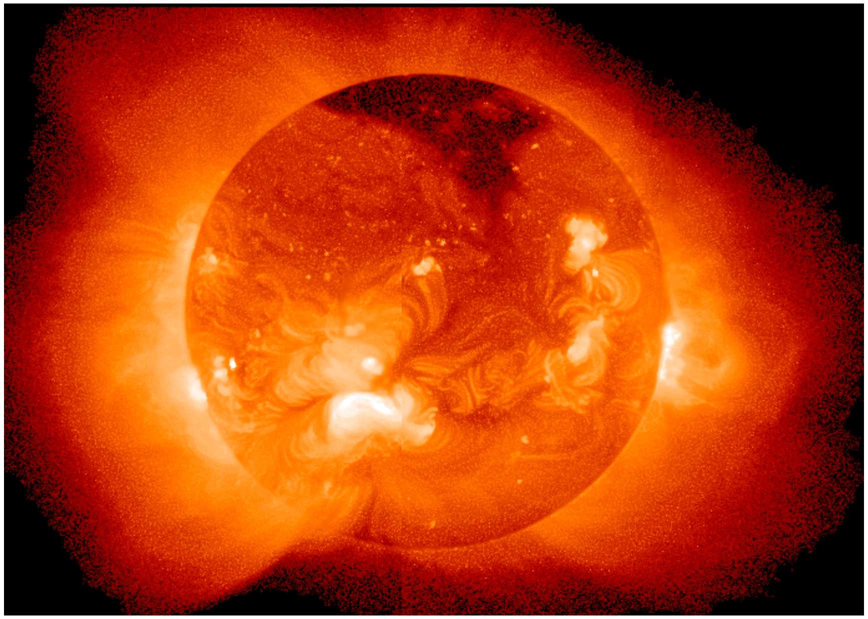
The Sun Supplies the Energy of Life

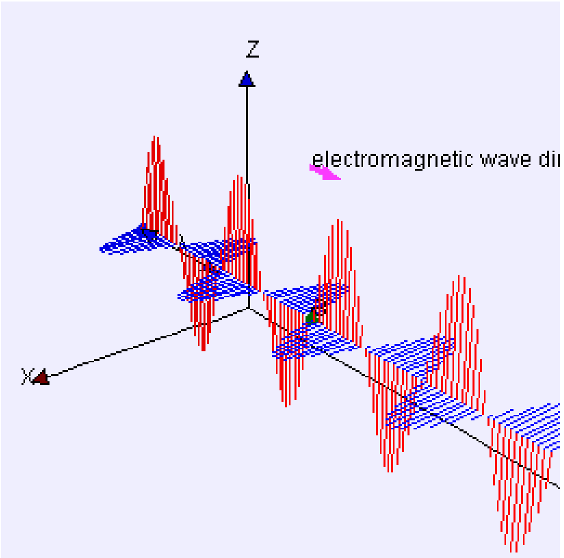
The energy of life begins as photons, created by nuclear fusion, traveling out of the sun at the speed of light.



Photons are packets of electromagnetic radiation.

Electromagnetic Waves

Electromagnetic Radiation is composed of an oscillating wave of magnetic and electric fields which travel through space



Electromagnetic Radiation

The distance between the crests of the waves determines the wavelength, and the number of crests per unit time determines the frequency

$$\lambda = \frac{v}{f}$$

Electromagnetic Radiation

The wavelength (and frequency) of the electromagnetic radiation in a photon determines the energy in that photon

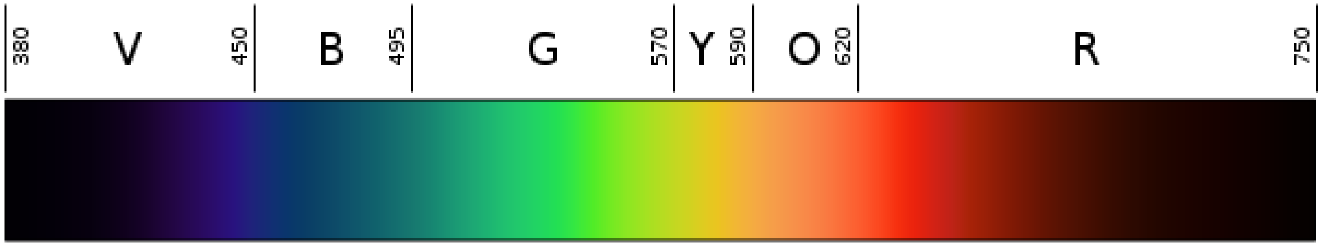
$$\lambda = \frac{v}{f}$$

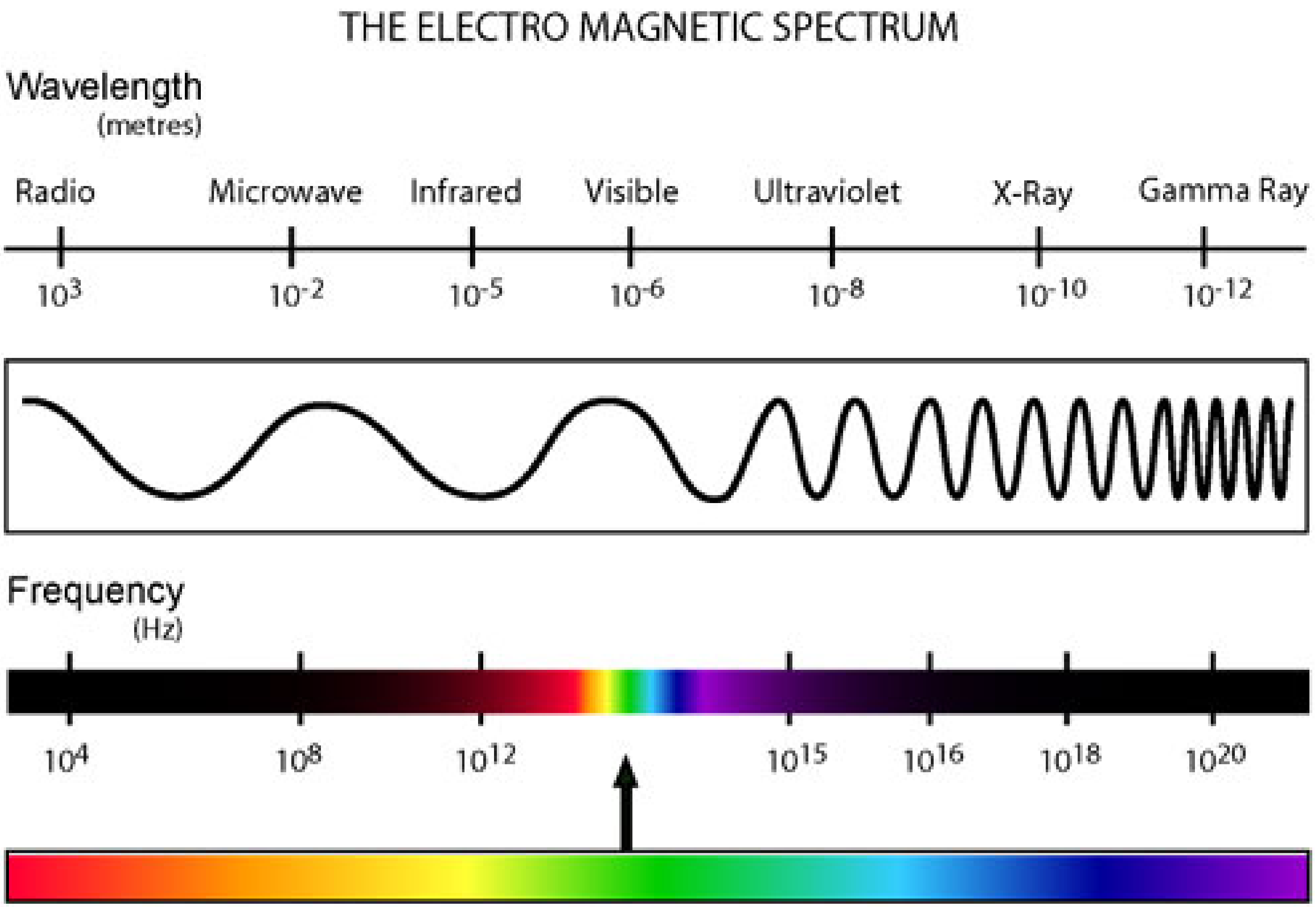
short wavelength = high frequency = high energy

long wavelength = low frequency = low energy

Electromagnetic Radiation

When the wavelength of electromagnetic radiation is between 400 and 700 nm, it can be detected by the human eye and is called **visible light.**

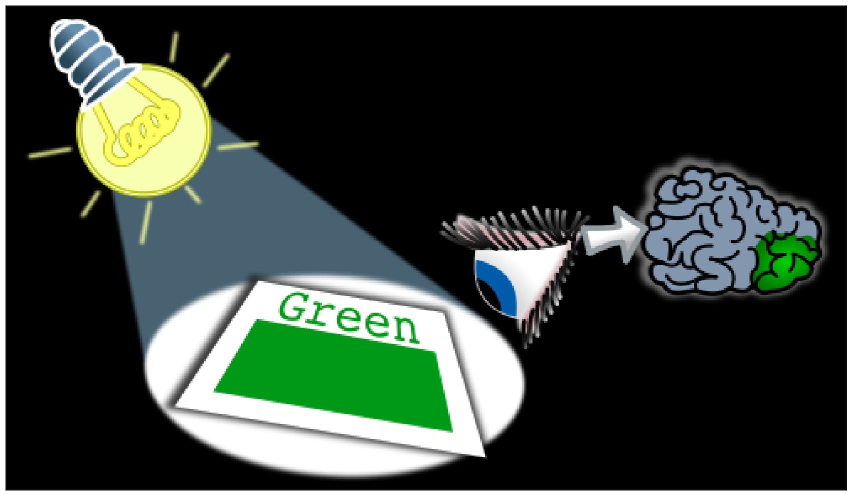




Visible light is only a small portion of the entire light spectrum

Electromagnetic Radiation

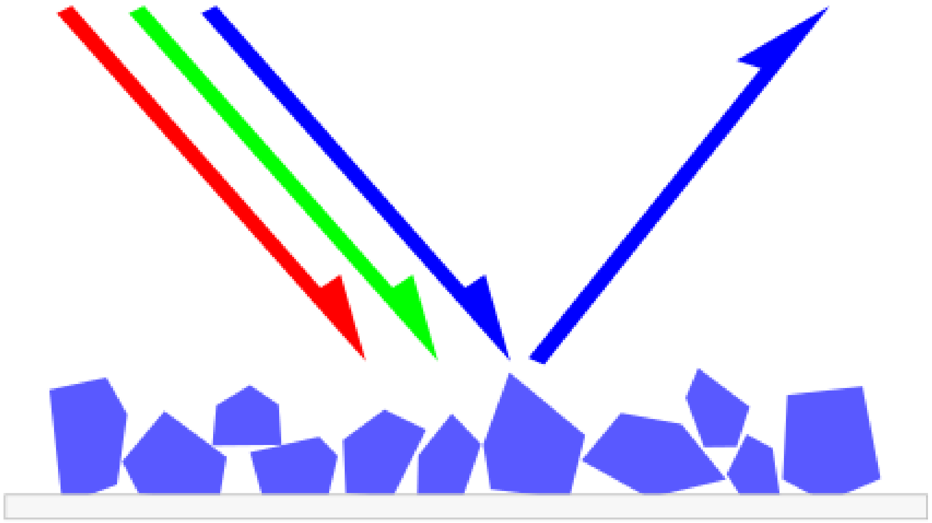
When we see a color, green for example, from an object it is because the object is absorbing some light waves while reflecting others. White light contains all color wavelengths.



In this example what light waves are being absorbed?

Pigments

Pigments are substances that have the ability to absorb light. We perceive their color as the wavelengths that they are not able to be absorbed.



1 A person's shirt looks red because red wavelength is being

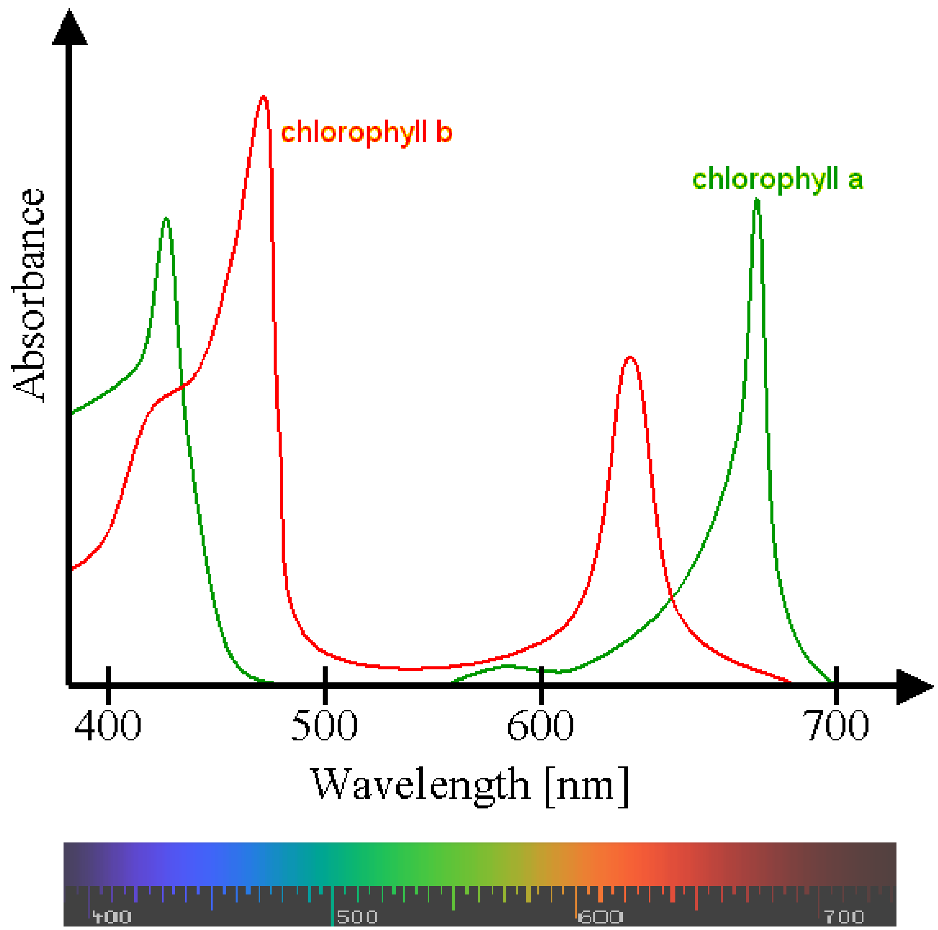
- A absorbed
- B reflected

answer

Absorbtion Spectrum

This graph represents the absorption spectrum of a pigment known as chlorophyll. The 2 lines represent 2 types of chlorophyll.

What color would these 2 pigments appear to be?



2 Plants appear green because the green wavelength is being

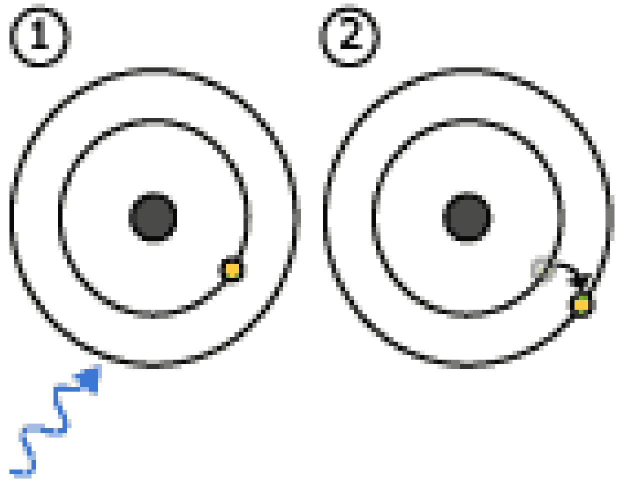
- A absorbed
- B reflected

answer

Pigments

The energy contained in the photon is transferred to an electron which allows the electron to become **excited.**

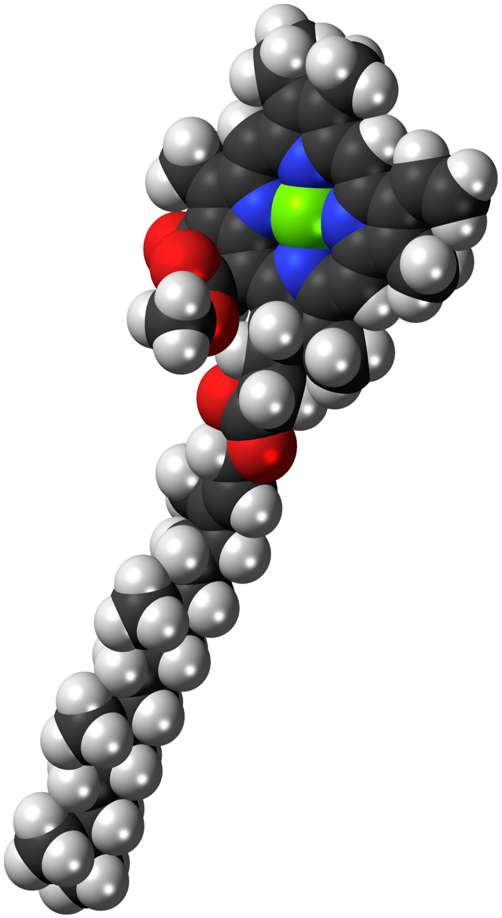
This means that the electron moves from a low energy level (ground state) to a higher energy level.



Pigments

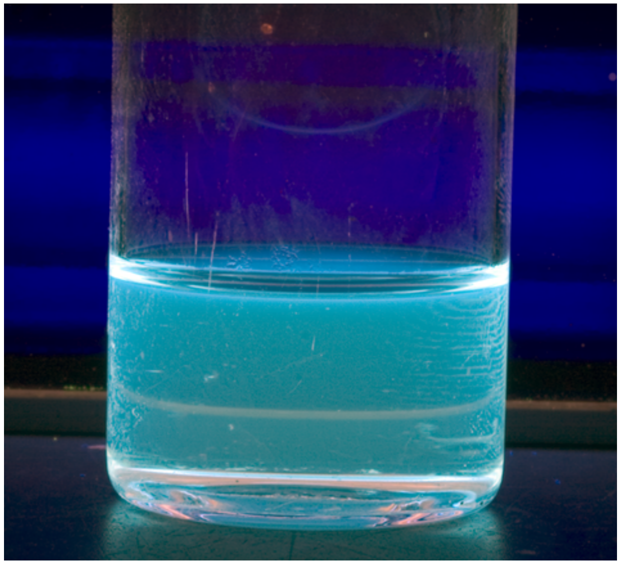
An excited electron is unstable in the higher energy level and must release the energy it gained from the photon.

In a pigment molecule the energy can be released in several ways:
- Fluorescence
- Resonance transfer
- Reaction initiation



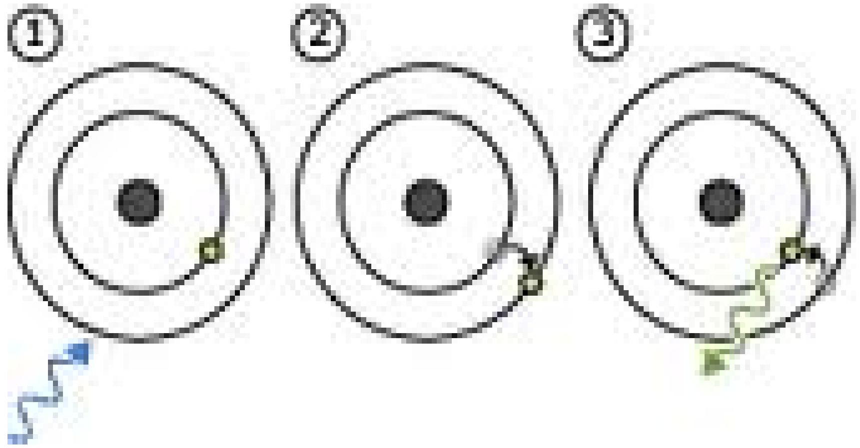
Fluorescence

If the electron has no other way to release its energy, it will drop back down to its ground state.



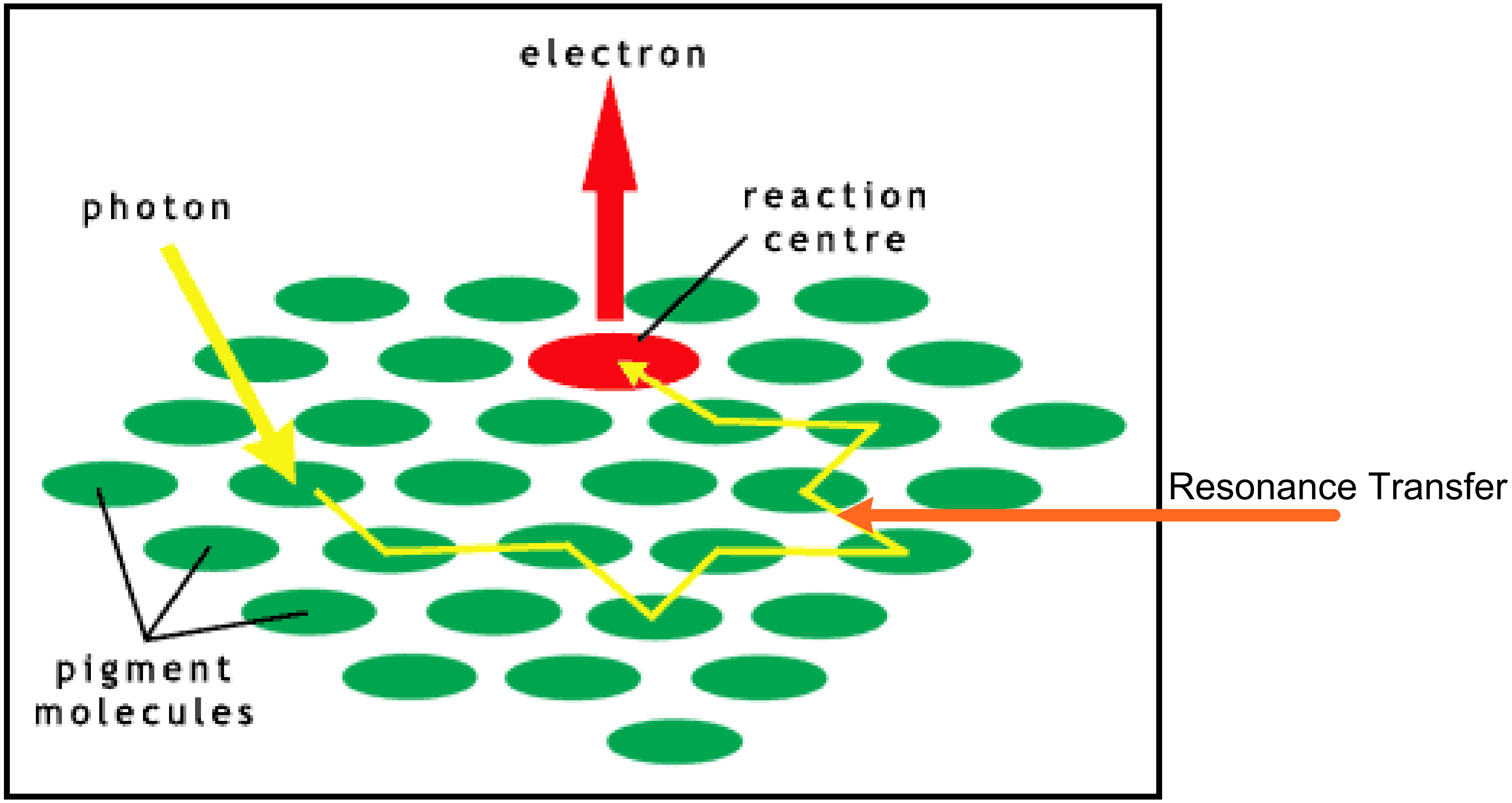
As the electron drops to its ground state, energy is released as a photon # (light). The energy released is slightly less than the energy, but with the same frequencey, of the photon that excited the electron.

This process is called fluorescence.



Resonance Transfer

If the excited electron is in close proximity to another pigment molecule, it can transfer its energy to an electron in the neighboring pigment molecule through a process called resonance transfer. The energy will continue to move between donor and acceptor pigment molecules without releasing a photon.



3 As the energy from photons is transferred to electrons, the electrons

- A move to lower energy levels and are more stable.
- B move to lower energy levels and are unstable.
- C become excited and more stable.
- D become excited and unstable.

answer

4 The process of electrons passing energy to electrons in neighboring pigment molecules is known as

- A flourescence
- B resonance
- C photon transfer
- D activation energy

answer

ATP & Photosystems

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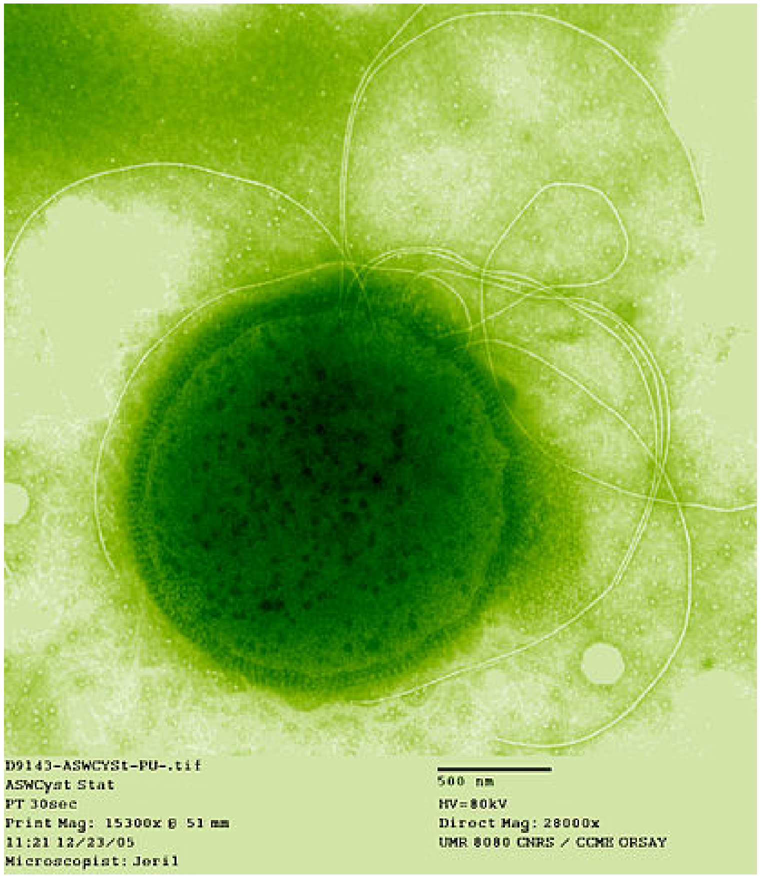
Evolution and Metabolism

Early prokaryotes used pigment and its properties to trap light energy and utilize it to do work.

They became more abundant because they had a new found, infinite energy source.

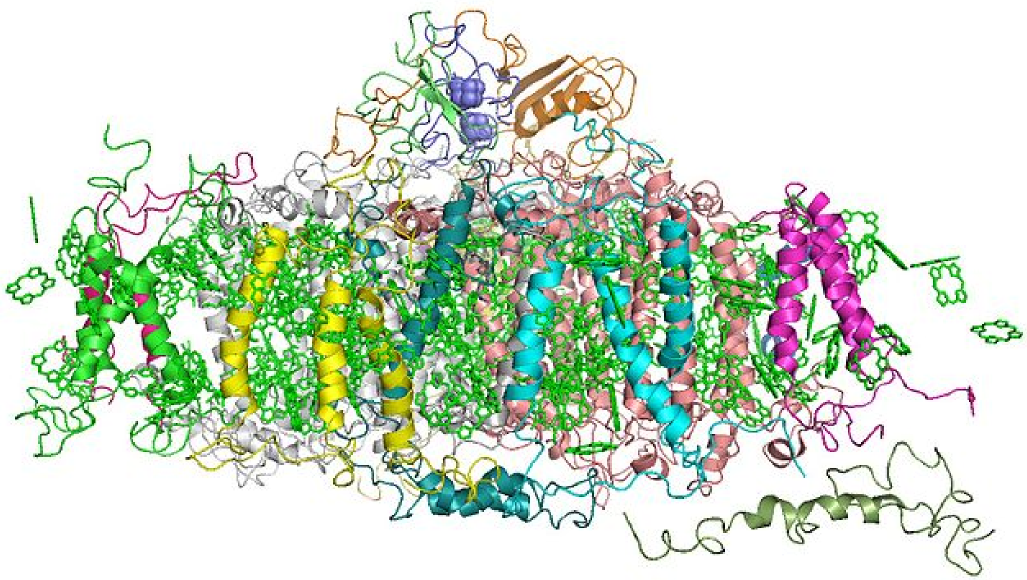
As they became more abundant new variations began to emerge, with more efficient ways to utilize the energy source.



Photosystems

Photosystems are the first organic system to turn energy from sunlight into chemical energy. They are a conglomeration of **protein pigments** that have the ability to use enzymatic activity and resonance transfer to produce a molecule of **ATP.**

A ribbon diagram of a photosystem. Remember proteins are chains of amino acids that fold up onto each other to produce useful functions.



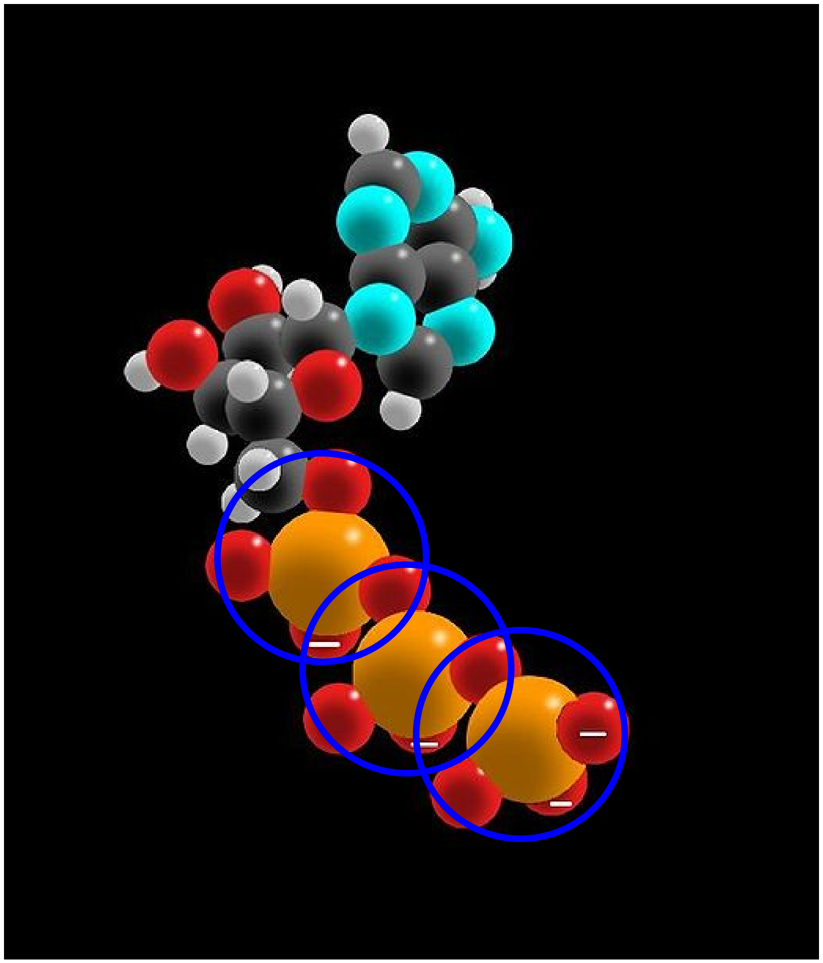
ATP

ATP (adenosine triphosphate) is the currency of energy in living systems.

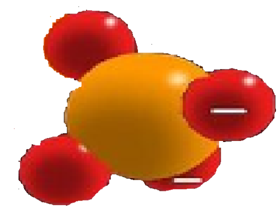
It stores the energy gained in exergonic reactions to power endergonic reactions at a later time.

ATP provides the energy for the processes of life.

ATP



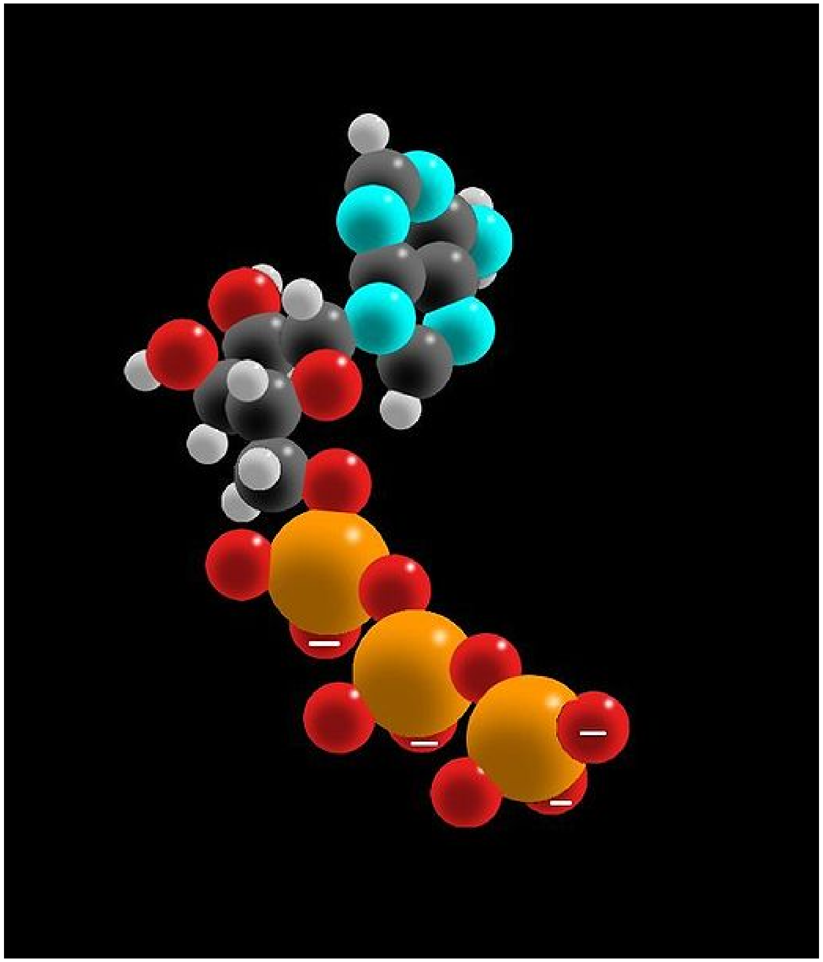
ATP (adenosine triphosphate) includes three phosphate groups (PO_4^{-3}).



Each Phosphate group has an ionic charge of -3e.

In this space filling model of ATP, each PO_4^{-3} is circled in blue.

ATP

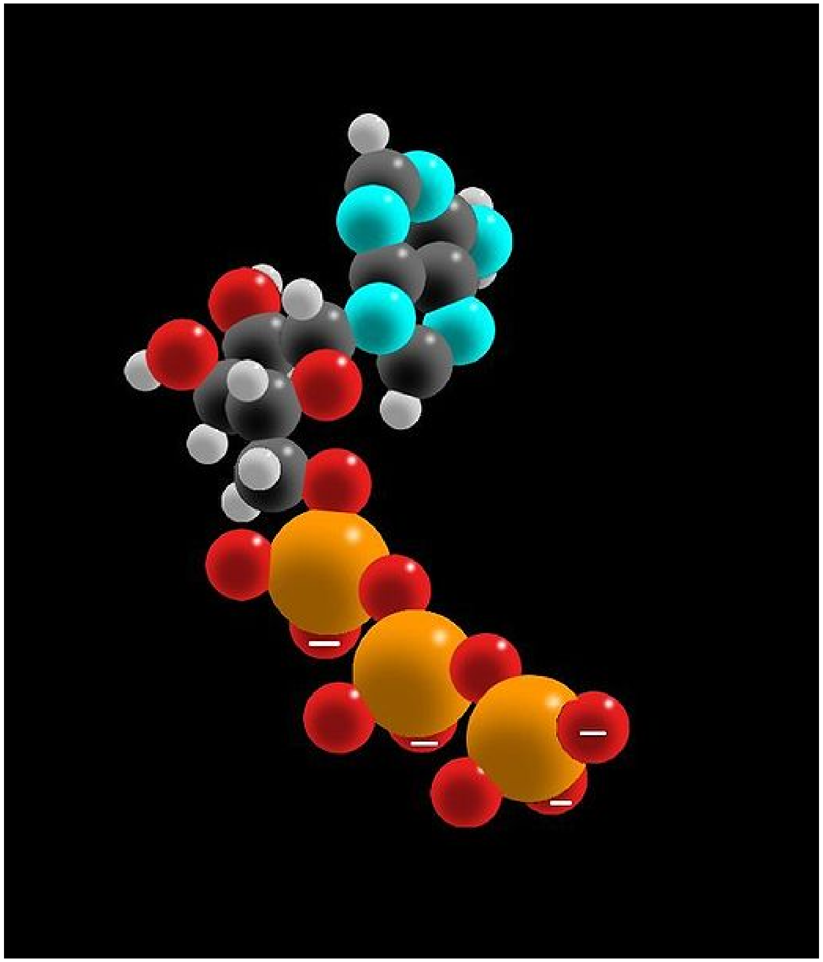


The phosphate groups repel each other, since they each have a negative charge.

Therefore it requires Work to add the second phosphate group; to go from AMP (monophosphate) to ADP (diphosphate).

To add the third group, to go from ADP to ATP (triphosphate), requires even more work since it is repelled by both of the other phosphate groups.

ATP



This is like the work in compressing a spring.

The energy from the work needed to bring each phosphate group to the molecule is stored in that phosphate bond.

When the bond is broken to go from ATP to ADP, significant energy is released.

Going from ADP to AMP releases less energy, since there is less total charge in ADP than ATP.

ATP

The bonds between the phosphate groups of ATP's tail can be broken by hydrolysis.

Energy is released from ATP when the terminal phosphate bond is broken.

The released energy is equal to the work that was done to form the bond. That work overcame the electrostatic repulsion between the last phosphate group and the initial ADP molecule.

The result is a chemical change to a state of lower free energy.

ATP Performs Work

In living systems, the energy from the exergonic reaction of ATP hydrolysis can be used to drive an endergonic reaction.

ATP drives endergonic reactions by phosphorylation, transferring a phosphate group to some other molecule, such as a reactant.

The recipient molecule is now "phosphorylated".

The three types of cellular work are powered by the hydrolysis of ATP: mechanical, transport, chemical.

The Regeneration of ATP

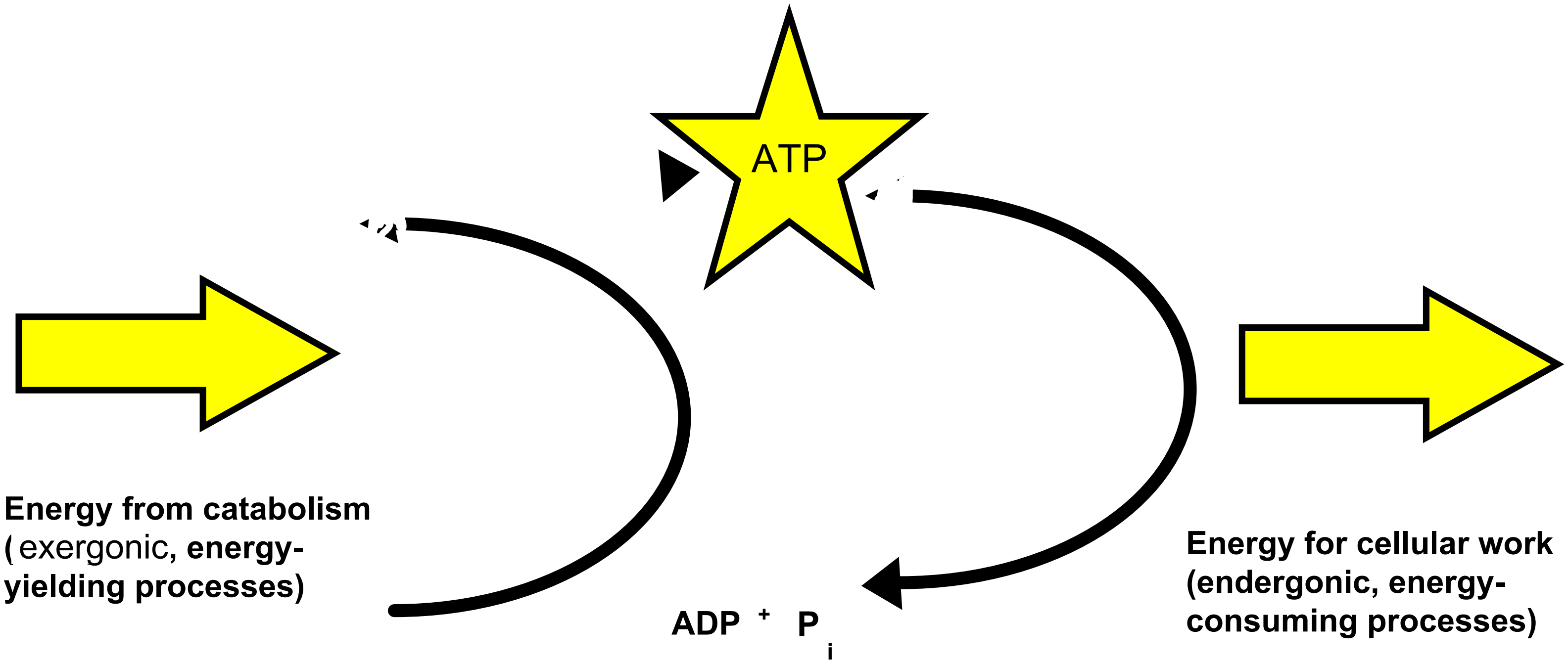
ATP is a renewable resource that is regenerated by addition of a phosphate group to ADP.

The energy to phosphorylate ADP comes from catabolic reactions in the cell.

The chemical potential energy temporarily stored in ATP drives most cellular work.

Each cell is converting millions of ATP to ADP and back again every second.

The Regeneration of ATP



5 In general, the hydrolysis of ATP drives cellular work by ____________.

- A releasing free energy that can be coupled to other reactions
- B releasing heat
- C acting as a catalyst
- D lowering the free energy of the reaction

answer

6 Which of the following is not an example of the cellular work accomplished with the free energy derived from the hydrolysis of ATP?

- A Mechanical work, such as the movement of the cell
- B Transport work, such as the active transport of an ion into the cell
- C Chemical work, such as the synthesis of new proteins.
- D The production of heat, which raises the temperature of the cell.

answer

7 Which best characterizes the role of ATP in cellular metabolism?

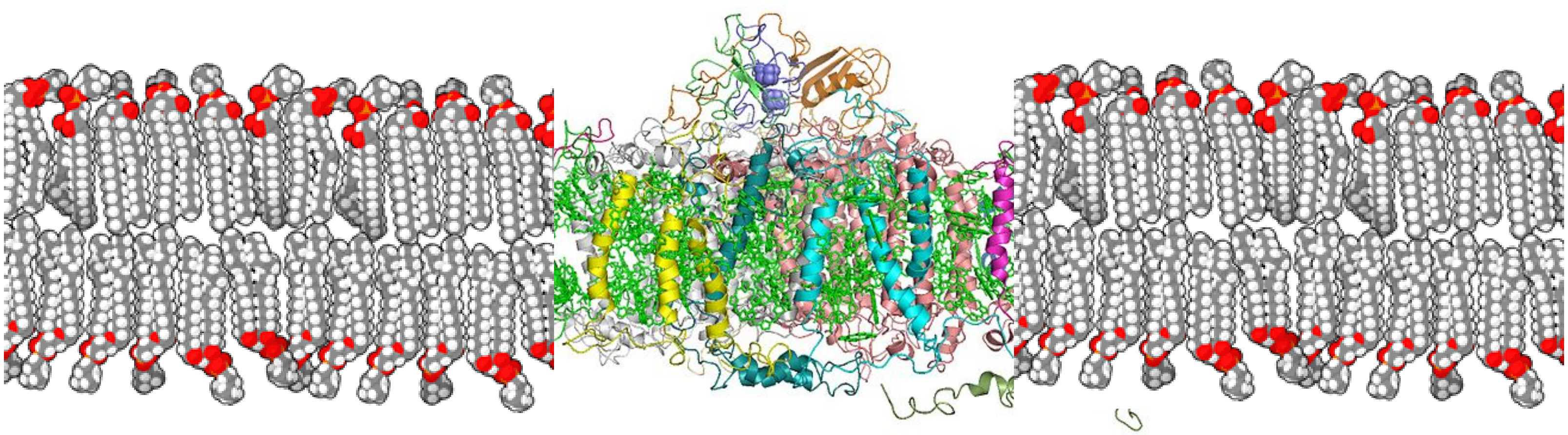
- A The release of free energy during the hydrolysis of ATP heats the surrounding environment.
- B The free energy released by ATP hydrolysis may be coupled to an endergonic process via the formation of a phosphorylated intermediate.
- C It is catabolized to carbon dioxide and water.
- D The ΔG associated with its hydrolysis is positive.

answer

Photosystems

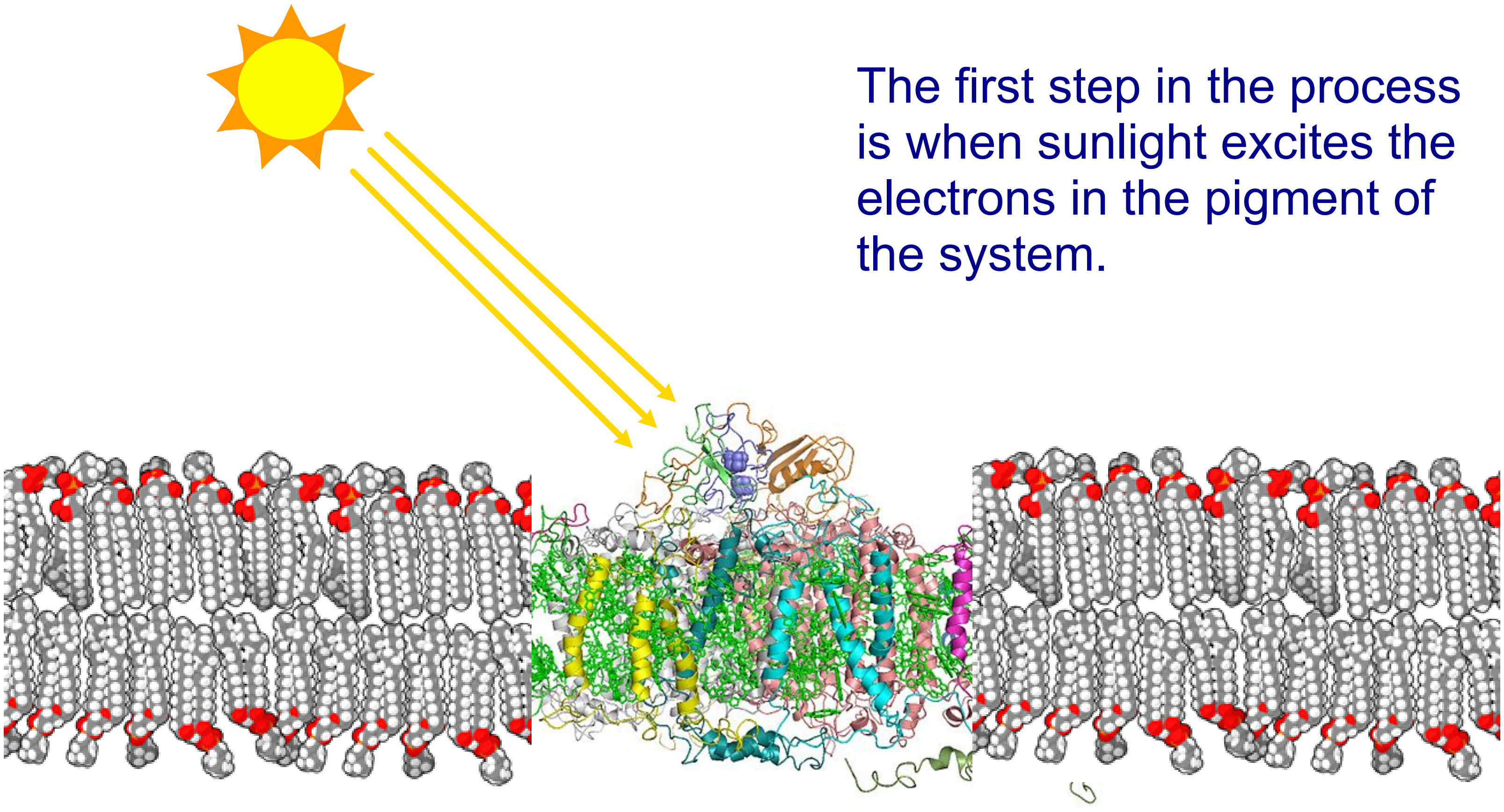
Photosystems need to be in a membrane. In other words they are a type of membrane bound protein, like the transport proteins we discussed earlier.

Outside the prokaryote (the environment)



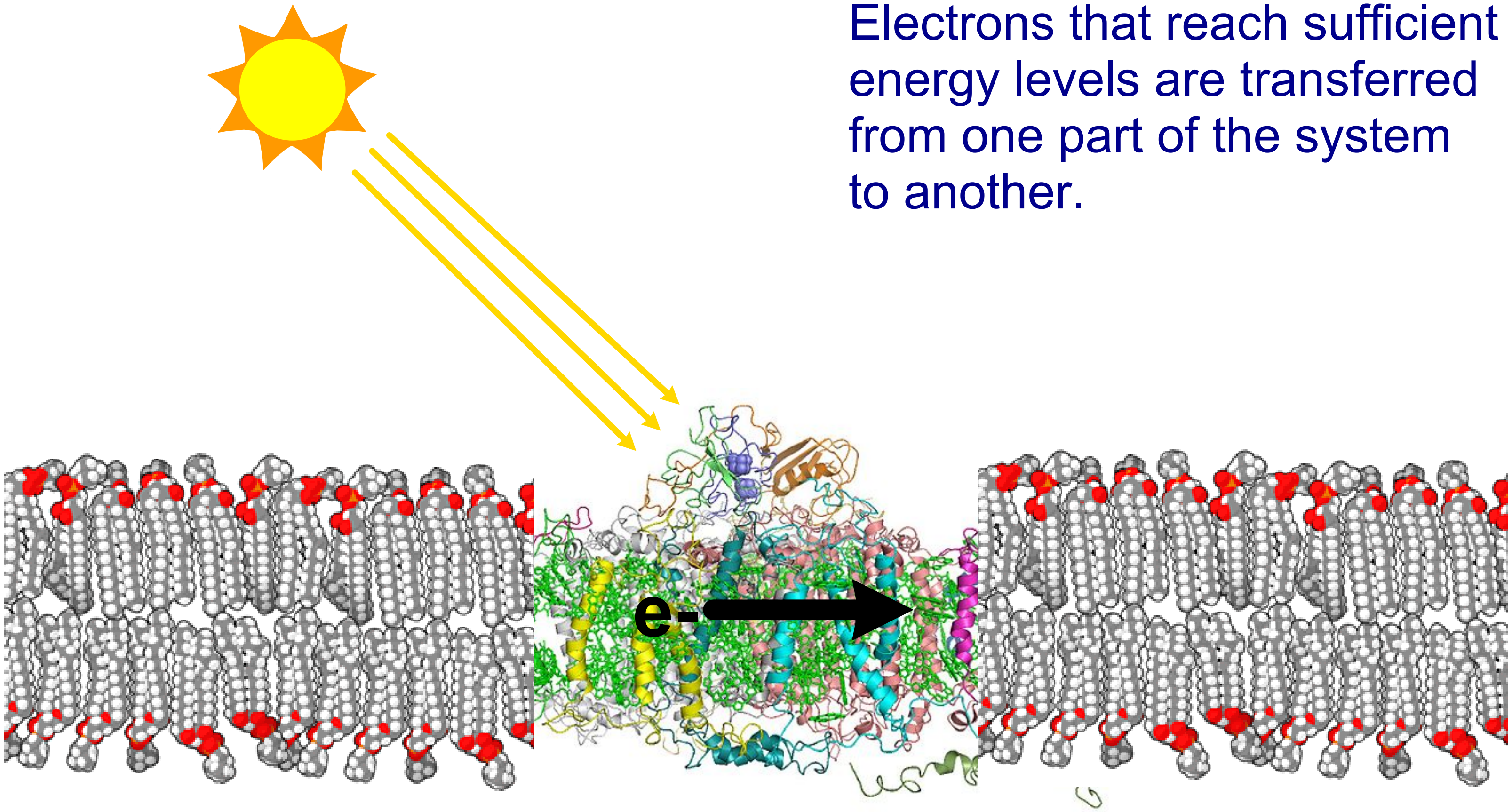
Inside the prokaryote (the biological system)

Photosystems



The first step in the process is when sunlight excites the electrons in the pigment of the system.

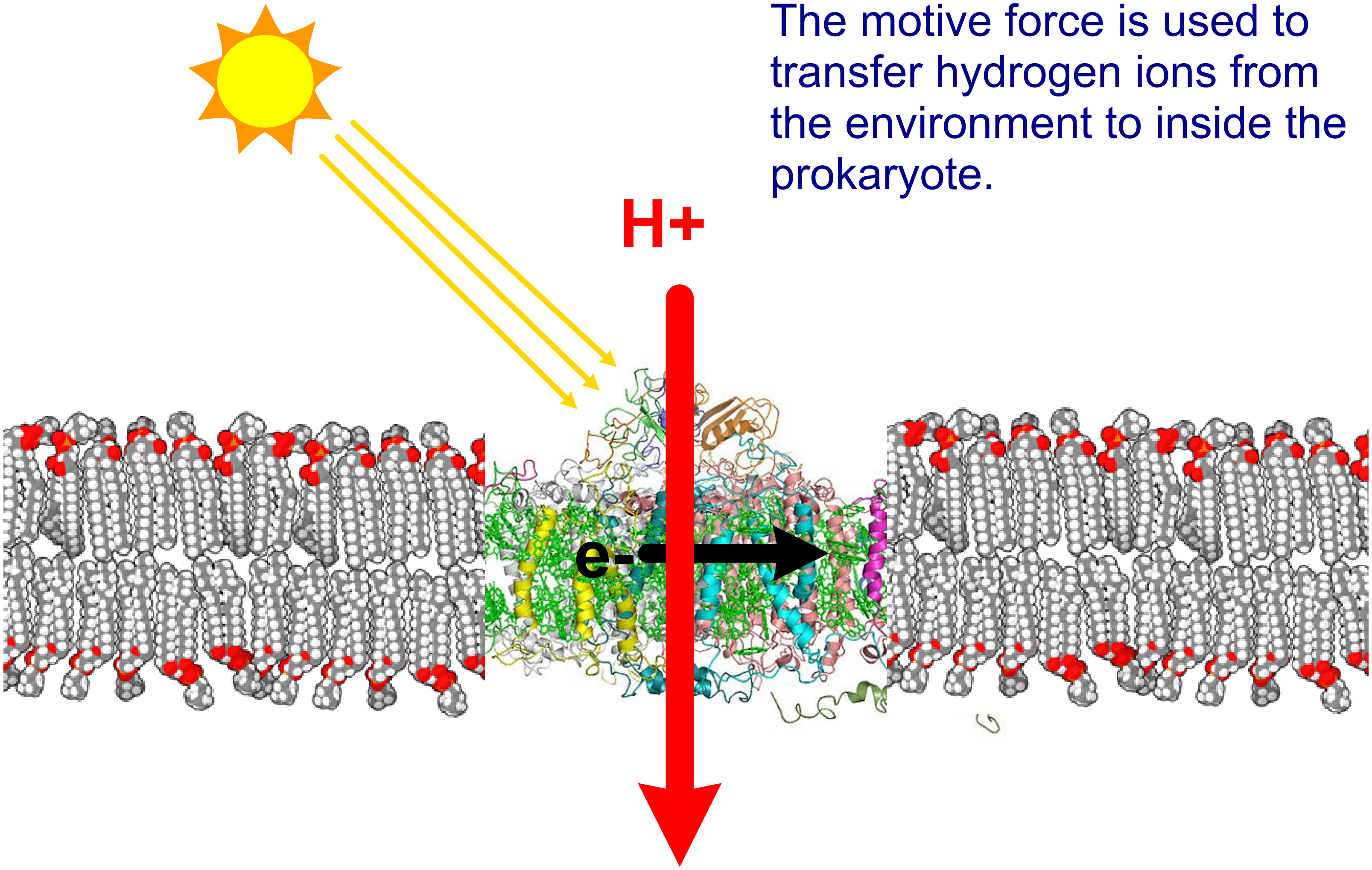
Photosystems



Electrons that reach sufficient energy levels are transferred from one part of the system to another.

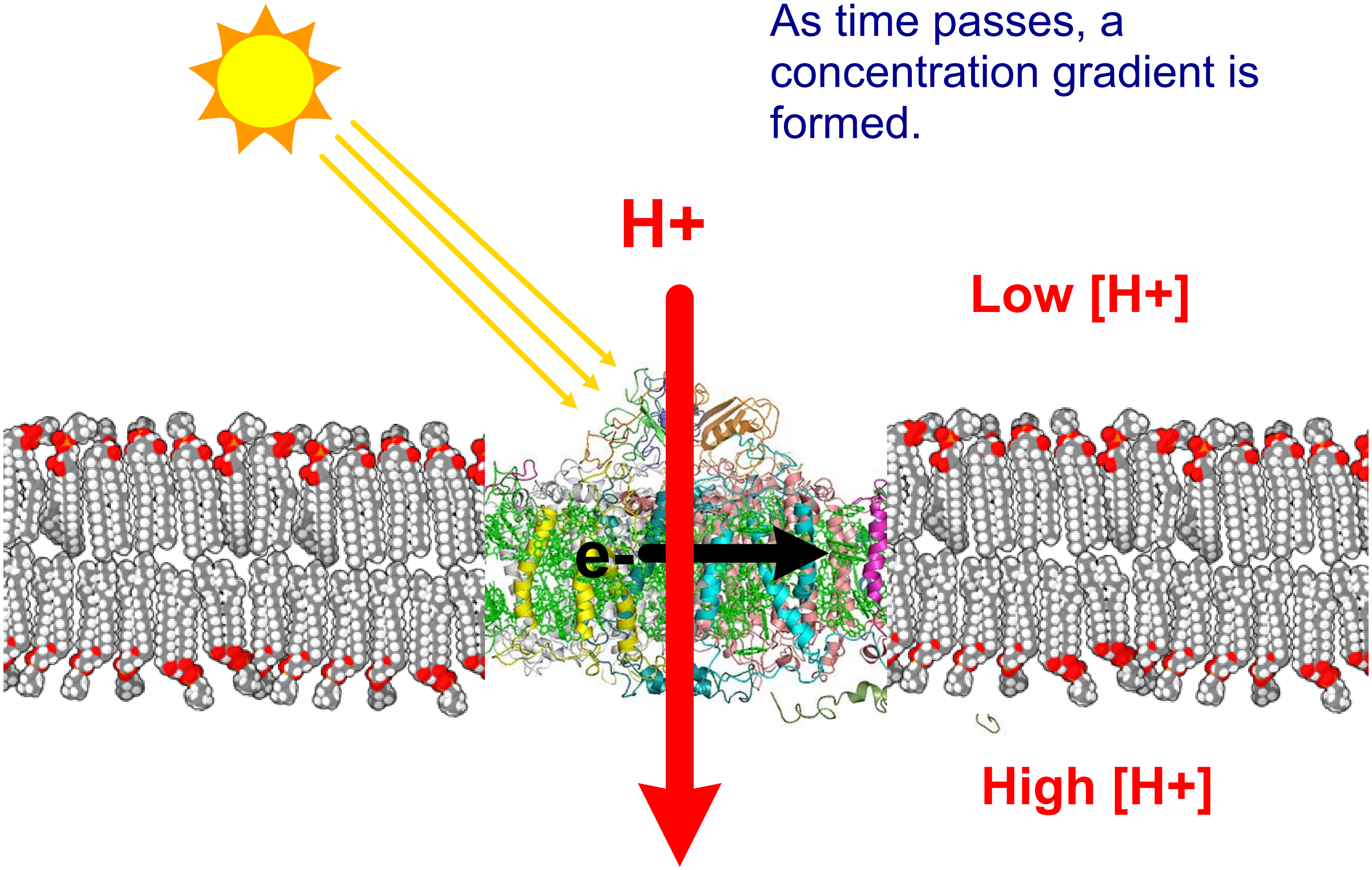
Photosystems

The motive force is used to transfer hydrogen ions from the environment to inside the prokaryote.



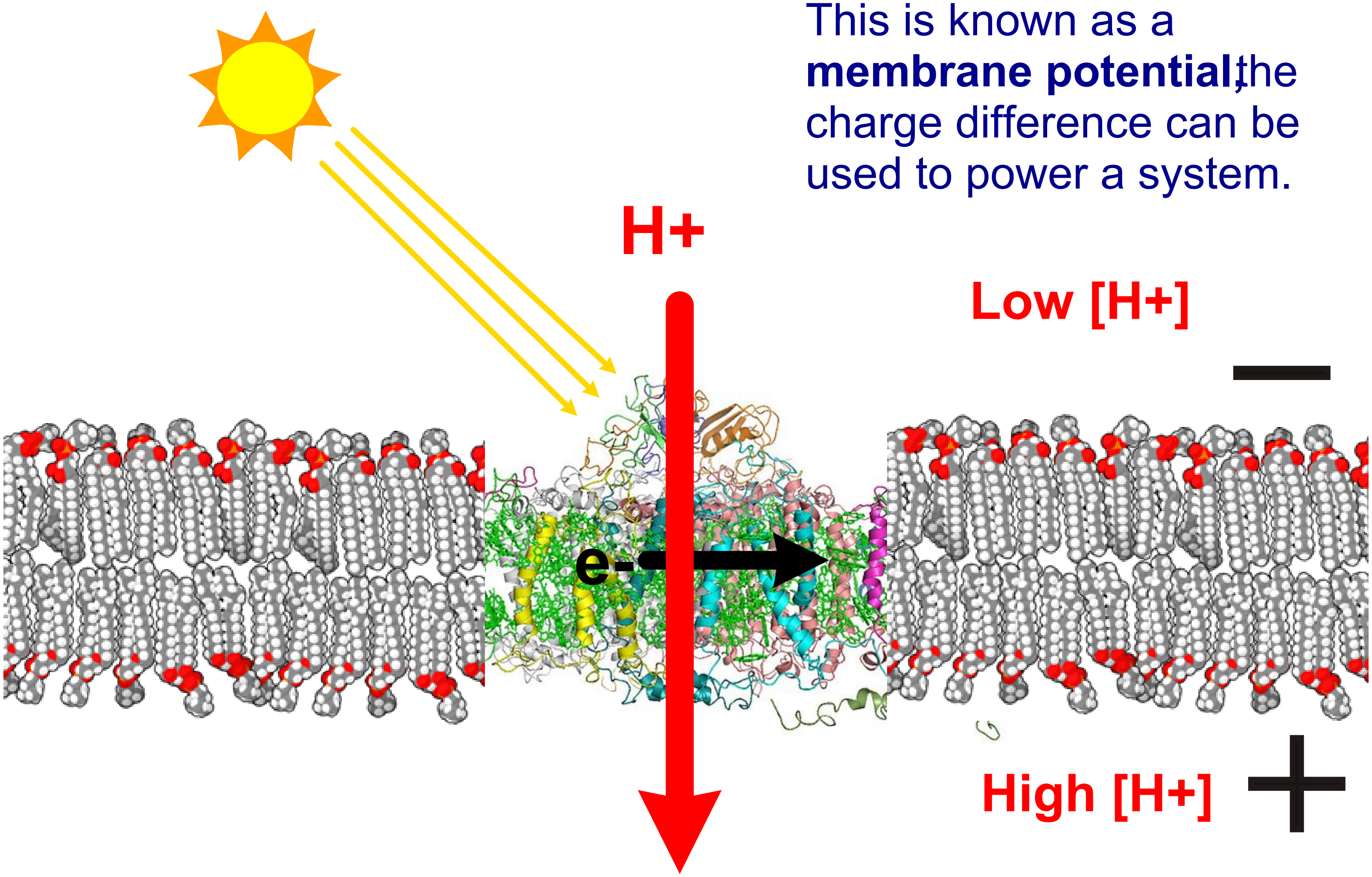
Photosystems

As time passes, a concentration gradient is formed.



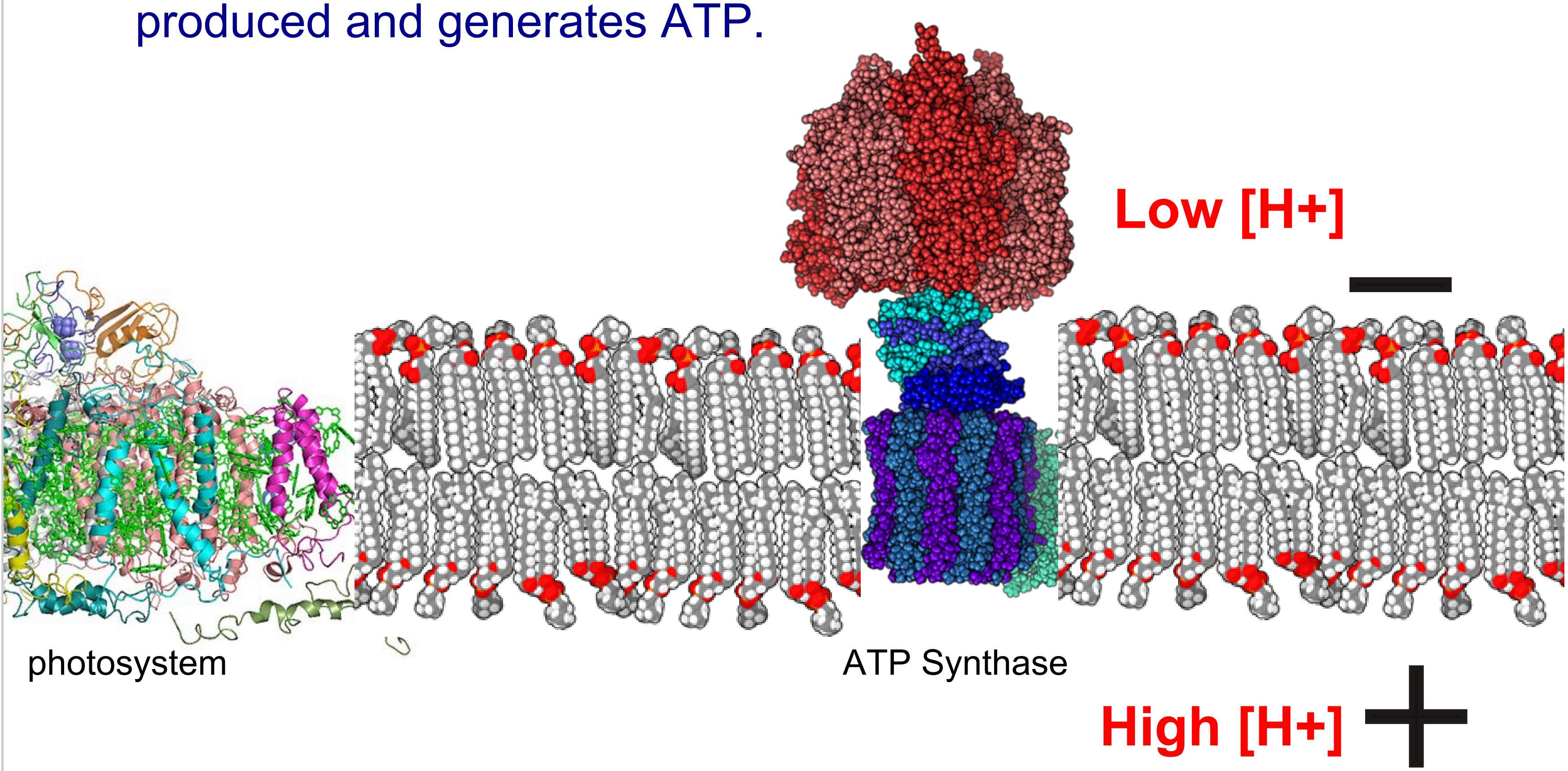
Photosystems

This is known as a **membrane potential**; the charge difference can be used to power a system.



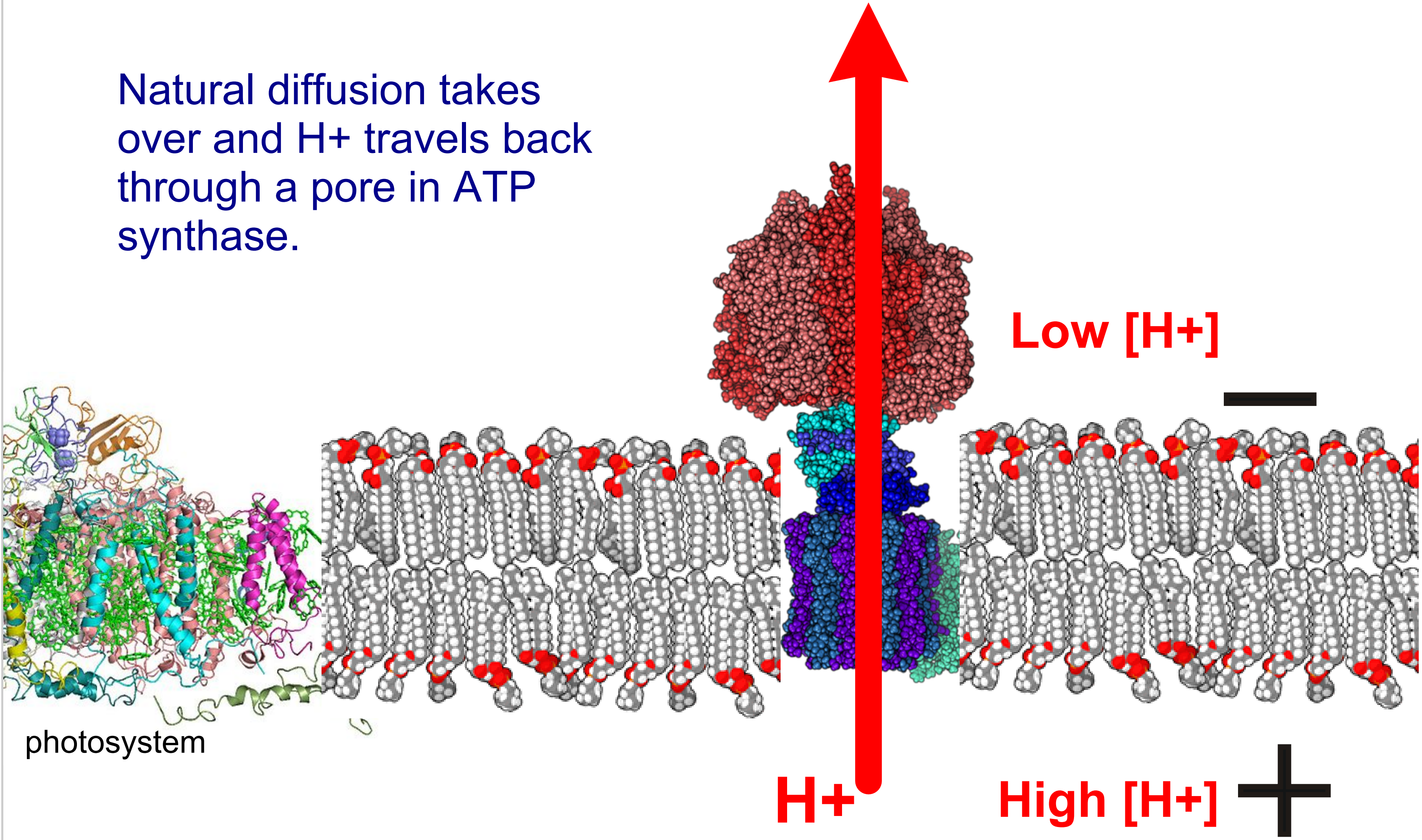
ATP Synthase

In another location of the same membrane is a protein known as **ATP synthase** This molecule takes advantage of the gradient produced and generates ATP.



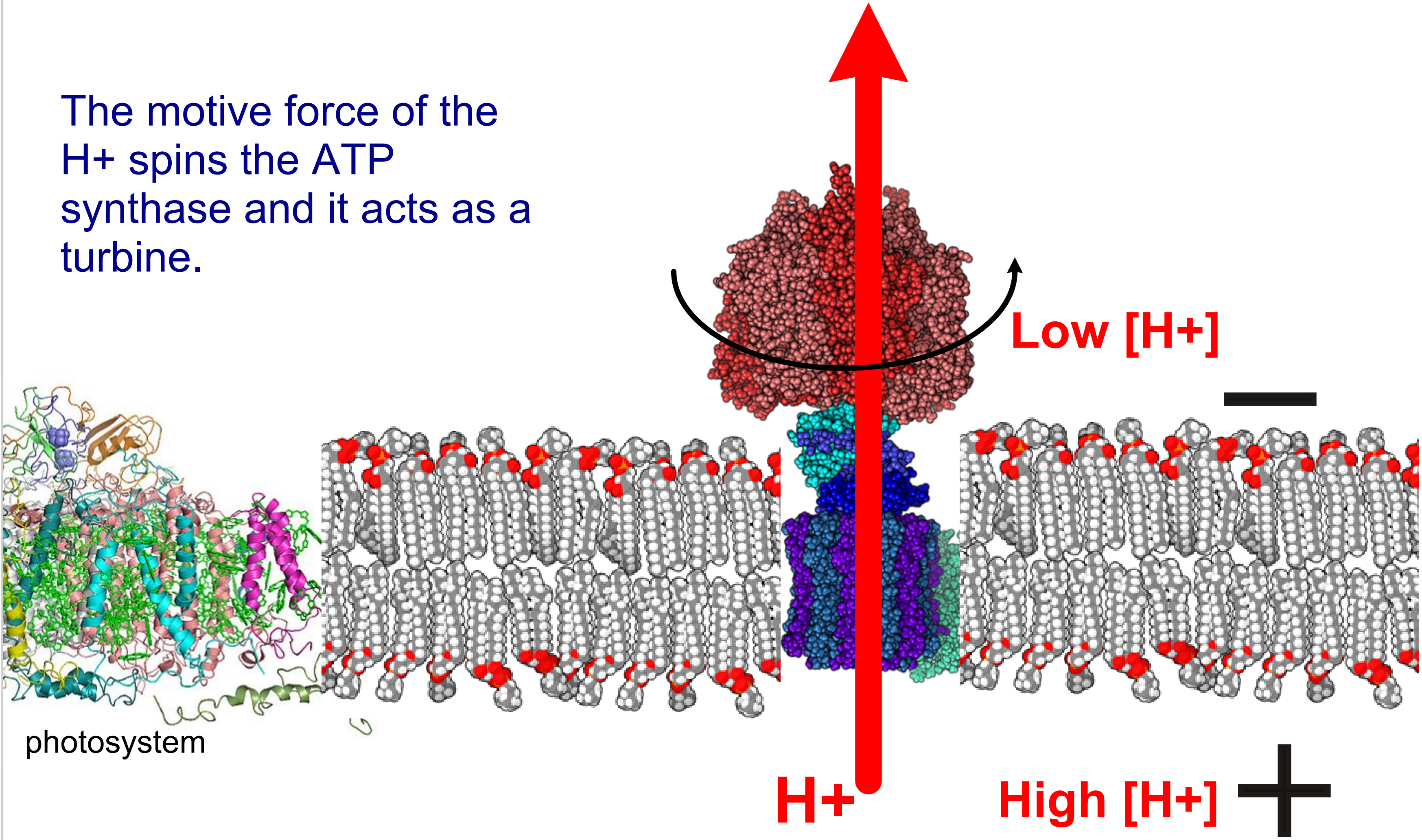
ATP Synthase

Natural diffusion takes over and H+ travels back through a pore in ATP synthase.



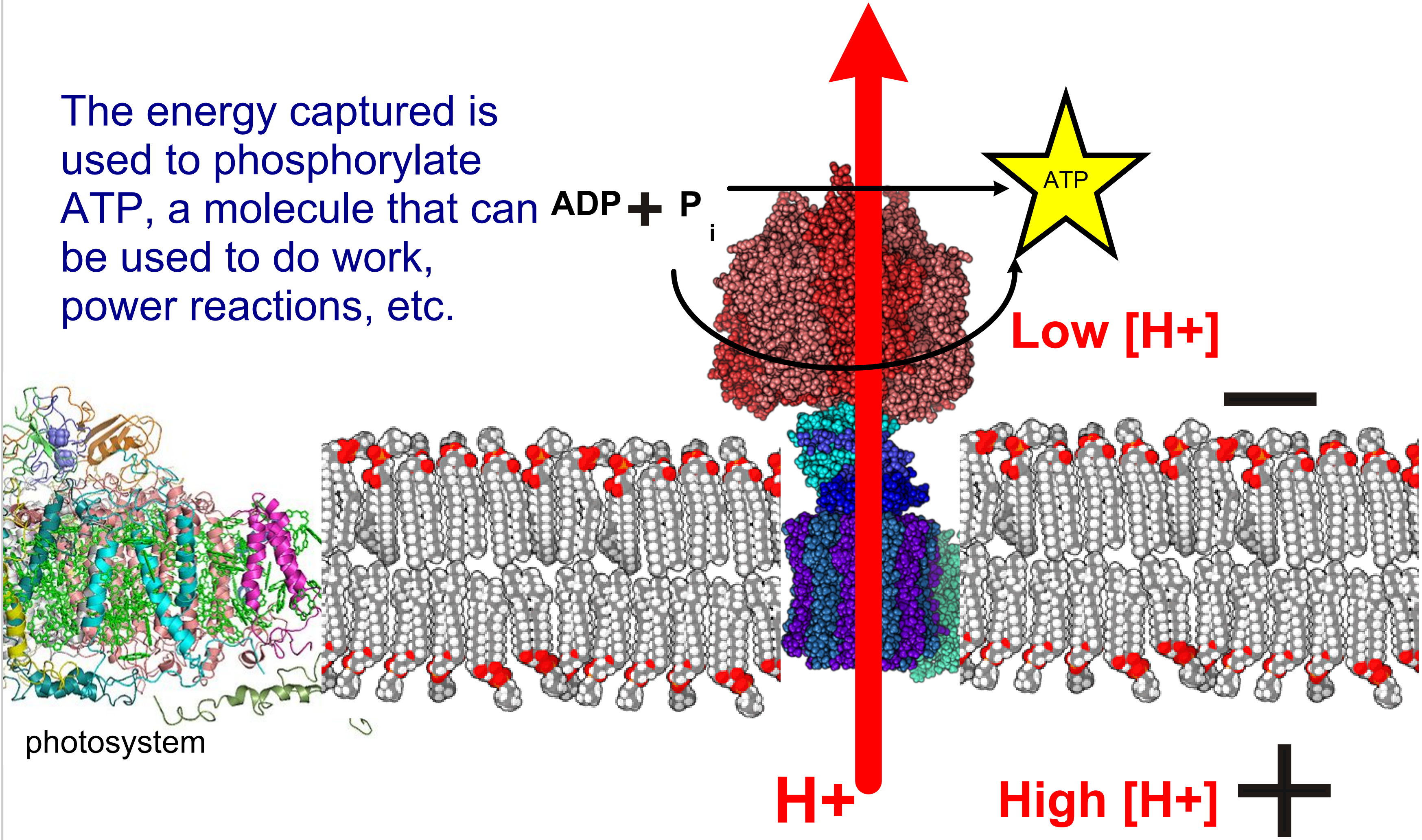
ATP Synthase

The motive force of the H+ spins the ATP synthase and it acts as a turbine.



ATP Synthase

The energy captured is used to phosphorylate ATP, a molecule that can be used to do work, power reactions, etc.



8 Which best describes a photosystem?

- A membrane bound protein
- B major enzyme activity center
- C synthesizer of ATP
- D light reflector

answer

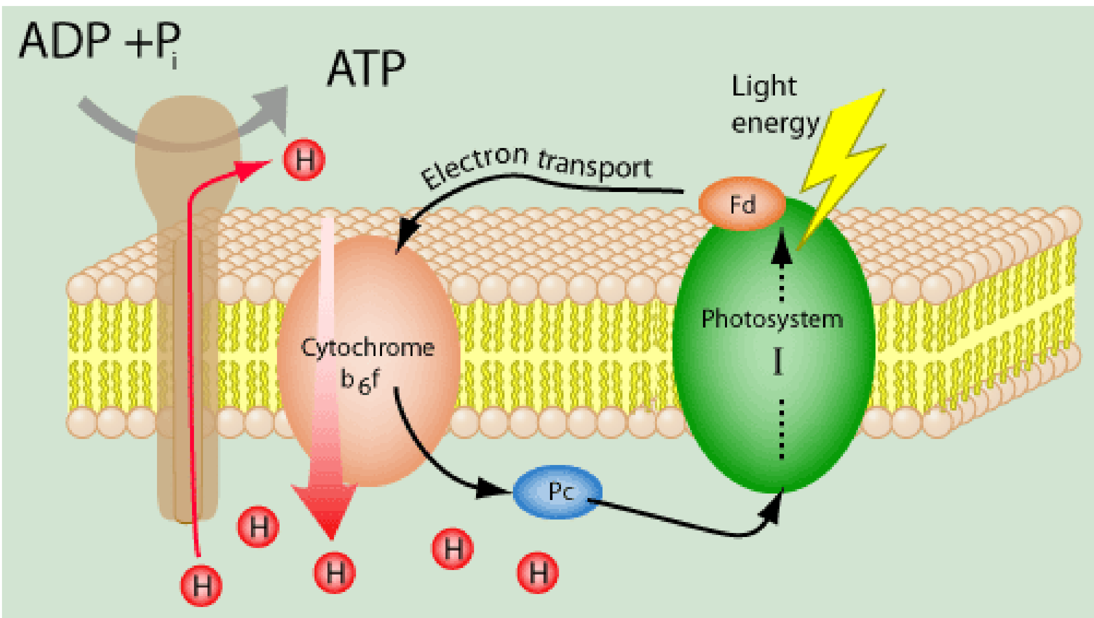
9 The transfer of electrons in a photosystem create a membrane potential with a ________ concentration of H+ molecules on the inside of the membrane and a __________ concentration on the outside of the membrane.

- A higher; lower
- B lower; higher

answer

Cyclic Electron Transport

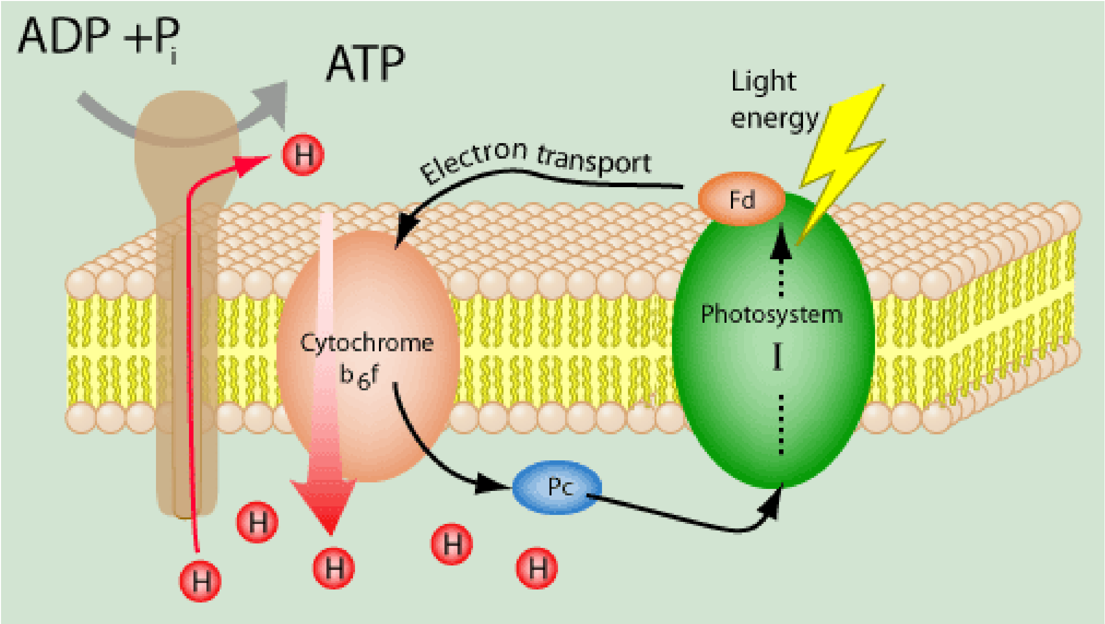
As these simple prokaryotes continued to evolve, the systems of ATP synthesis and electron transport evolved more efficient and more complex systems. Below is a diagram of **cyclic electron transport.**



http://hyperphysics.phy-astr.gsu.edu/hbase/biology/etcyc.html

Cyclic Electron Transport

Notice the addition of **cytochrome** and the transport of electrons from the photosystem to this specialized protein that functions as an efficient transporter of hydrogens across the membrane.



http://hyperphysics.phy-astr.gsu.edu/hbase/biology/etcyc.html

Using Nature to Design Technology

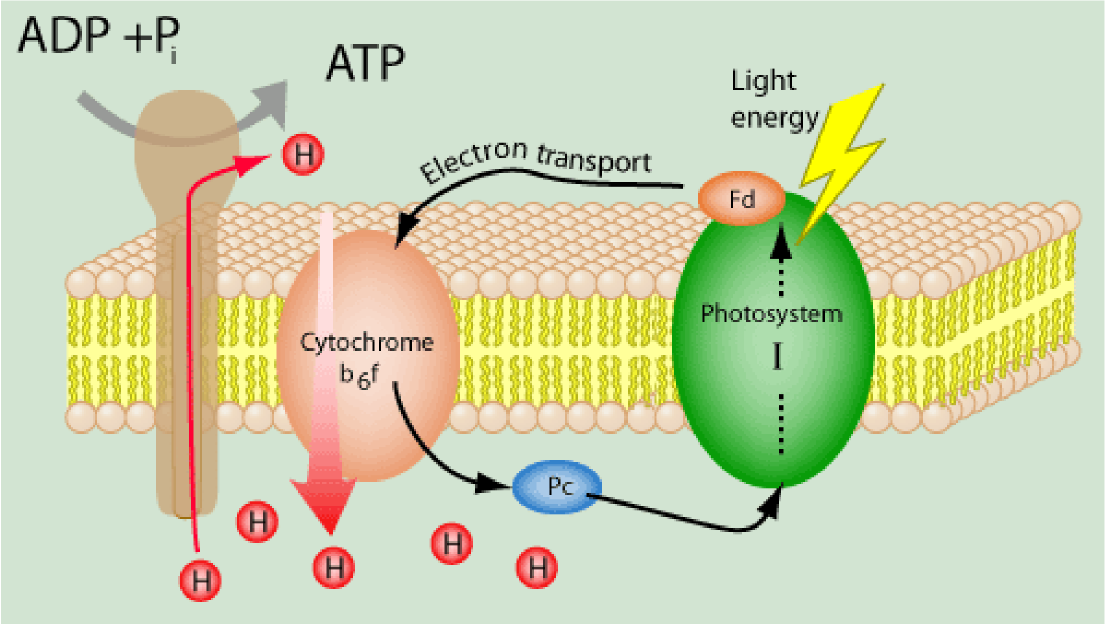
An engineering student is interested in designing a solar panel that is more efficient than the current variety. As an elective, the student is taking a biology class and learns about cyclic electron transport. She decides that this system could be used to design a better solar panel.

Work with a group and use what you have learned about cyclic electron transport to design a solar panel. Sketch out a flow chart of the system.

Can you think of any ways to improve upon your design?

Evolution Continues...

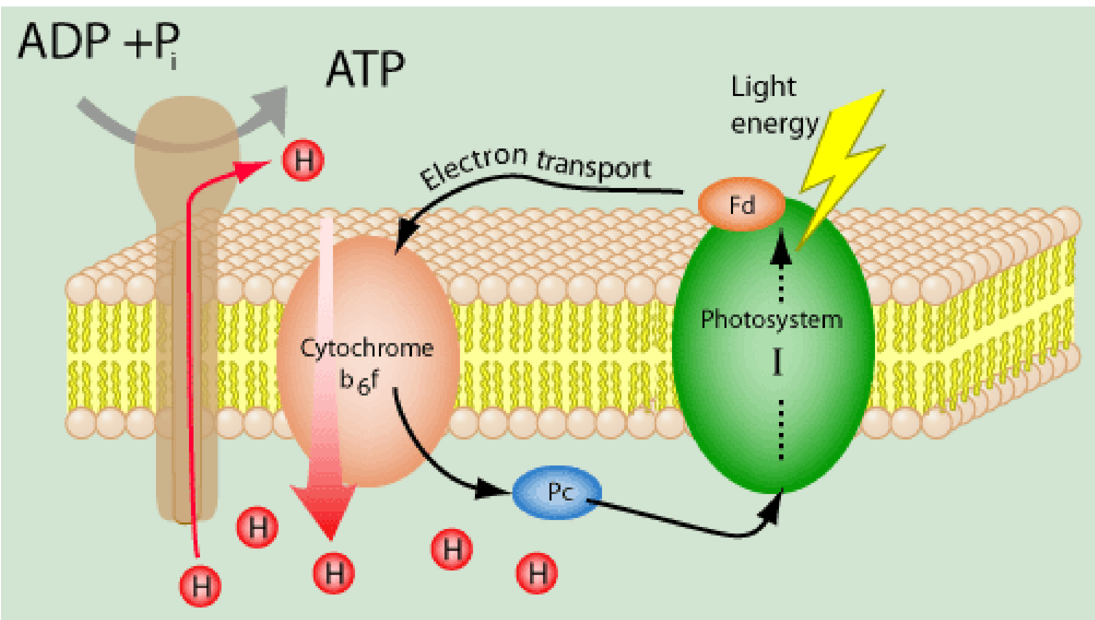
Though this system was highly advanced at the time, evolution continued to tinker with the parts of this system to make it more efficient.



http://hyperphysics.phy-astr.gsu.edu/hbase/biology/etcyc.html

Evolution continues...

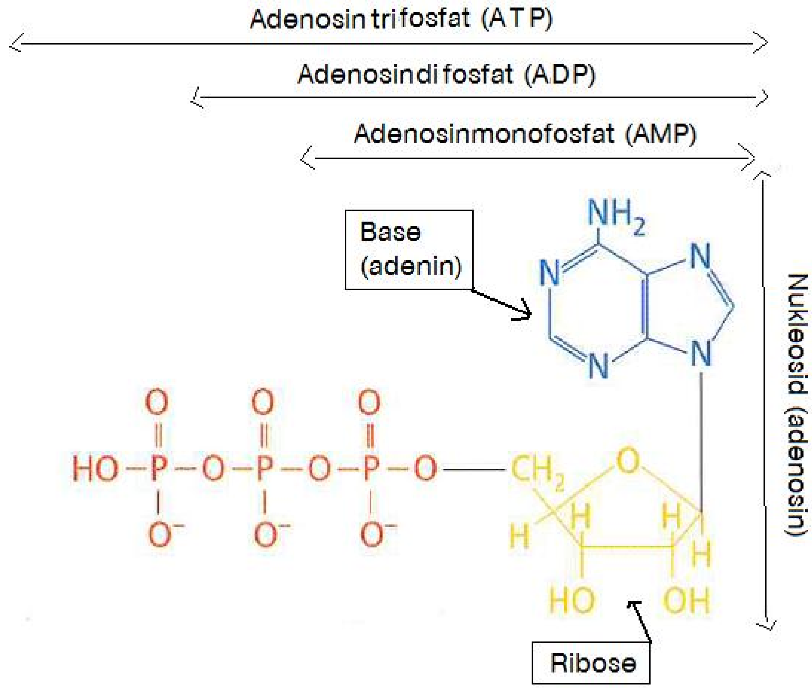
One of the major problems with this system, is that the ATP is being released outside the cell. The cell must uptake the ATP from its surroundings



http://hyperphysics.phy-astr.gsu.edu/hbase/biology/etcyc.html

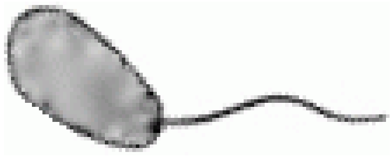
Evolution Continues...

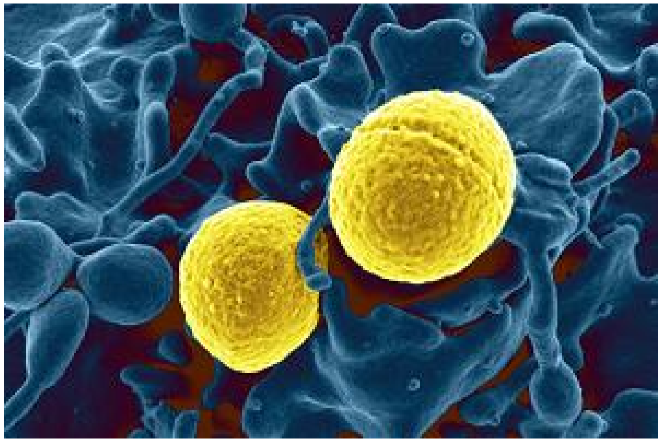
Also, ATP is a good molecule for management of energy but cannot be used for storage of energy because its reactivity makes it break down quickly. So ATP producing organisms can only survive when sunlight is available, or if they flood their environment with ATP.

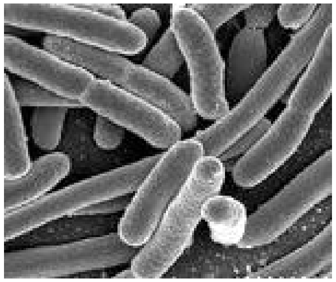


Evolution Continues...

However, evolution was not just tinkering with the production of ATP. Simultaneously other types of prokaryotes were being selected for other reasons.





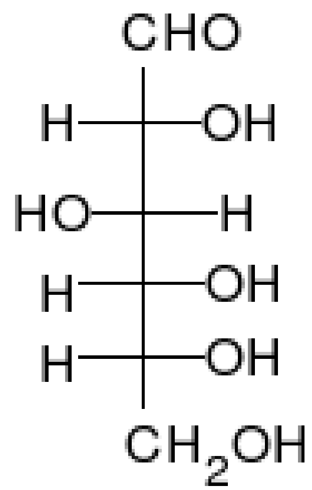


Evolution Continues...

3 of the most important advancements of this era:

Energy Storage- Glucose is produced by cells taking advantage of ATP and carbon dioxide.

This marks the beginning of sugar and carbohydrates on planet Earth.



Evolution Continues...

3 of the most important advancements of this era:

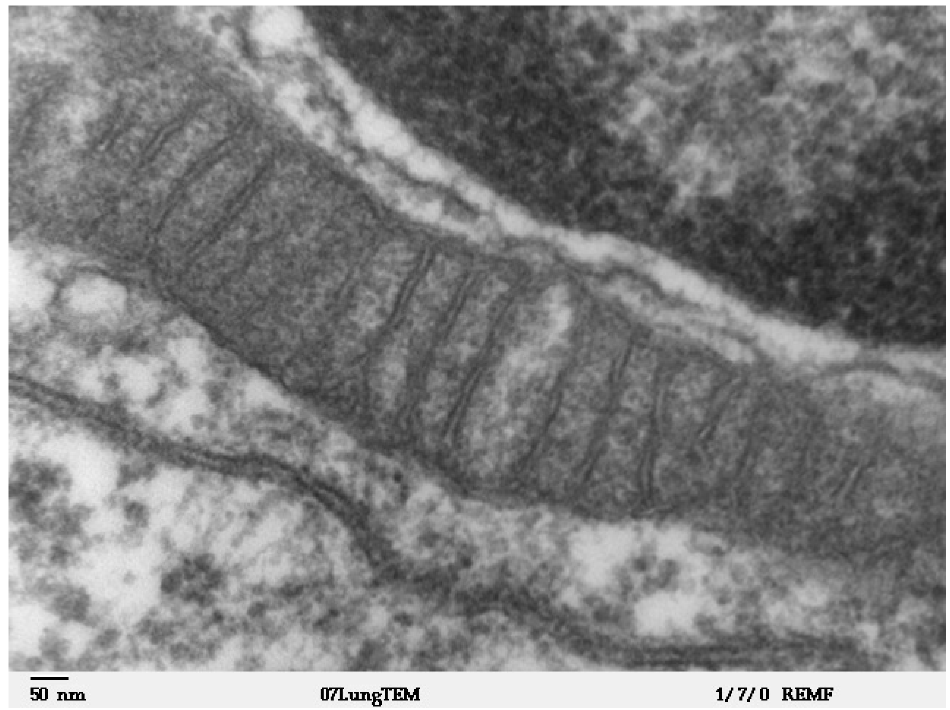
Symbiosis- Bacterial cells of different species tightly associate with one another and use each others' products as reactants.

Evolution Continues...

3 of the most important advancements of this era:

Compartmentalization- Some cells begin to get in-foldings and more complex systems of membranes. This produces isolated pockets that can house separate chemical reactions.

Bacterial cells can do multiple reactions without cross interference.



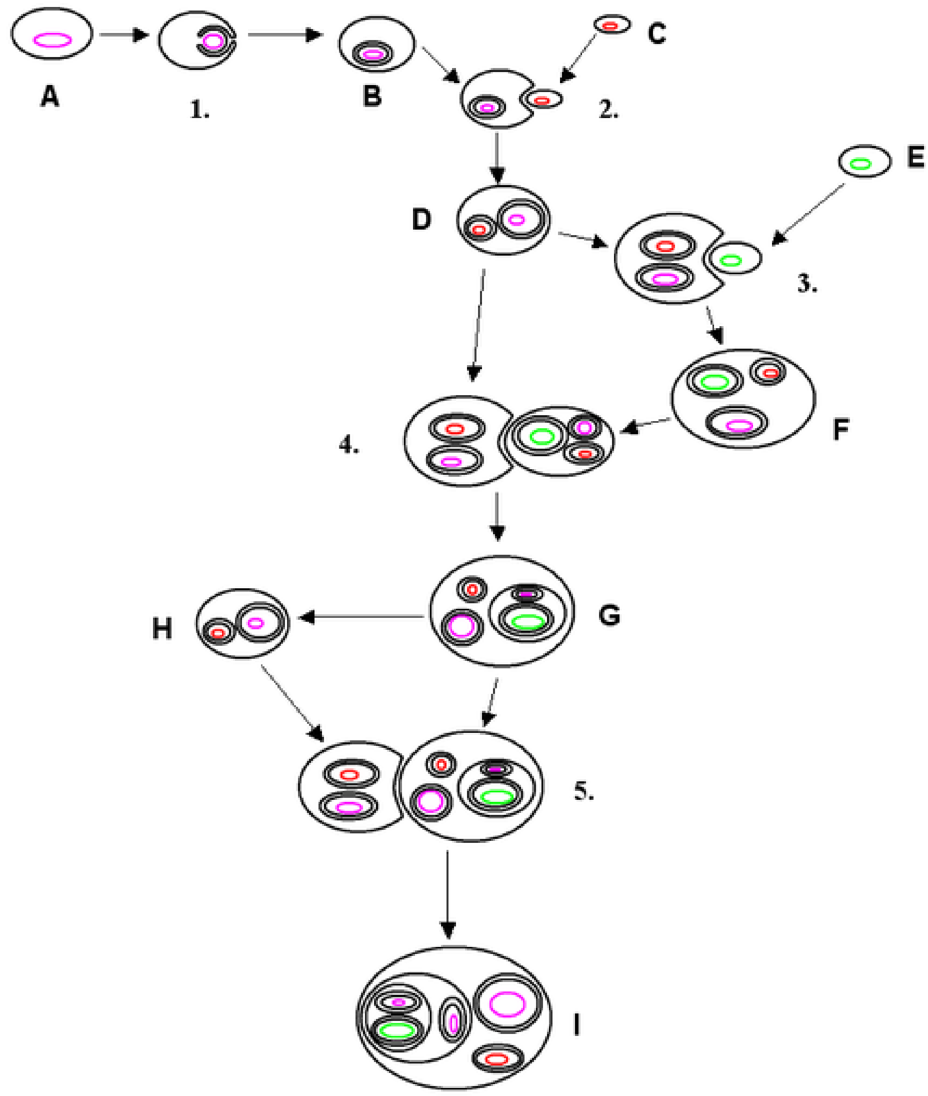
Endosymbiosis

Arguably the biggest progression in the evolution of life is the point at which prokaryotic cells begin to combine into more complex eukaryotic cells.

Endosymbiosis

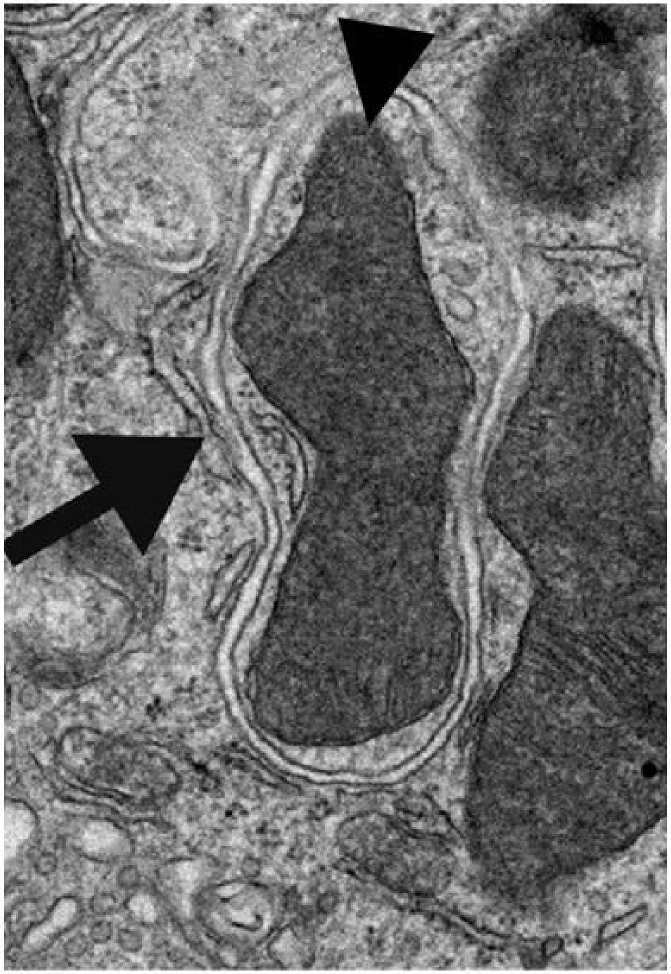
This image represents several species of prokaryote, each with a separate function, coming together to form one cell capable of multiple functions.

This endosymbiosis increases the metabolic ability of cells descendant of this process.



Double membranes

Notice as the smaller cells, known as **plastids**, are engulfed by the larger cells they become doubly wrapped in membranes



Endosymbiosis

When the more complex eukaryotic cells become capable of all 3 of the previously mentioned advancements, life was able to achieve higher levels of complexity.

This is primarily because metabolic processes can become more complex.

Photosynthesis

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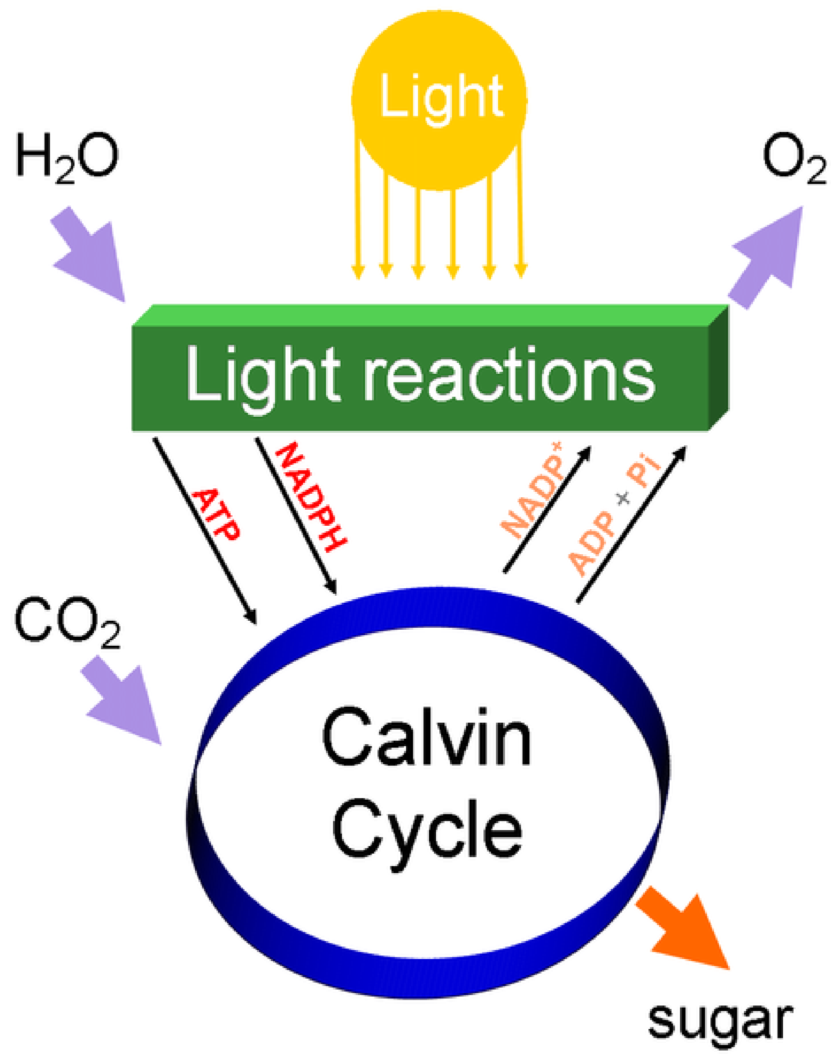
Photosynthesis

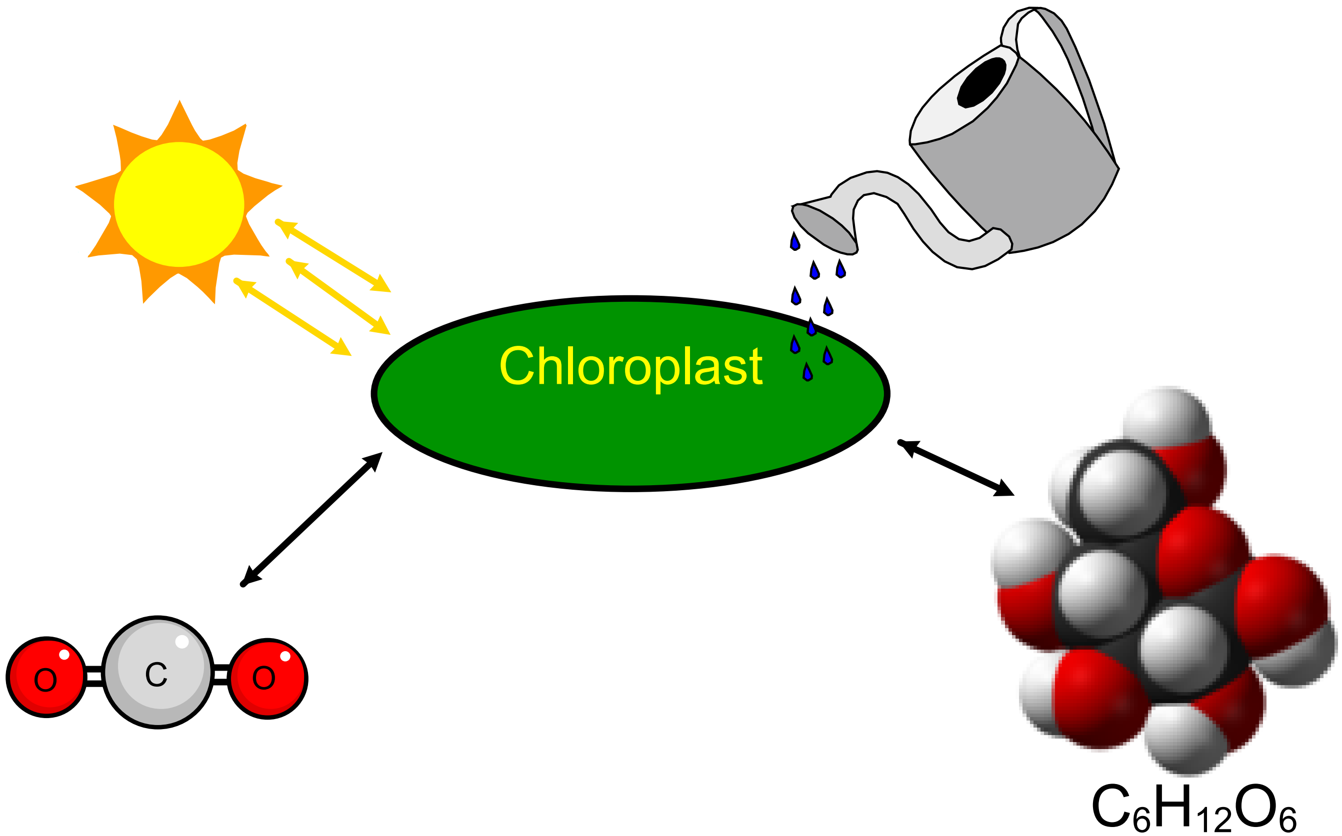
From a combination of cyclic electron transport and the storing of energy in the bonds of carbon atoms, a new process is born.

This is the process that produces all sugars and carbohydrates.



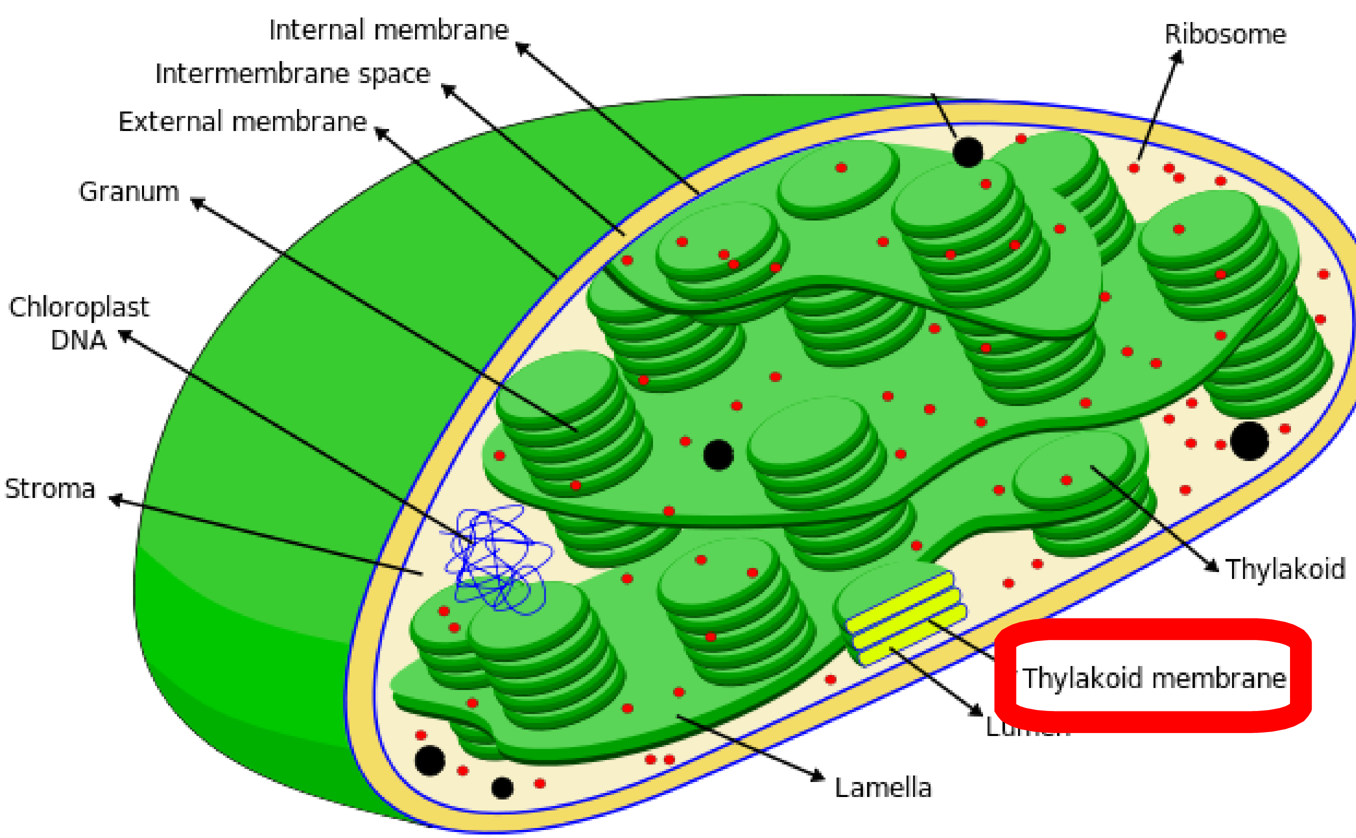
Photosynthesis

Remember our chloroplast from earlier. This is a simple representation of a **photosynthetic organelle**. An organelle is a small molecular machine inside a cell.



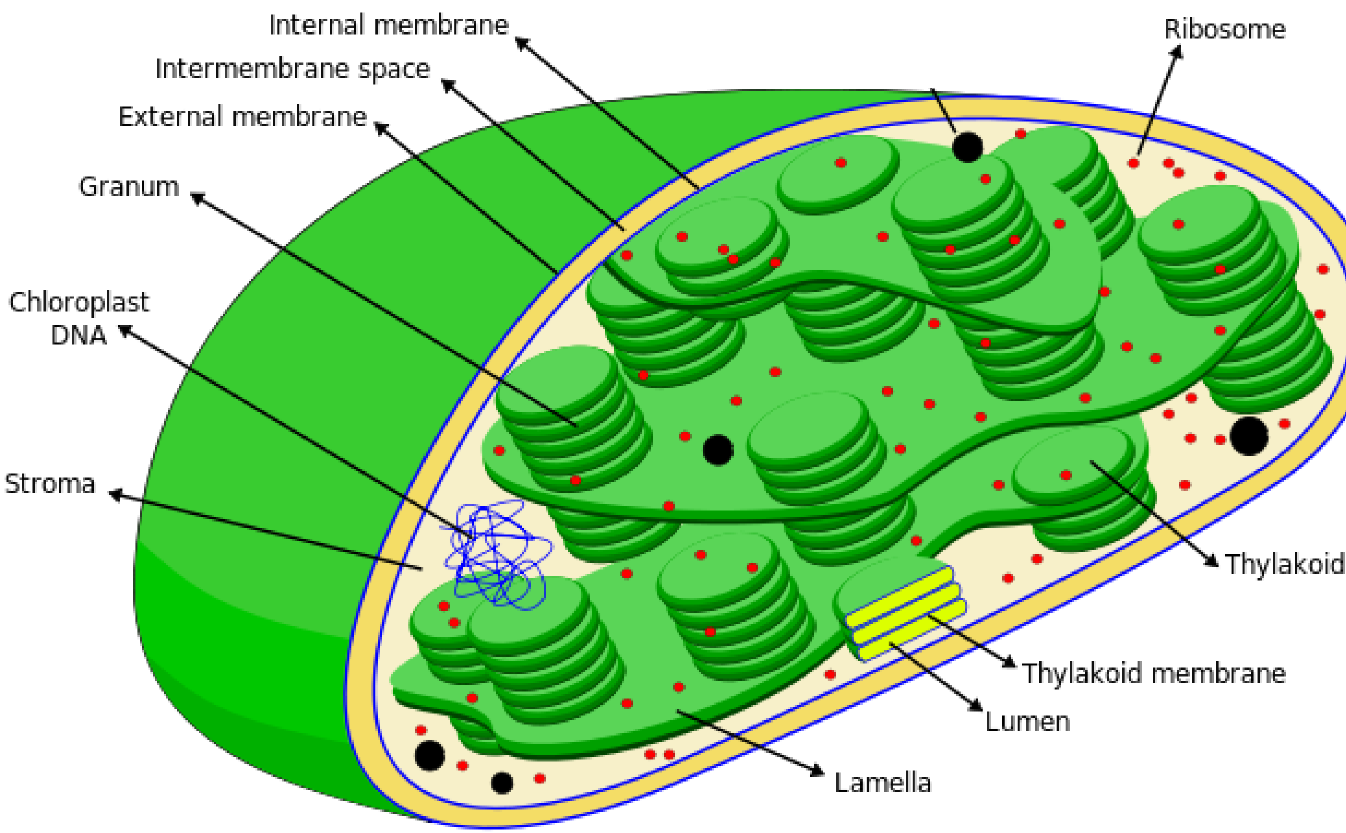
Photosynthesis

The gradient and mechanism for the light energy gathering phase, or the **light reactions**, of photosynthesis takes place in the thylakoid membrane.



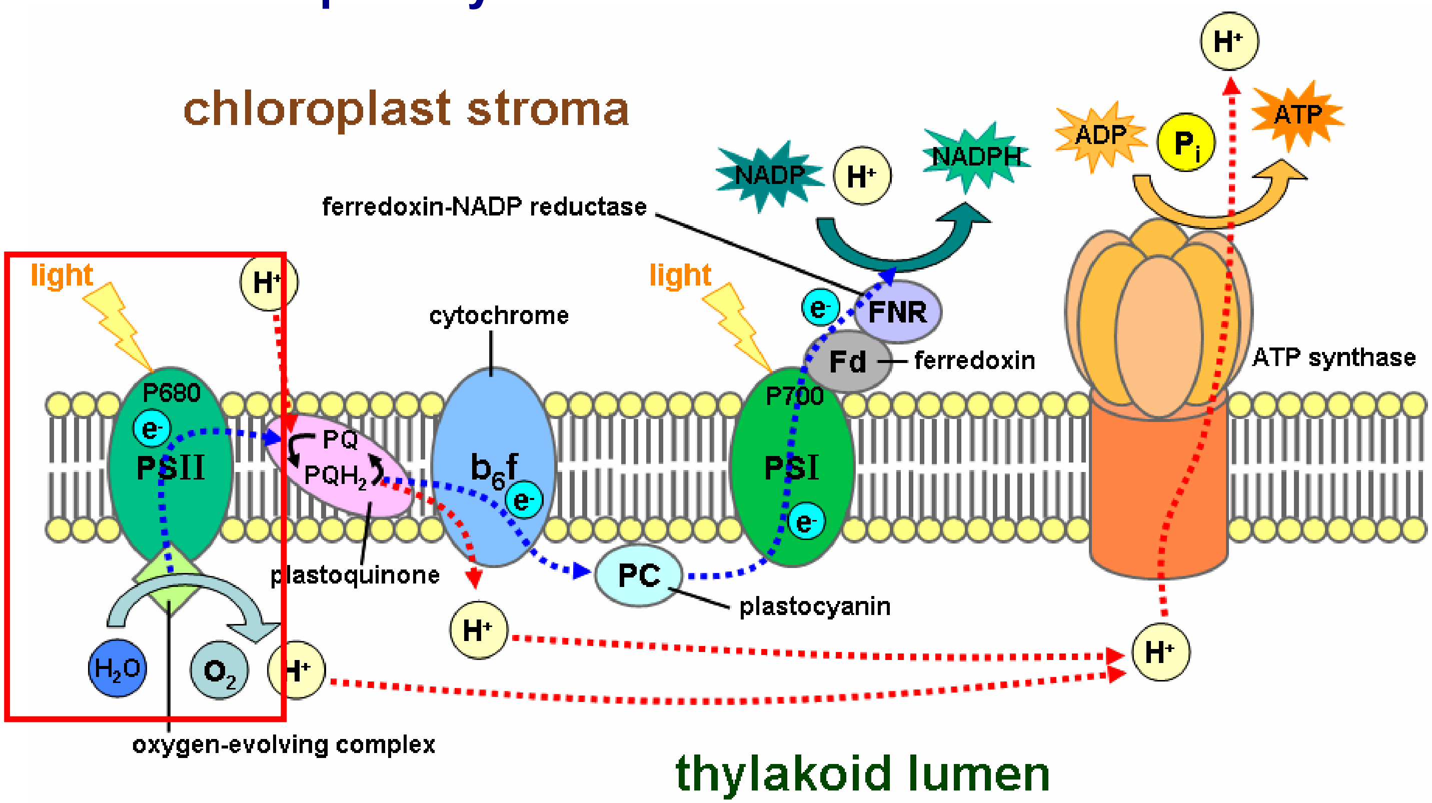
Photosynthesis

The chloroplast is a double membraned structure that utilizes a concentration gradient and compartmentalization to maximize its production of the energy storage molecule glucose.



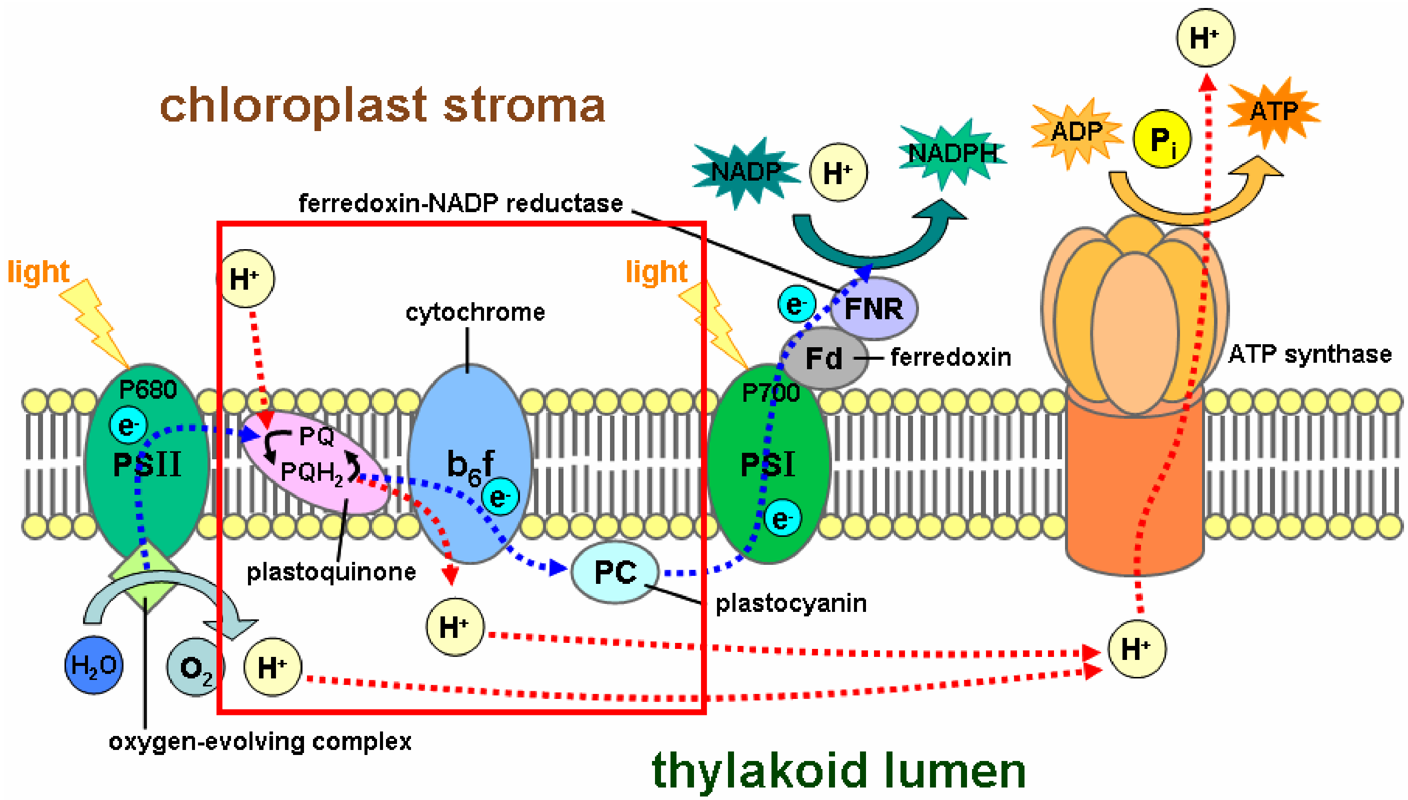
The Light Reaction

Photosystem II is the first structure in the series. Light excites the photosystem and electrons are sent to the **electron transport chain (ETC)**. Simultaneously, water molecules are being split and providing their electrons to the photosystem. Water is the **primary donor** of electrons.



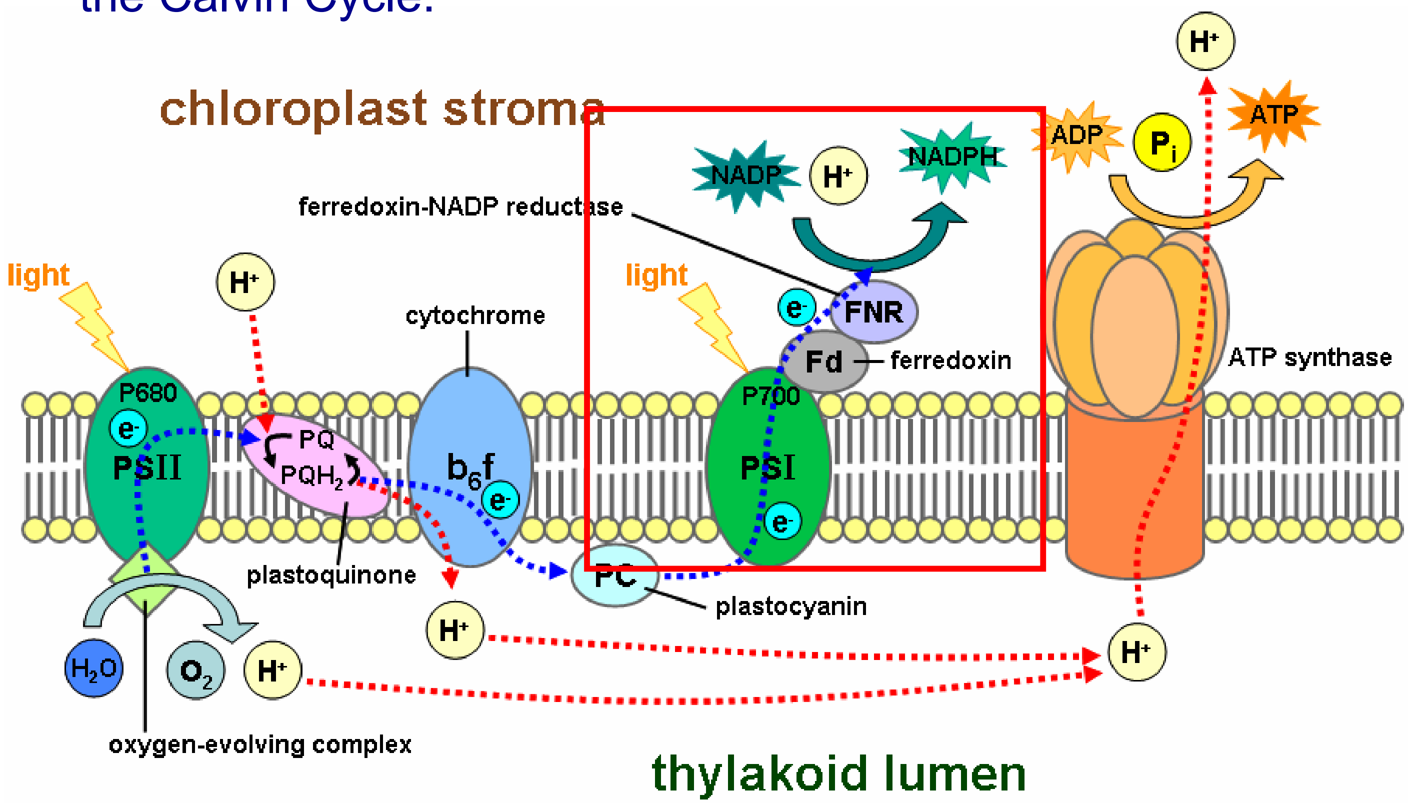
The Light Reaction

The electron transport chain moves protons as described in cyclic electron transfer. The electrons are no longer excited because of the energy transfer. They are then donated to the next step.



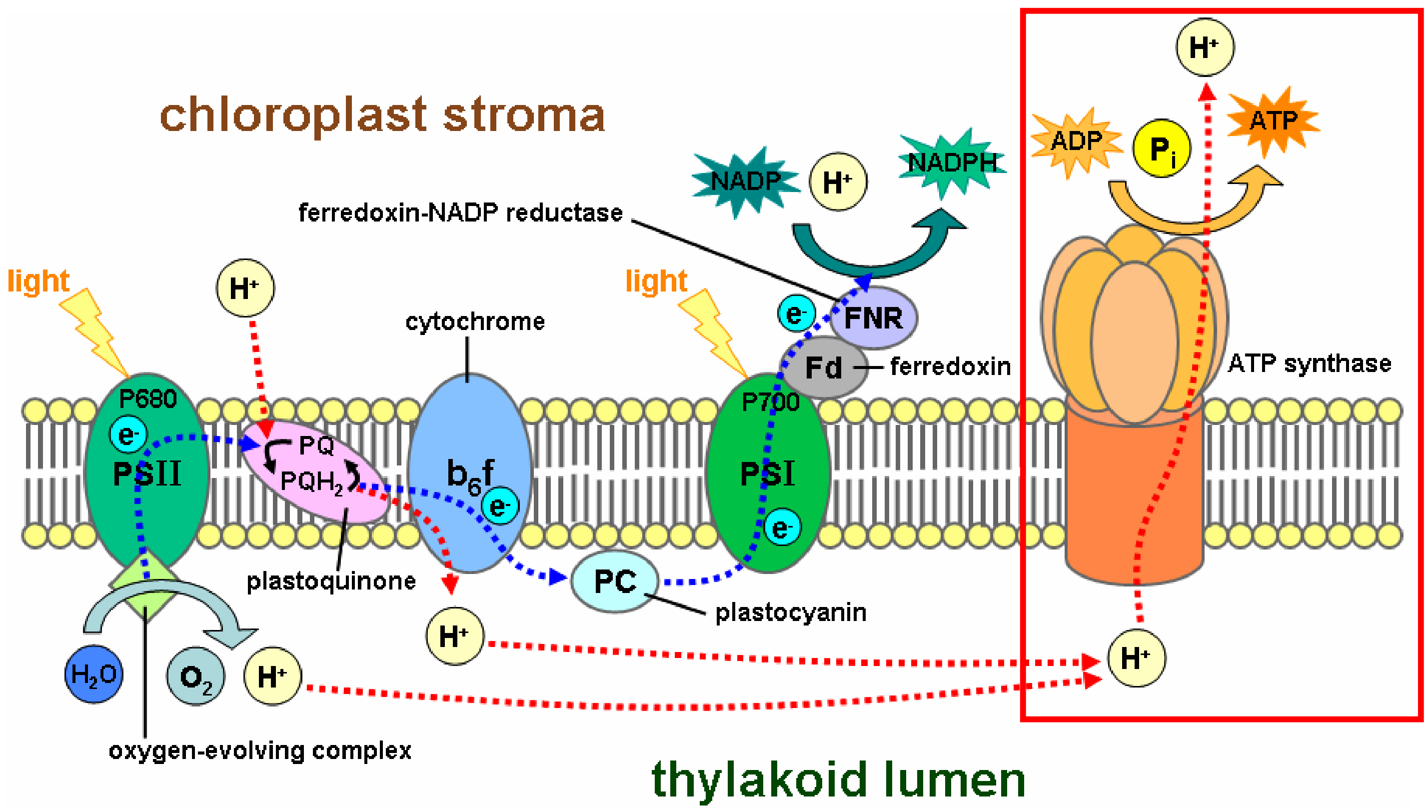
The Light Reaction

Photosystem I re-excites the electrons using light energy. These high energy electrons are used to reduce a molecule of NADP to NADPH. This will carry the electrons to the second stage of photosynthesis: the Calvin Cycle.



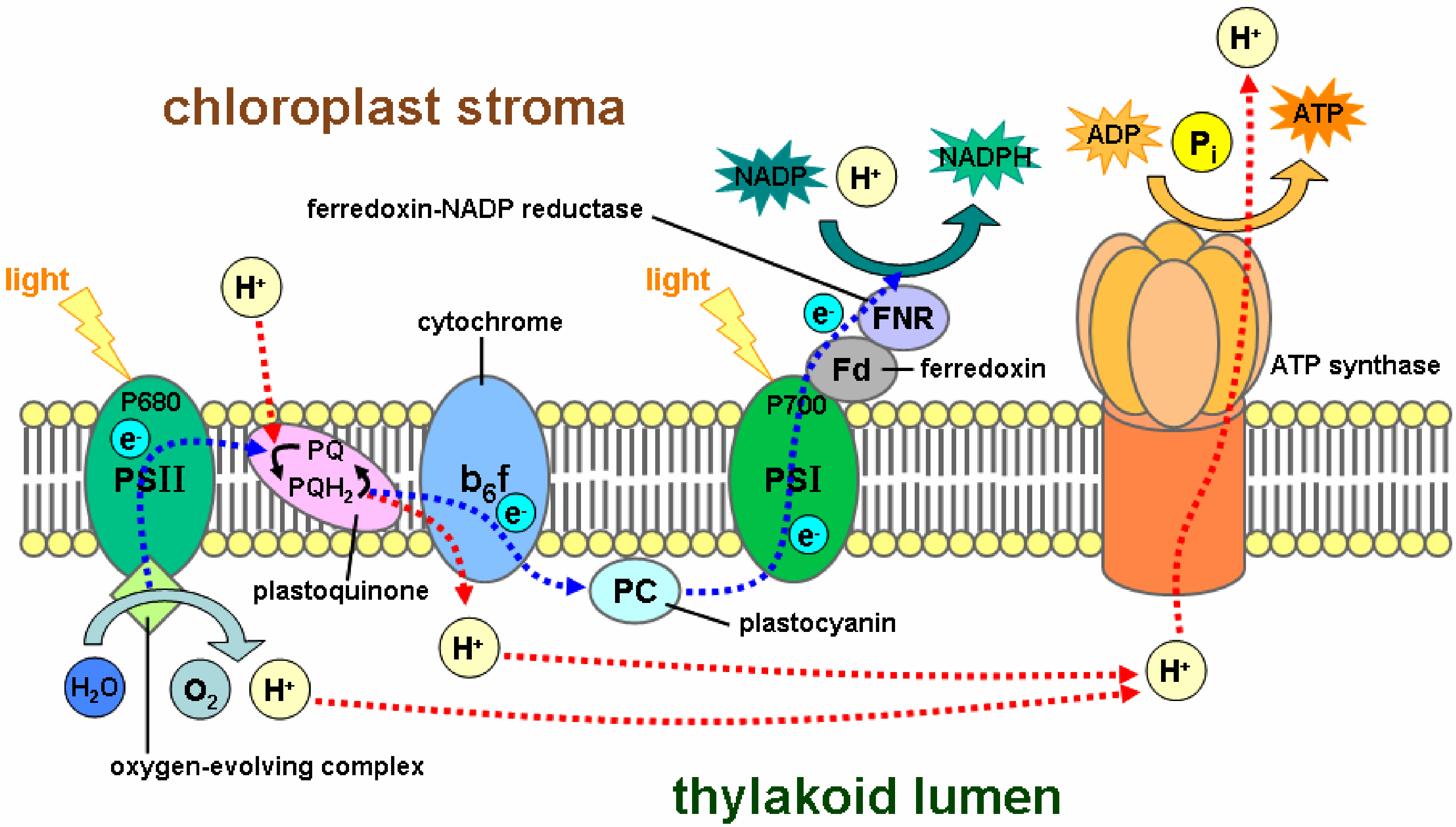
The Light Reaction

Finally, the proton gradient is used to generate ATP. The enzyme ATP synthase takes advantage of the energy of the hydrogen ions' natural diffusion down its gradient. The energy is used to attach a phosphate to ADP.



Light Reactions Video

Click for a video explanation of the Light Reactions



10 The inside of the thylakoid is called the __________ and the outside is called the __________.

- A lumen, stroma
- B stroma, lumen

answer

11 Water is split, releasing O_2, in which protein complex?

- A photosystem I
- B photosystem II
- C ATP synthase
- D NADP reductase

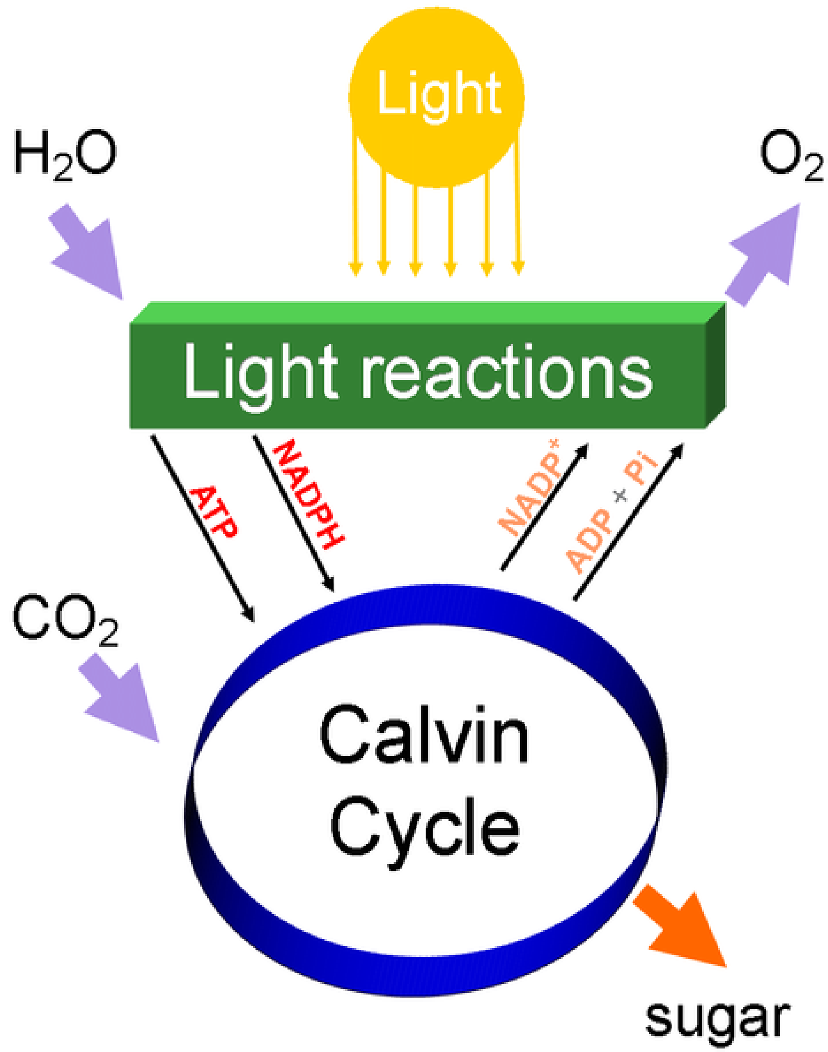
answer

The Calvin Cycle

The light dependent reactions are the first part of photosynthesis.

The remaining reactions are called the Calvin Cycle.

In the Calvin Cycle the ATP and NADPH produced by the light reactions are utilized to build high energy glucose molecules that store energy for later use.



The Calvin Cycle

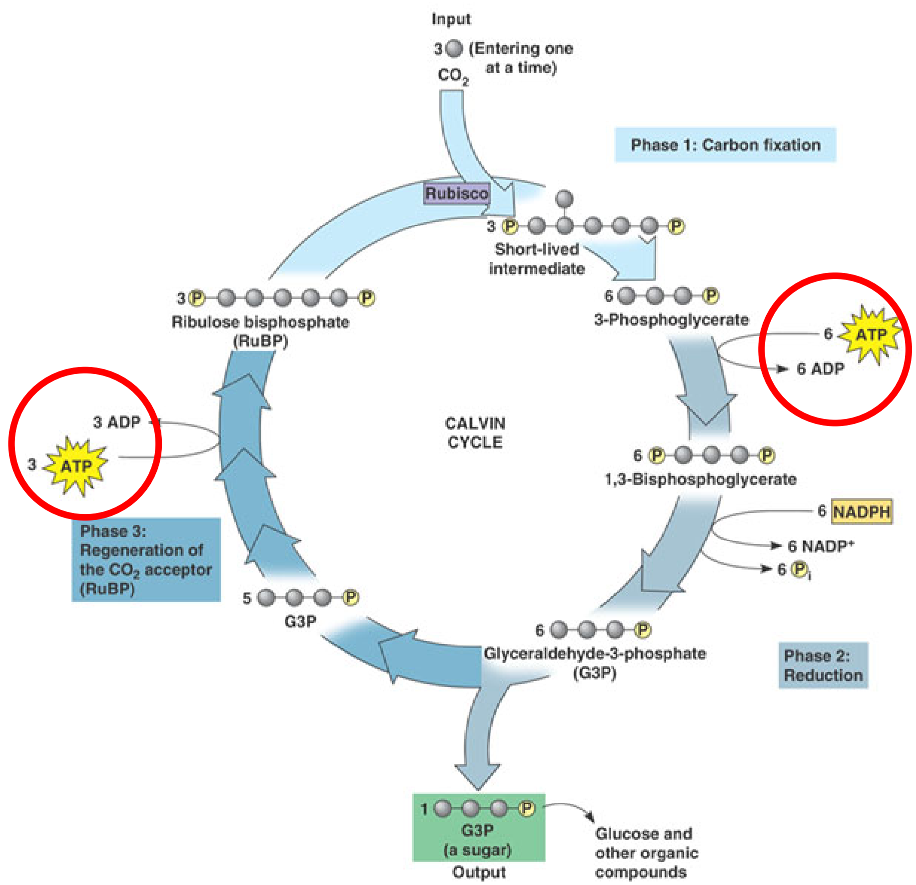
The Calvin Cycle uses NADPH and ATP produced from the light-dependent reactions to reduce CO_2 and produce sugar - this is called **carbon fixation.**

The sugar produced is a 3 carbon molecule called **glyeraldehyde-3-phosphate (G3P).**

The Calvin Cycle must occur three times to produce 1 G3P since it only fixes one CO_2 molecule in each cycle.

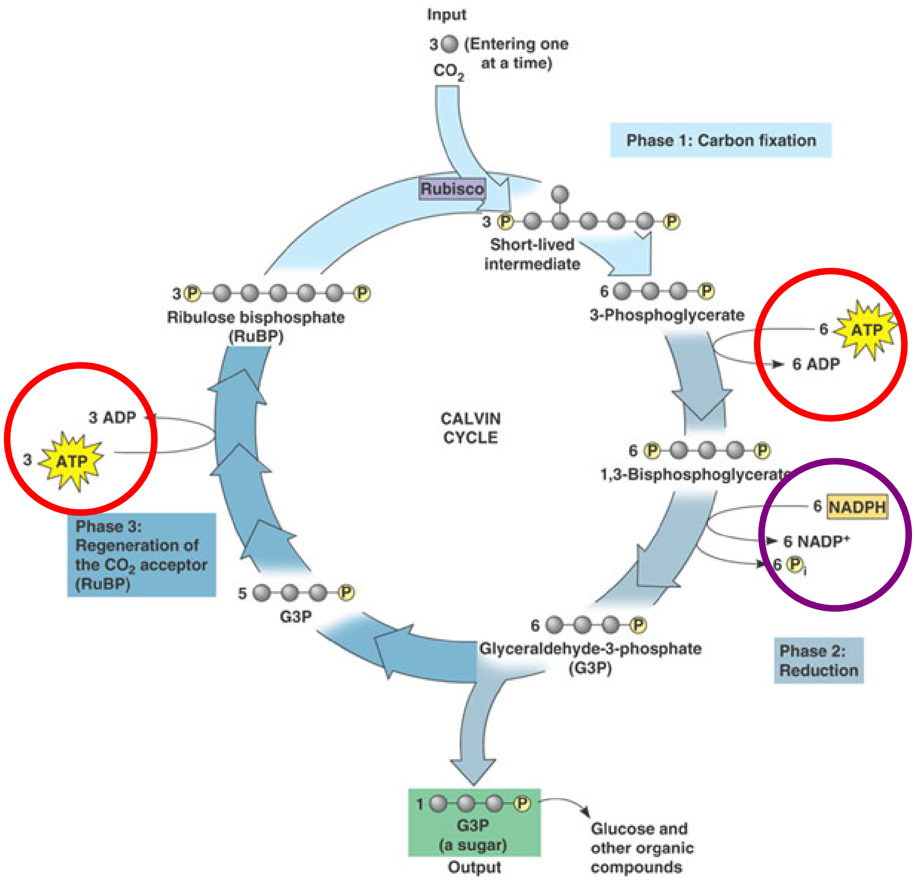
Calvin Cycle

In 3 turns of the cycle we use
9 ATP



Calvin Cycle

In 3 turns of the cycle we use
9 ATP
and
6 NADPH



Calvin Cycle

In 3 turns of the cycle we use
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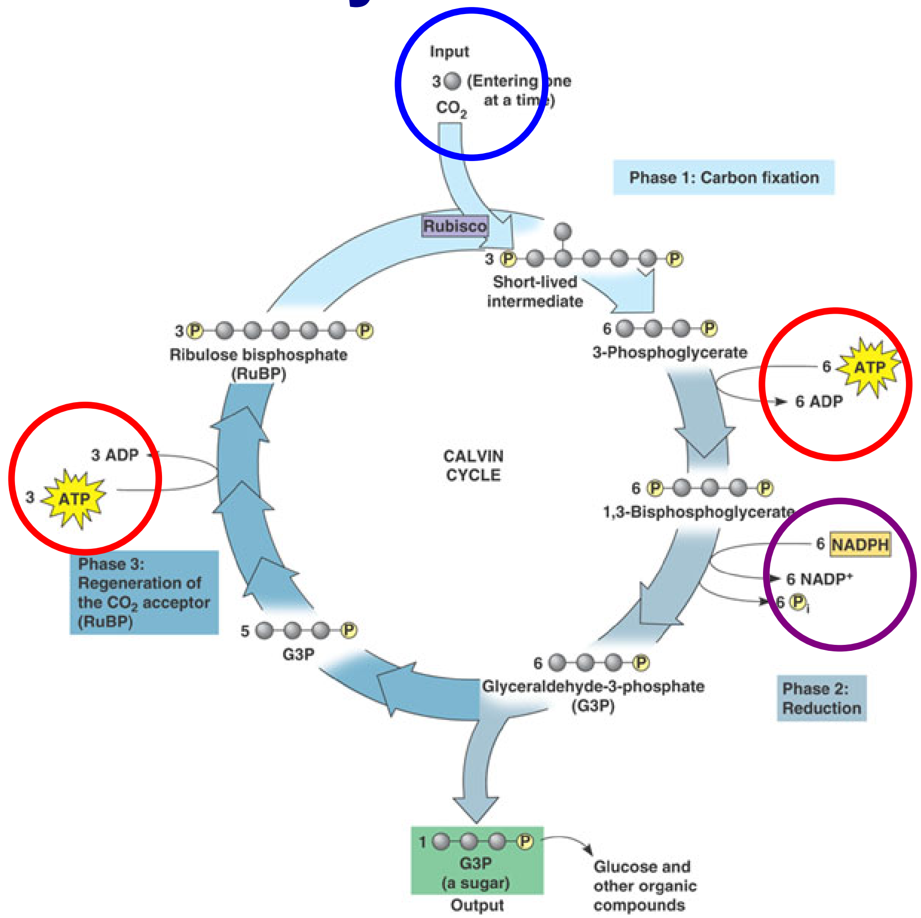
and
3 CO_2



Calvin Cycle

In 3 turns of the cycle we use
9 ATP
and
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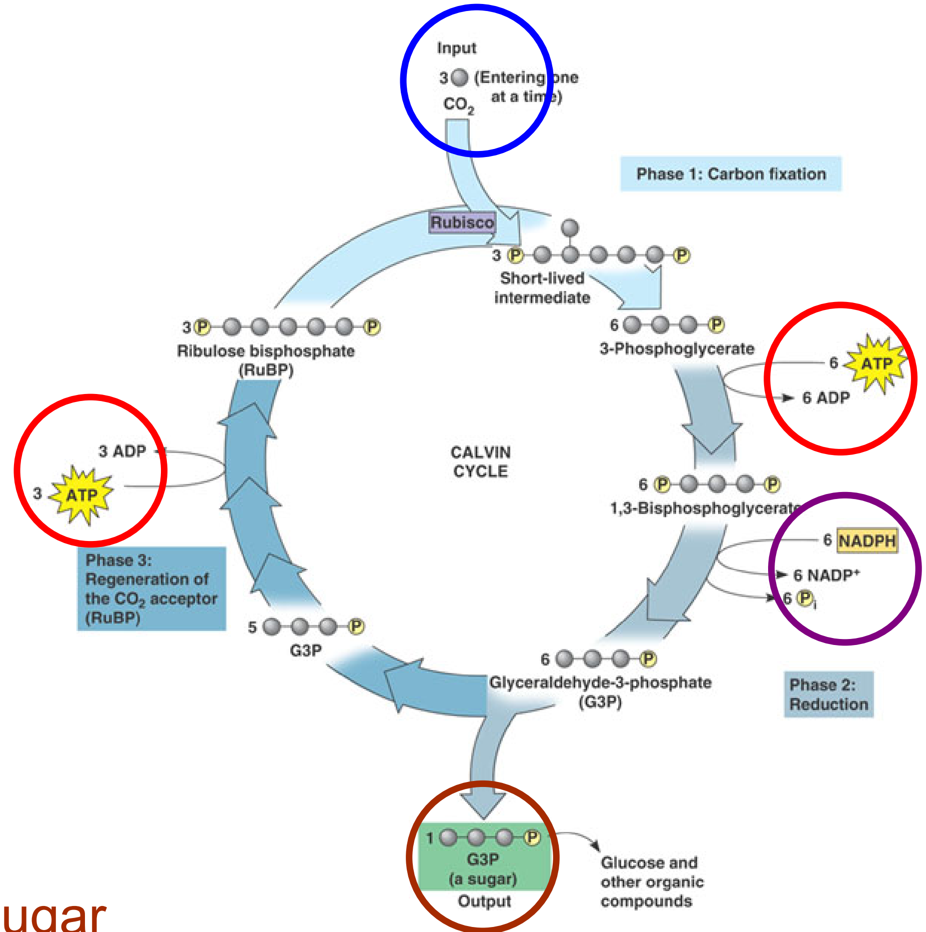
and
3 CO_2



to make
1 3-carbon sugar

Photosynthesis Recap

Photosynthesis consists of two separate series of chemical reactions that together serve to capture electromagnetic radiation and transform it into stored chemical energy.

Light Reactions
- occur in the thylakoid or on the thylakoid membrane
- require light
- use light, H_2O, ADP, and $NADP^+$ to produce O_2, ATP, and NADPH

Calvin Cycle
- occurs in the stroma
- creates sugars using CO_2, ATP, and NADPH
- ADP and NADP+ are released as byproducts

Photosynthesis Equation

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

12 How many turns of the Calvin cycle are necessary to produce one molecule of glucose?

- A 1
- B 2
- C 3
- D 6

answer

13 The Calvin cycle is an anabolic pathway.

- True
- False

answer

Cellular Respiration

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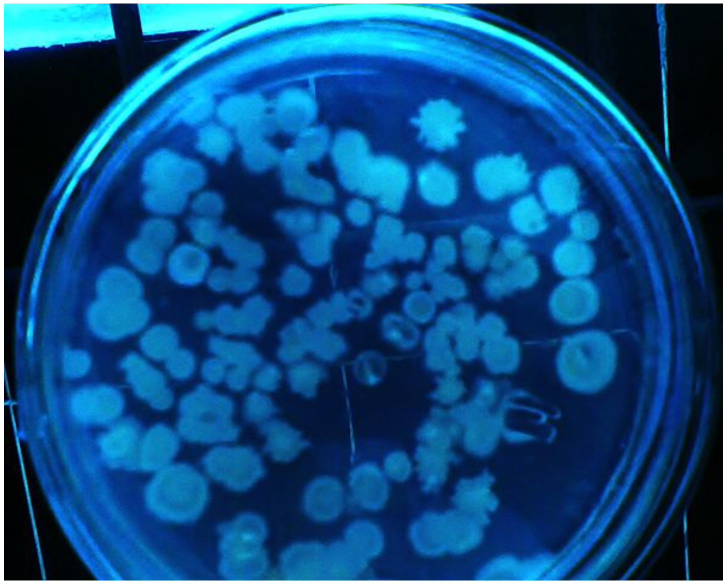
Sugar is Storage Only

Just as ATP cannot be used for storing energy, glucose is not usable as energy. Glucose must be converted back into ATP before it can be used to do work.

Glucose Conversion Bacteria

In much the same way photosynthesis developed through evolution tinkering with energy production, the utilization of glucose utilization in bacteria continued to evolve to be more efficient.



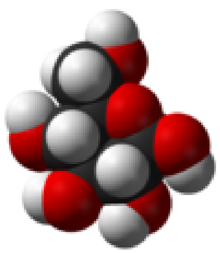
Breakdown of Glucose

Building glucose is an anabolic process that builds single carbon atoms into a 6 carbon molecule by building chemical bonds using energy.

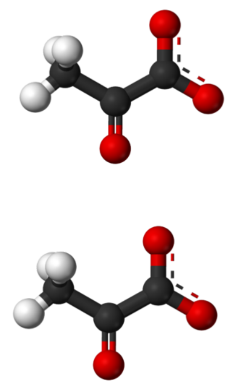
The breakdown is exactly the opposite, or catabolic. A six carbon molecule is broken into individual carbon atoms and energy is released from the broken chemical bonds.

Breakdown of Glucose

The earliest form of glucose breakdown is a catabolic reaction known as **glycolysis.**



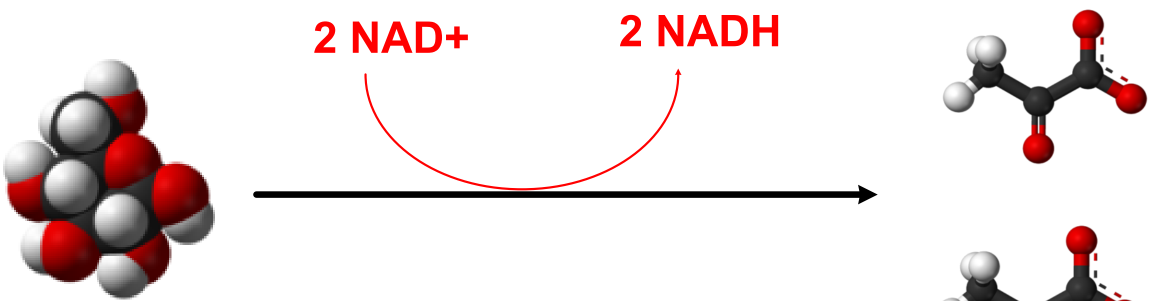
Glucose:
6 carbons



2 pyruvate
3 carbons each

Glycolysis

It requires an **oxidative** molecule known as NAD+.
Oxidative molecules pull electrons from other molecules.
Once NAD+ takes on the electrons from glucose it becomes NADH.

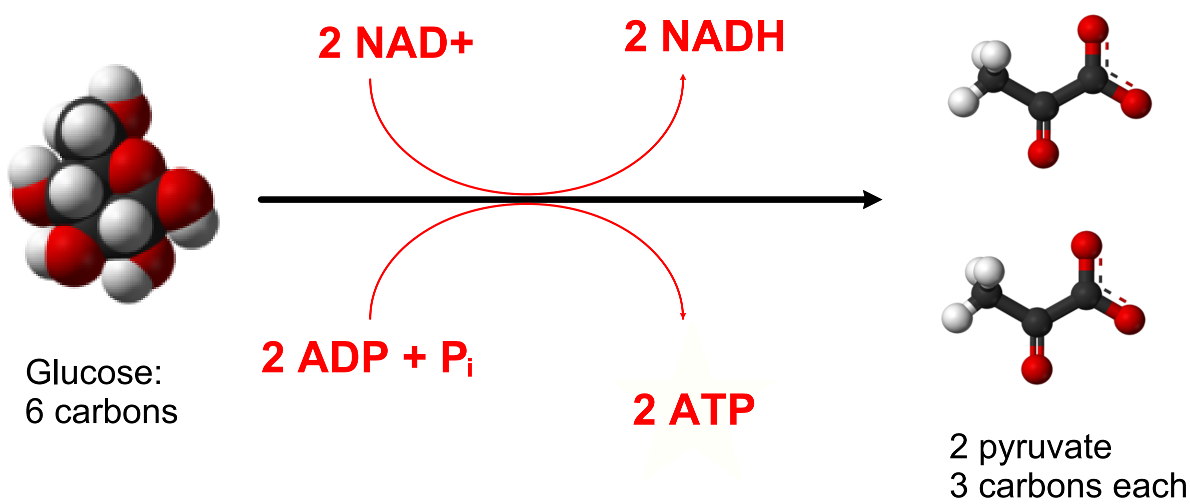


Glucose:
6 carbons

2 pyruvate
3 carbons each

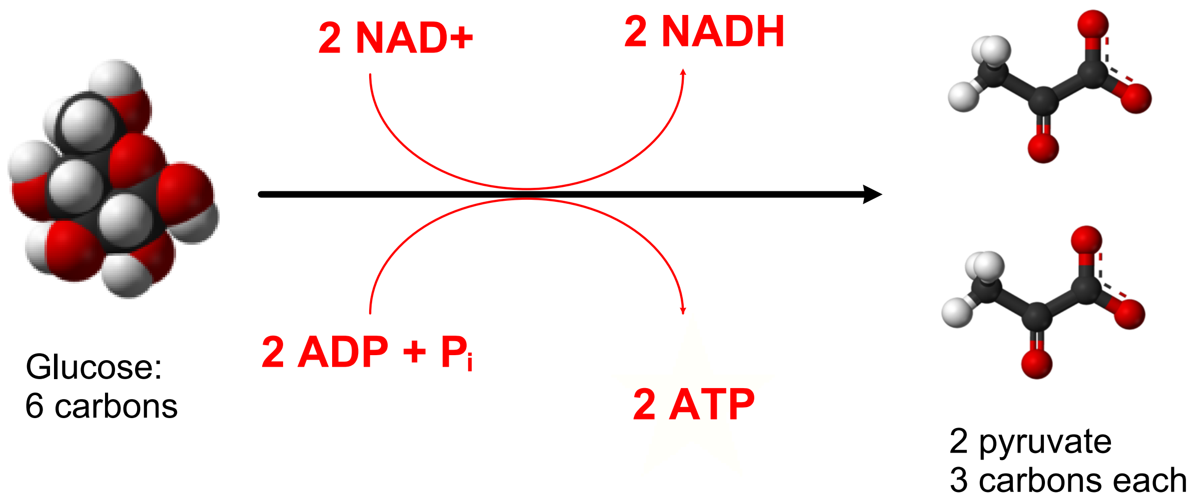
Glycolysis

This process releases energy that can be used to phosphorylate ADP into ATP. In total only 2 ATP are released from a glucose molecule. Not very efficient when you consider it took 18 ATP and many electrons to make the glucose molecule.



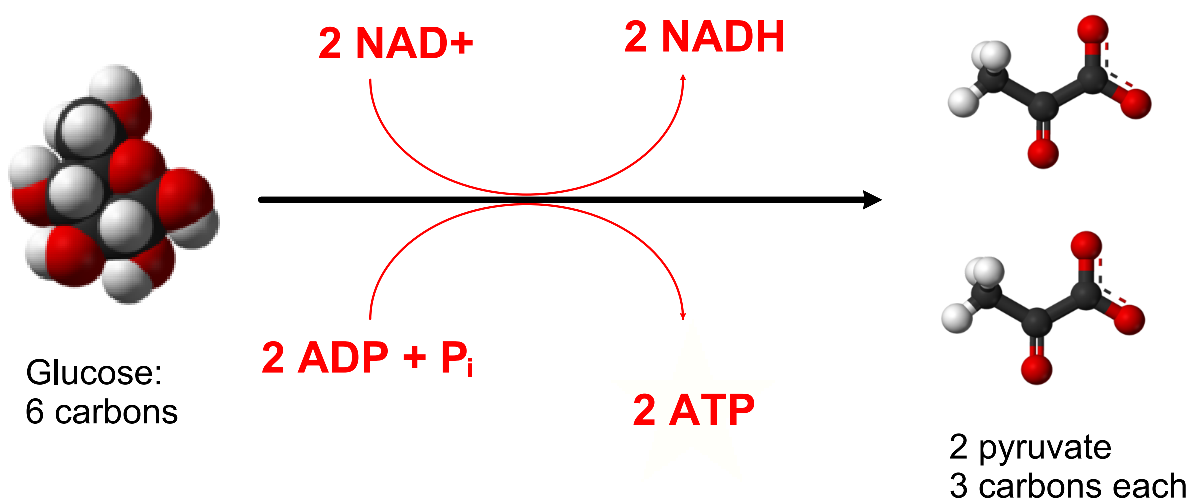
Glycolysis

Another problem, is that you will eventually use up the NAD+ because all the local molecules are being converted to NADH, slowing the process.



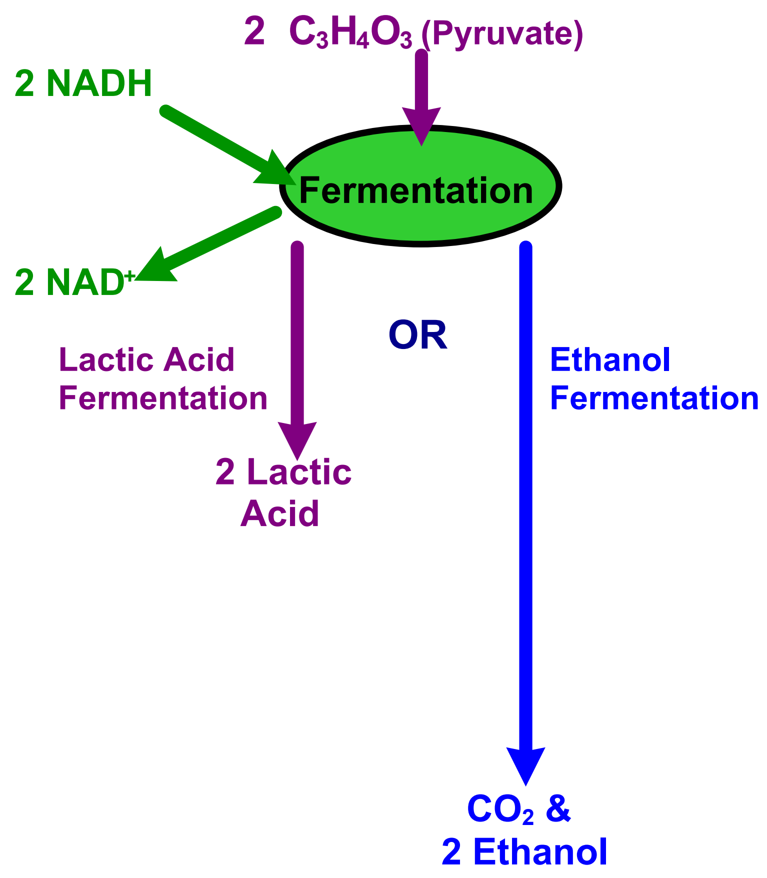
Glycolysis

Evolution's answer to this problem was a process capable of regenerating NAD+. This process is known as **fermentation**.



Fermentation

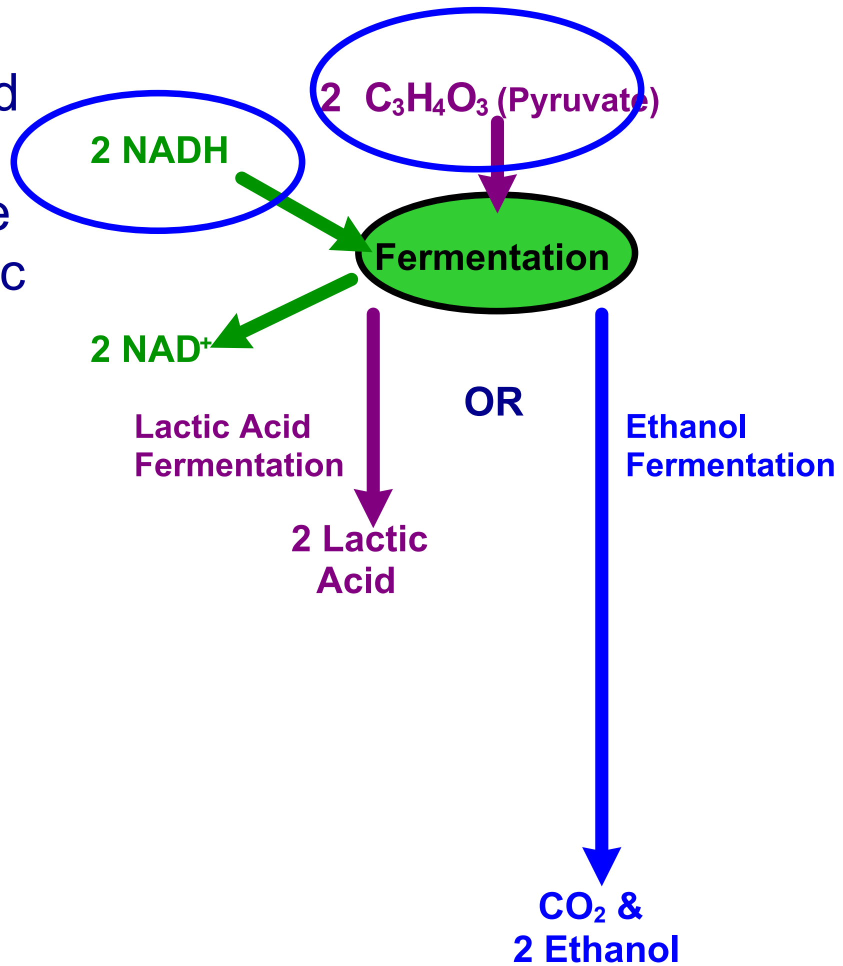
Fermentation breaks down the products of glycolysis so that glycolysis can be repeated with another glucose molecule.



Fermentation

Fermentation breaks down the products of glycolysis so that glycolysis can be repeated with another glucose molecule.

1 glucose molecule had yielded 2 ATPs, 2 Pyruvates and 2 NADHs. That is the input to the fermentation stage of anaerobic respiration.

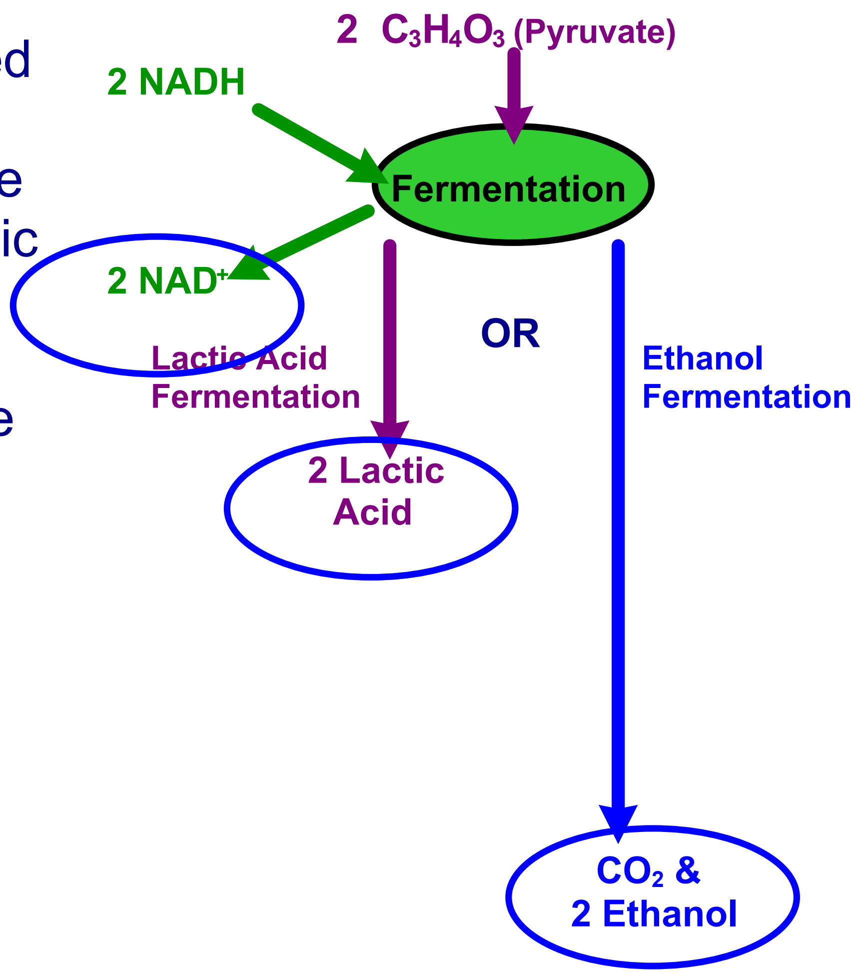


Fermentation

Fermentation breaks down the products of glycolysis so that glycolysis can be repeated with another glucose molecule.

1 glucose molecule had yielded 2 ATPs, 2 Pyruvates and 2 NADHs. That is the input to the fermentation stage of anaerobic respiration.

The pyruvates and NADHs are fermented into 2 NAD^+ and either Lactic Acid or CO_2 & Ethanol.

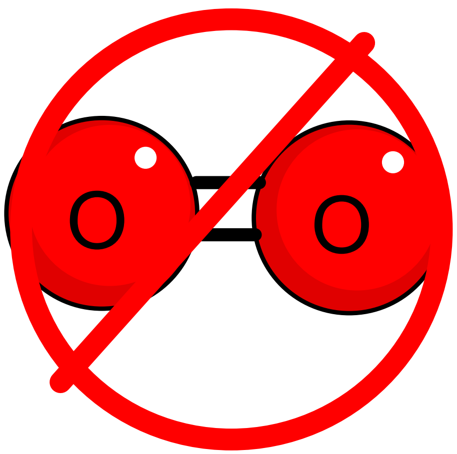


Anaerobic Respiration

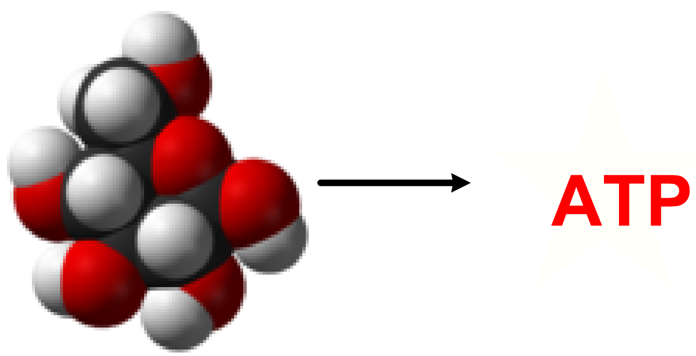
The combined steps of glycolysis and fermentation are collectively known as **anaerobic respiration:**

Anaerobic - because **no oxygen** is used in the process

Respiration - because the breakdown of glucose to produce ATP is known as cellular respiration.



anaerobic



respiration

Anaerobic Respiration

The overall result of anaerobic respiration:

- The input is 1 Glucose + 2 ATP molecules
- The output is 4 ATP molecules (for a net gain of 2 ATP's)

In addition,

- Lactic Acid fermentation results in lactic acid
- Ethanol fermentation results in ethanol and CO_2

14 When a cell has completed glycolysis and lactic acid fermentation, the final products are:

- A I, II, III, IV, V
- B I, II, III, V
- C I, IV, V
- D I, V

I Lactic acid

II Ethanol

III Carbon dioxide

IV NADH

V ATP

answer

Photosynthesis and Oxygen

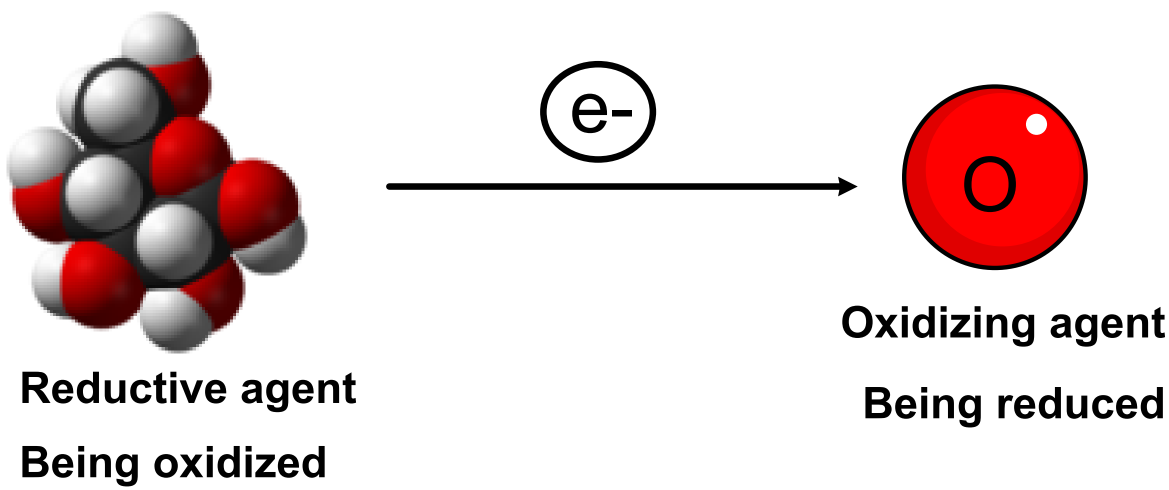
As life continued to use photosynthesis as the primary means of capturing light energy, the by-product oxygen began to build up on planet Earth. Over BILLIONS of years, the early atmosphere was transformed into an oxygen-rich environment.

This phenomenon made the next step in the evolution of glucose breakdown possible.

Oxygen and Oxidation

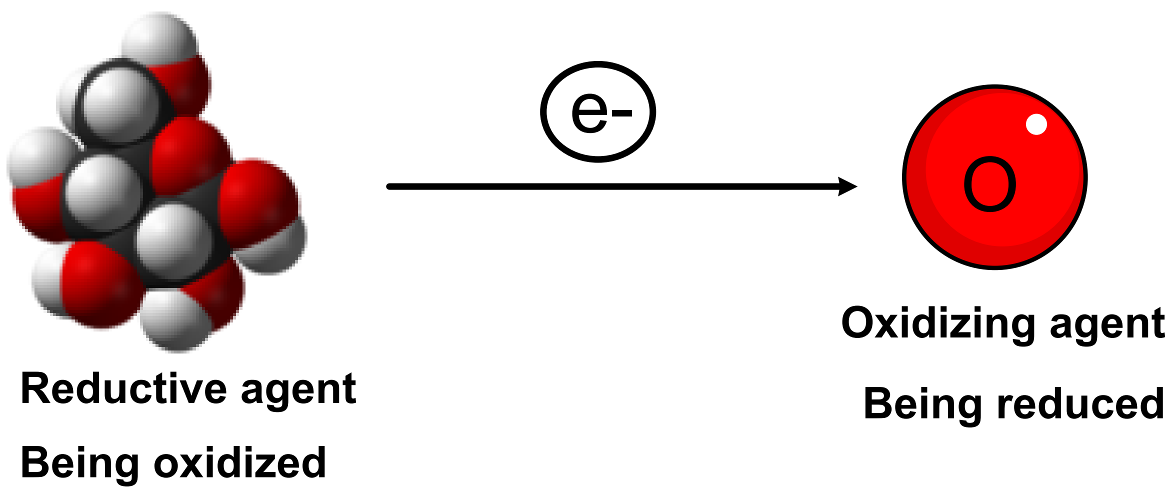
Oxygen is highly **electronegative**, which means it attracts electrons and pulls them from other molecules. This is an oxidative process.

When oxygen takes on new electrons it is **reduced**, this refers to its drop in charge.



Redox

Redox is the term used to describe this process. It notes that one molecule must be reduced in order to oxidize another. It is essentially the transfer of an electron.



Redox

Oxidation

loses electrons

$$6\,CO_2 + 12\,H_2O + light \Rightarrow C_6H_{12}O_6 + 6\,O_2 + 6\,H_2O$$

Reduction

gains electrons

The overall reaction for photosynthesis is a redox reaction.

Redox

Oxidation
loses electrons

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

Reduction
gains electrons

H_2O is oxidized when it is converted to O_2 (it loses an electron).

CO_2 is reduced when it is converted into a sugar (it gains an electron).

H_2O is the reducing agent because it donates and electron.

CO_2 is the oxidizing agent because it accepts an electron.

15 The loss of an electron is __________ and the gain of an electron is ______________.

- A oxidation, reduction
- B reduction, oxidation
- C catalysis, phosphorylation
- D phosphorylation, catalysis

answer

Cellular Respiration with Glucose and Oxygen

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Energy in this equation is in 2 forms:
- ATP for use in coupled reactions
- Heat released as entropy

This reaction is a redox reaction.
- Which molecules are being reduced?
- Which molecules are being oxidized?

Cellular Respiration with Glucose and Oxygen: Aerobic Respiration

$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$ + Energy

This equation represents the overall reaction, but it is happening in three stages.

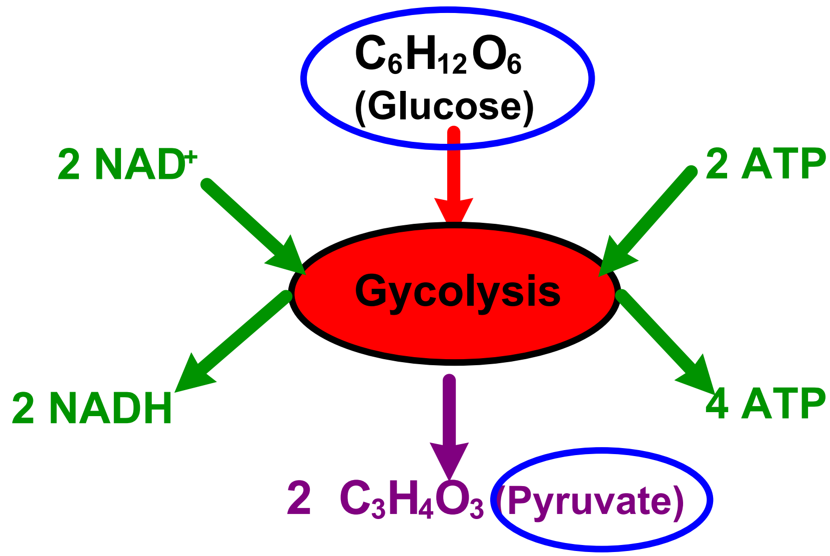
1) Glycolosis - the splitting of glucose into 2 pyruvic acid molecules **in the cytoplasm** of a cell.

2) The citric acid cycle - the stripping of electrons from the pieces of the glucose molecule **in the mitochondria.**

3) Oxidative phosphorylation - Using the electrons to set up a concentration gradient and energize the formation of ATP**in the mitochondria.**

Glycolysis

This is the first stage of aerobic respiration.



Counting the Molecules

What is the net number of molecules present after glycolysis of 1 glucose molecule?

(Click on the box to reveal the answer)

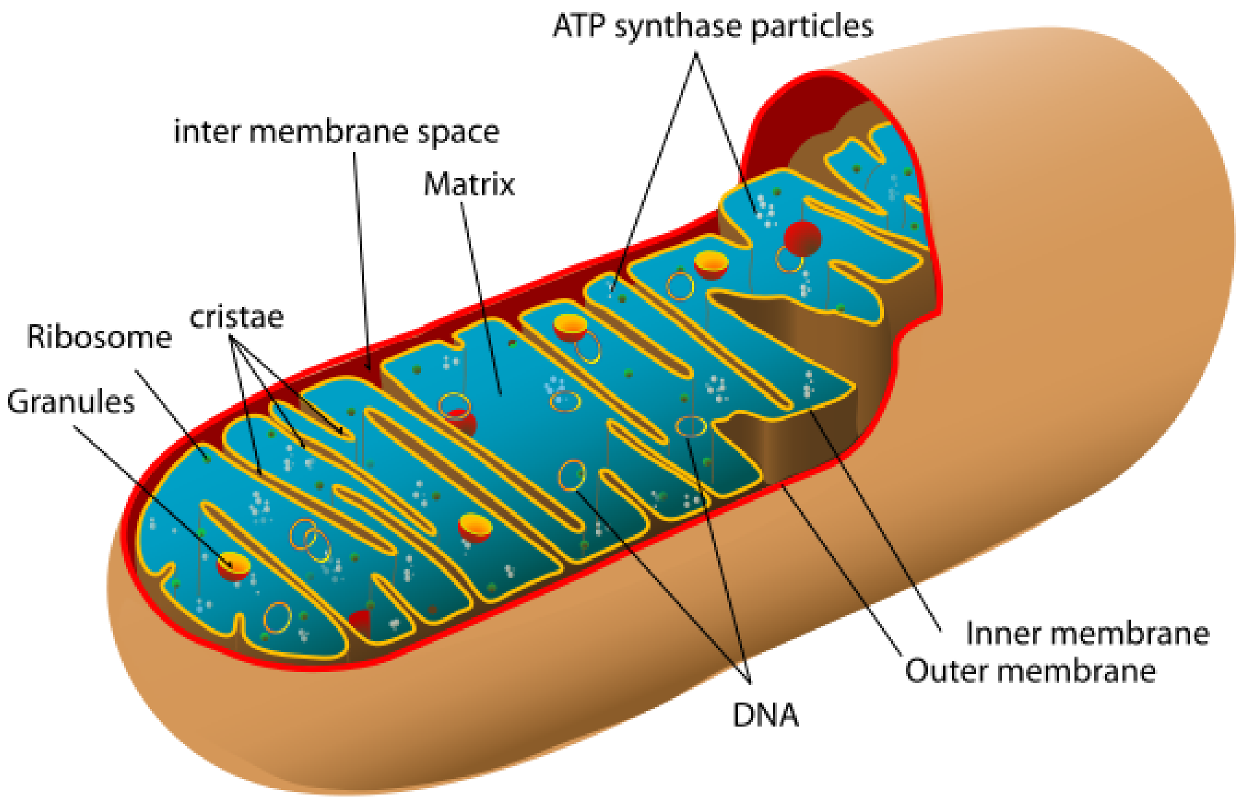
ATP

Carbon Dioxide

NADH

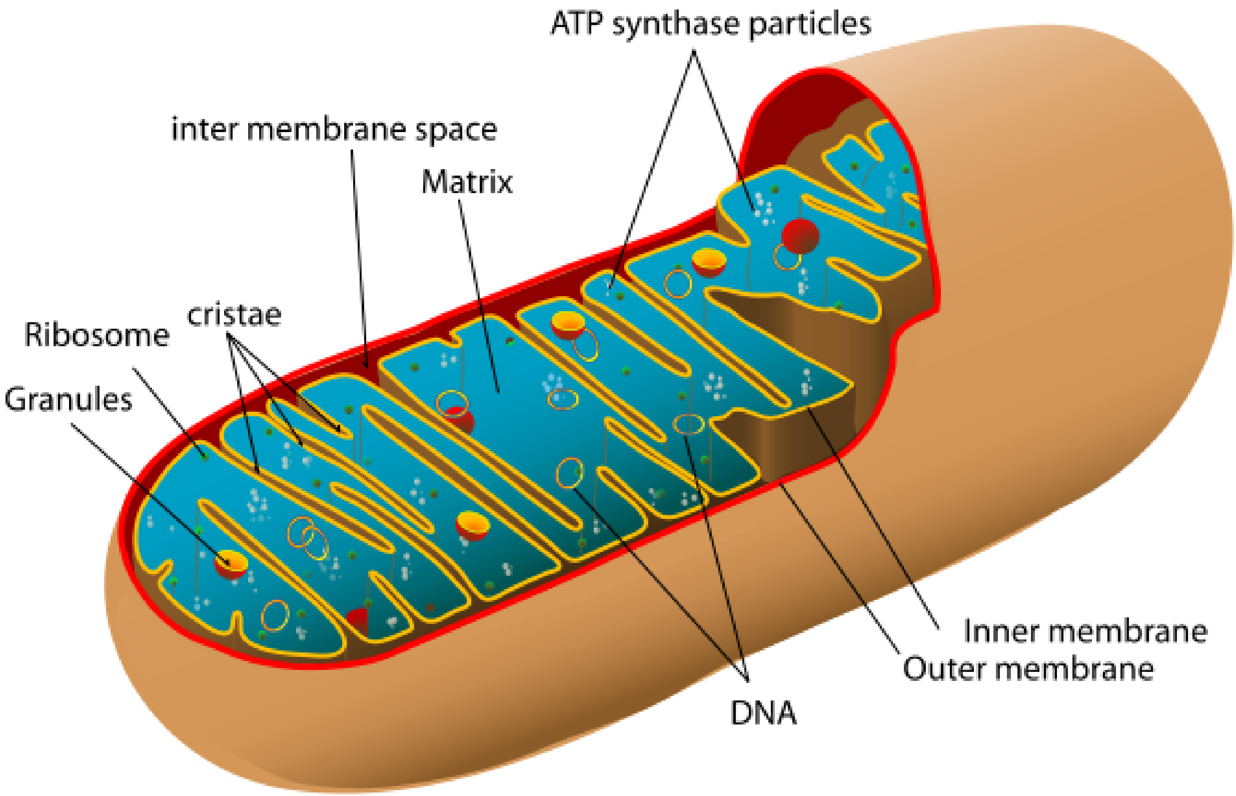
Mitochondria

In the same way that the prokaryotic chloroplast became part of the more complex eukaryotic cell, mitochondria also became part of the eukaryotic cell. This evolutionary process is known as endosymbiosis.



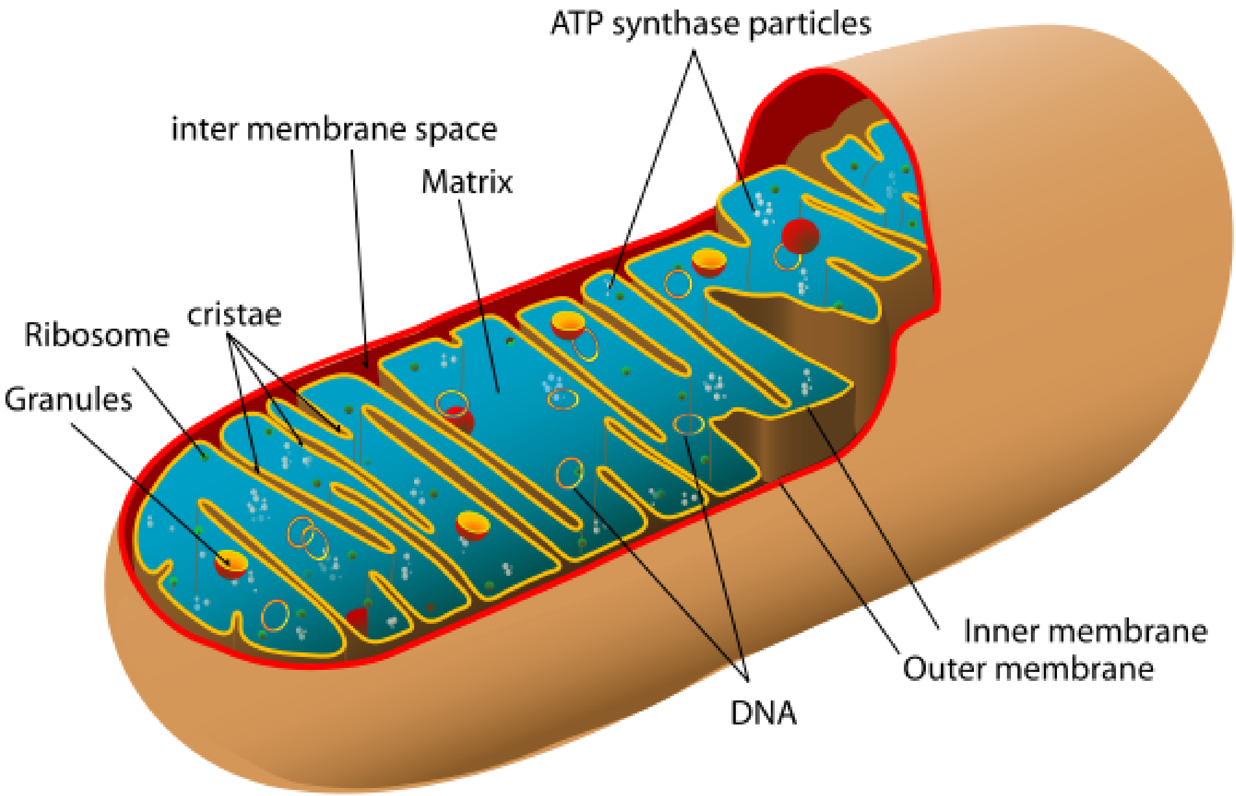
Mitochondria

Mitochondria specialized in the breakdown of glucose into ATP, or cellular respiration. They represent the state of the art in glucose breakdown in biological machinery.



Mitochondria

They are extremely efficient, producing about 36 ATPs per glucose molecule by using the oxidizing power of oxygen.



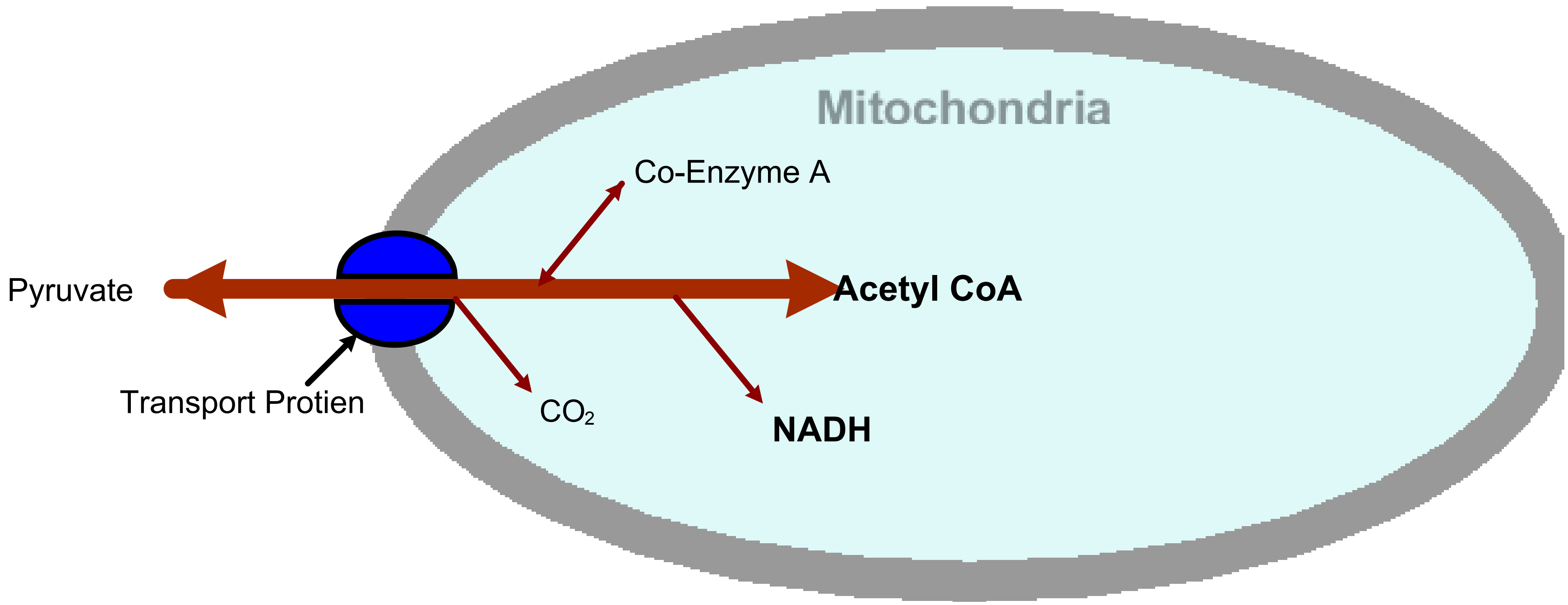
Entering the Mitochondria

Pyruvate will be broken down further in the citric acid cycle. First the pyruvate must enter the mitochondria which is the site of this cycle.

In the process of transport, a carbon atom is striped from each of the pyruvate molecules. The carbon leaves the system as carbon dioxide. **Co-Enzyme A** is combined with the remainder of the pyruvate molecule.

The pyruvate is thus changed into a molecule called **acetyl CoA** and 2 more molecules of NADH are produced. This is known as the Pyruvate Dehydrogenase process.

Entering the Mitochondria



A transport protein in the membrane of the mitochondria is utilized to transport the pyruvate and help convert it to acetyl CoA.

Counting the Molecules

How many of each of the following molecules are produced from glycolysis and the uptake of pyruvate into the mitochondria per glucose molecule?

(Click on the box to reveal the answer)

ATP

Carbon Dioxide

NADH

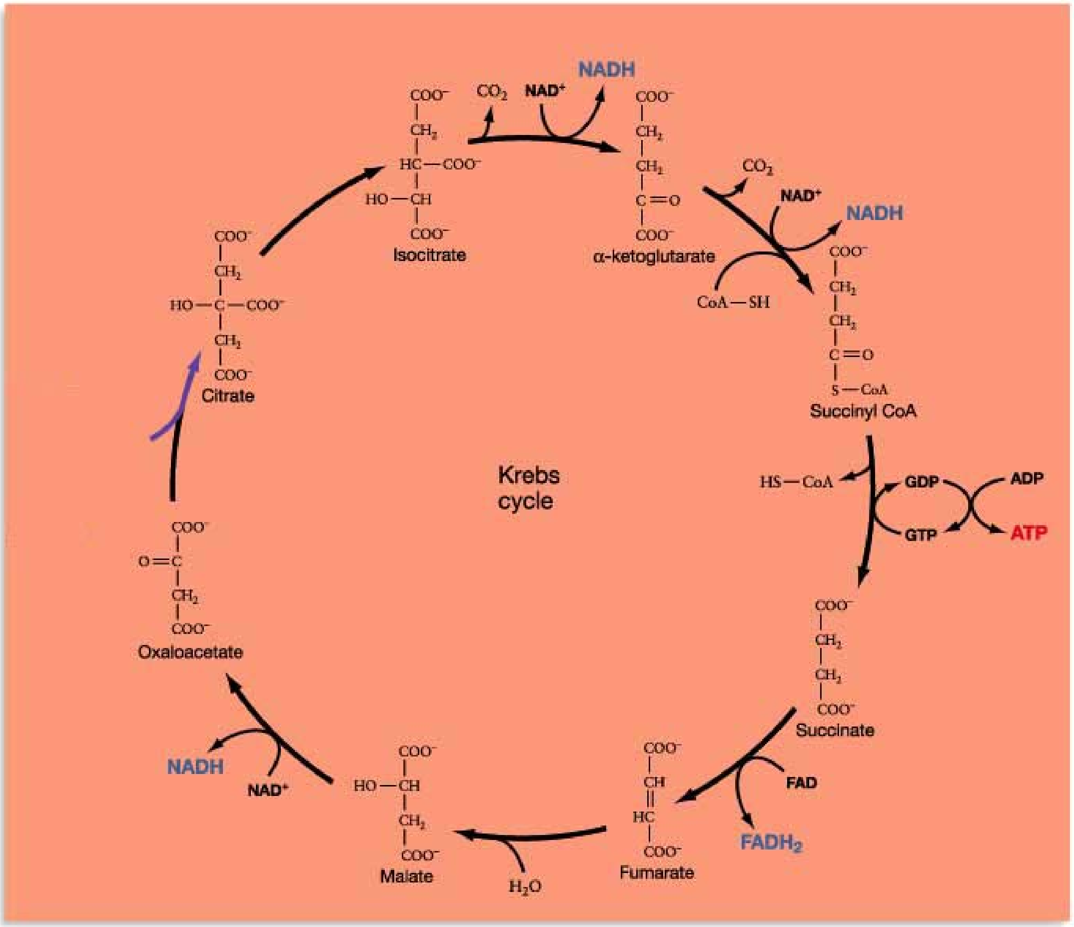
Citric Acid Cycle

The Citric Acid Cycle, sometimes called the Krebs cycle, takes place within the mitochondrial matrix.

It is the cycle that finishes the complete breakdown of the glucose molecule.

It is a metabolic pathway made up of 8 steps and produces carbon dioxide, ATP, NADH and another molecule called **$FADH_2$**

The Citric Acid Cycle

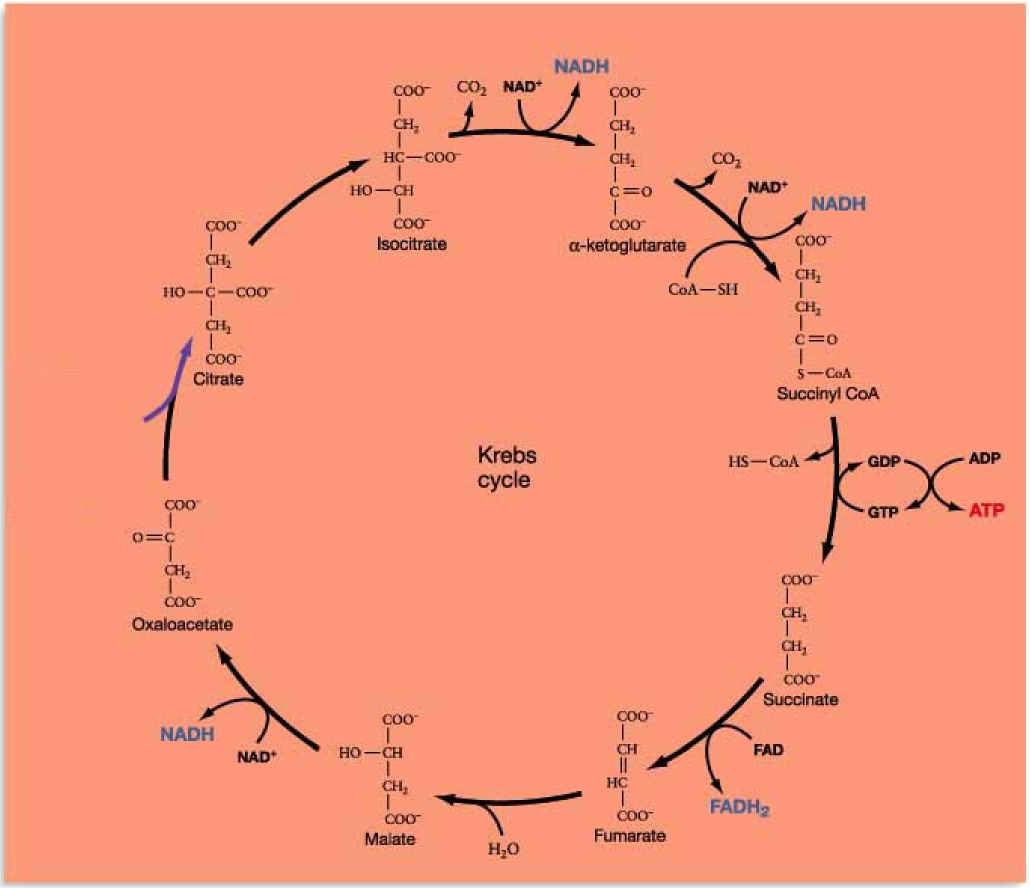


This shows one cycle, which is due to one Acetyl Co-A molecule.

To account for one glucose molecule, two cycles are needed.

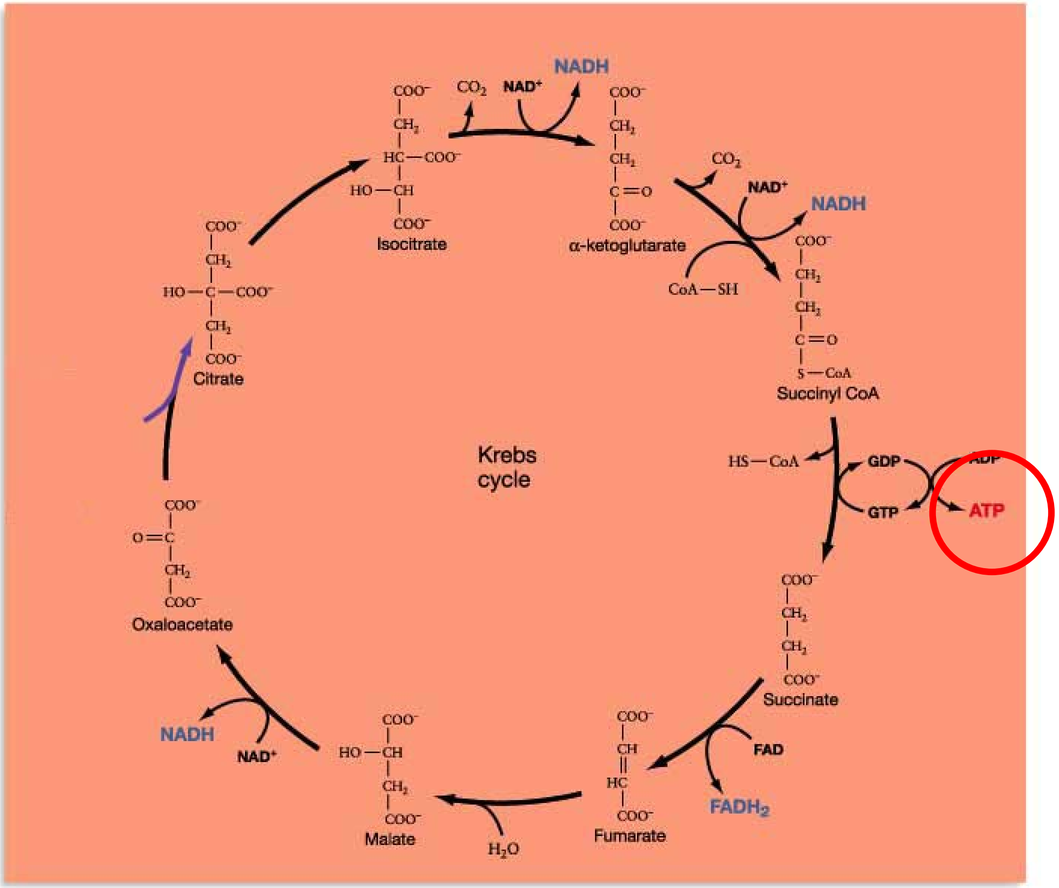
Let's tally up the output for one cycle to confirm our results.

The Citric Acid Cycle



This is one turn of the cycle, due to 1 Acetyl Co-A. Note the production of:

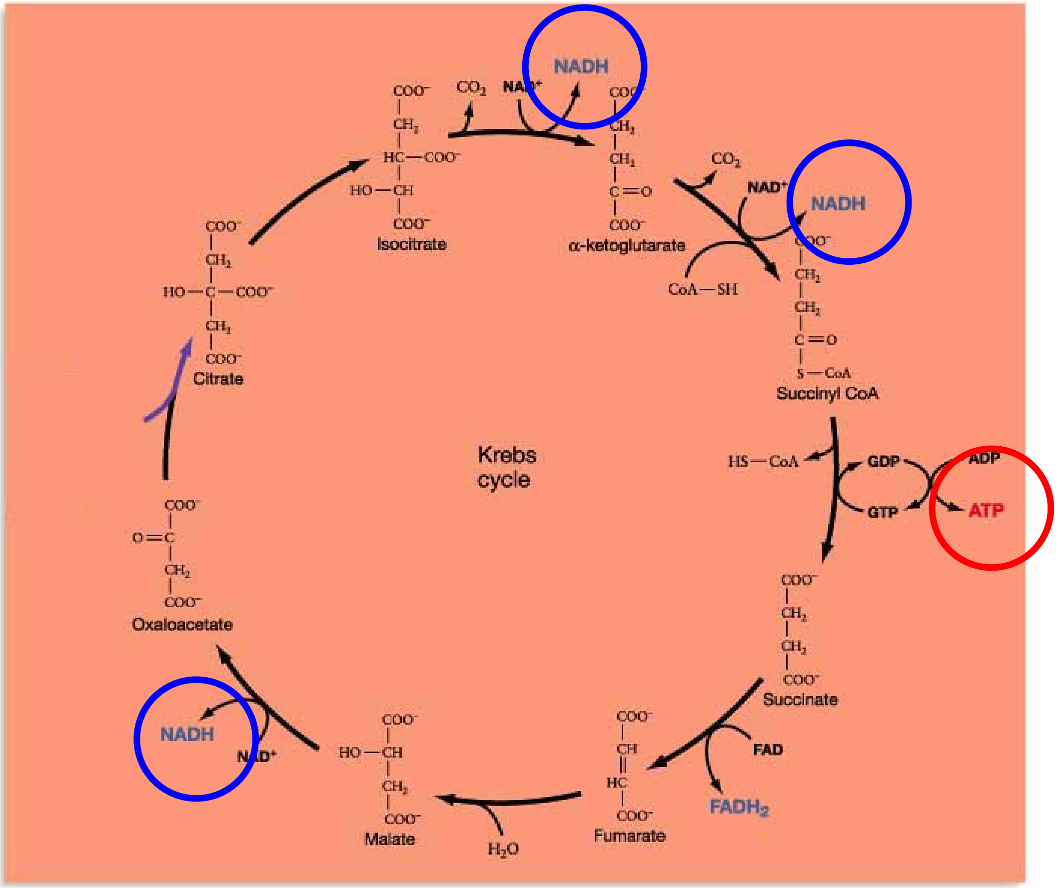
The Citric Acid Cycle



This is one turn of the cycle, due to 1 Acetyl Co-A. Note the production of:

1 ATP

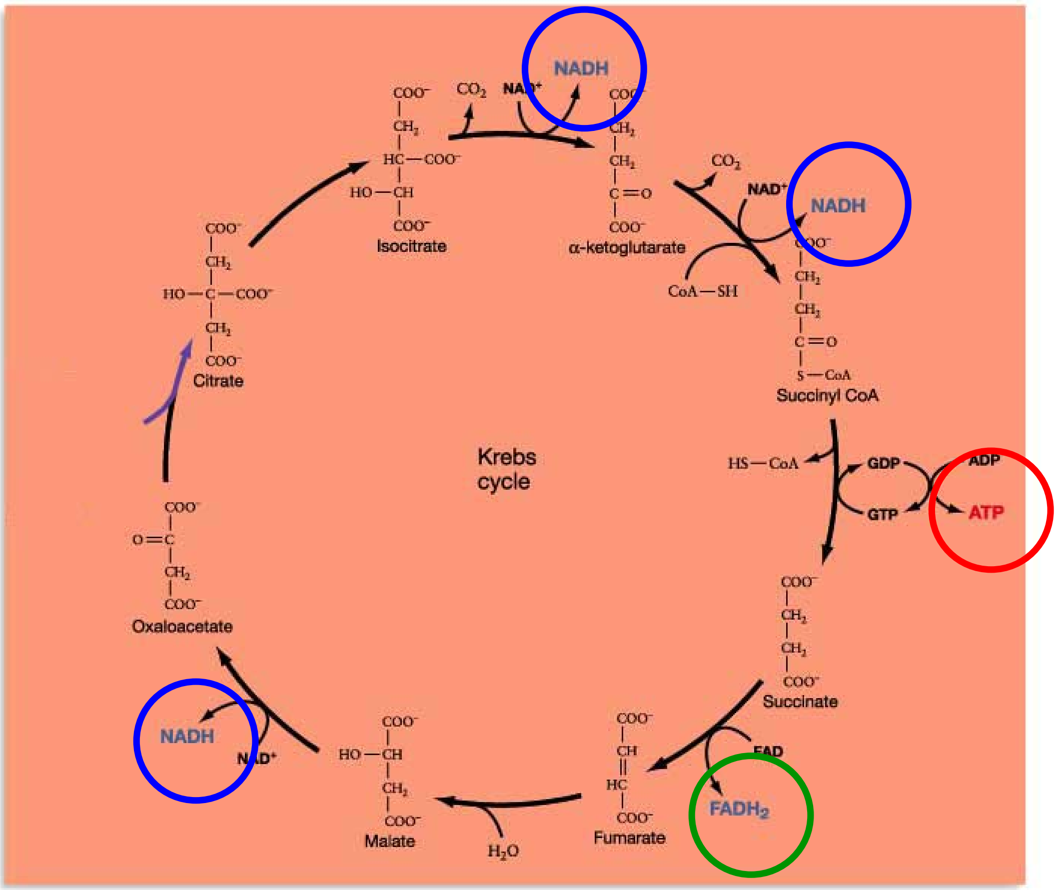
The Citric Acid Cycle



This is one turn of the cycle, due to 1 Acetyl Co-A. Note the production of:

1 ATP
3 NADH

The Citric Acid Cycle



This is one turn of the cycle, due to 1 Acetyl Co-A. Note the production of:

1 ATP
3 NADH
1 $FADH_2$

How many CO_2 molecules are produced in one turn of the cycle?

Counting the Molecules

How many of each of the following molecules in total are produced from the process of glycolysis, pyruvate decarboxylase Process, and the citric acid cycle per glucose molecule?

(Click on the box to reveal the answer)

ATP

Carbon Dioxide

NADH

$FADH_2$

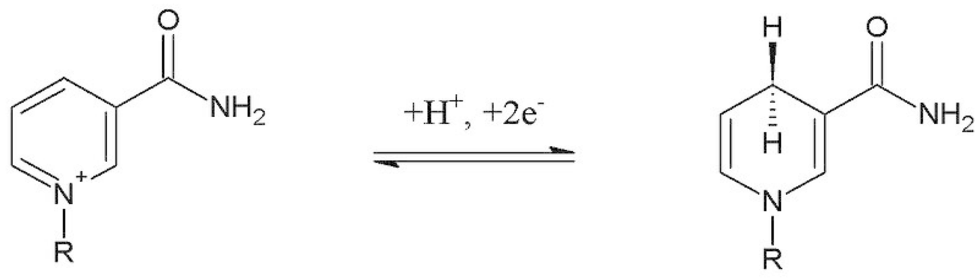
NADH and $FADH_2$

These 2 molecules are used to make the bulk of the ATP produced by aerobic cellular respiration in the last step.

They have been harvesting electrons, reduced, as the glucose molecule has broken down through the previous processes.

They will now shuttle those electrons to be used in oxidative phosphorylation where they will offload the electrons, becoming oxidized.

NADH and FADH$_2$

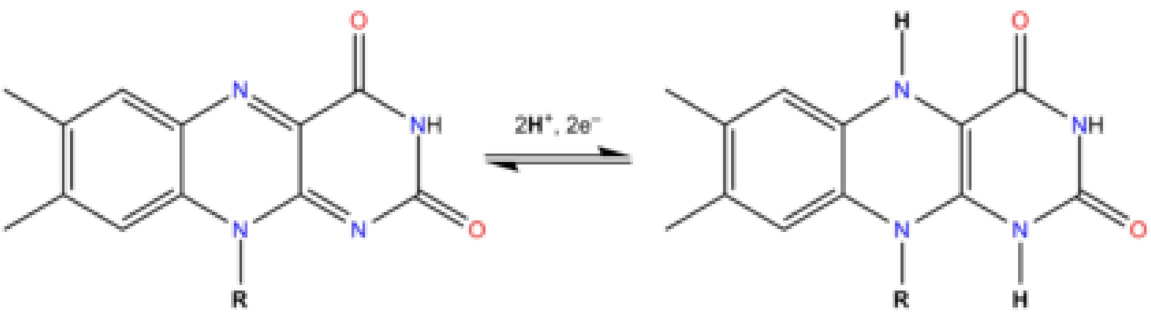


NAD$^+$

NADH

NAD$^+$ is the oxidized version of NADH

FAD is the oxidized version of FADH$_2$



FAD

FADH2

16 NAD+ is the reduced from of NADH?

- ○ True
- ○ False

answer

Oxidative Phosphorylation

This is the final process of aerobic cellular respiration.

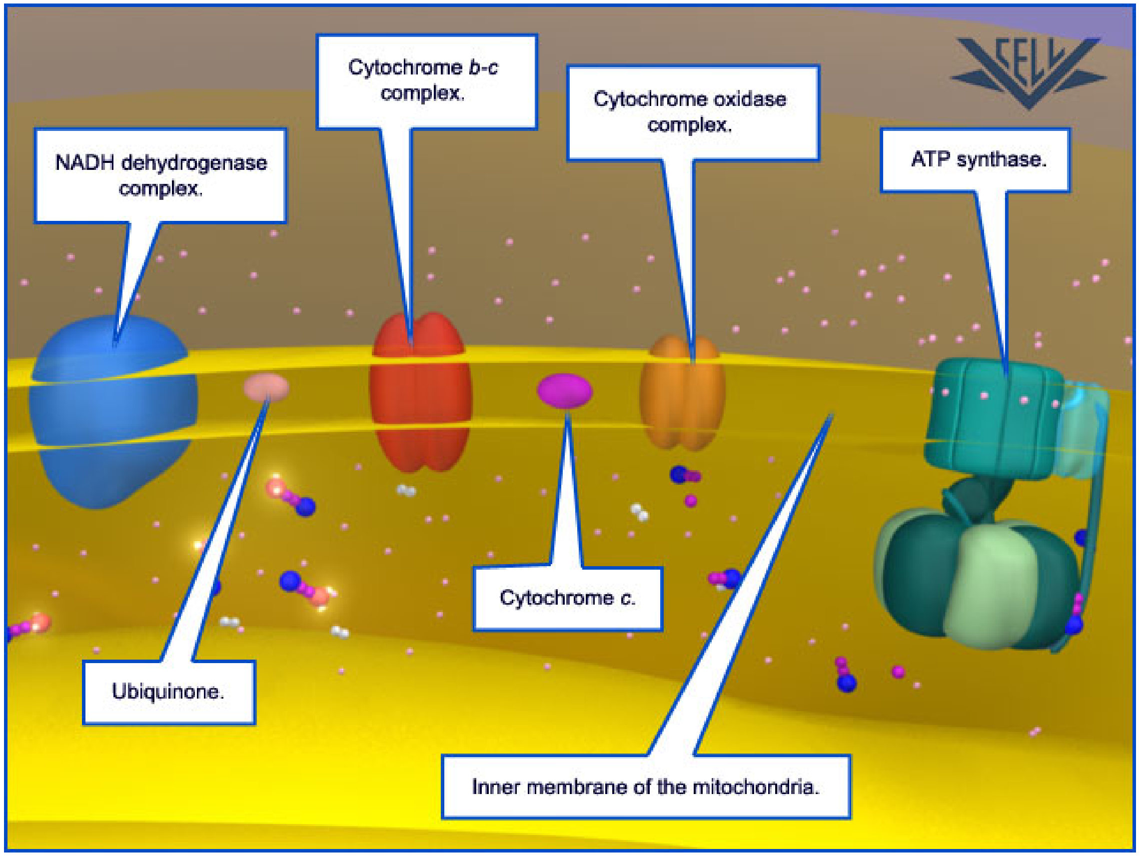
The energy from the electrons harvested from the previous steps is used to set up a proton concentration gradient across the inner membrane of the mitochondria. Then the gradient is used to power the production of **32 ATP** molecules.

This takes place in two steps:
1) **Electron transport chain** - uses the energy in the electrons to actively transport protons against their gradient.

2) **Chemiosmosis** - protons pass through a passive transport molecule that is also an enzyme called **ATP synthase** with their gradient.

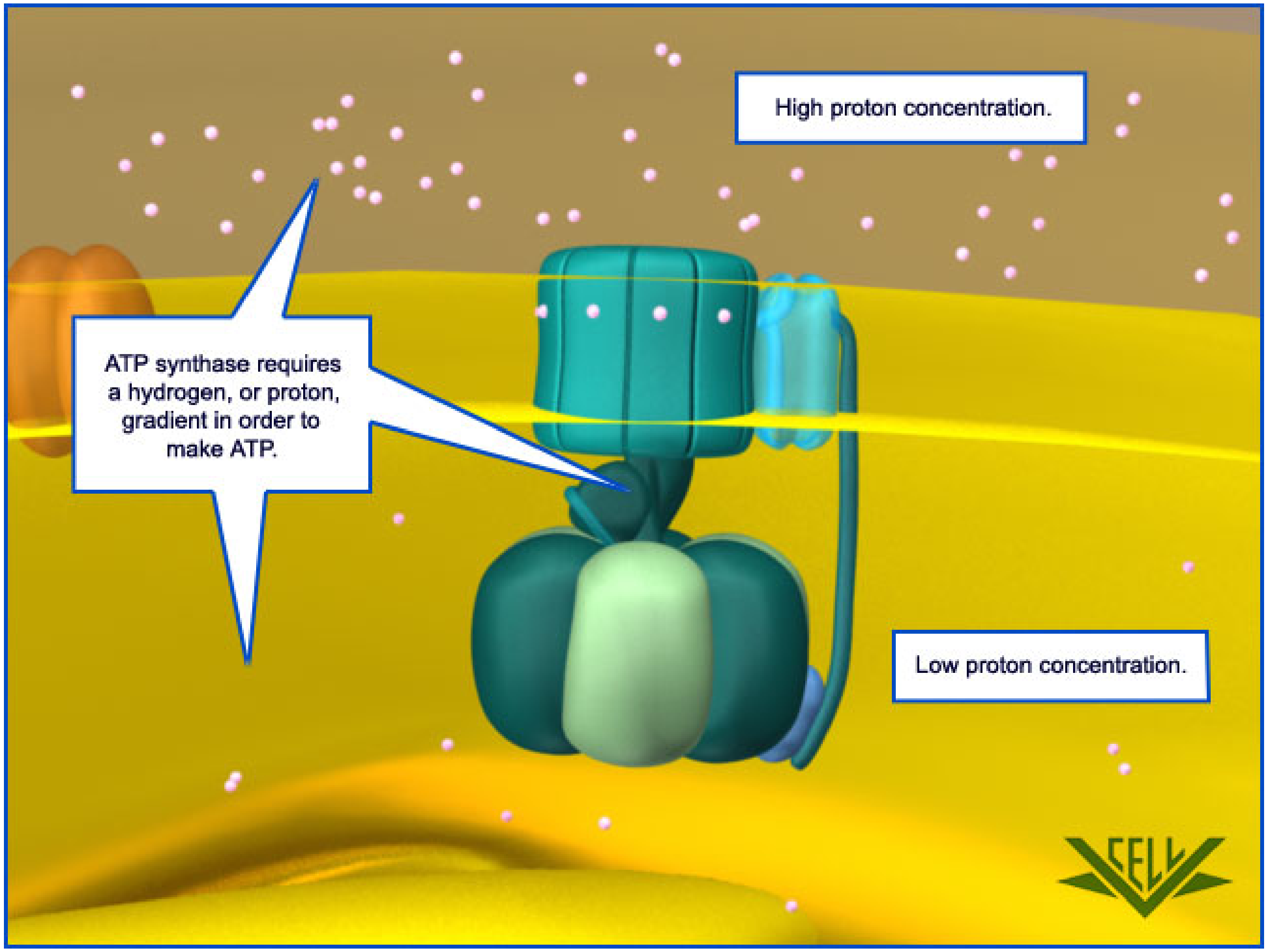
Electron Transport Chain

Click here for a video of the Electron Transport Chain



Chemiosmosis

Click here for a video of Chemiosmosis



Counting the Molecules

How many of each of the following molecules are present after the complete breakdown of a glucose in aerobic respiration?

(Click on the box to reveal the answer)

ATP

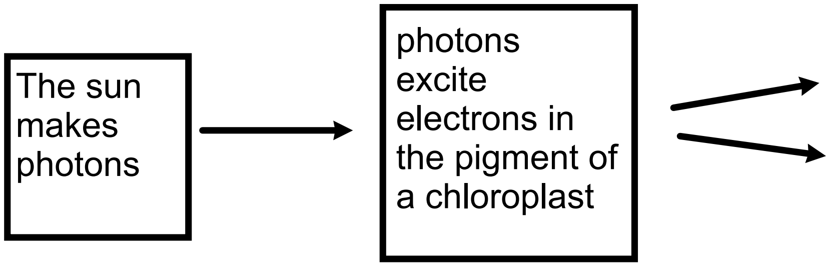
Carbon Dioxide

NADH

$FADH_2$

Summarizing the Energy Flow of Life

Working in small groups, create a flow chart that shows the flow of energy through a cell. Start like this...

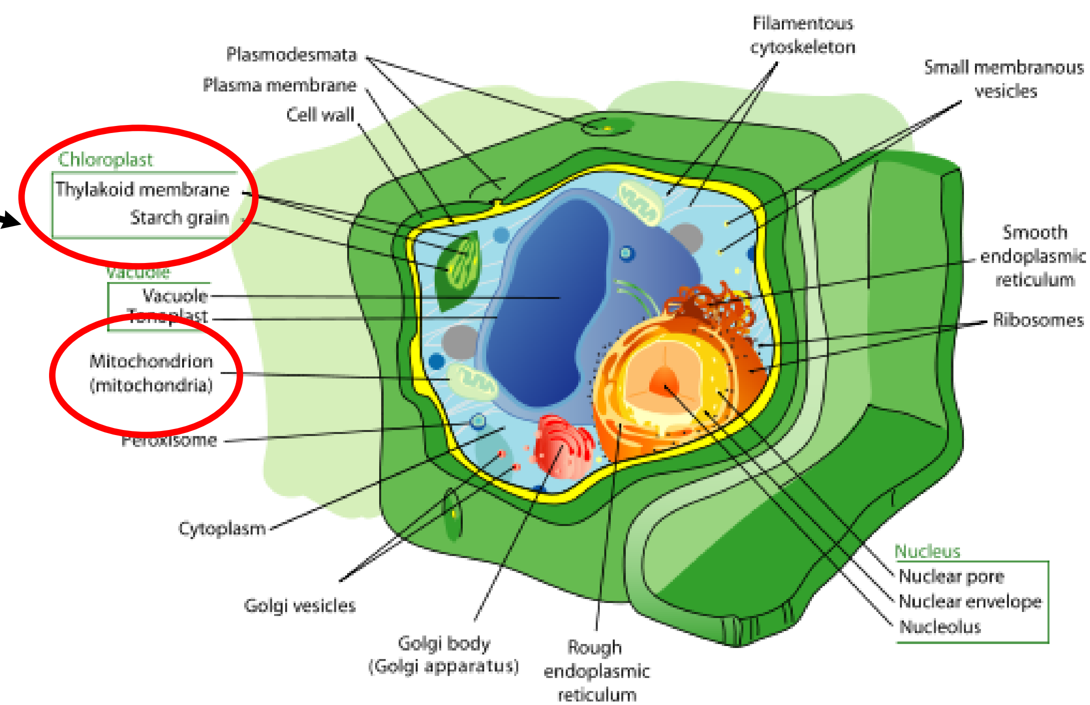


Directions Continued...

Summarizing the Energy Flow of Life

To help frame this activity, think of a cell in a leaf which has both chloroplasts and mitochondria. How does this leaf cell produce the chemical energy that will directly do work in the cell?

Be as detailed as possible. The groups should combine their flowcharts into one detailed study guide for the whole class.



Bioenergetics

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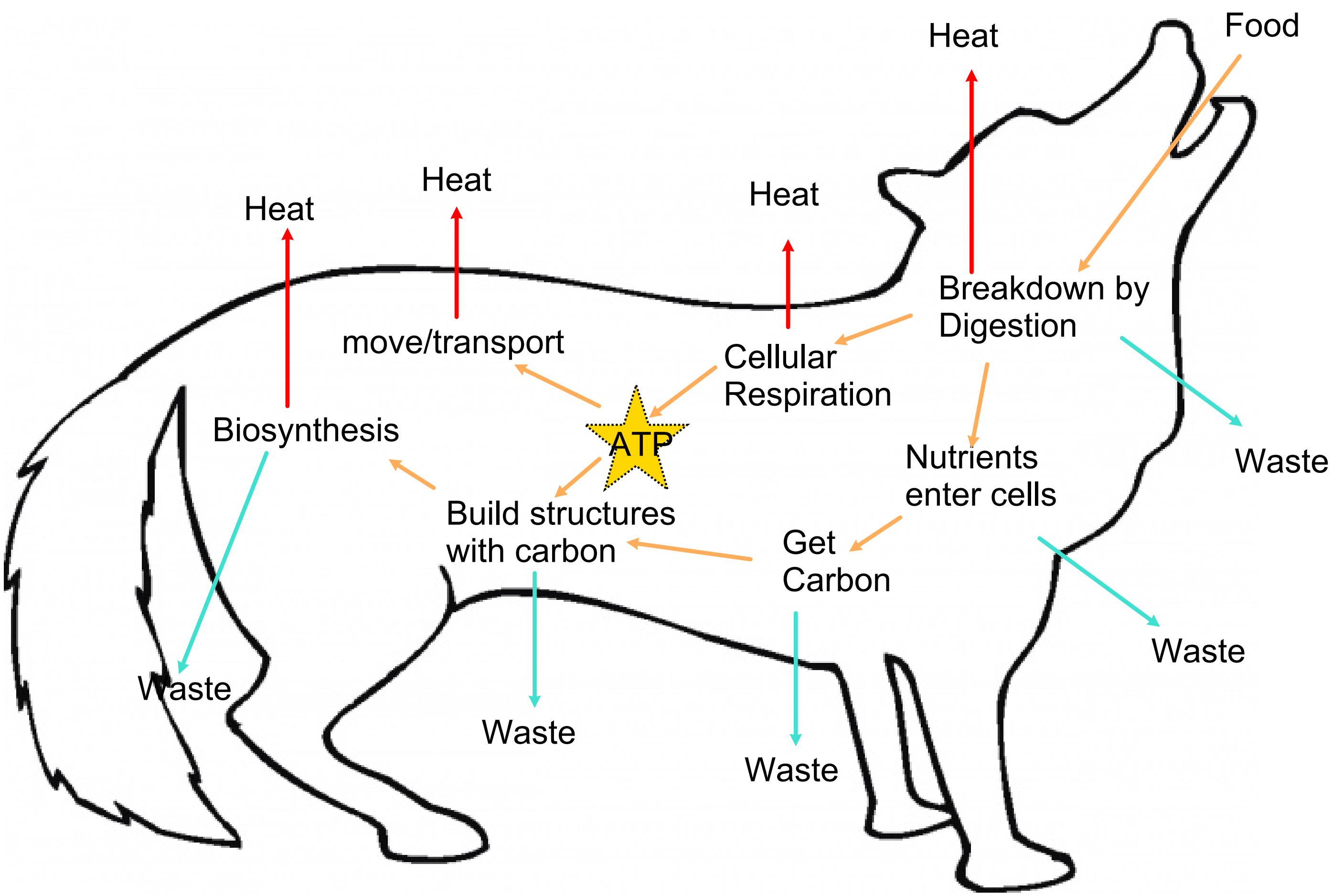
Bioenergetics

Gathering or managing energy is the first consideration for any species because without efficient **bioenergetics** all other metabolic processes will fail.

For this reason most specializations of biological systems are the result of adaptations to gather energy.

Bioenergetics

General view of energy management in animals.

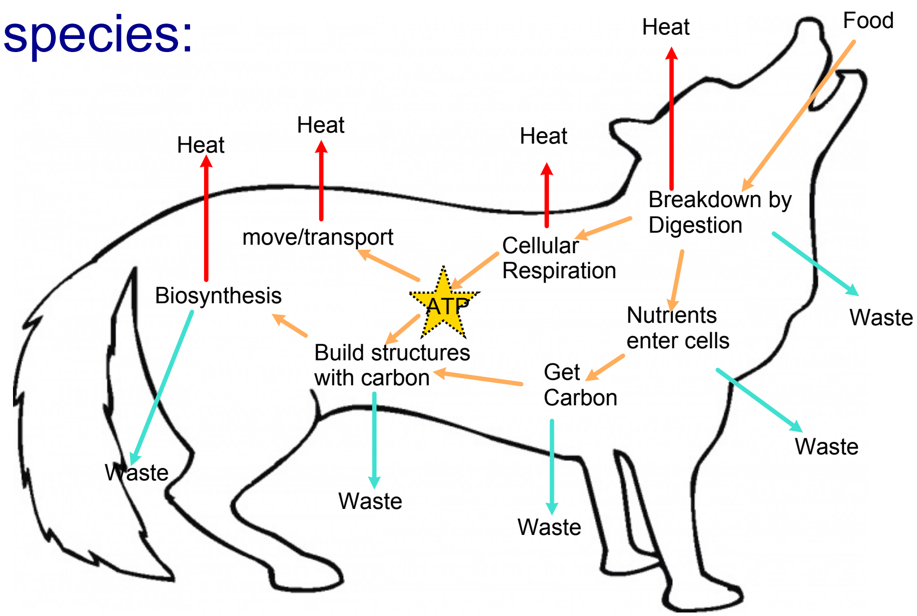


Bioenergetics

All organisms must maximize efficiency in the getting and using of food for energy. However, each species achieves this with a different **energy strategy**. There are 2 factors that contribute to the bioenergetics of any species:

Evolution - Which variations became available to the species.

Environment - Which adaptations were effective in the environment.



Energy Strategies

Lets compare 2 different animal species and examine their energy strategies.

Species 1: The wolffish is generally about 5 feet long and weighs about 40 pounds. It has an eel- like body and swims slowly. It has six fan like teeth, and three rows of crushing teeth.They like cold water Their blood contains a natural antifreeze. Their favorite food is urchins and green crabs.

Energy Strategies

Lets compare 2 different animal species and examine their energy strategies.

Species 2:

A lion is one of the largest members of the cat family. They typically live in Africa. Lions are animals that usually hunt in groups. Weights for adult lions are around 500 lb. Lions spend much of their time resting and are inactive for about 20 hours per day. They spend an average of two hours a day walking and 50 minutes eating. They eat large herbivores.

Energy Strategies

Using the information on the previous slides and information you already know about fish and lions, draw a chart that examines the similarities and differences between the energy strategies of these 2 animals.

Once you have a list explain how the differences are adaptations to the given environment.

Energy Strategies

One of the major differences between these and other animals is the overall strategy of being endothermic, warm blooded, or ectothermic, cold blooded.

Each of these energy strategies has strengths and weaknesses.

Ectotherms

Ectotherms are "cold blooded" animals. Most animals fit into this category.

Most of their heat energy escapes into the environment so their body temperature is close to that of their surroundings. Activity of these animals is drastically affected by temperature changes in their environment. When outside temperatures rise, they become more active. When external temperatures drop, they become more sluggish in their activity.

Ectotherms

Cons:
When an animal is cold the chemical reactions that drive metabolic pathways slow down considerably. This means when they are cold they cannot move quickly. Cold blooded animals must rely on environmental factors to supply heat or have a warm up period before they can move at a faster speed.

When they are cold they are more vulnerable to predators because they cannot react quickly to get away.

Ectotherms

Pros:
Since these animals do not have to maintain a high body temperature they can minimize the amount of cellular respiration necessary for generating heat and staying alive. This means they require less food and can expend even less energy because they minimize the need to hunt for food.

17 Which of the following are ways an ectotherm might regulate its internal body temperature?

- ☐ A Move into underground burrows to dissipate heat on a hot day
- ☐ B Change body color from dark to light when temperatures rise outside
- ☐ C Heat from arterial blood warms the cold venous blood returning to the heart
- ☐ D Position their bodies to maximize solar radiation in cold climates

Endotherms

Endotherms are the "warm blooded" animals, such as mammals and birds.   These animals have evolved homeostatic mechanisms that allow them use the heat they generate.

They have adaptations such as hair, fur, feathers, and fat that help prevent heat loss. They maintain constant body temperatures that are higher than their environment.

Endotherms

Cons:
Warm blooded animals burn far more **calories** (unit of energy) than ectotherms of the same mass. This means they must hunt and constantly find new food sources to stay alive.

Endotherms

Pros:
Warm blooded animals never need to warm up. At a moment's notice they can be at maximum metabolism which means they are prepared to hunt or run from predators all the time.

These hyenas hunt in packs and defend there hunting territories constantly. They must be on guard for their natural predators, lions or wild dogs.

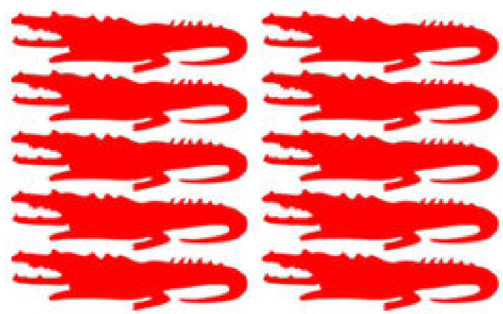
Evolution of Endothermy

The uniform temperatures of the seas suggest that endothermy did not evolve until dry land was invaded by the early reptilian ancestors of bird and mammals.

Ecto v Endo

A lion must eat approximately 50 antelopes or other large herbivore per year to maintain his warm blooded metabolism.

This much food would sustain 10 cold blooded alligators of the same weight as the lion.



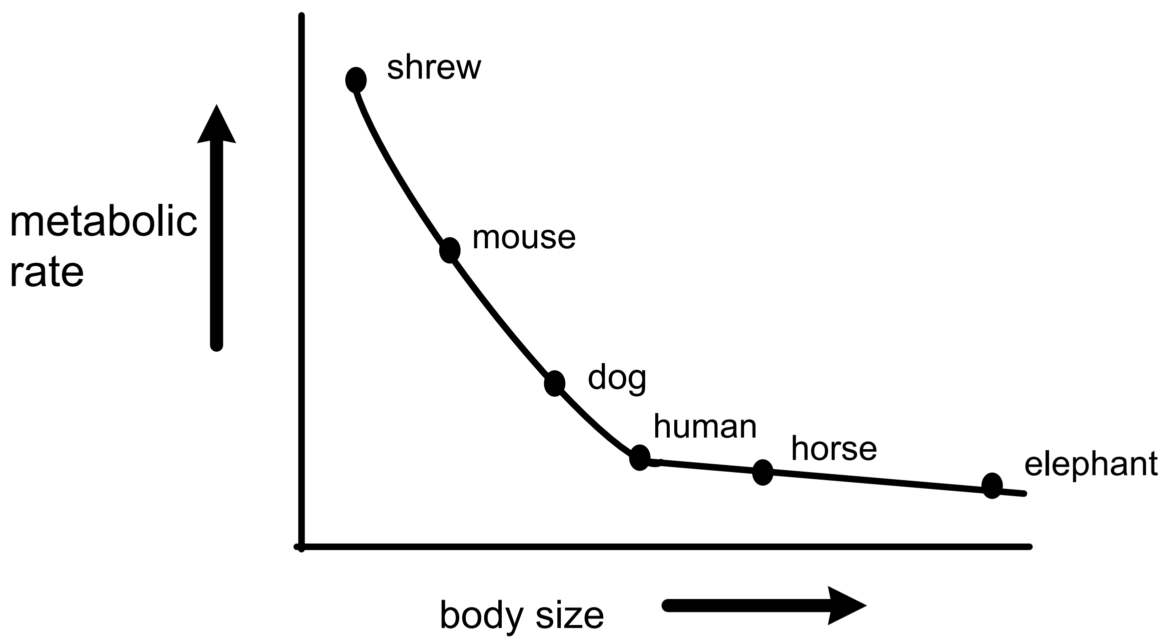
Muscle Mass and Heat

The major source of heat for endotherms is the large muscle mass covering their entire body. Muscle contractions may account for more than 80% of the total heat produced.

Shivering is a bodily function in response to early hypothermia in warm-blooded animals. When the core body temperature drops, the shivering reflex is triggered to maintain homeostasis. Muscle groups around the vital organs begin to shake in small movements in an attempt to create warmth by expending energy.

Body Size and Metabolic Rate

On a specific basis (per gram of body weight), smaller animals produce more heat than larger animals. This inverse relationship between body size and metabolic rate is universal and is demonstrated by both endotherms and ectotherms.



18 Organisms that can regulate and maintain a constant internal body temperature can be called homeotherms or endotherms.

- True
- False

19 Unlike ectotherms, endotherms

- A Gain or lose significant amounts of heat by way of the environment
- B Are sluggish and have lower metabolic rates in colder temperatures
- C Live in water that stays at a constant temperature
- D Maintain a fairly stable body temperature regardless of external conditions

20 Which of the following is a method endotherms use to regulate internal body temperature?

- ☐ A Changing color
- ☐ B Burrowing under ground
- ☐ C Shivering
- ☐ D Expanding folds of skin