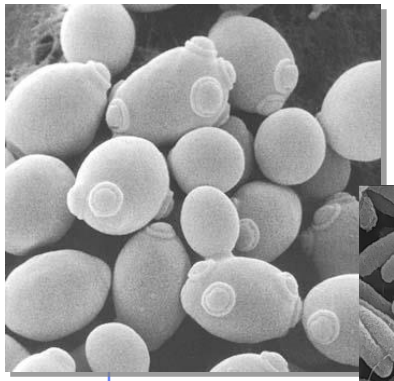
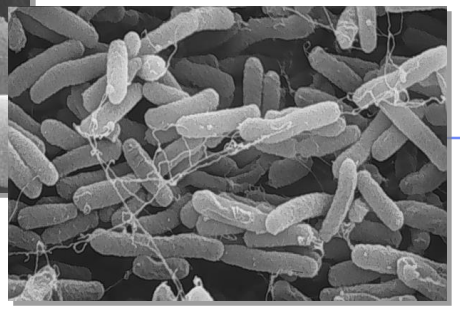
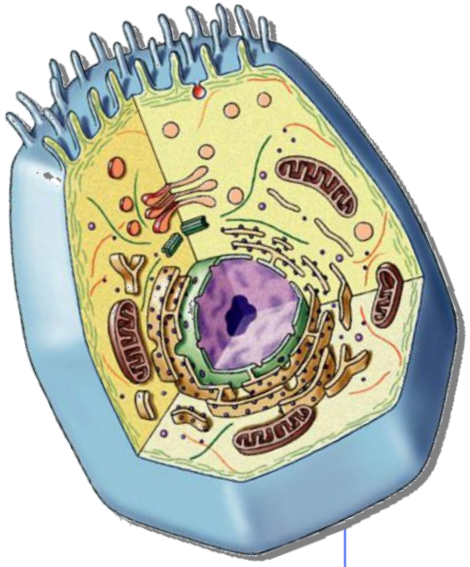


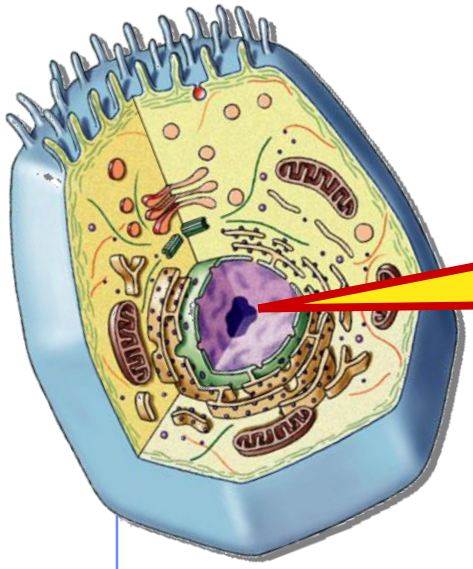




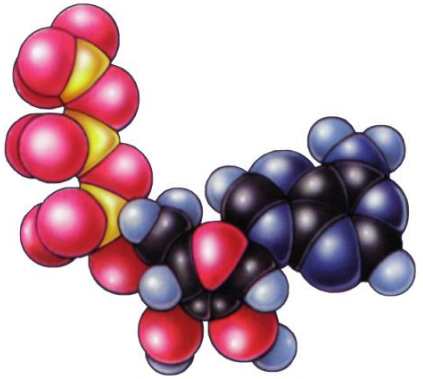
Cellular Respiration

Stage 1:

Glycolysis

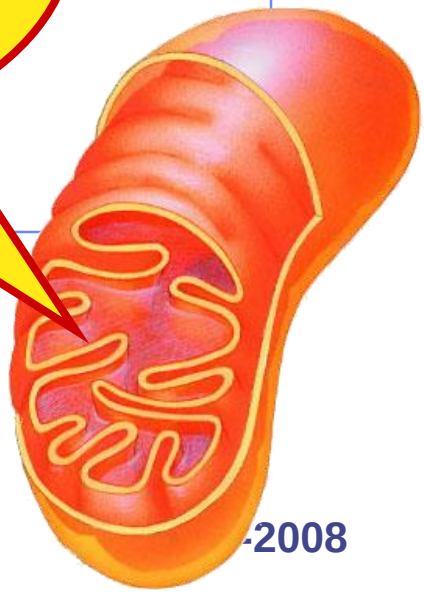


What's the point?



The point is to make ATP!

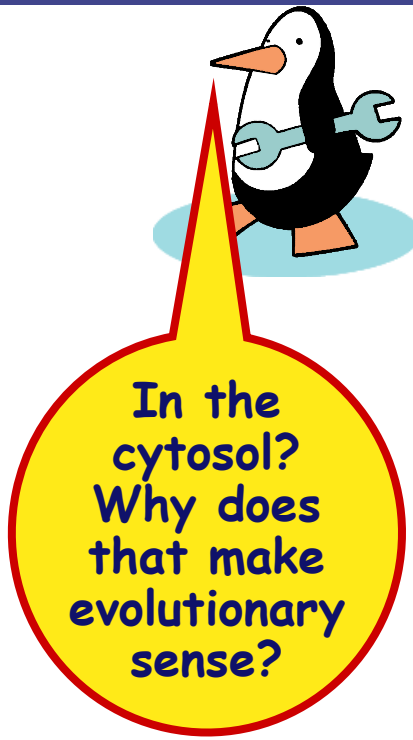
ATP



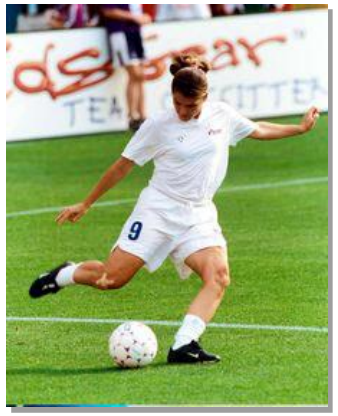
Glycolysis

- **Breaking down glucose**
  - "glyco – lysis" (splitting sugar)

glucose → → → → → pyruvate
6C 2x 3C

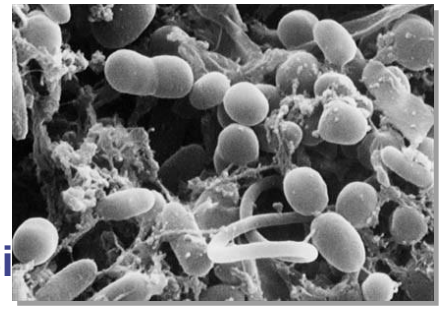


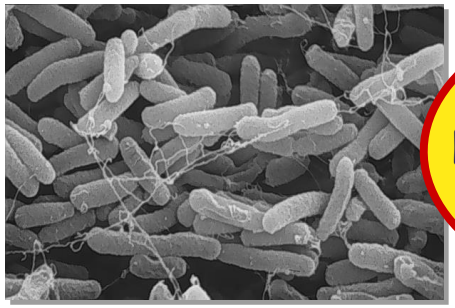
  - ancient pathway which harvests energy
    - where energy transfer first evolved
    - transfer energy from organic molecules to ATP
    - still is starting point for all cellular respiration
  - but it's inefficient
    - generate only 2 ATP for every 1 glucose
  - occurs in cytosol



Evolutionary perspective

- **Prokaryotes**
  - first cells had no organelles
- **Anaerobic atmosphere**
  - life on Earth first evolved without free oxygen (O_2) in atmosphere
  - energy had to be captured from organic molecules in absence of O_2
- **Prokaryotes that evolved glycolysis are ancestors of all modern life**
  - ALL cells still utilize glycolysis

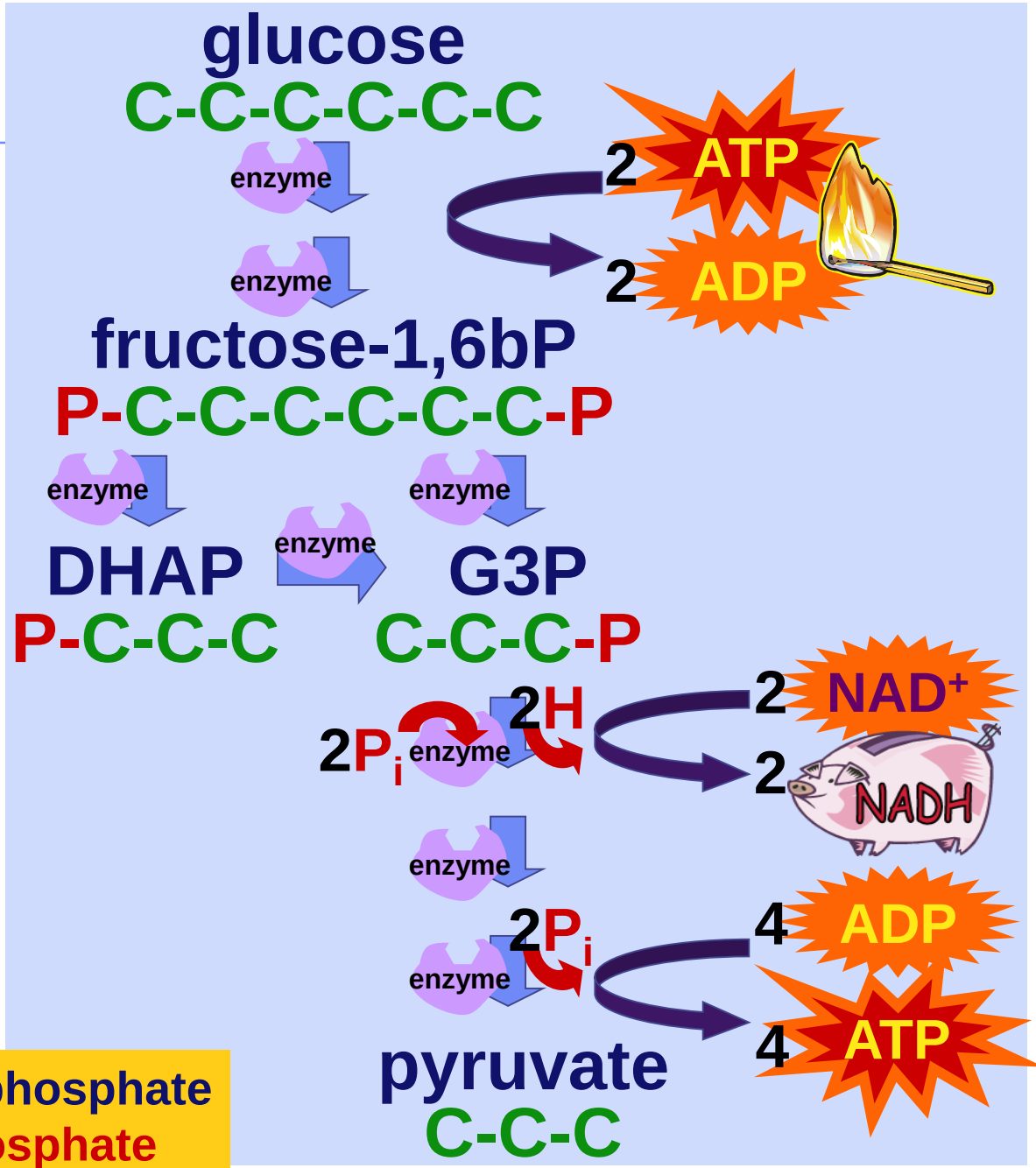




Overview

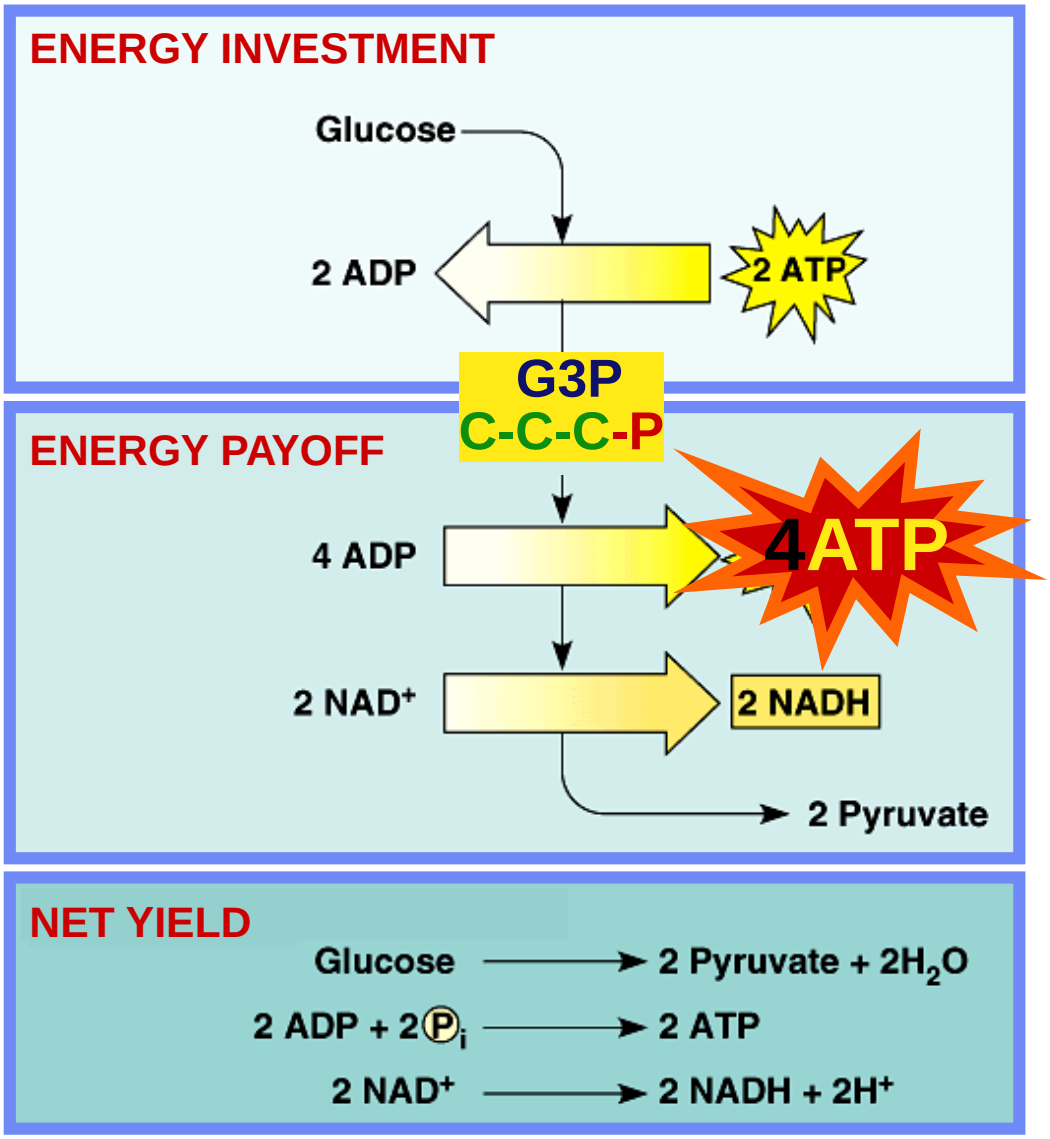
10 reactions

- convert <u>glucose (6C)</u> to <u>2 pyruvate (3C)</u>
- produces: <u>4 ATP & 2 NADH</u>
- consumes: <u>2 ATP</u>
- net: <u>2 ATP & 2 NADH</u>



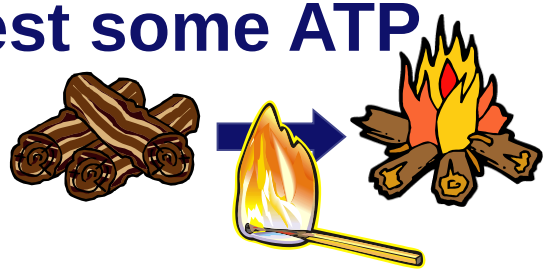
DHAP = dihydroxyacetone phosphate
G3P = glyceraldehyde-3-phosphate

Glycolysis summary



endergonic

invest some ATP



exergonic

harvest a little ATP & a little NADH

yield

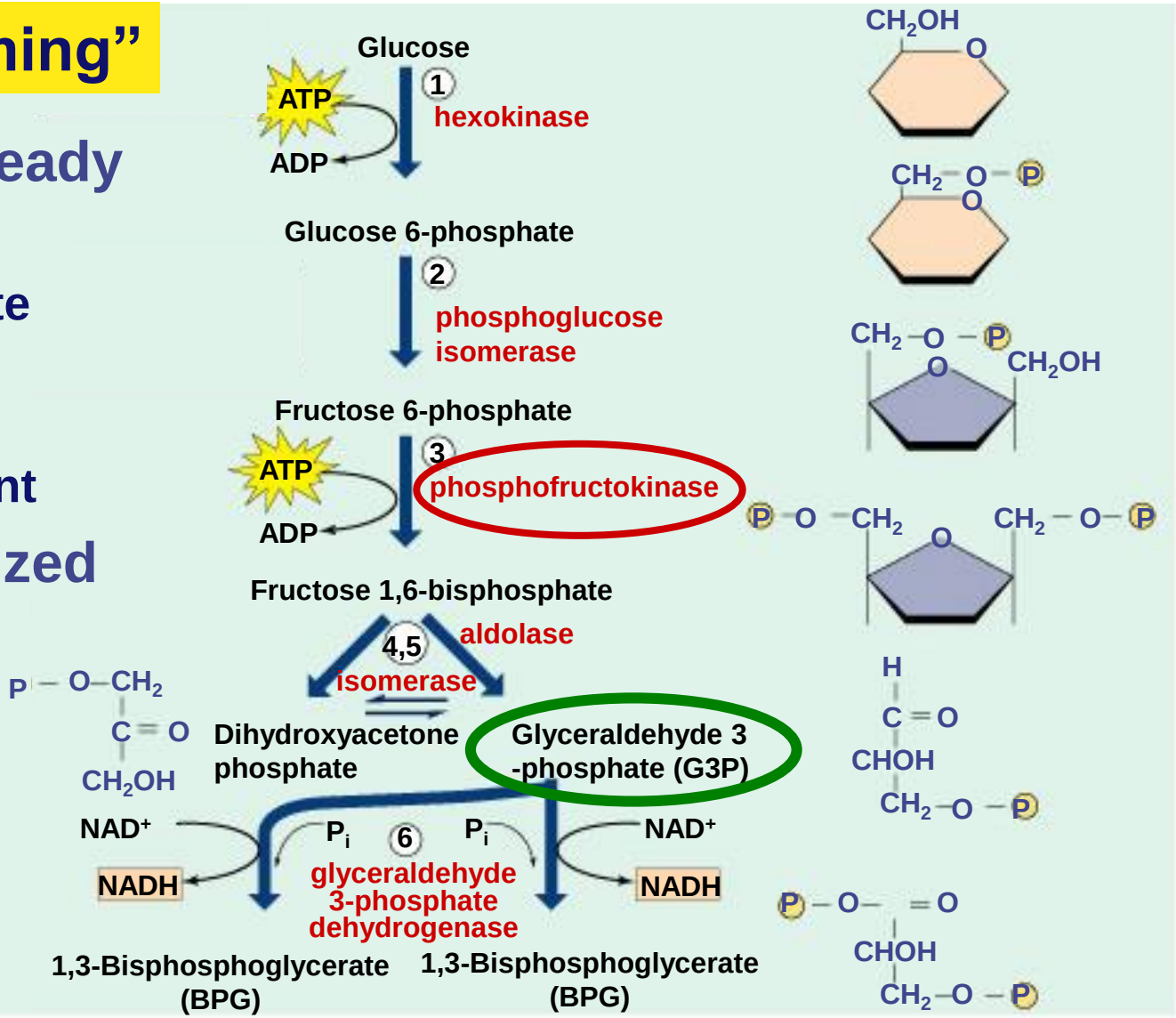
2 ATP

2 NADH

1st half of glycolysis (5 reactions)

Glucose "priming"

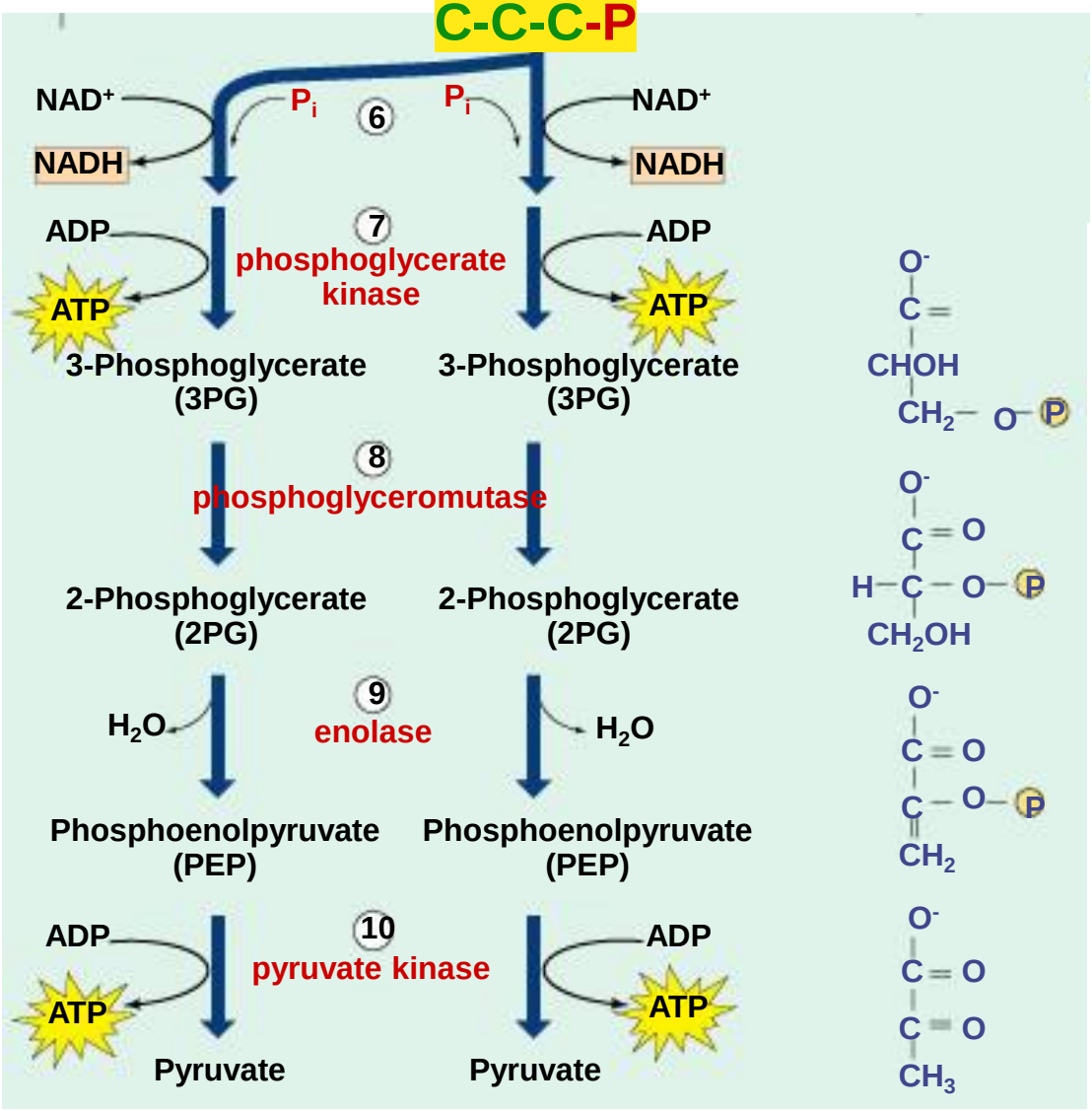
- get glucose ready to split
  - phosphorylate glucose
  - molecular rearrangement
- split destabilized glucose



2nd half of glycolysis (5 reactions)

Energy Harvest

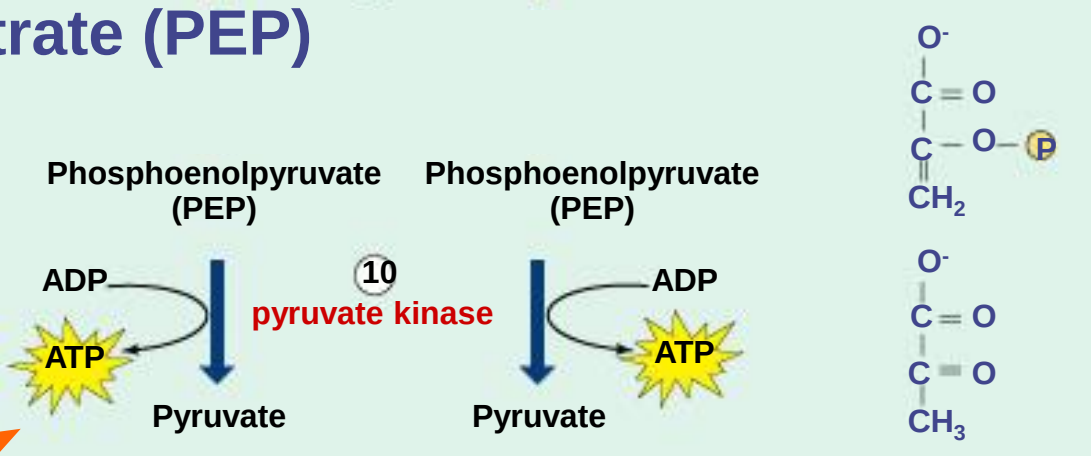
- NADH production
  - G3P donates H
  - oxidize sugar
  - reduce NAD^+
  - $NAD^+ \rightarrow$ NADH
- ATP production
  - G3P $\rightarrow$ pyruvate
  - PEP sugar donates P
  - ADP $\rightarrow$ ATP

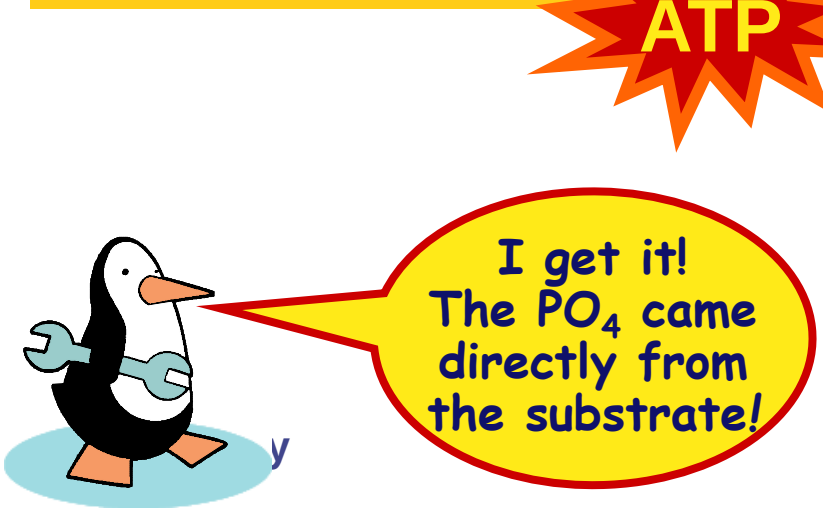


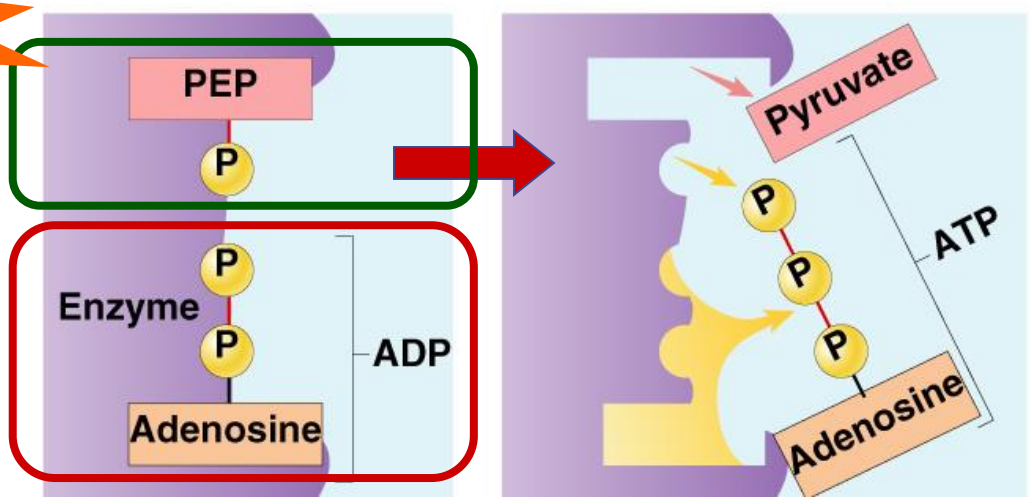
Substrate-level Phosphorylation

- In the last steps of glycolysis, where did the P come from to make ATP?
  - the sugar substrate (PEP)

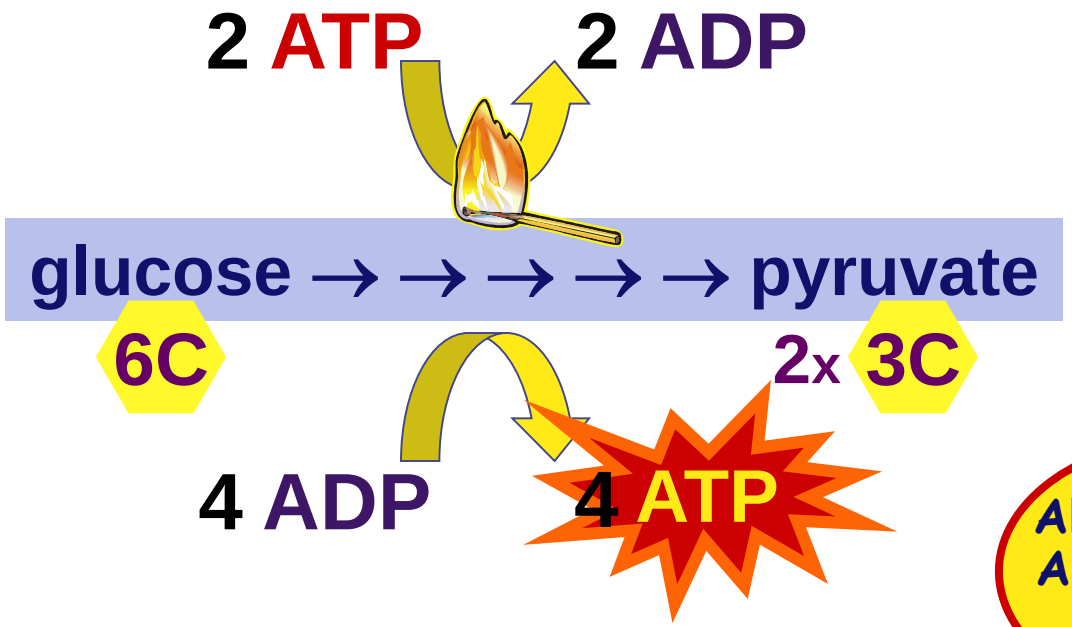
P is transferred from PEP to ADP
- **kinase enzyme**
- **ADP → ATP**







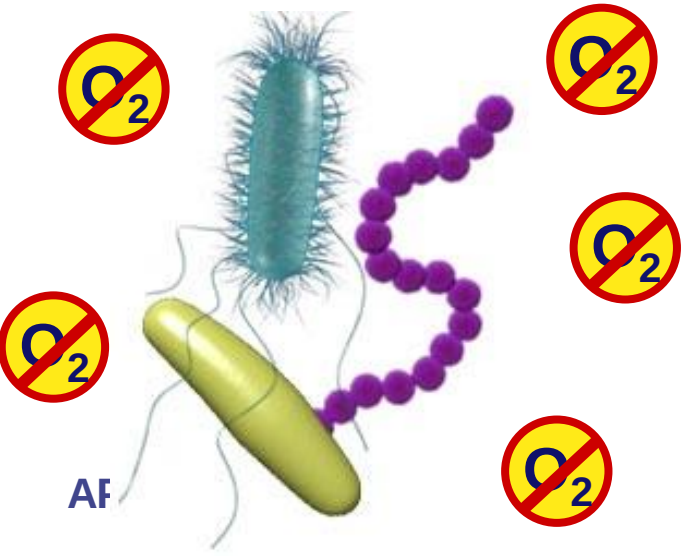
Energy accounting of glycolysis



- Net gain = 2 ATP
  - some energy investment (-2 ATP)
  - small energy return (+4 ATP)
- 1 6C sugar → 2 3C sugars

Is that all there is?

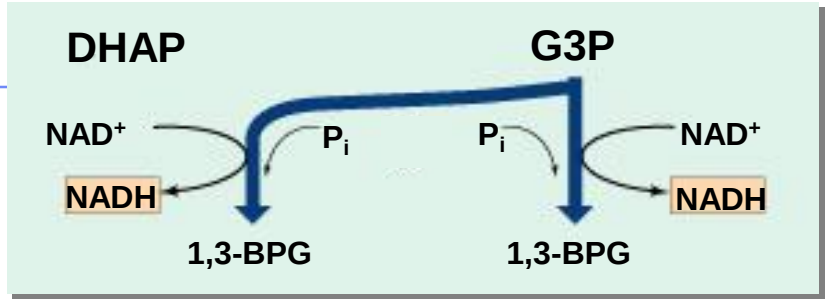
- **Not a lot of energy…**
  - **for 1 billon years⁺ this is how life on Earth survived**
    - **no O_2= slow growth, slow reproduction**
    - **only harvest 3.5% of energy stored in glucose**
      - **more carbons to strip off = more energy to harvest**



glucose → → → → pyruvate

6C **2x 3C**

We can't stop there!



Glycolysis

glucose + 2ADP + 2P_i + 2 NAD^+ → 2 pyruvate + 2ATP + 2NADH

- Going to run out of NAD^+
  - without regenerating NAD+, energy production would stop!
  - another molecule must accept H from NADH

How is NADH recycled to NAD+?

Another molecule must accept H from NADH

which path you use depends on who you are…

with oxygen
aerobic respiration

without oxygen
anaerobic respiration
fermentation

pyruvate

H_2O NAD^+ O_2 NADH

acetyl-CoA

Krebs cycle

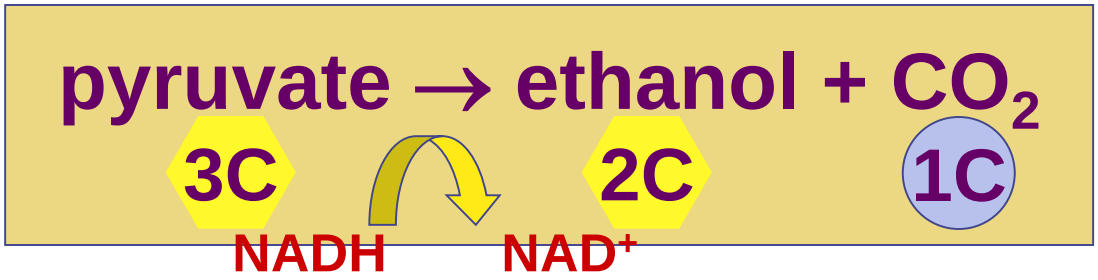
NADH NAD^+ lactate

(lactic acid)

CO^2 acetaldehyde NADH NAD^+ ethanol

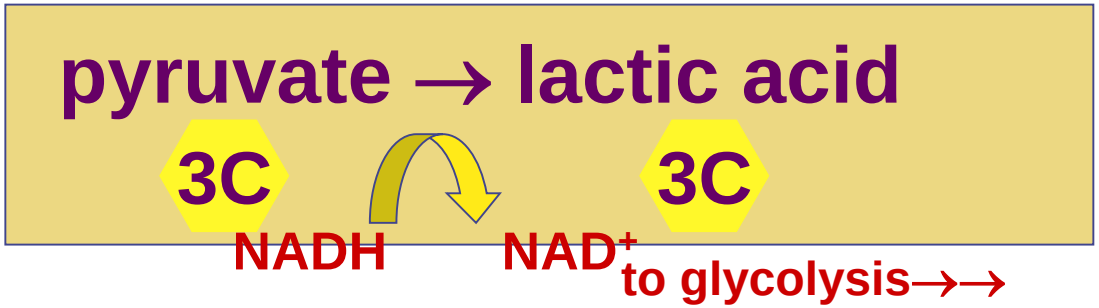
Fermentation (anaerobic)

- **Bacteria, yeast**



  - beer, wine, bread

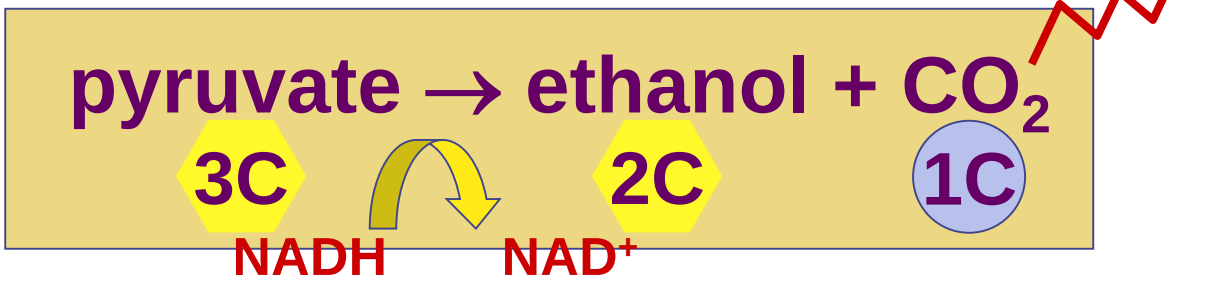
- **Animals, some fungi**



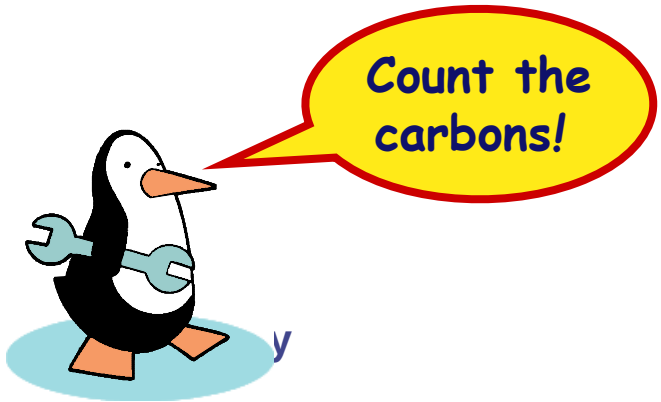
  - cheese, anaerobic exercise (no O_2)

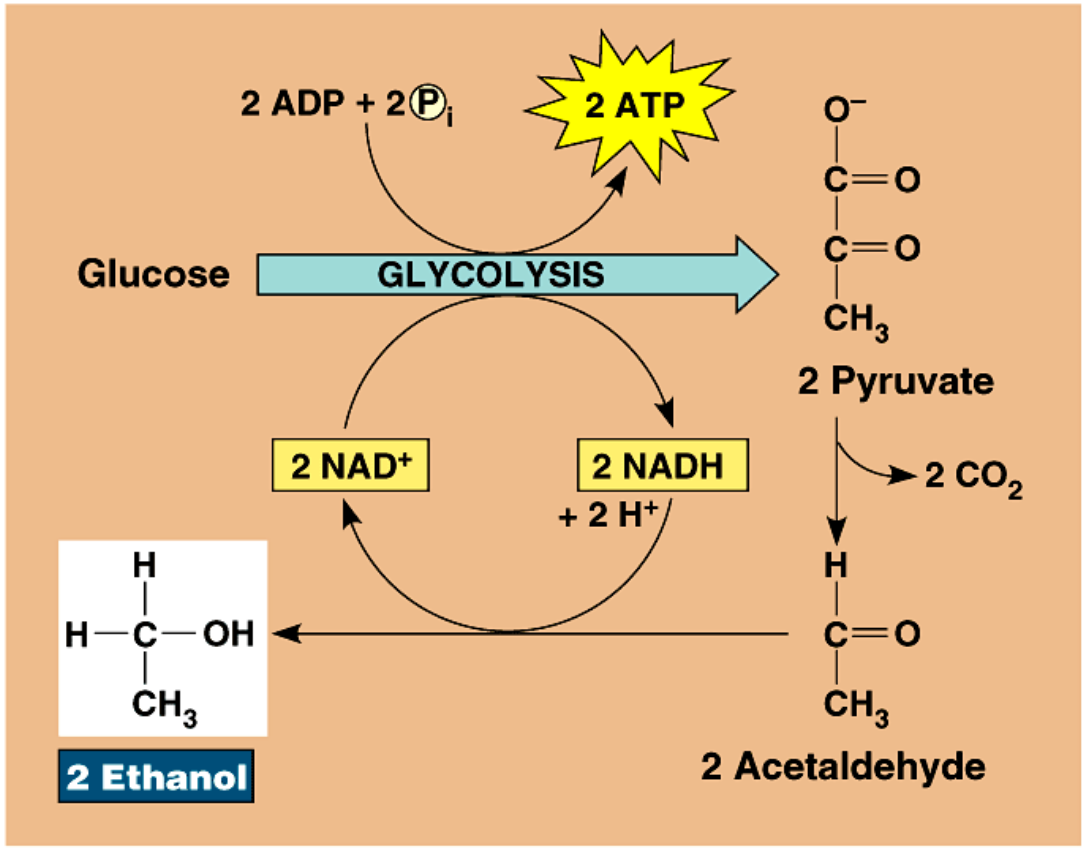
Alcohol Fermentation

bacteria
yeast



- **Dead end process**
  - at ~12% ethanol, kills yeast
  - can't reverse the reaction





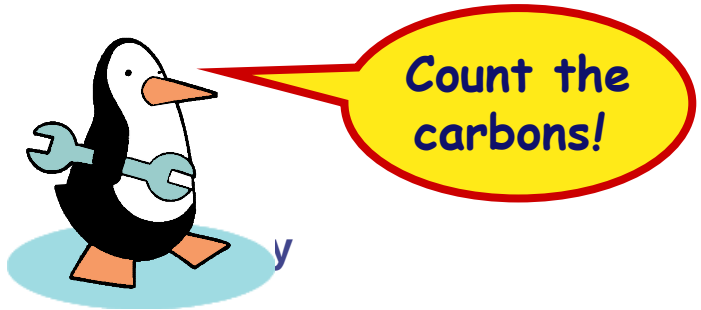
Lactic Acid Fermentation

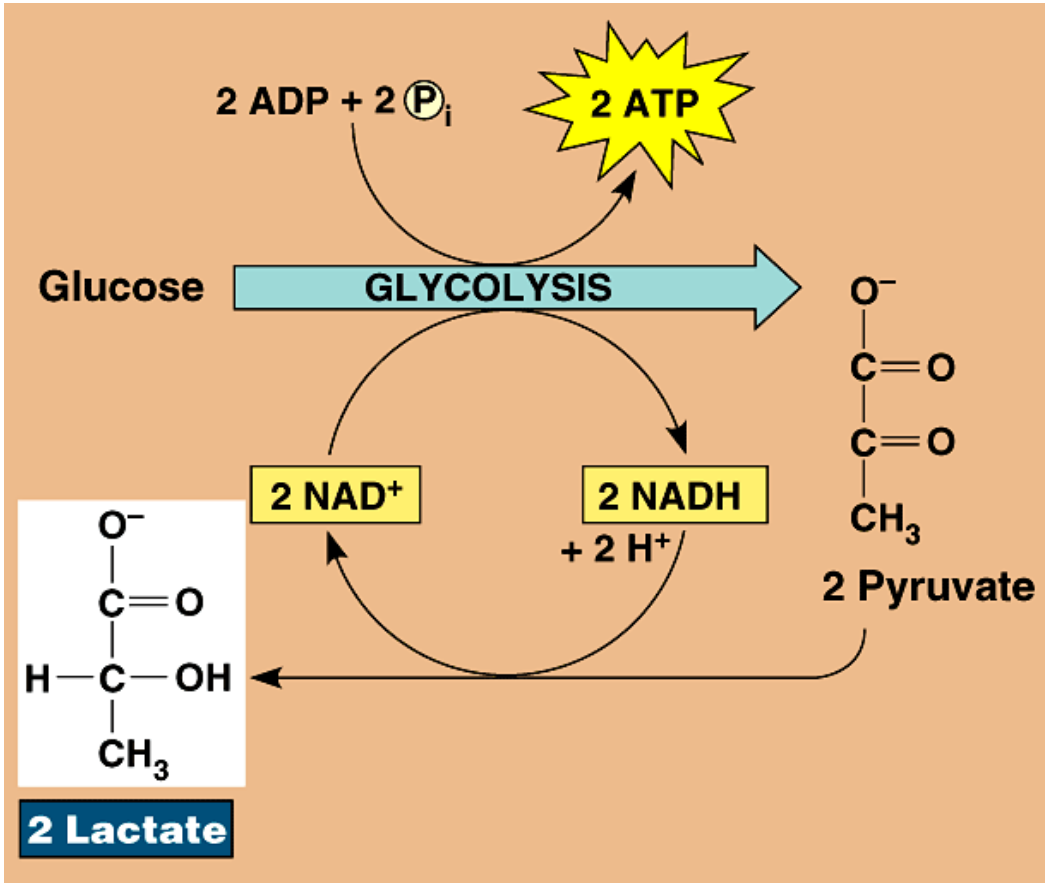
pyruvate ↔ lactic acid

O_2

3C NADH ↔ 3C NAD^+

- Reversible process
  - once O_2 is available, lactate is converted back to pyruvate by the liver





Pyruvate is a branching point

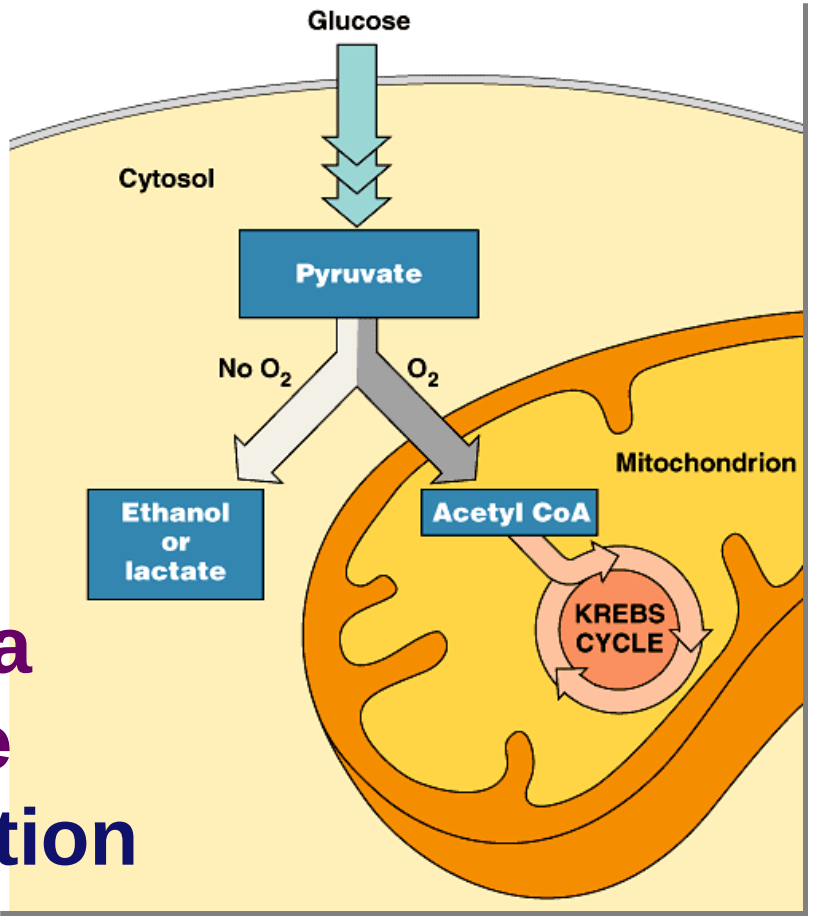
Pyruvate

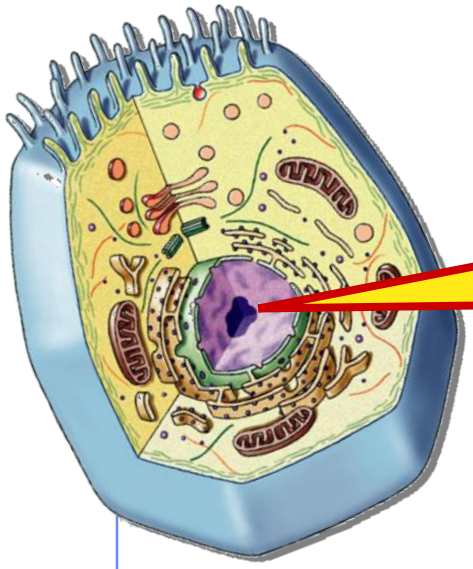
O_2

O_2

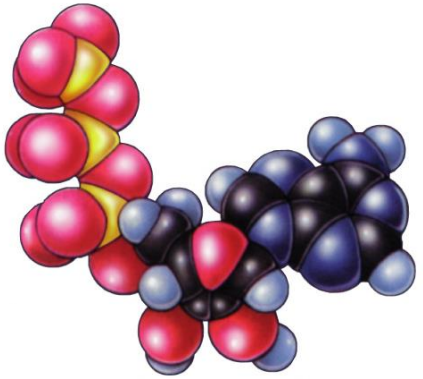
fermentation
anaerobic
respiration

mitochondria
Kreb's cycle
aerobic respiration



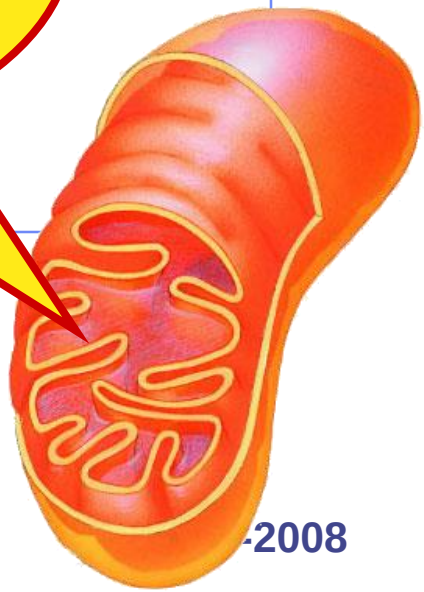


What's the point?



The point is to make ATP!

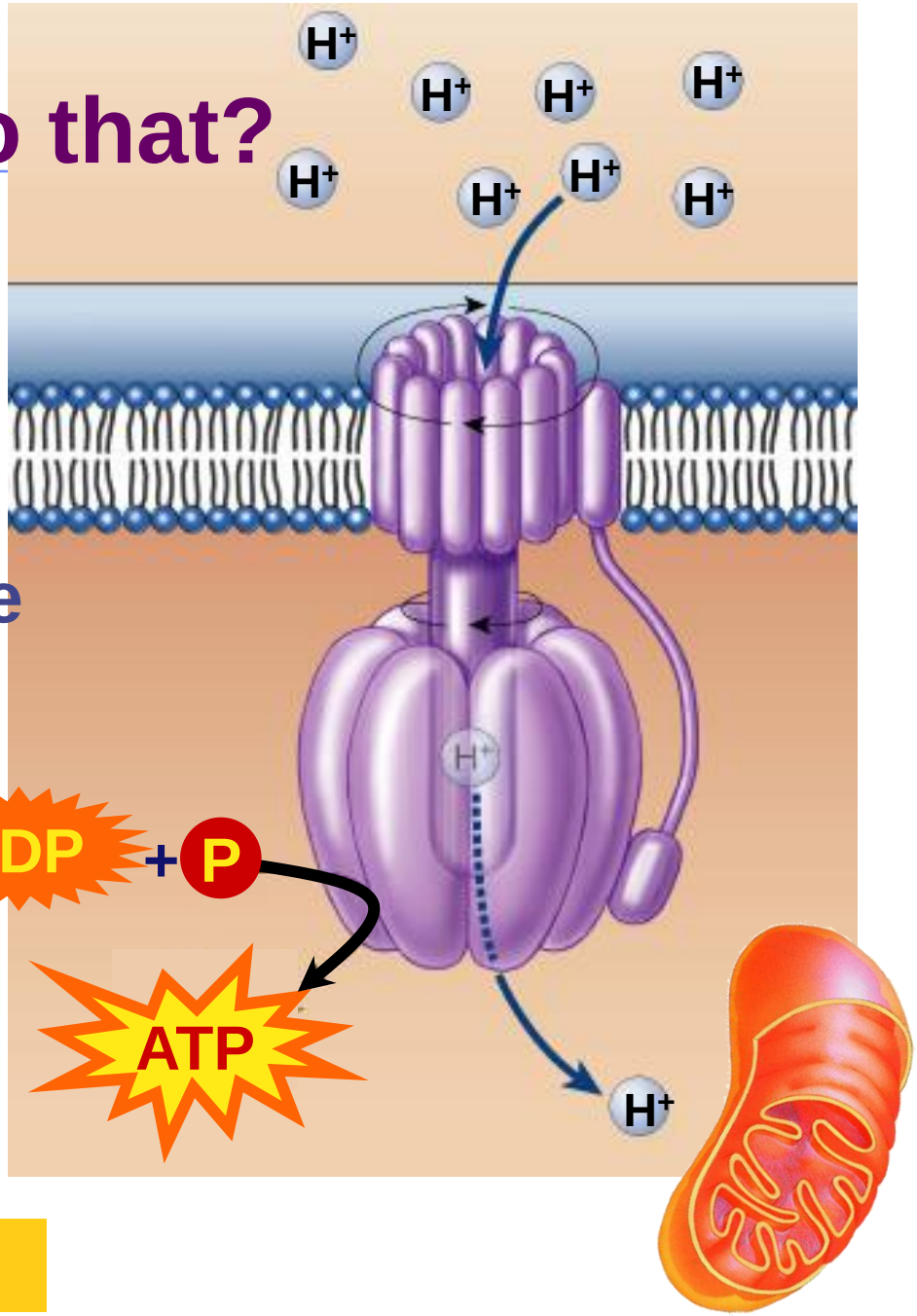
ATP



And how do we do that?

- **ATP synthase**
  - set up a H^+ gradient
  - allow H^+ to flow through ATP synthase
  - powers bonding of P_i to ADP

$$ADP + P_i \rightarrow ATP$$



But… Have we done that yet?

NO!
There's still more to my story!
Any Questions?