Biology 350: Animal Physiology

https://www.youtube.com/watch?v=N0h7ycVCMqI

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

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

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Director Emerita, Center for Academic Success
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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

Counting Vowels in 45 seconds

How accurate are you?

Count all the vowels
in the words on the next slide.

Dollar Bill
Dice
Tricycle
Four-leaf Clover
Hand
Six-Pack
Seven-Up
Octopus
Cat Lives
Bowling Pins
Football Team
Dozen Eggs
Unlucky Friday
Valentine's Day
Quarter Hour

How many *words* or *phrases* do you remember?

Let’s look at the words again…

What are they arranged according to?

Dollar Bill
Dice
Tricycle
Four-leaf Clover
Hand
Six-Pack
Seven-Up
Octopus
Cat Lives
Bowling Pins
Football Team
Dozen Eggs
Unlucky Friday
Valentine's Day
Quarter Hour

NOW, how many words or phrases do you remember?

What were two major *differences* between the two attempts?

1. We knew what the task was

2. We knew how the information was organized

What we know about learning

- Active learning is more lasting than passive learning
  -- Passive learning is an oxymoron*

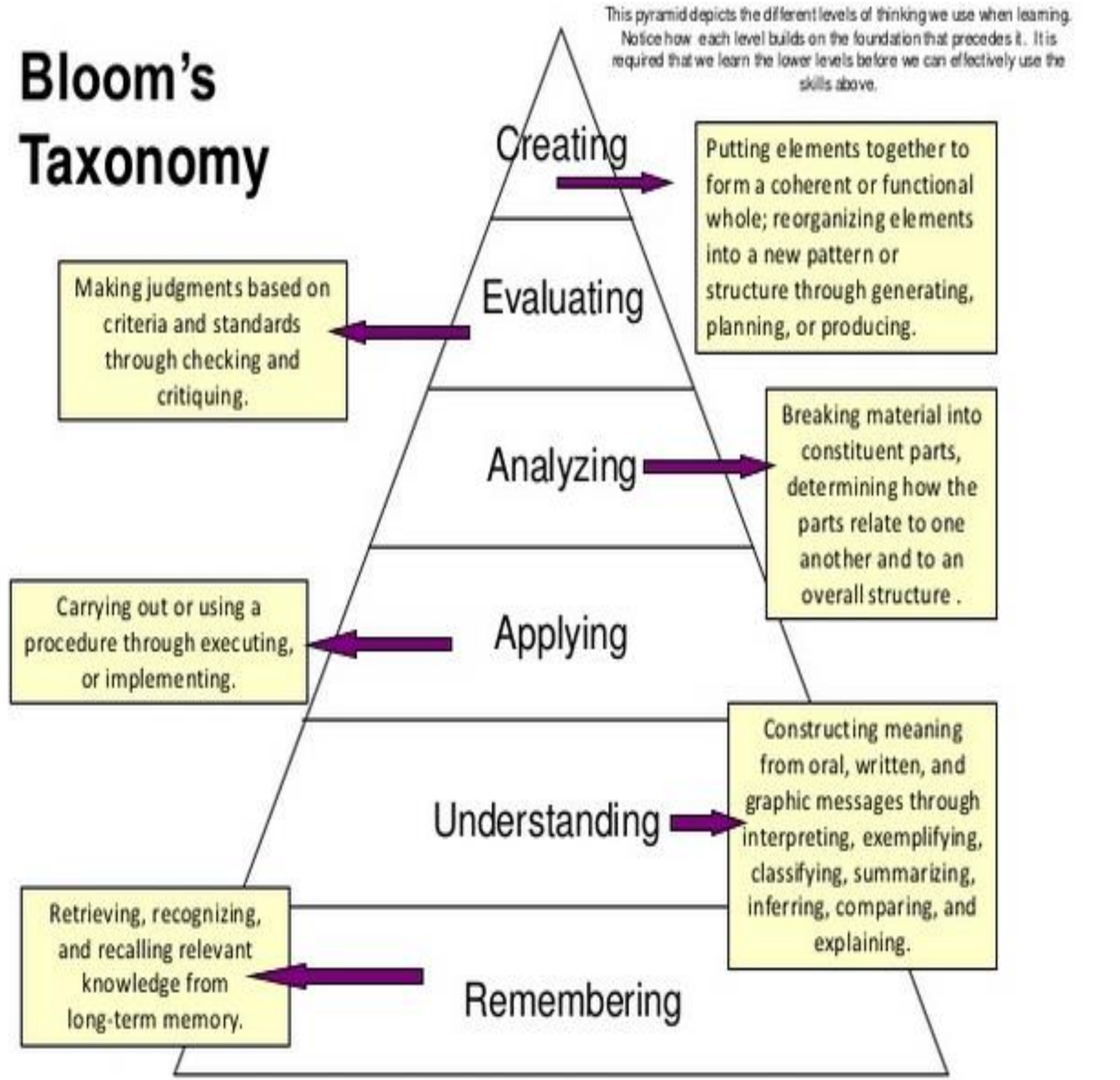
- Thinking about thinking is important
  – Metacognition**

- The level at which learning occurs is important
  – Bloom's Taxonomy***

*Cross, Patricia, "Opening Windows on Learning" League for Innovation in the Community College, June 1998, p. 21.

** Flavell, John, "Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry." *American Psychologist*, Vol 34(10), Oct 1979, 906-911.

*** Bloom Benjamin. S. (1956). *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain.* New York: David McKay Co Inc.

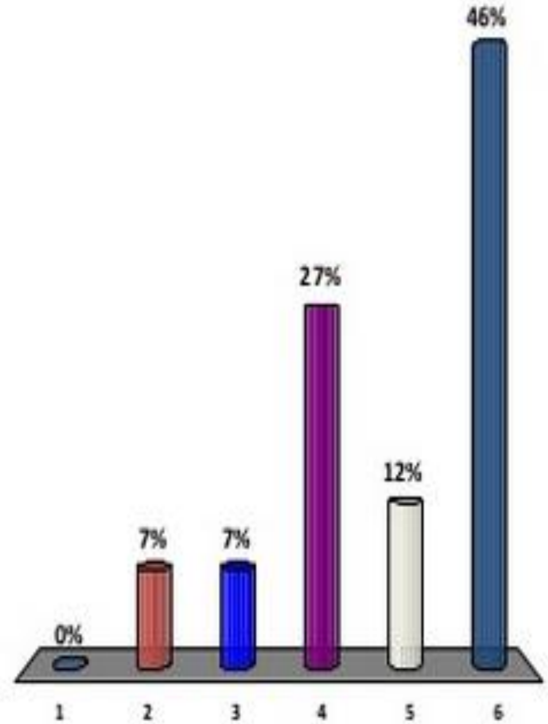


http://www.odu.edu/educ/llschult/blooms_taxonomy.htm

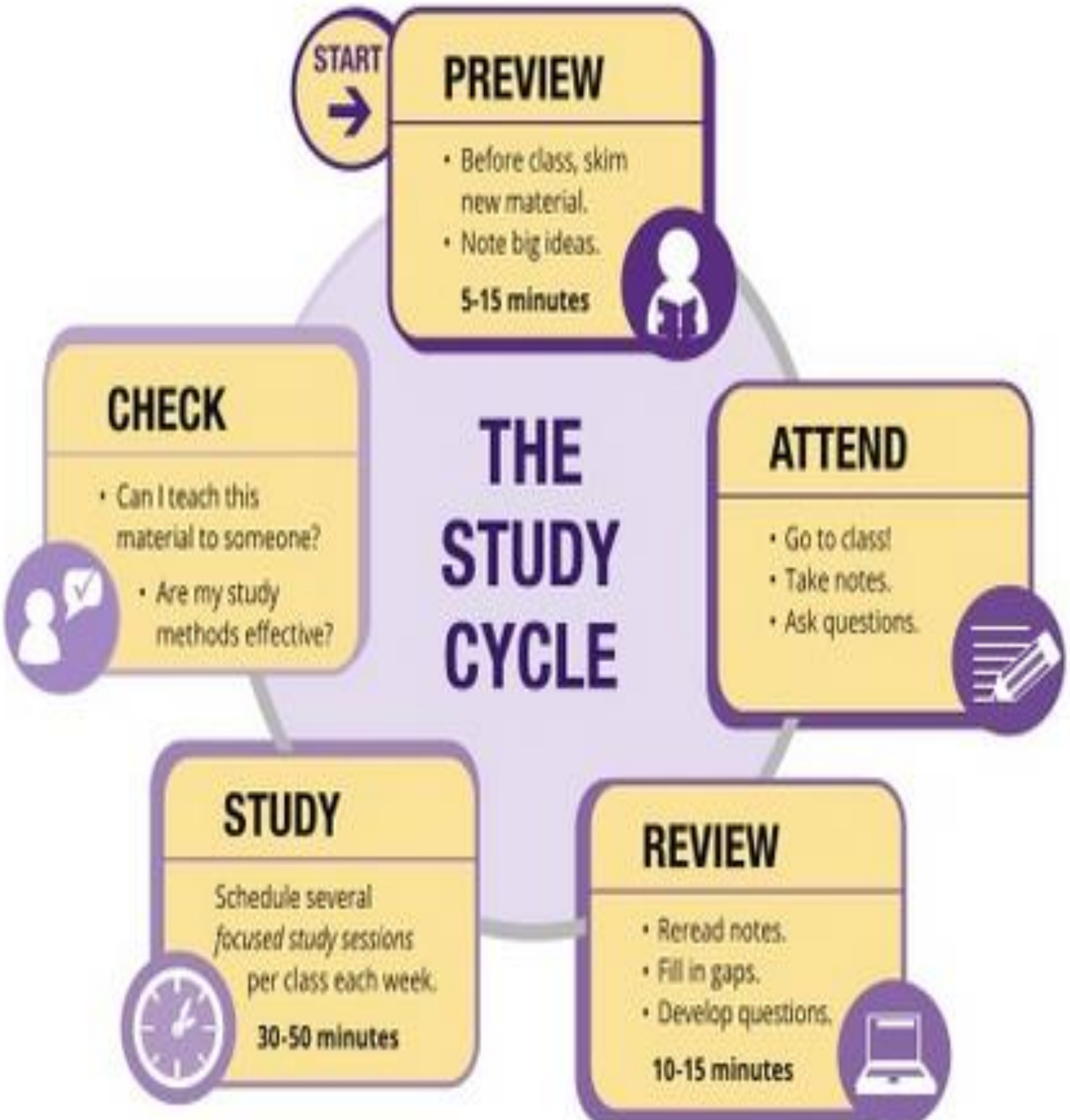
How students answered (in 2014)

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



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.

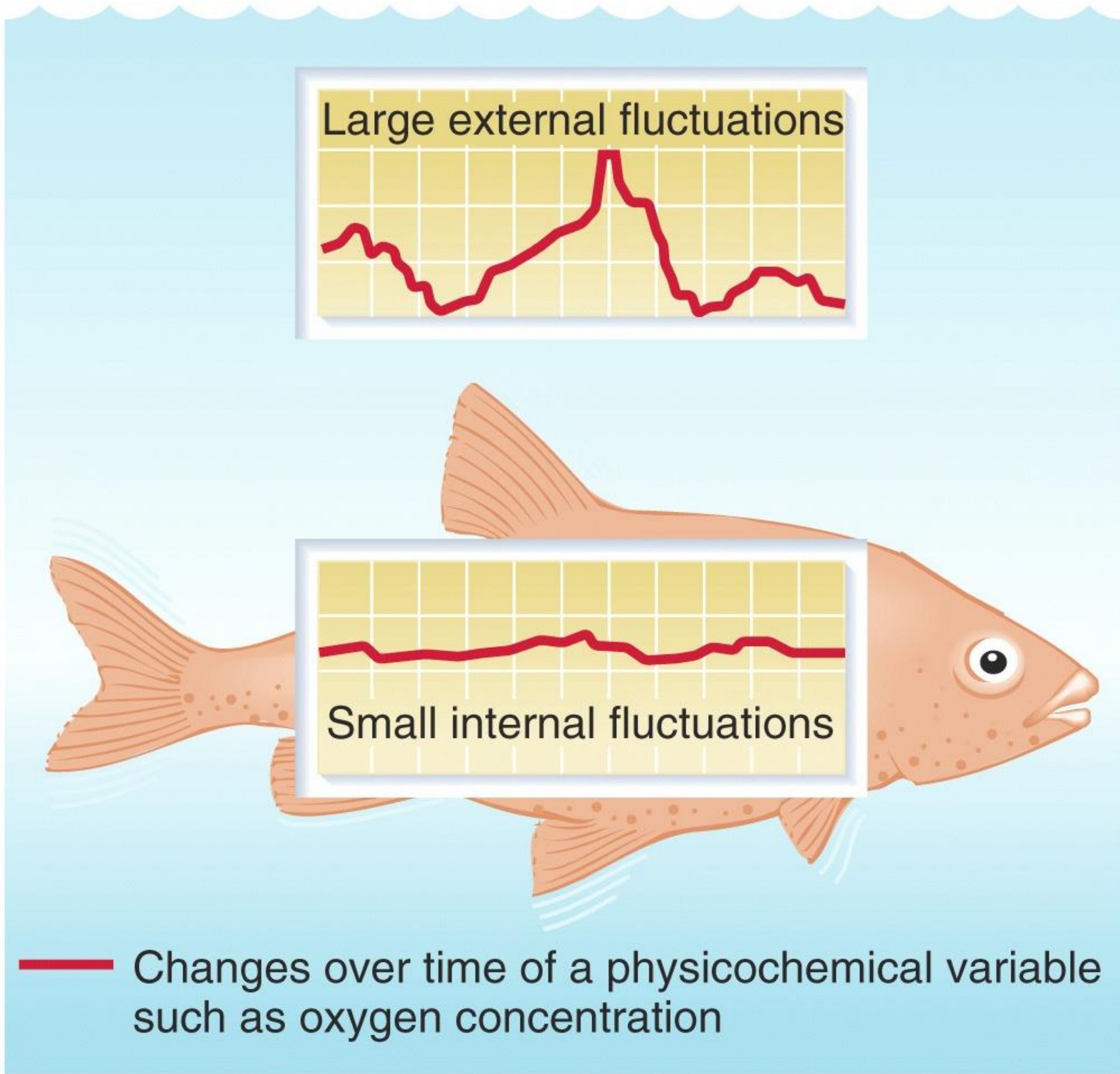
- The physiology of an animal is well suited to the environment in which it has evolved.

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.

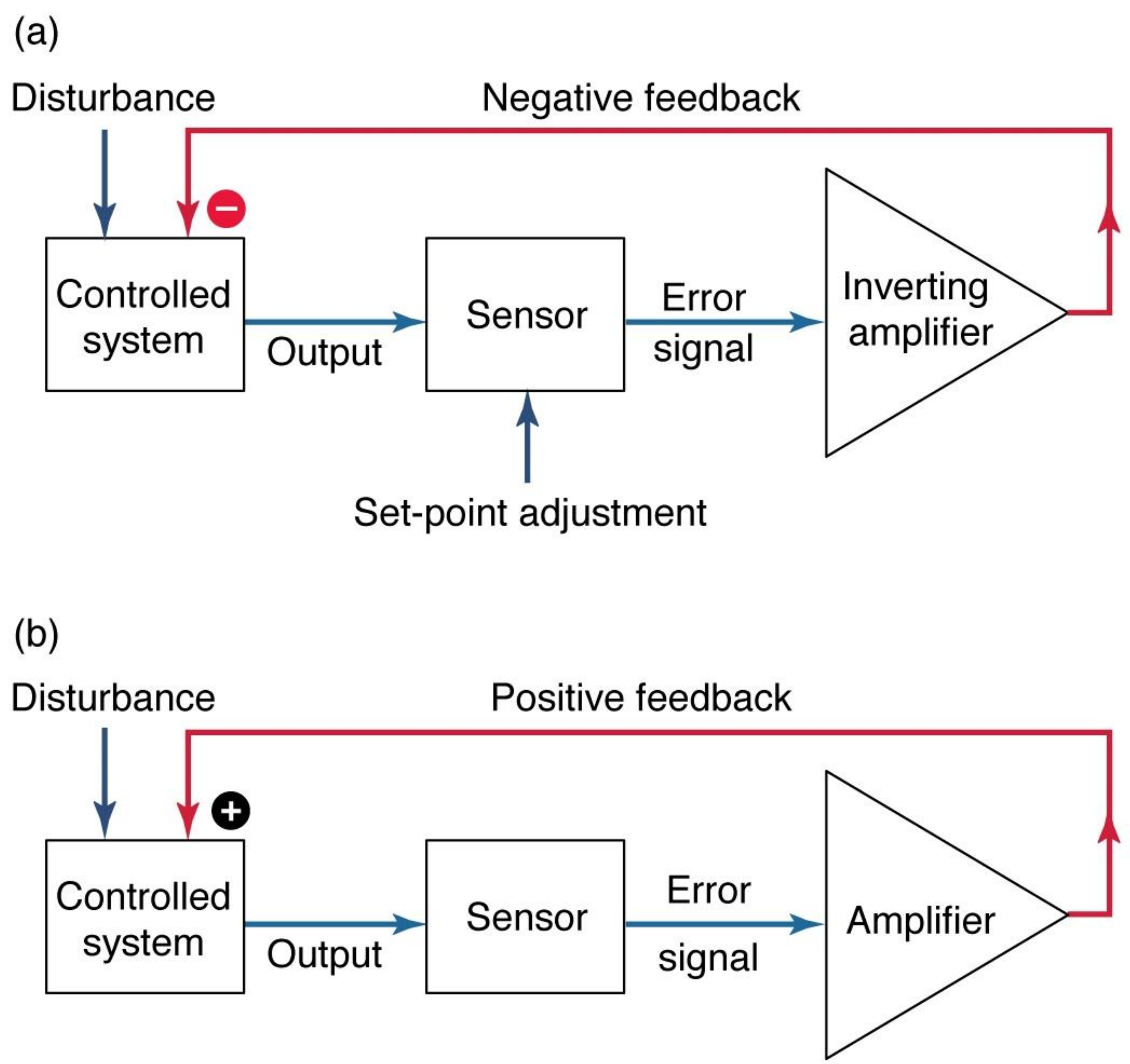
- Cannon coined this term 1929

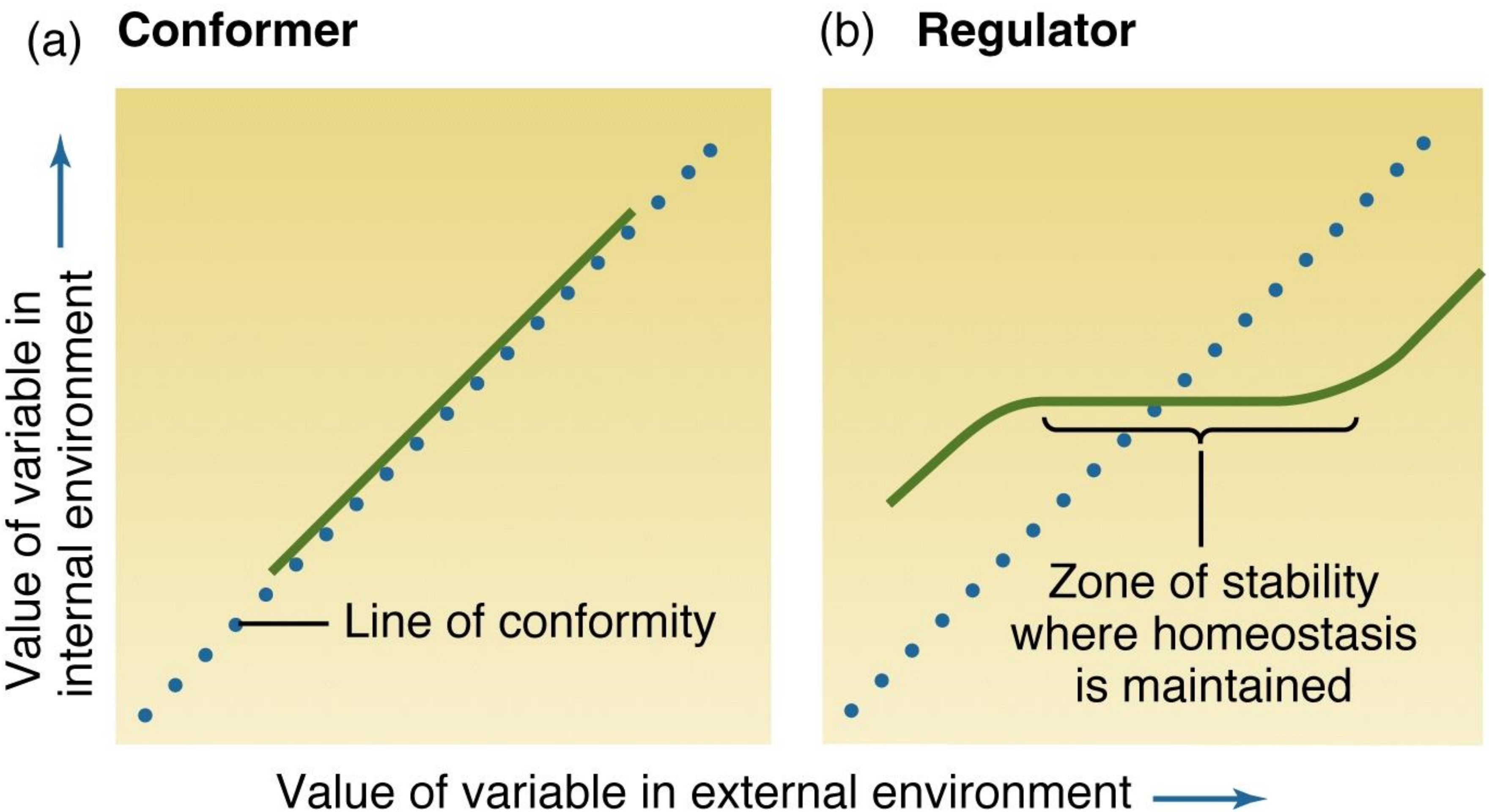

Large external fluctuations
Small internal fluctuations
Changes over time of a physicochemical variable such as oxygen concentration

This mostly works by a feed back control.

Such as by a negative feedback.

Examples - Temp, pH, salinity within the body


(a)
Disturbance
Negative feedback
Controlled system
Output
Sensor
Error signal
Inverting amplifier
Set-point adjustment
(b)
Disturbance
Positive feedback
Controlled system
Output
Sensor
Error signal
Amplifier


(a) Conformer
(b) Regulator
Value of variable in internal environment
Line of conformity
Zone of stability where homeostasis is maintained
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

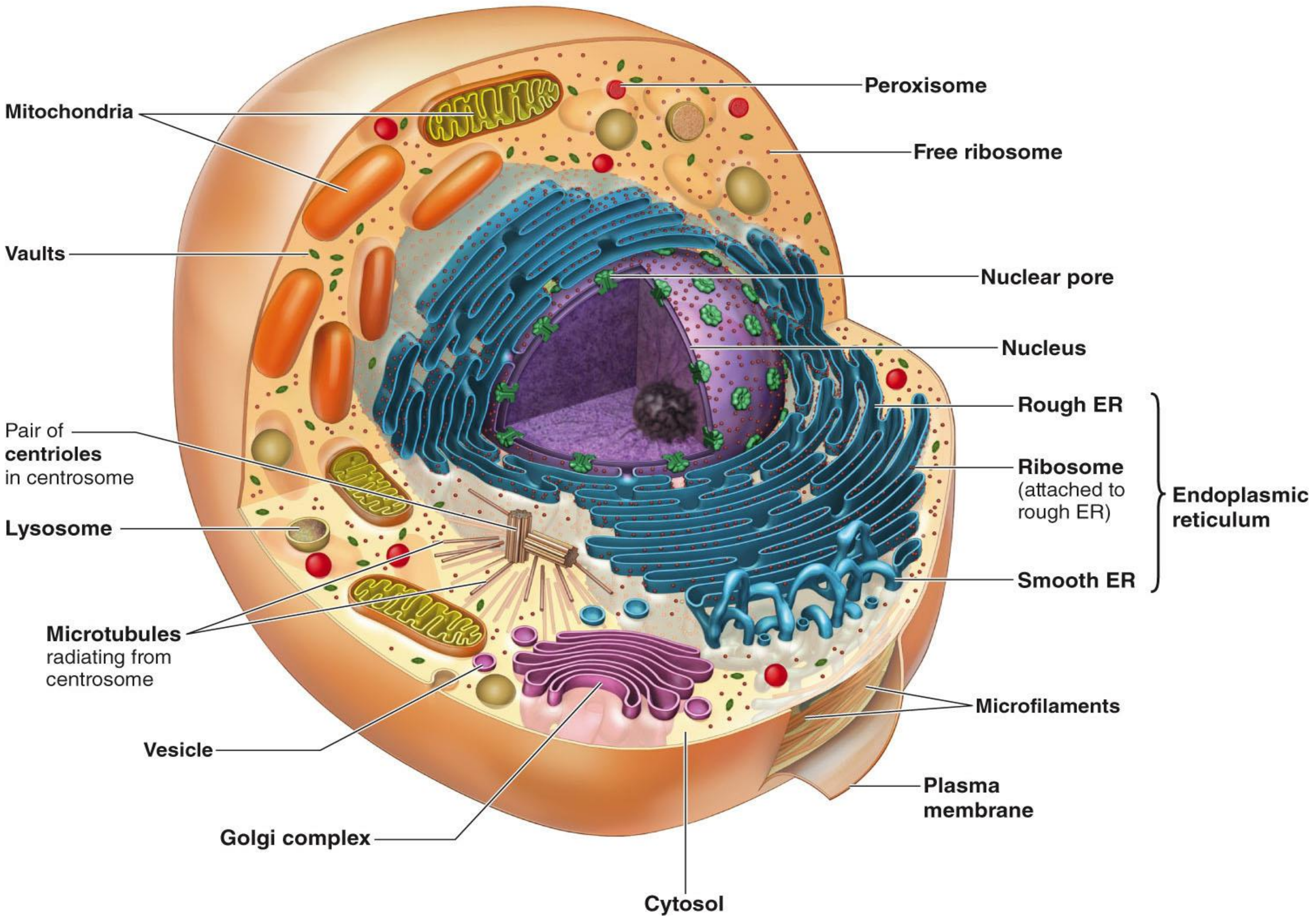
- Categories of organic molecules
  - **Carbohydrates**
    - Monosaccharides (e.g. glucose)
    - Polysaccharides (e.g. glycogen, cellulose, chitin)
  - **Lipids**
    - Fatty acids
    - Triglycerides
    - Phospholipids
    - Cholesterol

- 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**

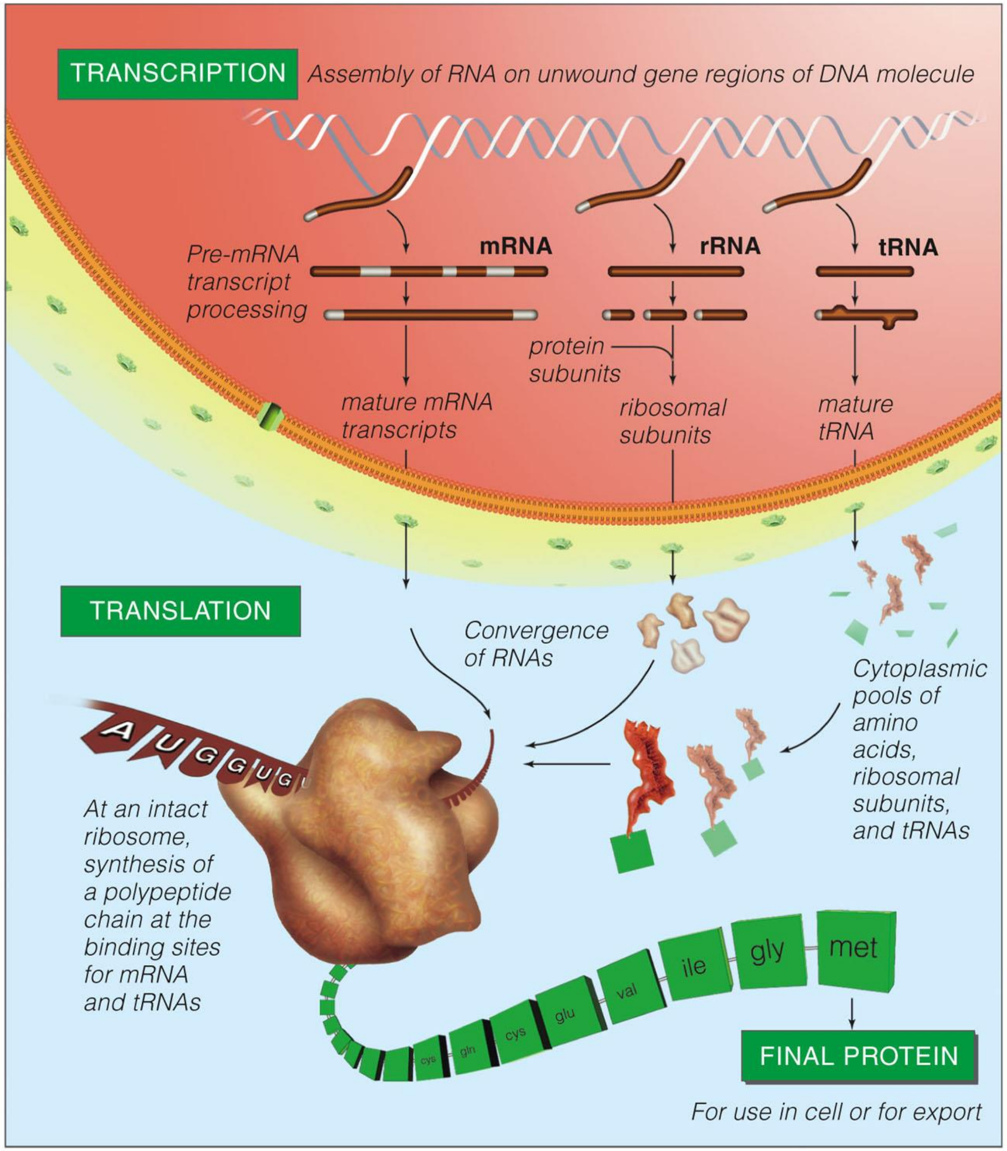
2.1 Introduction



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



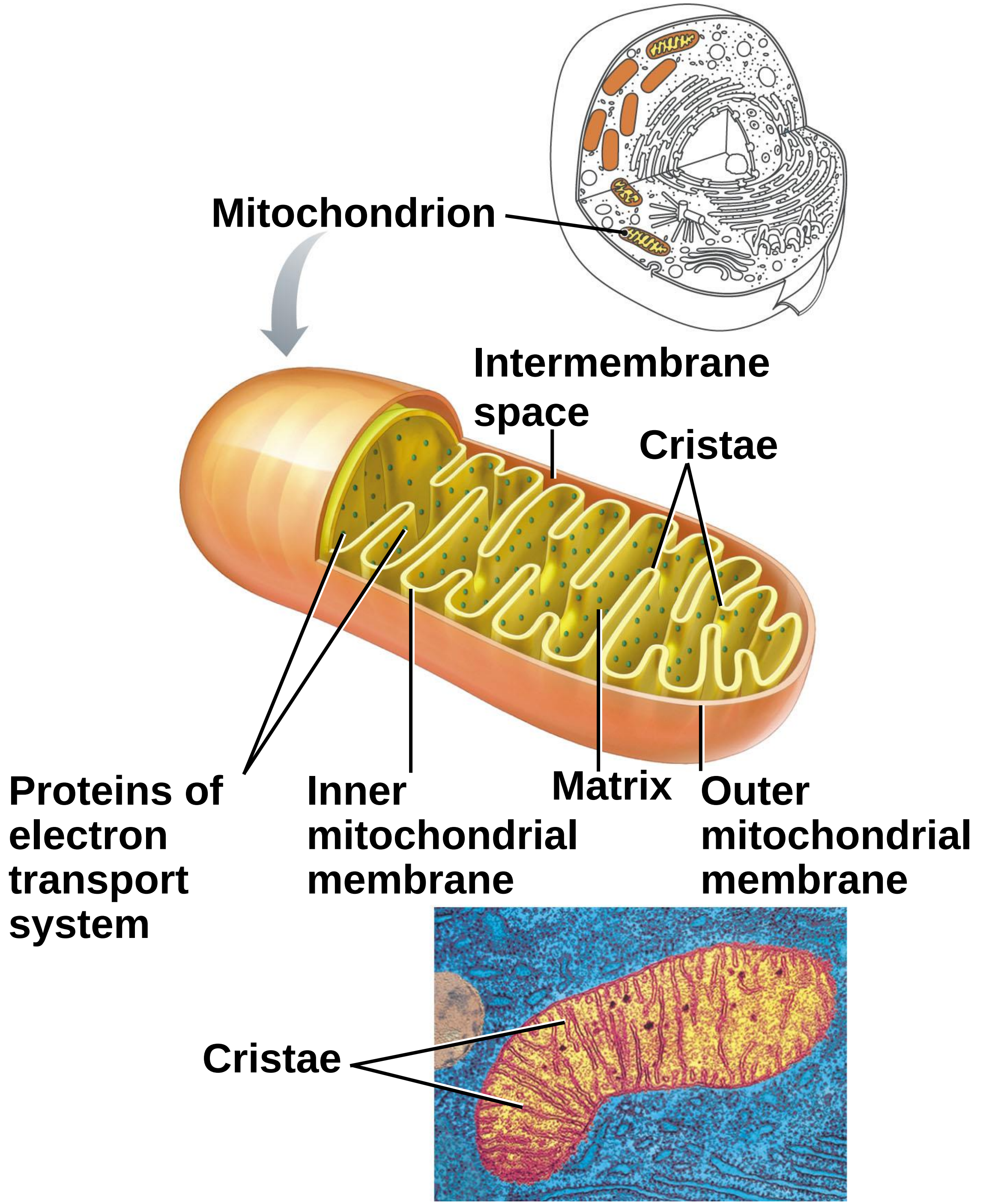


Figure 2-16 p47

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

$$ATP \xrightarrow{\text{splitting}} ADP + P_i + \text{energy}$$

  - **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 O_2, the final electron acceptor

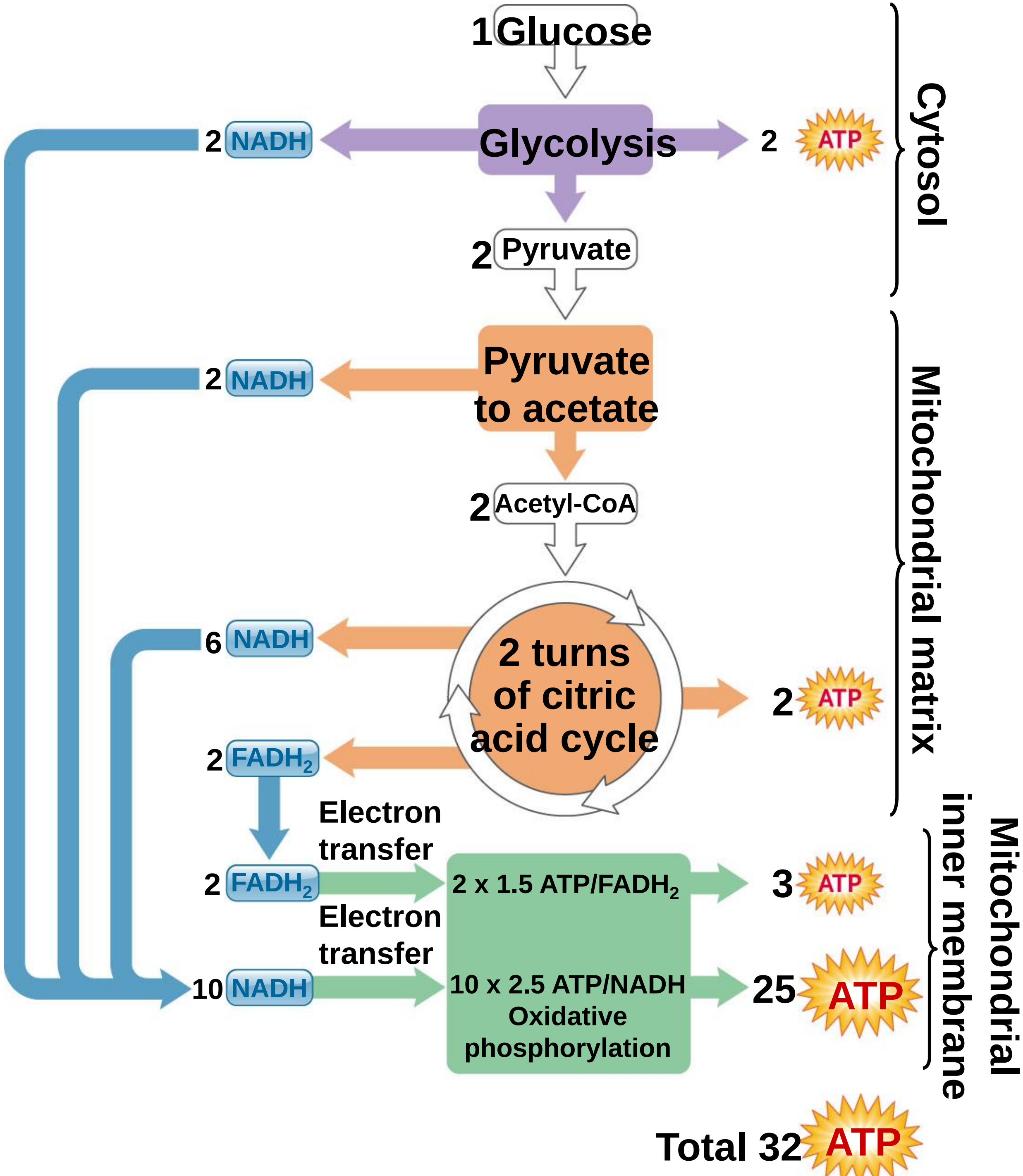
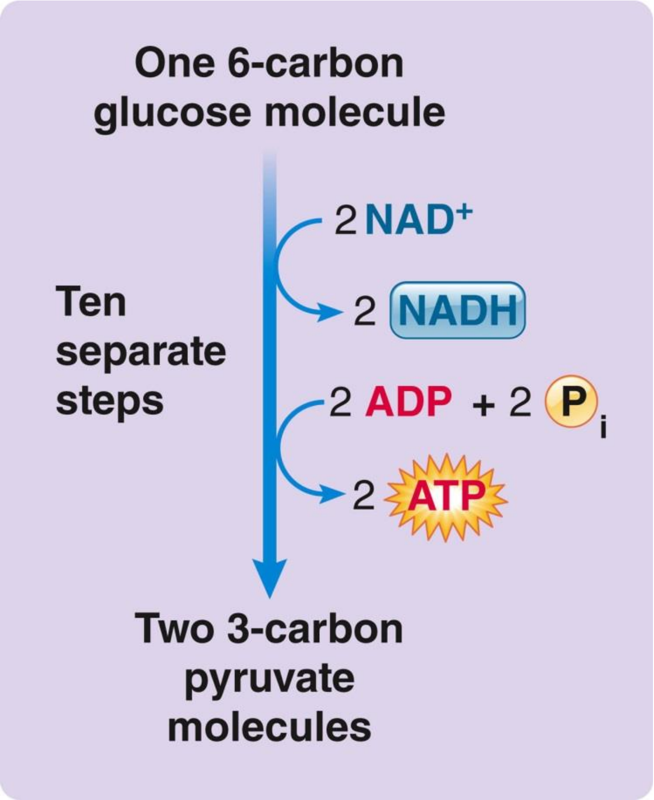


Figure 2-17 p49

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 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**

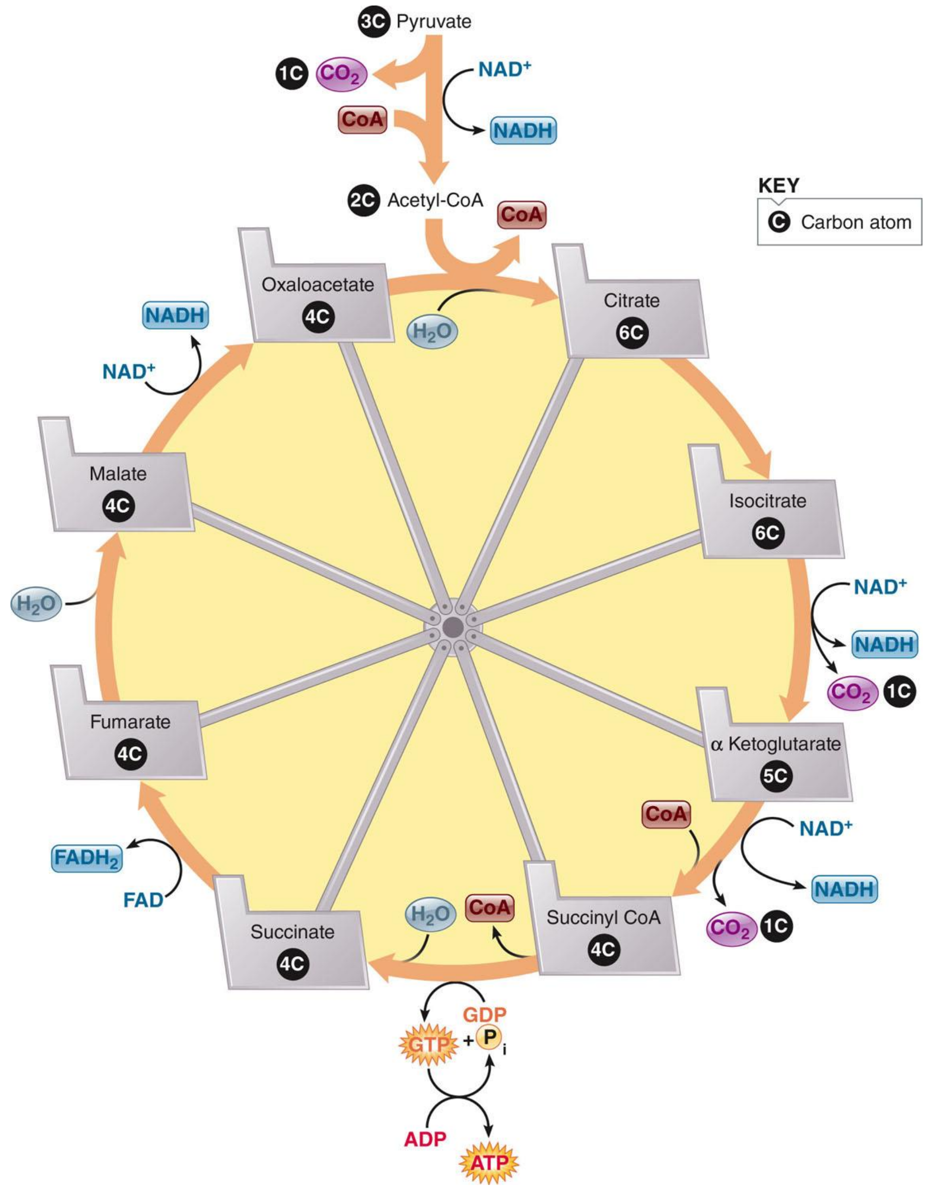
  - **Pyruvate** produced by glycolysis enters the mitochondrial matrix

  - Pyruvate is converted to **acetyl CoA** by removal of a carbon and formation of CO_2

2.8 Mitochondria and Energy Metabolism

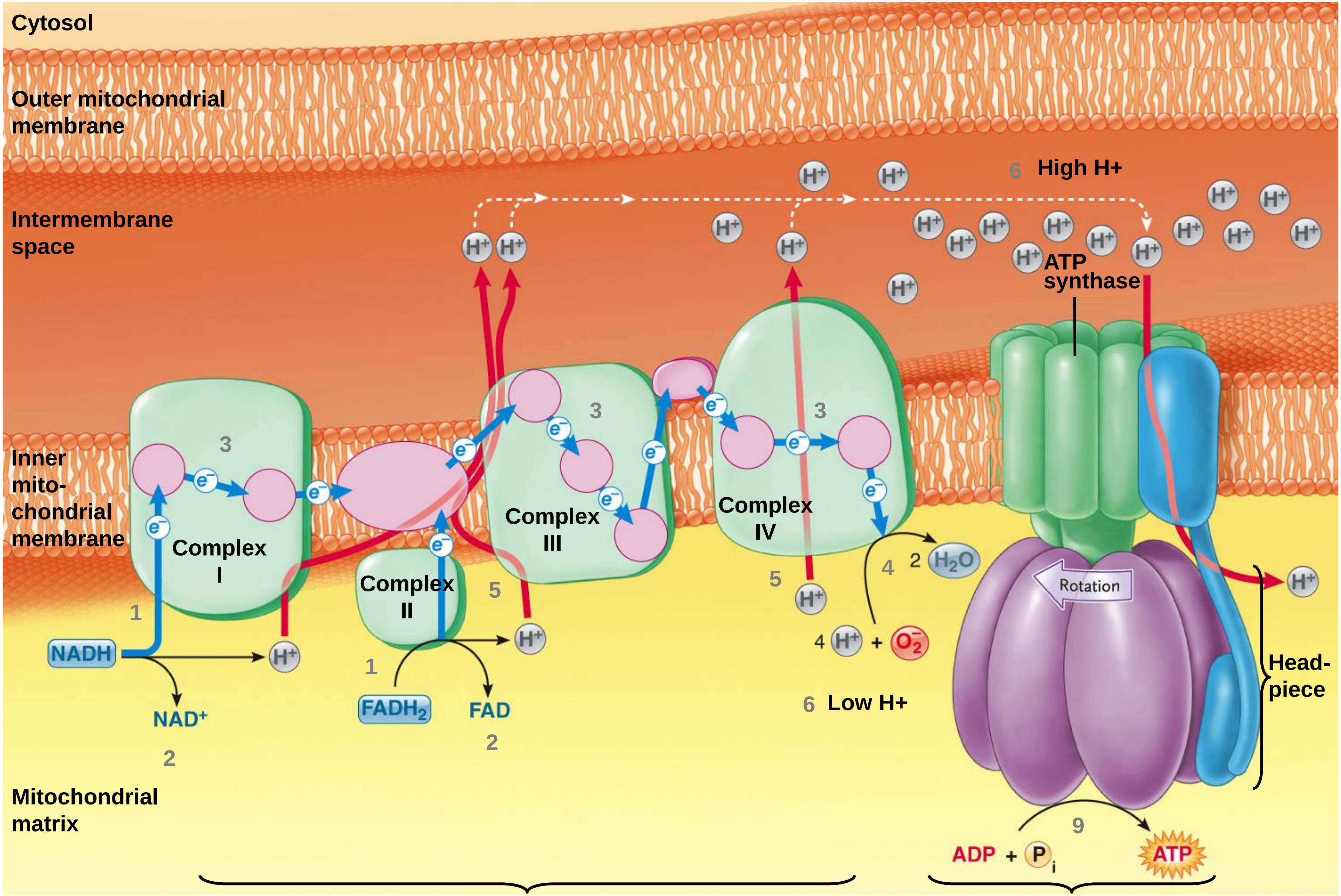
- **Citric acid cycle**
  - Acetyl CoA enters the citric acid cycle by combining with oxaloacetic acid to form **citric acid**
  - Two carbons are released as CO_2
  - One ATP is produced for each turn of the cycle
  - The key purpose of the cycle is to produce **hydrogens** for entry into the **electron 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 H+ gradient across the inner mitochondrial membrane.

Chemiosmosis
ATP synthase catalyzes ATP synthesis using energy from the H+ gradient across the membrane.

Oxidative phosphorylation

Figure 2-20 p52

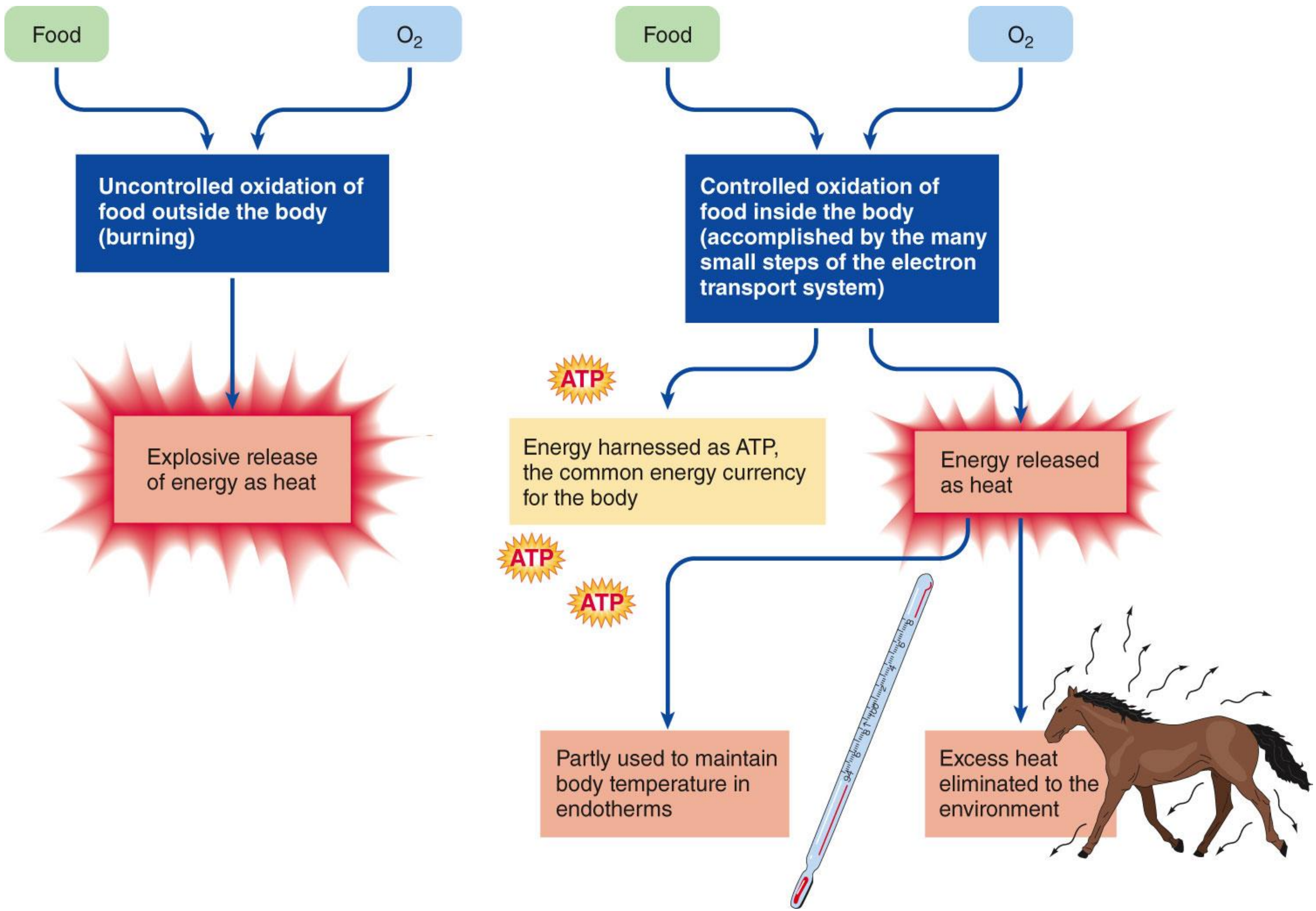
2.8 Mitochondria and Energy Metabolism

- **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

$$\text{Food} + O_2 \longrightarrow CO_2 + H_2O + \text{ATP}$$

Food + O_2	CO_2	H_2O
(necessary for oxidative phosphorylation)	(produced primarily by the citric acid cycle)	(produced primarily by the electron transport chain)

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

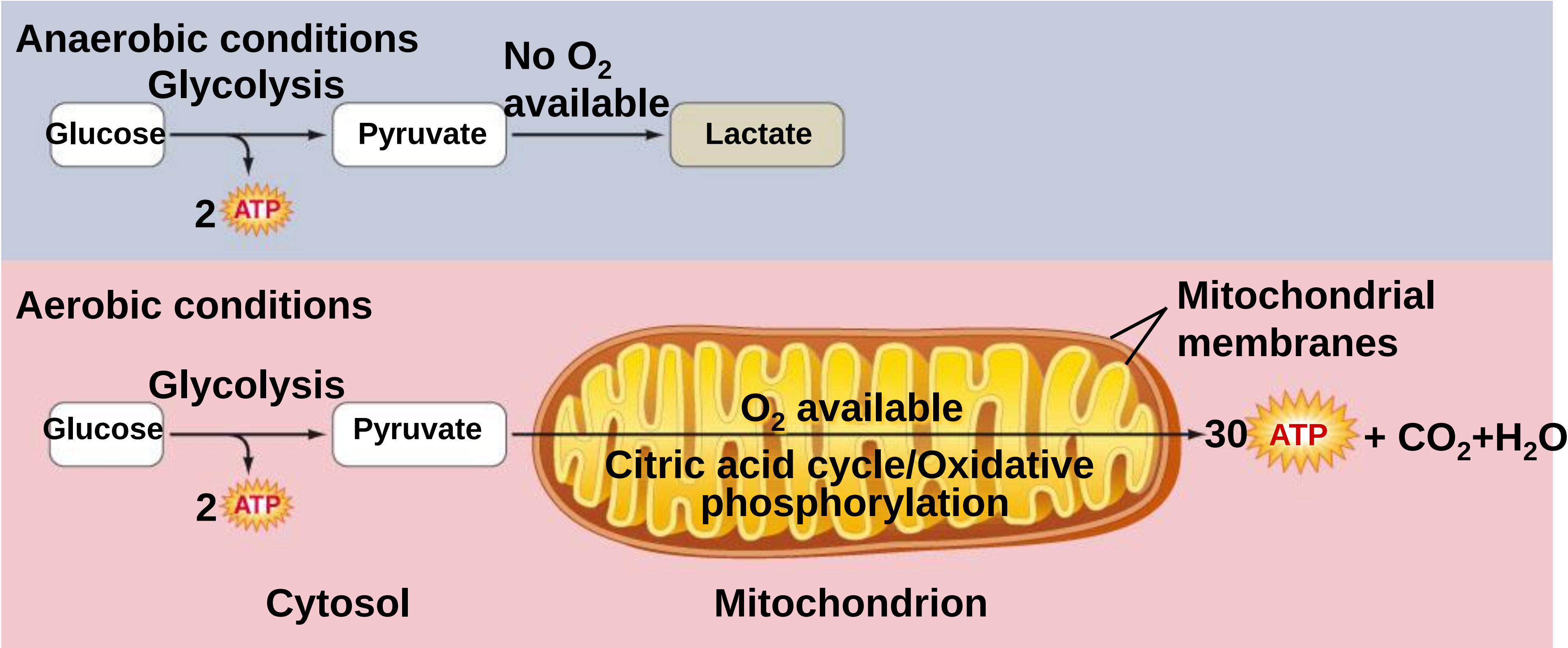
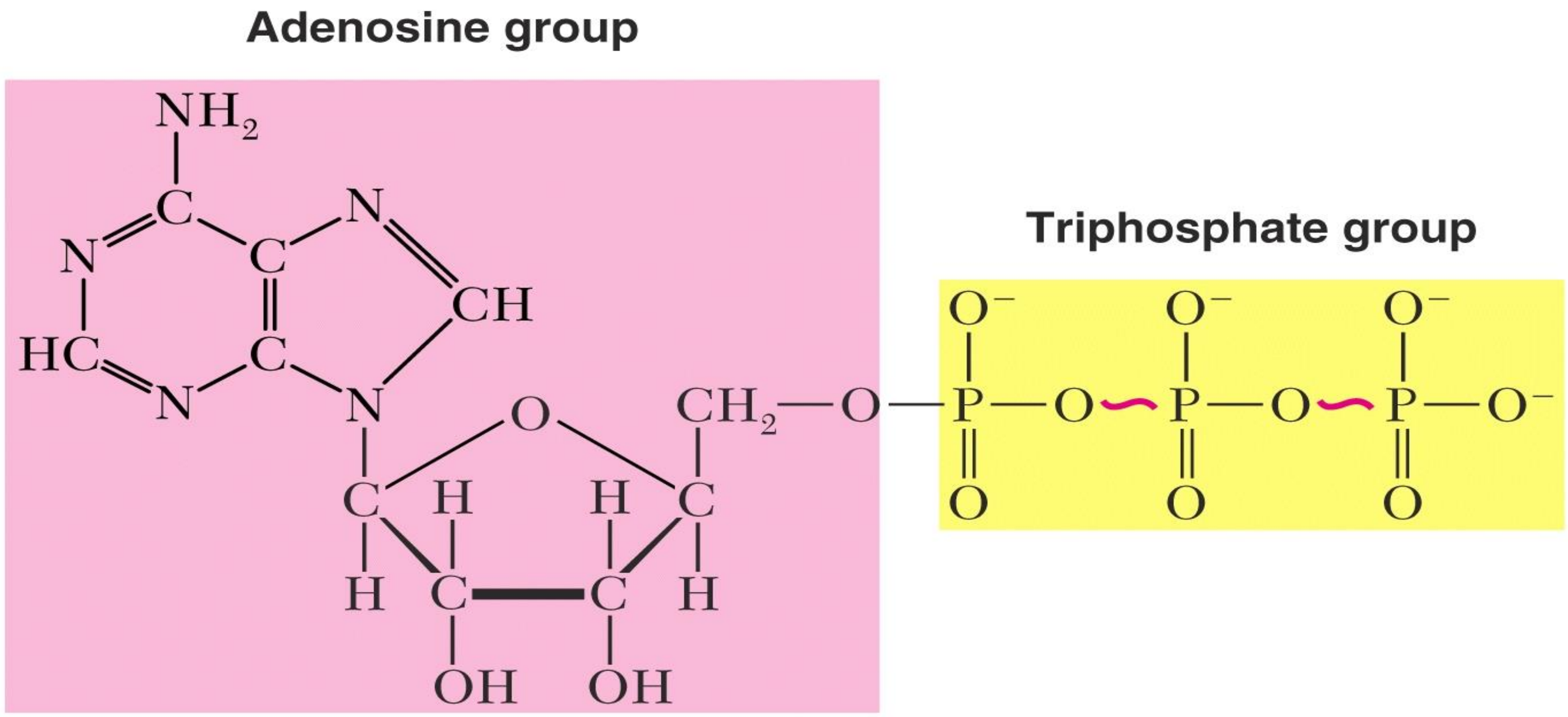
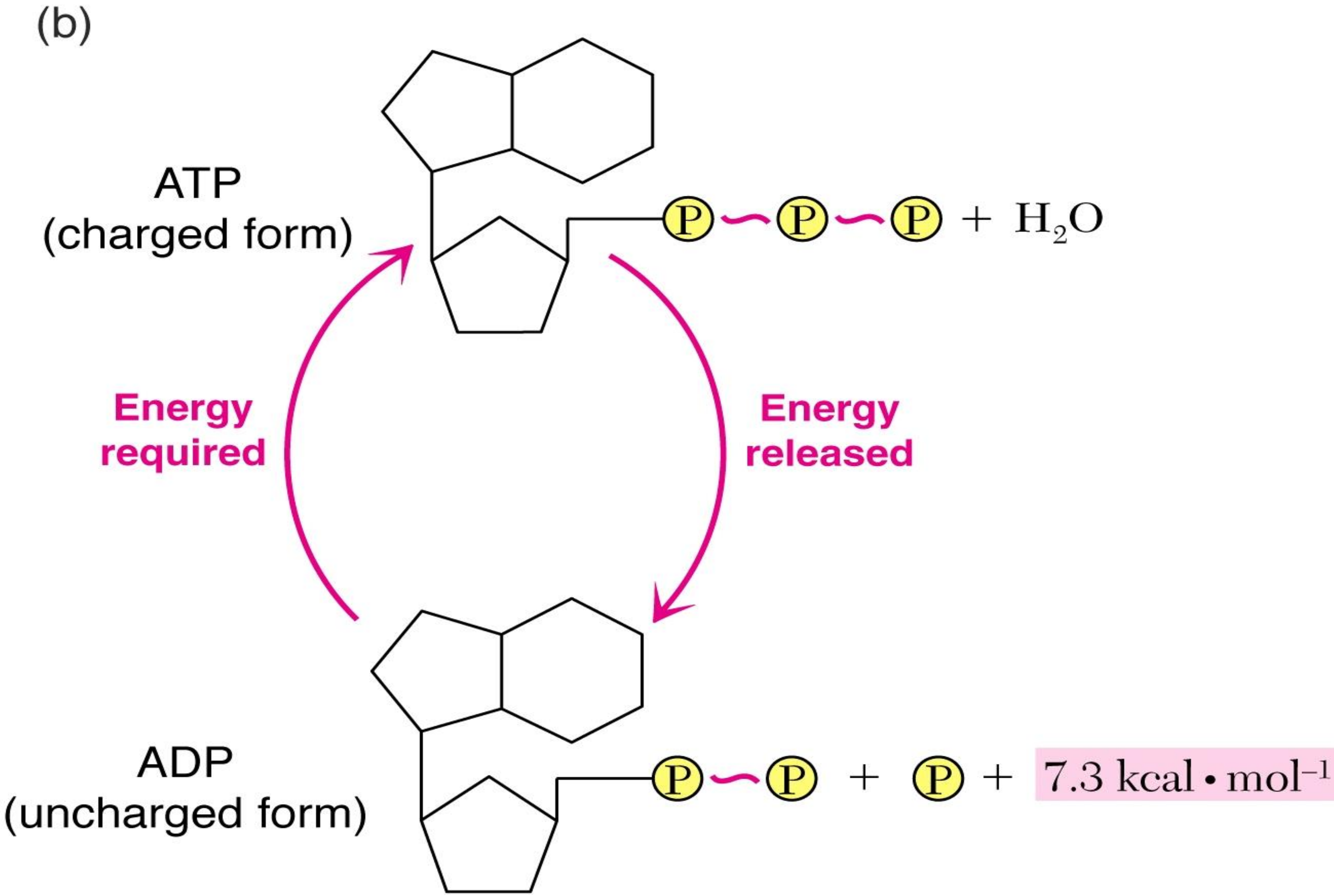
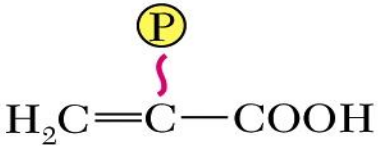


Figure 2-23 p56

(a)

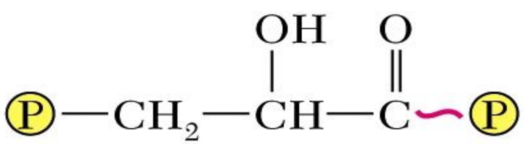

Adenosine group
Triphosphate group
NH2
N
C
N
C
CH
HC
C
N
N
O
CH2
O
P
O
P
O
P
O−
O−
O−
O−
O
O
O
C
H
H
C
H
C
C
H
H
OH
OH


(b)
ATP
(charged form)
P ~ P ~ P + H_2O
Energy
required
Energy
released
ADP
(uncharged form)
P ~ P + P + 7.3 kcal • mol^{-1}



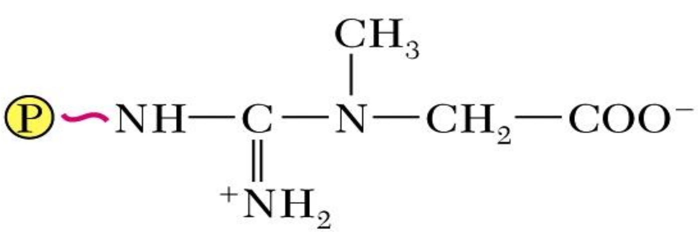
Phosphoenolpyruvate

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



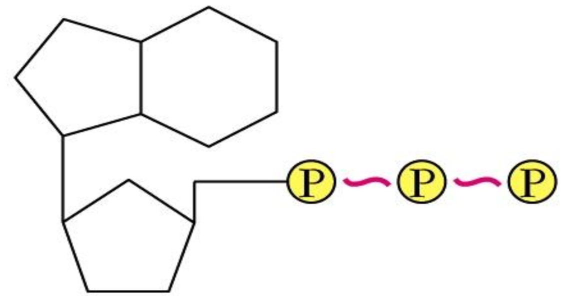
1,3-Diphosphoglycerate

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



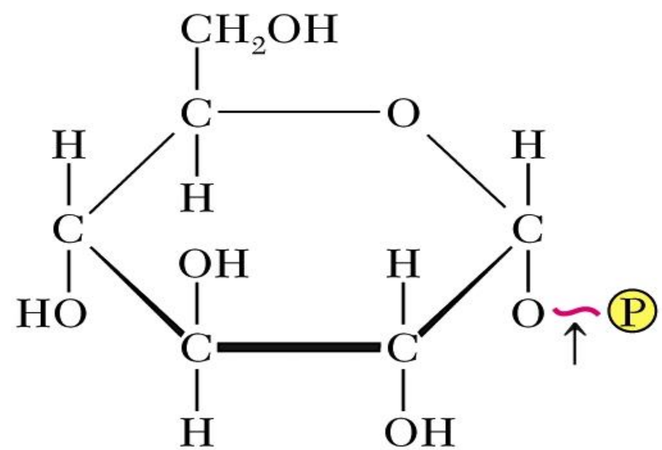
Phosphocreatine

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



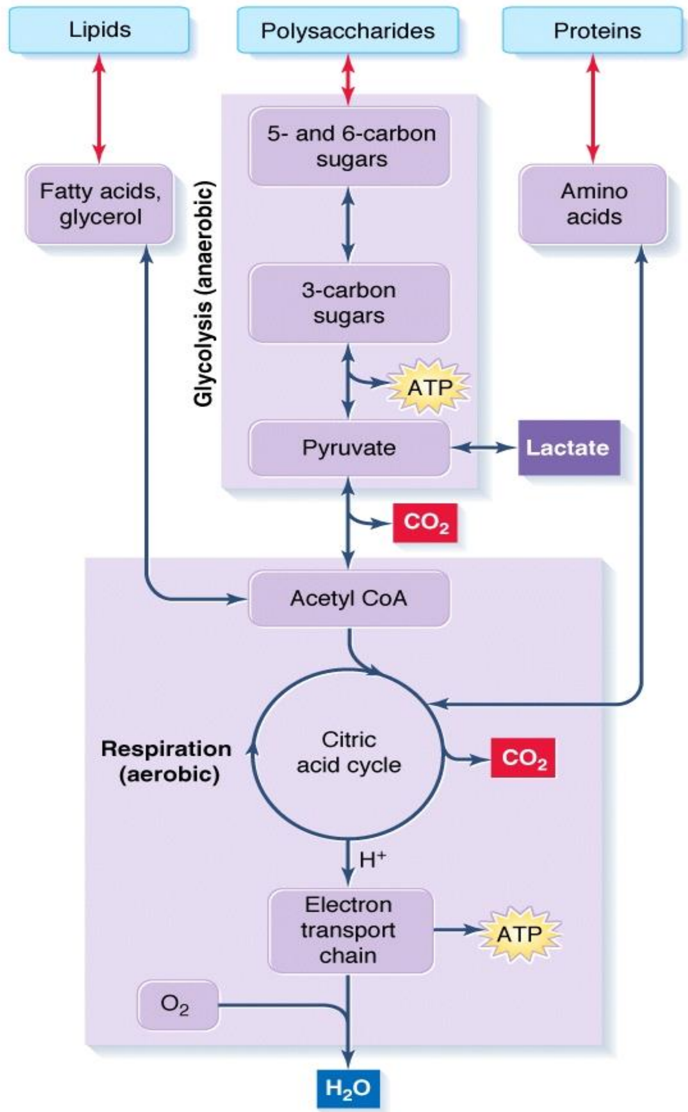
ATP

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



Glucose 1-phosphate

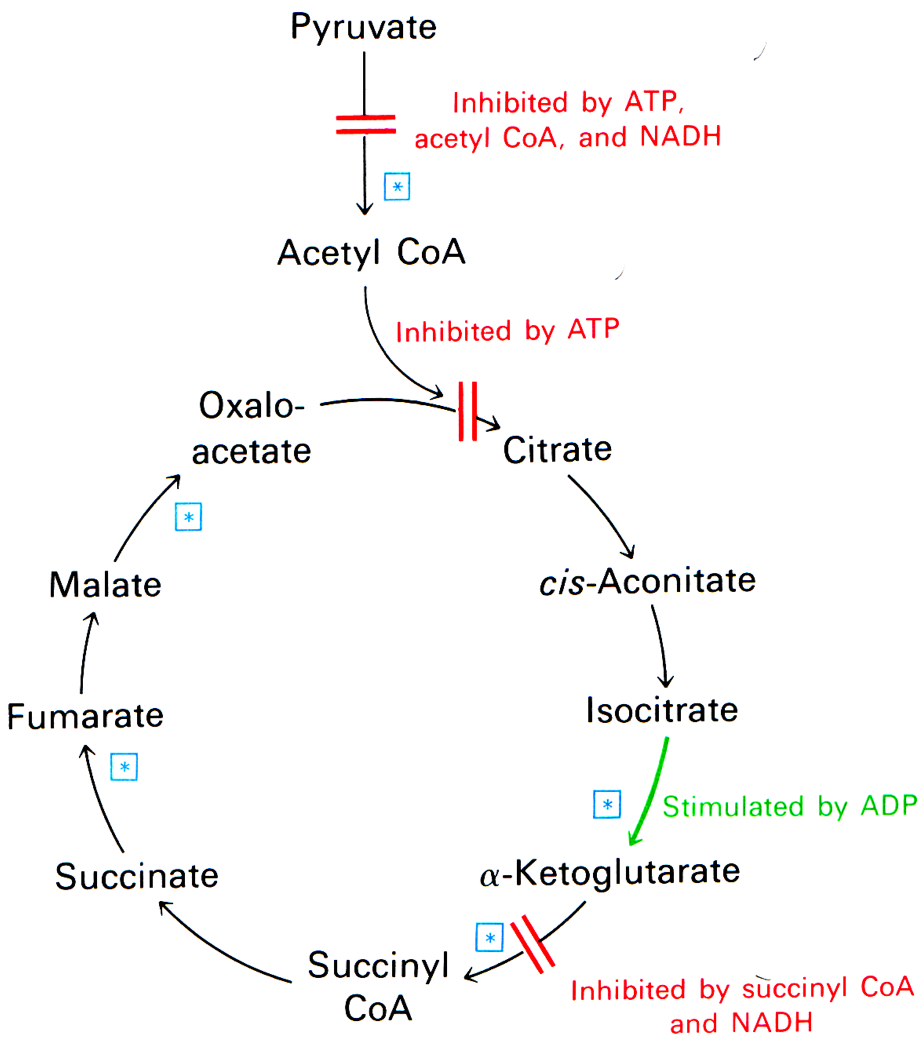
$\Delta G^\circ = -5.0\ \text{kcal}\cdot\text{mol}^{-1}$

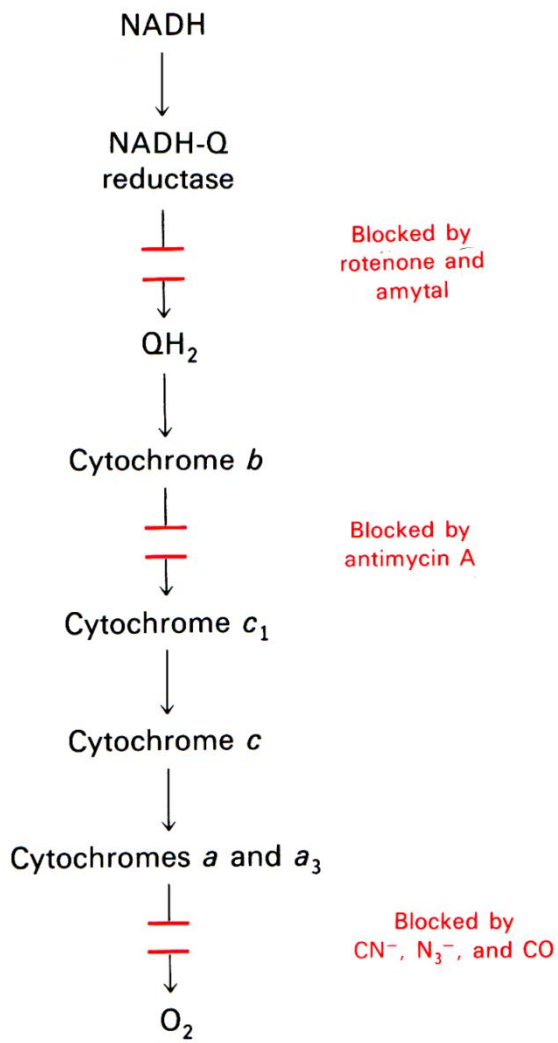


2 ATP

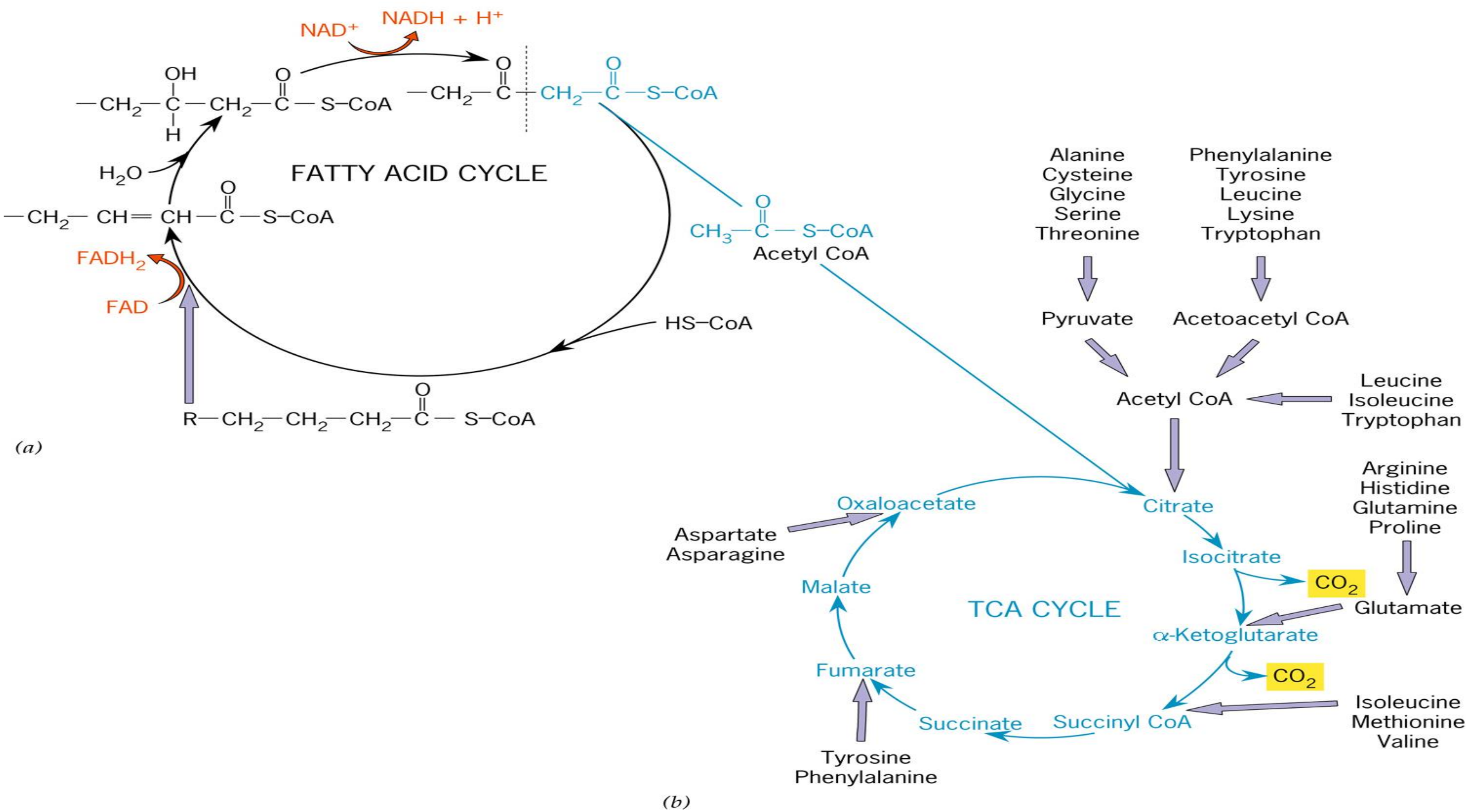
36 ATP (?)

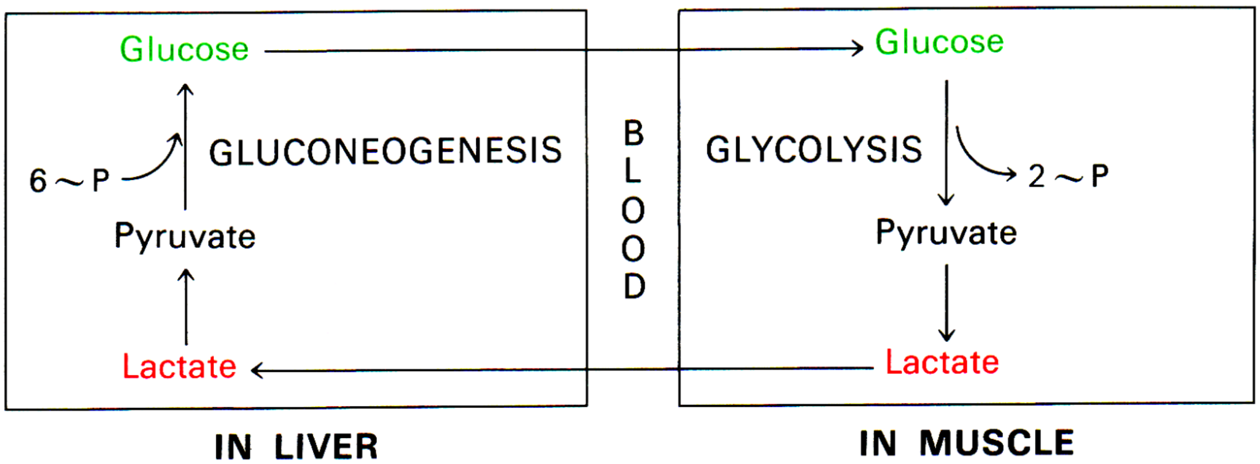
Total 38 ATP (?)


Pyruvate
Inhibited by ATP,
acetyl CoA, and NADH
Acetyl CoA
Inhibited by ATP
Oxalo-
acetate
Citrate
cis-Aconitate
Isocitrate
Stimulated by ADP
α-Ketoglutarate
Inhibited by succinyl CoA
and NADH
Succinyl
CoA
Succinate
Fumarate
Malate



Endosymbiotic theory
Lynn Margulis


NAD+
NADH + H+
FATTY ACID CYCLE
H2O
FADH2
FAD
HS–CoA
Acetyl CoA
R—CH2—CH2—CH2—C—S–CoA
(a)
Alanine
Cysteine
Glycine
Serine
Threonine
Phenylalanine
Tyrosine
Leucine
Lysine
Tryptophan
Pyruvate
Acetoacetyl CoA
Acetyl CoA
Leucine
Isoleucine
Tryptophan
Citrate
Arginine
Histidine
Glutamine
Proline
Isocitrate
CO2
Glutamate
α-Ketoglutarate
CO2
Succinyl CoA
Isoleucine
Methionine
Valine
Succinate
Fumarate
Tyrosine
Phenylalanine
Malate
Oxaloacetate
Aspartate
Asparagine
TCA CYCLE
(b)



Glucose
Glucose
GLUCONEOGENESIS
6 ~ P
Pyruvate
Lactate
BLOOD
GLYCOLYSIS
2 ~ P
Pyruvate
Lactate
IN LIVER
IN MUSCLE

Glycogen-storage of glucose

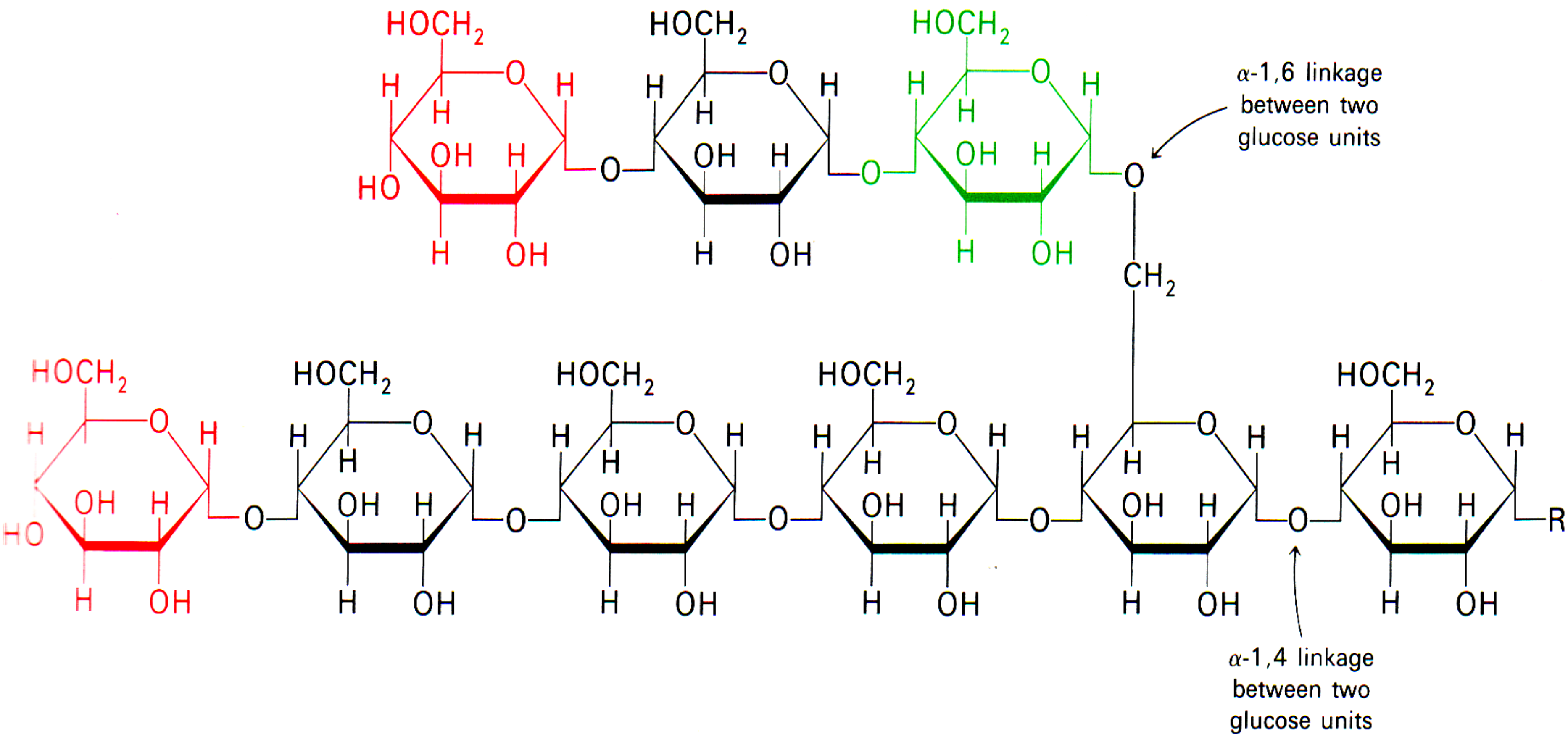


Table 16-1
Glycogen storage diseases

Type	*Defective enzyme*	*Organ affected*	*Glycogen in the affected organ*	*Clinical features*
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, ketosis, hyperuricemia, hyperlipemia.
II POMPE'S DISEASE	α-1,4-Glucosidase (lysosomal)	All organs	Massive increase in amount; normal structure.	Cardiorespiratory failure causes death, usually before 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 (α-1,4 $\longrightarrow$ α-1,6)	Liver and spleen	Normal amount; very long outer branches.	Progressive cirrhosis of the liver. Liver failure causes death usually before 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 normal 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.

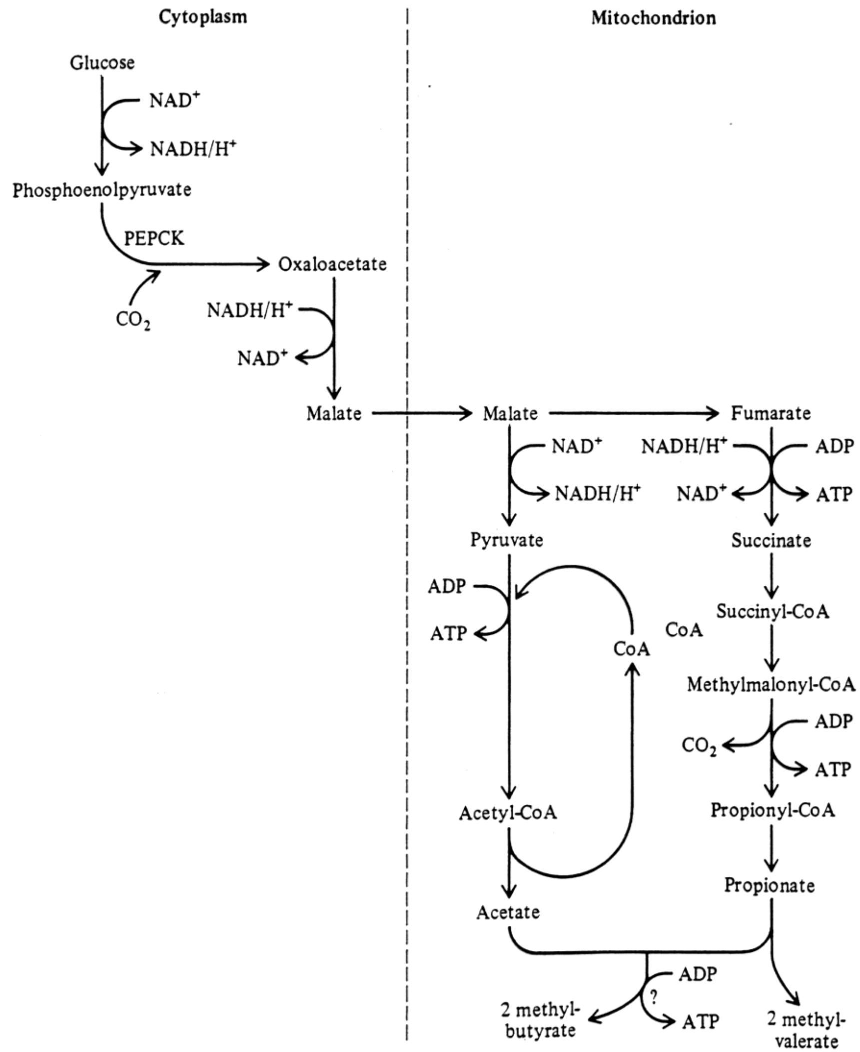


FIGURE 3–18 Linkage of glycolysis with citric acid cycle pathways is an anaerobic metabolic pathway that provides additional ATP formation. These pathways are found, for example, in many platyhelminth worms.

2.8 Mitochondria and Energy Metabolism

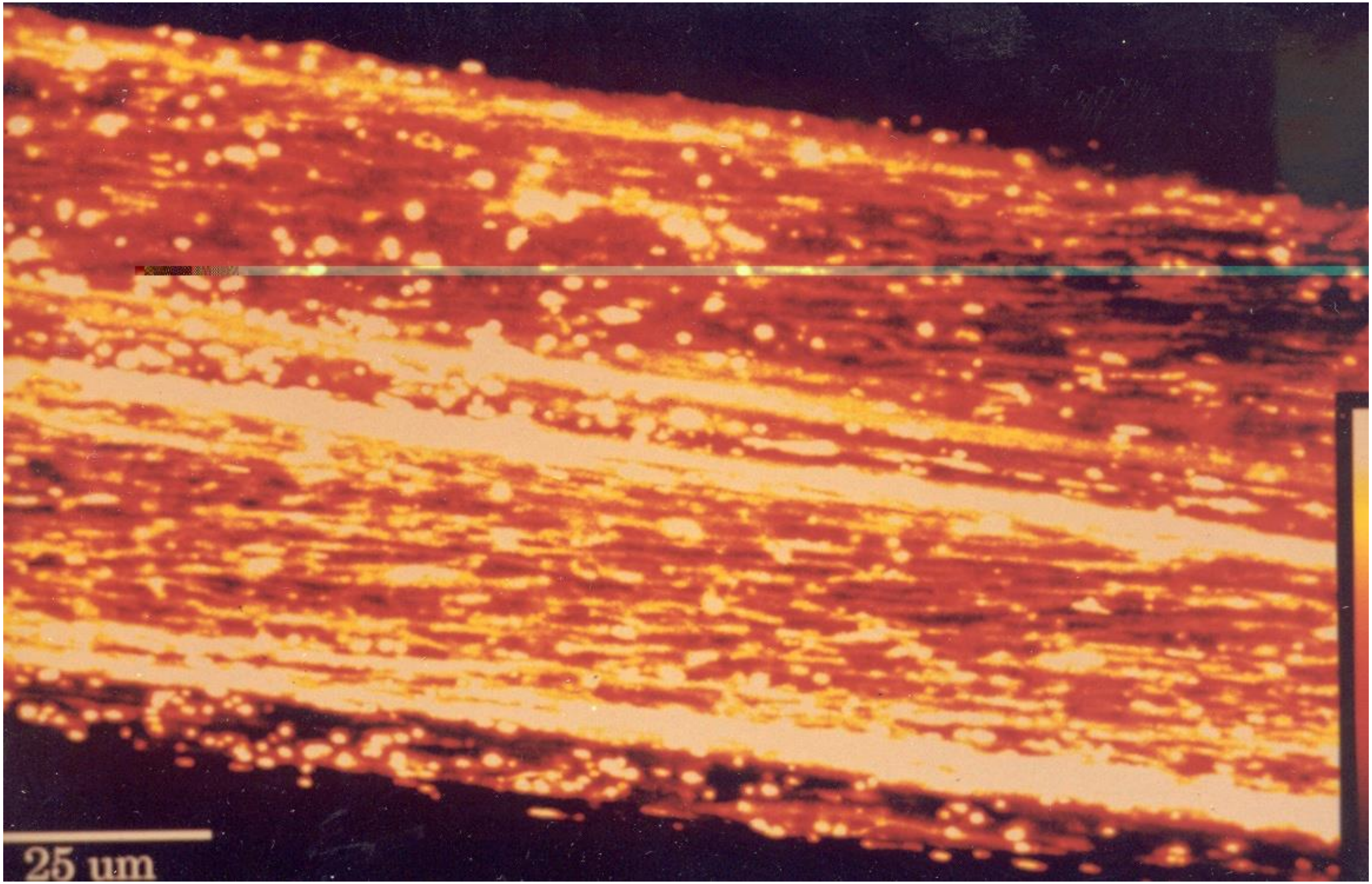
- **Tolerance of O_2 deficiency varies widely among organisms**
  - **Obligate aerobes** -- require O_2 continuously for survival (e.g. mammals)
  - **Facultative anaerobes** -- can adapt to anaerobic conditions for days or months (e.g. brine shrimp embryos)
  - **Obligate anaerobes** -- thrive in anaerobic environments
    - Inhibited or killed in the presence of O_2
    - Archaea, bacteria (e.g. *Clostridium*), and protozoa (e.g. *Entamoeba*)

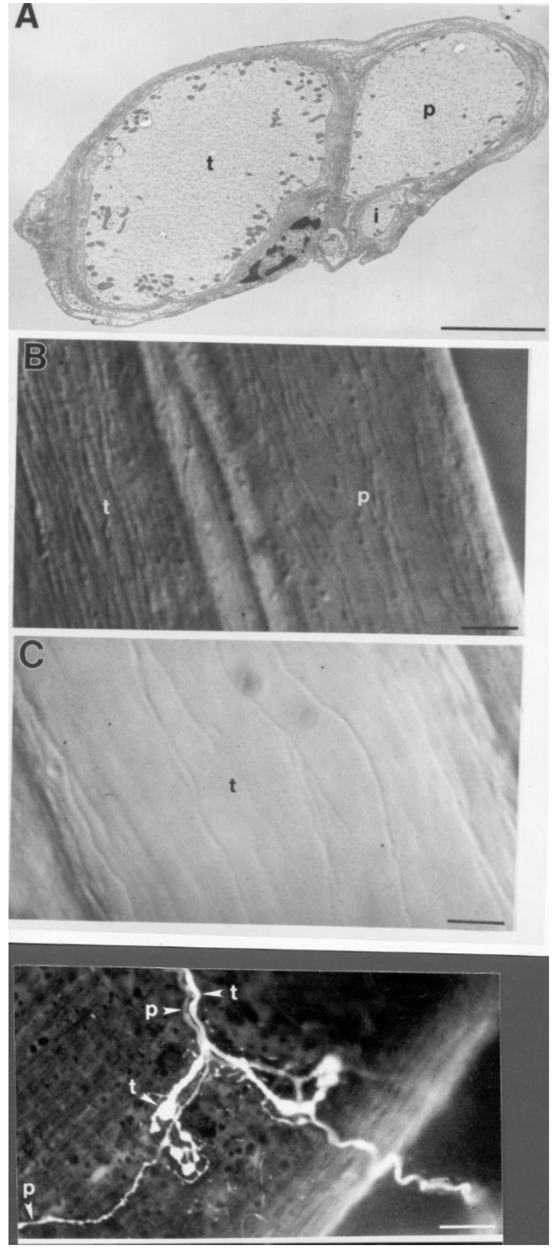
Anaerobic- Bacteria, some yeasts, some invertebrates can live in low O_2.

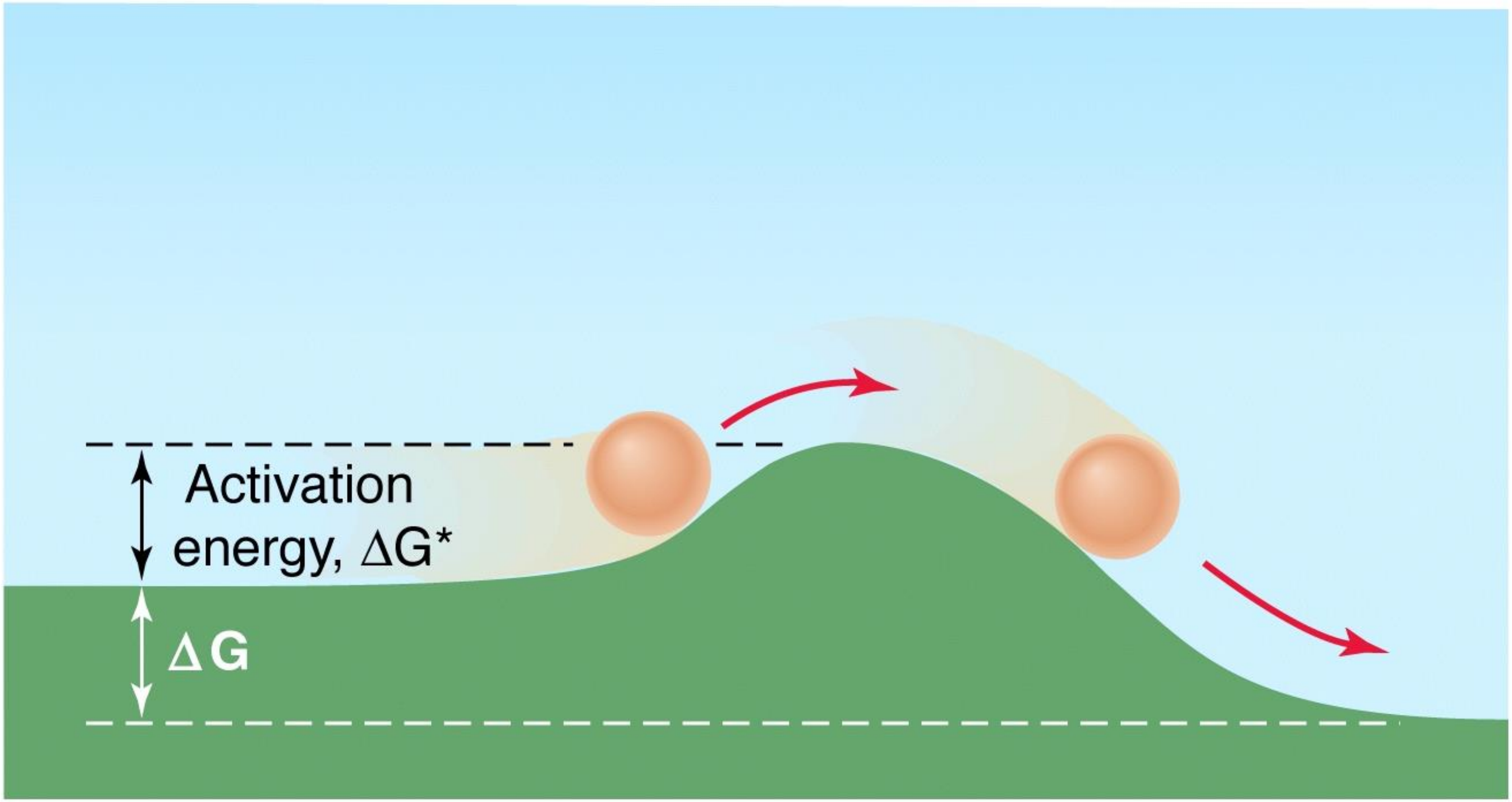
Ex. Clostridium botulinum can not grow in O_2.

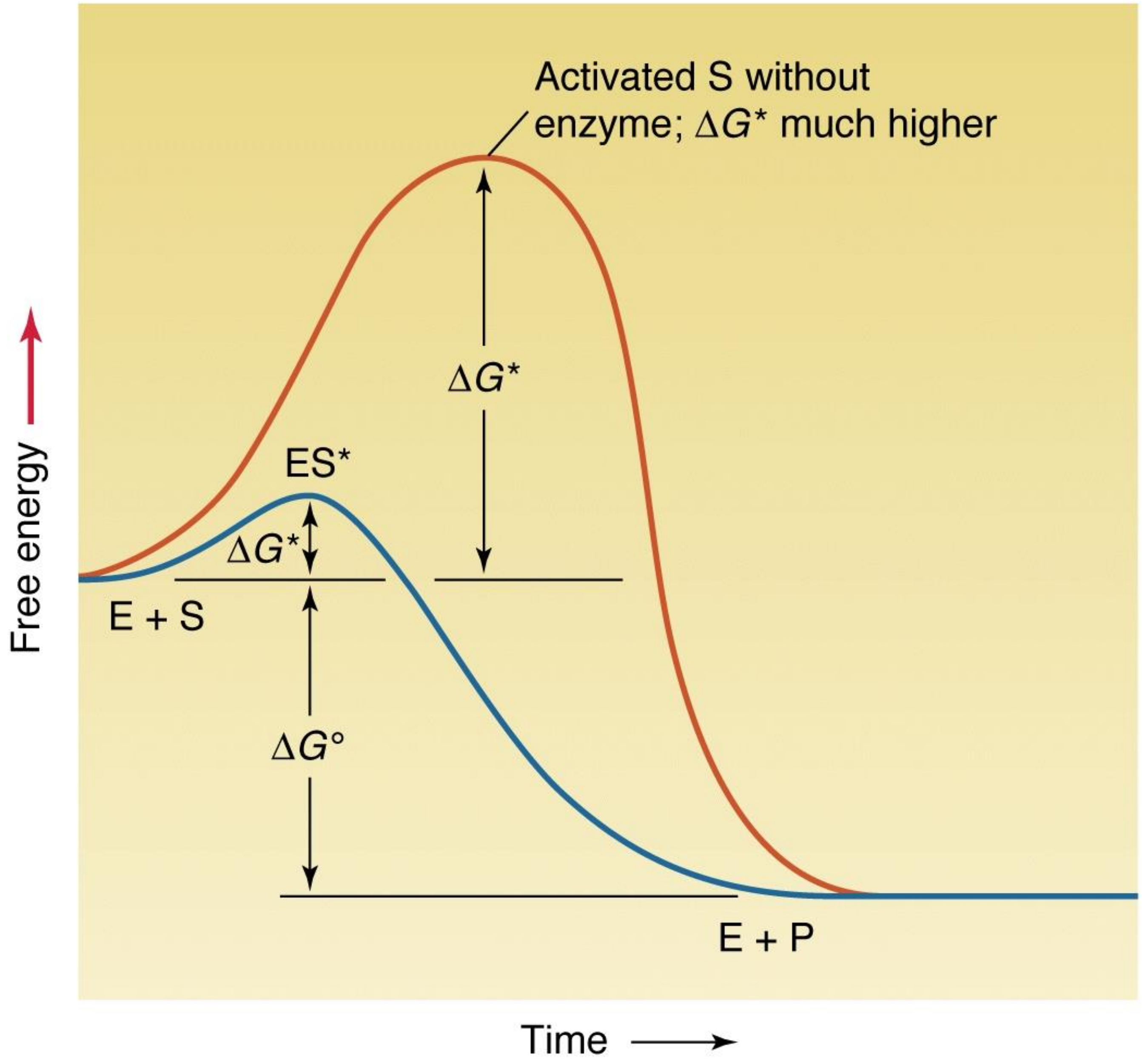
Aerobic- require a supply of O_2. Some tissues like muscle can function anaerobically and build up an "O_2 debt" but pay back occurs.

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

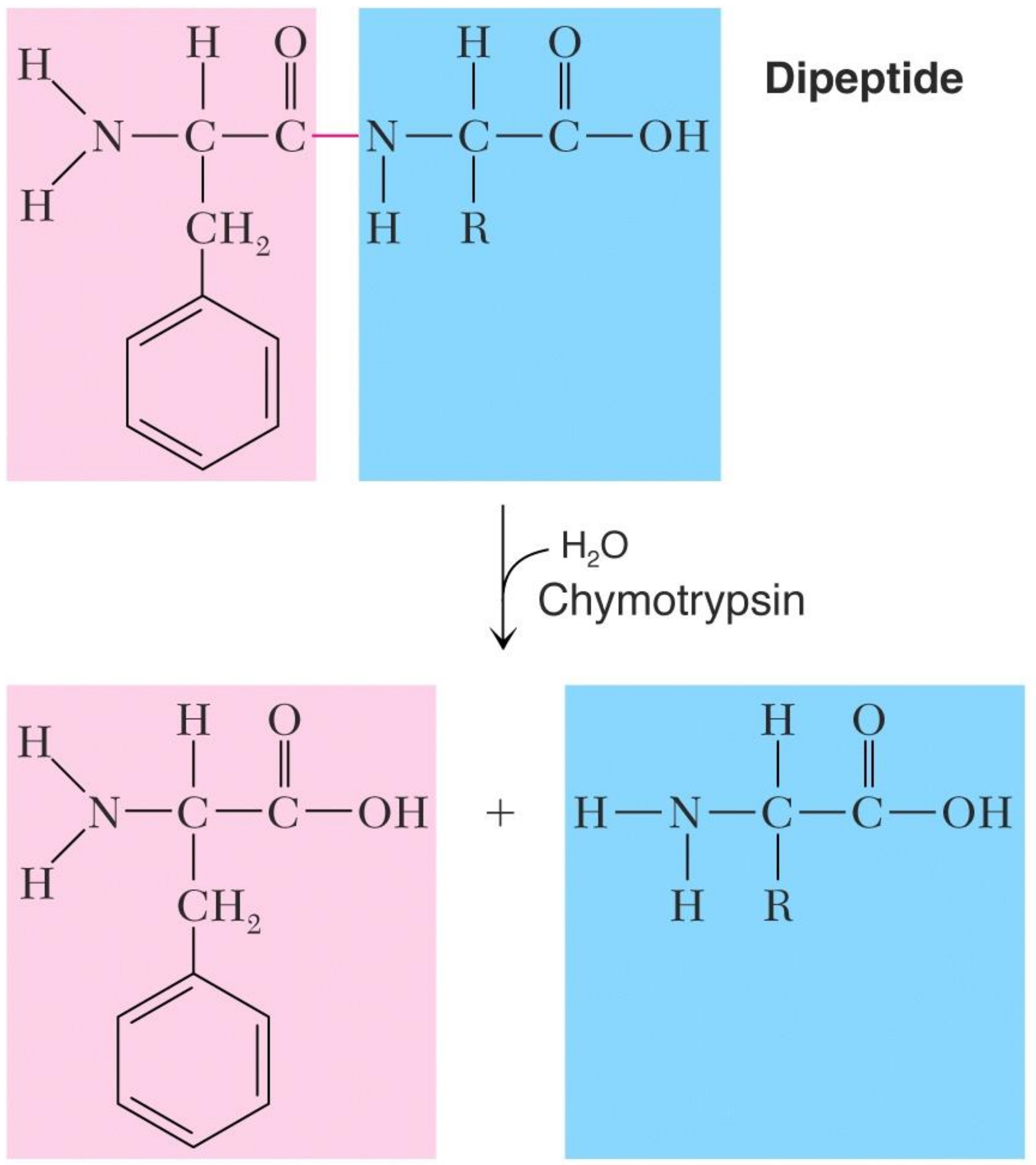

25 um


A
t
p
i
B
t
p
C
t
p
t
t
p

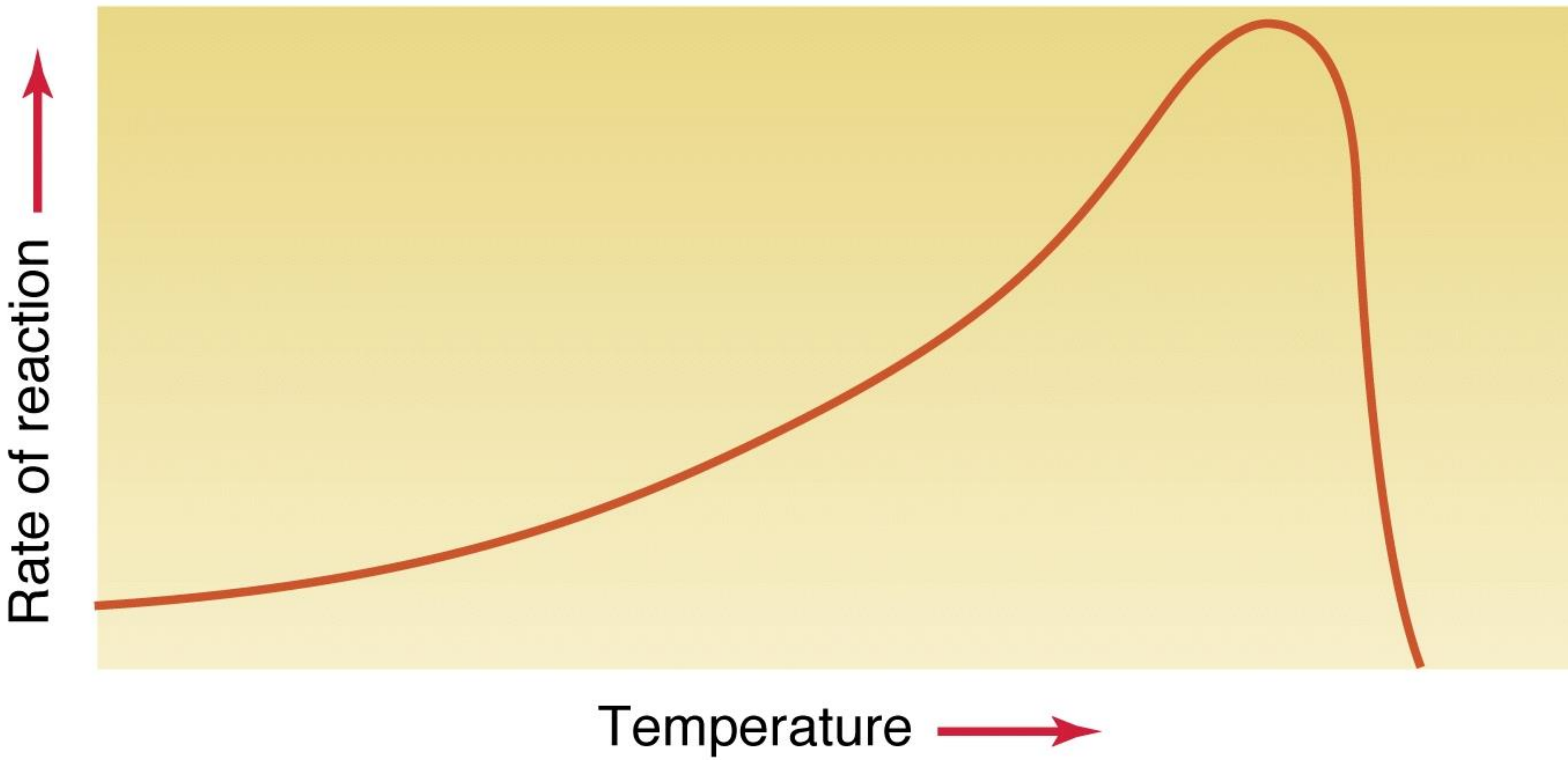

Activation
energy, ΔG*
ΔG



Activated S without
enzyme; ΔG* much higher
ΔG*
ES*
ΔG*
E + S
ΔG°
E + P
Free energy
Time


Dipeptide
H2O
Chymotrypsin

(a) Enzyme activity versus temperature



(b) Enzyme activity versus pH

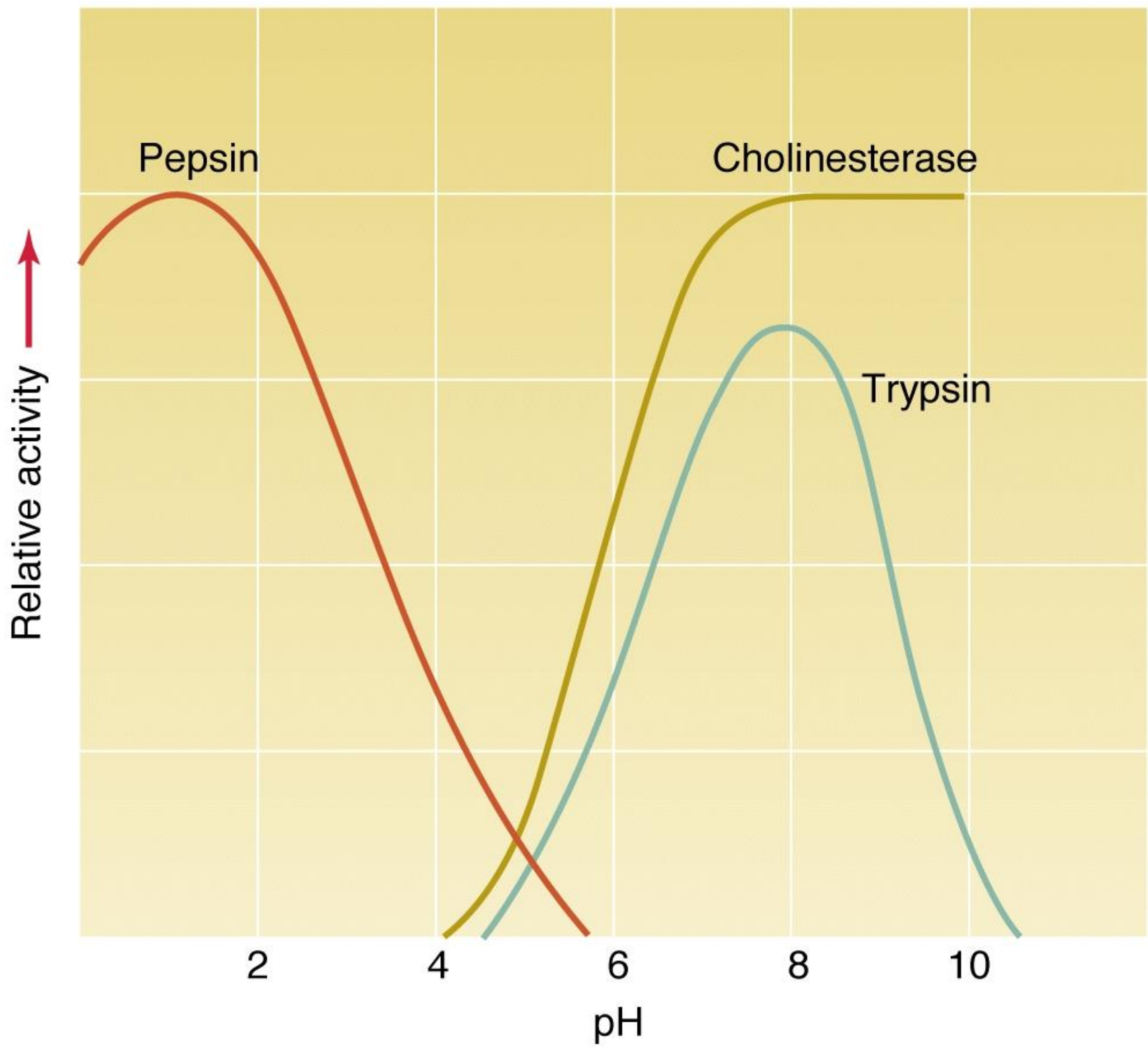


Table 3-6 Metal ions functioning as cofactors

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

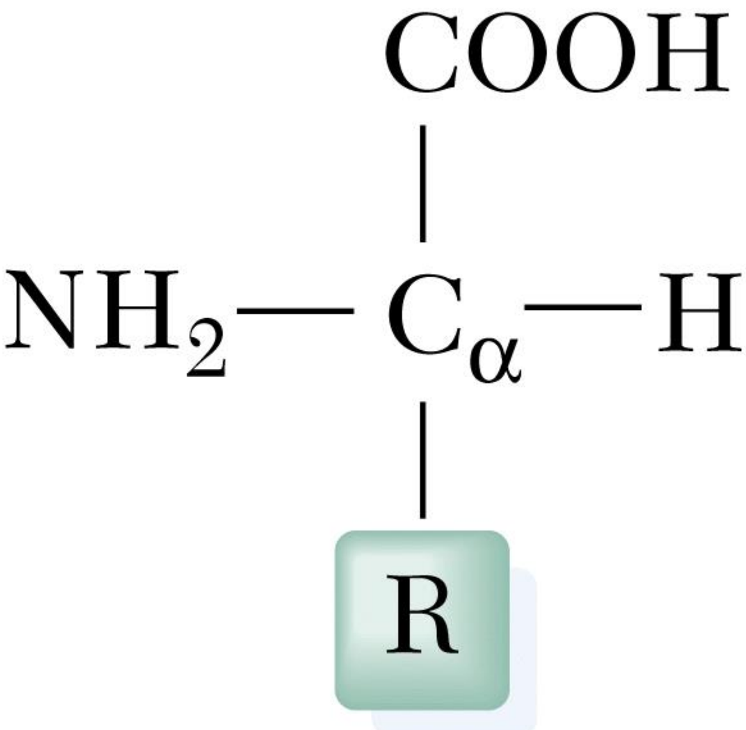
Source: Adapted from Nelson and Cox, 2000.

Proteins

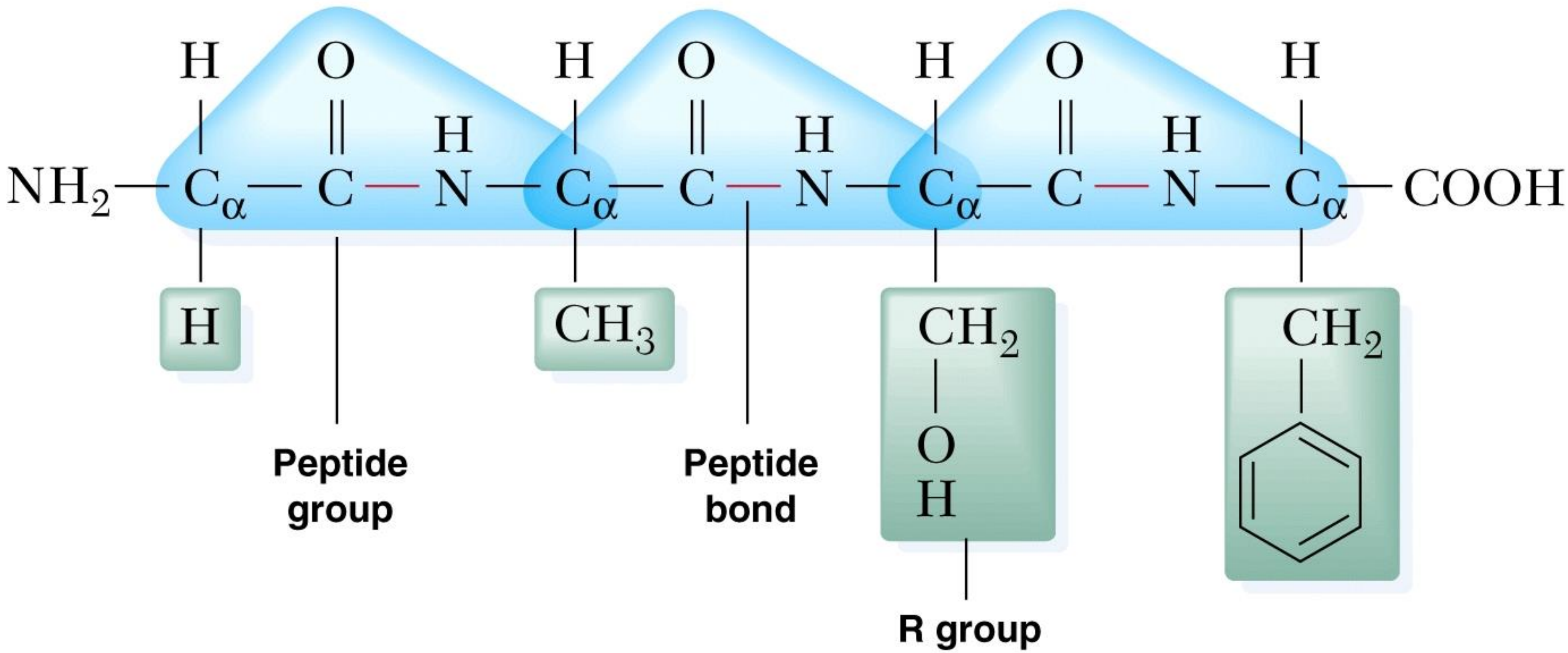
- A lot in cells. ½ of the dry mass.
- Various structures.

-Primary, secondary, tertiary, and quaternary

(a) General structure of alpha-amino acids

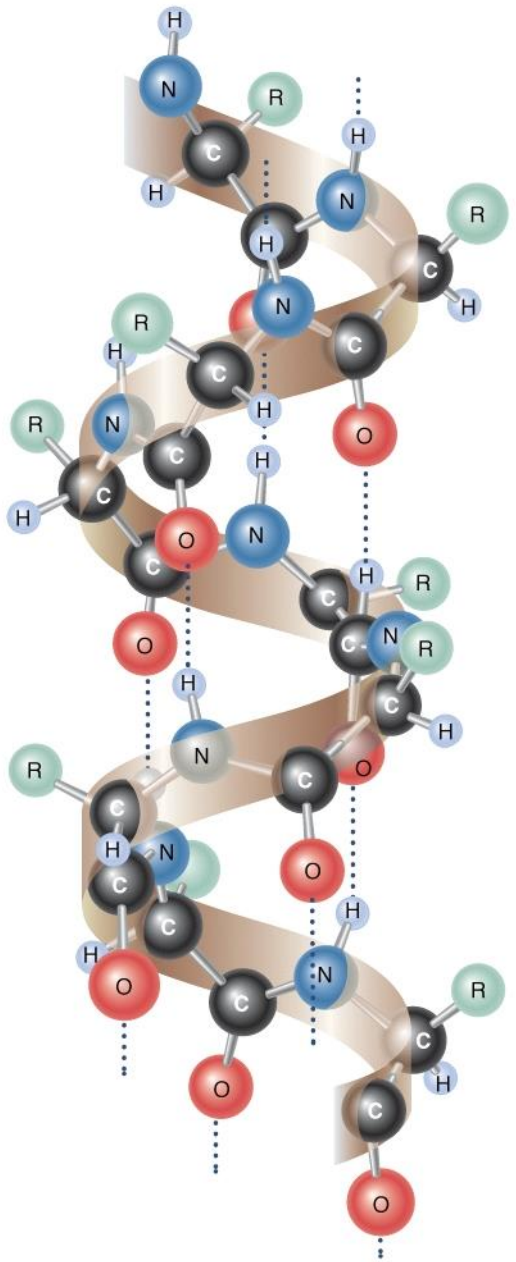


(b) Structure of a tetrapeptide



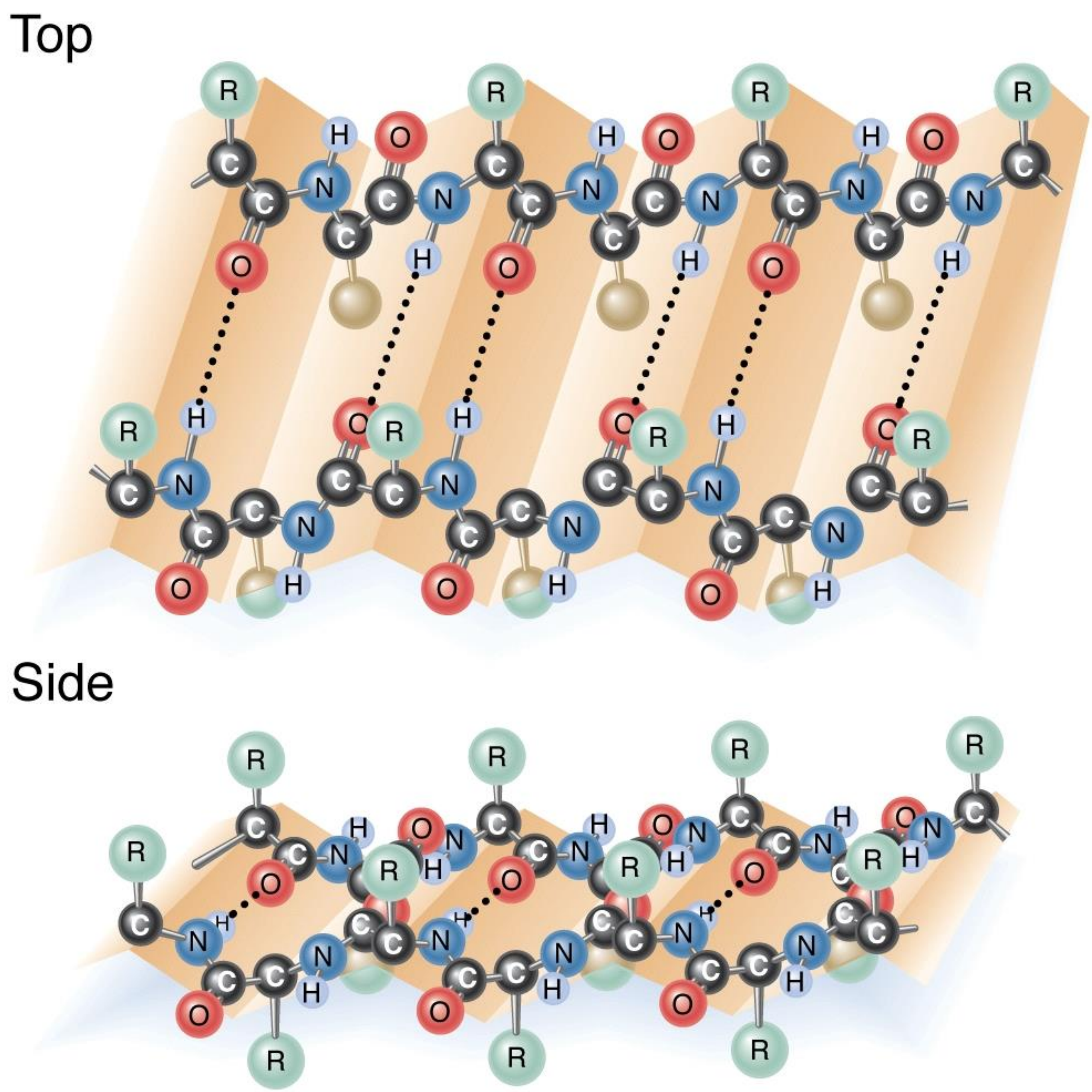
Secondary

Alpha helix



Secondary

Beta- sheet

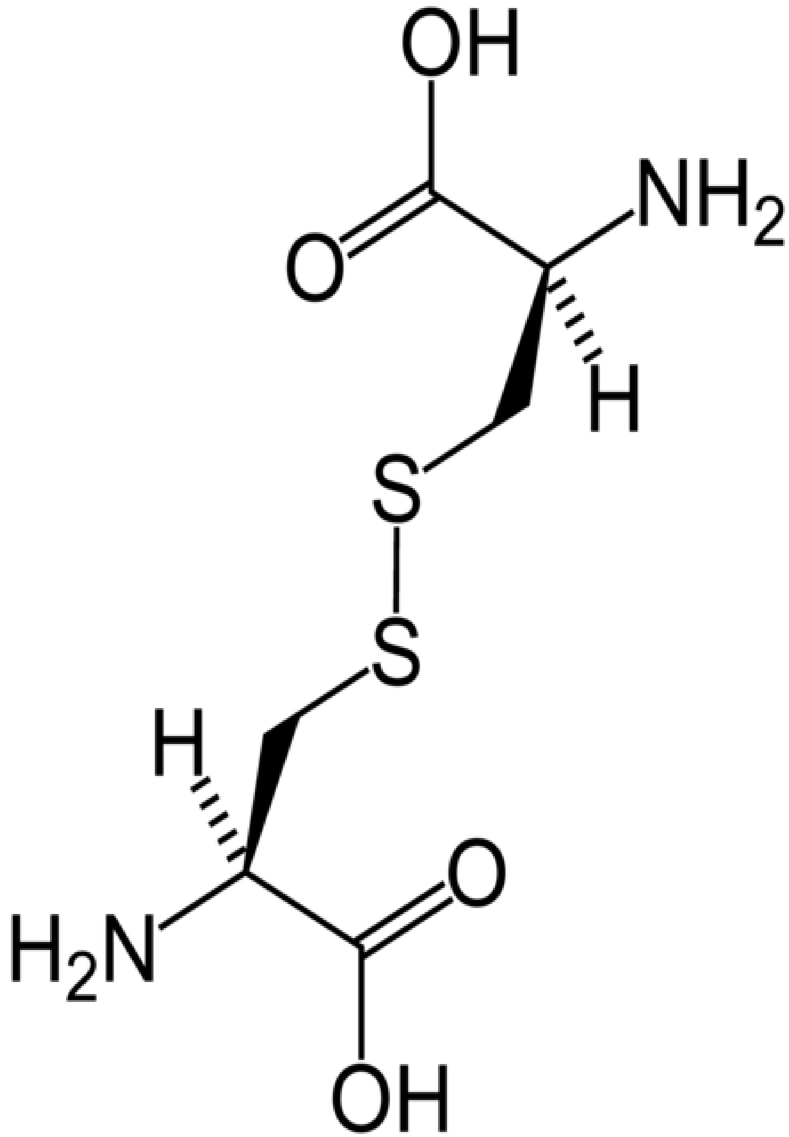


Secondary types

- 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