

# Biology 350: Animal Physiology

<https://www.youtube.com/watch?v=N0h7ycVCMql>

<https://www.youtube.com/watch?v=rkqKoyGhZL4>

<https://www.youtube.com/watch?v=zb1YFpmuIXA>



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Director Emerita, Center for Academic Success  
Louisiana State University

# Metacognition

The ability to:

- think about one's own thinking
- be consciously aware of oneself as a problem solver
- monitor, plan, and control one's mental processing (e.g. "Am I *understanding* this material, or just *memorizing* it?")
- accurately judge one's level of learning

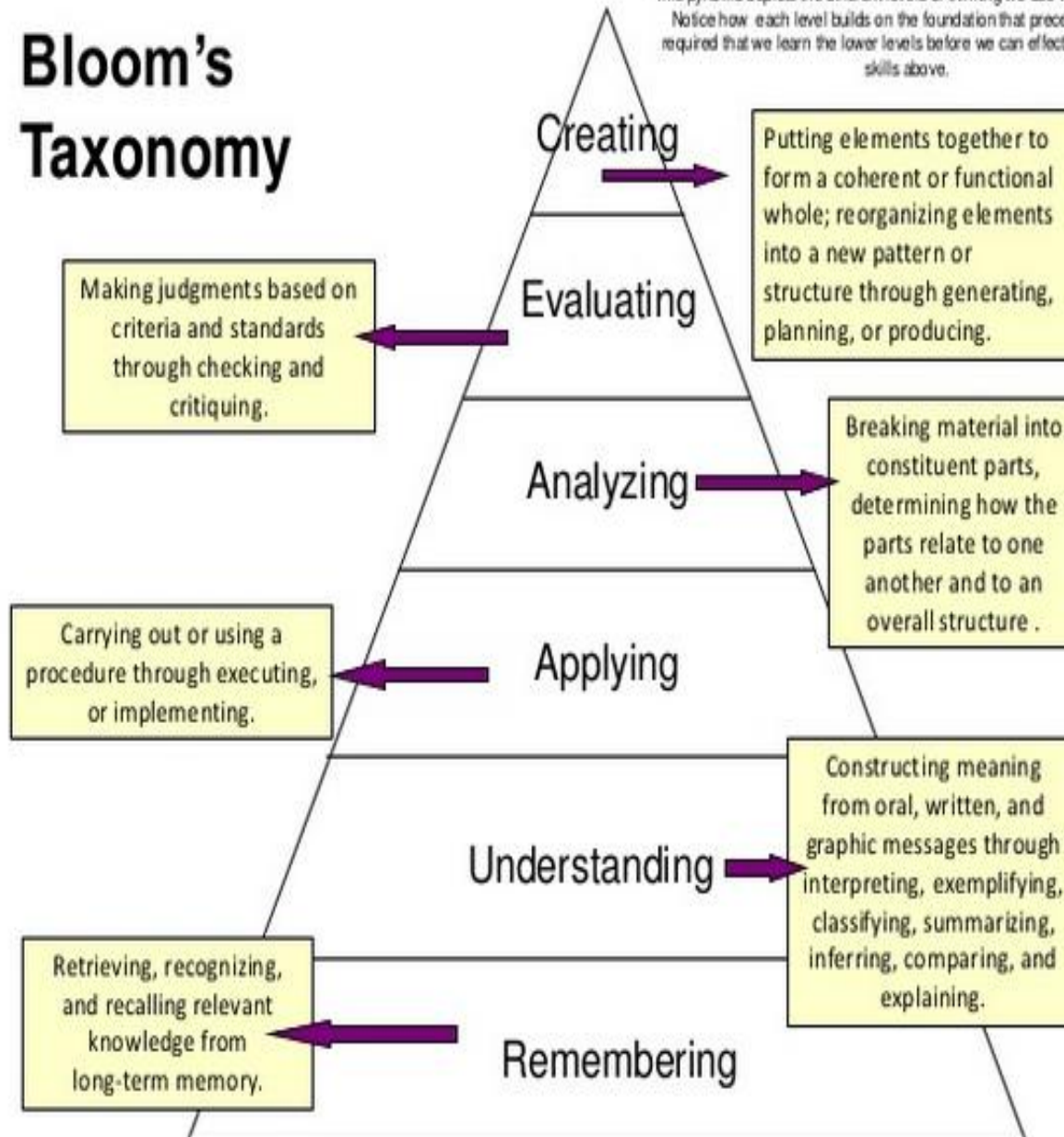
Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.), *The nature of intelligence* (pp.231-236). Hillsdale, NJ: Erlbaum

## Reflection Questions

- What's the difference, if any, between *studying* and *learning*?
- For which task would you work harder?
  - A. Make an A on the test
  - B. Teach the material to the class

# Bloom's Taxonomy

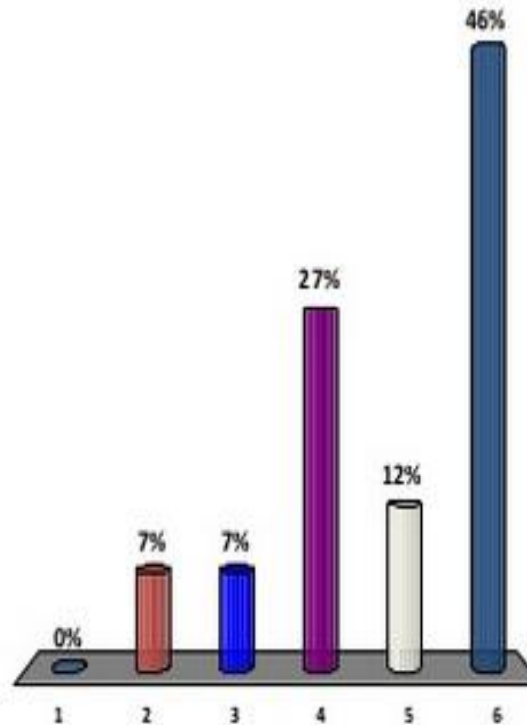
This pyramid depicts the different levels of thinking we use when learning. Notice how each level builds on the foundation that precedes it. It is required that we learn the lower levels before we can effectively use the skills above.



## *How students answered (in 2014)*

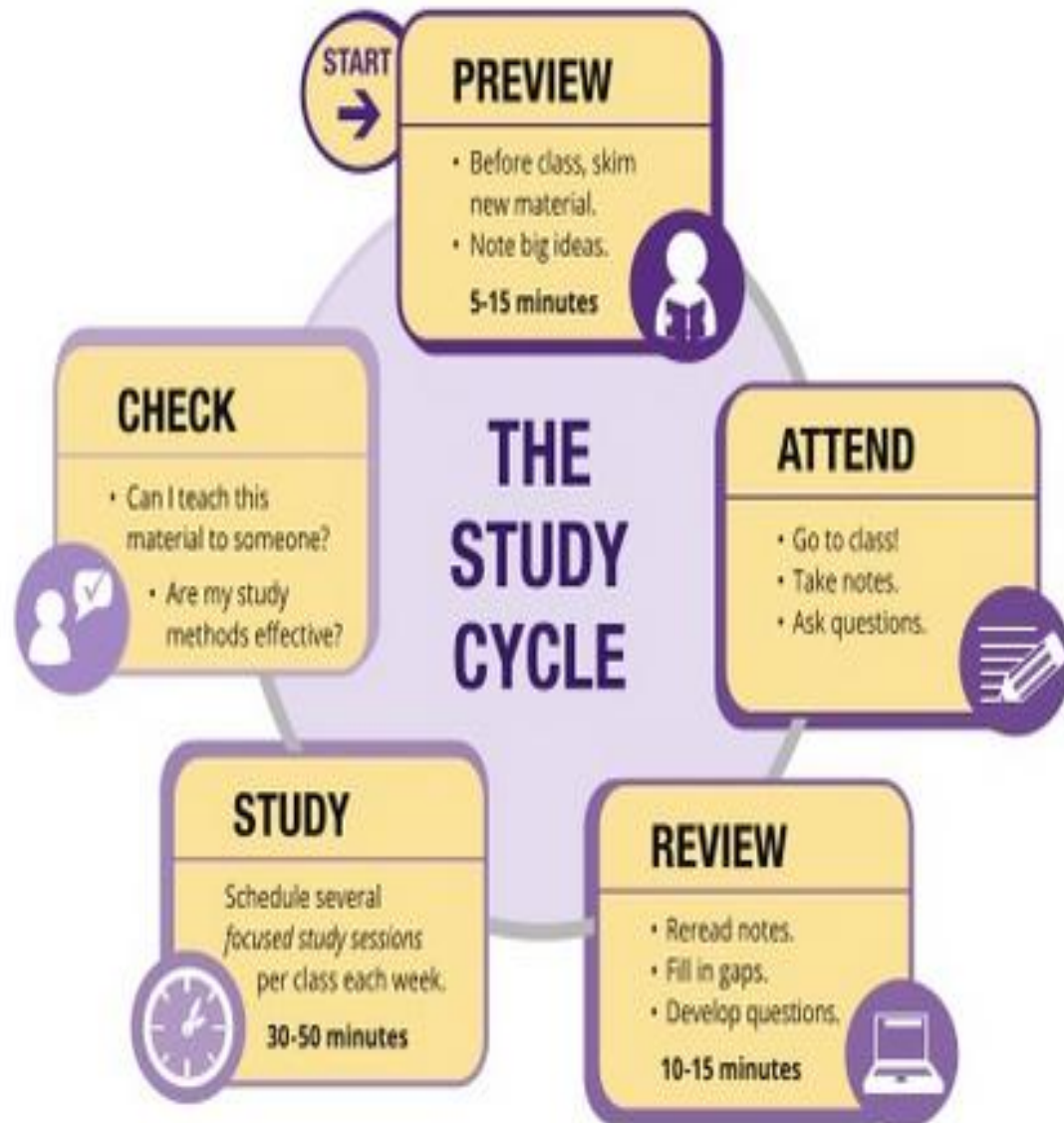
**At what level of Bloom's do you think you'll need to operate to make A's in college?**

1. Remembering
2. Understanding
3. Applying
4. Analyzing
5. Evaluating
6. Creating





# The Study Cycle



Why increase HR, Breathing, vision changes with a scare?

Why shiver when cold ?

Why sneeze looking at the sun ?

Why sleep?

When is development finished ?

What age do we start to degrade ?

Why sense cold / warm....why not just extremes ?

How do muscles work ?

Can humans hibernate ?



<http://www.ukclimbing.com/news/item.php?id=49981>

# Physiology

- **Define:** The study of how living organisms function
- Structure & function are important to understand function
- Why study: Curiosity. Better understand how humans function under normal conditions. Thus, modifications of pathological states back to a 'normal' state might be possible.

- Many of the physiological process are described by chemical and physical properties
- It is important to integrate these concepts with biology.

- The physiology of an animal is well suited to the environment in which it has evolved.

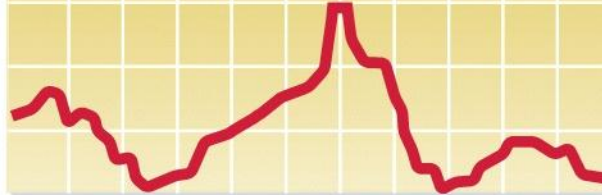
This is explained by the process of

**ADAPTATION**- gradual change over many generations.

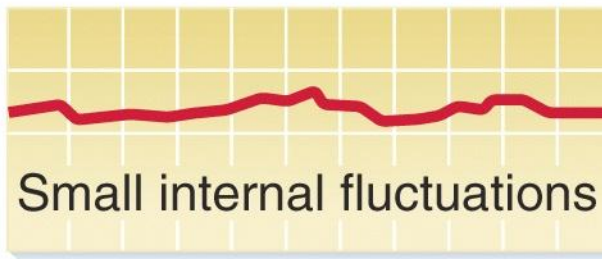
- **Acclimatization** is a change of an individual over its lifetime of biochemical or anatomical alterations
- **Acclimation** is like acclimatization but induced by experimentation.

- Homeostasis- The tendency of an organism to regulate and maintain relative internal stability.
- Cannon coined this term 1929

Large external fluctuations



Small internal fluctuations



— Changes over time of a physicochemical variable such as oxygen concentration

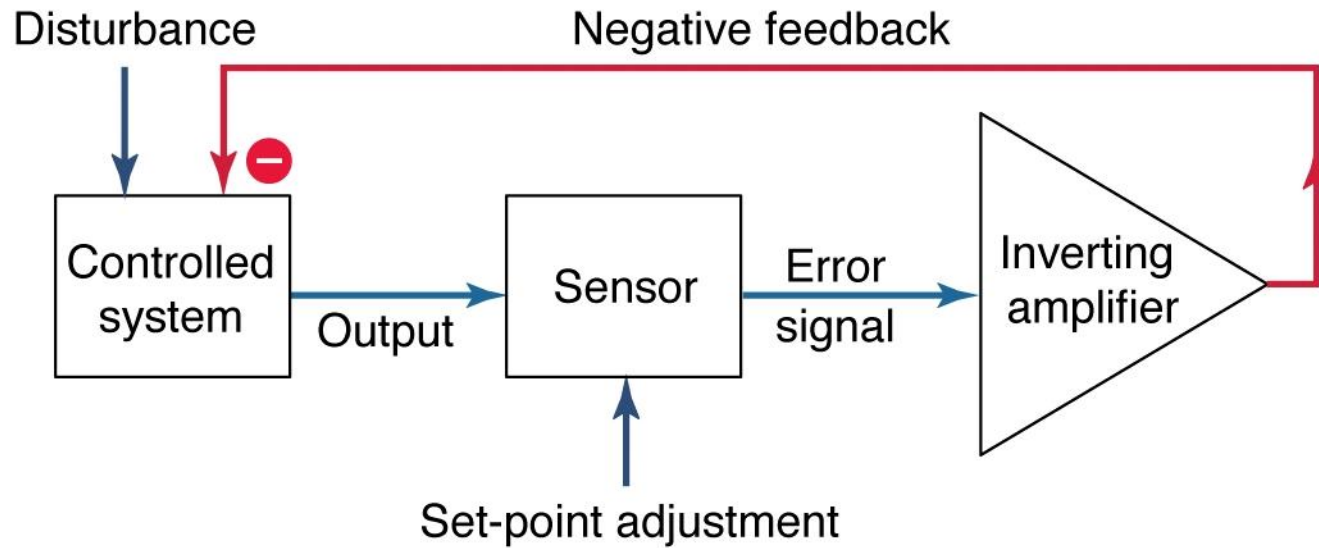
This mostly works by a feed back control.

Such as by a negative feedback.

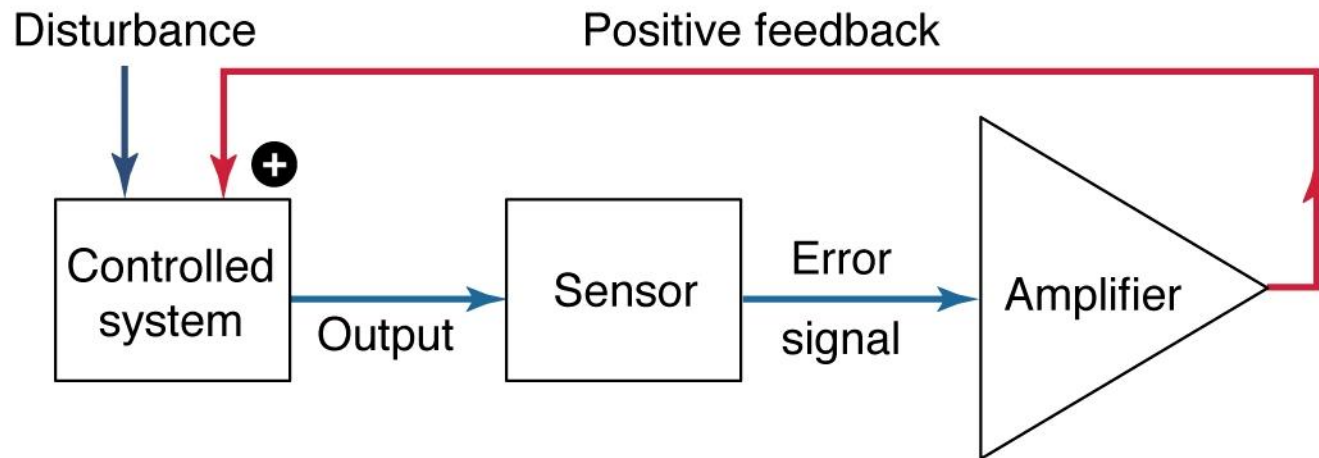
Examples - Temp, pH, salinity within the body



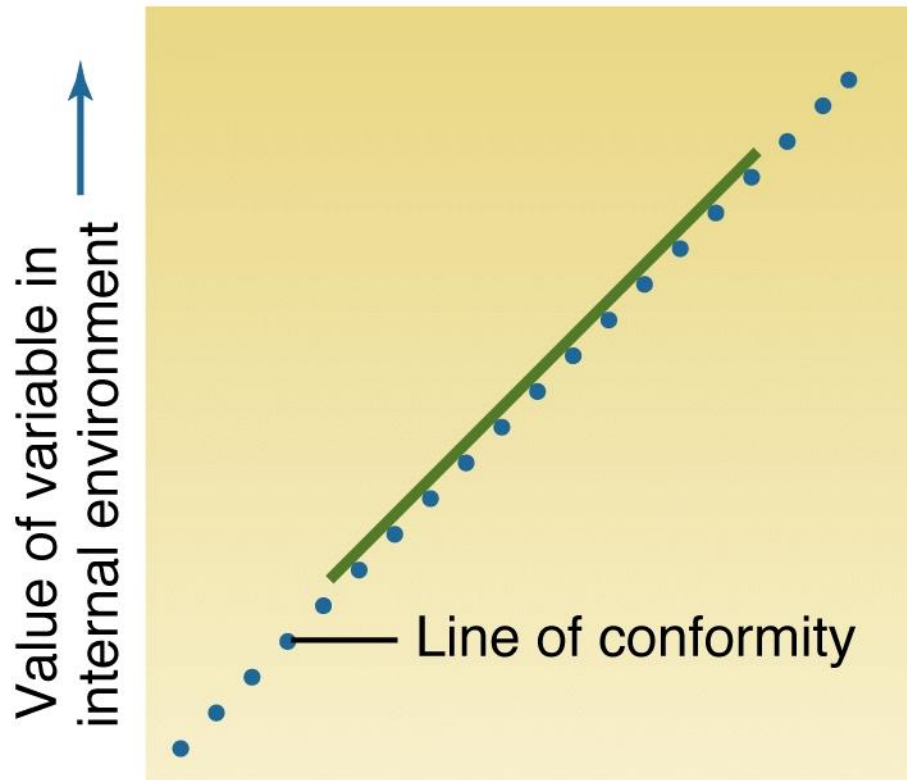
(a)



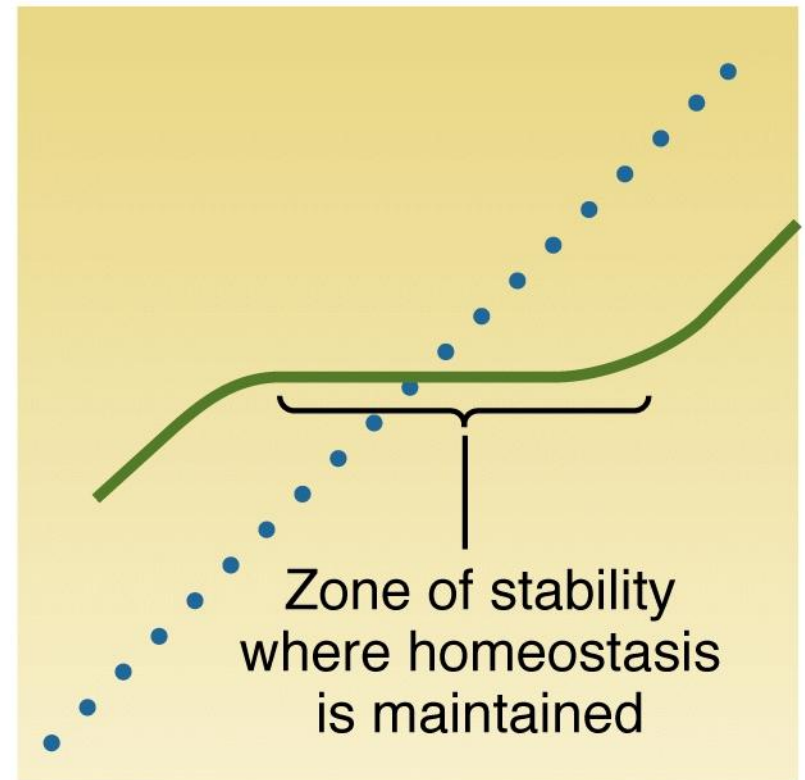
(b)



(a) **Conformer**



(b) **Regulator**



Value of variable in external environment →

- Know August Krogh principle.
- that there is an animal optimally suited to yield an answer of a physiological problem to be addressed



# Cell level – it all starts here

- Categories of organic molecules
  - **Carbohydrates**
    - Monosaccharides (e.g. glucose)
    - Polysaccharides (e.g. glycogen, cellulose, chitin)
  - **Lipids**
    - Fatty acids
    - Triglycerides
    - Phospholipids
    - Cholesterol

## ■ Categories of organic molecules

- **Proteins**

- Composed of **amino acids**
- Highly complex three-dimensional structures
- Peptides are smaller chains of amino acids

- **Nucleic acids**

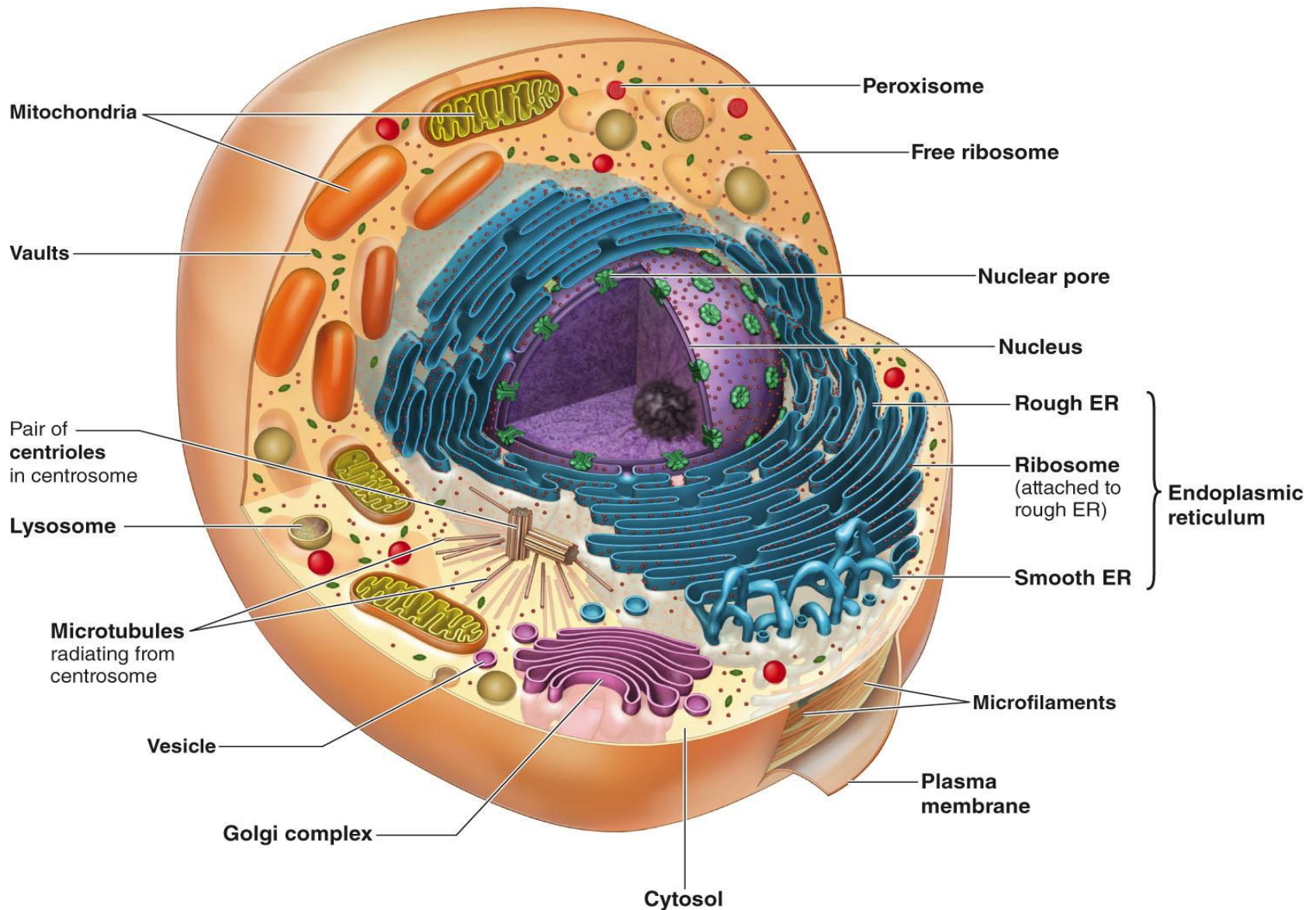
- Composed of **nucleotides**
- Deoxyribonucleic acid (DNA)
- Ribonucleic acid (RNA)

# 2.1 Introduction

- Major subdivisions of eukaryotic cells
  - **Plasma membrane** (cell membrane)
    - Separates the cell's contents from the surrounding environment
    - Selectively controls movement of molecules between **intracellular fluid** (ICF) and **extracellular fluid** (ECF)
  - **Nucleus**
    - Contains DNA
  - **Cytoplasm**
    - Contains **organelles** and **cytoskeleton** dispersed within the **cytosol**



# 2.1 Introduction

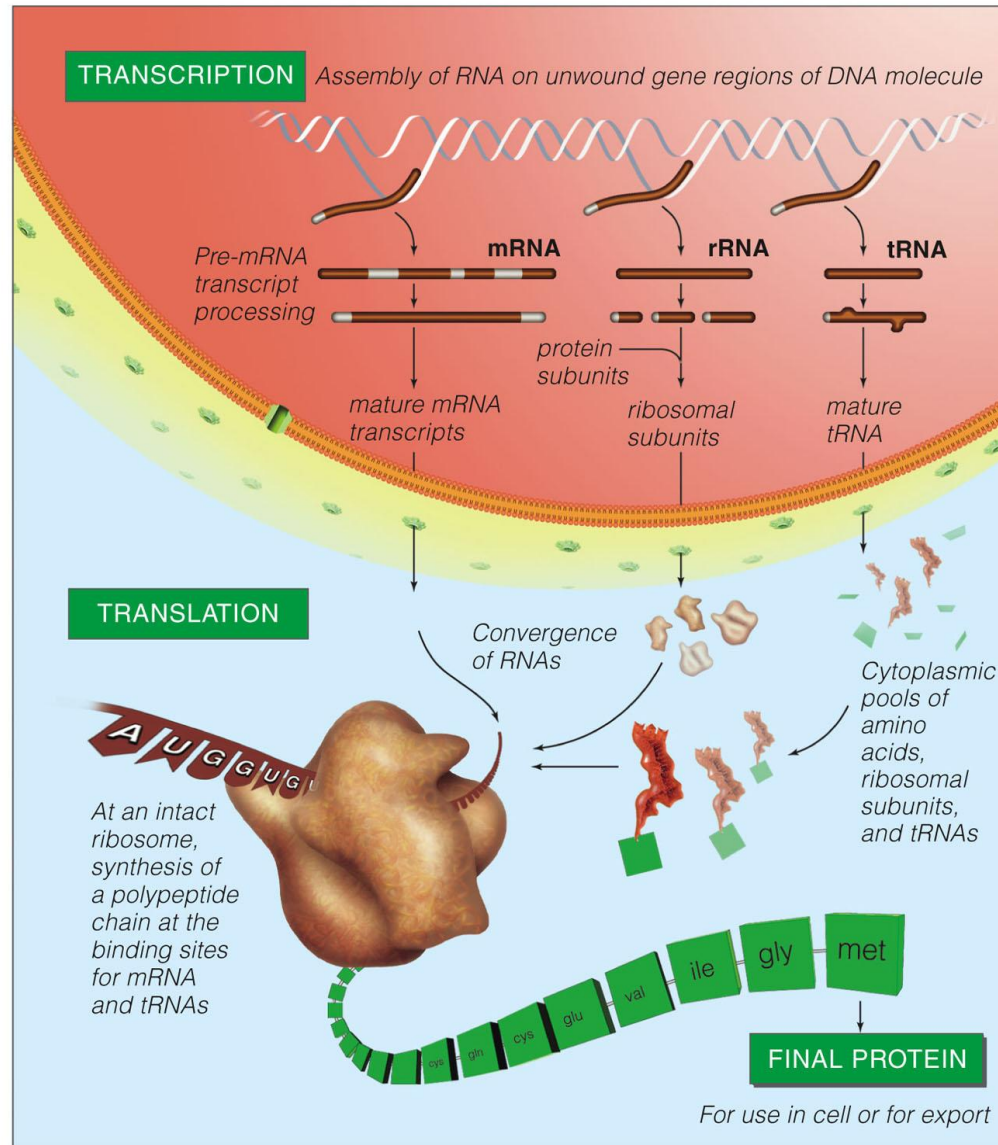


## 2.2 Nucleus, Chromosomes, and Genes

### ■ Nucleus

- Contains materials for **genetic instructions** and **inheritance**
- DNA is packaged with **histones** to form **chromosomes**
- **Functions of DNA**
  - Provides a code of information for RNA and protein synthesis
  - Serves as a genetic blueprint during cell replication
- Nucleus is the **control center** of the cell

# 2.2 Nucleus, Chromosomes, and Genes



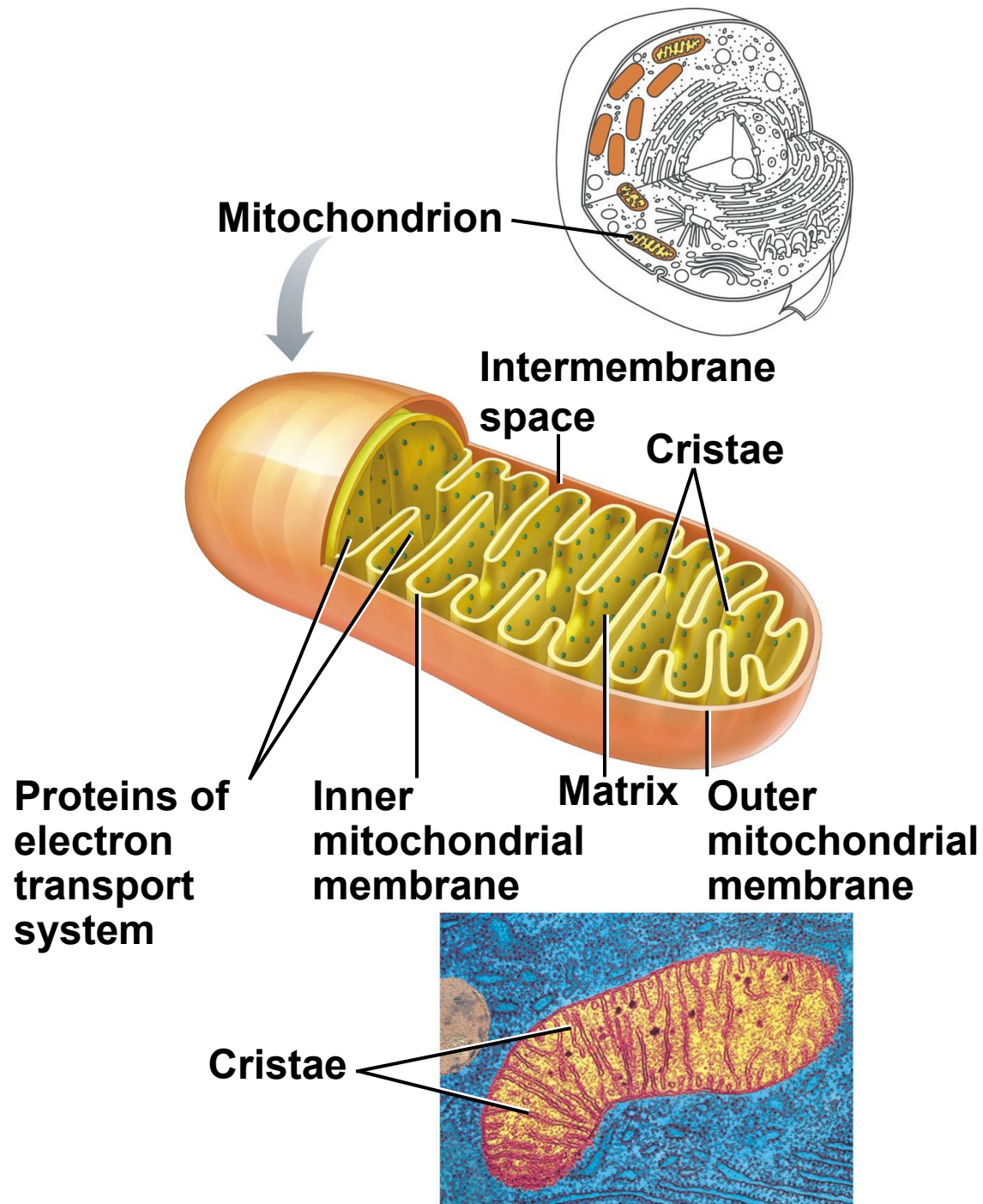


Figure 2-16 p47

## 2.8 Mitochondria and Energy Metabolism

- **Aerobic metabolism** in mitochondria relies on  $O_2$  to convert energy in food into **ATP**.
  - **Aerobic** pathways require consumption of  $O_2$
  - **Anaerobic** pathways can proceed in the absence of  $O_2$
  - Energy is released when electrons are transferred from high-energy bonds to **electron acceptors** in **oxidation-reduction** reactions

## 2.8 Mitochondria and Energy Metabolism

- Universal energy carriers
  - **Adenosine triphosphate (ATP)** carries a high-energy bond in the terminal phosphate
    - When the terminal phosphate bond is split, energy is released



- **Nicotinamide adenine dinucleotide (NADH)** carries energy-rich electrons that can be used to reduce other organic molecule
  - Each NADH is worth almost 3 ATPs
  - Electrons of NADH are transferred to  $\text{O}_2$ , the final electron acceptor



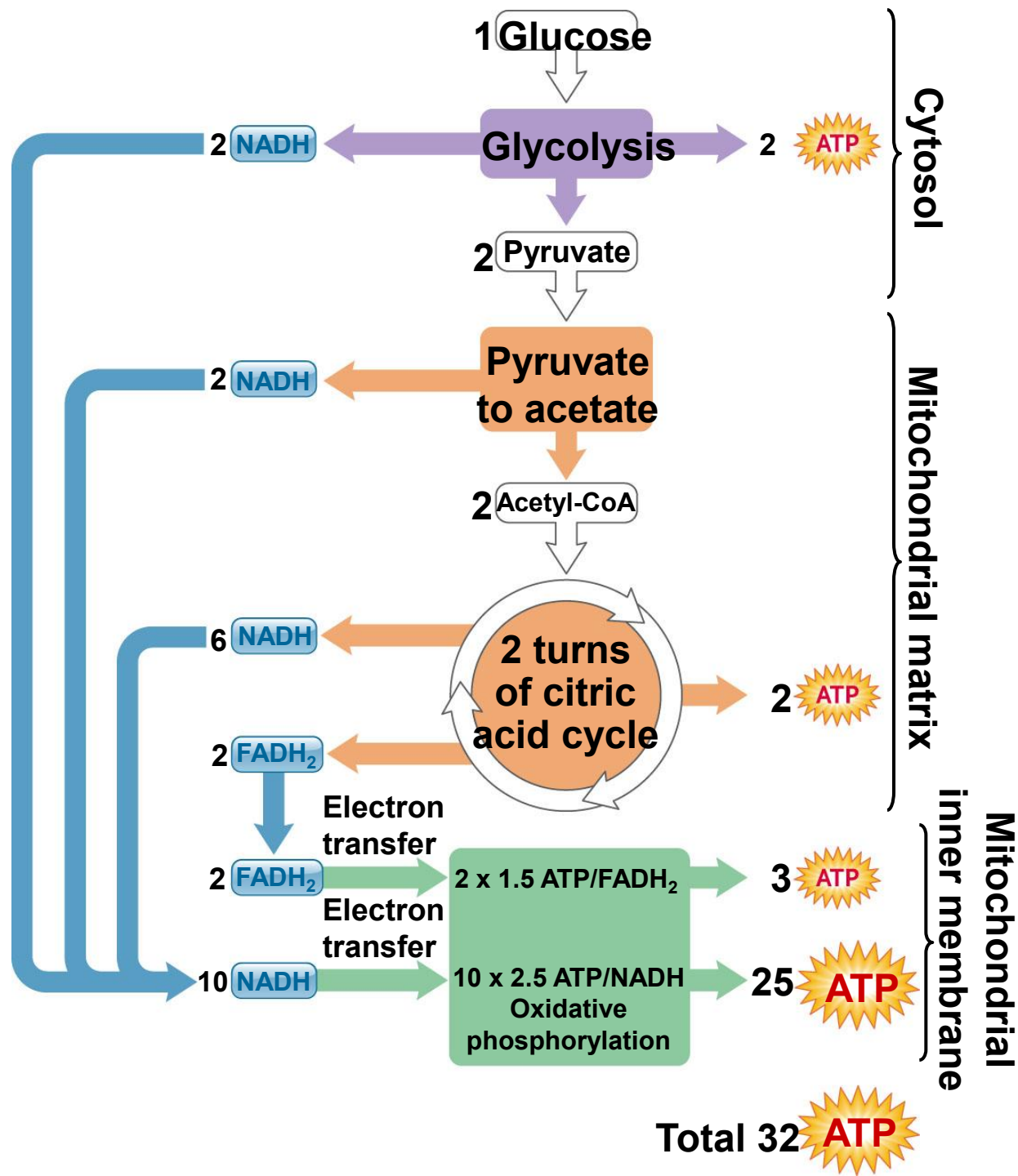


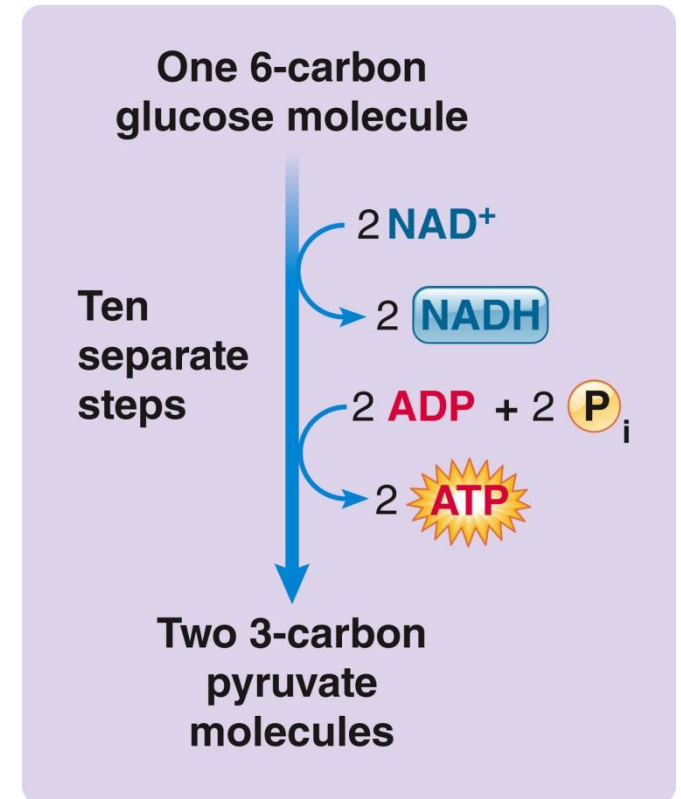
Figure 2-17 p49



## 2.8 Mitochondria and Energy Metabolism

### ■ Glycolysis

- Chemical process that breaks down **glucose** into two **pyruvate** molecules
- Involves **10 sequential reactions**, each catalyzed by a separate enzyme



## 2.8 Mitochondria and Energy Metabolism

### ▪ **Glycolysis**

- All glycolytic enzymes are found in the **cytoplasm**
- Glycolysis can proceed in the absence of oxygen (**anaerobic** conditions)
- Releases **two electrons** that are transferred to  $\text{NAD}^+$  to form NADH
- **Not very efficient** -- one molecule of glucose yields only two molecules of ATP

## 2.8 Mitochondria and Energy Metabolism

### ■ Citric acid cycle

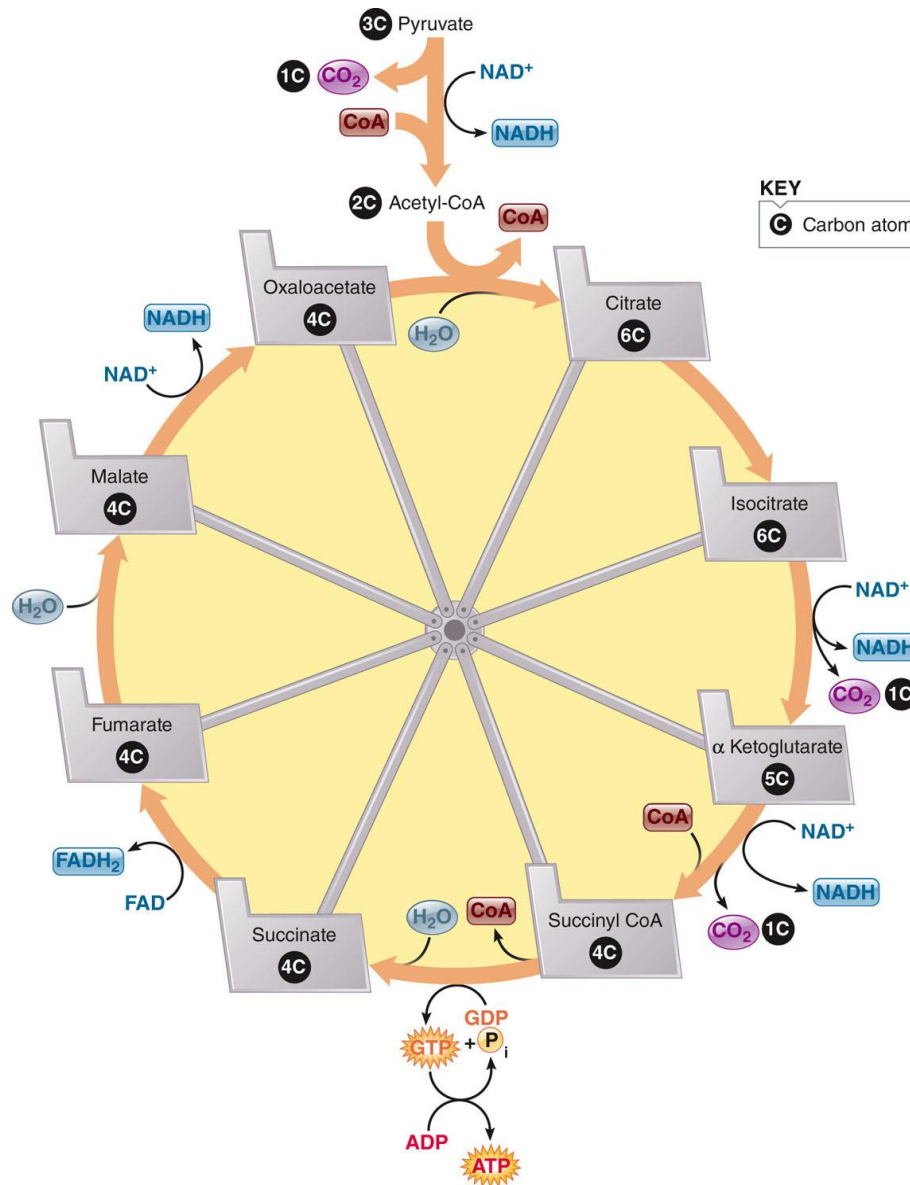
- Cyclical series of 8 reactions catalyzed by enzymes in the **mitochondrial matrix**
- **Pyruvate** produced by glycolysis enters the mitochondrial matrix
- Pyruvate is converted to **acetyl CoA** by removal of a carbon and formation of  $\text{CO}_2$

## 2.8 Mitochondria and Energy Metabolism

### ■ Citric acid cycle

- Acetyl CoA enters the citric acid cycle by combining with oxaloacetic acid to form **citric acid**
- Two carbons are released as  $\text{CO}_2$
- One ATP is produced for each turn of the cycle
- The key purpose of the cycle is to produce **hydrogens** for entry into the **electron transport chain**

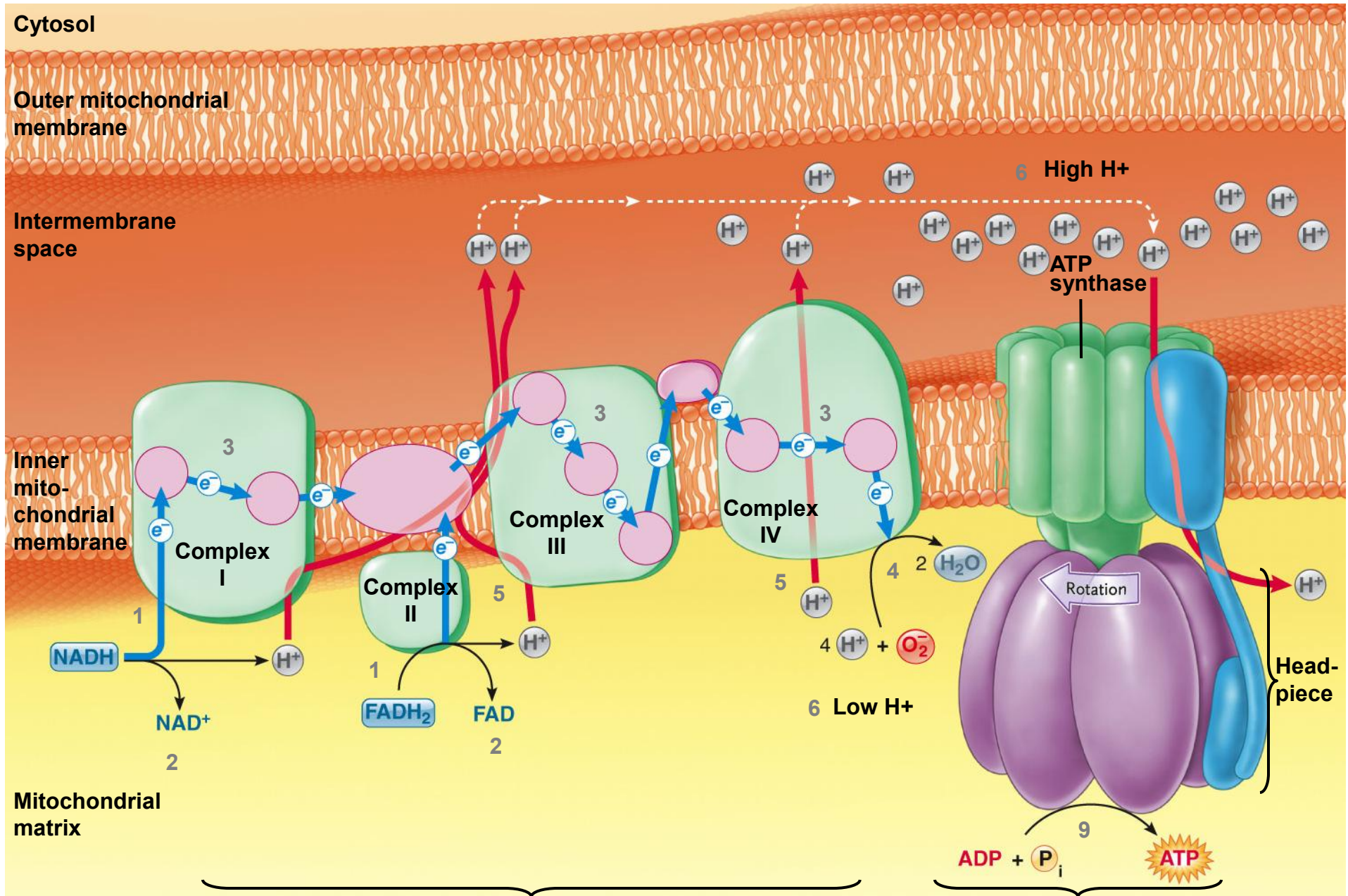
# 2.8 Mitochondria and Energy Metabolism



## 2.8 Mitochondria and Energy Metabolism

### ▪ **Electron transport chain**

- Electron carrier molecules are located in the **inner mitochondrial membrane**
- Electrons are transferred through a **chain of reactions** with the electrons falling to lower energy levels at each step
- $O_2$  is the **final electron acceptor** of the electron transport chain (also called respiratory chain)
  - $O_2$  combines with electrons and hydrogen to form  $H_2O$



**Electron transport system**  
Electrons flow through a series of electron carriers from high-energy to low-energy levels; the energy released builds an  $\text{H}^+$  gradient across the inner mitochondrial membrane.

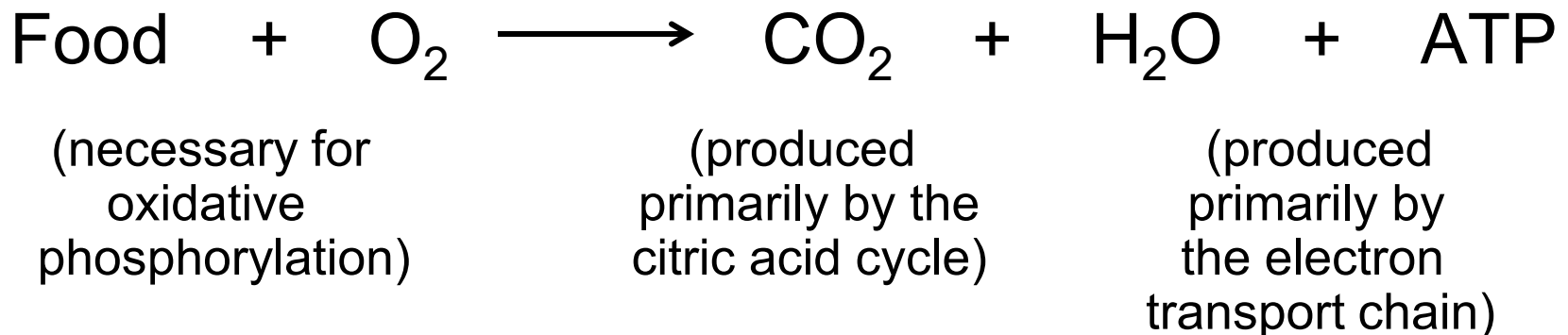
**Chemiosmosis**  
ATP synthase catalyzes ATP synthesis using energy from the  $\text{H}^+$  gradient across the membrane.



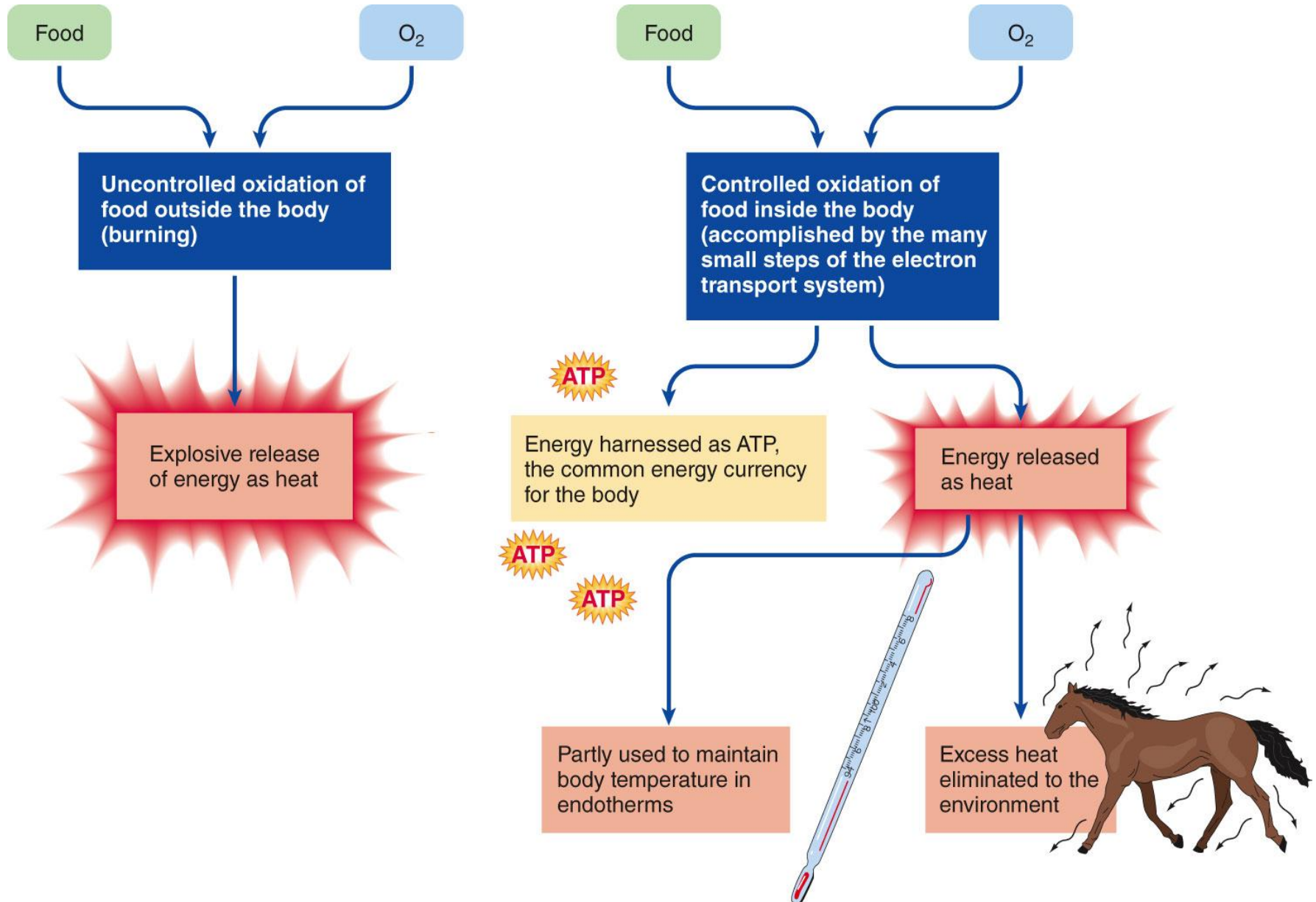
## 2.8 Mitochondria and Energy Metabolism

### ▪ Electron transport chain

- Some of energy released during transfer of electrons is used to synthesize **ATP** (**oxidative phosphorylation**)
- Total ATP yield is 30 ATPs per molecule of glucose



# 2.8 Mitochondria and Energy Metabolism



## 2.8 Mitochondria and Energy Metabolism

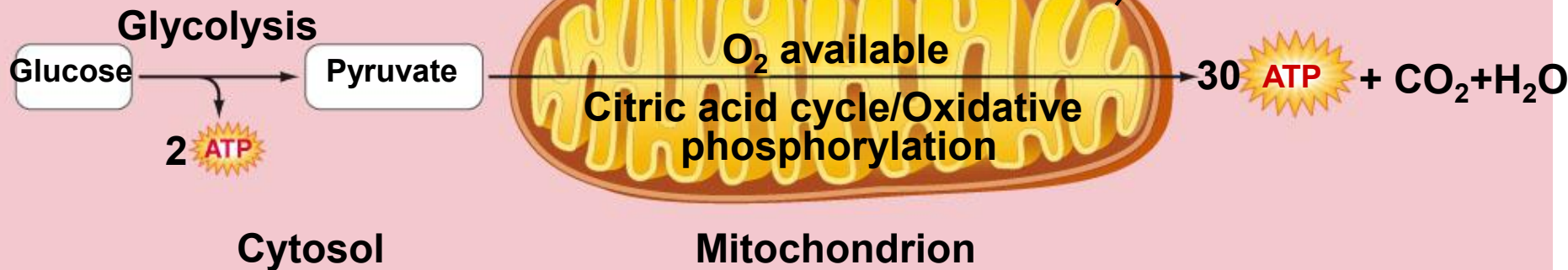
### ▪ **Metabolism under anaerobic conditions**

- $O_2$  deficiency forces cells to rely on glycolysis
- Pyruvate is converted to **lactate**
- Lactate accumulates in the tissues and reduces pH
- Lactate can be converted back to pyruvate

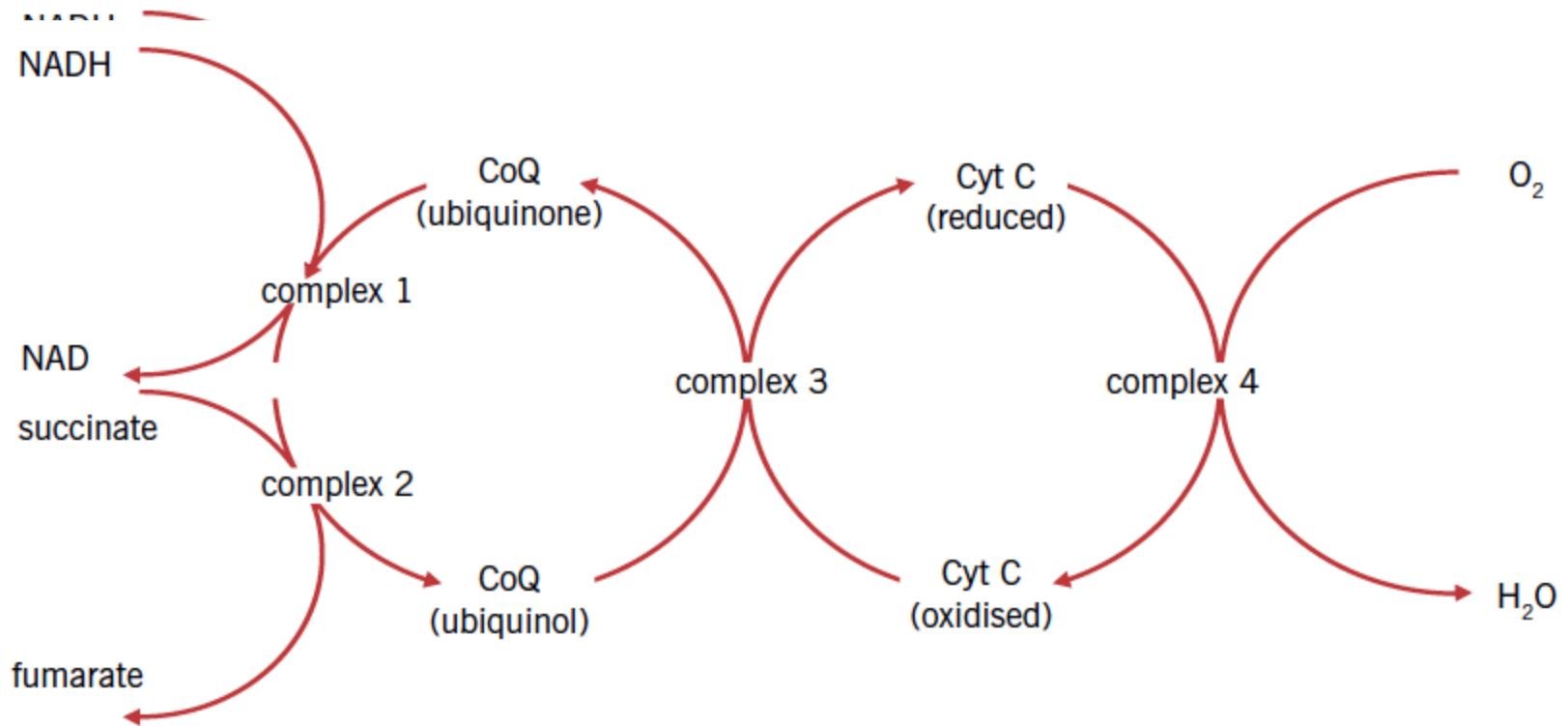
## Anaerobic conditions



## Aerobic conditions



# Coenzyme Q10 in Mitochondria

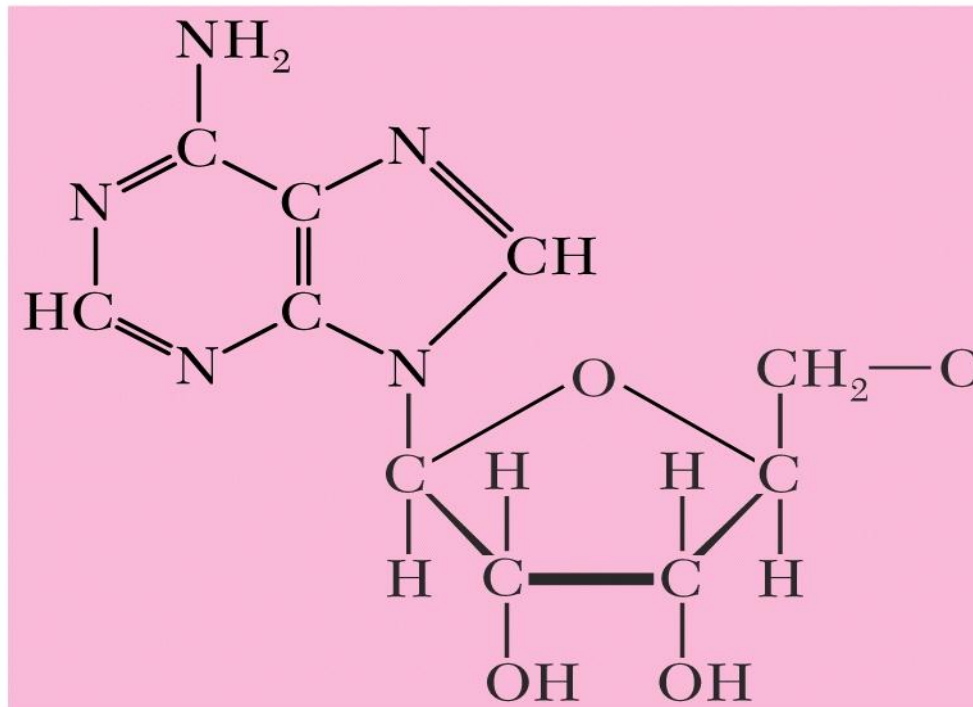


**Key:** NADH = nicotinamide adenine dinucleotide hydride; NAD = nicotinamide adenine dinucleotide; CoQ = coenzyme Q10; Cyt C = cytochrome C

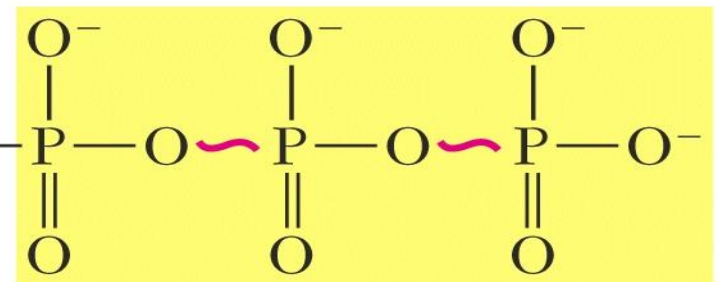
<https://bjcardio.co.uk/2015/10/coenzyme-q10-and-cardiovascular-disease-an-overview/>

(a)

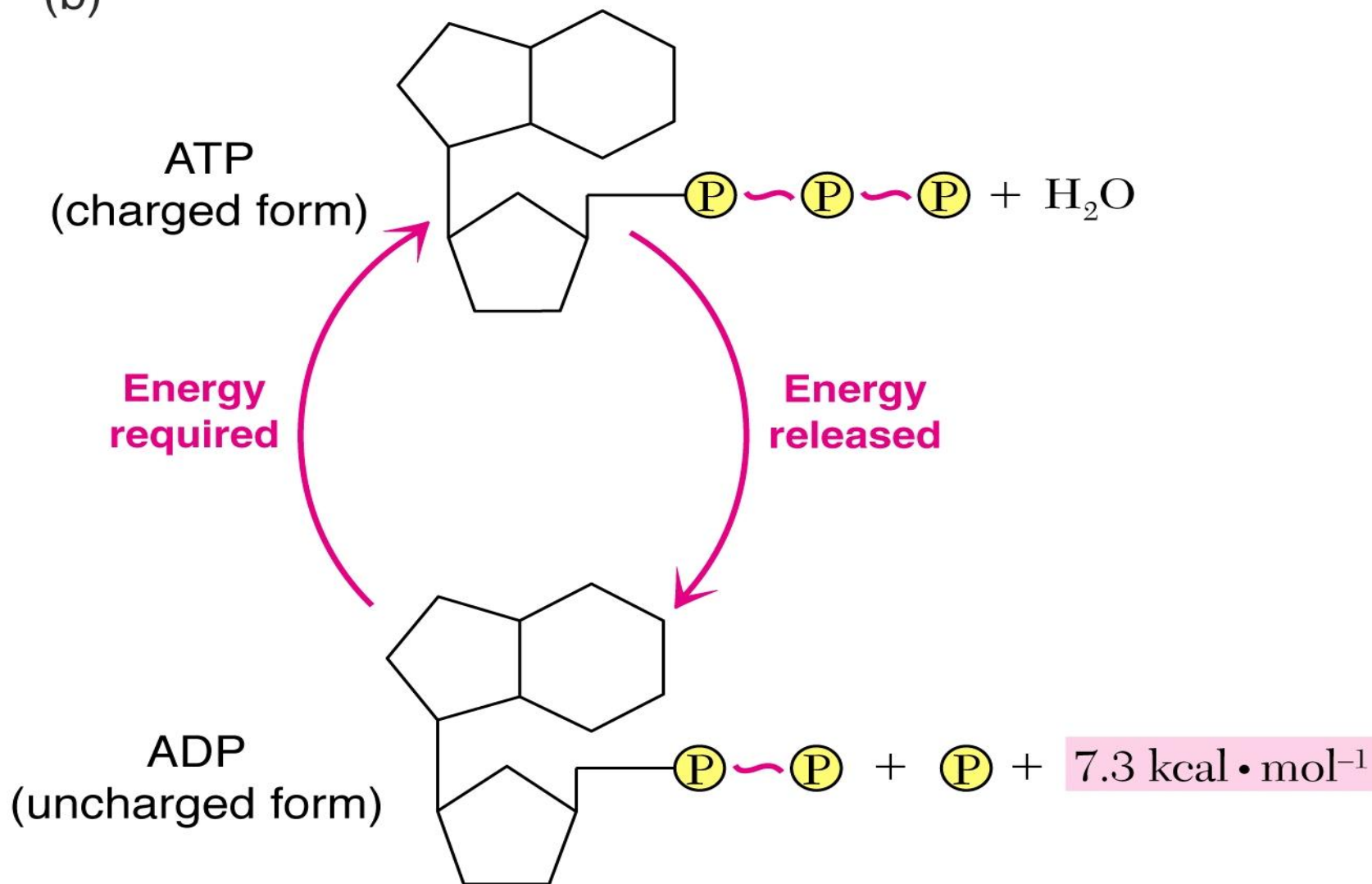
### Adenosine group

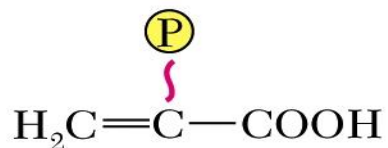


### Triphosphate group



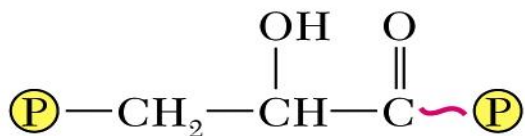
(b)





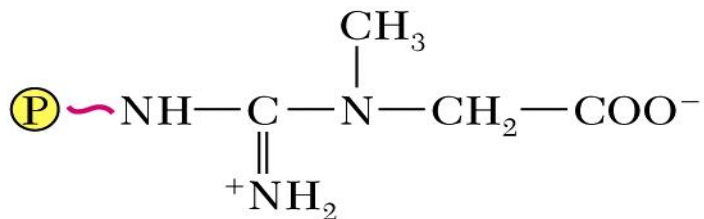
**Phosphoenolpyruvate**

$$\Delta G^\circ = -14.8 \text{ kcal} \cdot \text{mol}^{-1}$$



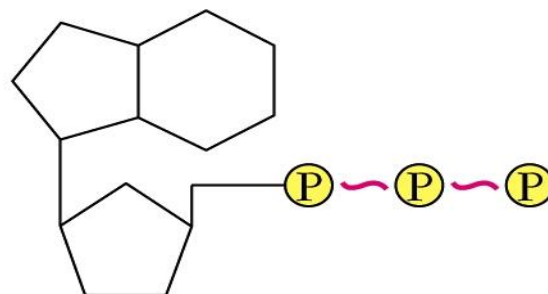
**1,3-Diphosphoglycerate**

$$\Delta G^\circ = -11.8 \text{ kcal} \cdot \text{mol}^{-1}$$



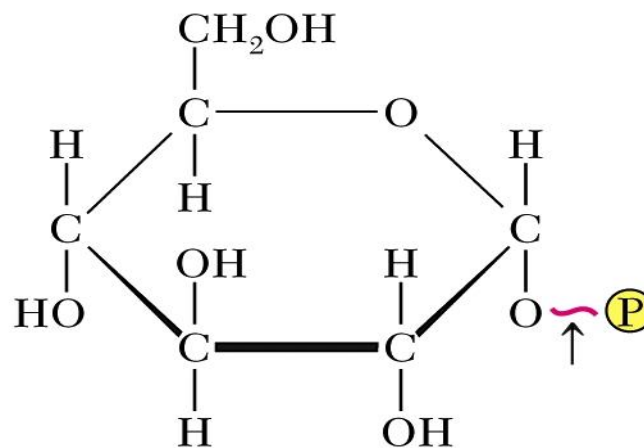
**Phosphocreatine**

$$\Delta G^\circ = -10.3 \text{ kcal} \cdot \text{mol}^{-1}$$



**ATP**

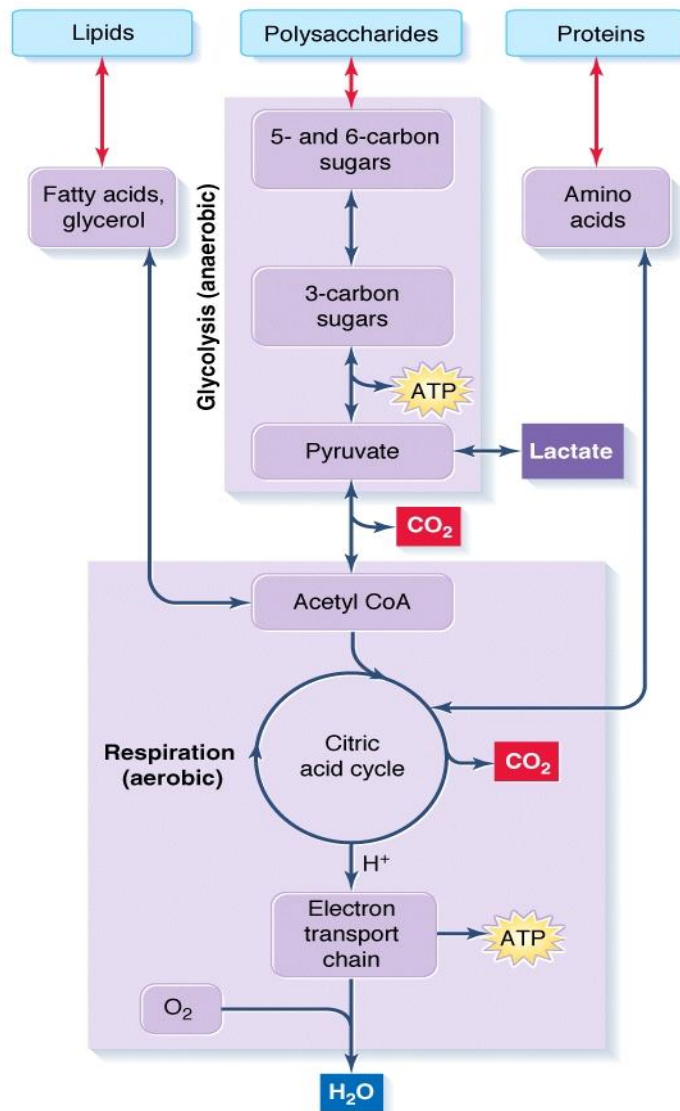
$$\Delta G^\circ = -7.3 \text{ kcal} \cdot \text{mol}^{-1}$$



**Glucose 1-phosphate**

$$\Delta G^\circ = -5.0 \text{ kcal} \cdot \text{mol}^{-1}$$

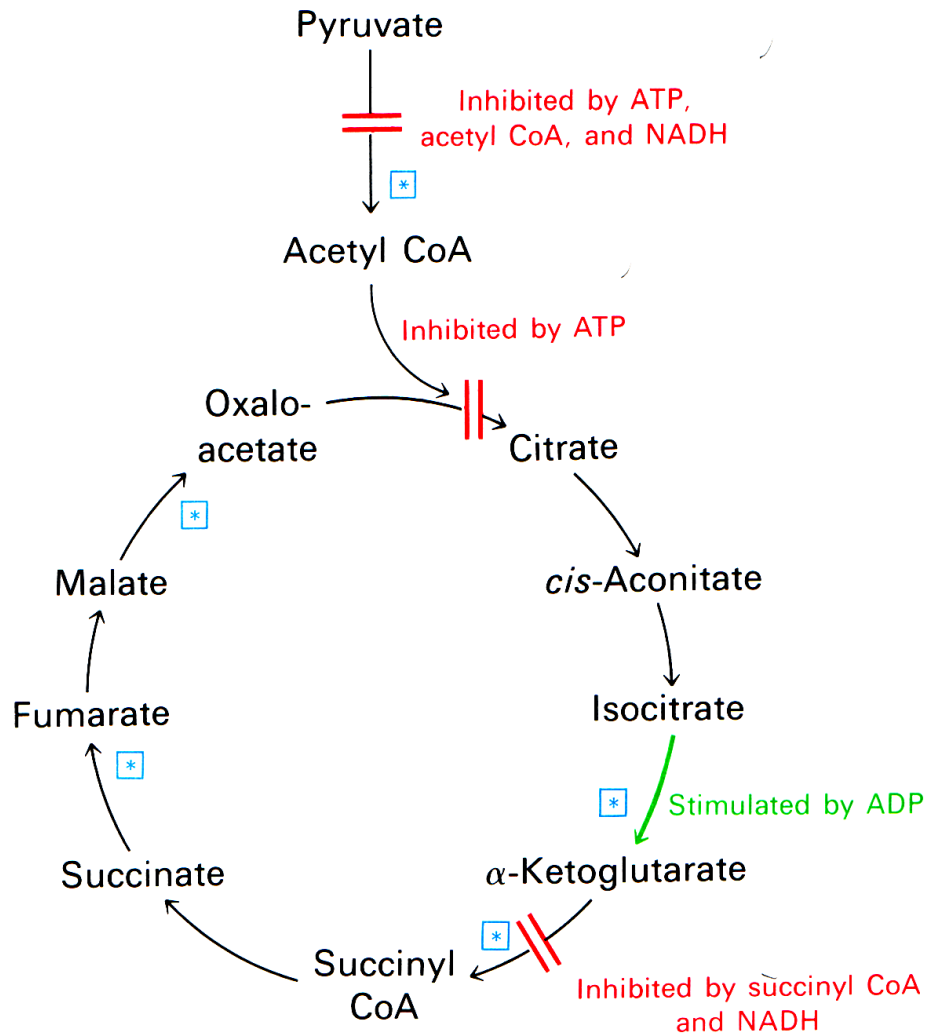


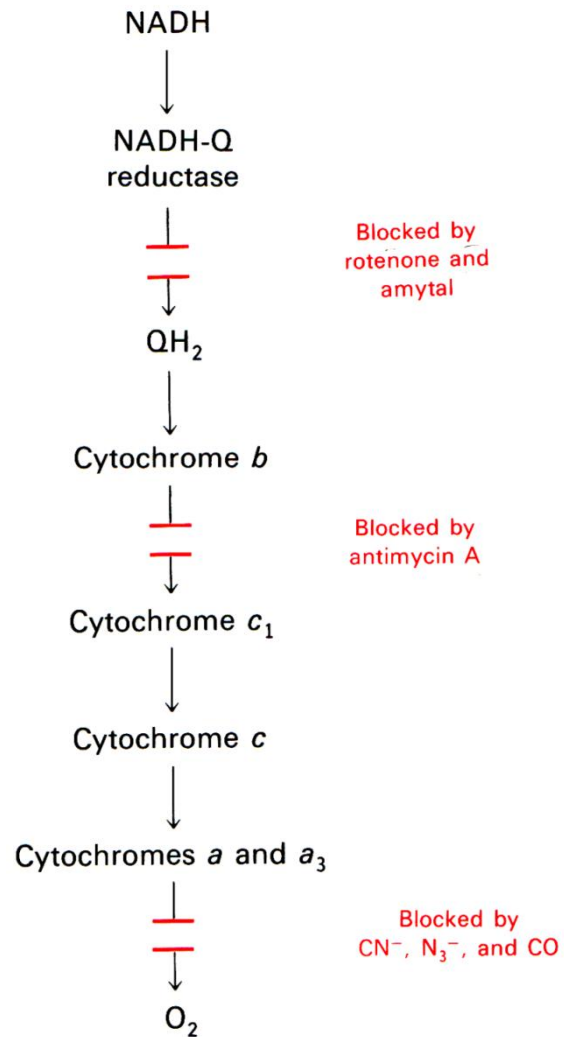


2 ATP

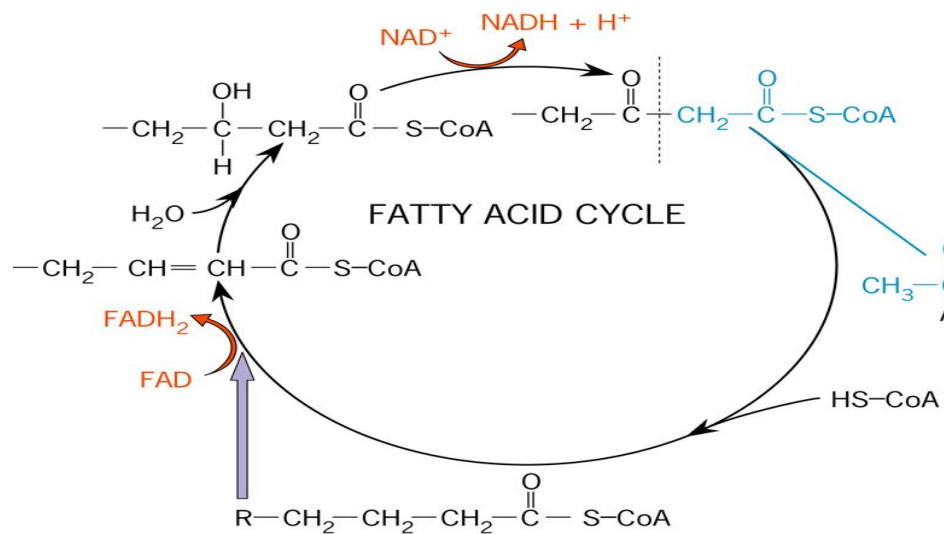
36 ATP (?)

Total 38 ATP (?)

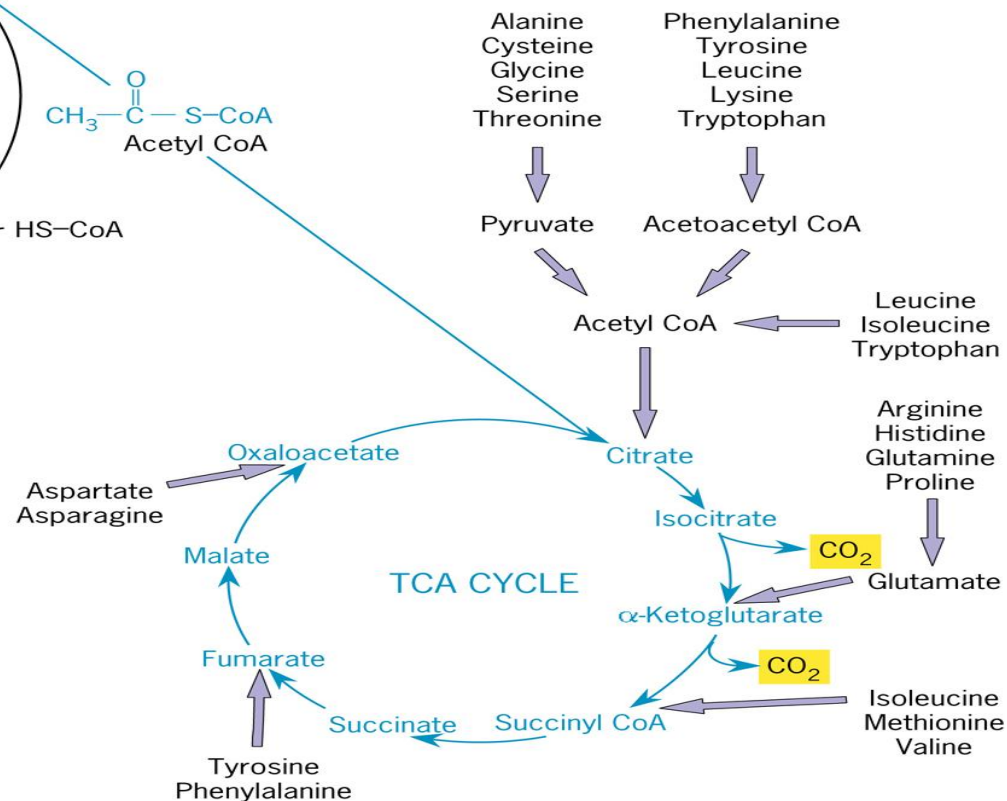




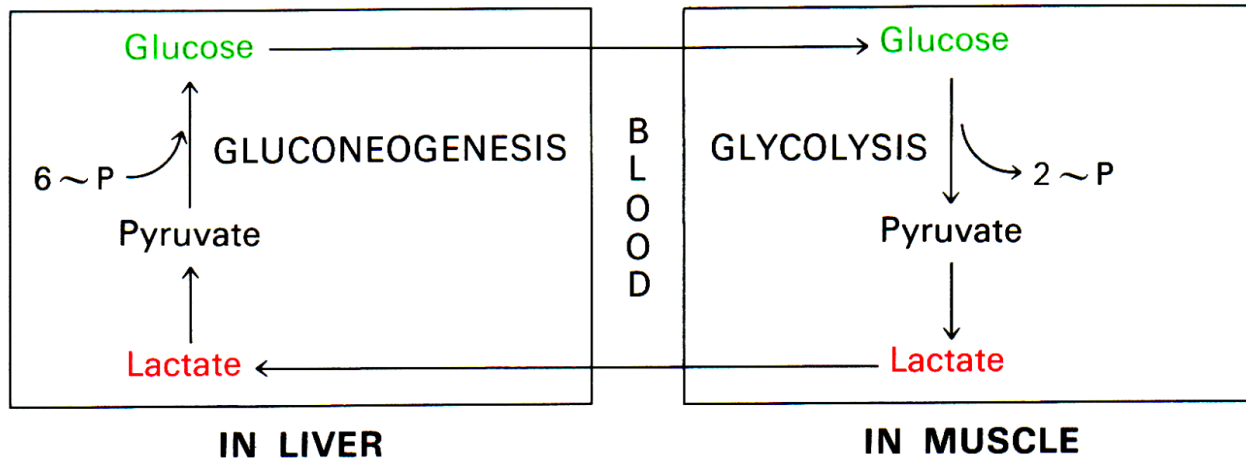
Endosymbiotic theory  
Lynn Margulis



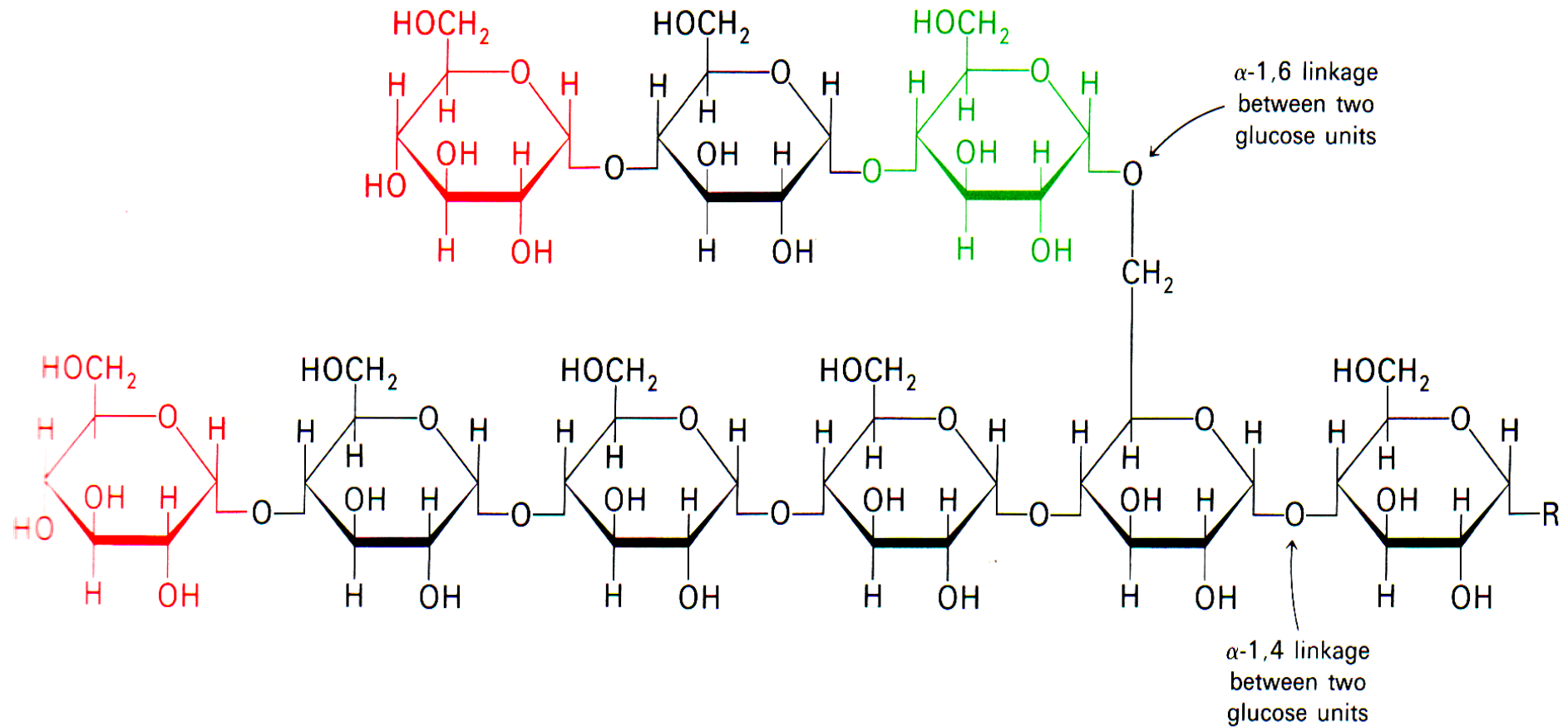
(a)



(b)



# Glycogen-storage of glucose



**Table 16-1**

## Glycogen storage diseases

<i>Type</i>	<i>Defective enzyme</i>	<i>Organ affected</i>	<i>Glycogen in the affected organ</i>	<i>Clinical features</i>
I VON GIERKE'S DISEASE	Glucose 6-phosphatase	Liver and kidney	Increased amount; normal structure.	Massive enlargement of the liver. Failure to thrive. Severe hypoglycemia, ke- tosis, hyperuricemia, hy- perlipemia.
II POMPE'S DISEASE	$\alpha$ -1,4-Glucosidase (lysosomal)	All organs	Massive increase in amount; normal structure.	Cardiorespiratory failure causes death, usually be- fore age 2.
III CORI'S DISEASE	Amylo-1,6-glucosidase (debranching enzyme)	Muscle and liver	Increased amount; short outer branches.	Like Type I, but milder course.
IV ANDERSEN'S DISEASE	Branching enzyme ( $\alpha$ -1,4 $\longrightarrow$ $\alpha$ -1,6)	Liver and spleen	Normal amount; very long outer branches.	Progressive cirrhosis of the liver. Liver failure causes death usually be- fore age 2.
V McARDLE'S DISEASE	Phosphorylase	Muscle	Moderately increased amount; normal structure.	Limited ability to perform strenuous exercise because of painful muscle cramps. Otherwise patient is nor- mal and well developed.
VI HERS' DISEASE	Phosphorylase	Liver	Increased amount.	Like Type I, but milder course.
VII	Phosphofructokinase	Muscle	Increased amount; normal structure.	Like Type V.
VIII	Phosphorylase kinase	Liver	Increased amount; normal structure.	Mild liver enlargement. Mild hypoglycemia.

Note: Types I through VII are inherited as autosomal recessives. Type VIII is sex-linked.

# Mitochondrial diseases

mitochondrial DNA:

At present, 46% of patients have died (median age: 13 months), 80% of whom were <3 years of age.

<https://pubmed.ncbi.nlm.nih.gov/17403843/>

<https://www.umdfrg.org/what-is-mitochondrial-disease-2/>

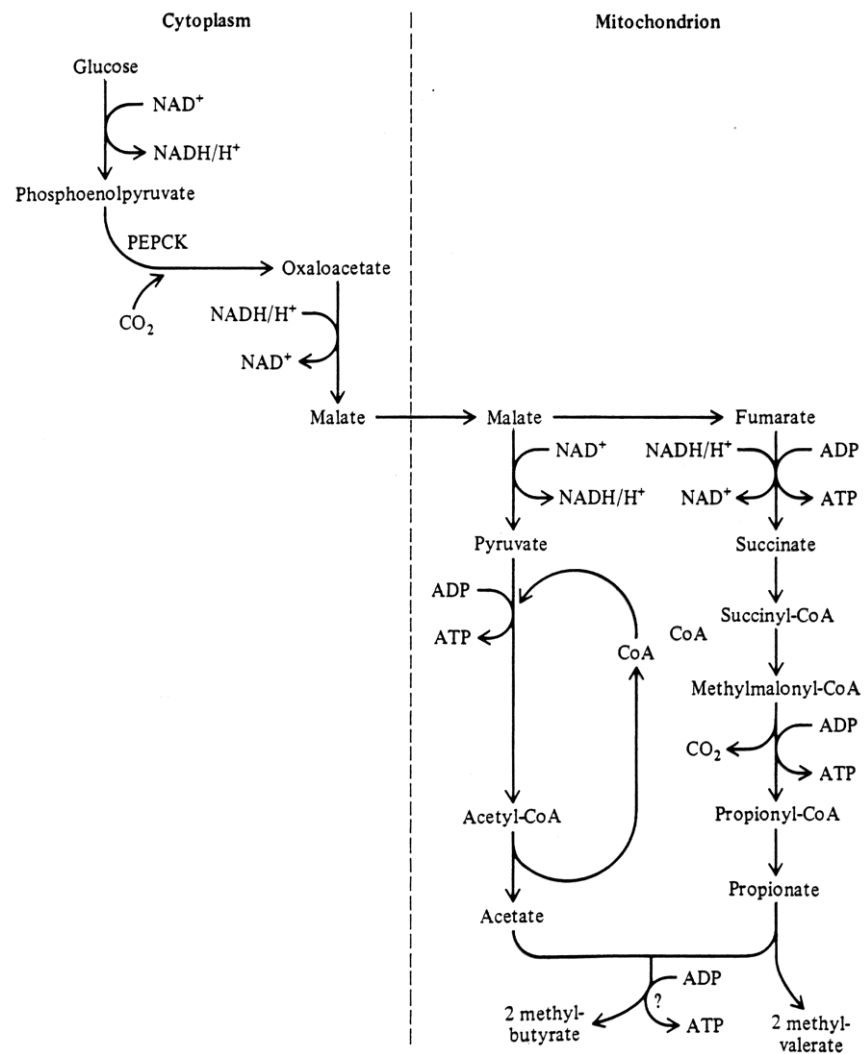
<https://www.ncbi.nlm.nih.gov/books/NBK1224/>

<https://elifesciences.org/articles/41927>

mtDNA

<https://www.genome.gov/genetics-glossary/Mitochondrial-DNA>





**FIGURE 3-18** Linkage of glycolysis with citric acid cycle pathways is an anaerobic metabolic pathway that provides additional ATP formation. These pathways are found, for example, in many platyhelminth worms.

## 2.8 Mitochondria and Energy Metabolism

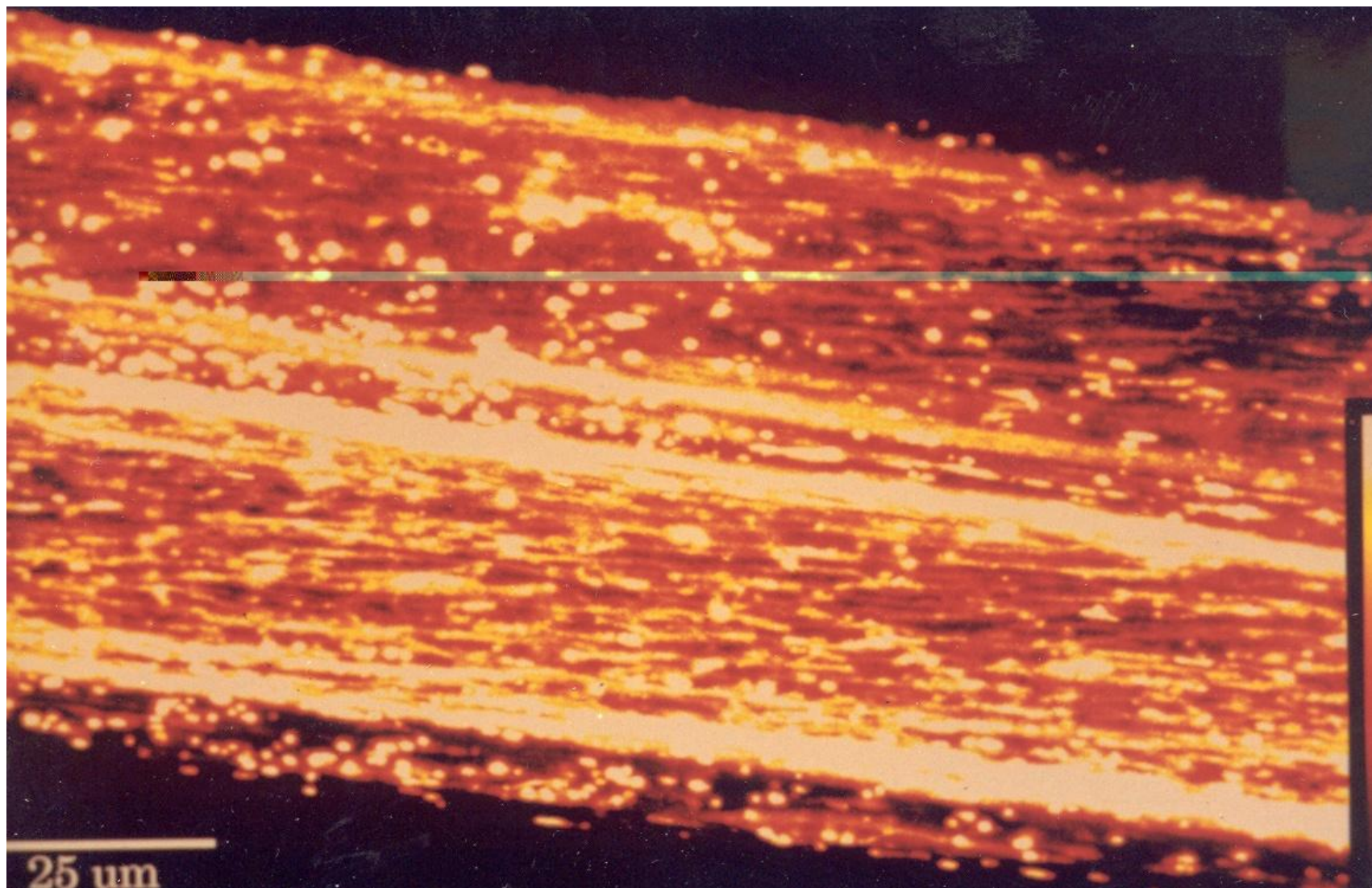
- **Tolerance of O<sub>2</sub> deficiency varies widely among organisms**
  - **Obligate aerobes** -- require O<sub>2</sub> continuously for survival (e.g. mammals)
  - **Facultative anaerobes** -- can adapt to anaerobic conditions for days or months (e.g. brine shrimp embryos)
  - **Obligate anaerobes** -- thrive in anaerobic environments
    - Inhibited or killed in the presence of O<sub>2</sub>
    - Archaea, bacteria (e.g. *Clostridium*), and protozoa (e.g. *Entamoeba*)

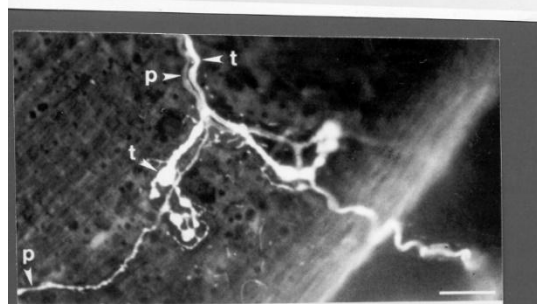
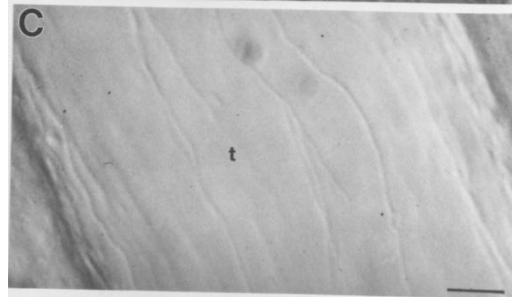
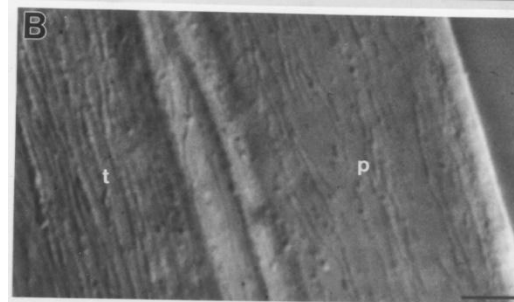
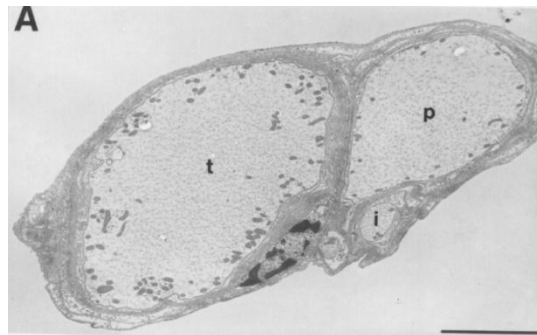
Anaerobic- Bacteria, some yeasts, some invertebrates can live in low  $O_2$ .

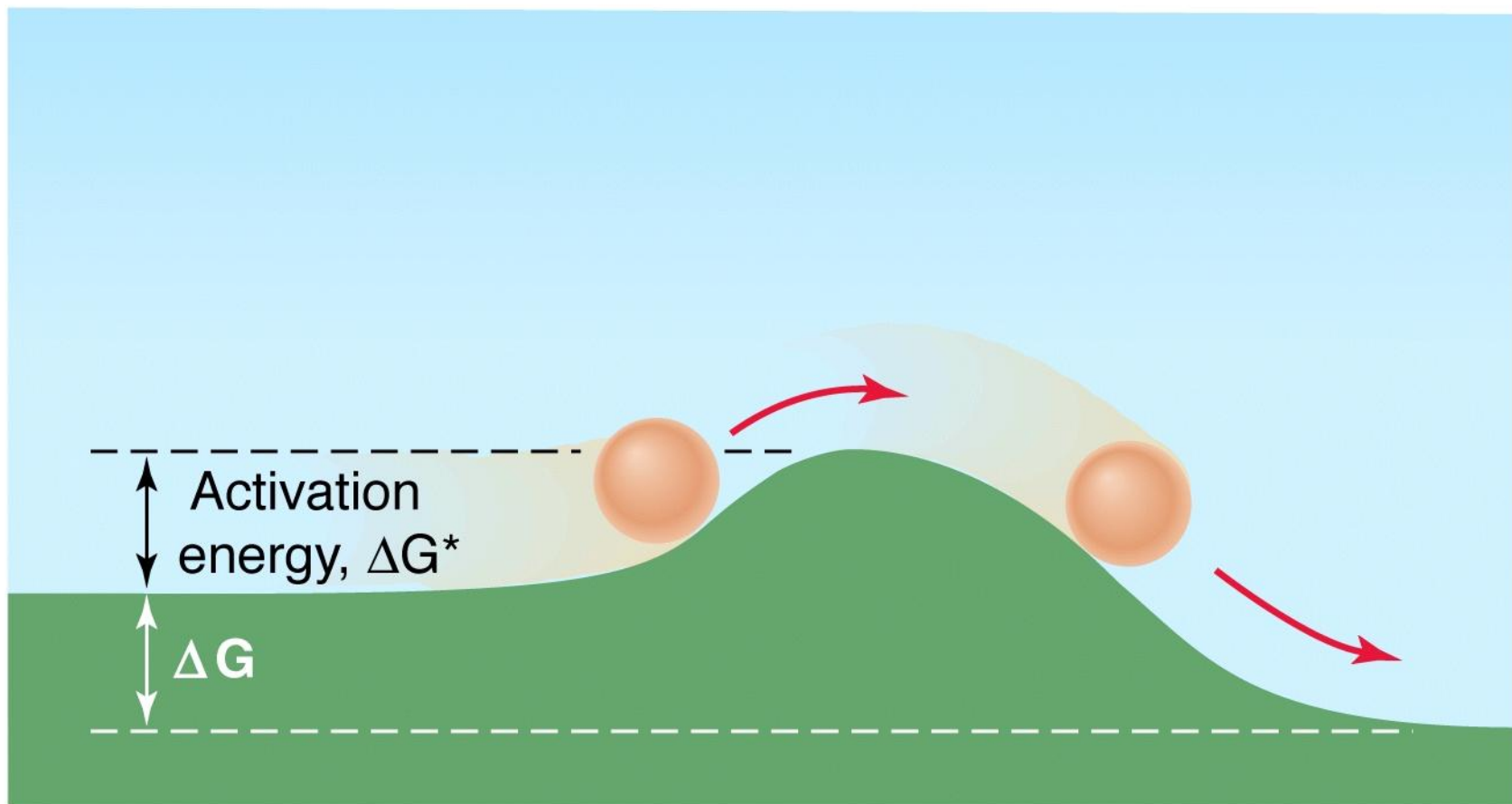
Ex. *Clostridium botulinum* can not grow in  $O_2$ .

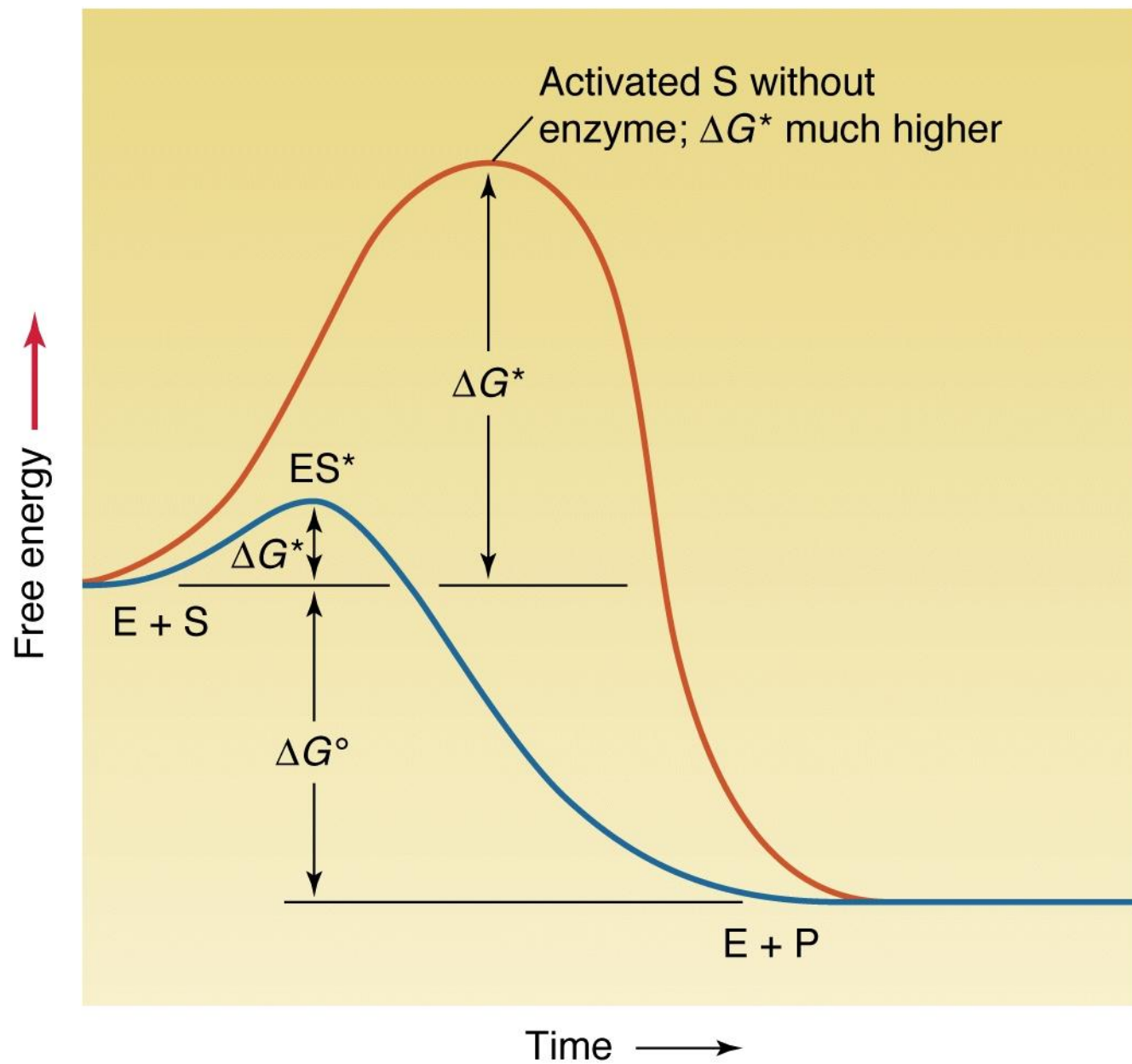
Aerobic- require a supply of  $O_2$ . Some tissues like muscle can function anaerobically and build up an “ $O_2$  debt” but pay back occurs.

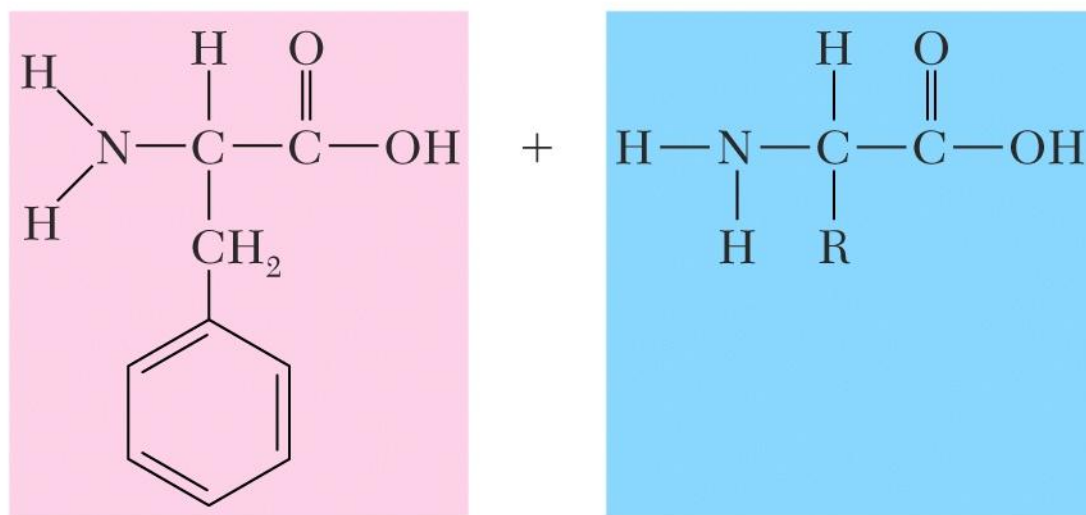
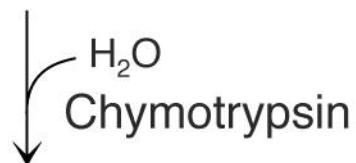
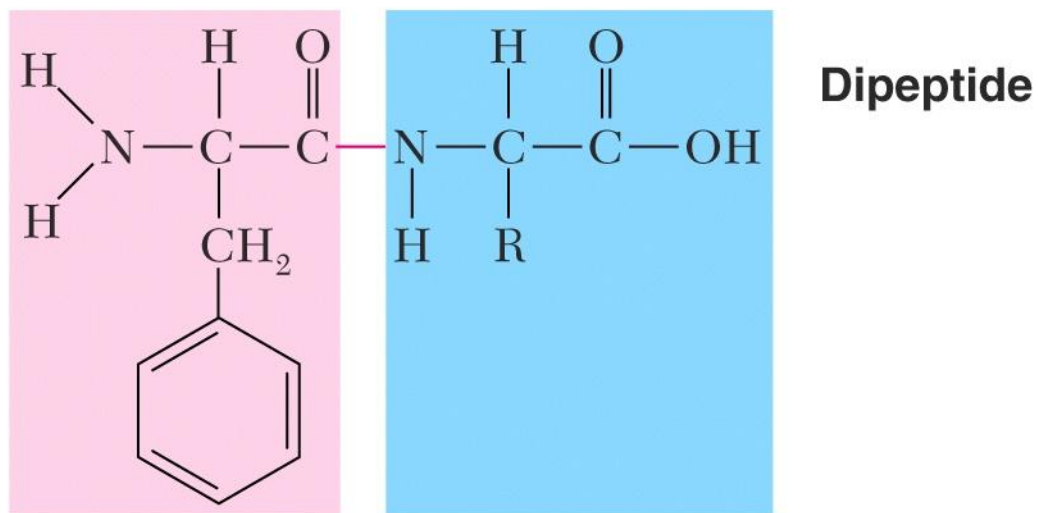
With  $O_2$  the cells are 20 times more efficient to produce ATP.





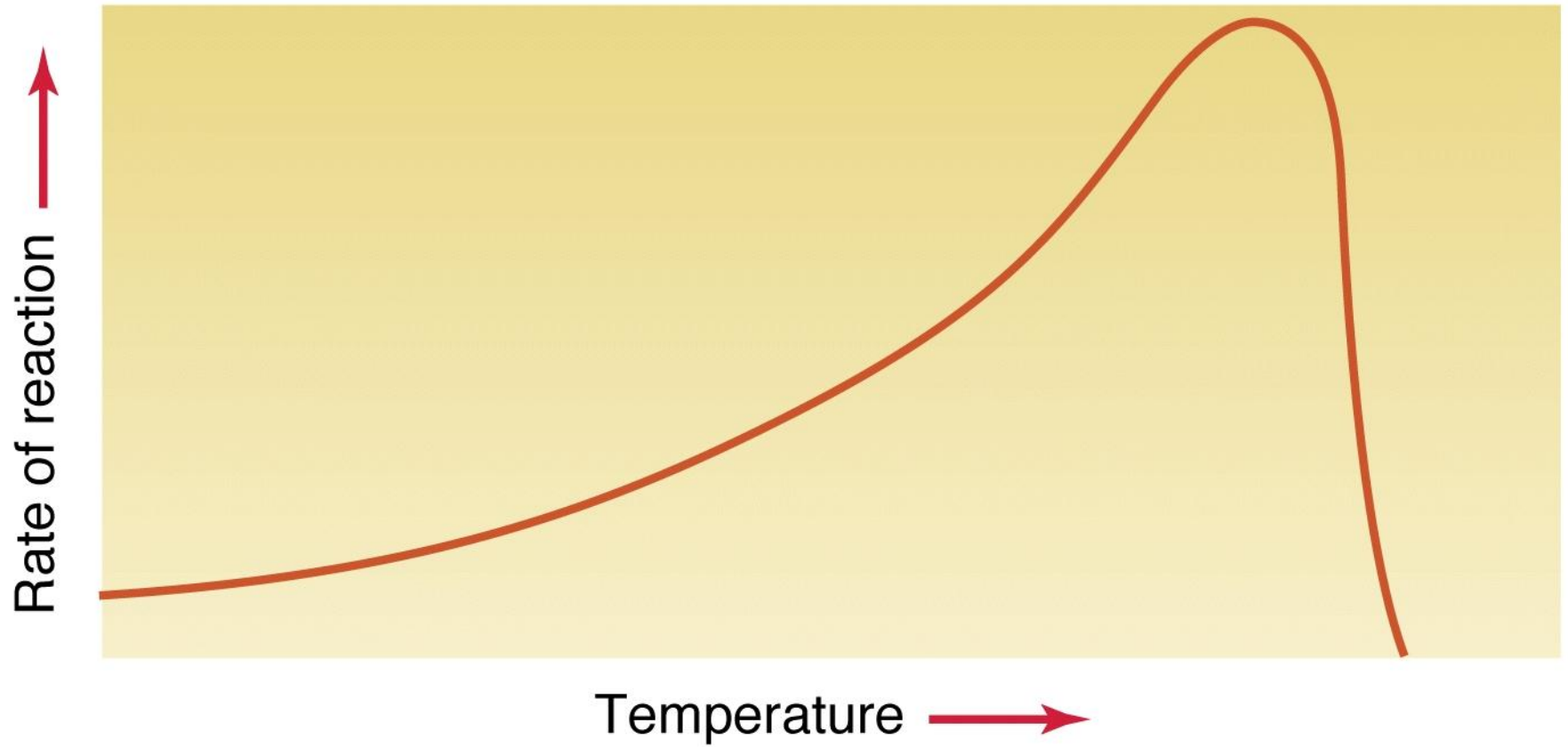




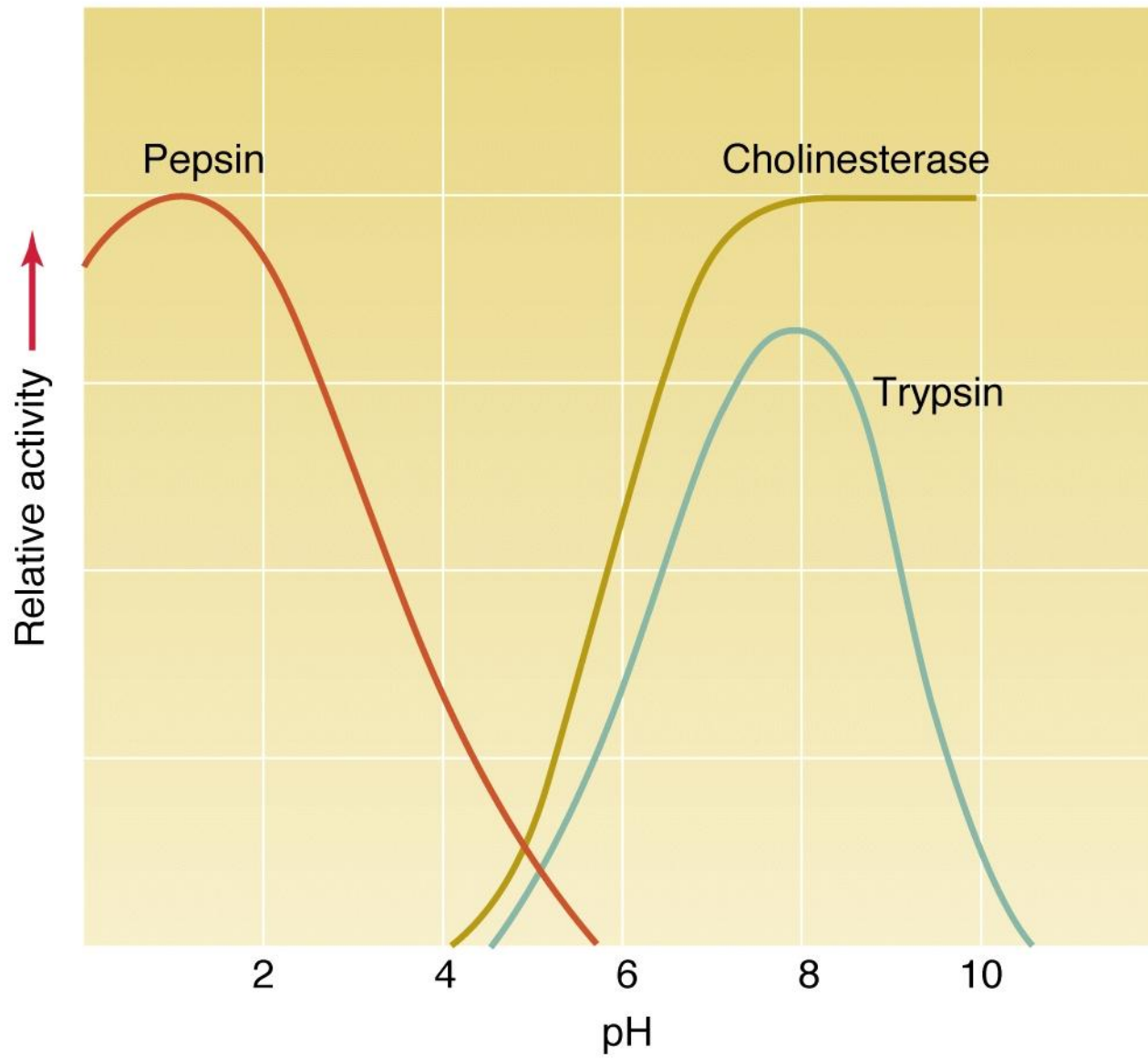




(a) Enzyme activity versus temperature



(b) Enzyme activity versus pH



**Table 3-6**      Metal ions functioning as cofactors

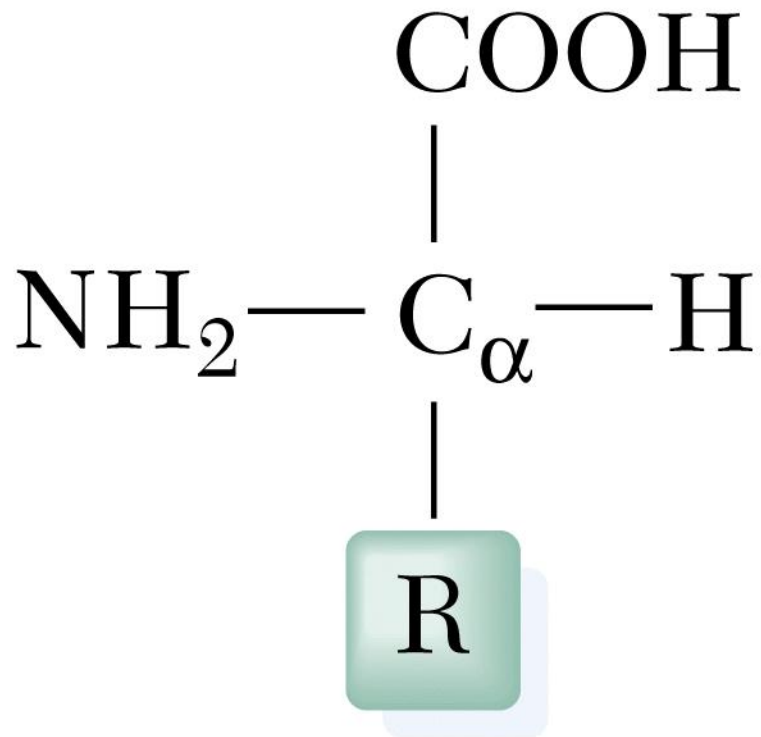
Metal ion	Some enzymes requiring this cofactor
$\text{Ca}^{2+}$	Phosphodiesterase Protein kinase C
$\text{Cu}^{2+}$ ( $\text{Cu}^{+}$ )	Cytochrome oxidase Tyrosinase
$\text{Fe}^{2+}$ or $\text{Fe}^{3+}$	Catalase Cytochromes Ferredoxin Peroxidase
$\text{K}^{+}$	Pyruvate phosphokinase (also requires $\text{Mg}^{2+}$ )
$\text{Mg}^{2+}$	Phosphohydrolases Phosphotransferases
$\text{Mn}^{2+}$	Arginase Phosphotransferases
$\text{Na}^{+}$	Plasma membrane ATPase (also requires $\text{K}^{+}$ and $\text{Mg}^{2+}$ )
$\text{Zn}^{2+}$	Alcohol dehydrogenase Carbonic anhydrase Carboxypeptidase

*Source:* Adapted from Nelson and Cox, 2000.

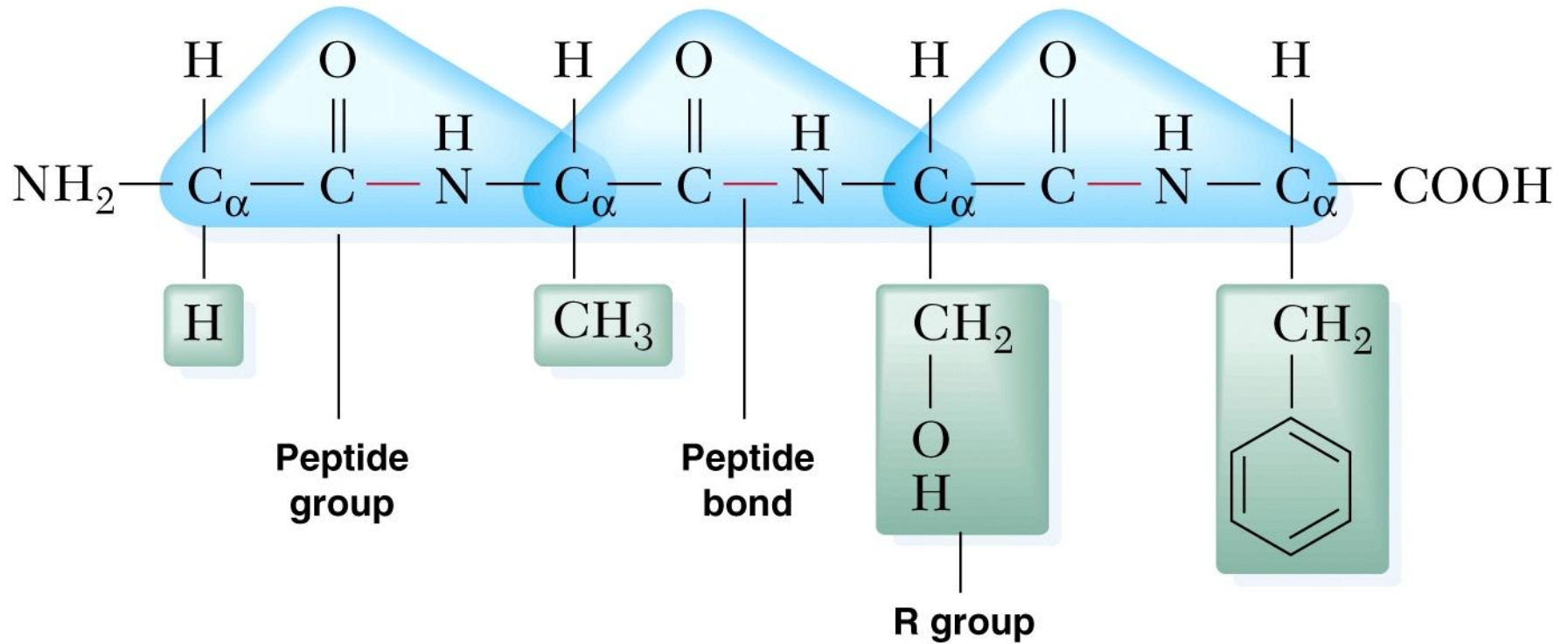
# Proteins

- A lot in cells.  $\frac{1}{2}$  of the dry mass.
- Various structures.
  - Primary, secondary, tertiary, and quaternary

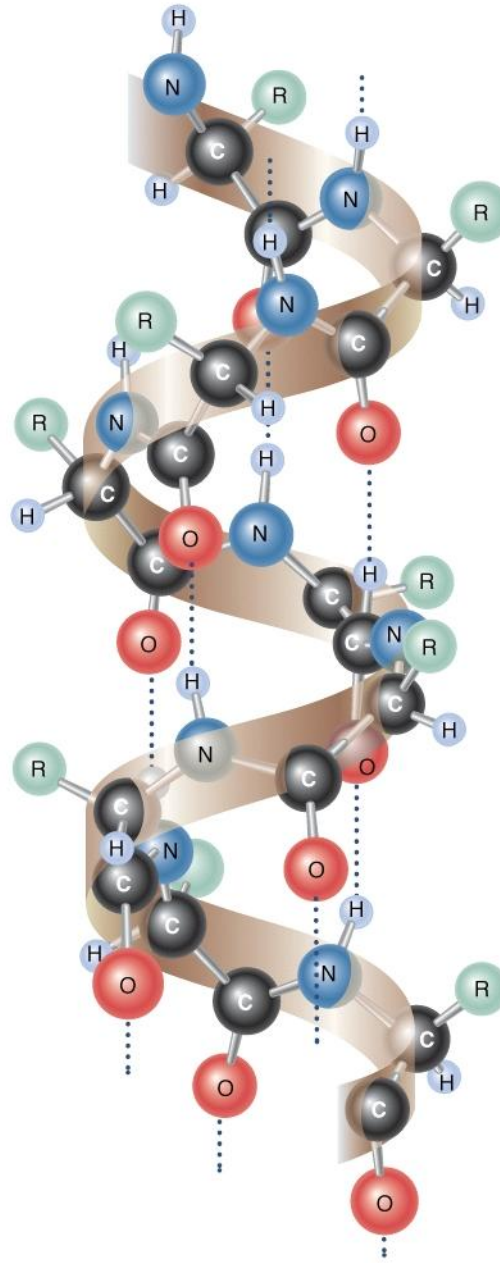
(a) General structure of alpha-amino acids



(b) Structure of a tetrapeptide

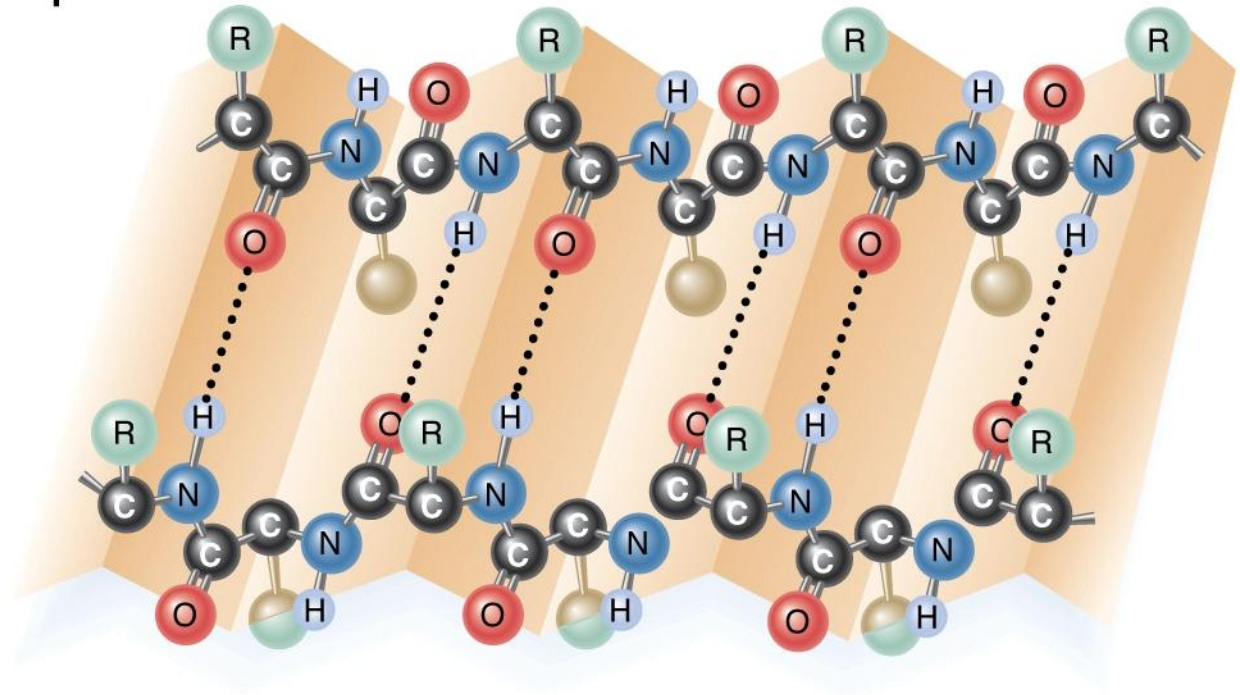


# Secondary Alpha helix

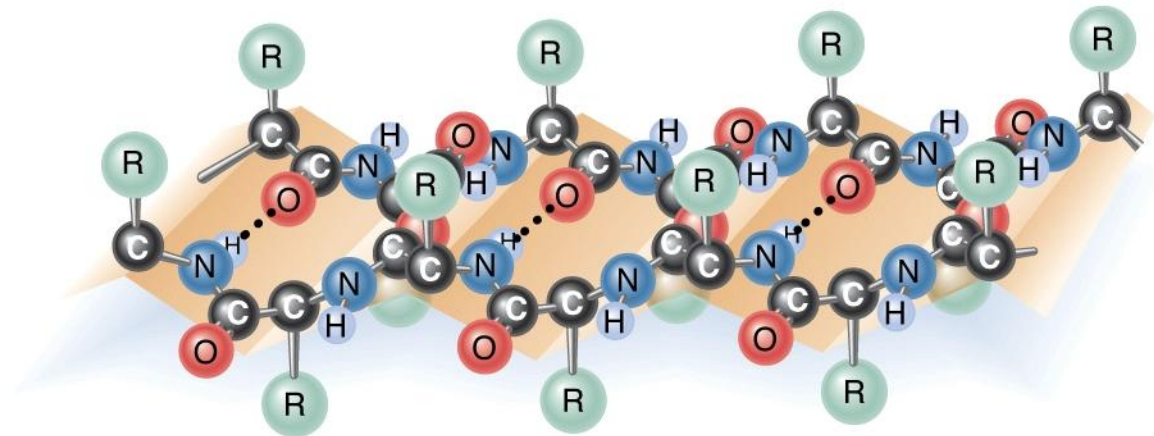


Secondary  
Beta- sheet

Top



Side

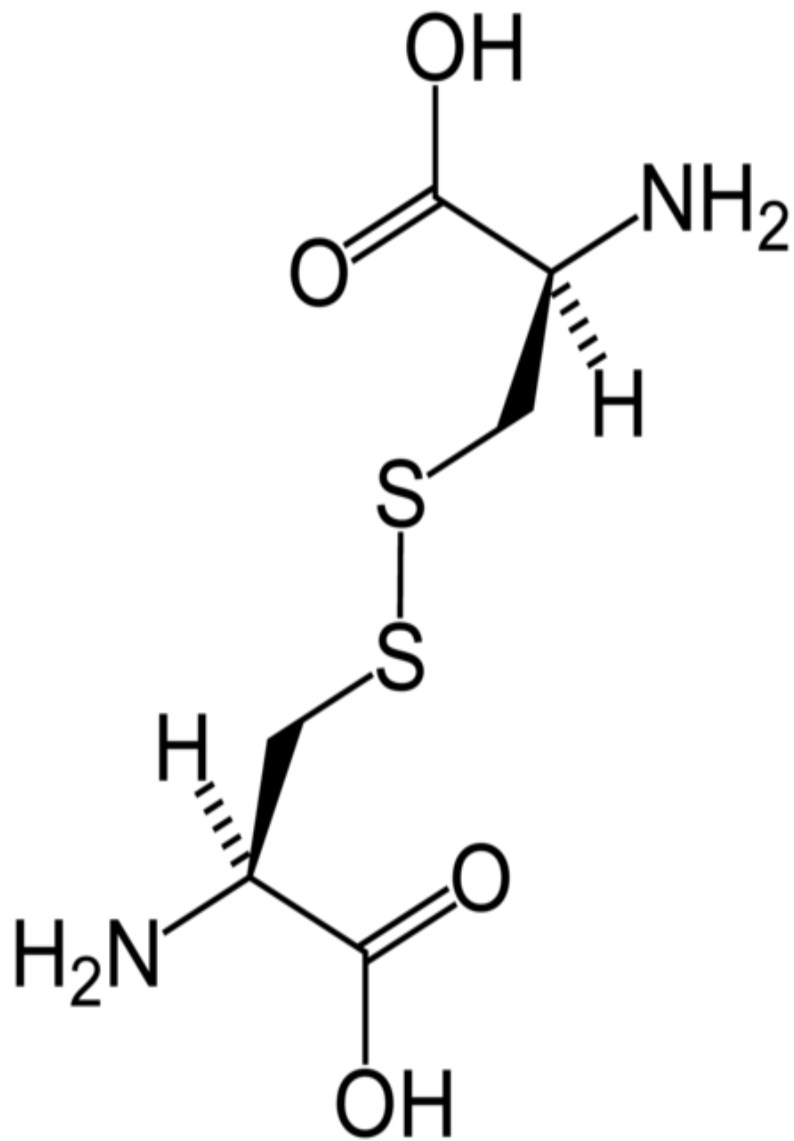




# Secondary types

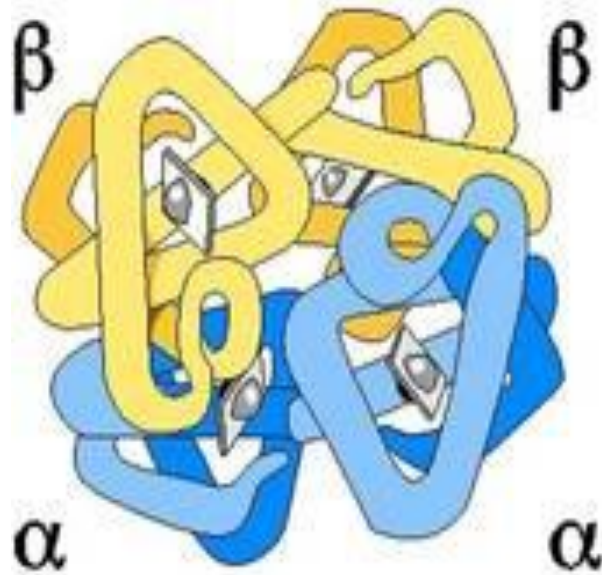
- alpha helix: alpha-Keratins for hair and wool
- Beta sheets: (Harder) beta- Keratins for reptile scales and turtle shells

Tertiary



Quaternary- a couple of subunits coming together like Heme units.

ie., Hemoglobin



# Thought questions:

- Many animals (herbivores) eat plants/grass and survive
- Earthworms eat dirt and thrive...reproduce etc..
- So, if lost in the woods/prairie and no hunting gear....why not just eat the grass, tree bark and even the dirt ? Is it better than starving to death?

Would one live longer eating these materials over not doing so?