Chapter 6:
CELLULAR RESPIRATION

1. Overview of Respiration

2. Glycolysis

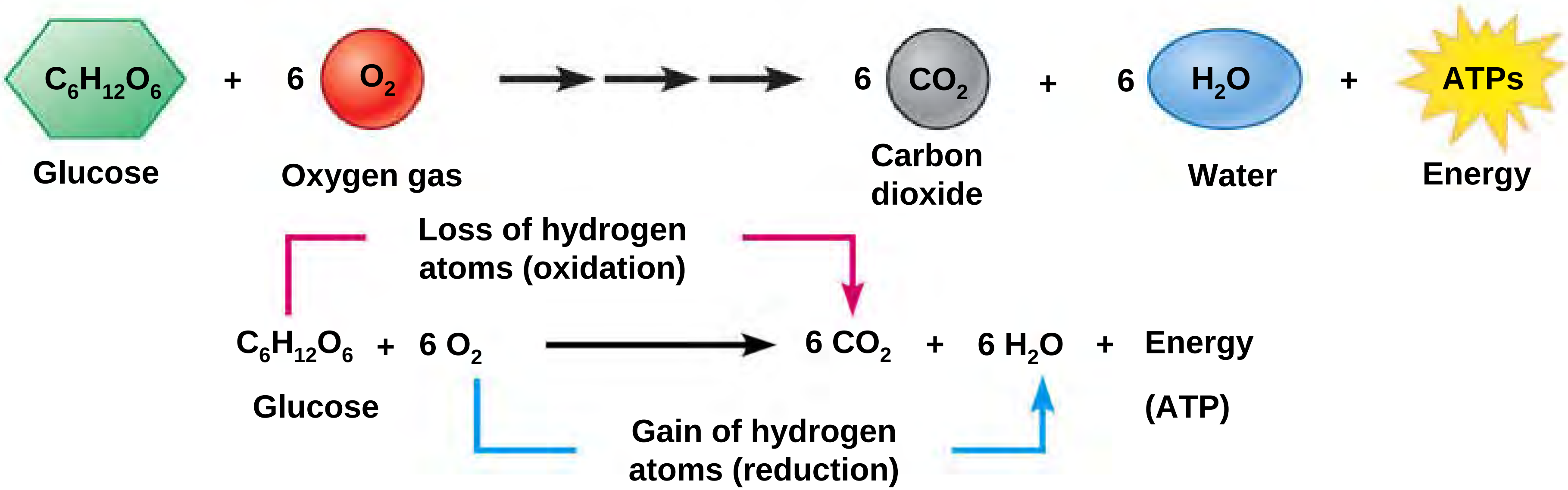
3. The Citric Acid Cycle

4. Oxidative Phosphorylation

1. Overview of Respiration

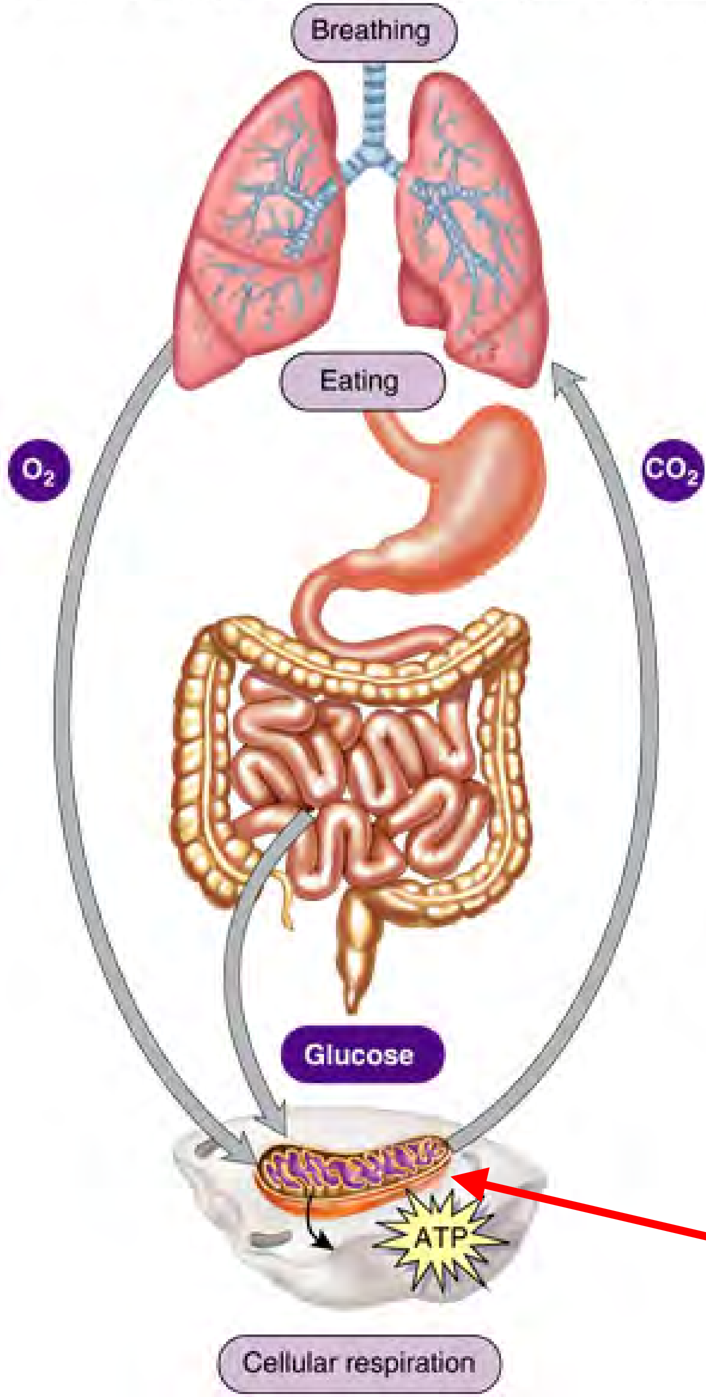
What is Cellular Respiration?

It is the process by which organisms use energy from "food" (e.g., glucose, fatty acids) to fuel the endergonic synthesis of ATP.



- **requires (O_2), occurs in most organisms (plants, too!)**
- **provides a supply of usable energy for cells (ATP)**

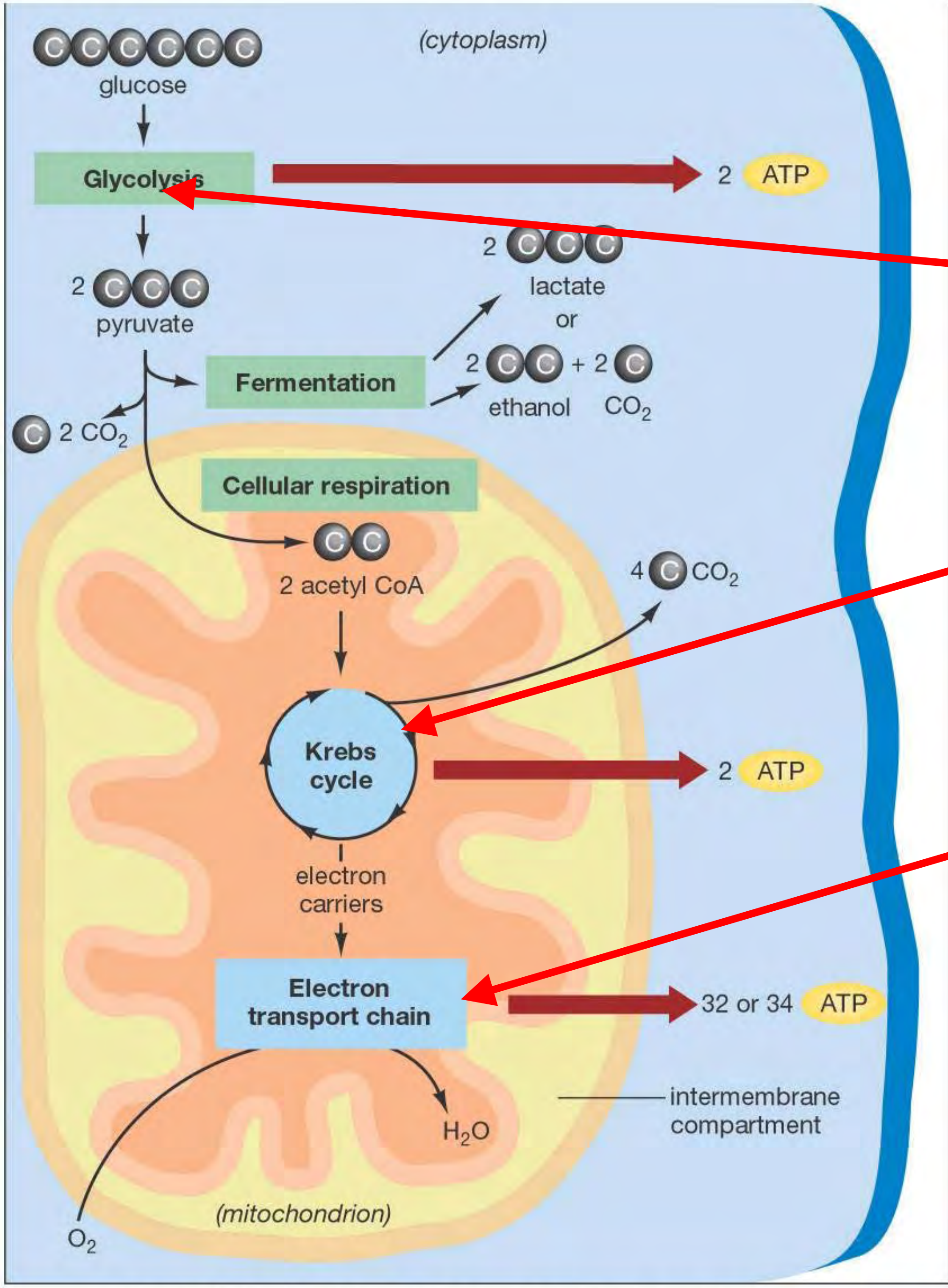
Cellular Respiration and the Human Body



- respiratory system acquires O_2, removes CO_2

- digestive system provides glucose and fats as a source of energy

<u>cellular</u> respiration takes place in mitochondria



Respiration occurs in 3 stages:

1) Glycolysis

- **initial break down of glucose**

2) Citric Acid Cycle

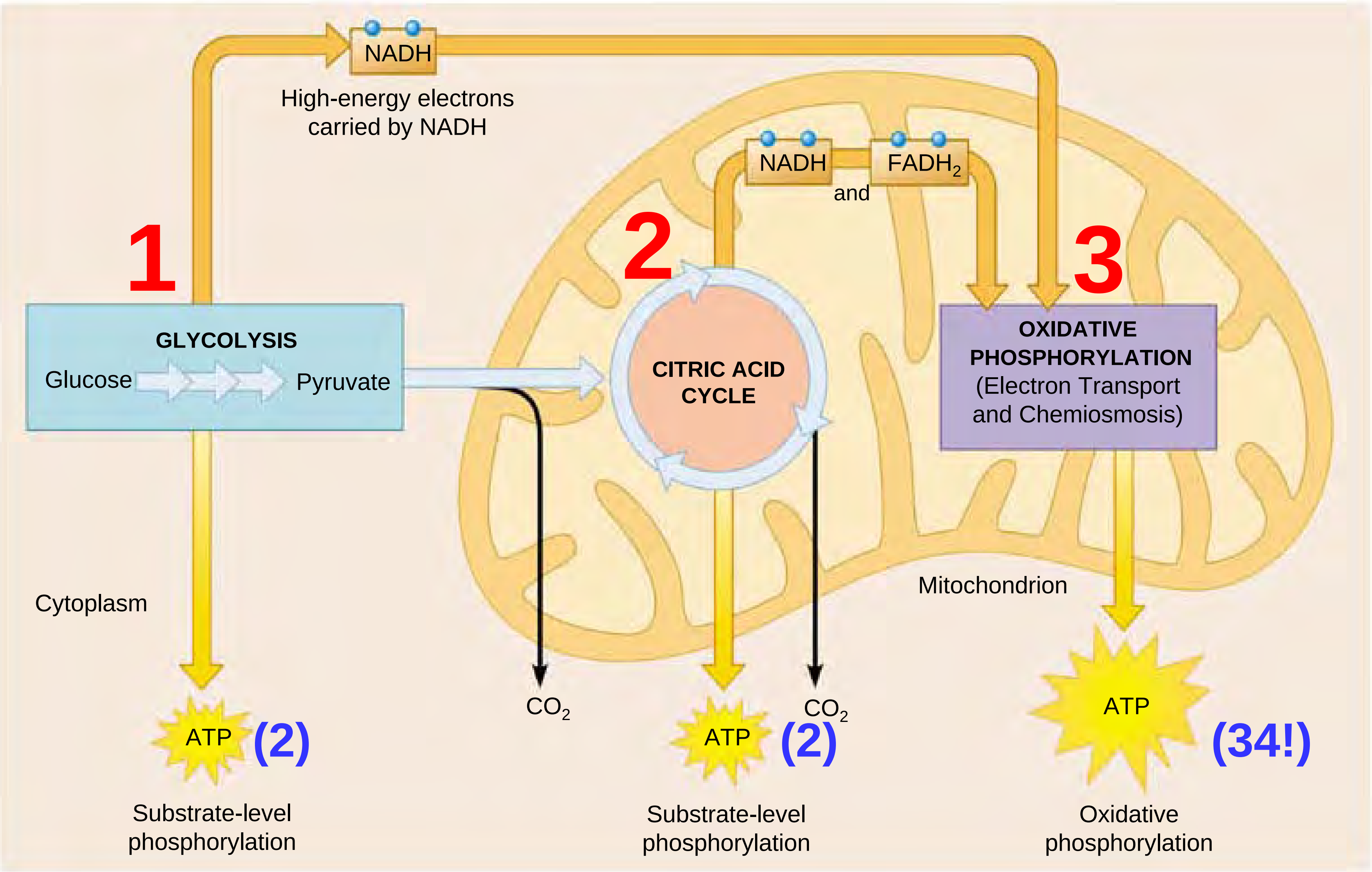
- **completes the break down of glucose**

3) Oxidative Phosphorylation

- **<u>electron transport</u> to generate H⁺ gradient**

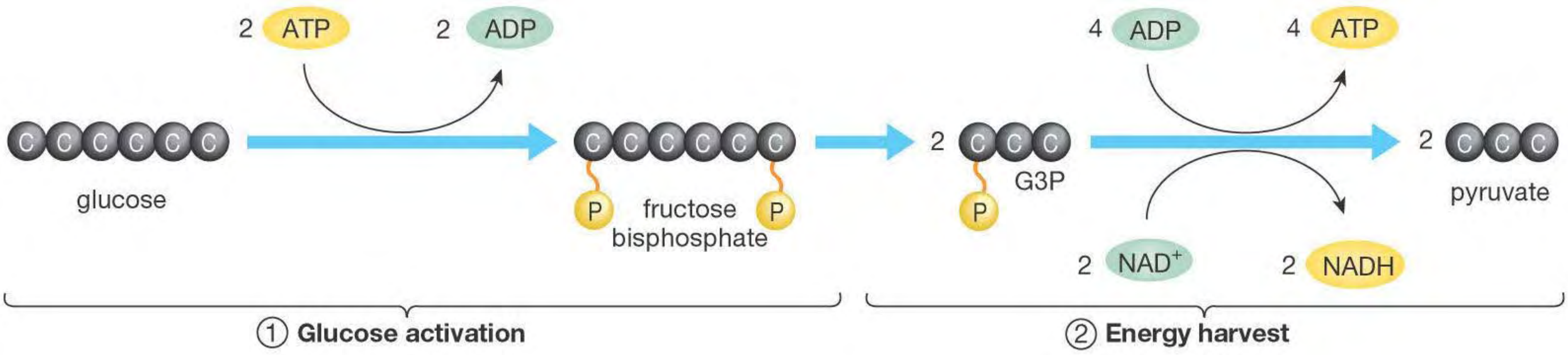
- **<u>chemiosmosis</u> to produce ATP!**

The Stages of Cellular Respiration



2. <u>Glycolysis</u>

What is Glycolysis?



A series of chemical reactions to break down glucose into two 3-carbon pyruvate molecules (1st step in glucose metabolism)

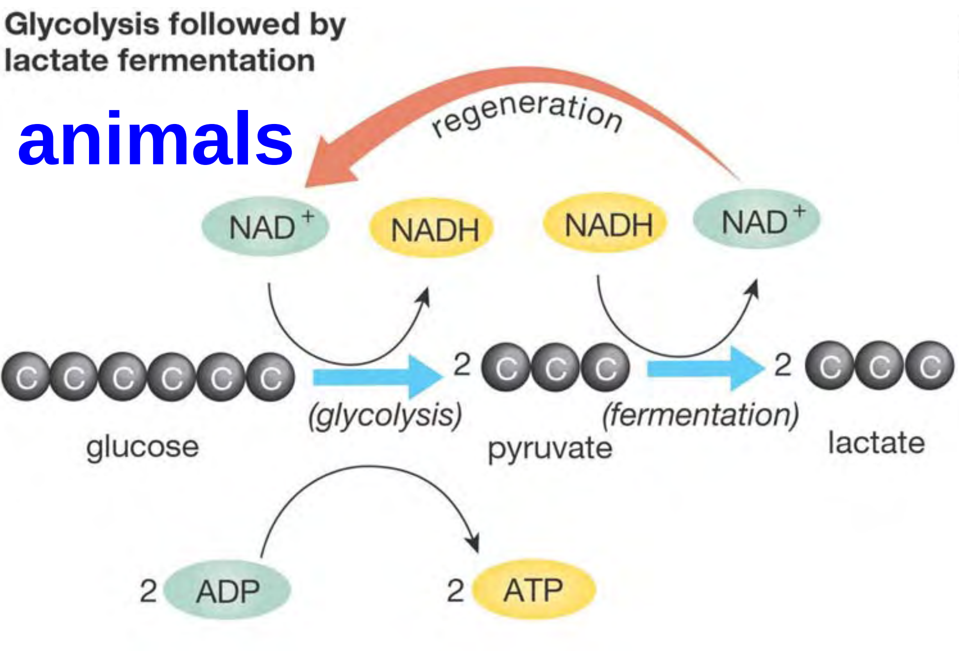
- **occurs in the cytoplasm, does NOT require O_2**
- **energy in the form of e^- captured by the e^- carrier NADH**
- **also yields 2 ATP, thus the products of glycolysis are:**

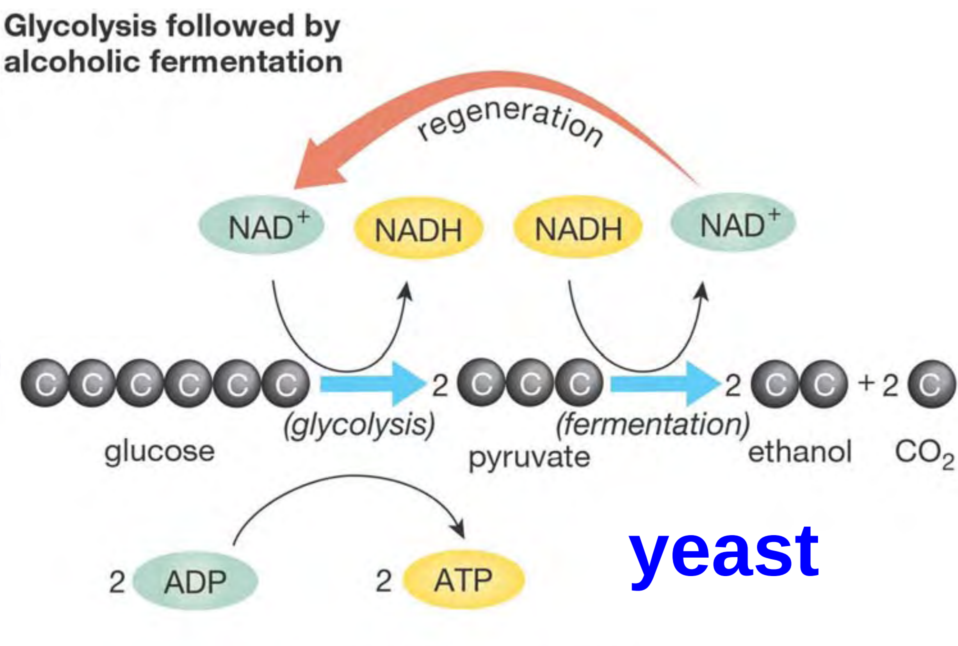
2 ATP   2 NADH   2 pyruvate

Fermentation

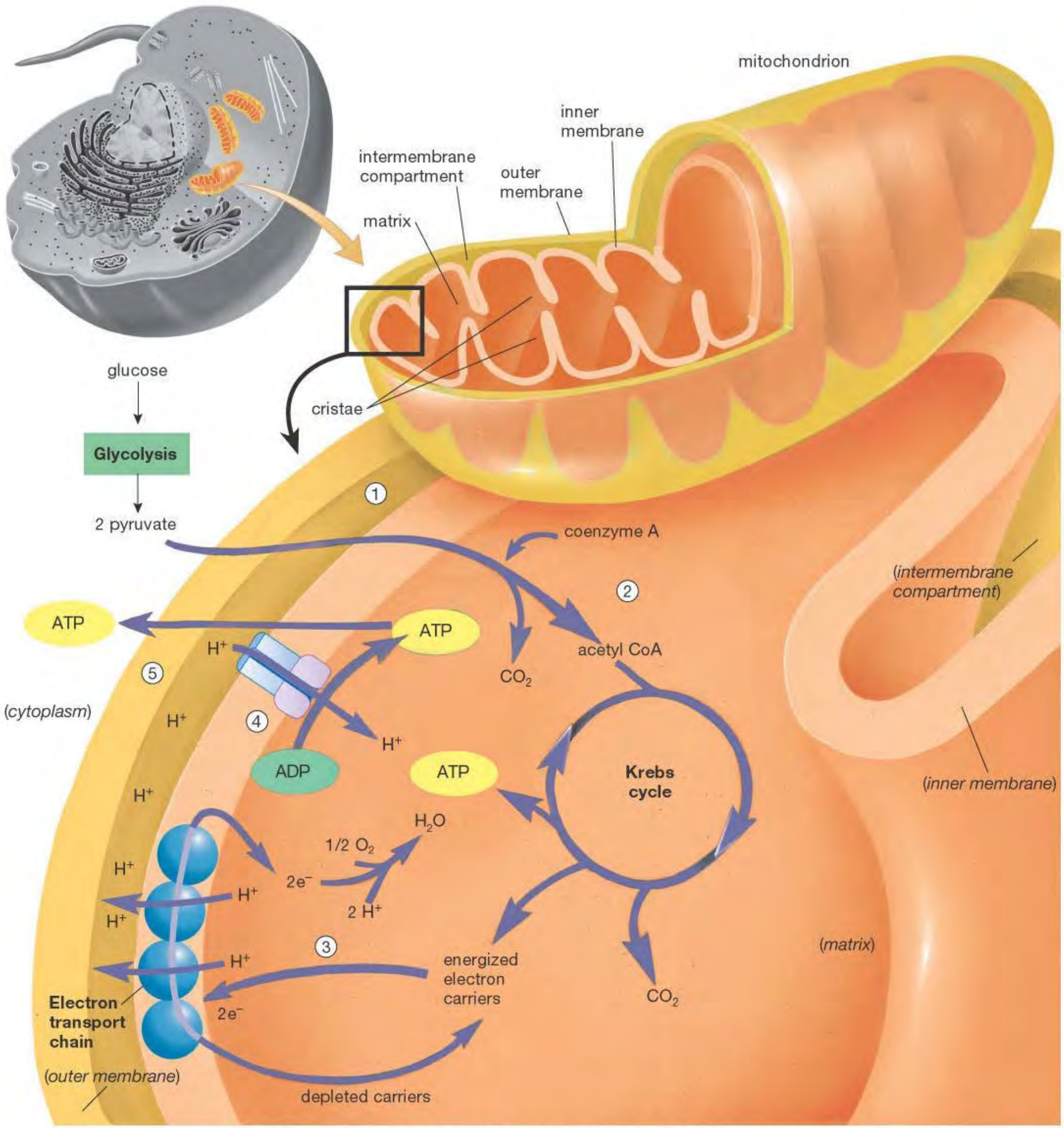
Instead of moving on to the Citric Acid Cycle, pyruvate will undergo <u>fermentation</u> when there's not enough O_2:

- **produces lactic acid (animals), ethanol (yeast), acetic acid, methane (other microbes) or other byproducts**
- **results in <u>relatively</u> <u>low</u> energy yield (2 ATP per glucose)**
- **important for "recycling" the electron carrier NAD^+**





3. <u>The Citric Acid Cycle</u>



The Citric Acid Cycle occurs in the "Matrix"

- **yield from 2 pyruvate (i.e., 1 glucose):**

2 ATP

8 NADH

2 $FADH_2$

What is the Citric Acid Cycle?

- series of chemical reactions that finish the break down of glucose
  - 3-C pyruvate from glycolysis broken down to 3 CO_2

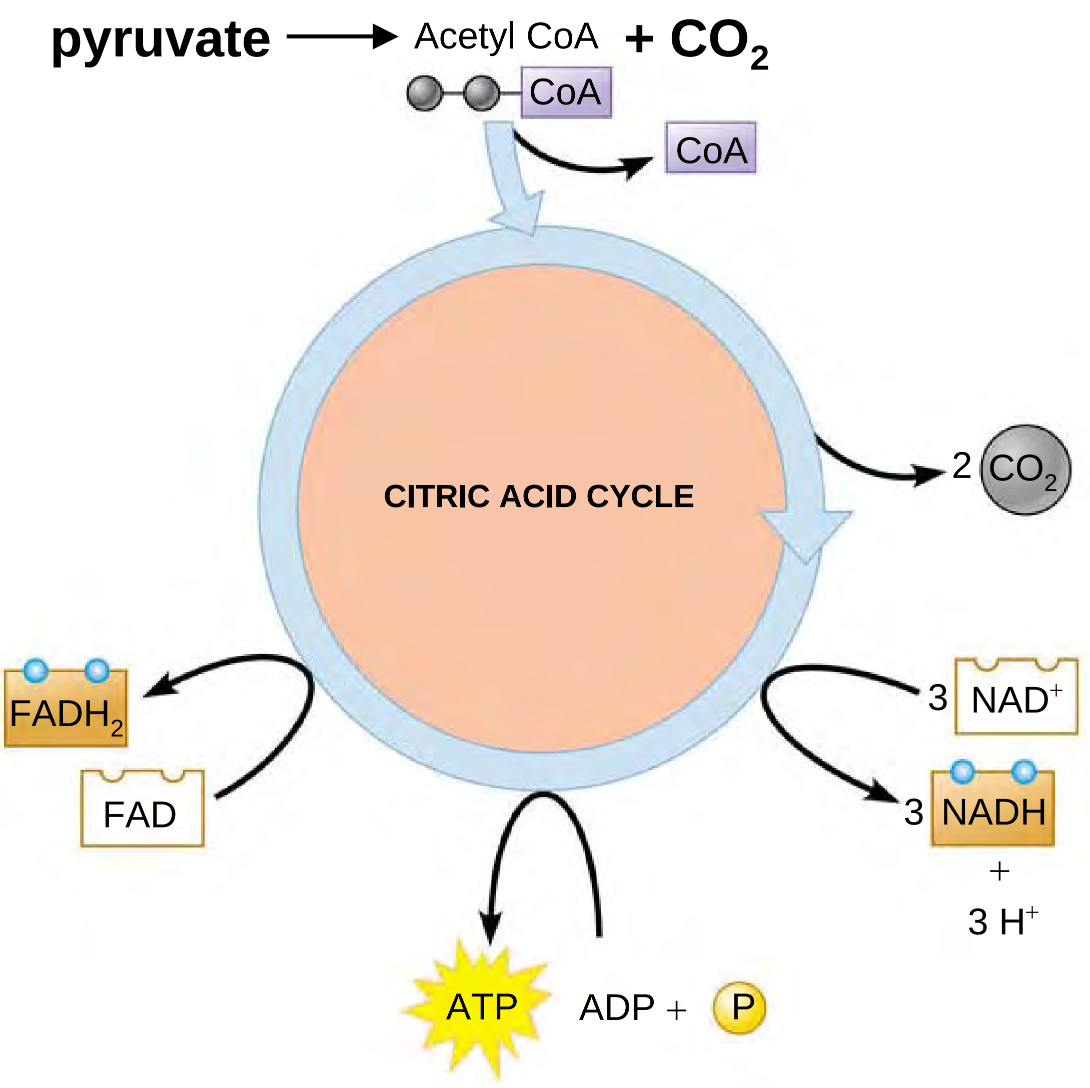
Where does it occur?

- in the mitochondrial matrix
  - pyruvate from cytoplasm gets transferred across inner mitochondrial membrane into the matrix

Where does the released energy end up?

- as high energy electrons (e^-) in the electron carriers NADH & $FADH_2$ (plus heat)
  - e^- passed on to the “electron transport chain” (ETC)

The Citric Acid Cycle



4. Oxidative Phosphorylation

Overview of Oxidative Phosphorylation

"Oxidative Phosphorylation" refers to the addition of a 3rd phosphate to make ATP ("phosphorylation") by a process that depends on oxidation-reduction reactions ("oxidative"), and occurs in 2 stages:

A) electron transport

- **e^- from NADH and $FADH_2$ are passed along the electron transport chain (ETC) via oxidation-reduction reactions**
- **convert energy from e^- into energy stored in H^+ gradient**

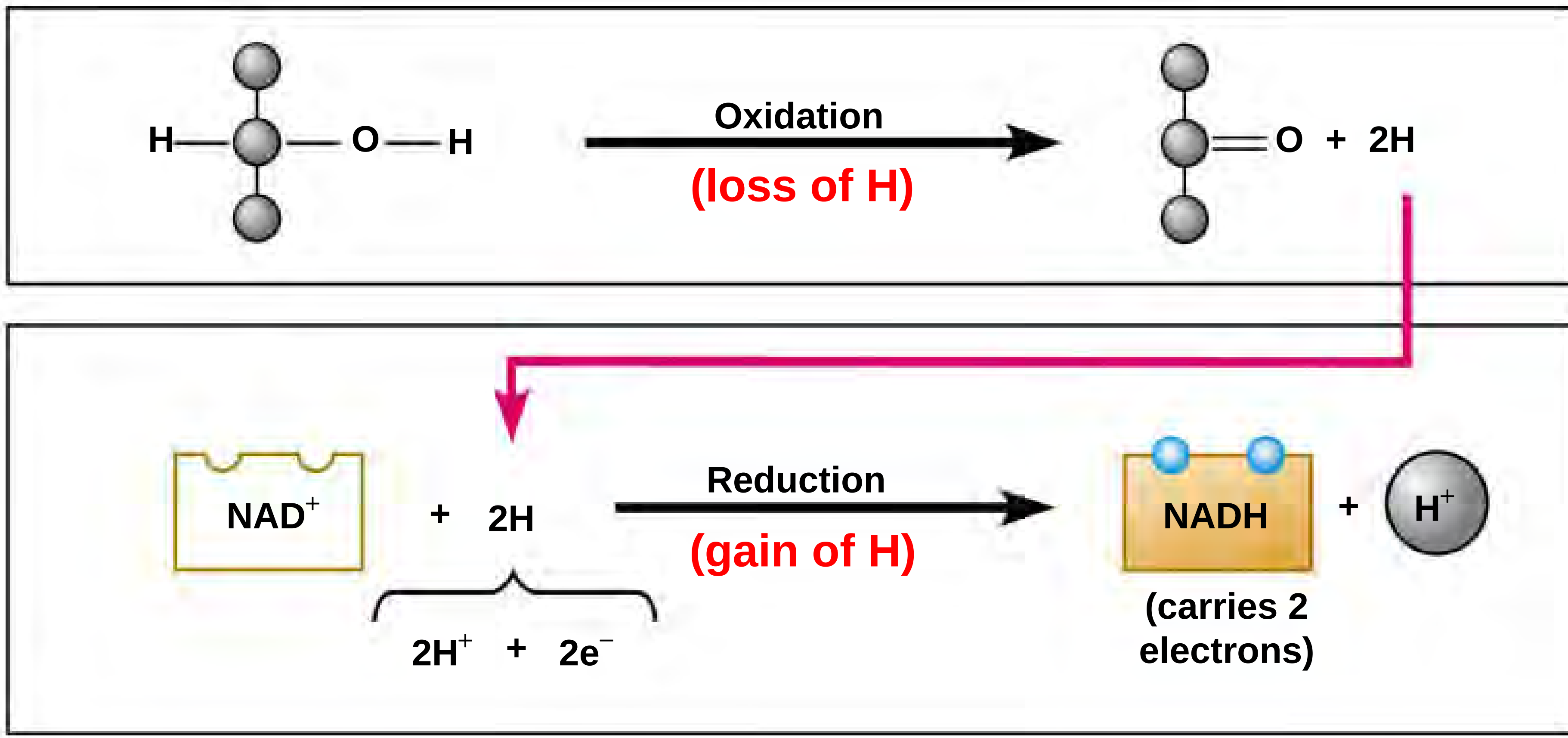
B) chemiosmosis

- **energy from H^+ gradient used to make ATP**

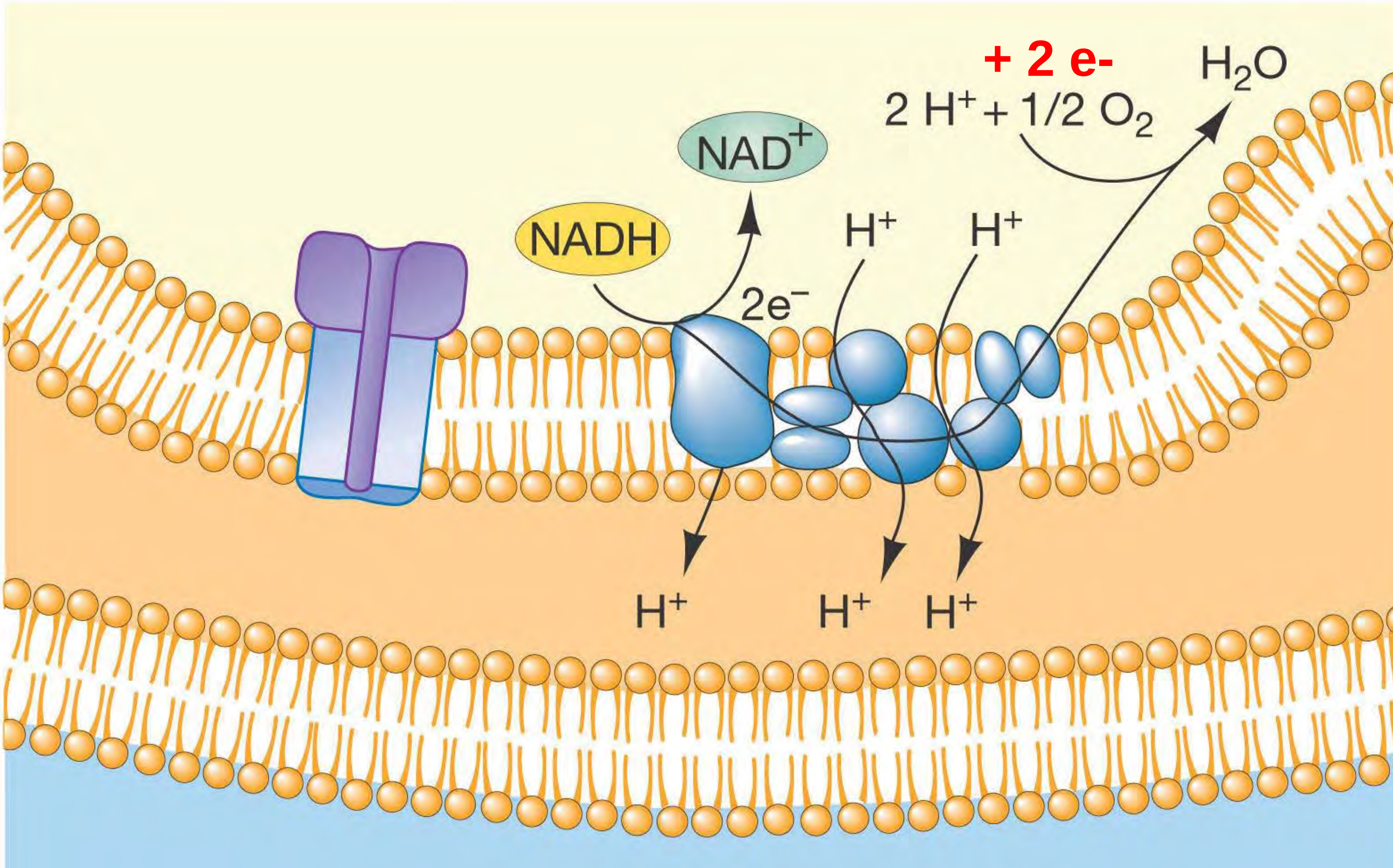
Oxidation & Reduction

OXIDATION – loss of e^- (usually with a hydrogen atom)

REDUCTION – gain of e^- (usually with a hydrogen atom)



e^- Transport generates H^+ Gradient



- **energy from e^- used to <u>pump</u> H^+ ions (fr. lo → hi conc)**

Electron Transport

High energy electrons (e^-) from NADH, $FADH_2$ transferred to e^- transport chain (ETC)

- **ETC is a series of proteins in the inner mitochondrial membrane through which e^- are passed**

Energy released through e^- transport used to create H^+ gradient (necessary to make ATP)

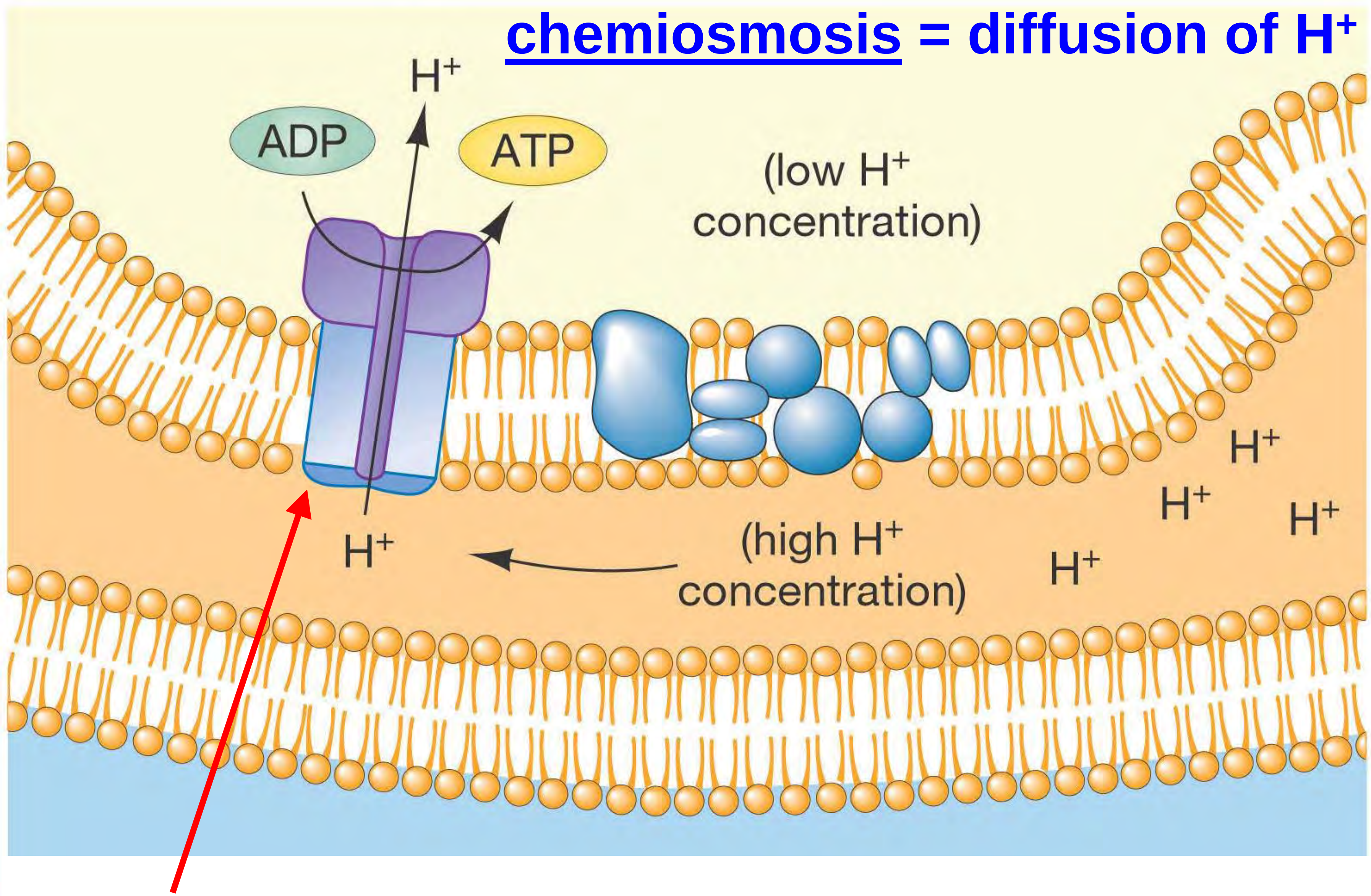
- **H^+ pumped across inner mitochondrial membrane out of the matrix into the <u>intermembrane</u> <u>space</u>**

Oxygen (O_2) is essential for electron transport!

- **O_2 is the <u>final electron acceptor</u> at the end of the ETC**

****no O_2 = no e^- transfer = no ATP production = death!****

Chemiosmosis used to make ATP



- **<u>ATP synthase</u> uses energy of H^+ flow to make ATP**

Chemiosmosis

"The flow of a substance (H^+) from high to low concentration"

Energy derived from the flow of H^+ is used to synthesize ATP (from ADP & P_i)

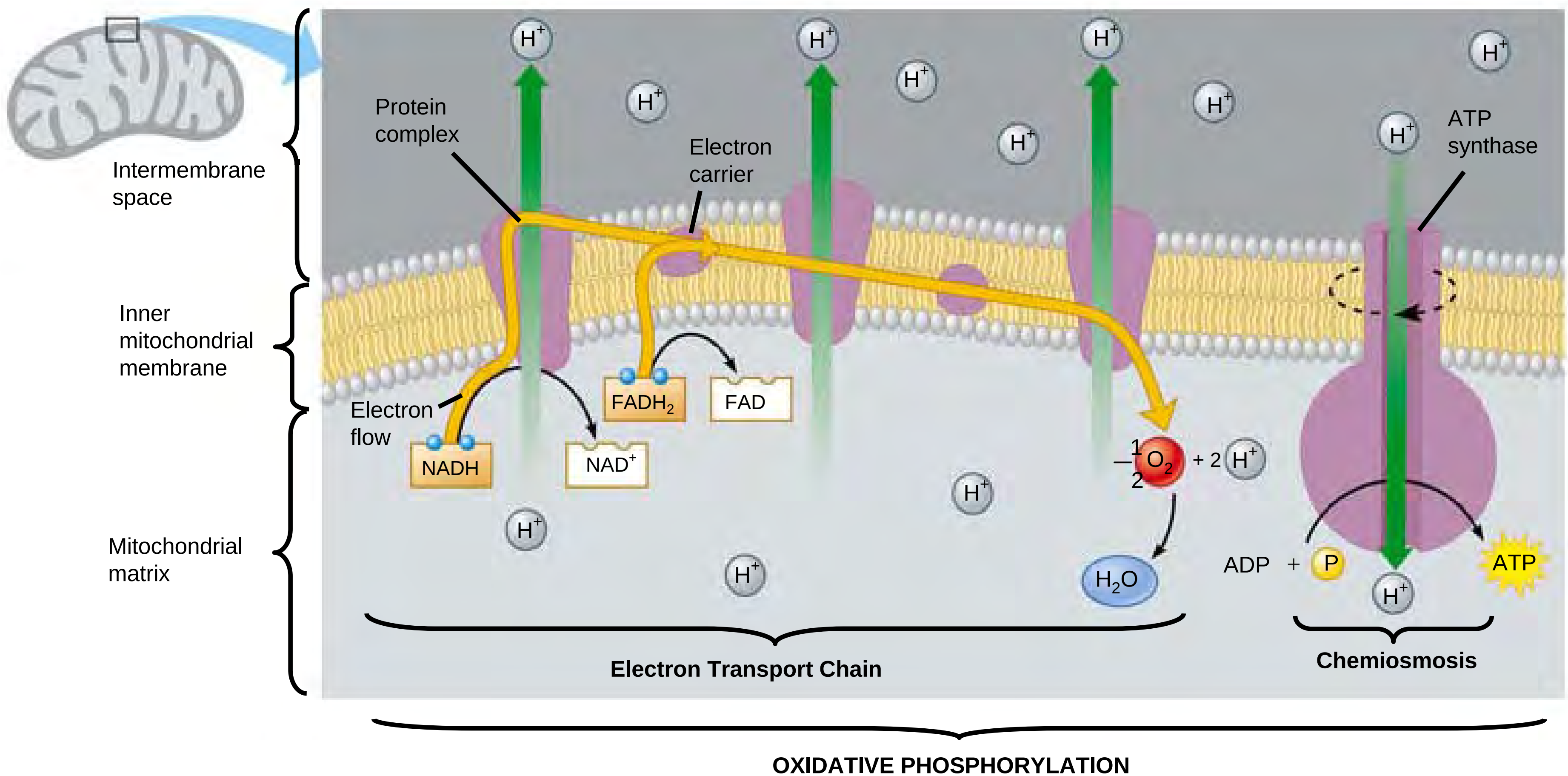
- **H^+ flows "down" concentration gradient through <u>ATP synthase</u> in the inner mitochondrial membrane**
- **ATP synthase = enzyme complex that catalyzes:**

$$\text{ADP} + P_i \xrightarrow{H^+ \text{ flow}} \text{ATP}$$

Yields up to 34 ATP per glucose molecule!

- **in addition to 2 ATP in glycolysis, 2 ATP in Krebs cycle**

Summary of Oxidative Phosphorylation



Respiration is simply a Series of Energy Conversions!

I. **Energy stored in sugars and fats is converted to energy temporarily stored in <u>electron carriers</u> (NADH & $FADH_2$)**
   - **via Glycolysis & the Krebs Cycle**

II. **Energy stored in NADH & $FADH_2$ is converted to energy temporarily stored in an <u>H^+ gradient</u>**
   - **via electron transport**

III. **Energy stored in an H^+ gradient is converted to energy stored in molecules of <u>ATP</u>**
   - **via chemiosmosis (which fuels ATP synthesis)**

Key Terms for Chapter 6

- glycolysis, fermentation
- Citric Acid Cycle
- electron carriers (NADH, $FADH_2$)
- oxidation vs reduction
- oxidative phosphorylation, chemiosmosis
- electron transport chain (ETC)
- ATP synthase

Relevant Review Questions:

1-4, 6, 9, 10, 14