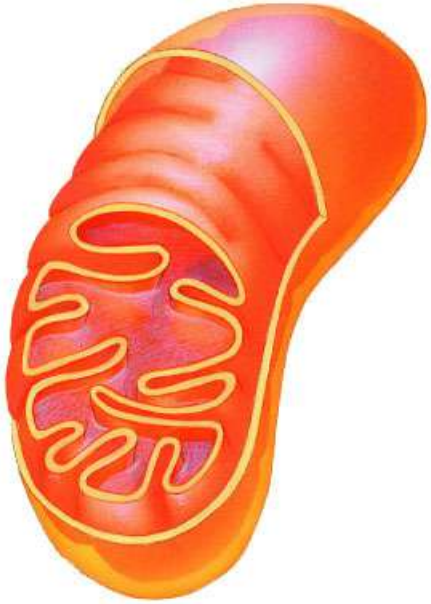
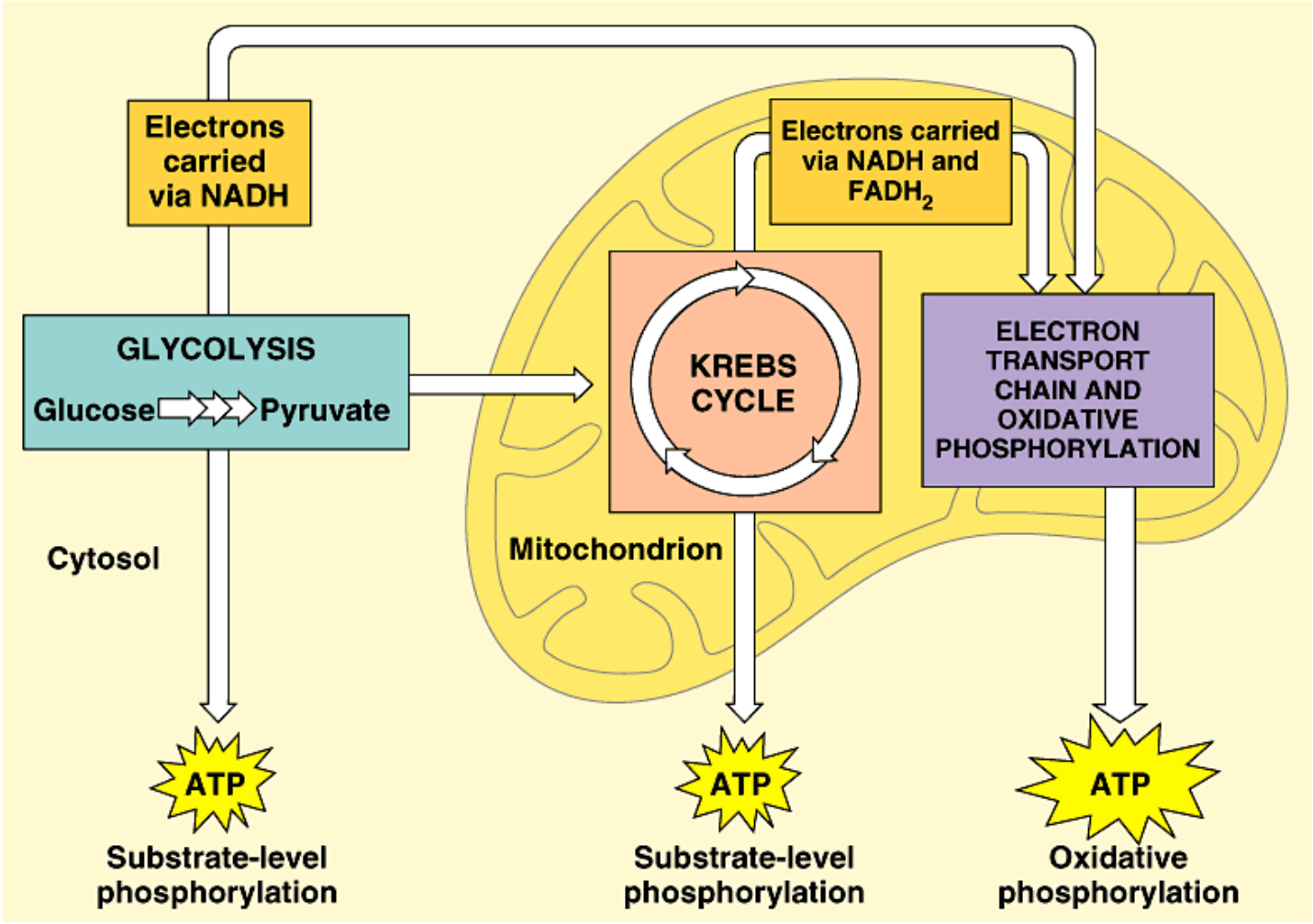
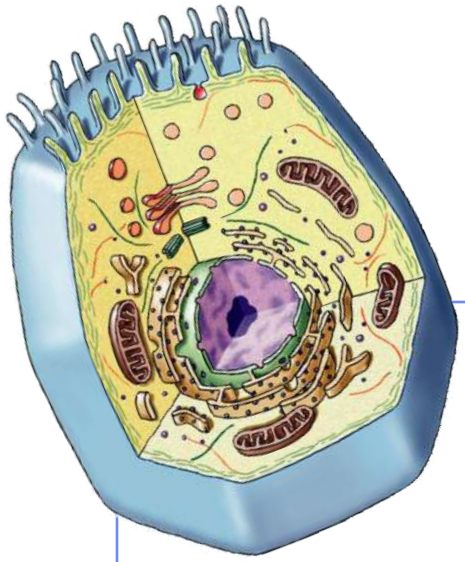
Cellular Respiration
Stage 4:
Electron Transport Chain

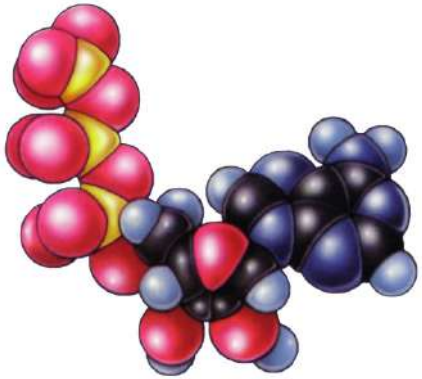


Cellular respiration



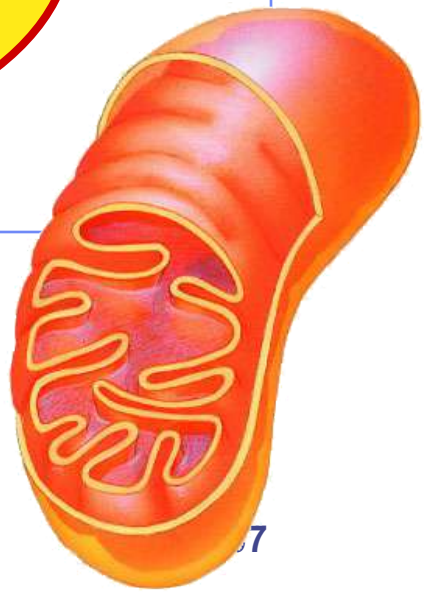


What's the point?



The point is to make ATP!

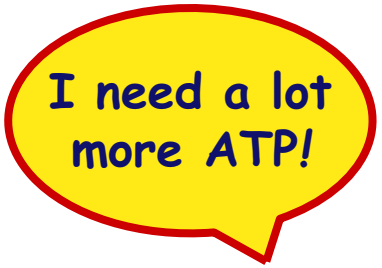
ATP

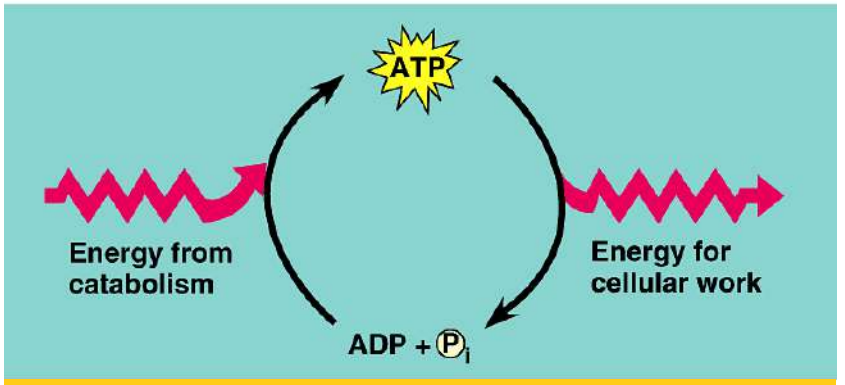


ATP accounting so far…

- Glycolysis → 2 ATP
- Kreb's cycle → 2 ATP
- Life takes a lot of energy to run, need to extract more energy than 4 ATP!

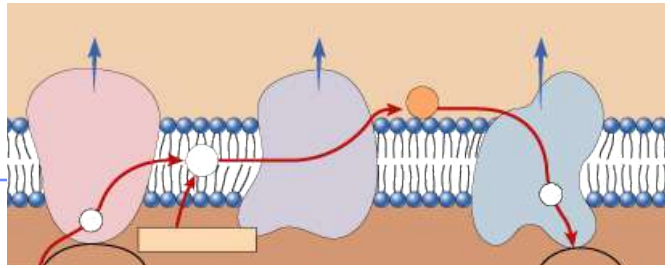
There's got to be a better way!



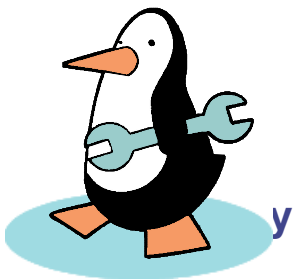


A working muscle recycles over 10 million ATPs per second

There *is* a better way!



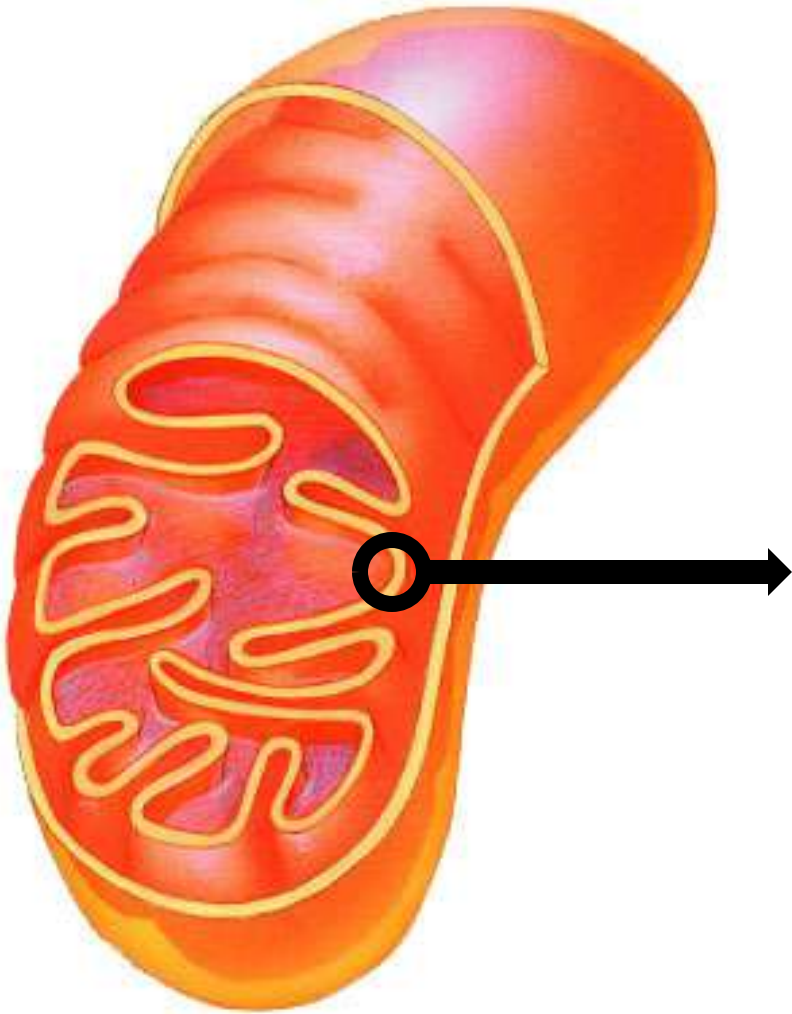
- Electron Transport Chain
  - series of proteins built into inner mitochondrial membrane
  - along cristae
    - transport proteins & enzymes
    - transport of electrons down ETC linked to pumping of H^+ to create H^+ gradient
  - yields ~36 ATP from 1 glucose*!*
  - only in presence of O_2 (aerobic respiration)

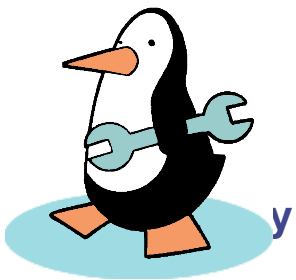


O_2

Mitochondria

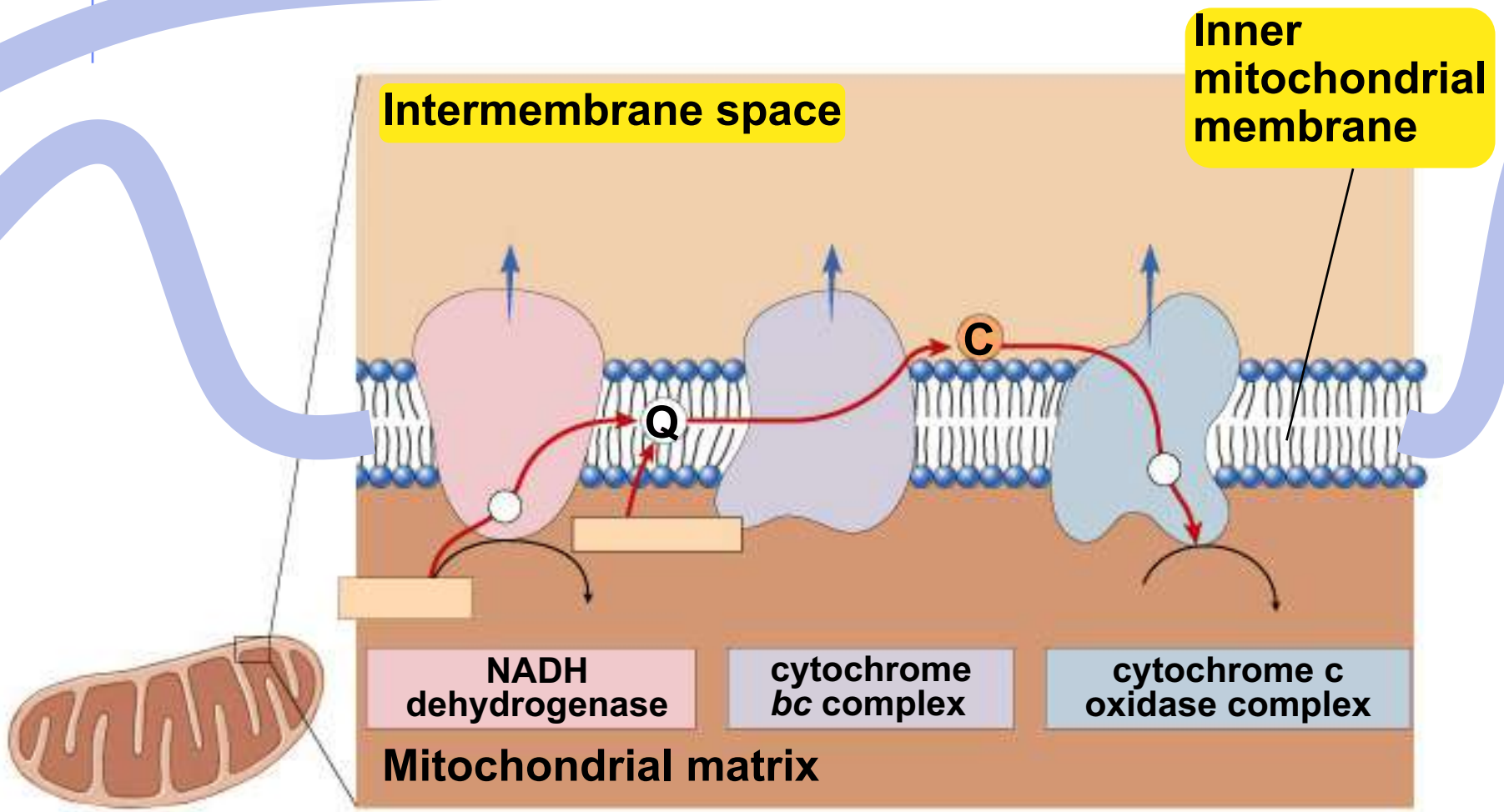
- Double membrane
  - outer membrane
  - inner membrane
    - highly folded cristae
    - enzymes & transport proteins
  - intermembrane space
    - fluid-filled space between membranes





Oooooh! Form fits function!

Electron Transport Chain

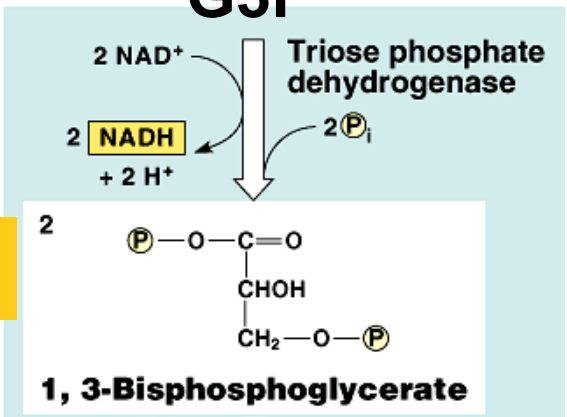


Remember the Electron Carriers?

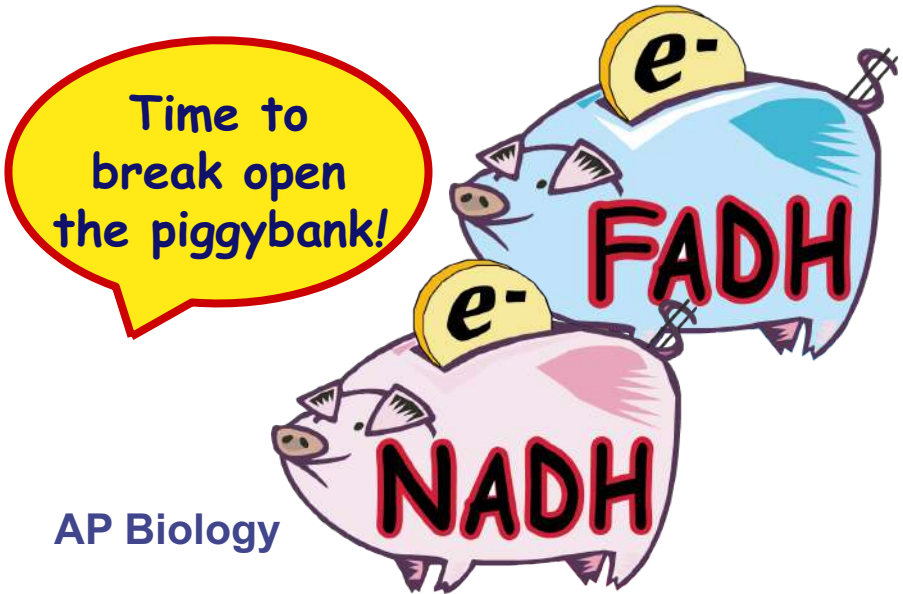
Glycolysis

glucose

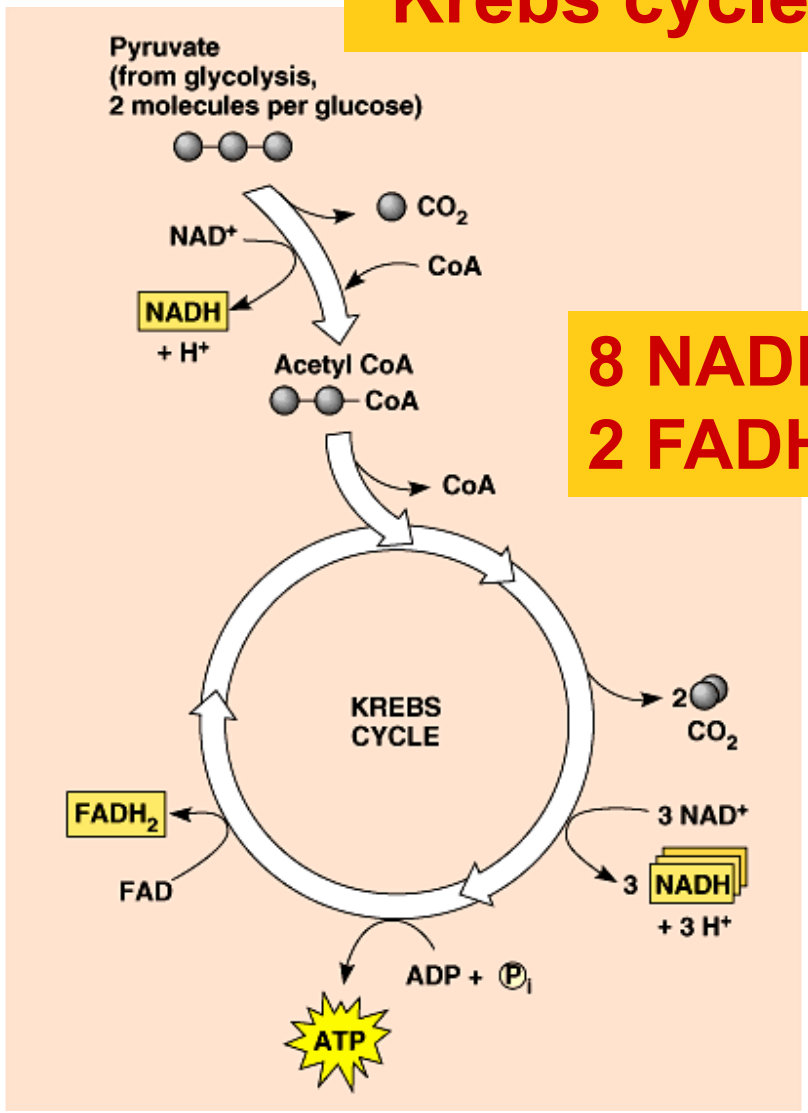
G3P



2 NADH



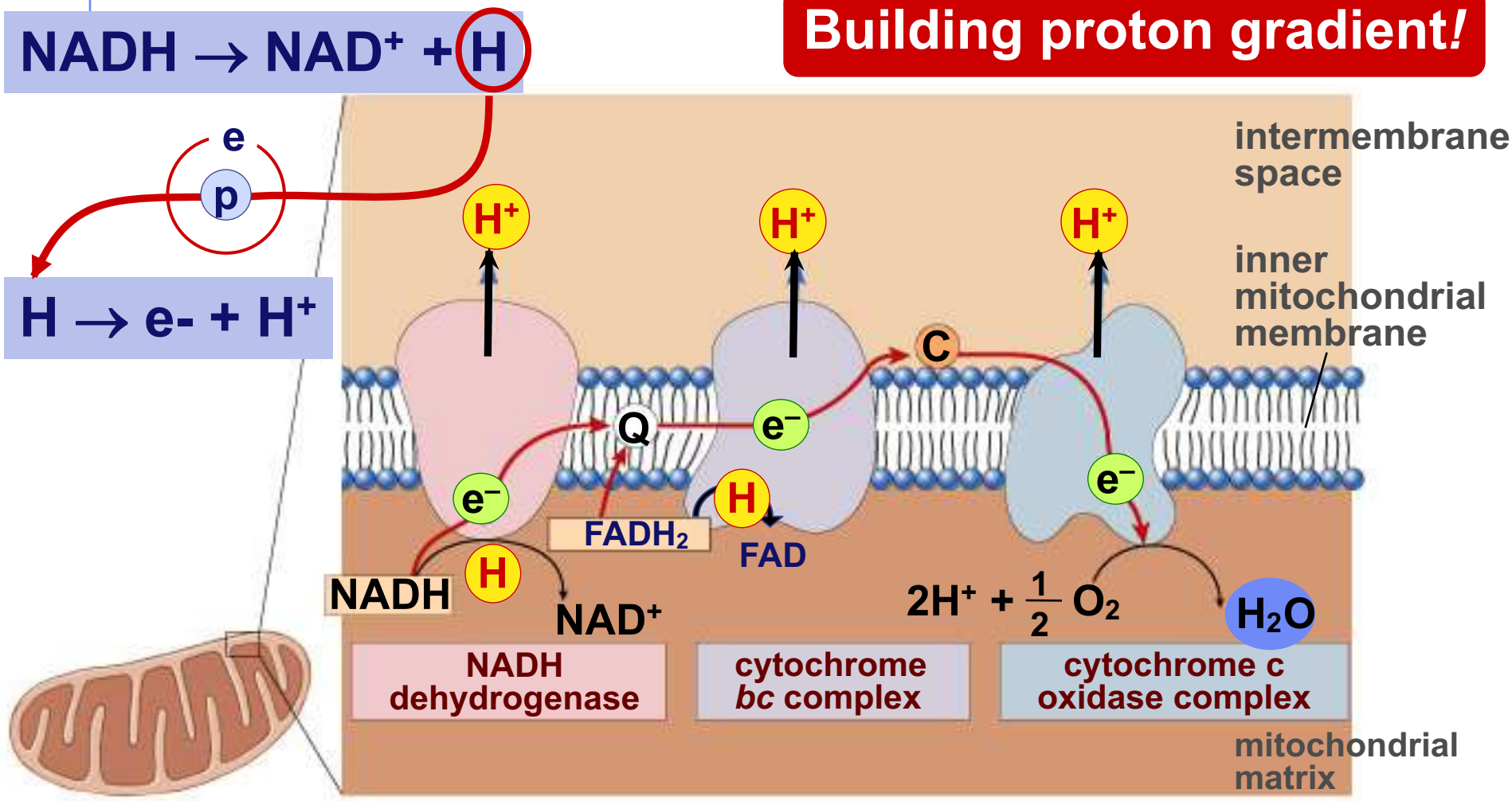
Krebs cycle



8 NADH
2 $FADH_2$

Electron Transport Chain

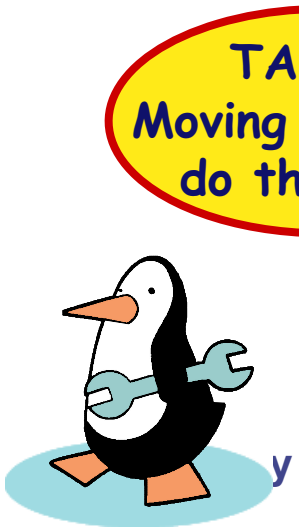
Building proton gradient!

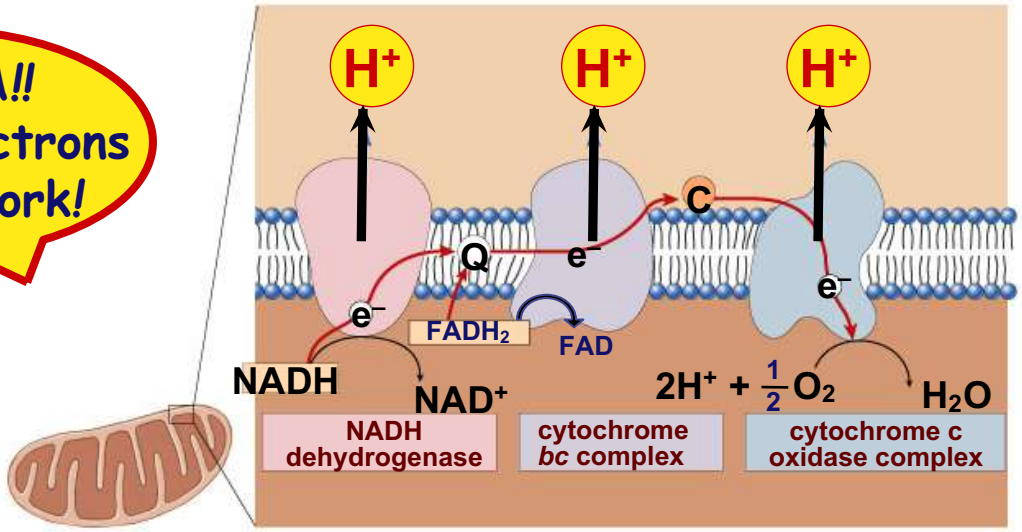


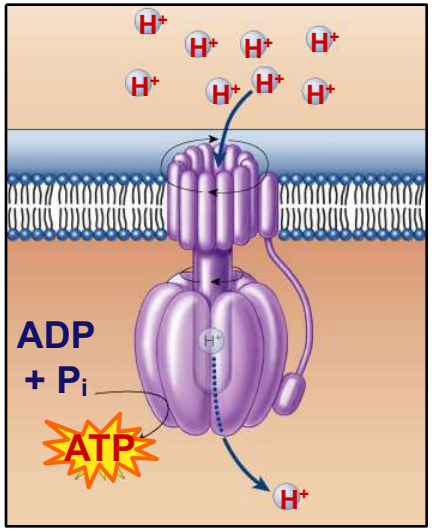
What powers the proton (H^+) pumps?…

Stripping H from Electron Carriers

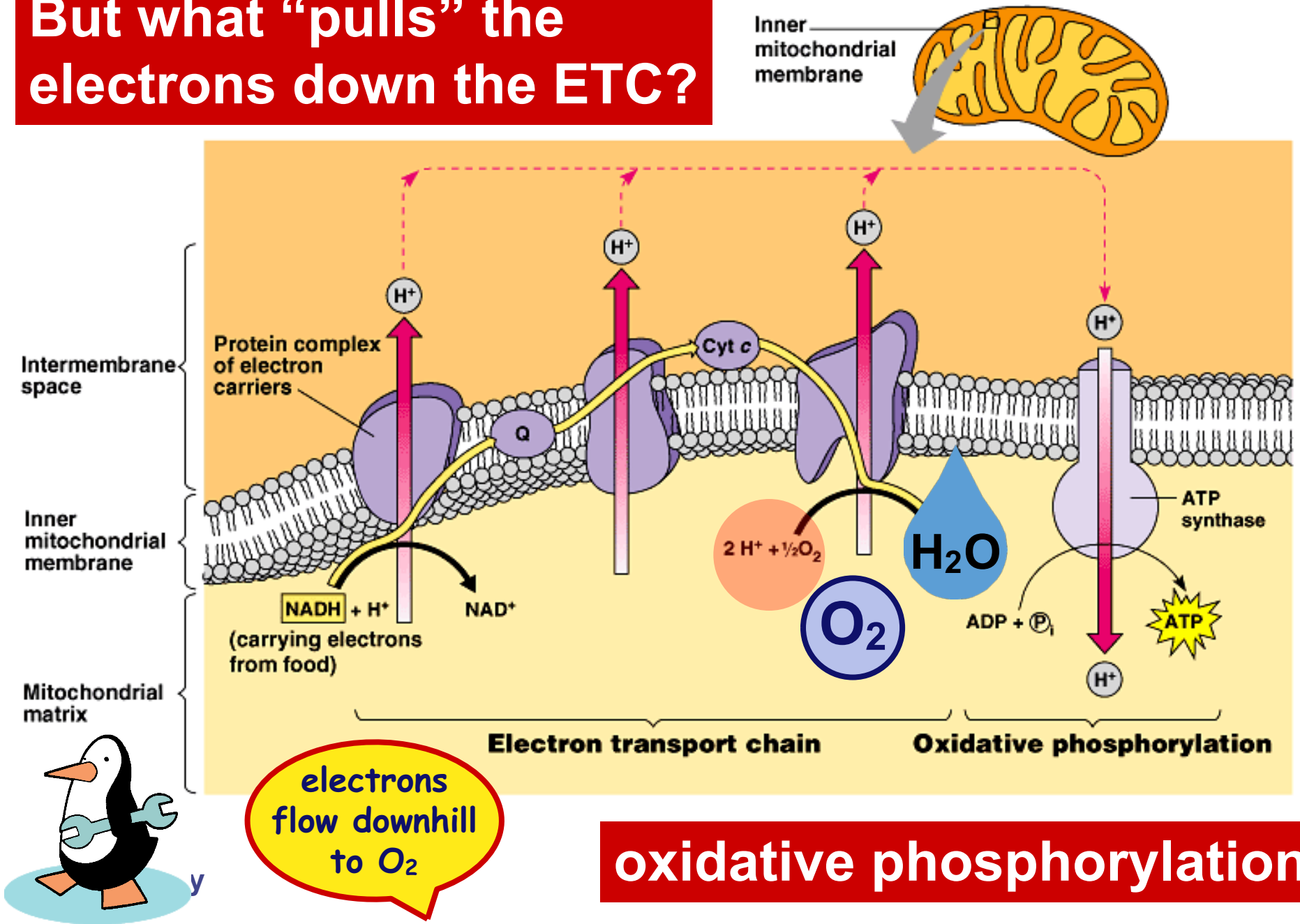
- **Electron carriers pass electrons & H^+ to ETC**
  - H cleaved off NADH & $FADH_2$
  - **electrons** stripped from H atoms → H^+ (**protons**)
    - electrons passed from one electron carrier to next in mitochondrial membrane (ETC)
    - flowing electrons = energy to do work
  - transport proteins in membrane pump H^+ (**protons**) across inner membrane to **intermembrane space**







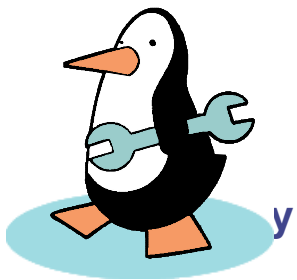
But what "pulls" the electrons down the ETC?

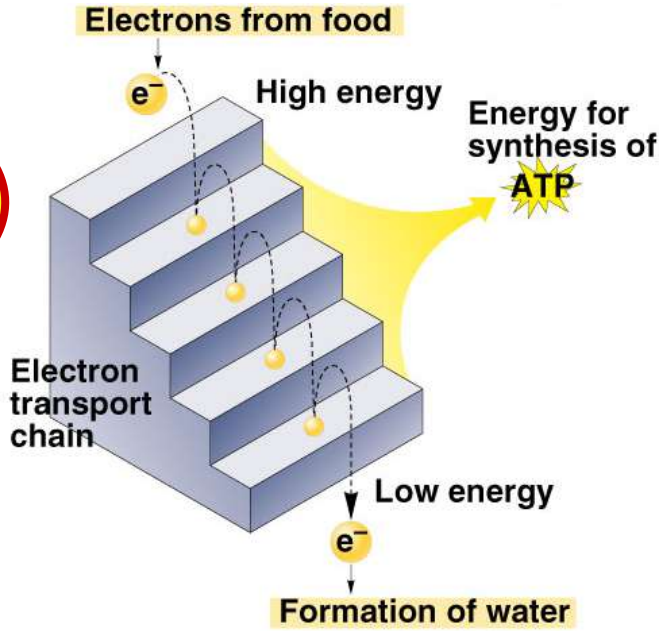


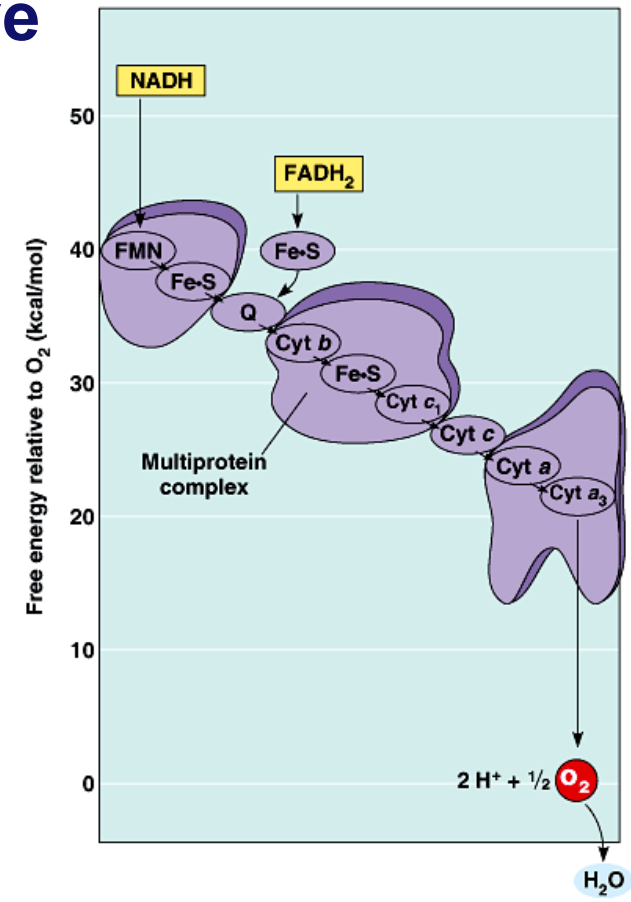
oxidative phosphorylation

Electrons flow downhill

- Electrons move in steps from carrier to carrier downhill to oxygen
- each carrier more electronegative
  - controlled oxidation
  - controlled release of energy





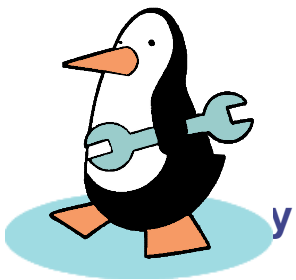


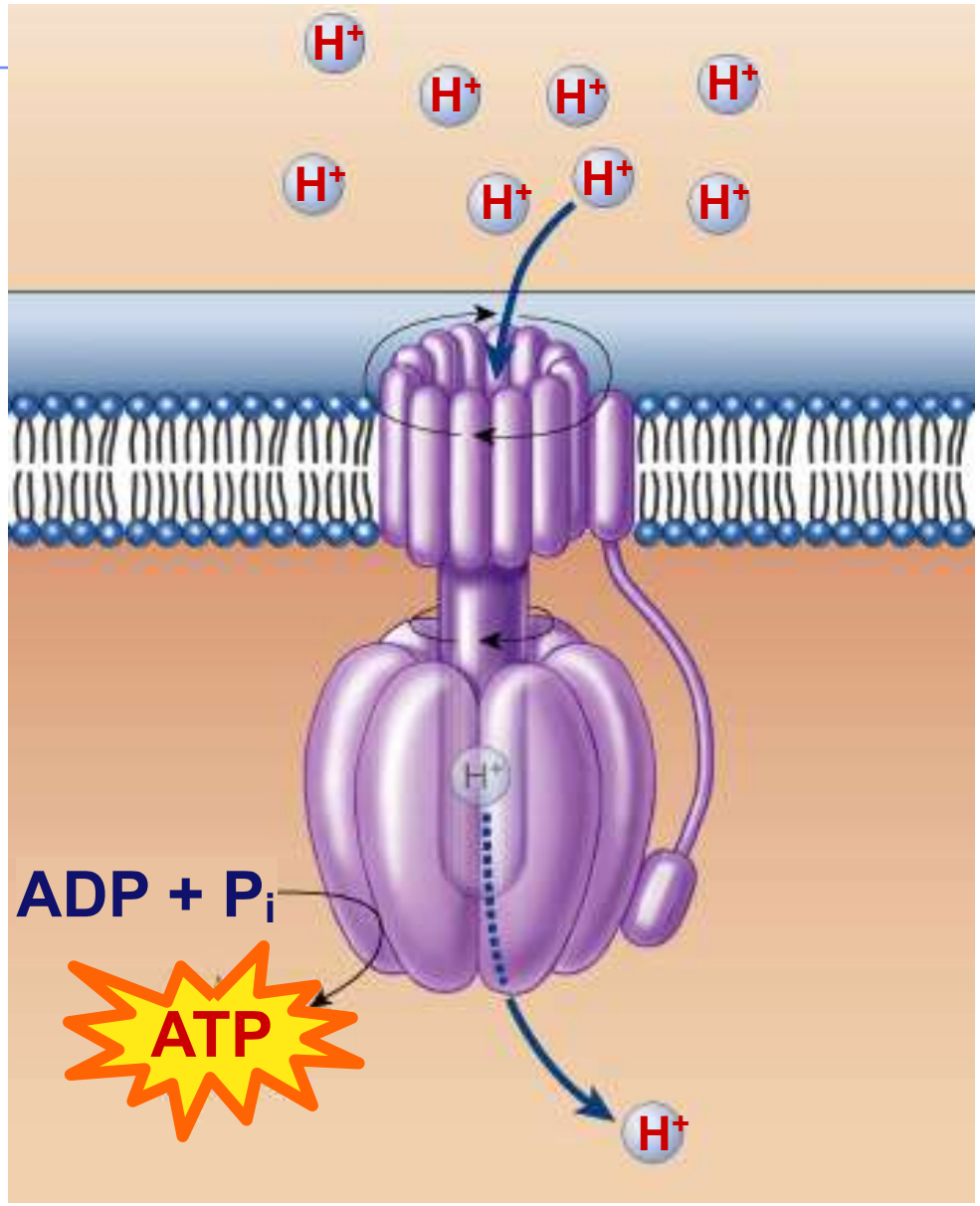
"proton-motive" force

We did it!

- Set up a H^+ gradient
- Allow the protons to flow through ATP synthase
- Synthesizes ATP

$ADP + P_i \rightarrow ATP$

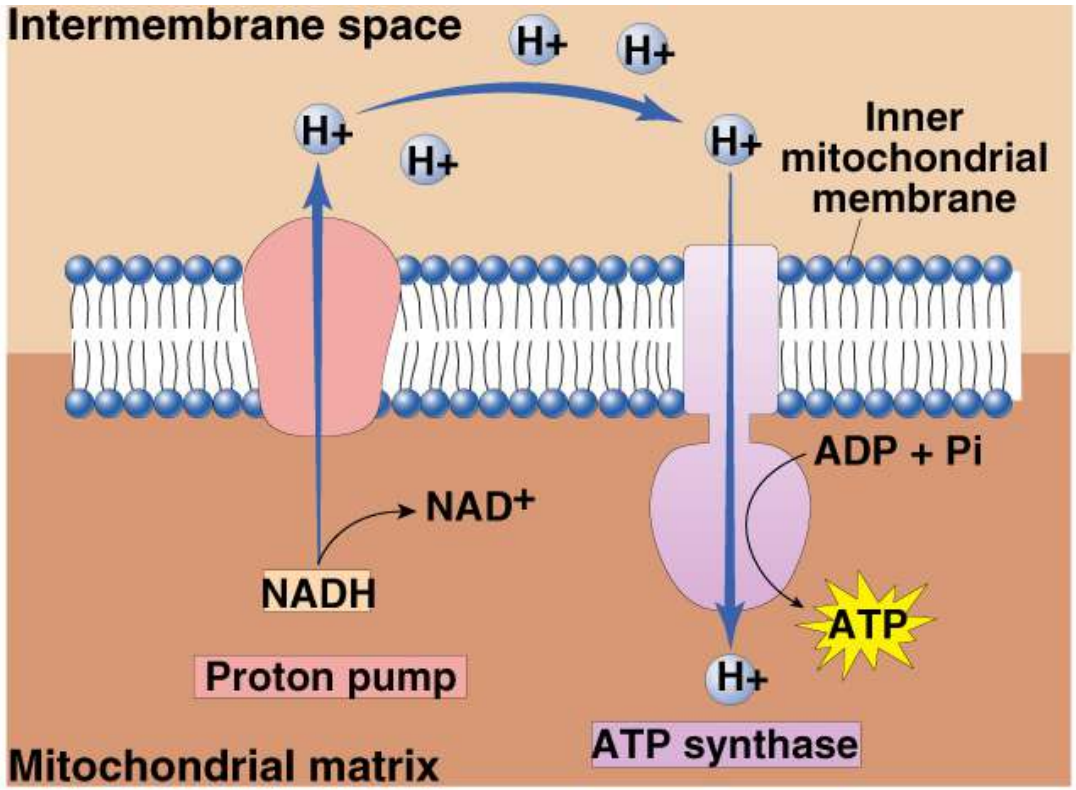


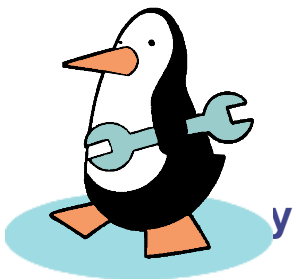


Chemiosmosis

- **The diffusion of ions across a membrane**
  - build up of proton gradient just so H+ could flow through ATP synthase enzyme to build ATP

Chemiosmosis links the Electron Transport Chain to ATP synthesis



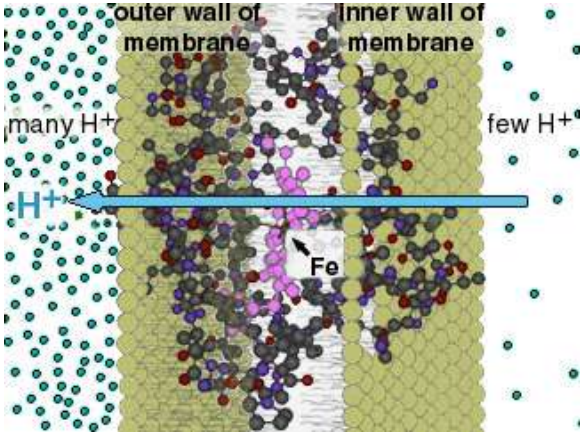


So that's the point!

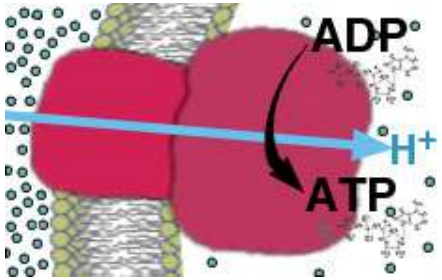
1961 | 1978

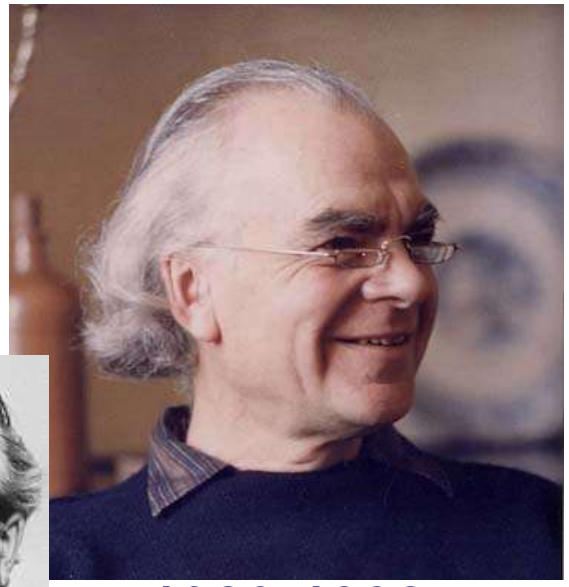
Peter Mitchell

- Proposed chemiosmotic hypothesis
  - revolutionary idea at the time

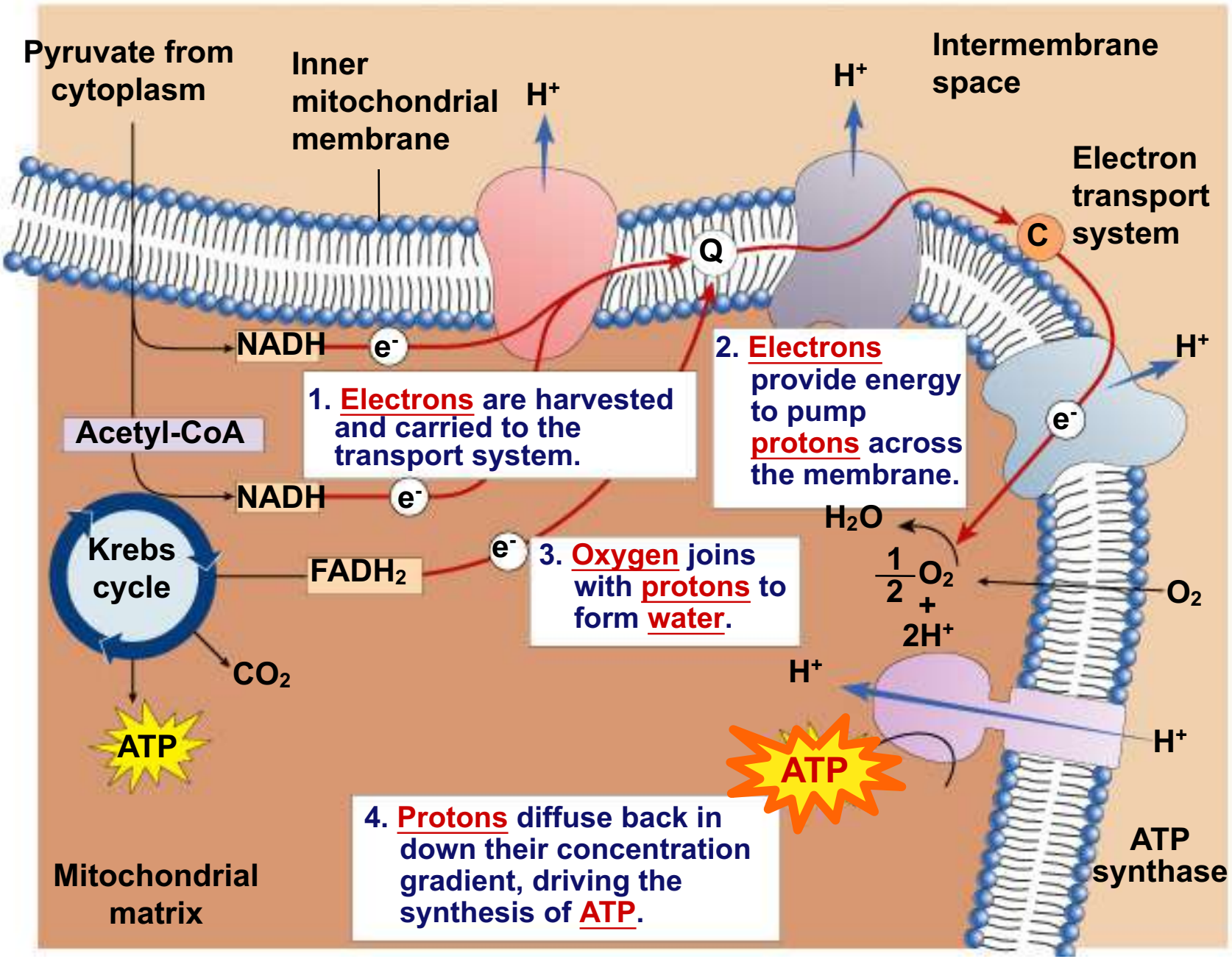


proton motive force



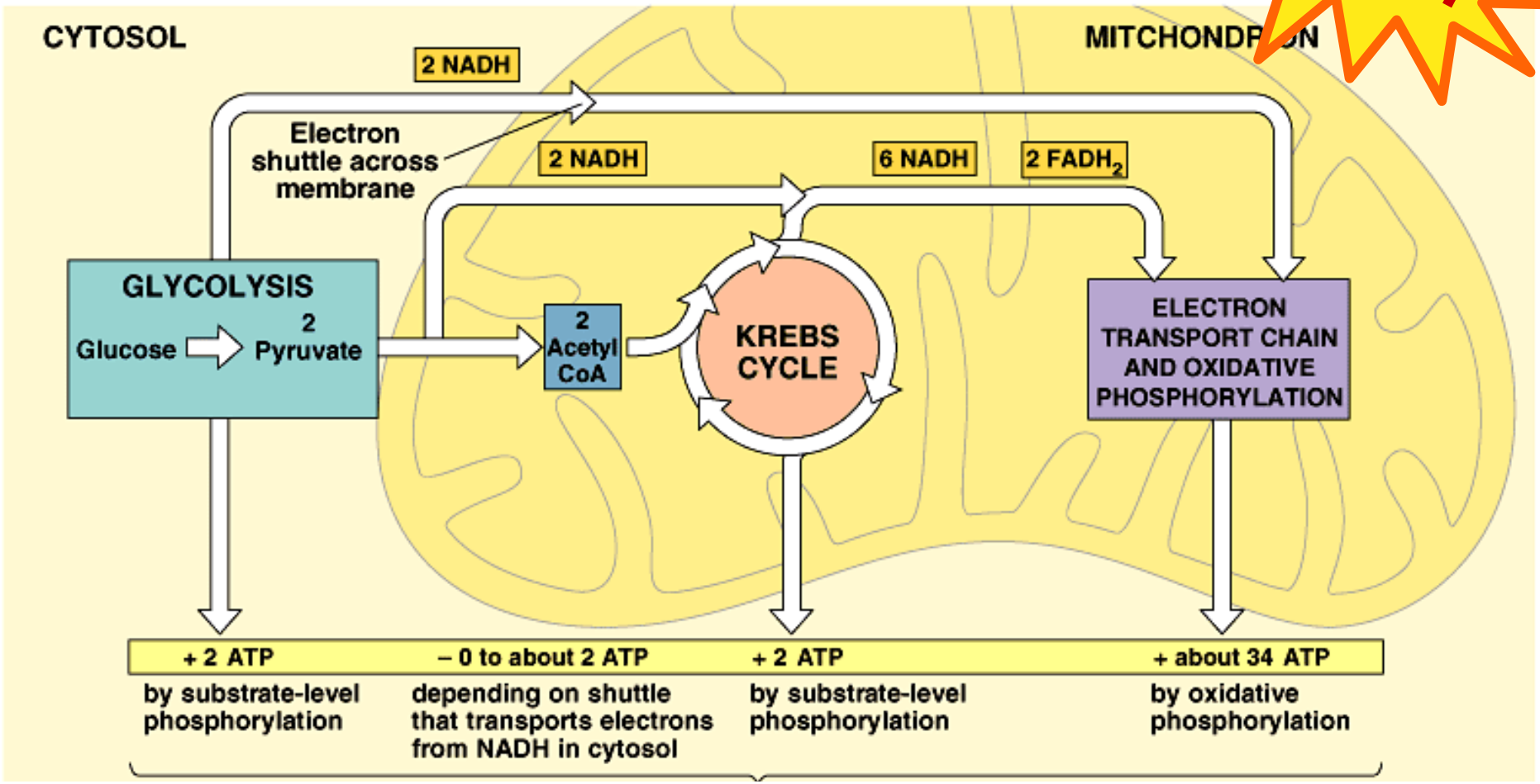


1920-1992


Pyruvate from cytoplasm
Inner mitochondrial membrane
H+
H+
Intermembrane space
Electron transport system
C
Q
NADH
e-
1. Electrons are harvested and carried to the transport system.
2. Electrons provide energy to pump protons across the membrane.
H+
e-
Acetyl-CoA
NADH
e-
Krebs cycle
FADH2
e-
3. Oxygen joins with protons to form water.
H2O
1/2 O2 + 2H+
O2
CO2
H+
ATP
ATP
H+
4. Protons diffuse back in down their concentration gradient, driving the synthesis of ATP.
Mitochondrial matrix
ATP synthase

Cellular respiration

~40 ATP



2 ATP + 2 ATP + ~36 ATP

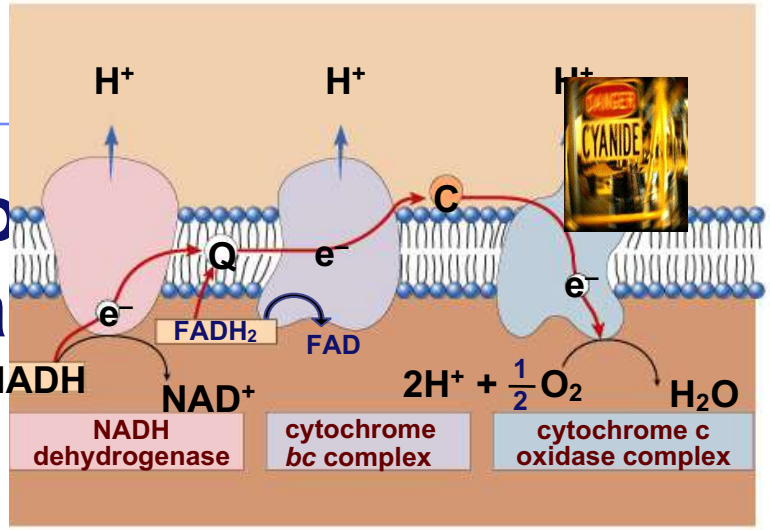
Summary of cellular respiration

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \sim 40\ ATP$$

- Where did the glucose come from?
- Where did the O_2 come from?
- Where did the CO_2 come from?
- Where did the CO_2 go?
- Where did the H_2O come from?
- Where did the ATP come from?
- What else is produced that is not listed in this equation?
- Why do we breathe?

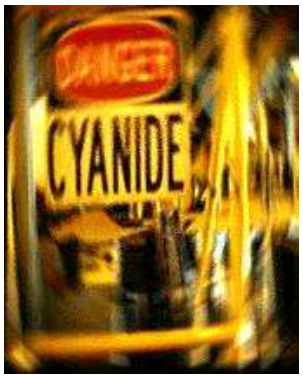
Taking it beyond…

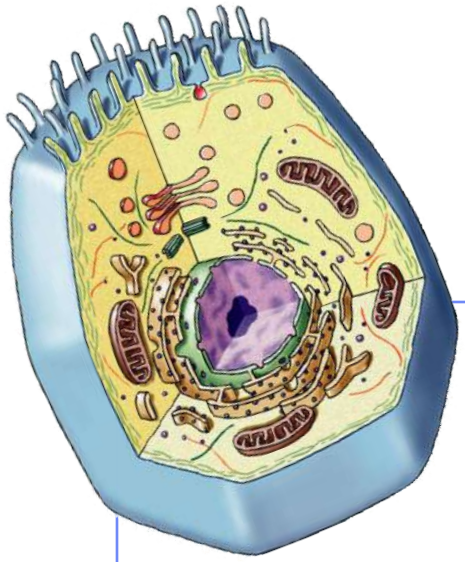
- What is the final electro
  Electron Transport Cha



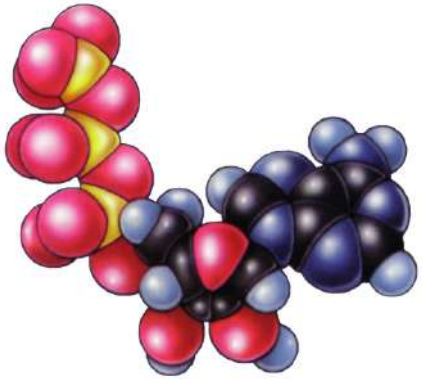
O_2

- So what happens if O_2 unavailable?
  - ETC backs up
    - nothing to pull electrons down chain
    - NADH & $FADH_2$ can't unload H
  - ATP production ceases
  - cells run out of energy
  - and you die*!*





What's the point?



The point is to make ATP!

ATP