Topics

- Cellular Respiration
  - Fermentation
  - Energy sources
- Exam Review

Step	Input	Output	Important Features
Glycolysis	• Glucose • ADP, P • NAD^+	• Pyruvic acid • 2 ATP • Electrons and H^+ carried by NADH	• Occurs in cytoplasm • All organisms use this pathway • NO O_2 required • ATP is produced by direct phosphate transfer
Citric Acid (Krebs) Cycle	• Pyruvic acid • ADP, P • NAD^+, FAD	• CO_2 • 2 ATP • Electrons and H^+ carried by NADH and $FADH_2$	• Occurs in mitochondria (central matrix) • Pyruvic acid first converted to Acetyl CoA • Other fuel molecules (fatty acids, amino acids) can be used for Citric Acid Cycle • Carbon atoms of original glucose completely converted to CO_2 • ATP is produced by direct phosphate transfer
Electron Transport Chain (E.T.C.)	• O_2 • Electrons and H^+ carried by NADH and $FADH_2$ from glucose • ADP, P	• H_2O • 34 ATP • NAD^+ and FAD recycled	• Occurs in mitochondria (inner membrane) • Oxygen is final electron acceptor and, with H^+, forms H_2O • Energy of electrons is used by proteins of E.T.C. to pump H^+ across inner membrane of mitochondrion to generate H^+ concentration gradient and potential energy • ATP synthase uses H^+ gradient to make ATP (like turbine) by chemi-osmosis

(Glucose is **oxidized**)

Loss of hydrogen atoms

$C_6H_{12}O_6$ (Glucose) + 6 O_2 → 6 CO_2 + 6 H_2O + Energy (ATP)

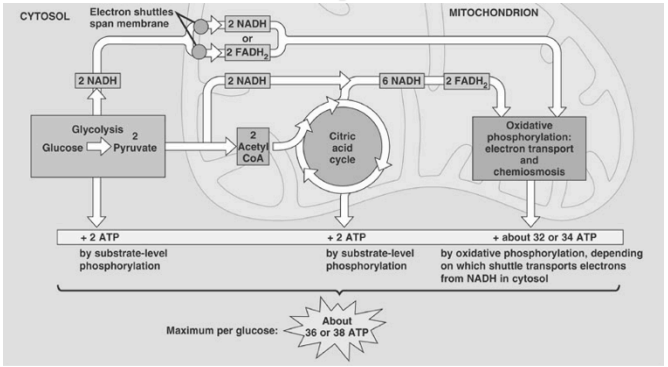
Gain of hydrogen atoms

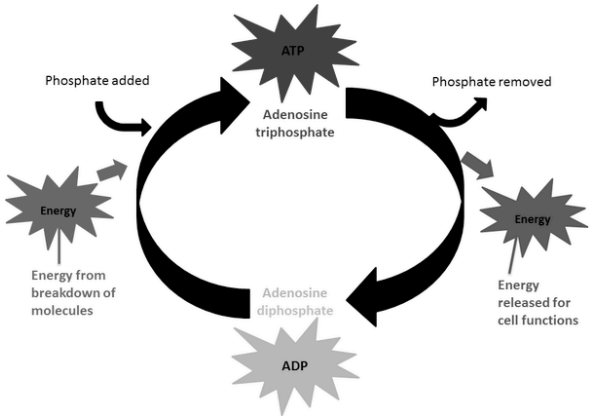
(Oxygen is **reduced**)

Oxidizing agent is said to be "reduced"
Reducing agent is said to be "oxidized"

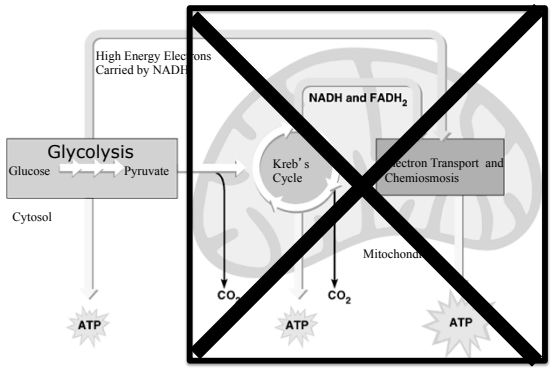
Final energy tally

- **~30-32 ATP Produced by ETC/Oxidative Phosphorylation**
- **Uses coenzymes NAD+ and FAD+ to accept e- from glucose**
- **NADH = 2.5 ATP's $FADH_2$ = 1.5 ATP's**





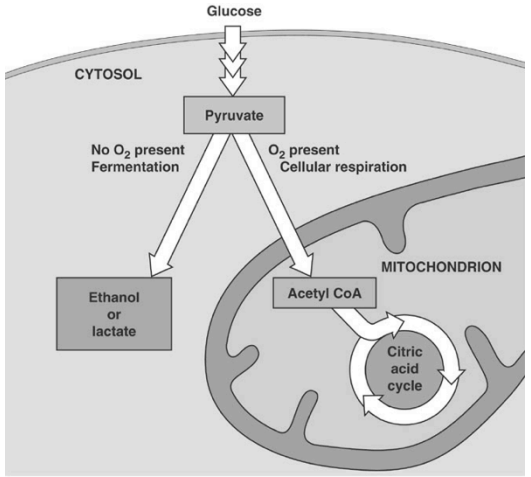
What If There Is No O_2?



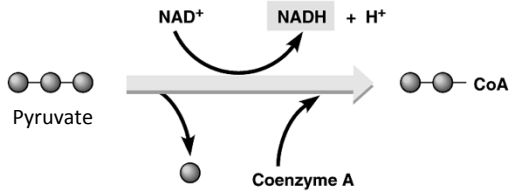
Anaerobic Cellular Respiration

- Some organisms thrive in environments with little or no oxygen
  - Marshes, bogs, gut of animals
- **No oxygen used = 'an' aerobic**
- Final electron acceptors differ, eg. sulfate and nitrate
- Less efficient at making ATP than aerobic respiration

VS. fermentation



In Aerobic Conditions



What if there is no O_2?...

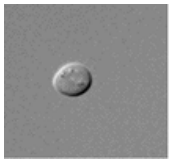
Without oxygen the cell cannot convert pyruvate to Acetyl-CoA **because it cannot oxidize NADH back to NAD^+**

...pyruvate and NADH build up!!

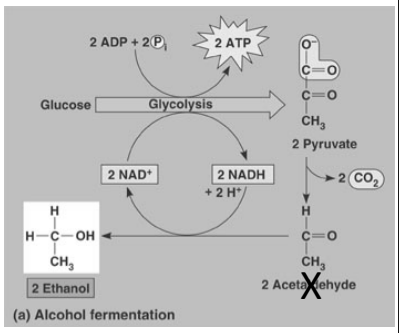
Fermentation

What if there is no O_2?...

1) Alcoholic fermentation
   Yeast
   Bacteria



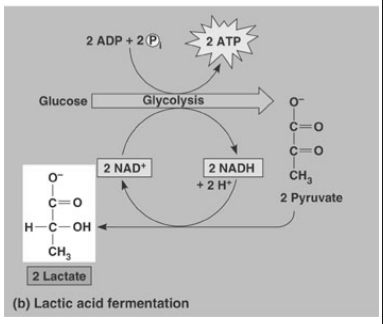
Saccharomyces cerevisiae



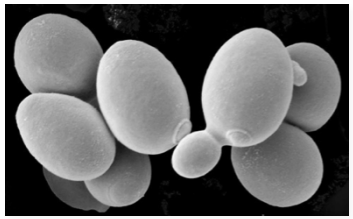
Fermentation

What if there is no O_2?...

2) Lactic acid fermentation
   Bacteria
   Animal cells (muscle)



Why use Fermentation?



Saccharomyces cerevisiae

Yeast are called *facultative anaerobic* organisms (they can do both **aerobic respiration** and **fermentation**)

Pros

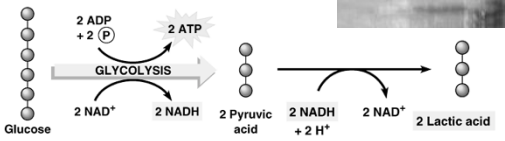
- Fermentation requires no oxygen
- Fermentation is MUCH faster than oxidative phosphorylation

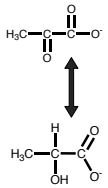
Cons

- Only creates **2 ATP** total
- Creates waste that is more difficult to remove (and toxic)than just water and CO_2

Fermentation

What about in humans?





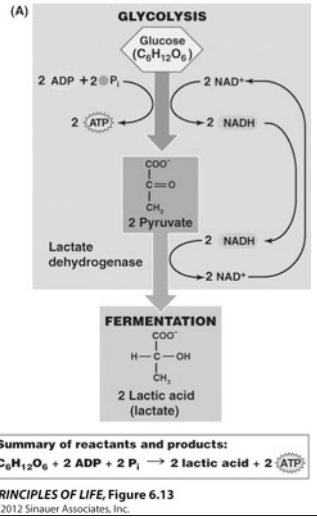
- Only creates **2 ATP** total, but is fast and efficient
- The brain **cannot** utilize fermentation
- The lactic acid must be converted back to pyruvic acid later…

Fast Twitch VS. Slow Twitch

Fermentation

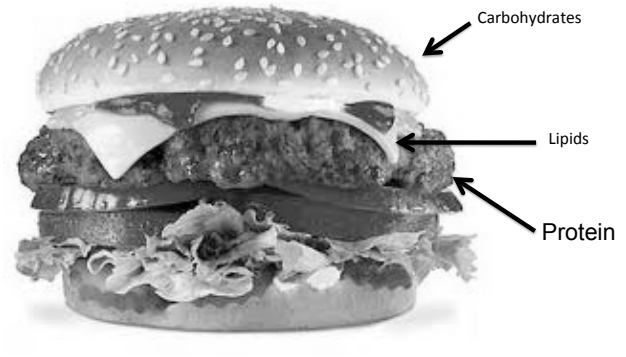
What if there is no O_2?...

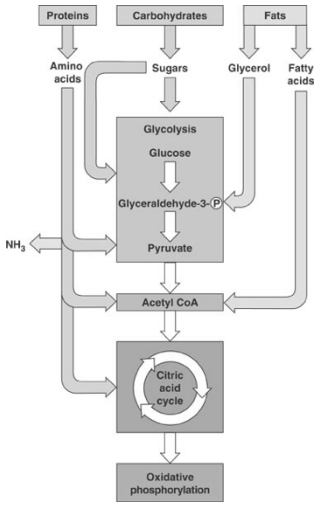
1) Lactic acid fermentation
   Bacteria
   Animal cells (muscle)



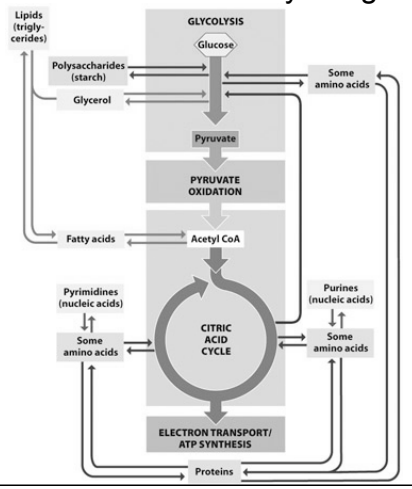
PRINCIPLES OF LIFE, Figure 6.13

Catabolic interconversion

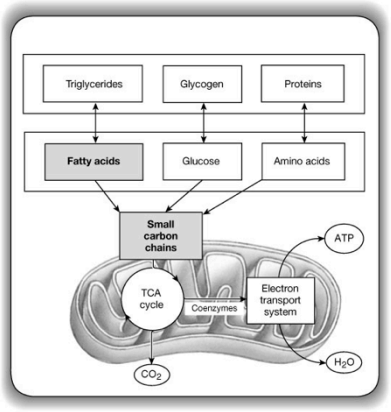




Catabolic-Anabolic Pathway Integration



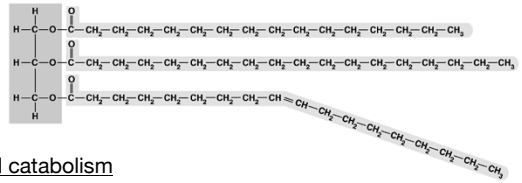
Lipid Catabolism



Lipid Catabolism

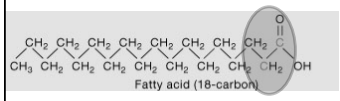
- ***Lipolysis*** breaks lipids down to components

  -**triglycerides** broken down to **fatty acids** and **glycerol**
  glycerol is further broken down and used in glycolysis
  Enters the citric acid cycle as **Acetyl-CoA**

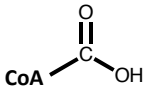


Fatty acid catabolism

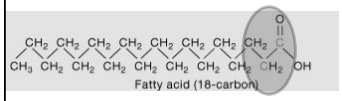
- Takes place in the mitochondria and/or peroxisomes
- Fatty acids are **highly reduced.** One average fatty acid can yield more ATP than 4.5 glucose molecules!



Beta-Oxidation



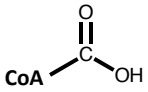
Acetyl-CoA



Beta-Oxidation

Each step creates:

1 NADH
1 FADH2
1 Acetyl-CoA



Acetyl-CoA

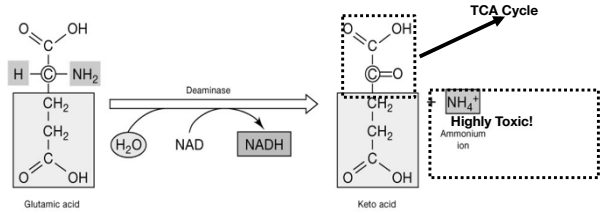
3	ATP
2	ATP
12	ATP
-1	ATP
16	ATP per round!

So, an 18 carbon FA would yield 144 ATPs!

Comparison of Glycolysis to Fatty acid Catabolism

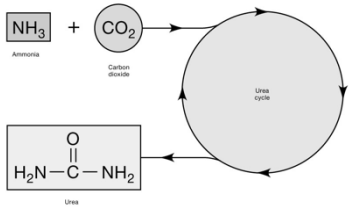
Fatty acid catabolism	Glycolysis
Highly productive (hundreds of ATP)	Only 2 ATP
Mitochondria	Cytosol
Completely O_2 dependent	O_2 *independent*
Slow	*Fast* (convert to lactate)

Amino Acid Metabolism



Deamination

The Urea Cycle



- NH4 (from amino group) is very toxic, urea is fairly harmless and very water soluble
- Takes place in the **Liver and Kidneys**
- Requires energy