



About Science Prof Online PowerPoint Resources

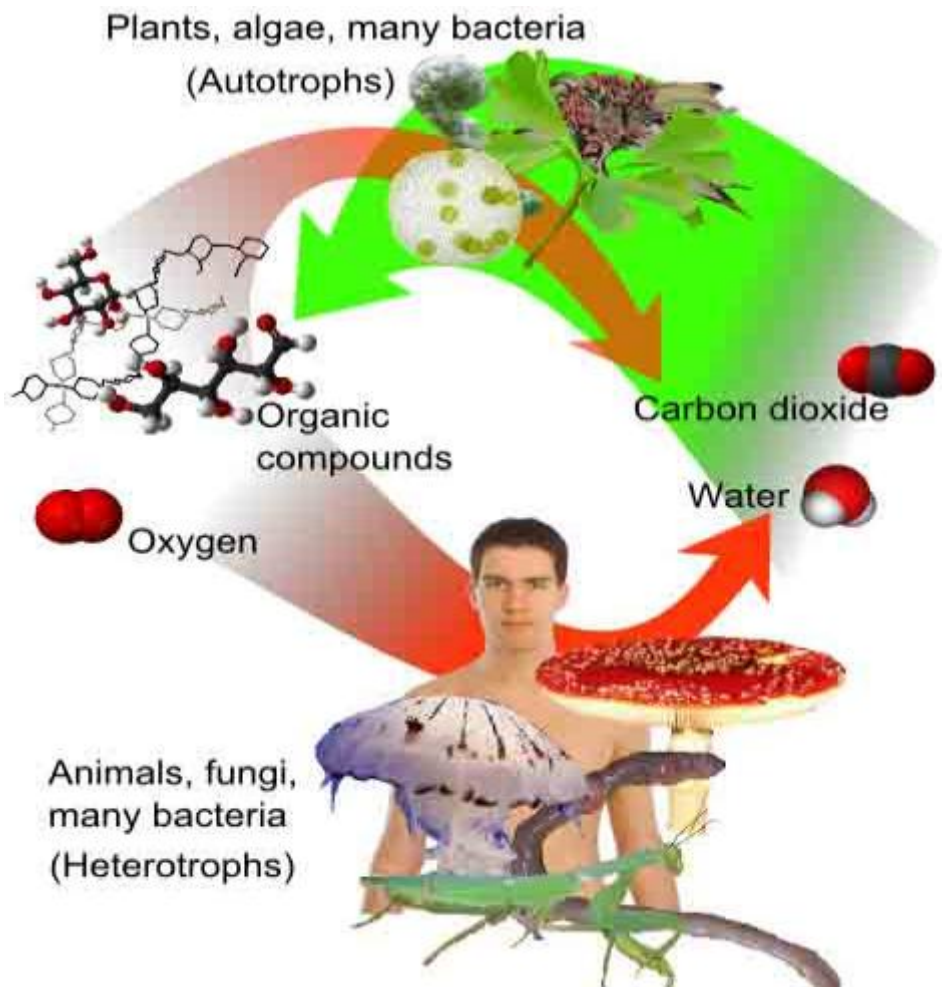
- Science Prof Online (SPO) is a free science education website that provides fully-developed Virtual Science Classrooms, science-related PowerPoints, articles and images. The site is designed to be a helpful resource for students, educators, and anyone interested in learning about science.
- The SPO Virtual Classrooms offer many educational resources, including practice test questions, review questions, lecture PowerPoints, video tutorials, sample assignments and course syllabi. New materials are continually being developed, so check back frequently, or follow us on Facebook (Science Prof Online) or Twitter (ScienceProfSPO) for updates.
- Many SPO PowerPoints are available in a variety of formats, such as fully editable PowerPoint files, as well as uneditable versions in smaller file sizes, such as PowerPoint Shows and Portable Document Format (.pdf), for ease of printing.
- Images used on this resource, and on the SPO website are, wherever possible, credited and linked to their source. Any words underlined and appearing in blue are links that can be clicked on for more information. PowerPoints must be viewed in *slide show mode* to use the hyperlinks directly.
- Several helpful links to fun and interactive learning tools are included throughout the PPT and on the Smart Links slide, near the end of each presentation. You must be in *slide show mode* to utilize hyperlinks and animations.
- This digital resource is licensed under Creative Commons Attribution-ShareAlike 3.0 :
<http://creativecommons.org/licenses/by-sa/3.0/>

Alicia Cepaitis, MS
Chief Creative Nerd
Science Prof Online
Online Education Resources, LLC
alicia@scienceprofonline.com

Tami Port, MS
Creator of Science Prof Online
Chief Executive Nerd
Science Prof Online
Online Education Resources, LLC
info@scienceprofonline.com

Metabolism

Aerobic Cellular Respiration

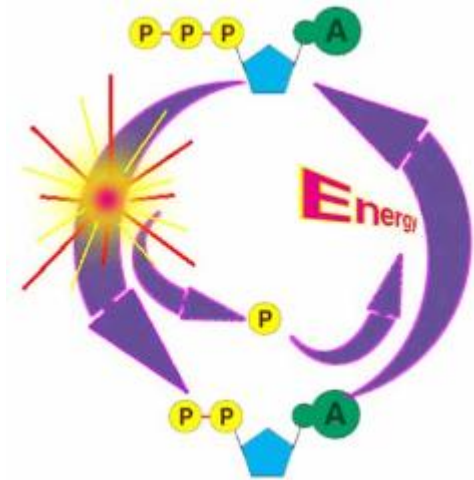
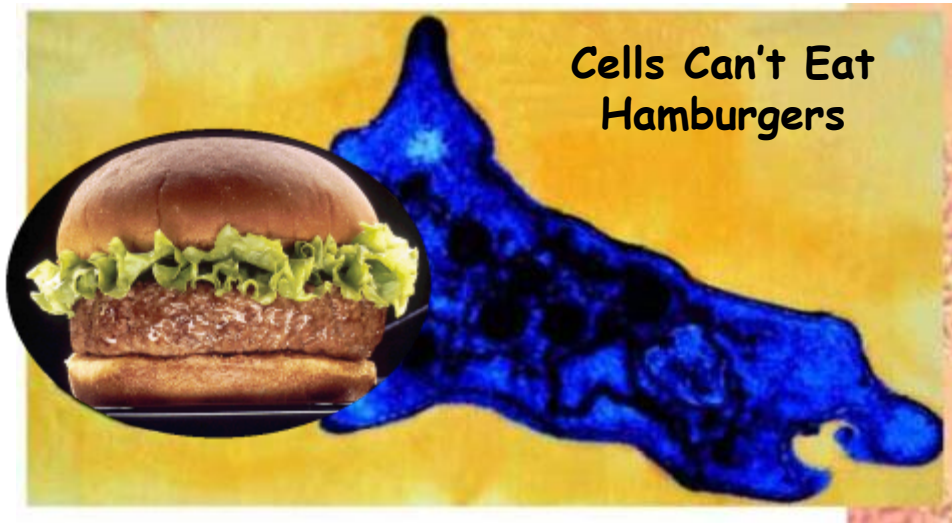


Metabolism

The Transformation of Energy

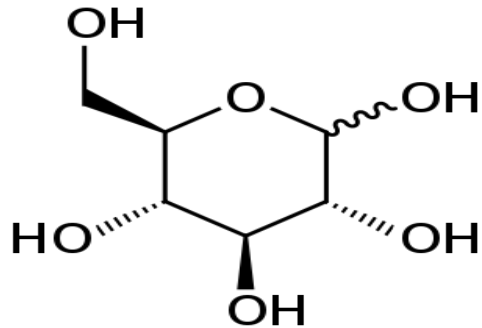
- Cells either get their energy either by photosynthesis or by eating stuff.
- But a cell can't just use sunlight or nutrients to run cellular reactions.

Q: What type of fuel is needed to run a cell?



Metabolism

Energy is obtained by breaking chemical bonds in foods we eat, like glucose.



Metabolism transfers food energy into **ATP energy**, the common energy currency of cells.



Basic Chemical Reactions Underlying Metabolism

1. Anabolism & Catabolism
2. Oxidation and Reduction Reactions
3. ATP Production and Energy Storage

This is stuff that you need to know before we begin discussing cellular respiration.

Building and Breaking Down Molecules

Anabolic Reaction

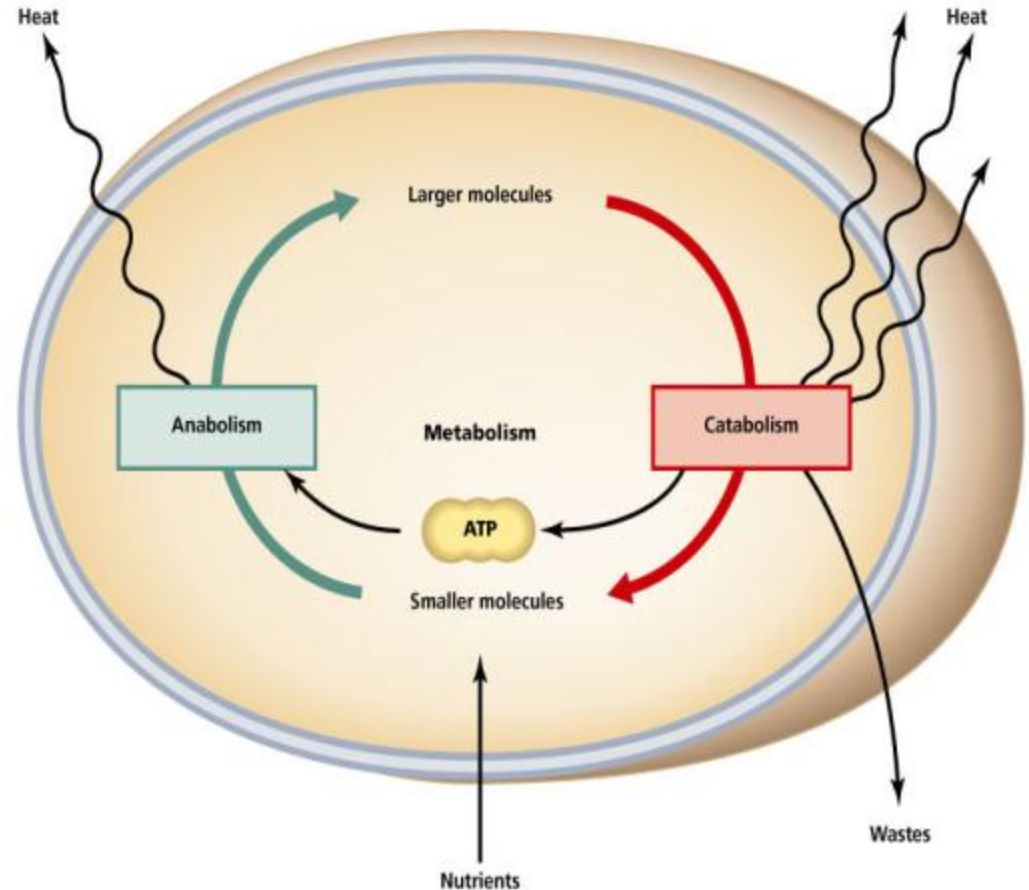
(*anabolism*)

The phase of metabolism in which simple substances are **synthesized** into the complex materials of living tissue.

Catabolic Reaction

(*catabolism*)

The metabolic **break down** of complex molecules into simpler ones, often resulting in release of energy.



Copyright © 2004 Pearson Education, Inc., publishing as Benjamin Cummings.

Basic Chemical Reactions Underlying Metabolism

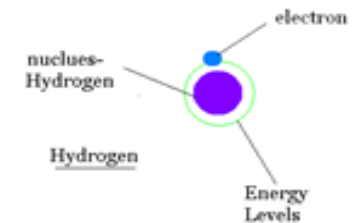
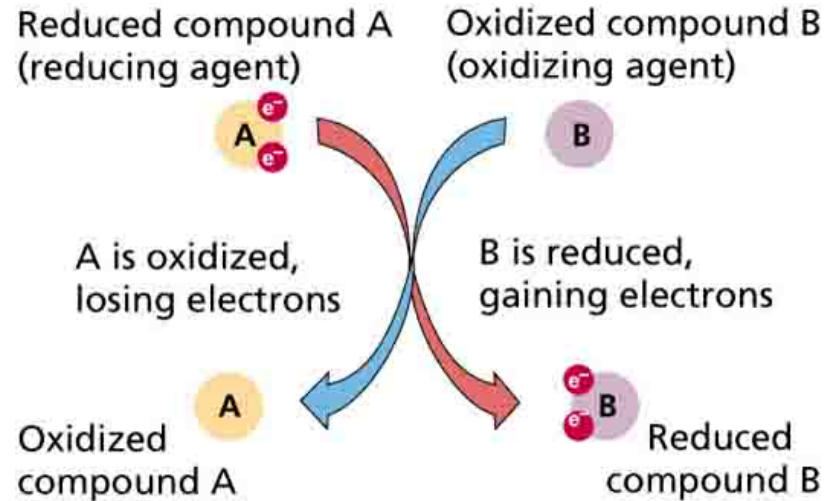
1. Catabolism and Anabolism

2. Oxidation Reduction (Redox) Reactions

3. ATP Production and Energy Storage

This is stuff that you need to know before we begin discussing cellular respiration.

Oxidation-Reduction Reaction



Because the Oxygen and Hydrogen are sharing two electrons. It has two have two Hydrogen Atoms, because Hydrogen only has one electron.

Oxidation and Reduction Reactions

What do they have to do with metabolism?

- Cells use special molecules to carry electrons (*often in H atoms*).



- This is potential energy.

REVIEW!
Animated lesson on
[Redox Reactions and
How NAD⁺ Works](#)

- Two important **electron carriers**:

- **Nicotinamide adenine dinucleotide (NAD⁺)** → add electrons & hydrogen → NADH
- **Flavine adenine dinucleotide (FAD)** → add electrons and hydrogen → FADH₂

- Think of these energy carriers as **rechargeable batteries**.
(When they have the electrons and hydrogens they are charged up, when they don't, they need charging.)

Basic Chemical Reactions Underlying Metabolism

1. Catabolism and Anabolism

2. Oxidation and Reduction Reactions

3. ATP Production and Energy Storage

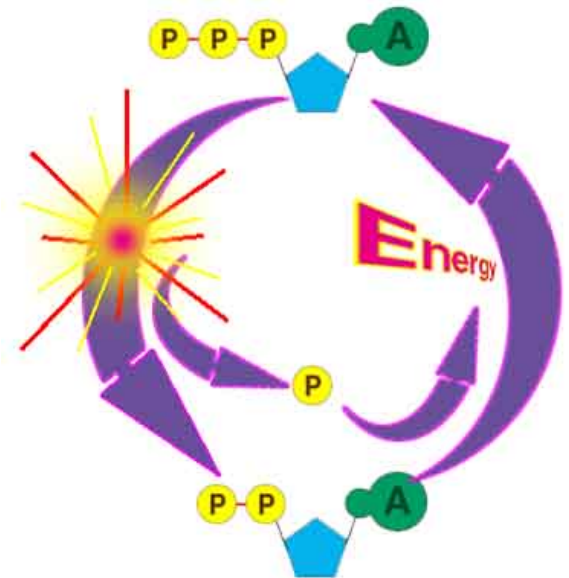
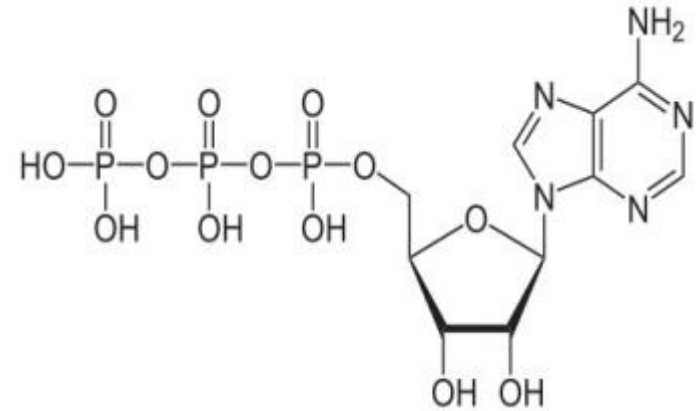
This is stuff that you need to know before we begin discussing cellular respiration.



Production & Energy Storage

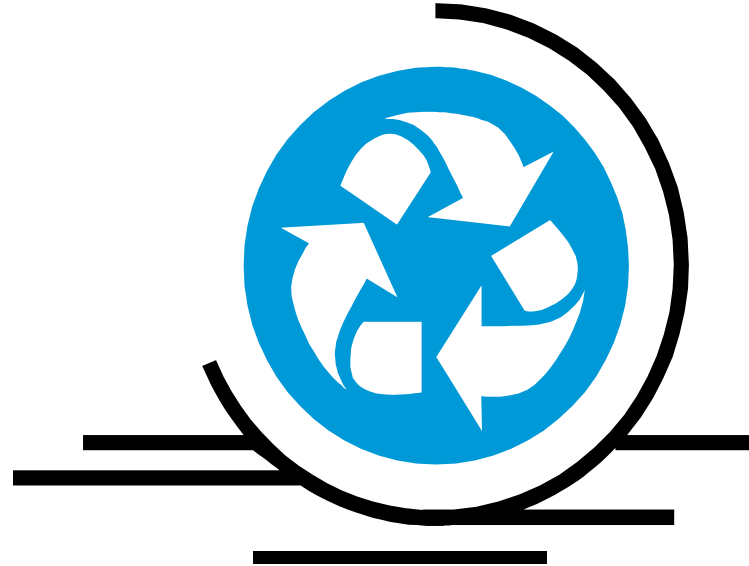
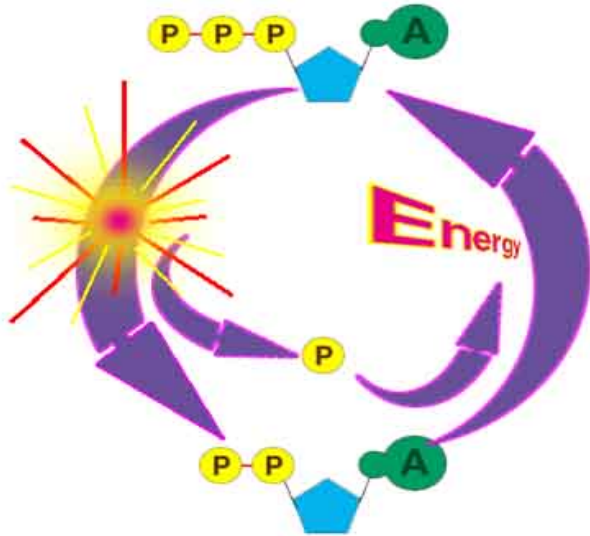
Q: This molecule has a sugar, a base and three phosphate groups. What kind of monomer is it?

- Adenosine 5'-triphosphate
- Multifunctional "molecular currency" of intracellular energy transfer.
- Metabolism releases energy from nutrients.
- That energy can be stored in **high-energy phosphate bonds** of ATP.
- ATP transports chemical energy within cells.
- ATP can be used to fuel many cellular reactions.







Production & Energy Storage



- In a working muscle cell the entire pool of ATP is recycled once each minute.
 - Over 10 million ATP per second per cell.
 - A biological “rechargeable battery!”

Aerobic Cellular Respiration *is* Carbohydrate Catabolism

- Organisms catabolize (break down) carbohydrates as the primary energy source for anabolic reactions.
- The monosaccharide **glucose** is used most commonly.
- Glucose catabolized by:
 - **Aerobic cellular respiration** → Results in complete breakdown of glucose to carbon dioxide, water and a lot of 
 - **Anaerobic respiration & Fermentation** → Only partially breaks down glucose, into pyruvic acid and organic waste products and a little 

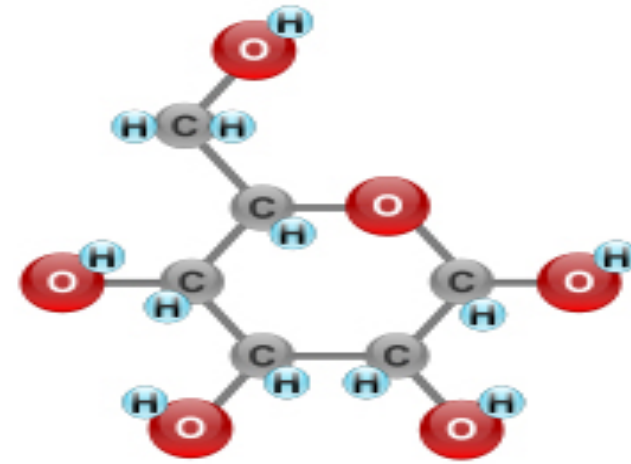
Aerobic Cellular Respiration →

Utilizes 1. _____, 2. synthesis of acetyl CoA, 3. Krebs cycle, and 4. electron transport chain; results in complete breakdown of glucose to carbon dioxide, water and

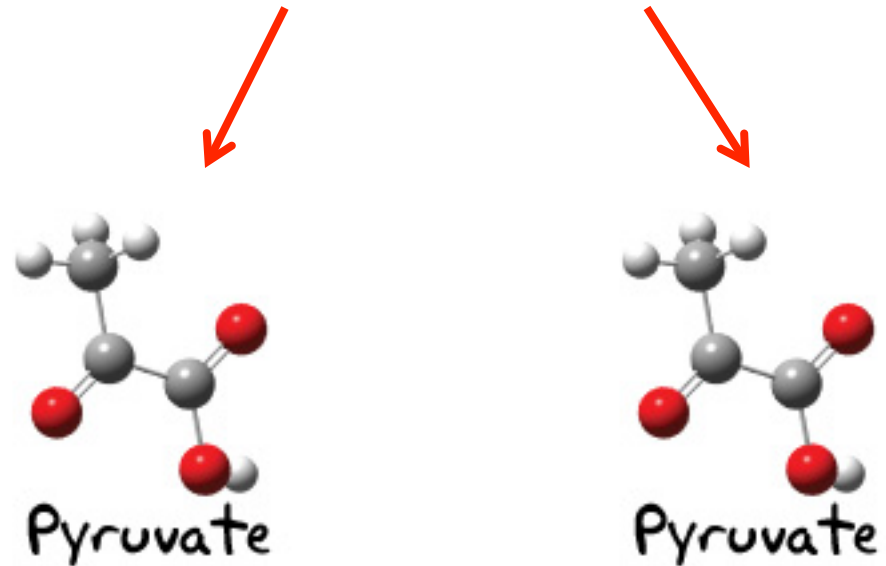


Glycolysis

- Occurs in cytoplasm of most cells.
- Involves splitting of a six-carbon glucose into two three-carbon molecules of pyruvate.



Glucose



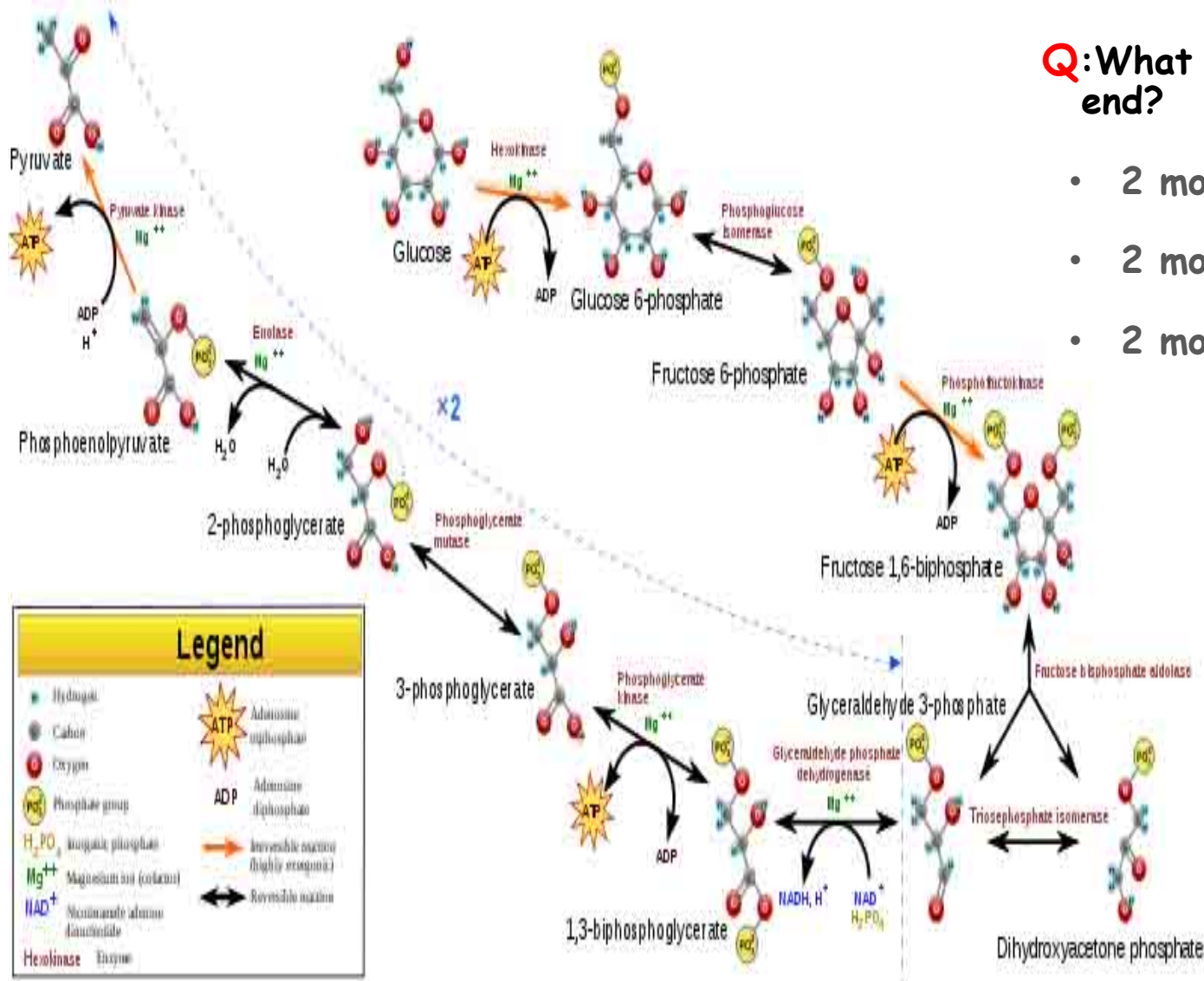
Pyruvate

Pyruvate

Glycolysis

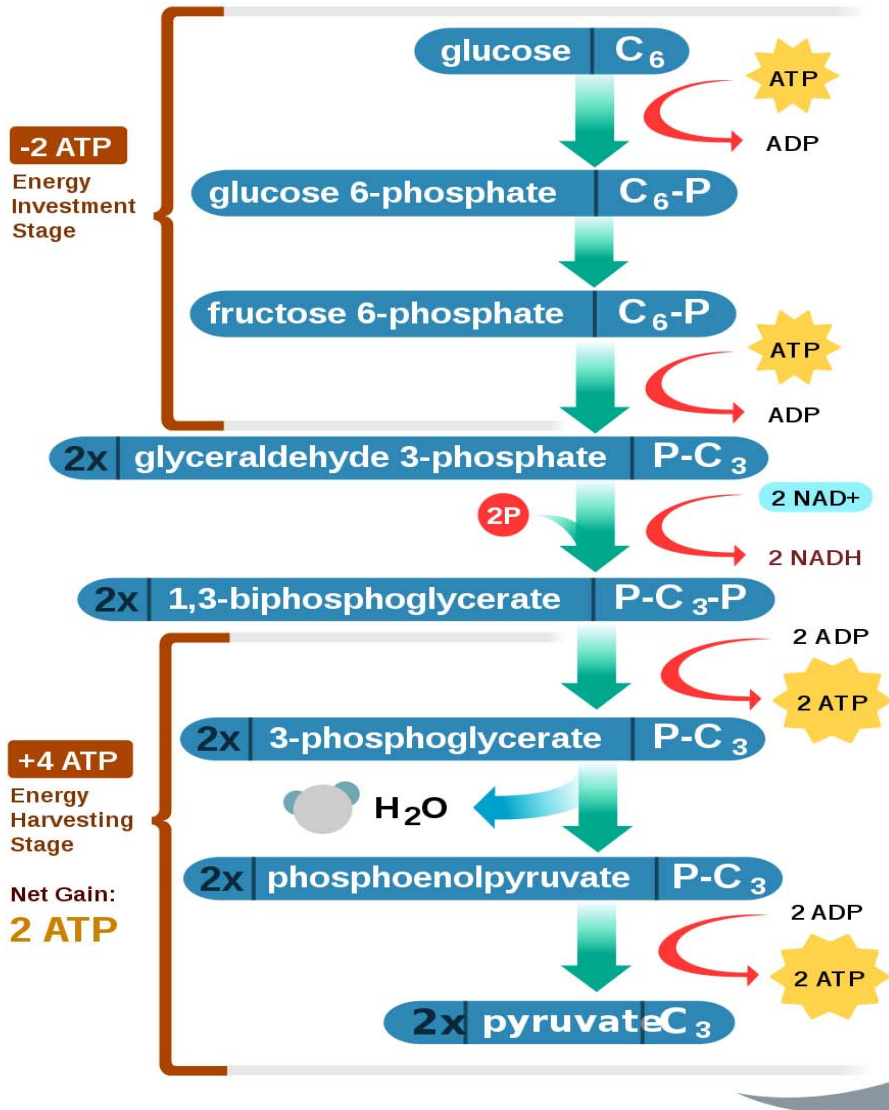
Q: What goes into this reaction?

Q: What is produced in the end?



- 2 molecules of _____
- 2 molecules of _____
- 2 molecules of _____

Glycolysis in the Cytoplasm



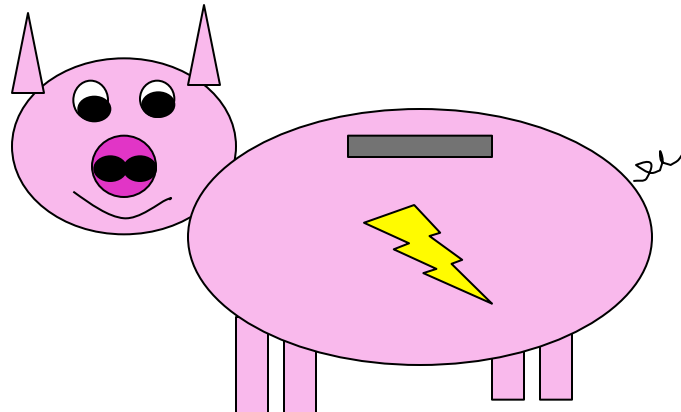
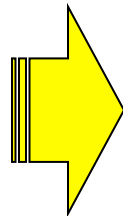
REVIEW!

Animated lesson on How Glycolysis Works

Aerobic Cellular Respiration

Subpathway	Molecule In	Molecule Out	Energy Obtained
1. glycolysis			
2. synth acetyl-CoA			
3. Krebs cycle			
4. ETC			

Let's put the energy extracted from glucose into our energy piggy bank.

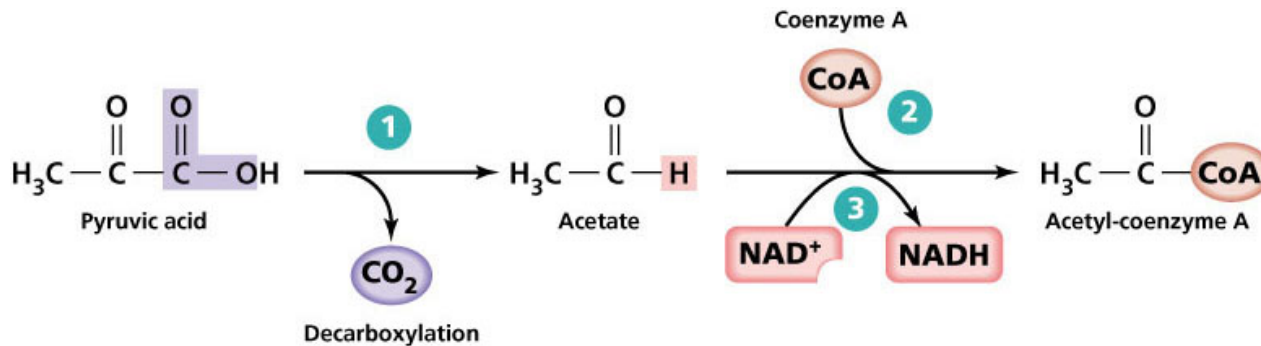
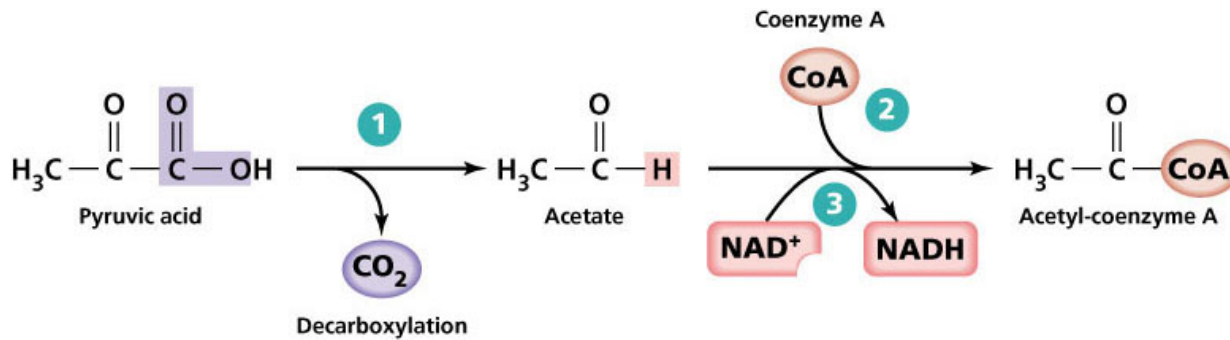


Aerobic Cellular Respiration →

Utilizes 1. glycolysis, 2. _____, _____,
3. Krebs cycle, and 4. electron transport chain;
results in complete breakdown of glucose to
carbon dioxide, water and



Synthesis of Acetyl-CoA



The two molecules of pyruvate (pyruvic acid above) result in:

- 2 molecules of _____
- 2 molecules of _____ (This is what generates carbon dioxide that you breathe out.)
- 2 molecules of _____ (electron carrier)

Aerobic Cellular Respiration →

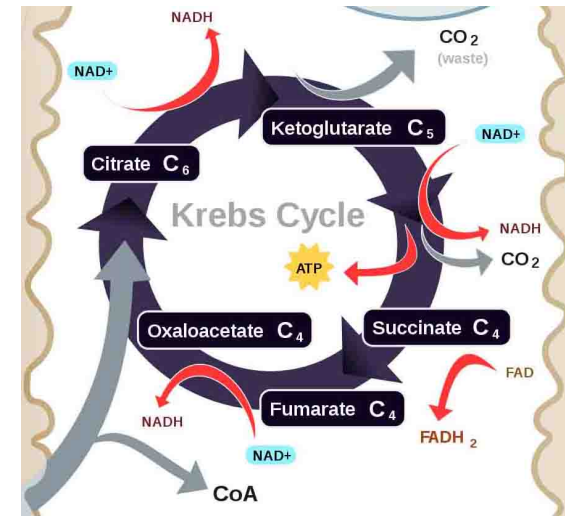
Utilizes 1. glycolysis, 2. synthesis of acetyl Co-A, 3. _____, and 4. electron transport chain; results in complete breakdown of glucose to carbon dioxide, water and



Krebs Cycle

(Citric Acid Cycle)


- Great amount of energy remains in bonds of acetyl-CoA.
- The Krebs cycle transfers much of this energy to electron carriers NAD^+ and FAD .
- Occurs in cytoplasm of prokaryotes and in matrix of mitochondria in eukaryotes.



Krebs Cycle

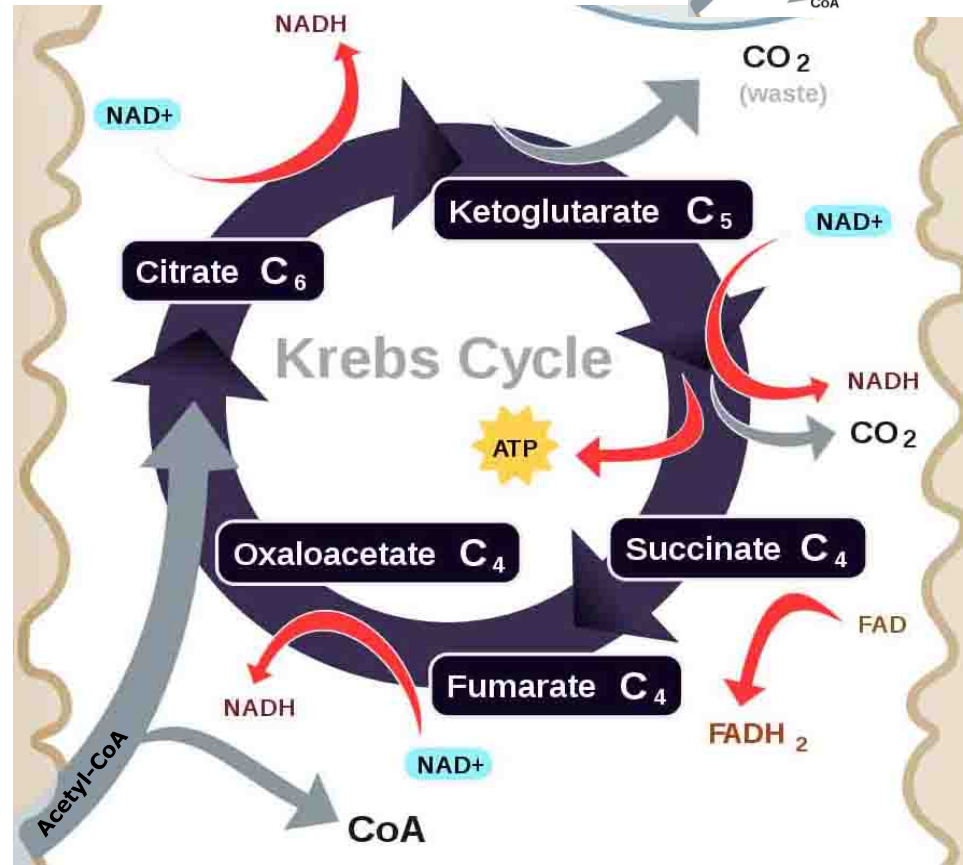
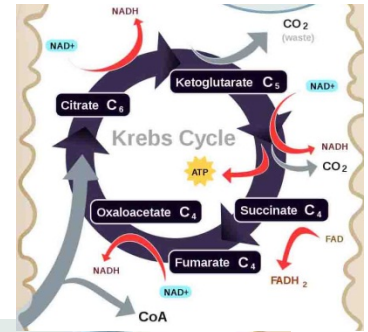
(a.k.a Citric Acid Cycle)

The **two molecules** of Acetyl Co-A result in:

- Two molecules of  (energy carrier)
- Two molecules of _____ (electron carrier)
- Six molecules of _____ (electron carrier)
- Four molecules of _____ (This is what generates carbon dioxide you breathe out.)

REVIEW!

Animated lesson and quiz on [Krebs Cycle](#)



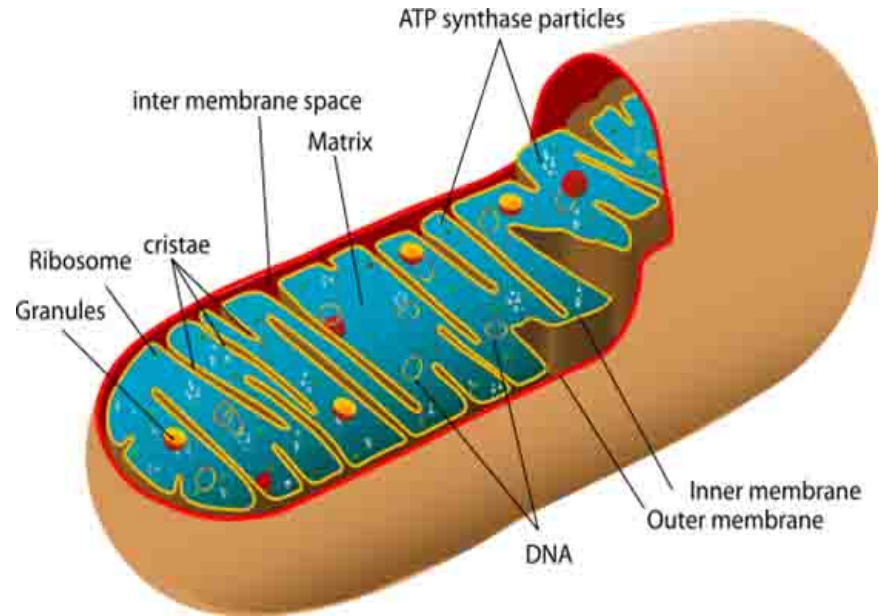
Aerobic Cellular Respiration →

Utilizes 1. glycolysis, 2. synthesis of acetyl Co-A,
3. Krebs Cycle and 4. _____;
results in complete breakdown of glucose to
carbon dioxide, water and



Electron Transport

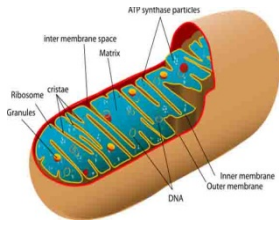
- Most of the [ATP](#) made in cellular respiration comes from the stepwise release of energy through a series of redox reactions between molecules known as the [electron transport chain](#) (ETC).



- Must occur in a membrane. The ETC is located in cristae of **mitochondria** in [eukaryotes](#).
- **Q:** Where would the ETC of [prokaryotes](#) be located?

Three main events important in the ETCs generation of ATP:

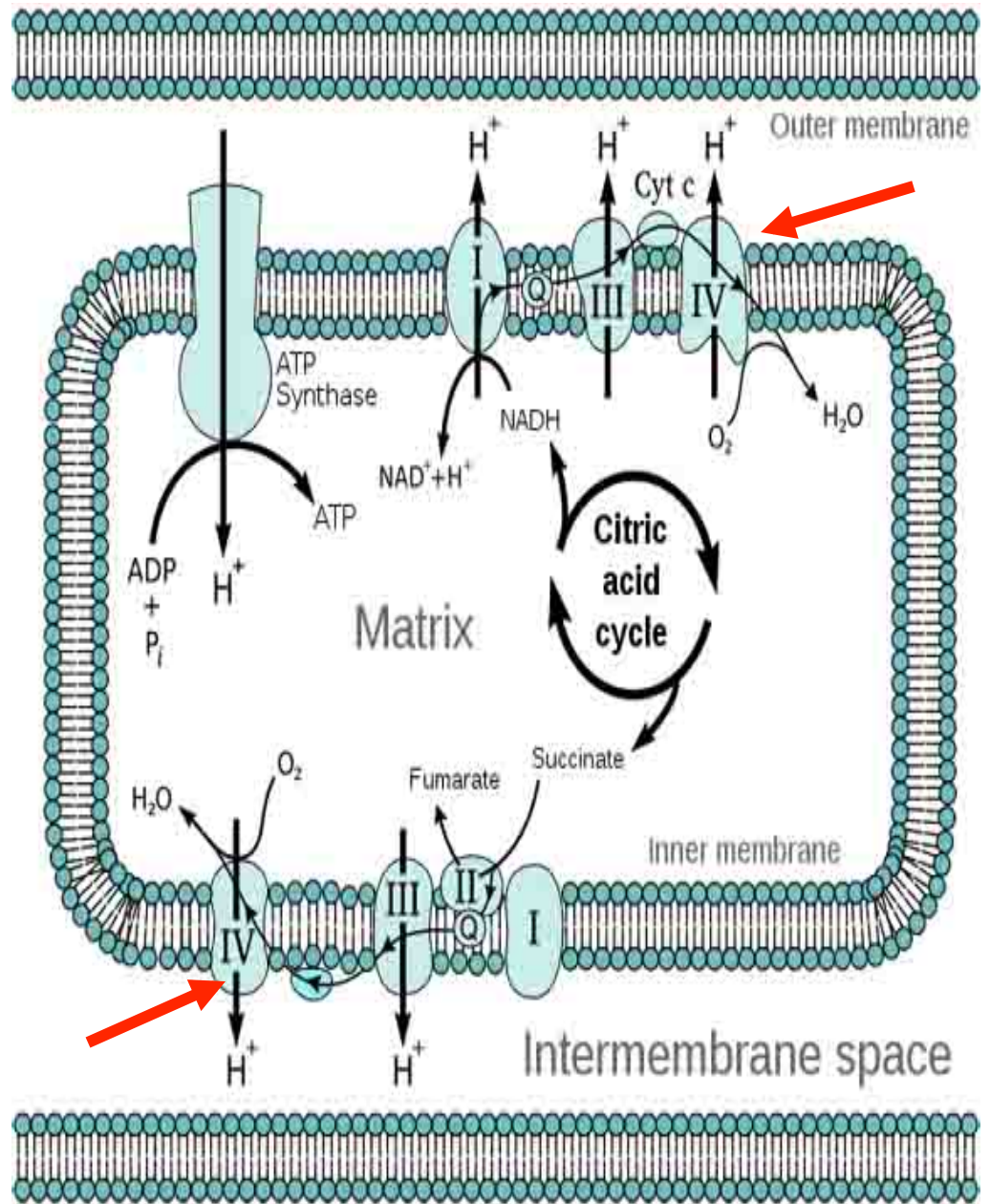
1. _____
2. _____
3. _____

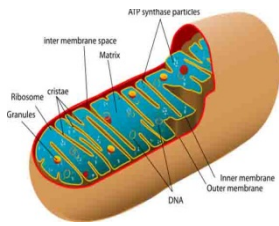


Electron Transport

1. Oxidation Reduction Reactions

- The electron carriers (NADH and FADH_2) bring electrons and protons (H^+) to the ETC.
- Carrier molecules in the membrane of the mitochondria pass electrons from one to another and ultimately to final electron acceptor.

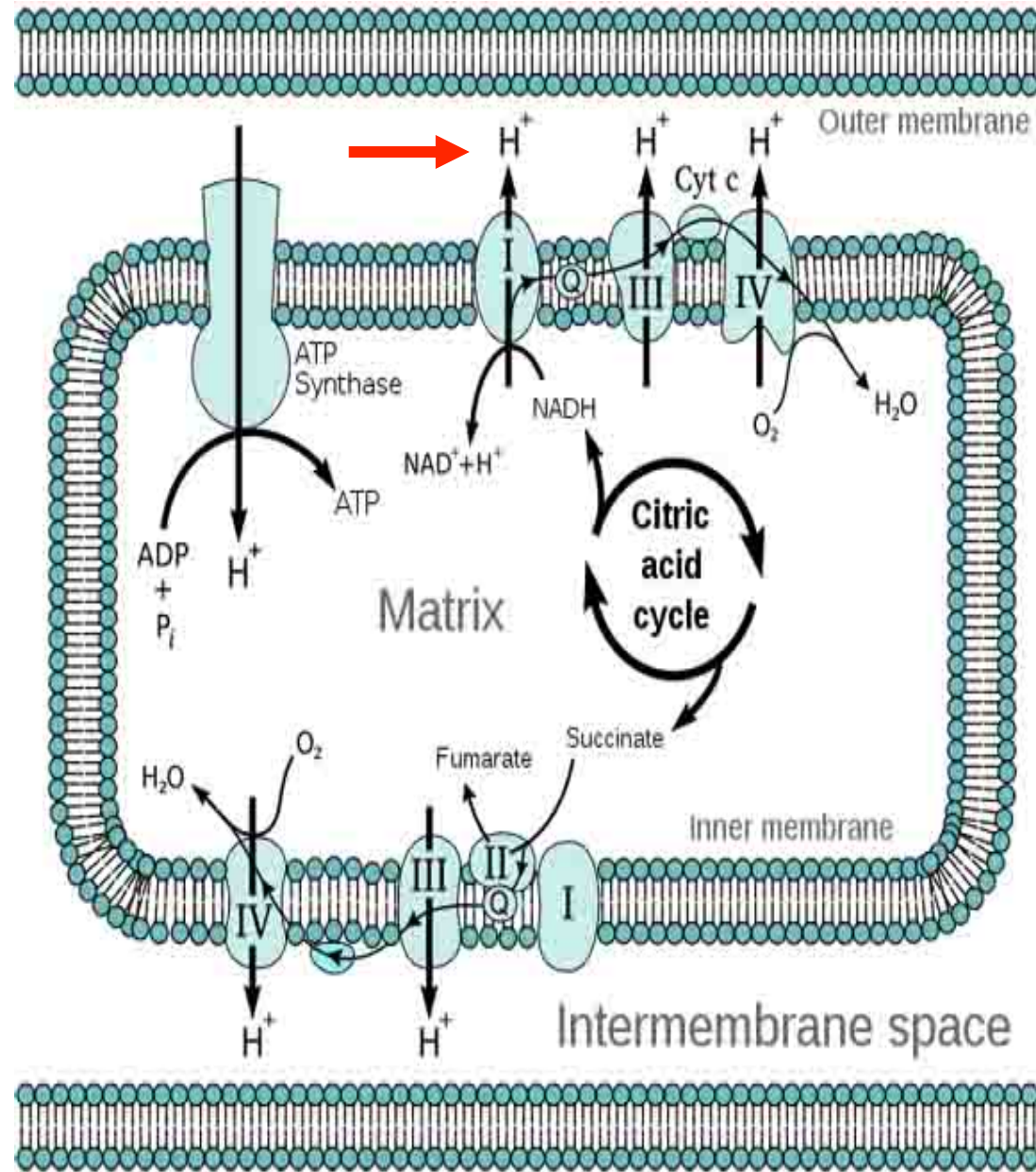


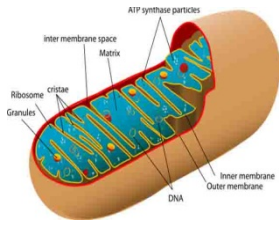


Electron Transport

2. Creation of a Proton Gradient

- Energy from each electron being passed down the chain is used to pump protons (H^+) from one side of the membrane to the other.
- Proton gradient = type of ion **gradient** (difference in ion concentration on either side of a membrane) ... potential energy available for work in cell.





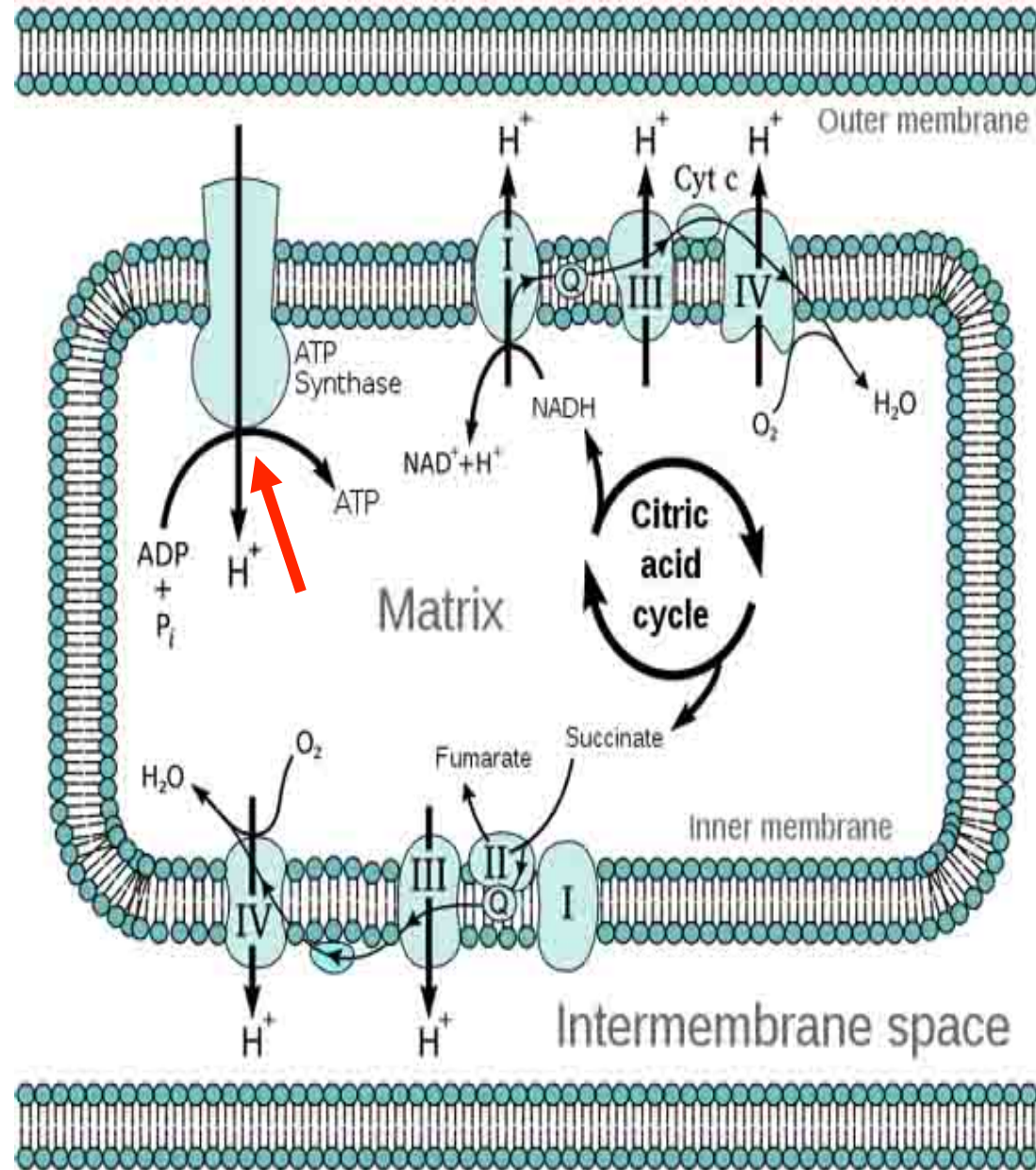
Electron Transport

3. Synthesis of ATP

H^+ ions flow down proton gradient through protein channels (ATP synthase) that phosphorylate ADP to make ATP.

REVIEW!

Animated lesson on [Electron Transport Chain](#)



Meet the Enzyme: ATP Synthase

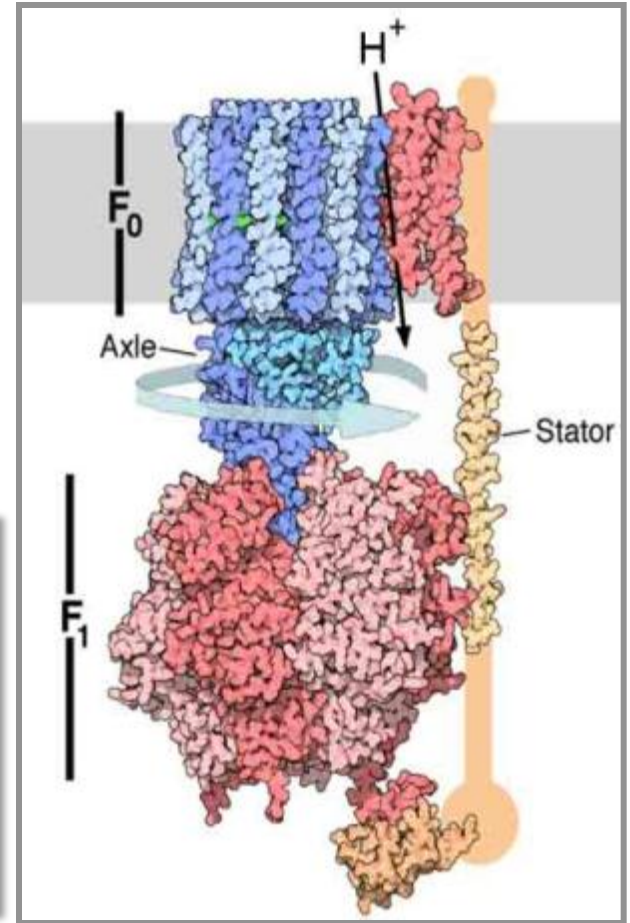
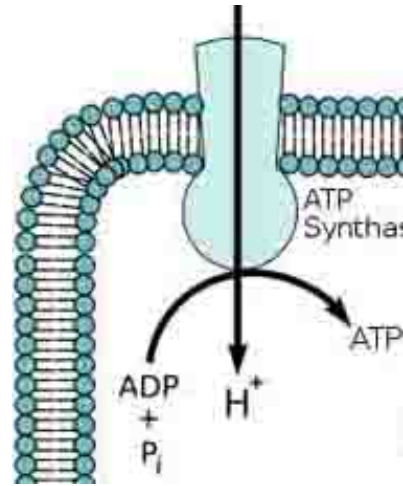
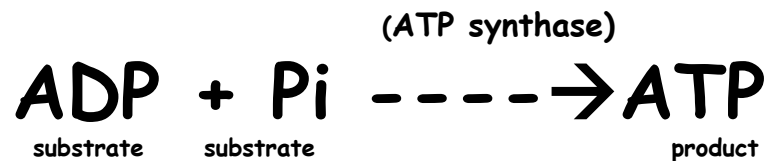
Important metabolic enzyme that harnesses energy for biological cells to use.

Involved in synthesis of adenosine triphosphate (**ATP**), from:

- adenosine diphosphate (ADP)
- a phosphate group and
- energy from H^+ ion
- gradient

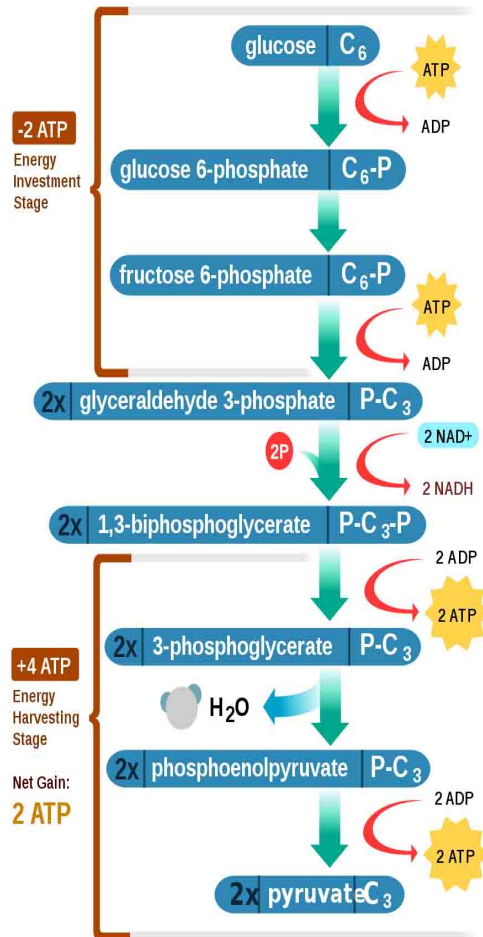
ATP is the most commonly used "energy currency" of cells.

Reaction:

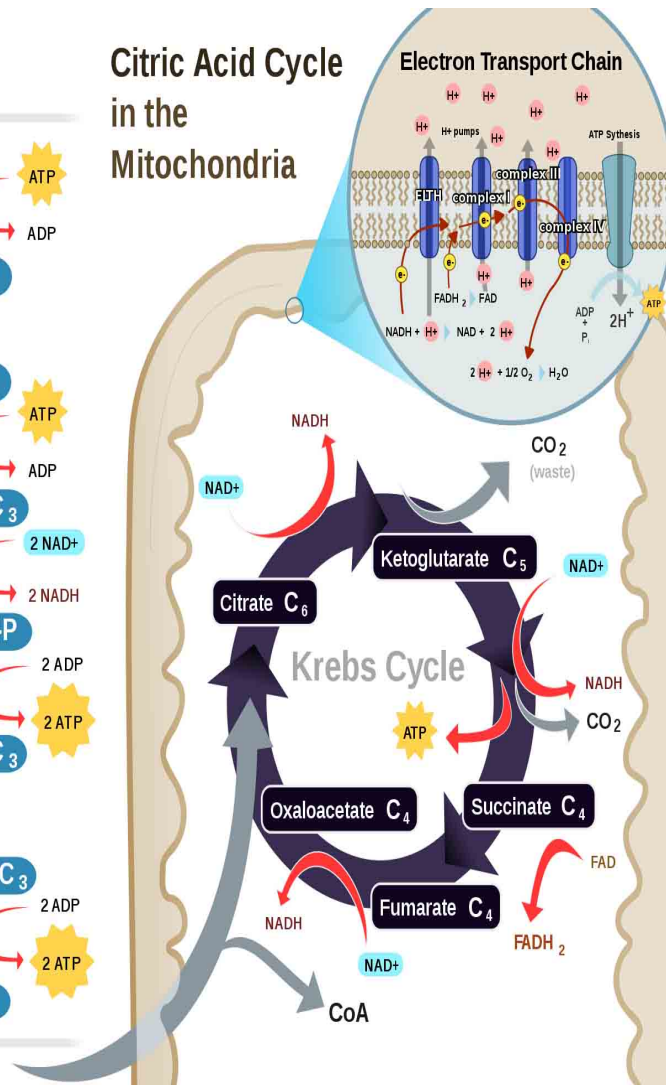


Aerobic Cellular Respiration

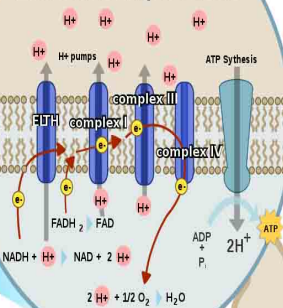
Glycolysis in the Cytoplasm



Citric Acid Cycle in the Mitochondria




Electron Transport Chain



REVIEW!

Animated lesson
and quizzes on
Cellular
Respiration

Aerobic cellular respiration →

Utilizes glycolysis, synthesis of acetyl-CoA, Krebs cycle, and electron transport chain; results in complete breakdown of _____ to carbon dioxide, water & 

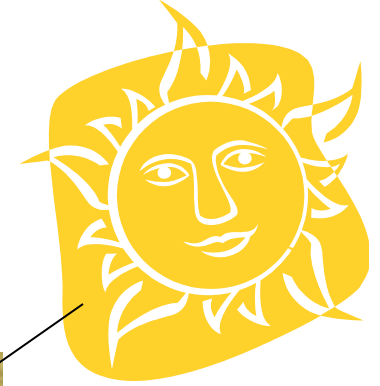
The ultimate objective is to make  molecules to do cellular work.

Each NADH results in 3 ATP, Each FADH₂ results in 2 ATP.

A total of **38** molecules of ATP are formed from one molecule of glucose.

Lets figure out how we got 38 ATP by the end of aerobic respiration.

Where does the energy come from?



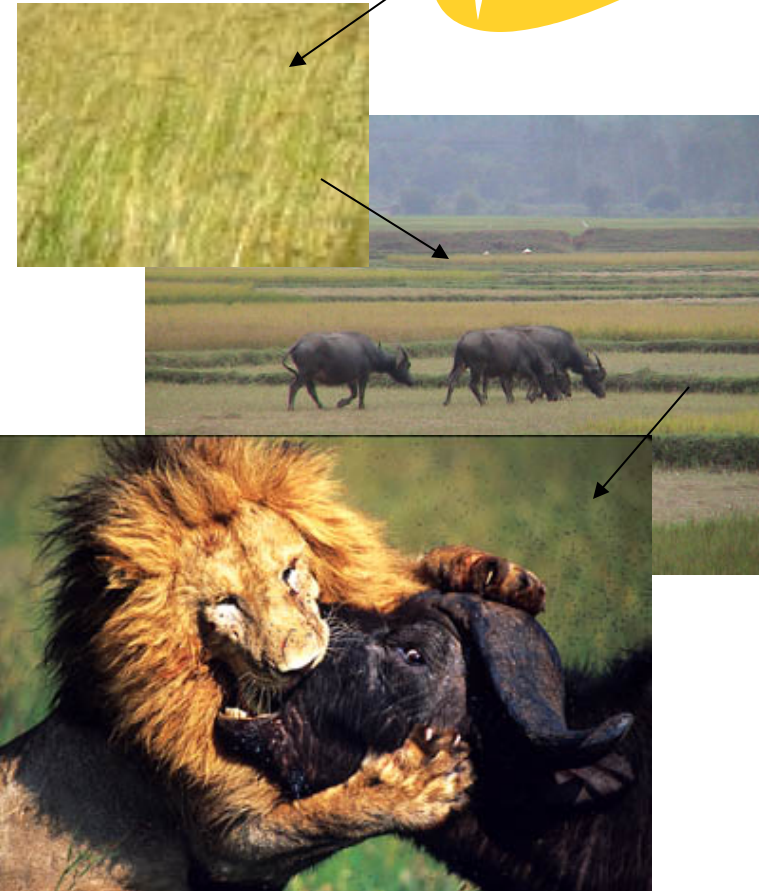
In other words, how do we get glucose to begin with?

Autotroph - organism that makes organic compounds from inorganic sources.

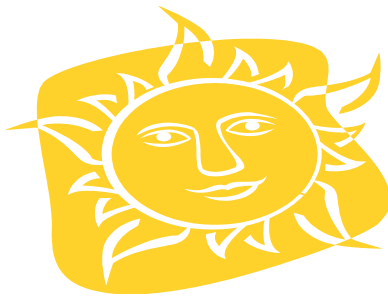
Plants, some bacteria, and some protista make their own food using light energy.

Heterotroph - organism that cannot make organic compounds from inorganic sources.

They obtain their organic compounds by consuming other organisms. Almost all animals, fungi and some Protista and bacteria.



Sun → Autotroph → Heterotroph



Conversion of Energy

- Every food chain begins with **anabolic** pathways in organisms that synthesize their own **organic molecules** from inorganic carbon dioxide.
- Most of these organisms capture **light** energy from the sun and use it to drive the synthesis of **glucose** from CO_2 and H_2O by a process called photosynthesis.

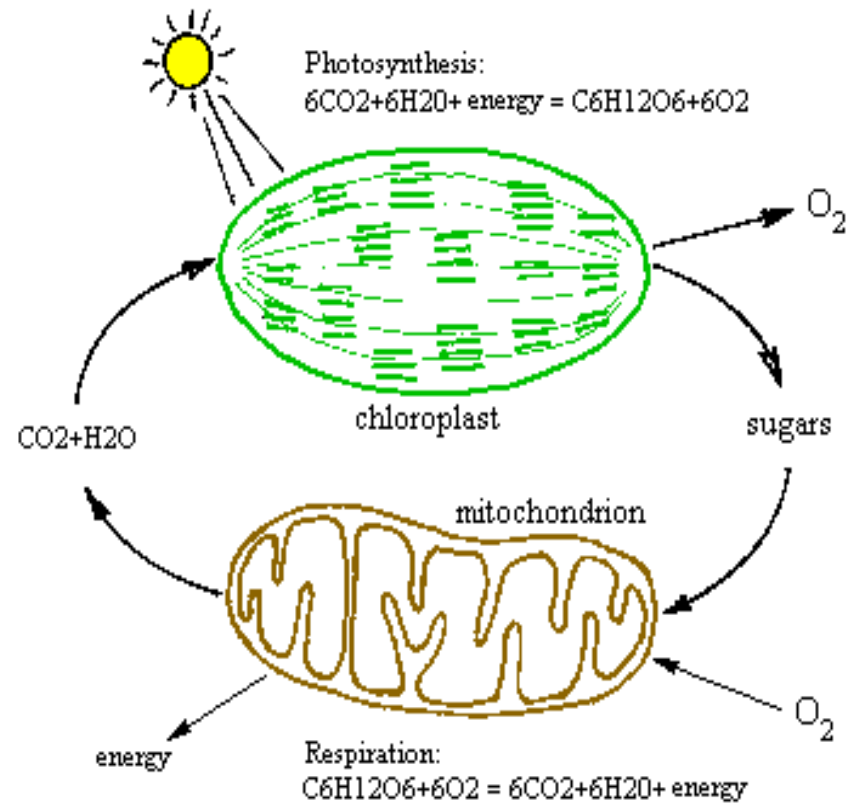
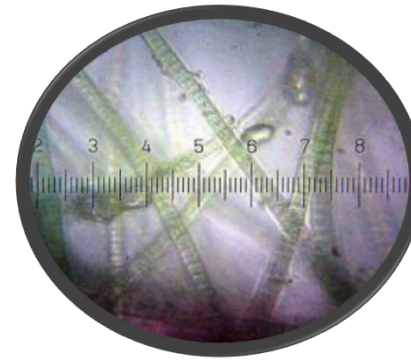


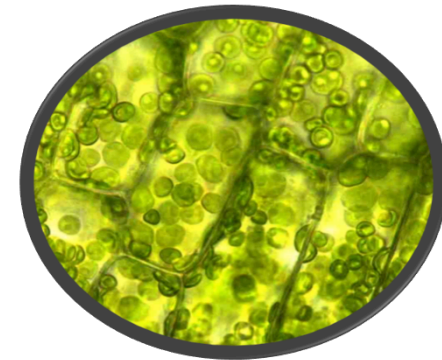
Figure 16 - With the photosynthesis, the solar energy is cumulated by the chloroplasts as sugar molecules. With the glycolysis and the respiration, made by mitochondria, the energy is liberated and supplied to the cell for its biochemical processes.

Cells that Run on Solar Power

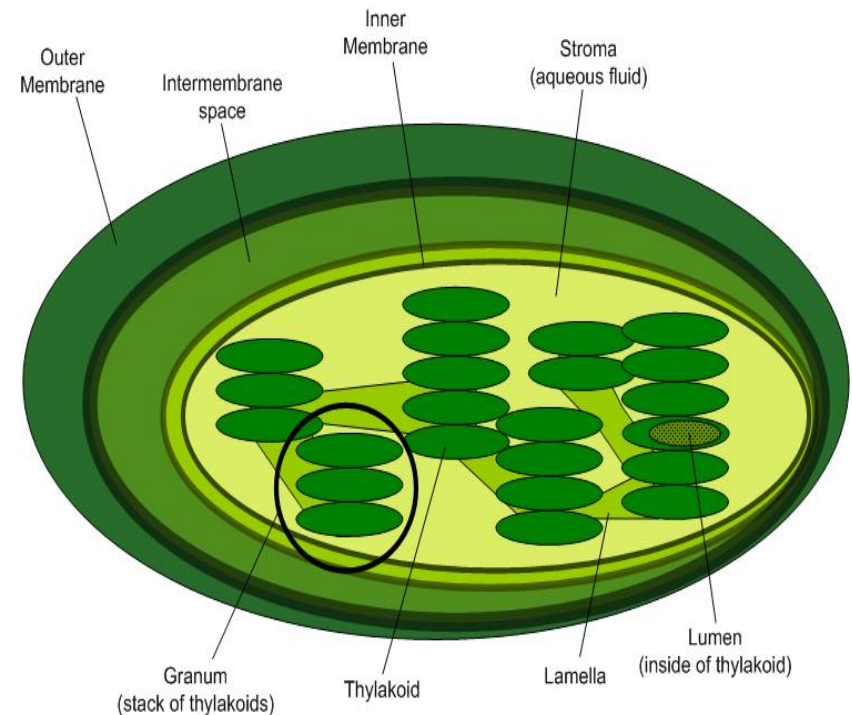
- Organisms capture light energy with pigment molecules; primarily **chlorophyll**.
- Prokaryotic autotrophs have chlorophyll in their cytoplasm.
- **Eukaryotic** autotrophs have chlorophyll organized in special photosystems within **chloroplast** organelles.



Cyanobacteria are photosynthetic bacteria.



Elodea plant cells with chloroplasts visible.



Metabolic Processes ... Bottom Line

Metabolism transforms food energy into energy that our cells can use.

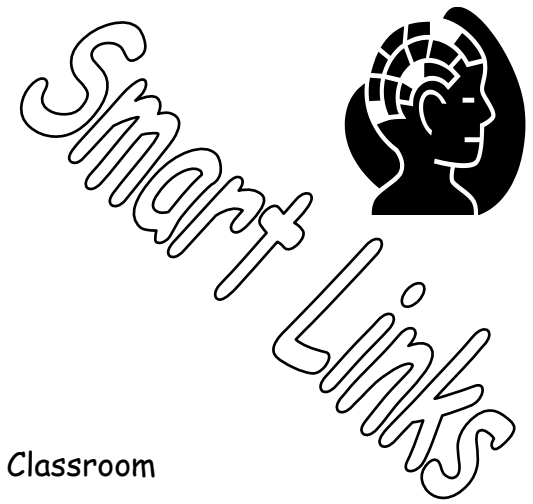
Q: What carbohydrate molecule is the basic component of your food energy?

Q: What is different about how animal cells and plant cells obtain this molecule?

Q: What molecule is the product of metabolism used to do cellular work?



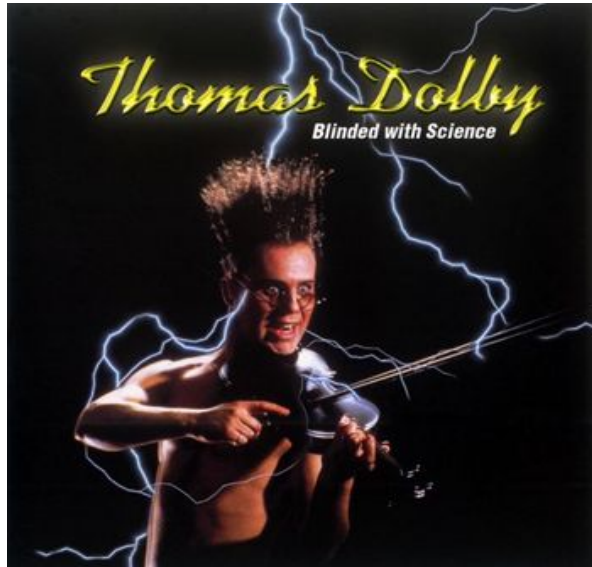
Confused?



Here are links to fun resources that further explain cellular respiration:

- [Aerobic Cellular Respiration Main Page](#) on the Virtual Cell Biology Classroom of [Science Prof Online](#).
- [Cellular Respiration](#) animation by Jay Phelan, "What is Life? A Guide to Biology", W. H. Freeman & Co.
- ["The Body Machine"](#) music video by School House Rock.
- [How NAD+ Works](#) animation and quiz from McGraw-Hill.
- [Glycolysis](#) animation and quiz from McGraw-Hill.
- [Krebs Cycle Animation & Quiz](#) from McGraw-Hill.
- [Electron Transport Chain](#) animation from Molecular & Cellular Biology Learning Center.
- [Electron Transport Chain](#) click through animation by Graham Kent Bio231 Cell Biology Laboratory.
- [Food Molecules](#) video from HowStuffWorks, a Discovery company.
- ["The Energy"](#) song by Audiovent.

(You must be in PPT slideshow view to click on links.)



Are you feeling blinded by science?

Do yourself a favor. Use the...

Virtual Cell Biology Classroom (VCBC)!

The VCBC is full of resources to help you succeed,
including:



- practice test questions
- review questions
- study guides and learning objectives
- PowerPoints on other topics

You can access the VCBC by going to the Science Prof Online website
www.ScienceProfOnline.com