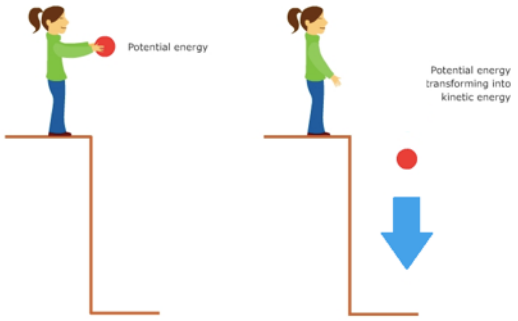
How Do We Use the Energy In Our Food?

- Kinetic
  - Heat/thermal energy
  - Motion energy
  - Sound
- Electromagnetic



- Potential
  - Gravitational
  - Stored mechanical (springs)
  - Electrical
  - Chemical

Energy is the capacity to do work

Kinetic

Heat/thermal energy is the vibration and movement of atoms and molecules within substances

Movement energy involves movement of one object or organism (or part of an organism) from one place to another

Sound energy is compression waves: vibration in matter

Potential

Gravitational potential energy is the potential to move towards extremely massive objects

Stored mechanical energy is due to stress put on springs

Electrical potential is energy due to charge differences

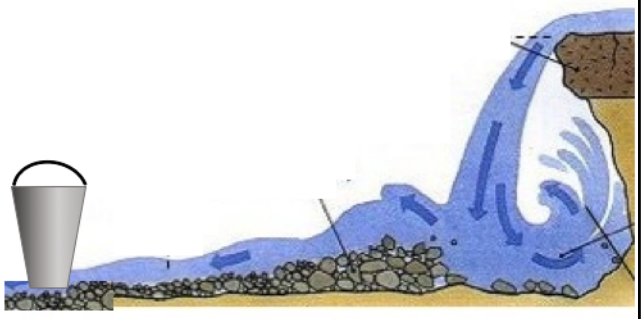
Chemical potential is energy found in chemical bonds

Electromagnetic

Energy from light waves

Dilemma…

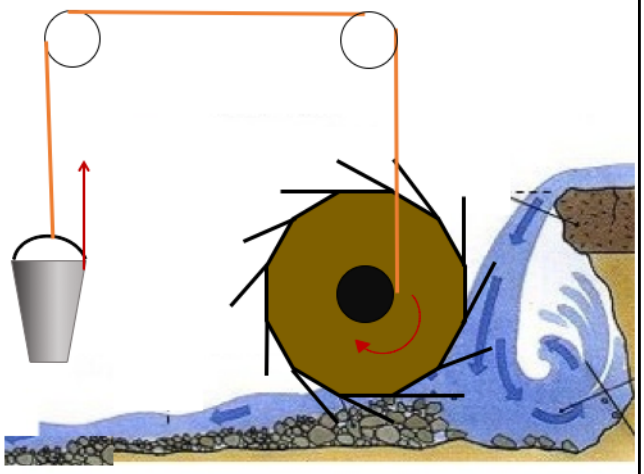
- You want to lift a heavy bucket that is close to a waterfall.
- How?



Spontaneous reactions will occur (says nothing about how quickly they will happen)
Non-spontaneous reactions need energy input. Lifting the bucket is non spontaneous

Water wheel

- Take advantage of potential/kinetic energy that is **favorable**
  - water falling
- To do something that is not **favorable**
  - lifting bucket



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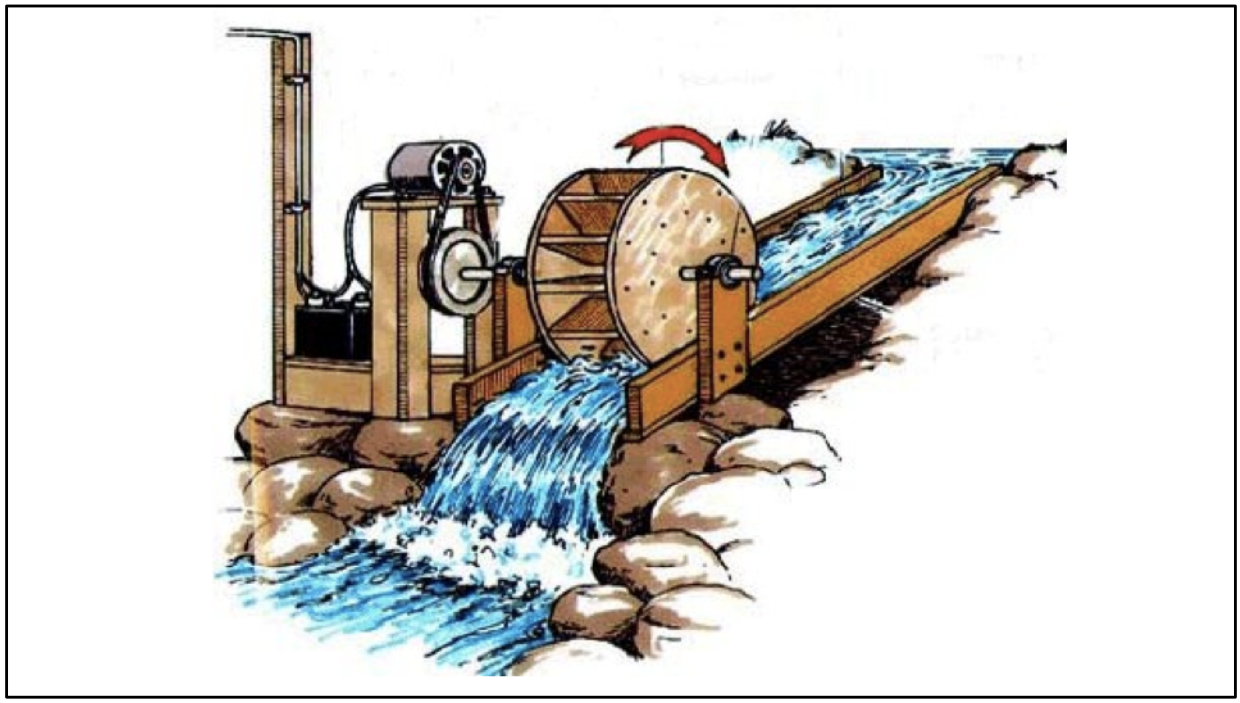


We can use water power to make electricity

Questions?

- Why is it important to be able to harness energy to use elsewhere?

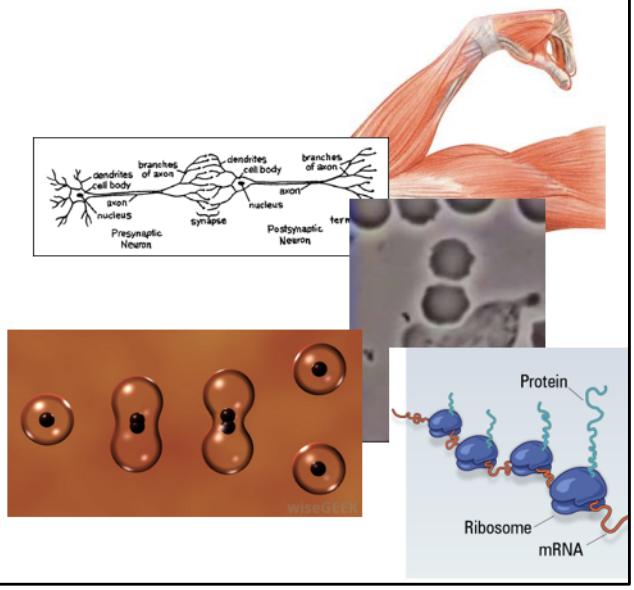
What does this have to do with our bodies?

- Food is full of potential energy!

The snacks you designed for your marathon runners are full of the Calories-units of potential energy-we need to power our bodies

What does this have to do with our bodies?

- Just need to get the energy to our muscles for movement
- To our neurons for electrical impulses and neurotransmission
- To our immune cells to deliver them to the germs
- To our cells to make new cells
- To our proteins to make new macromolecules



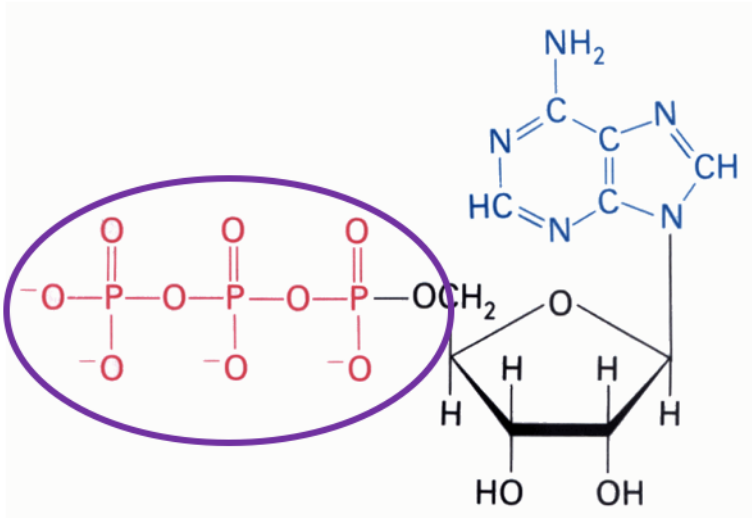
Remember the video of the immune cell (neutrophil) chasing down the bacterium!

But we can't just put an apple into our biceps…

What does this mean for getting energy from the food we eat?

Accessing the energy

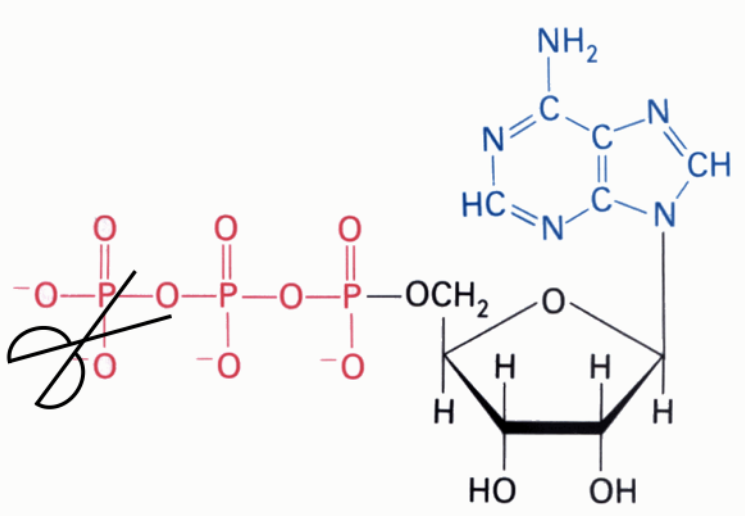
- Energy currency of the cell
- ATP: Adenosine triphosphate



It takes a lot of energy to have all the negative charges so close together

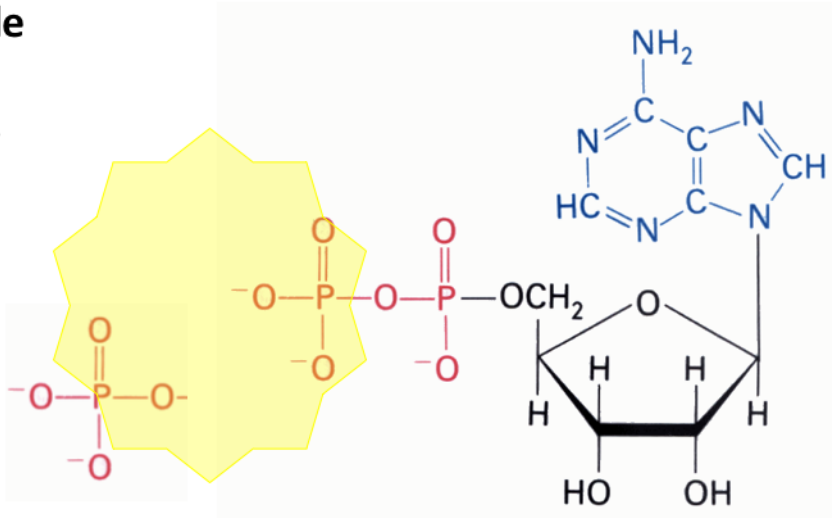
Accessing the energy

- Use a **favorable** reaction (exothermic)…



Accessing the energy

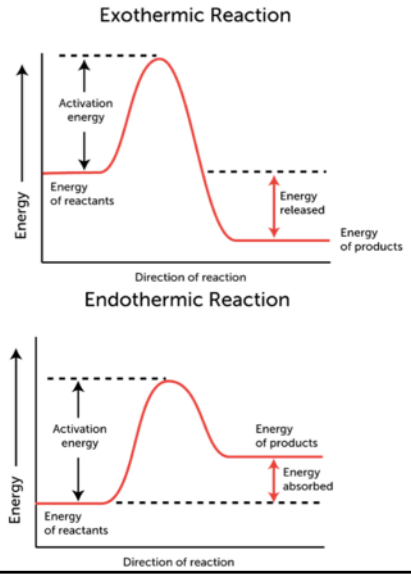
- Use a **favorable** reaction (exothermic)…
- …to get the energy to do something **unfavorable** (endothermic)



Unfavorable: cell division, building new proteins, moving muscles

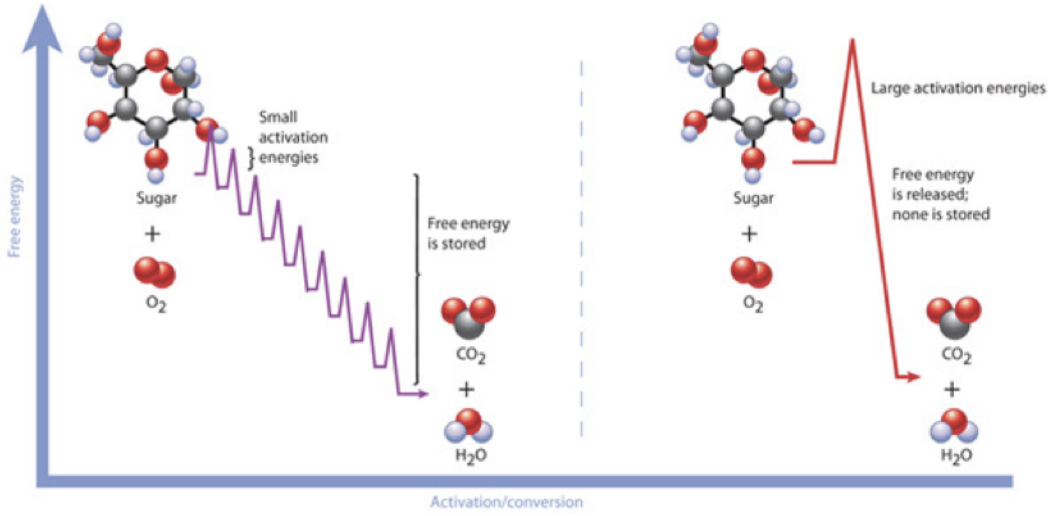
Accessing the energy

- **Enzymes** are proteins that decrease energetic barriers to chemical reactions (**activation energy**)
  - Amylase
  - ATPase, ATP synthase
- Enzymes often **couple,** or pair, reactions together so overall reaction is favorable



Reaction coupling: Use ATP→ADP to drive another reaction forward: like using waterwheel to lift bucket.

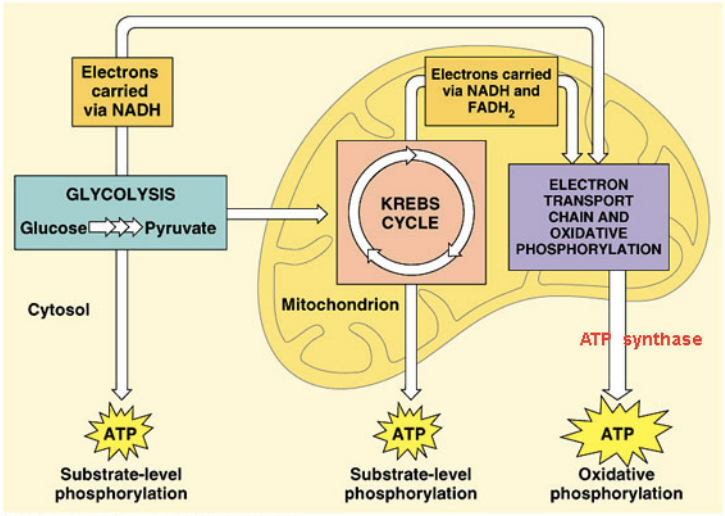
So how do cells get ATP (safely)?



Left graph: what we do in our bodies-get small packets of energy in a gradual process
Right graph: what happened with the exploding flour-get a lot of energy all at once

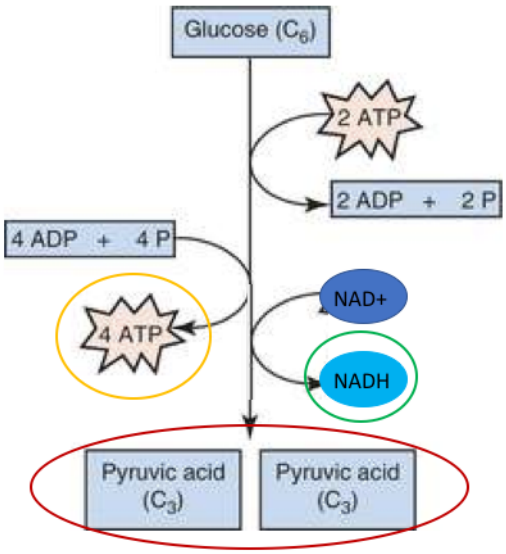
So how do cells get ATP?

- Glycolysis
- Krebs cycle
- Electron transport system



So how do cells get ATP?

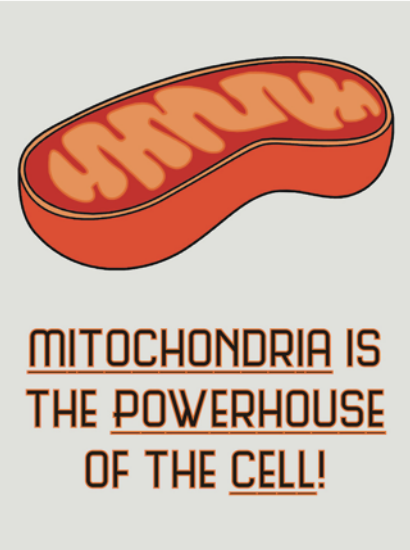
- **Glycolysis**
  - "glyco" = sugar
  - "lysis" = breaking apart
- Breaks down glucose to get some energy
  - Pyruvic acid
  - Net 2 ATP
  - NADH (electron transport shuttle)
  - Heat



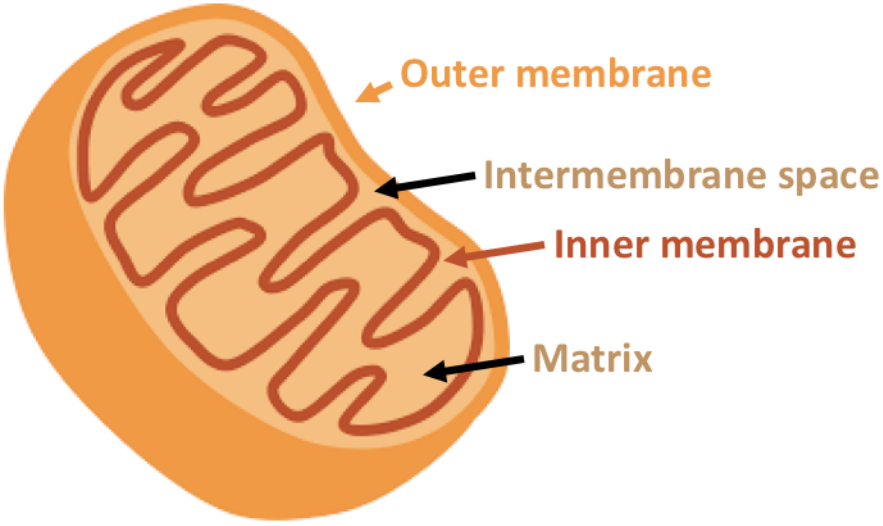
Words like glycolysis:
Glycogen (carbohydrate that stores energy in animals)
Cytolysis (killing cells, think "cytolytic T cell")

So how do cells get ATP?

- **Aerobic respiration**
  - If there is Oxygen (O_2)
  - Eukaryotic cell
  - Pyruvic acid and NADH go to the mitochondria

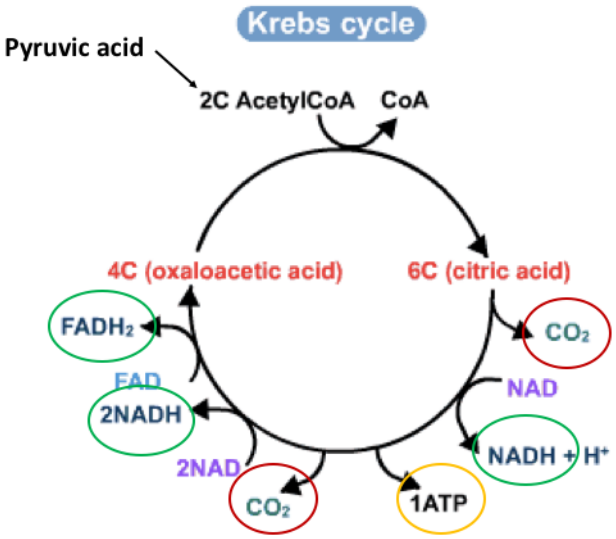


Anatomy of mitochondria



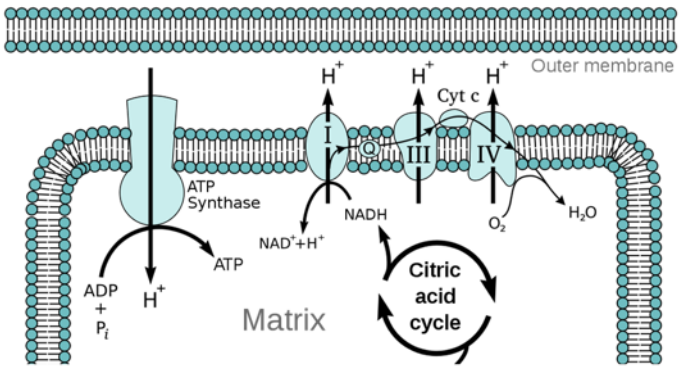
So how do cells get ATP?

- **Krebs Cycle**
  - Pyruvic acid goes in
  - Products
    - CO_2
    - ATP
    - NADH, FADH (electron transport shuttles)
    - Heat



All that for 4 ATP?!?

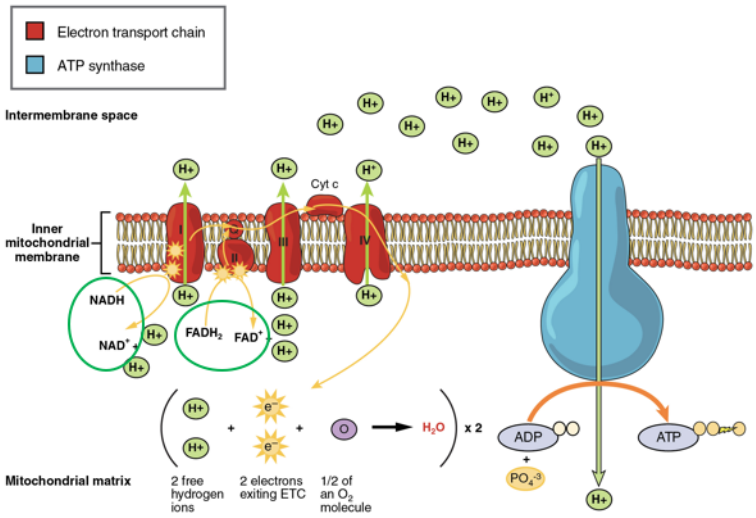
- What do we do with all that NADH and $FADH_2$?
- **Electron transport chain**

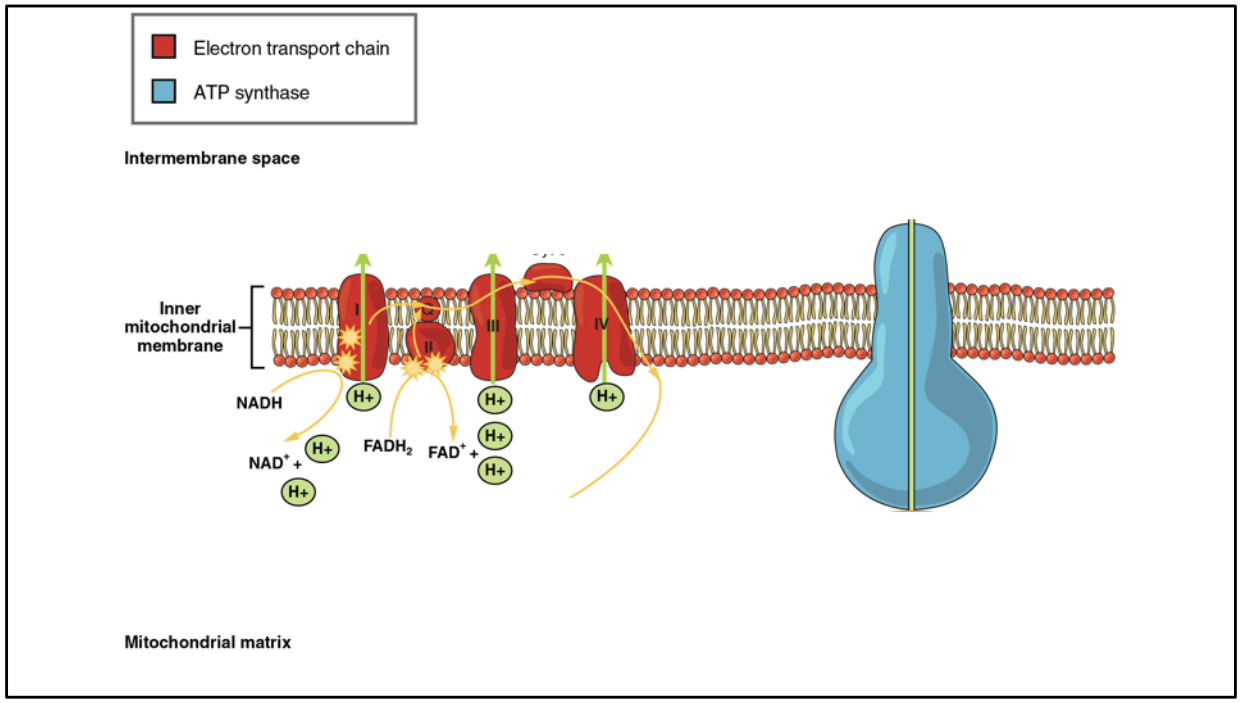


2 net ATP from glycolysis, 2 from the Krebs cycle
It takes about 200 molecules of ATP to make a single small protein
Every step that myosin takes uses ATP.

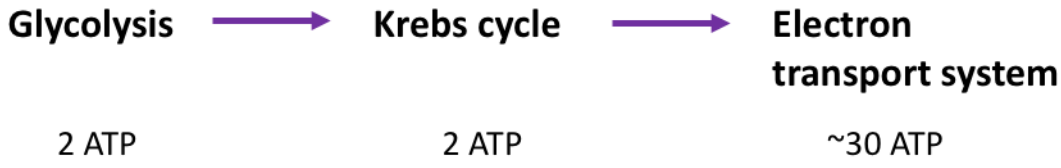
The rest of the energy

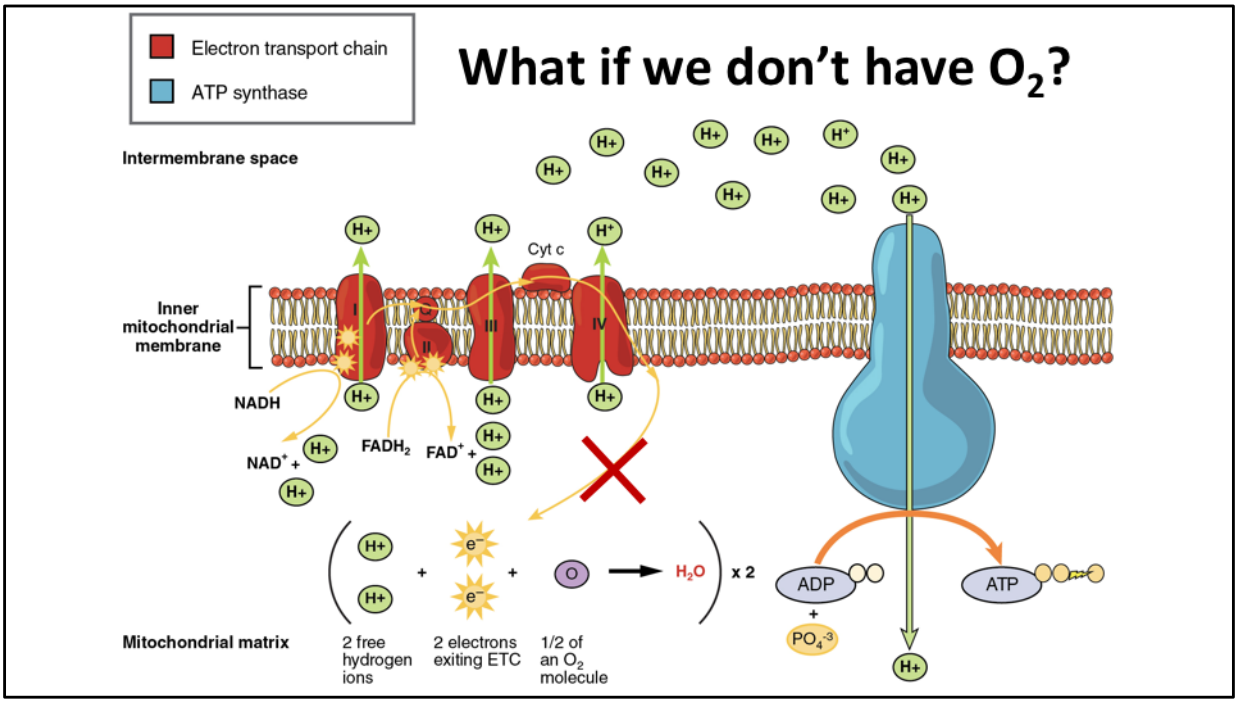
- **Electron transport chain**
- (AKA oxydative phosphorylation)
- Uses the electrons from the electron transporter shuttles to make a H^+ gradient




Electron transport chain
ATP synthase
Intermembrane space
Inner mitochondrial membrane
I
II
III
IV
NADH
NAD+ +
H+
FADH2
FAD+ +
Mitochondrial matrix

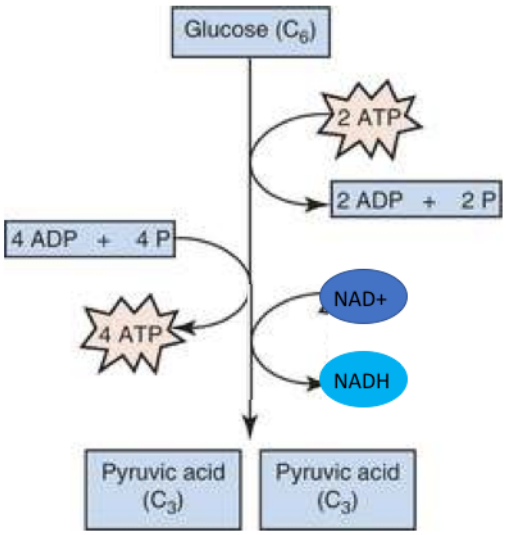
Aerobic Cellular Respiration in a nutshell…



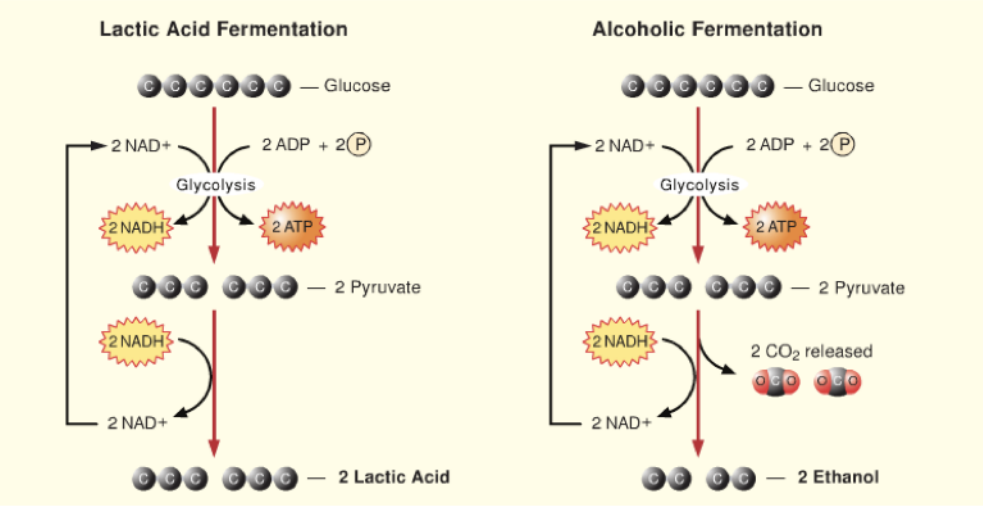

Electron transport chain
ATP synthase
What if we don't have O_2?
Intermembrane space
Inner mitochondrial membrane
Cyt c
I
II
III
IV
NADH
NAD^+ +
$FADH_2$
FAD^+ +
H+
e^-
O
H_2O
x 2
ADP
+
PO_4^{-3}
ATP
Mitochondrial matrix
2 free hydrogen ions
2 electrons exiting ETC
1/2 of an O_2 molecule

Anaerobic Respiration

- Still need to recycle electron transport shuttles
- Only have 2 net ATP from glycolysis!



Anaerobic Respiration



For each molecule of glucose that goes through fermentation: net 2ATP

Questions?

- Why does it make sense for animal cells to use aerobic respiration rather than anaerobic?
- Why is it beneficial for organisms to do anaerobic respiration?
- What would happen if we didn't have oxygen for an extended period?