METABOLISME MIKROBA

Mengenal Diversitas Metabolisme Pada Mikroorganisme

By: KUSNADI,MSI.

- **Metabolisme** **Semua reaksi kimia dan bioogi yang terjadi dalam sel**

- Mteabolisme pada semua organisme pada prinsipnya memiliki kesamaan (***Unity in biochemeistry***) namun ada beberapa perbedaan tergantung pada jenis organismenya.
- Metabolisme mikroba: meliputi semua reaksi biokimia yang terjadi dalam sel mikroba yang berperan penting dalam regenerasi energi dan metabolit

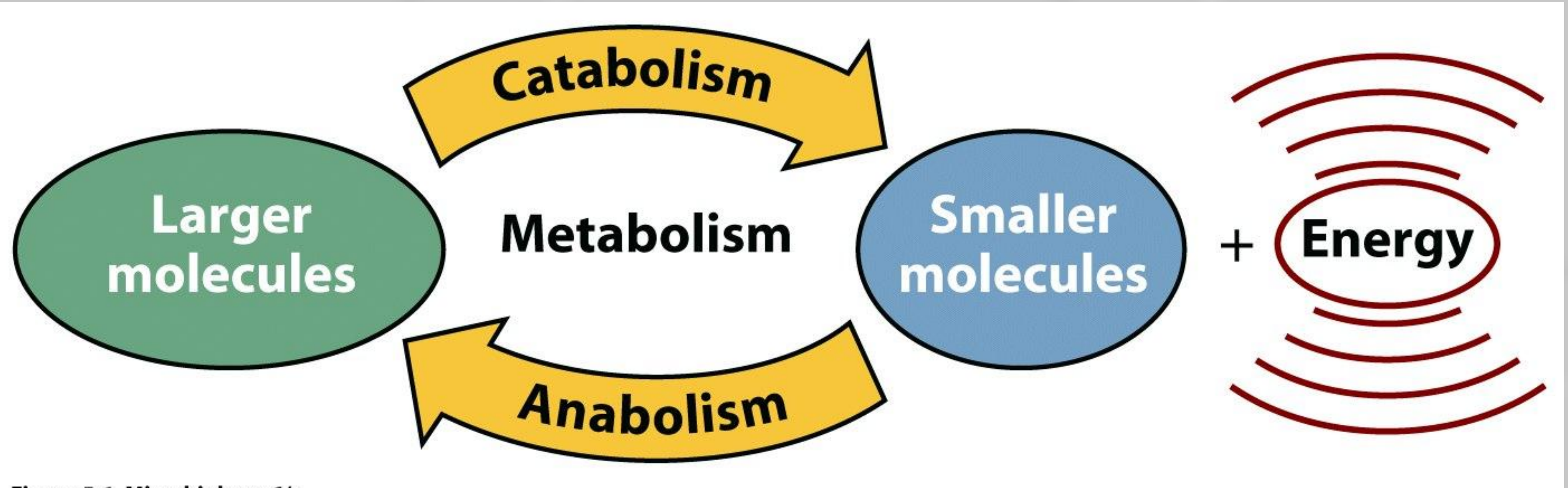


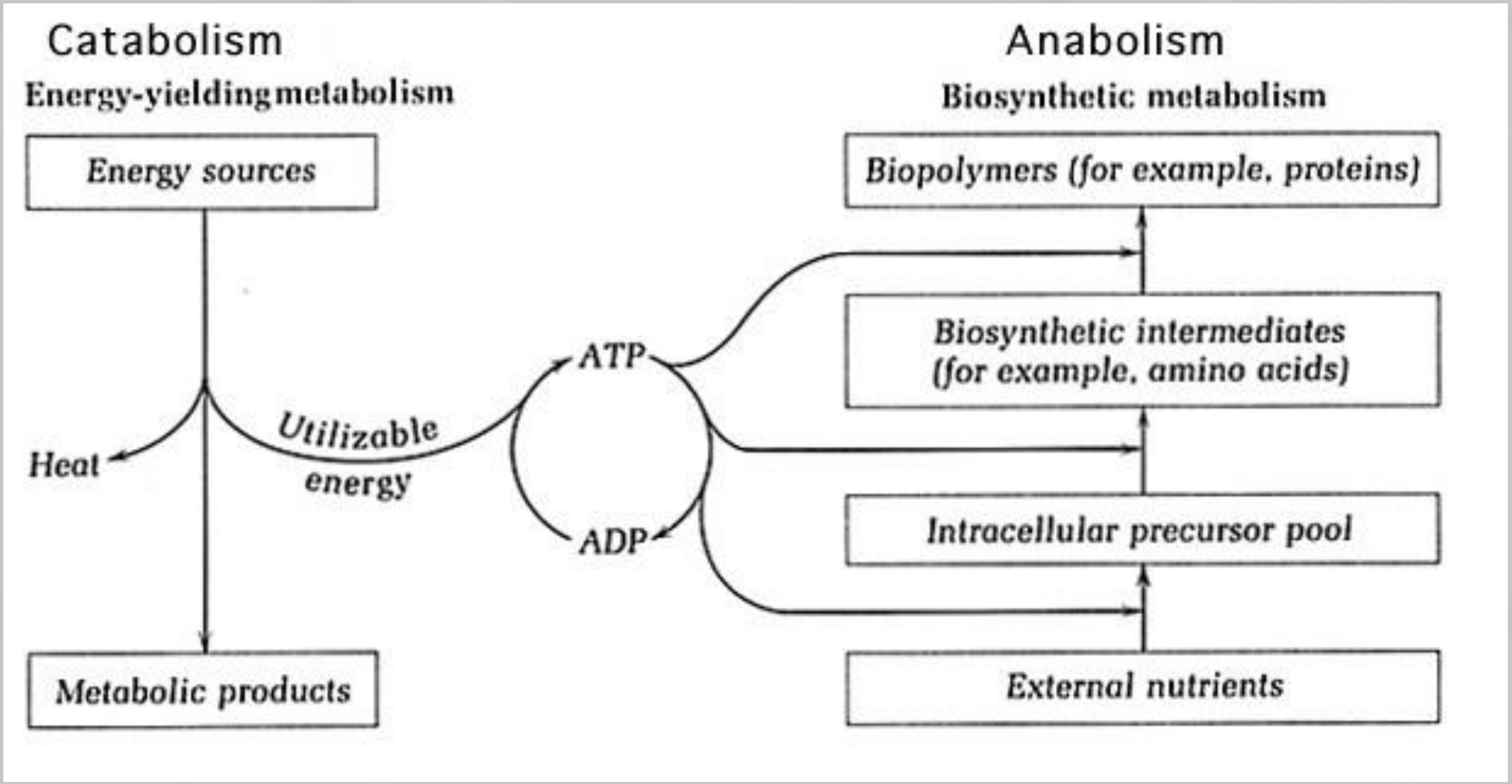
Figure 5-1 Microbiology, 6/e

Catabolism : degradasi/proses penguraian = mengubah molekul besar menjadi moekul kecil dengan menghasilkan energi

Anabolism: sintesis molekul dan komponen sel yang biasanya membutuhkan energi

Metabolit : ***Suatu senyawa yang dihasilkan dari rekasi metabolsime***

KONSEP DASAR METABOLISME



ANABOLISME DAN KATABOLISME

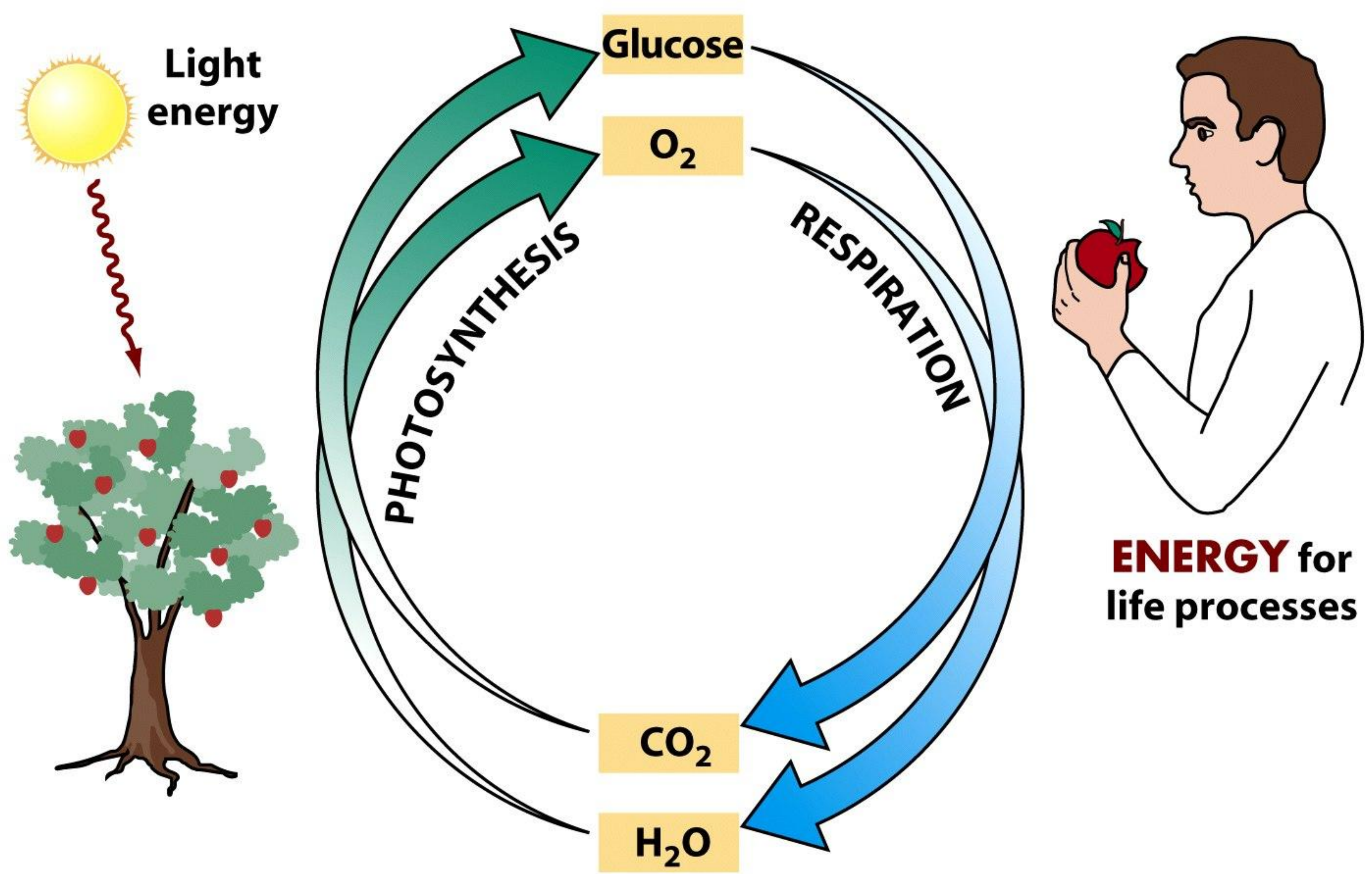
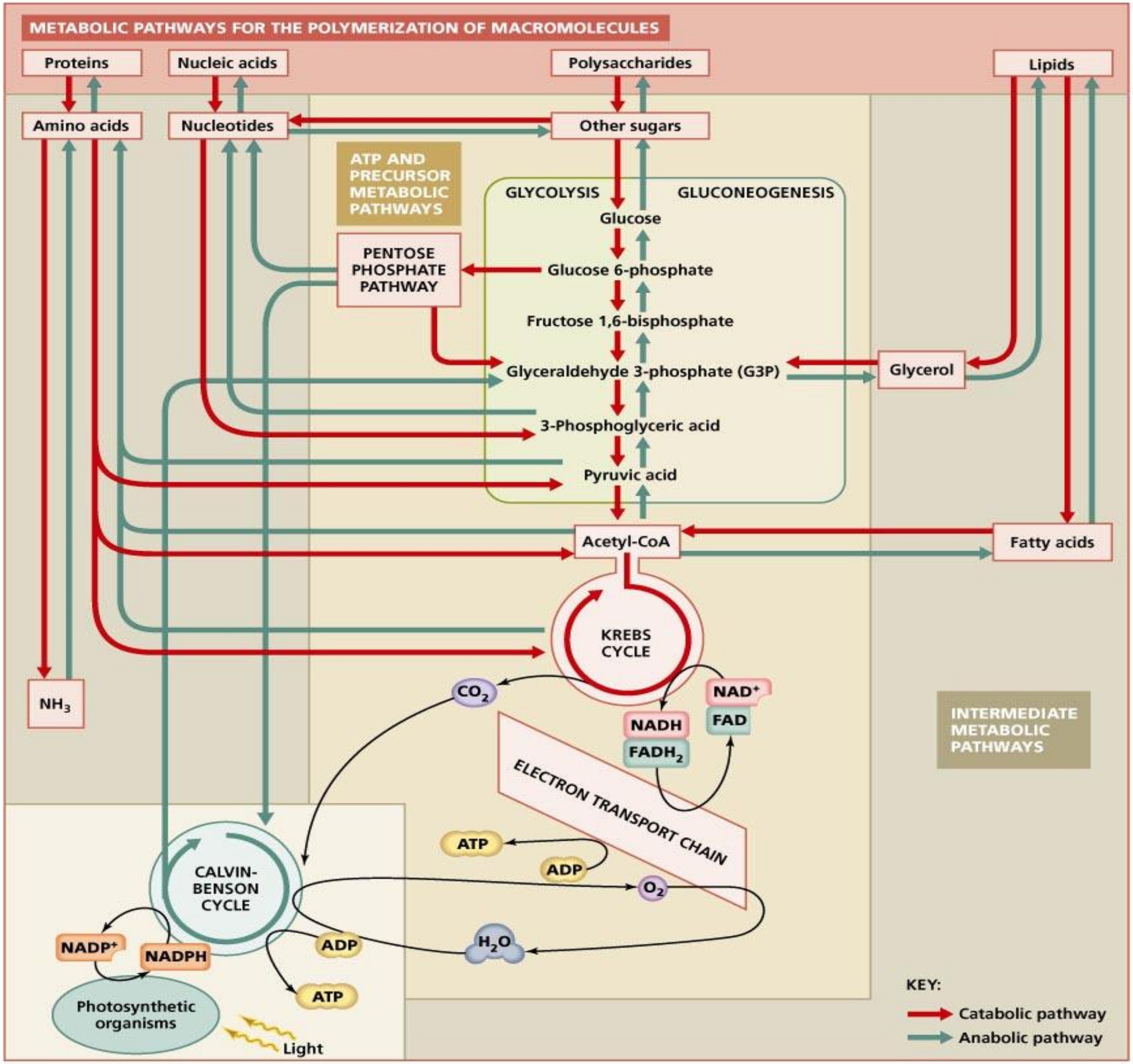


Figure 5-3 Microbiology, 6/e

KATABOLISME



METABOLISME PADA MIKROORGANISME

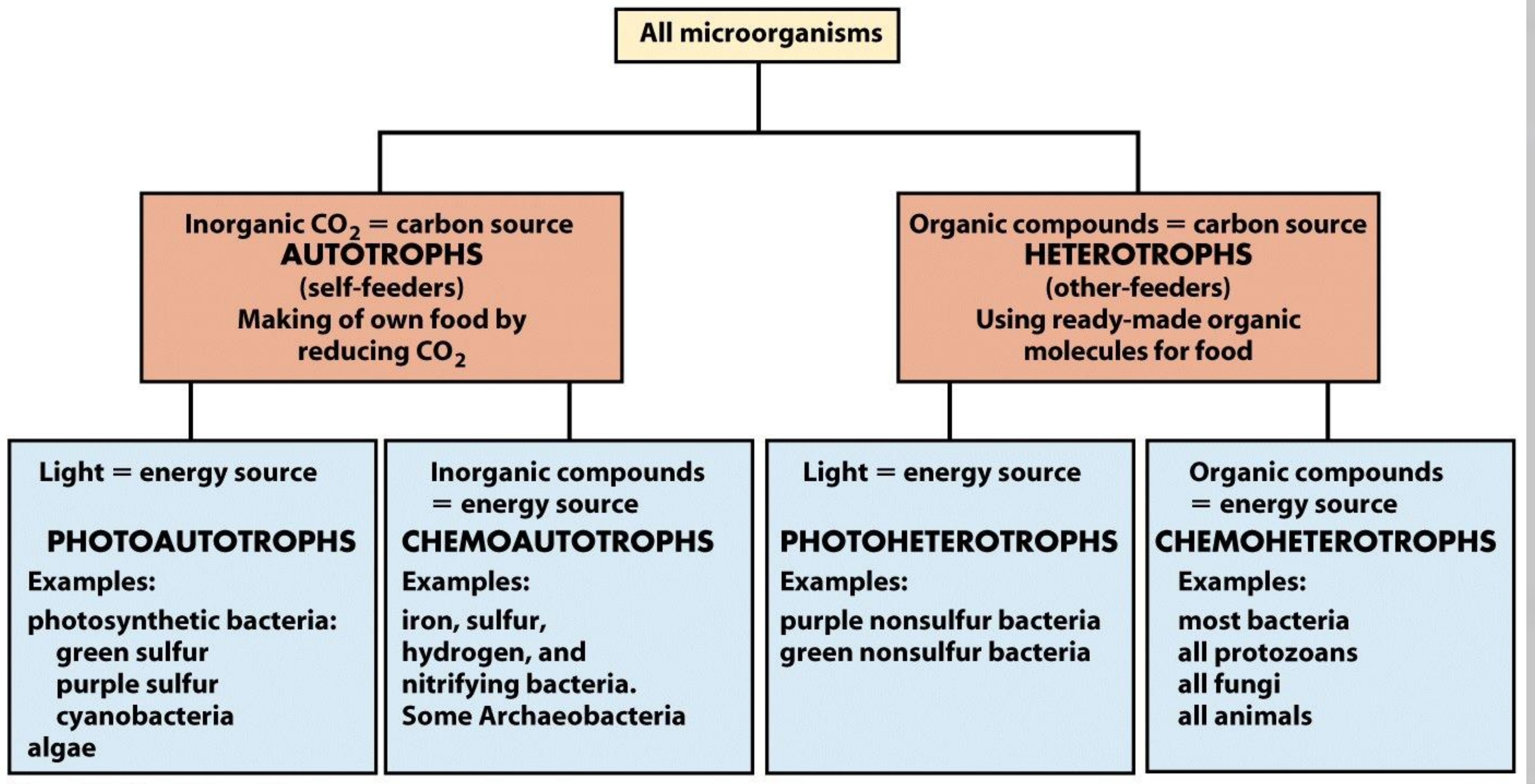


Figure 5-2 Microbiology, 6/e

Chemoheterotrophs	•Carbon source: from organic compounds made by other organisms •Energy source: from oxidation of organic compounds •Examples: most bacteria, protozoa, all fungi and animals
Chemoautotrophs	•Carbon source: CO_2 •Energy source: oxidize inorganic compounds which are used to fix CO_2 •Examples: nitrifying, hydrogen, sulfur and iron-utilizing bacteria. Archaea which live among hydrothermal ocean vents
Photoheterotrophs	•Carbon source: from organic compounds made by other organisms •Energy source: light •Examples: green and purple nonsulfur bacteria
Photoautotrophs	•Carbon source: CO_2 •Energy source: light •Examples: cyanobacteria, green and purple sulfur bacteria, algae, plants.

RESPIRASI PADA MIKROORGANISME

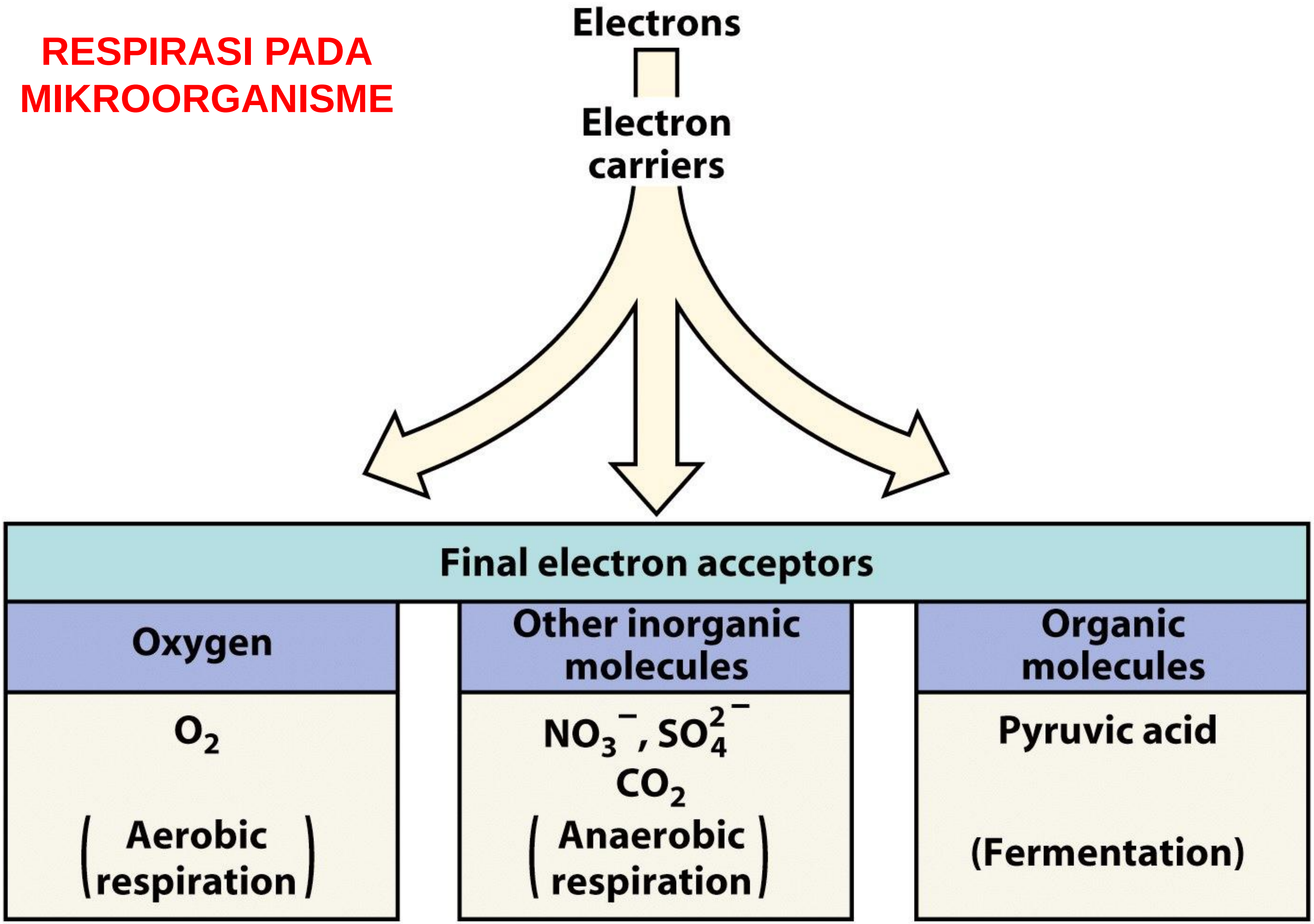


Figure 5-21 Microbiology, 6/e

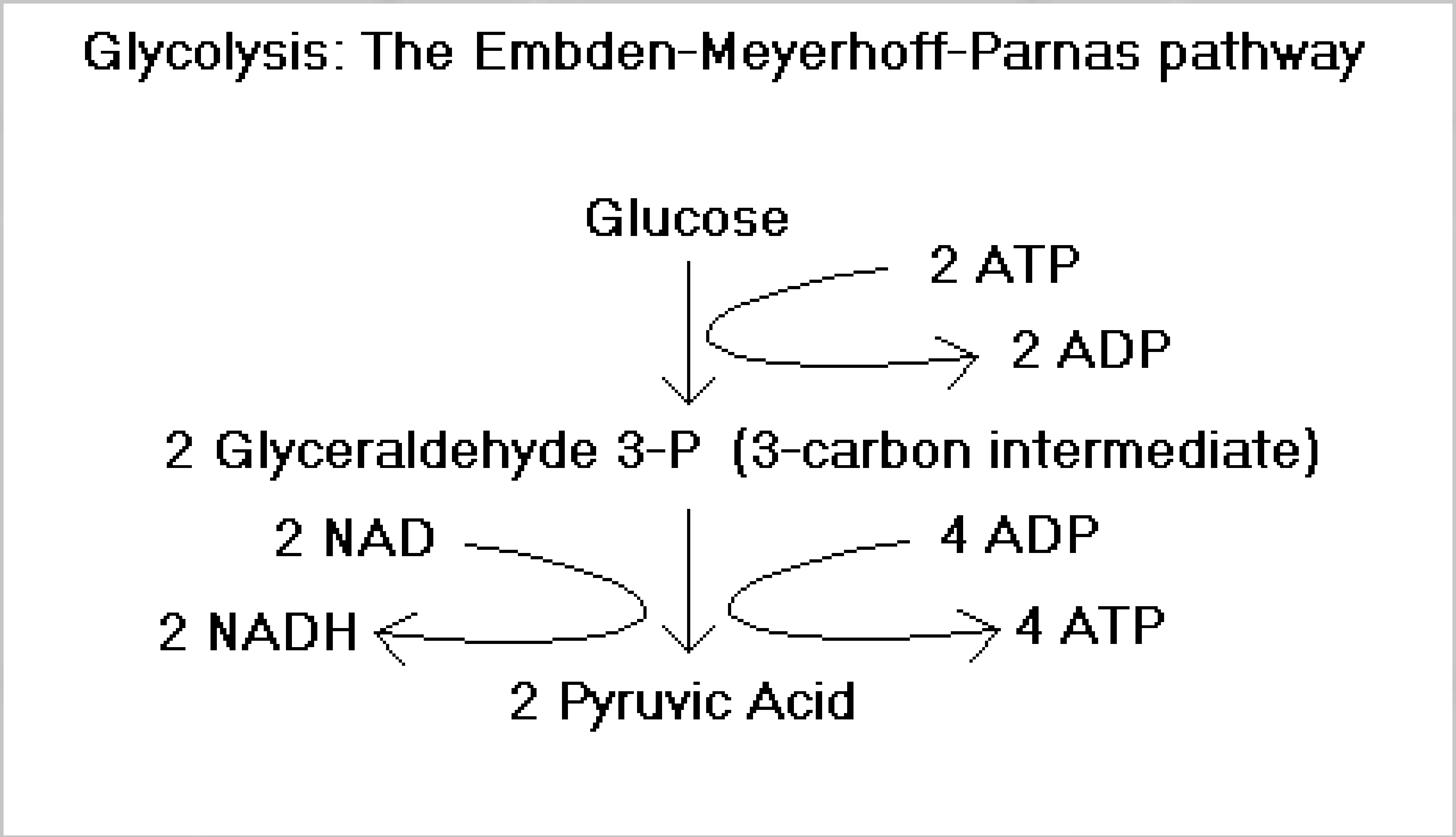
PERBEDAAN PRINSIP TIPE RESPIRASI PADA MIKROORGANISME

Akseptor electron	**Reduksi dan produk**	**Proses metabolsime**	**organisme**
O_2	H_2O	Respirasi aerobik	*Escherichia*, *Streptomyces*
NO_3	NO_2, NH_3 or N_2	Respirasi anaerobik : denitrifikasi	*Bacillus*, *Pseudomonas*
SO_4	S or H_2S	Respirasi anaerobik : reduksi sulfat	*Desulfovibrio*
fumarate	succinate	Respirasi anaerobik : Menggunakan akseptor elektron organik	*Escherichia*
CO_2	CH_4	methanogenesis	*Methanococcus*

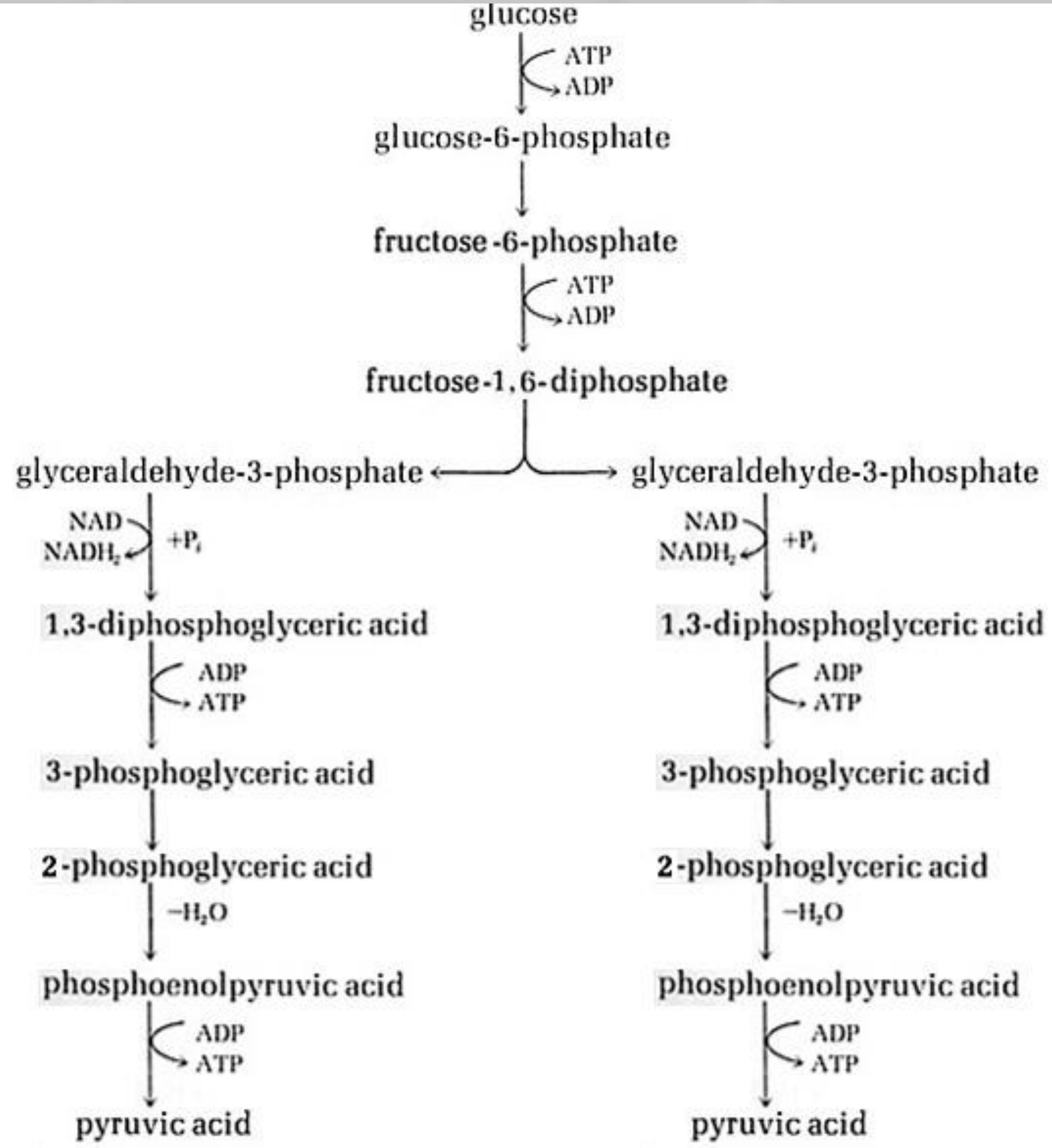
JALUR METABOLISME KARBOHIDRAT PADA MIKROBA

1. Jalur EMP (Embden-Meyerhof Parnas Pathway) atau glikolisis, ditemukan pada fungi,kebanyakan bakteri dan manusia
2. Jalur Entner-Doudoroff (ED): hanya ditemukan pada beberapa bakteri spt. *Zymomonas, Pseudomonas*
3. Jalur Heksosa Monofosfat (HMF) atau jalur pentosa fosfat ditemukan pada berbagai mikroba spt. *Leuconostoc*
4. Jalur fosfoketolase (FK) ditemukan pada bakteri laktobasili heterofermentatif spt. *Lactobacillus*

Jalur EMP

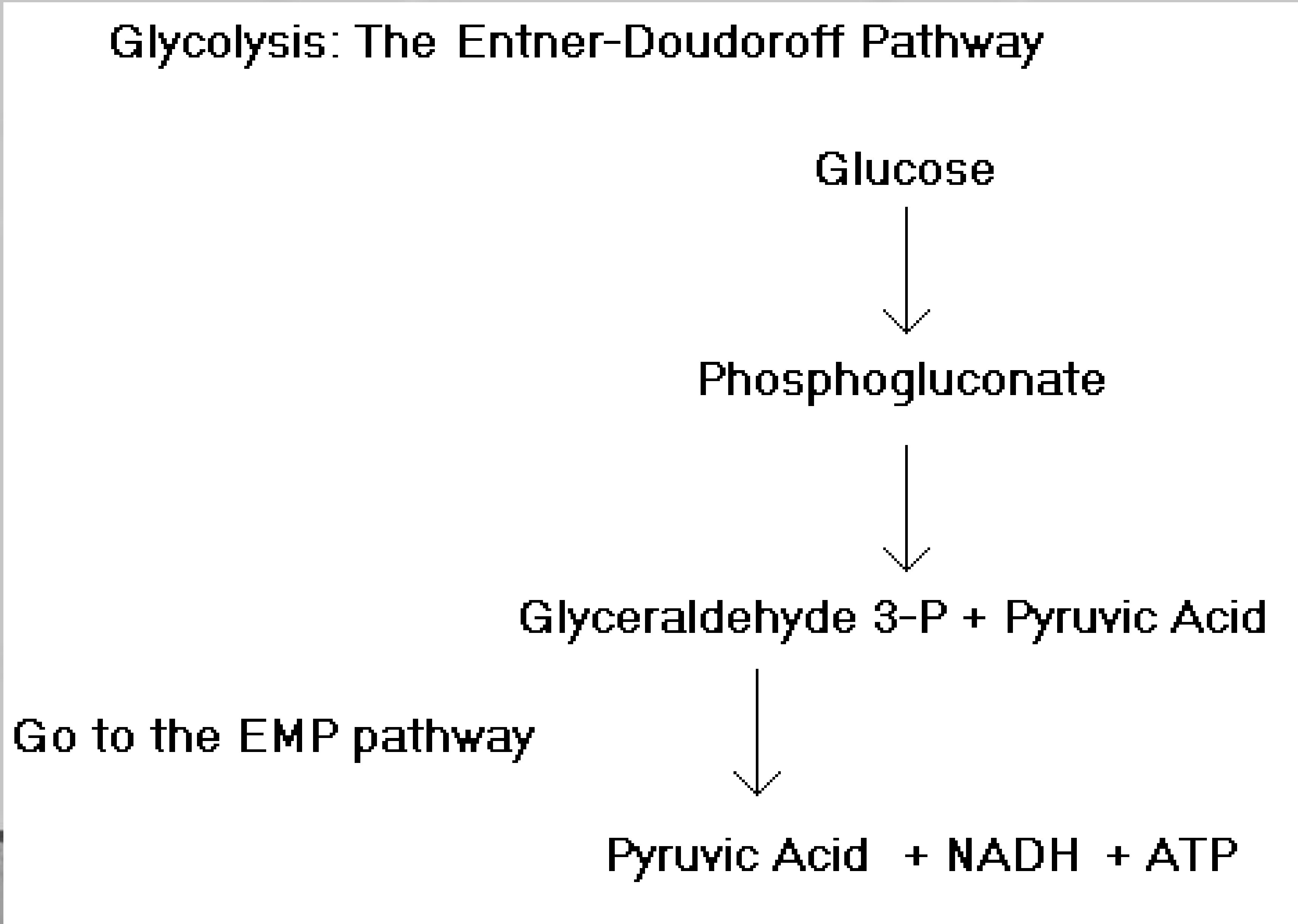

Glycolysis: The Embden-Meyerhoff-Parnas pathway
Glucose
2 ATP
2 ADP
2 Glyceraldehyde 3-P (3-carbon intermediate)
2 NAD
2 NADH
4 ADP
4 ATP
2 Pyruvic Acid

Jalur EMP

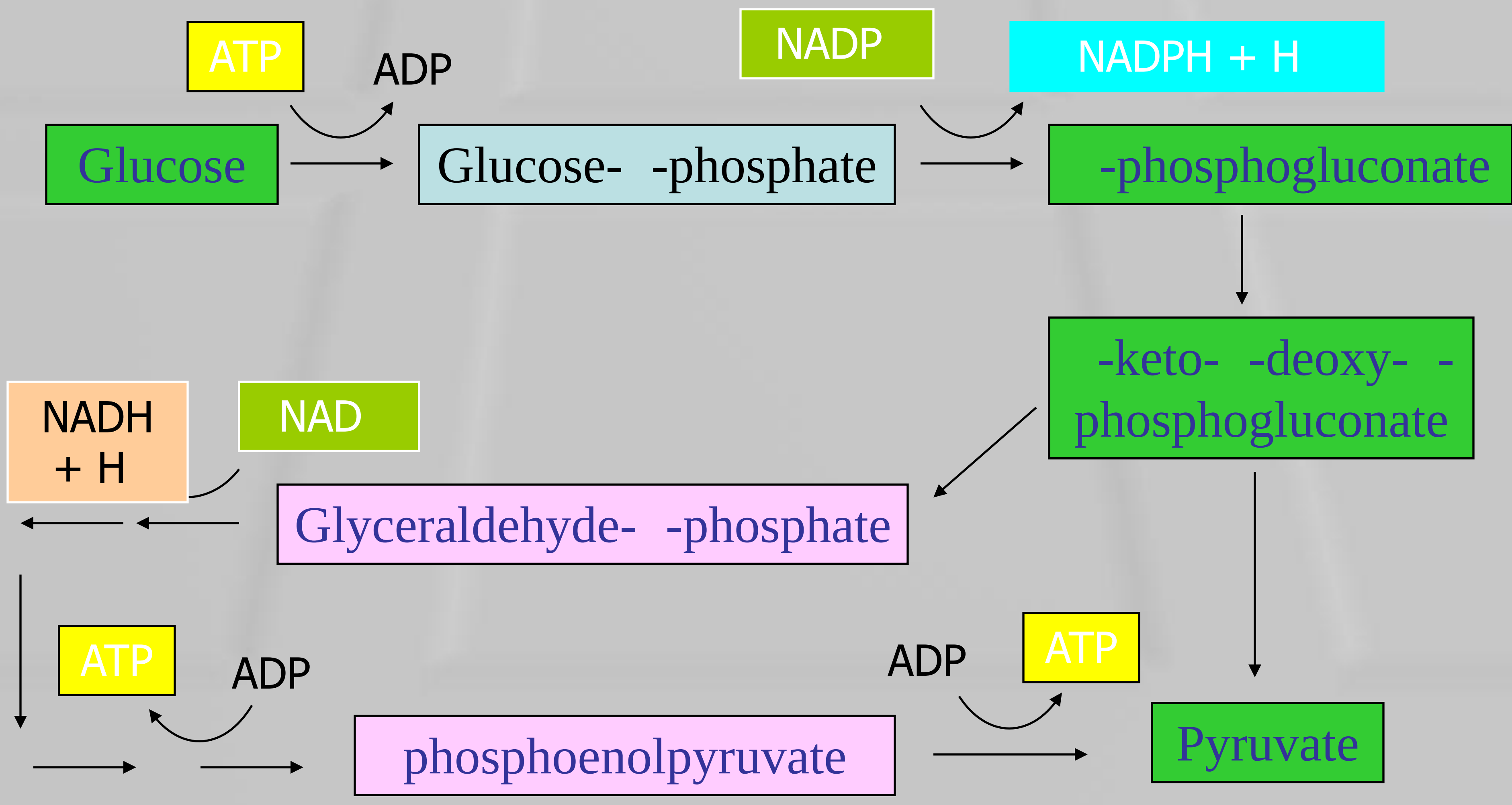


glucose
ATP
ADP
glucose-6-phosphate
fructose-6-phosphate
ATP
ADP
fructose-1,6-diphosphate
glyceraldehyde-3-phosphate
glyceraldehyde-3-phosphate
NAD
NADH2
+Pi
NAD
NADH2
+Pi
1,3-diphosphoglyceric acid
1,3-diphosphoglyceric acid
ADP
ATP
ADP
ATP
3-phosphoglyceric acid
3-phosphoglyceric acid
2-phosphoglyceric acid
2-phosphoglyceric acid
−H2O
−H2O
phosphoenolpyruvic acid
phosphoenolpyruvic acid
ADP
ATP
ADP
ATP
pyruvic acid
pyruvic acid

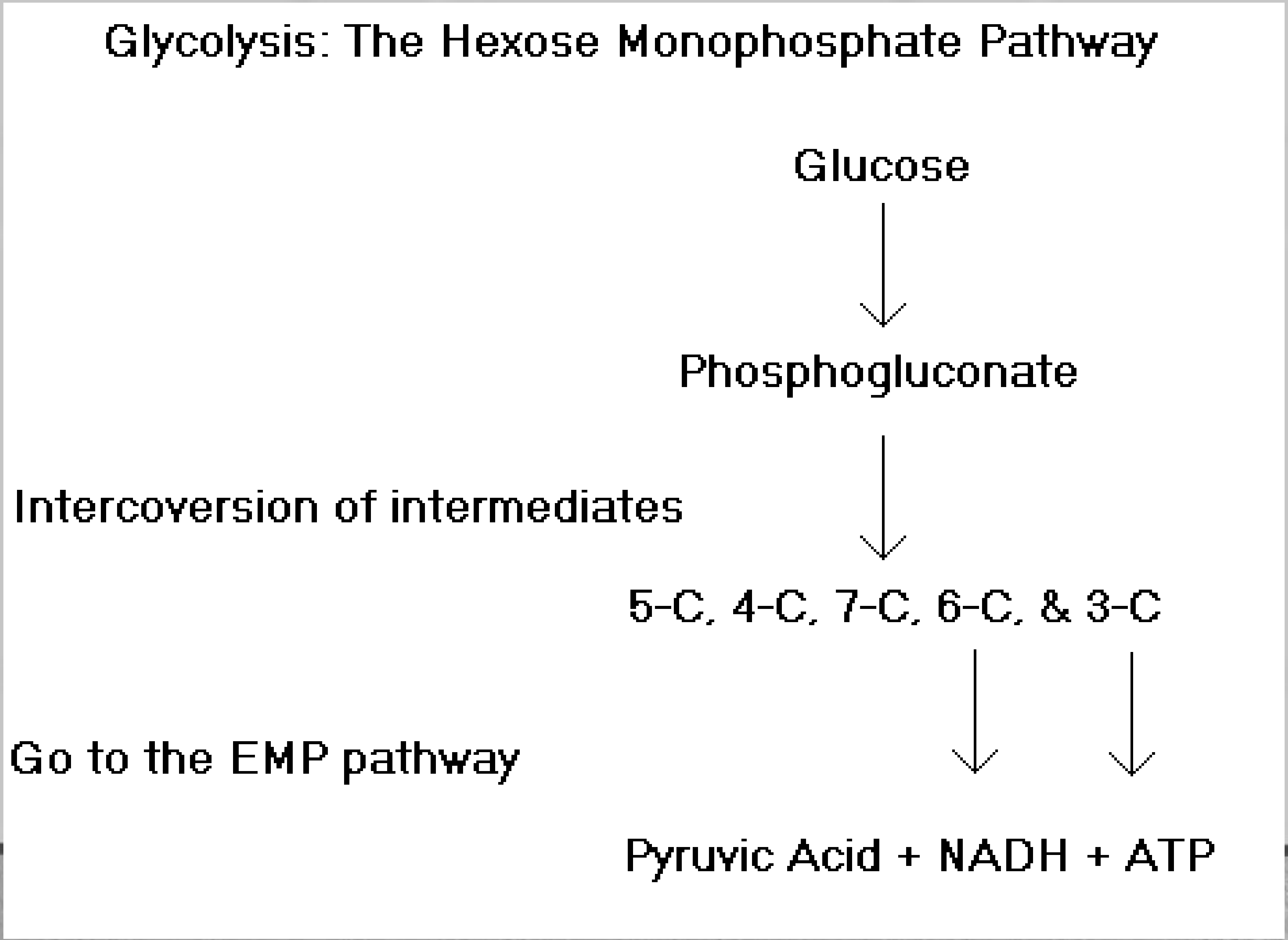
Jalur entner-Doudoroff (ED)



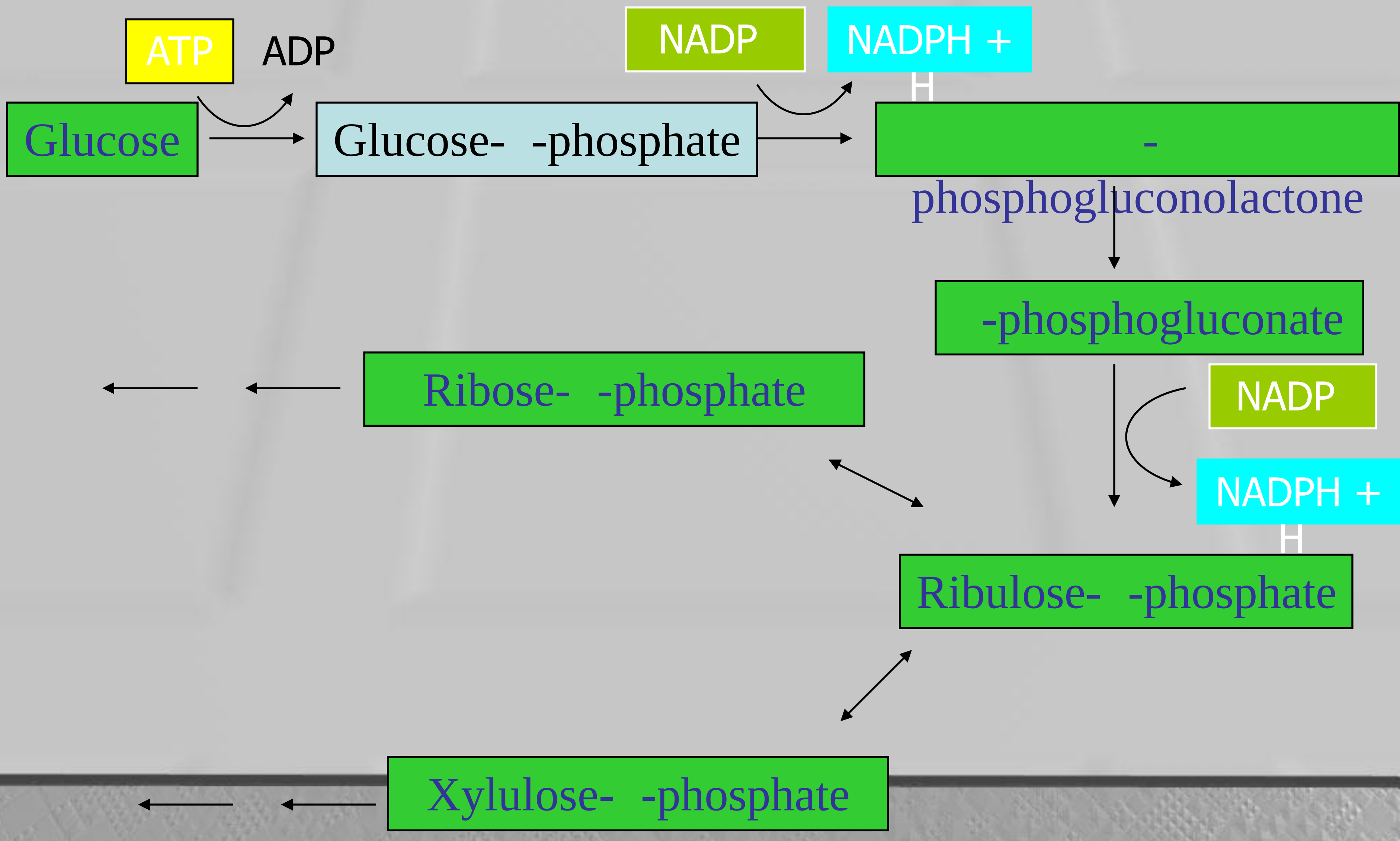
Jalur Entner-Doudoroff



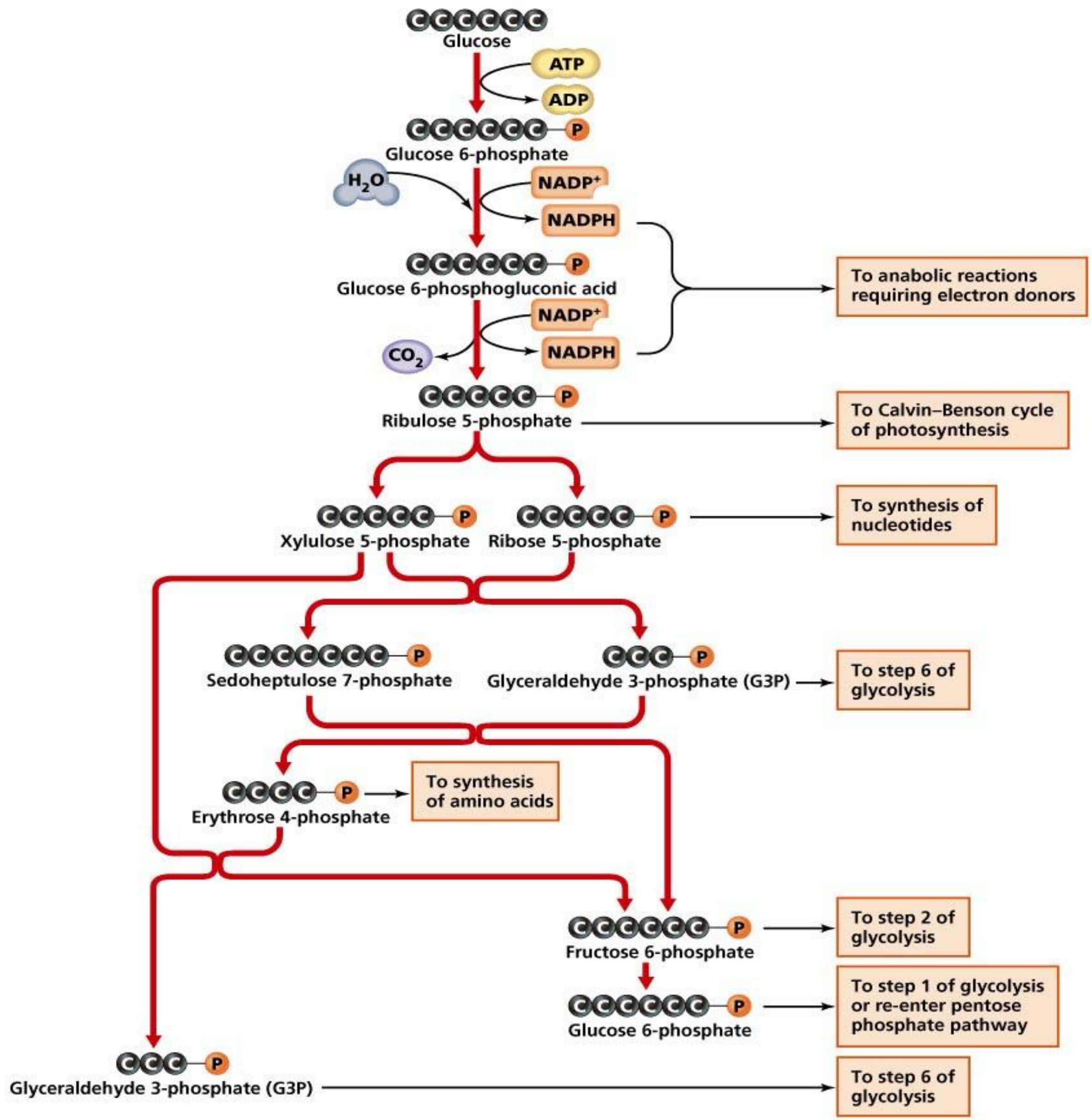
Jalur Heksosa Monofosfat (HMF)/Pentosa fosfat



Jalur Pentose Phosphat atau HMF



Pentose phosphate pathway



Glycolysis: The Phosphoketolase Pathway

Glucose

↓

Phosphogluconate

↓

5-C intermediate + CO_2

↓

Glyceraldehyde 3-P + Acetyl CoA

↓

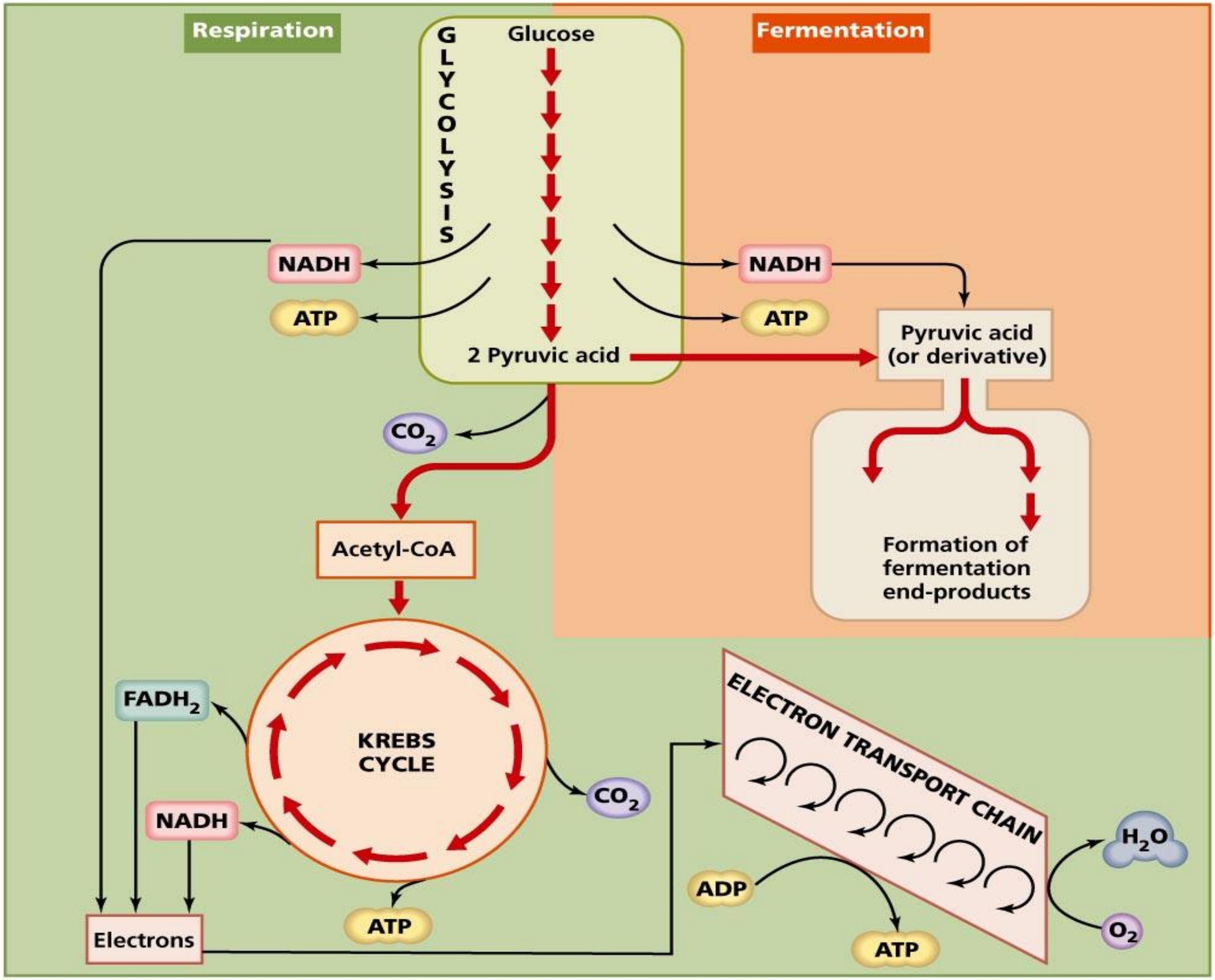
Go to the EMP pathway

Pyruvic Acid + NADH + ATP

Fermentasi

- Fermentasi berasal dari kata “fervere” artinya mendidih, pertama kali dicetuskan oleh Louis Pasteur; mengamati buah anggur yang berubah menjadi anggur (wine).
- Fermentasi adalah proses perombakan senyawa organik dalam kondisi anaerob menghasilkan produk berupa asam-asam organik, alkohol dan gas
- Berperan penting dalam identifikasi mikroba secara biokimia

Respirasi Vs fermentasi



TIPE FERMENTASI

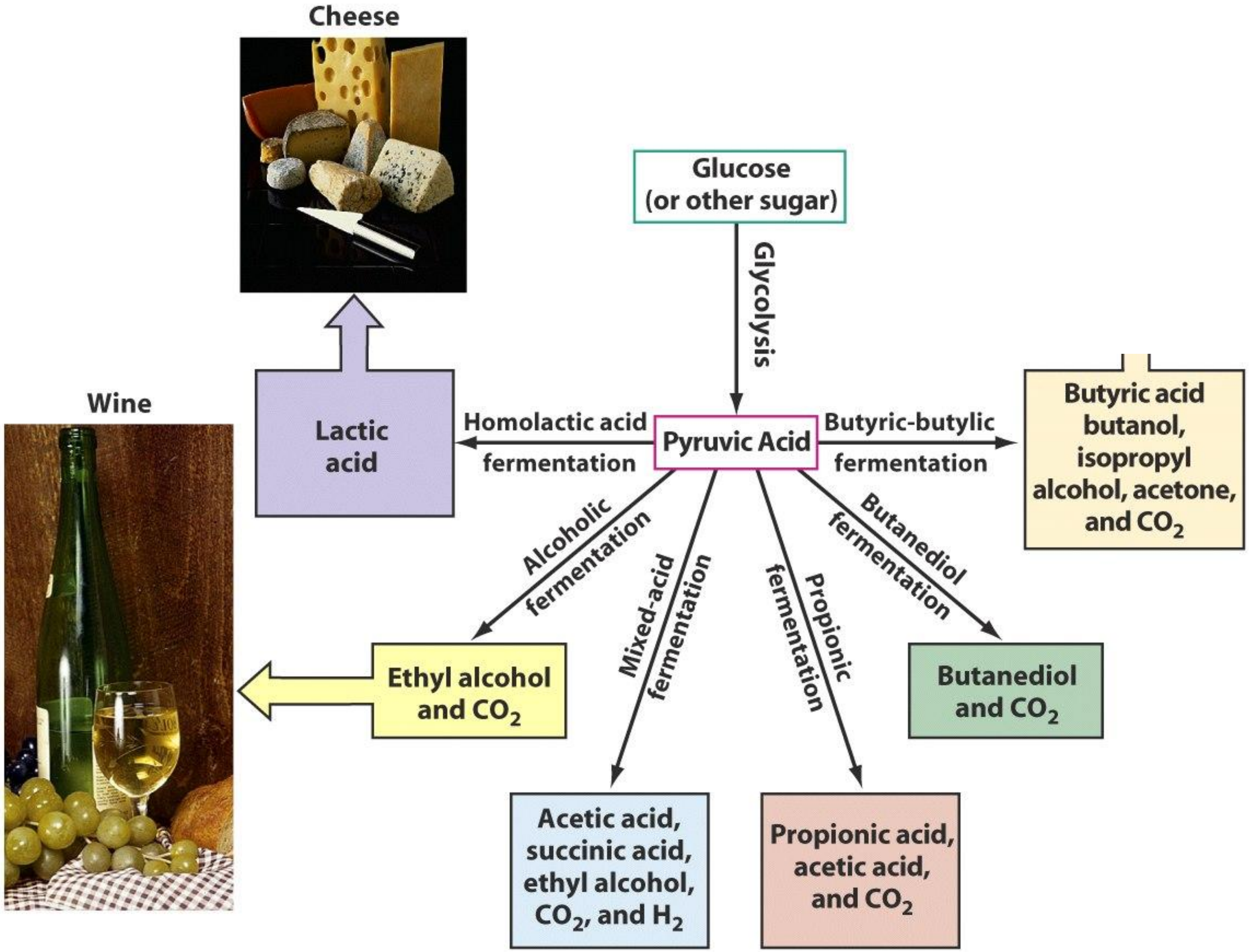


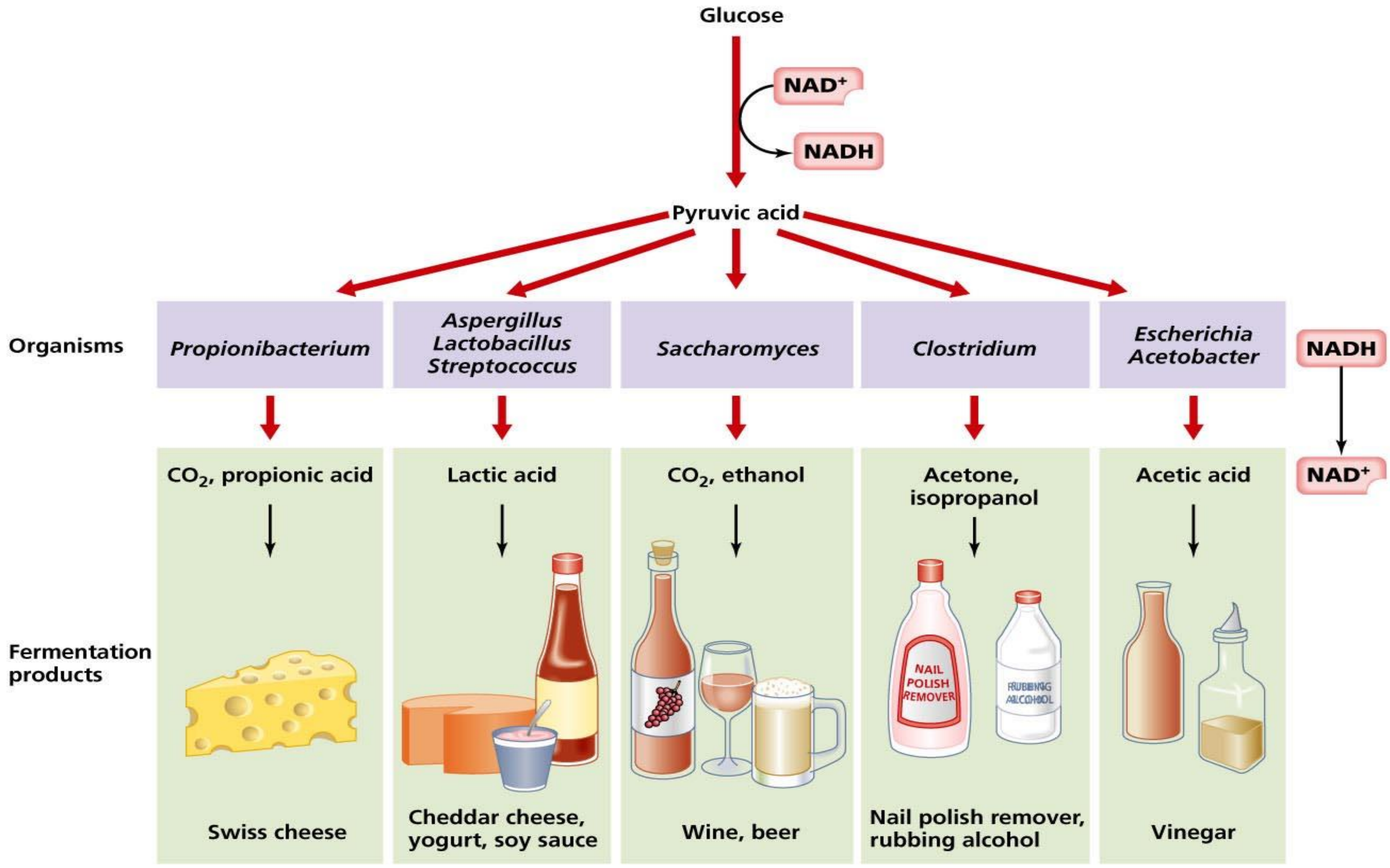
Figure 5-12 Microbiology, 6/e

Fermentasi

- Contoh tipe fermentasi
  - Fermentasi asam Lactat
    - Ditemukan pada bakteri;
      contoh: *Streptococcus cremoris, Lactobacillus acidophilus*
  - Fermentasi campuran (Mixed acid fermentation)
    - Contoh: *Escherichia coli*
    - Dasara dari uji methyl red
  - Fermentasi 2,3-Butanediol
    - Contoh: *Enterobacter aerogenes*
    - Dasar dari Uji reaksi Voges-Proskauer

Tipe Fermentasi		
PATHWAY	**END PRODUCTS**	**EXAMPLES**
Lactic acid (Homolactic)	lactic acid (2 molecules)	*Lactobacillus*, *Enterococcus*, *Streptococcus* spp. Pathway can result in food spoilage
Heterolactic	lactic acid, ethanol and CO_2	*Leuconostoc* Used in sauerkraut production
Alcohol	ethanol and CO_2	*Saccharomyces* (yeast) Important in production of alcoholic beverages, bread and gasohol
Proprionic acid	proprionic acid and CO_2	*Proprionibacterium acnes*: metabolizes fatty acids in oil glands to proprionic acid *Proprionibacterium freudenreichii* gives flavor to and produces holes in Swiss cheese
Butyric acid	Butyric acid, butanol, acetone, isopropyl alcohol and CO_2	*Clostridium* spp. produce butyric acid that causes butter and cheese spoilage Butanol and acetone are important organic solvents
Butanediol	Butanediol and CO_2	Butanediol produced by *Enterobacter*, *Serratia*, *Erwinia* and *Klebsiella*. The intermediate, acetoin, is detected by the **VP test**. This test is used together with the MR test often to distinguish Enterobacter from Escherichia coli (VP-). E.coli is an important indicator organism of fecal contamination.
Mixed acid	ethanol, acetic acid, lactic acid, succinic acid, formic acid and CO_2	Variety of acid products. Typically carried out by members of the Enterobacteriaceae including *E. coli*, *Salmonella* and *Shigella* pathogens. Products detected by reaction with **methyl red** pH indicator.
Methanogenesis	methane and CO_2	certain Archaea. majority of earth's methane production

Mikroorganisme dan Produk fermentasi



FERMENTASI ASAM LAKTAT

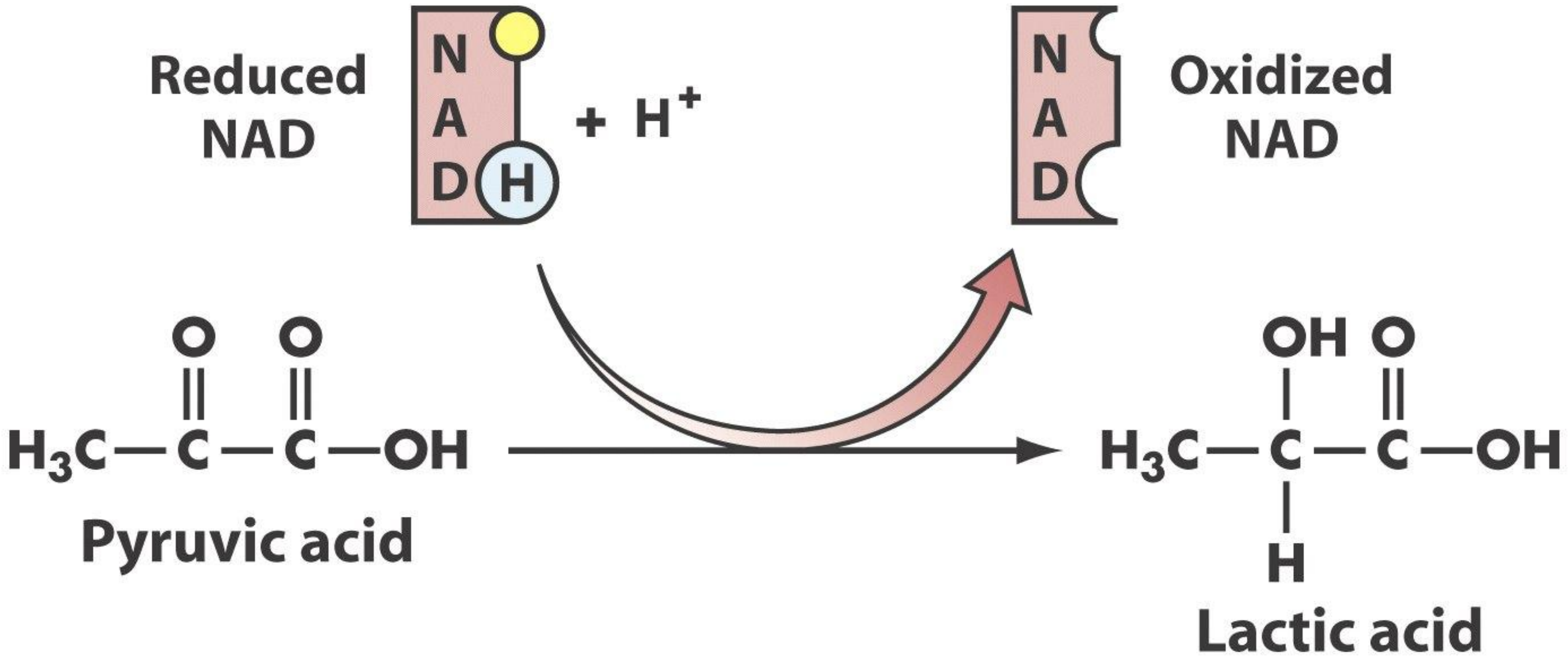


Figure 5-13 Microbiology, 6/e

FERMENTASI ALKOHOL

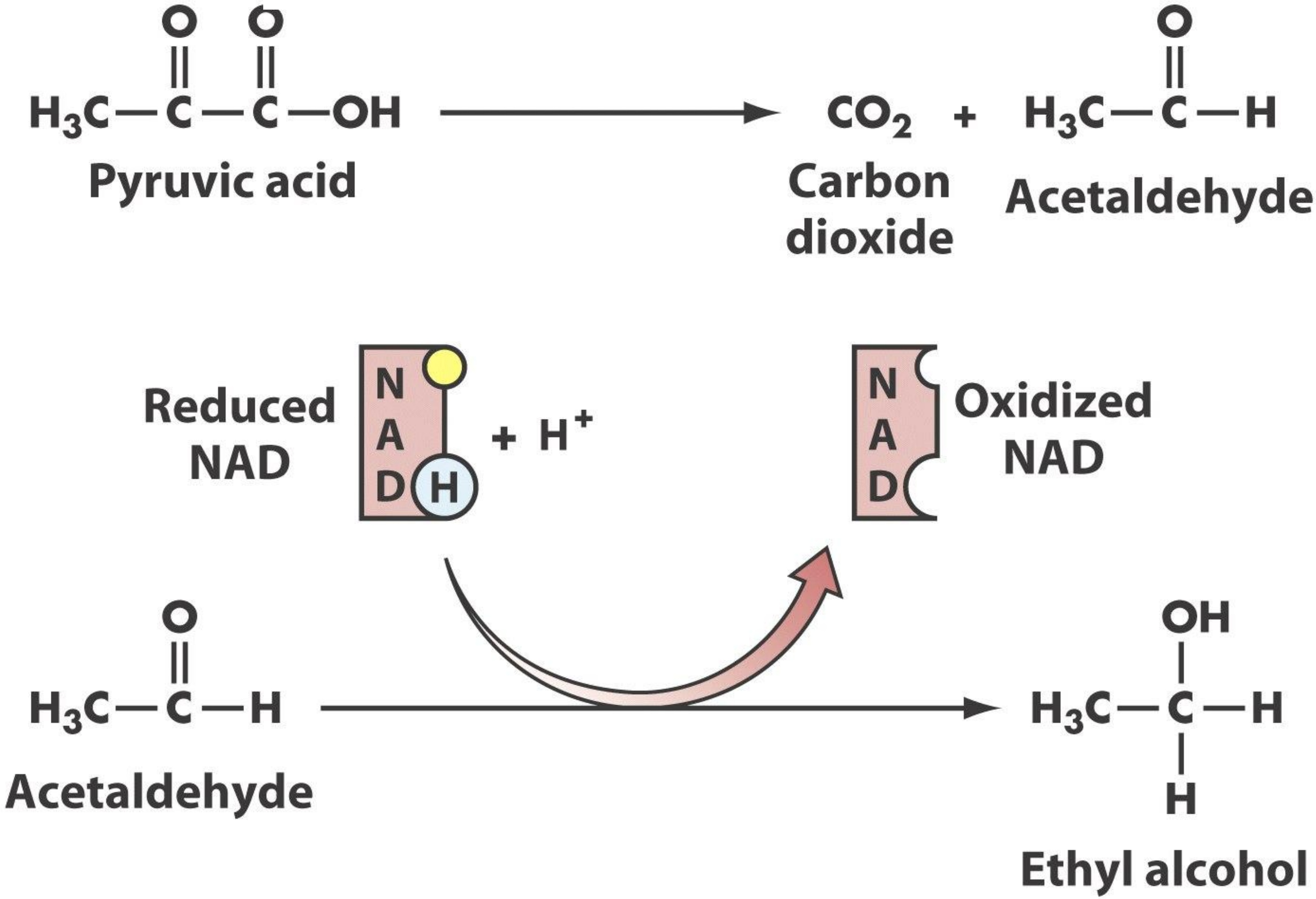
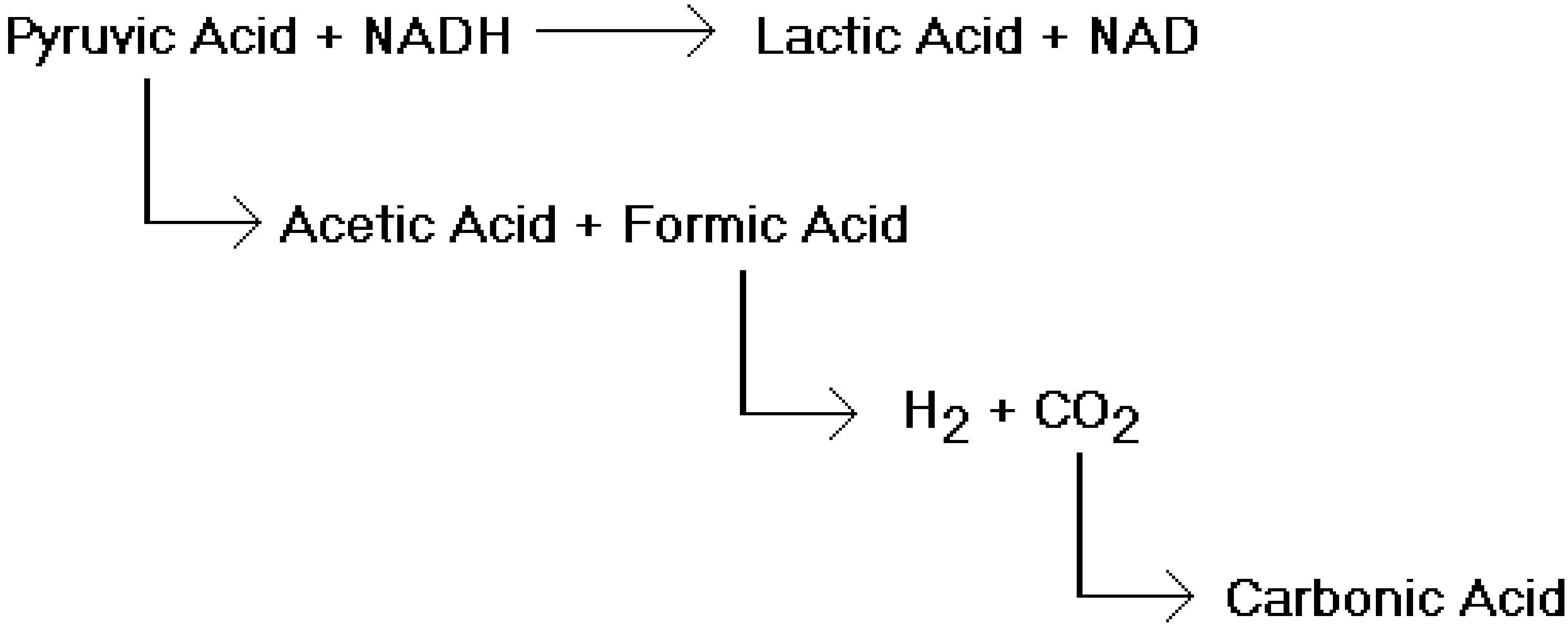


Figure 5-14 Microbiology, 6/e

Fermentation Pathways: Mixed acid fermentation



RESPIRASI AEROB

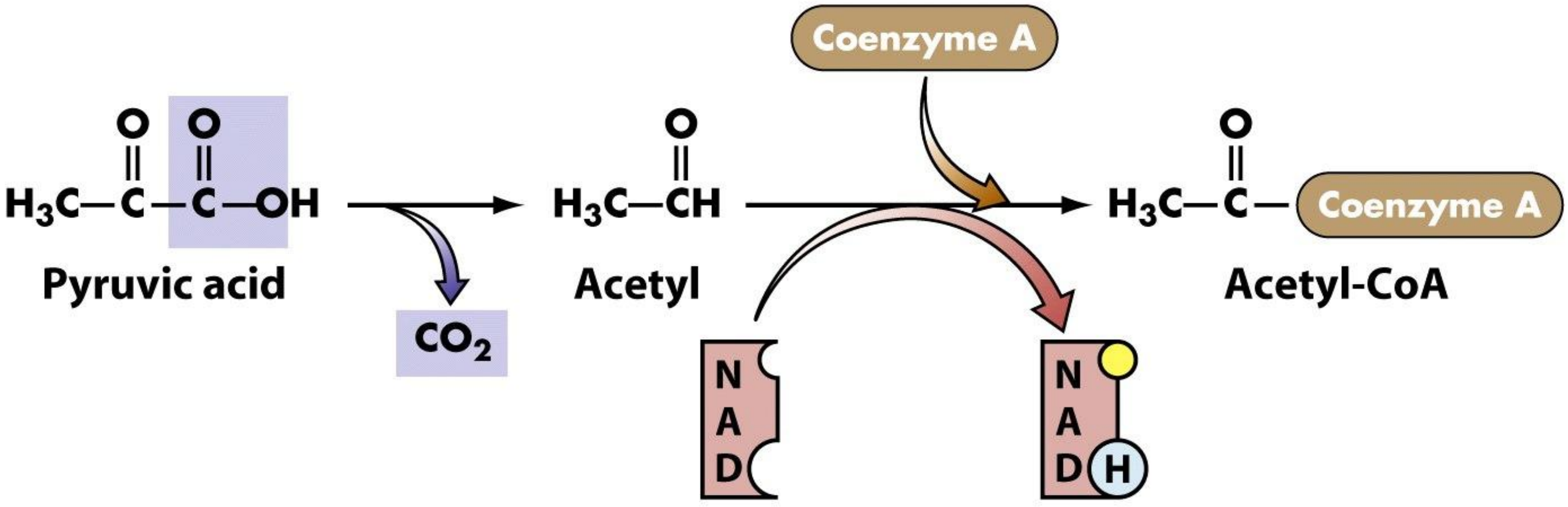


Figure 5-16 Microbiology, 6/e

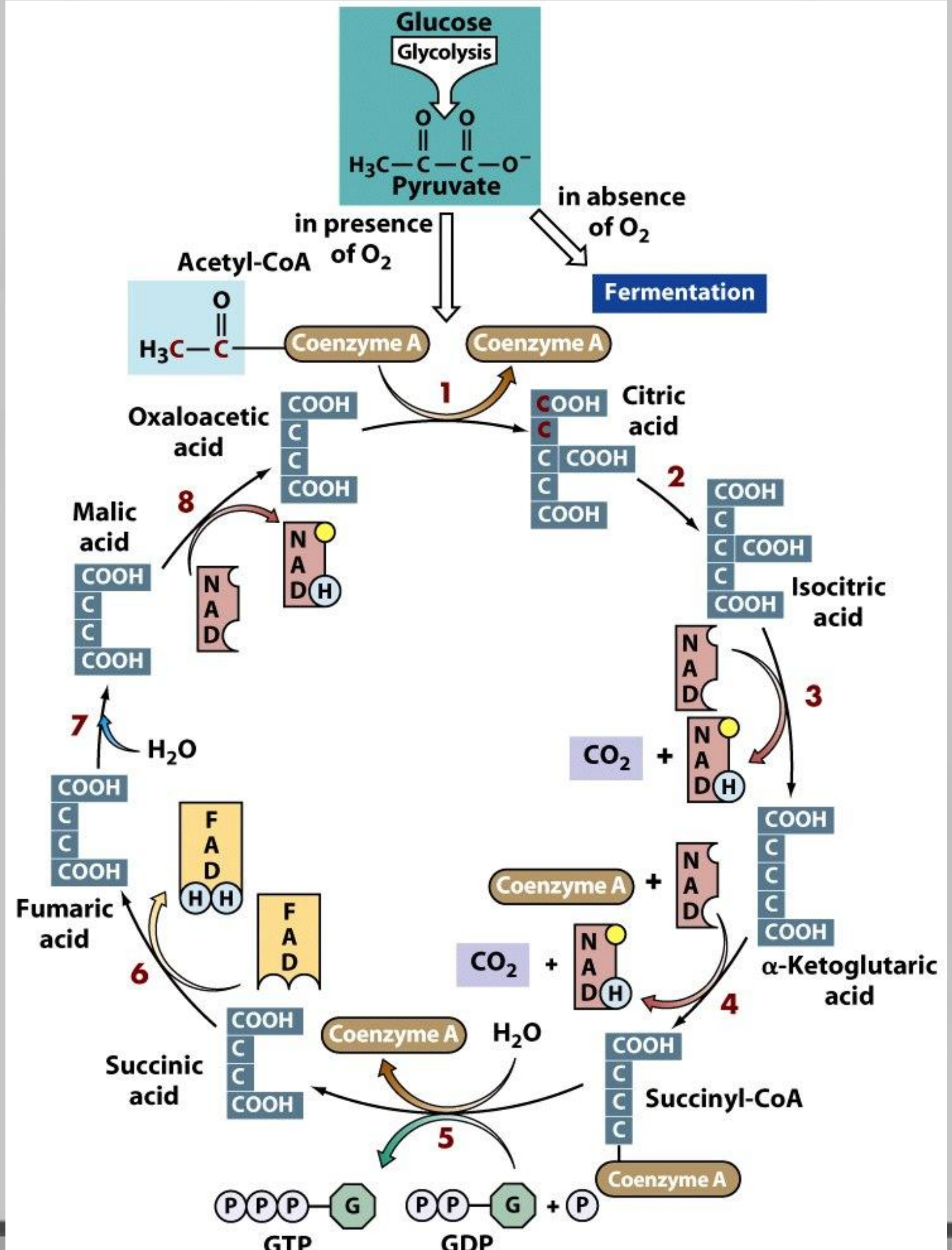
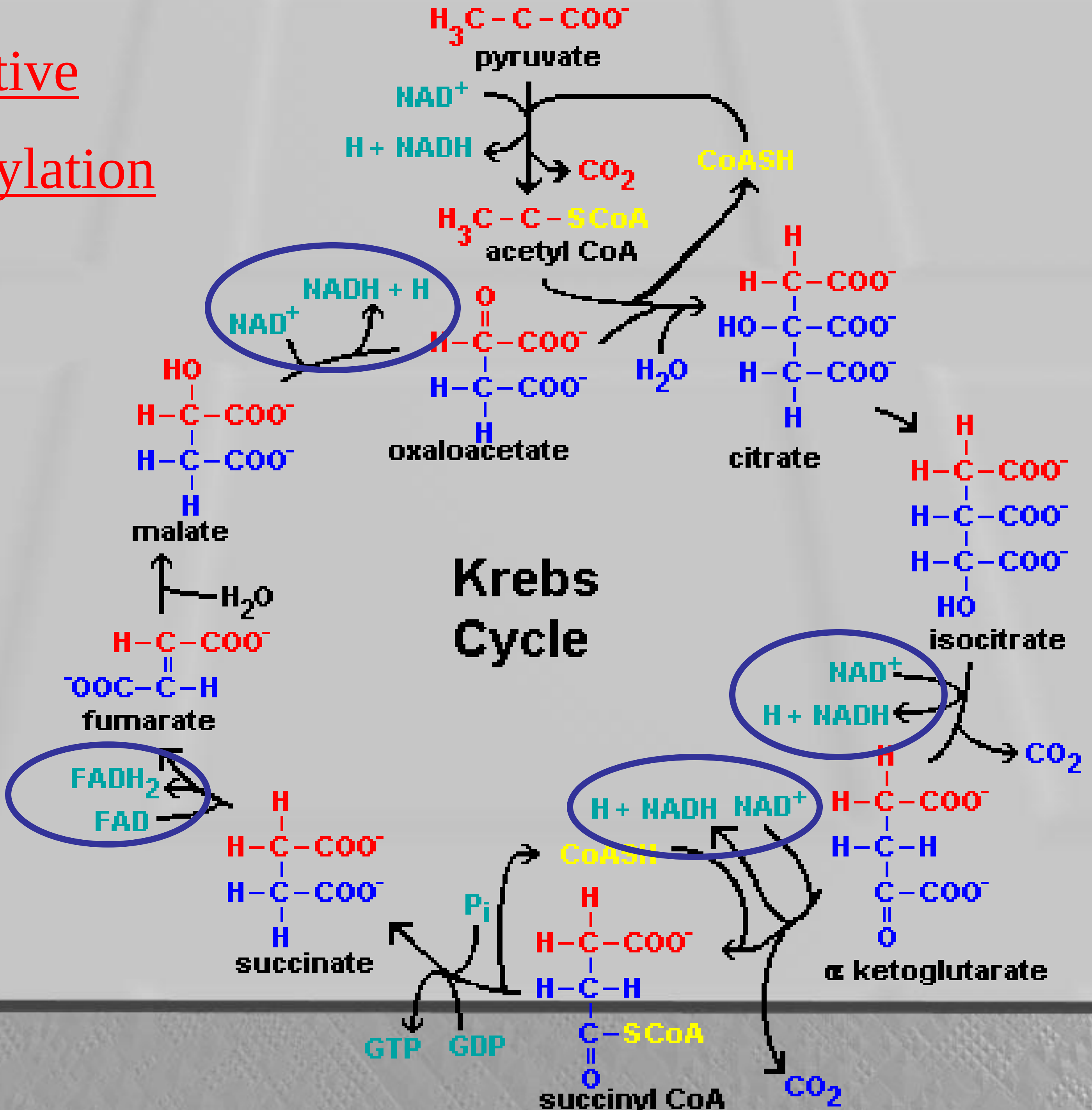


Figure 5-17 Microbiology, 6/e

Oxidative Phosphorylation



TRANSFER ELEKTRON

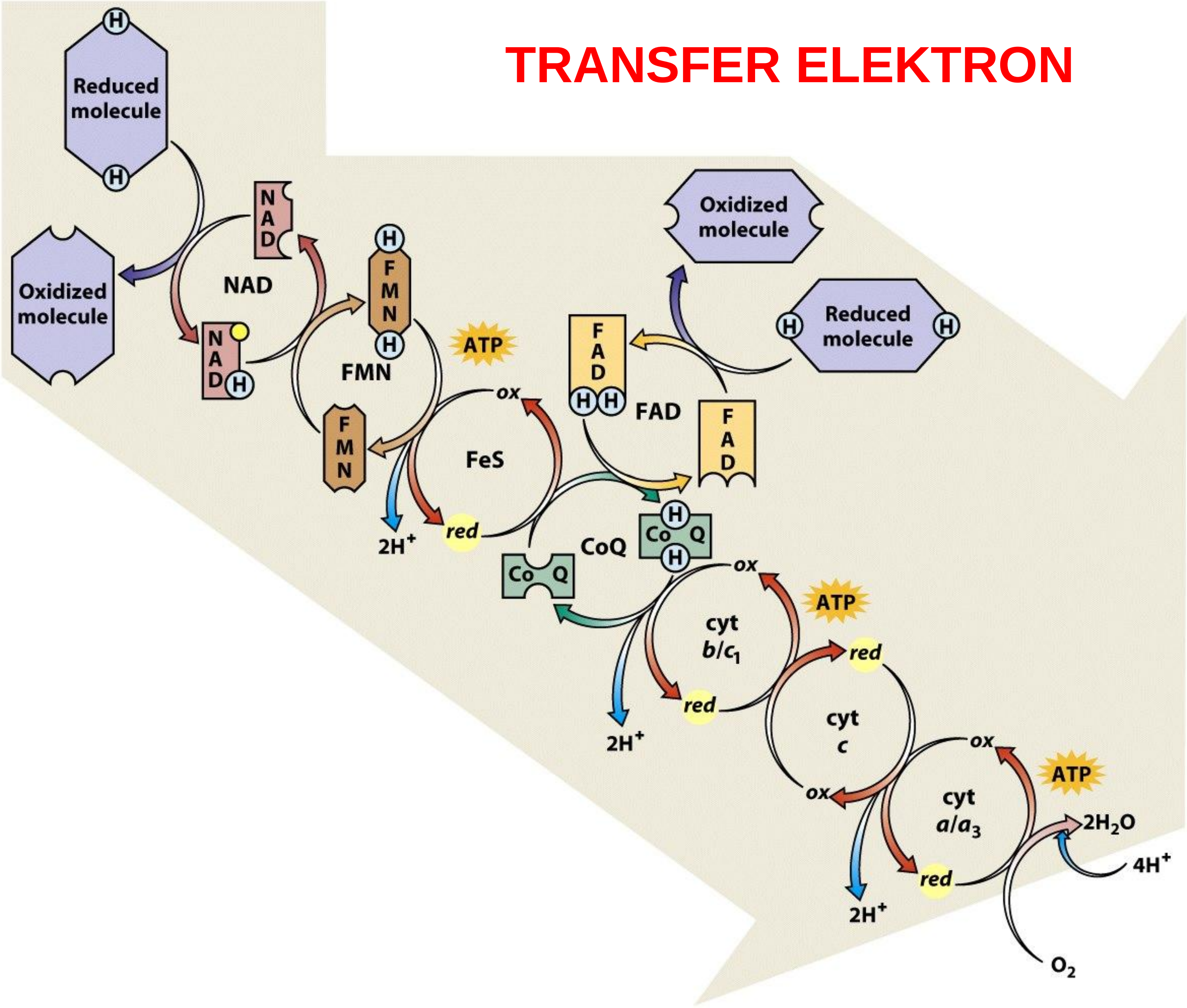


Figure 5-19 Microbiology, 6/e

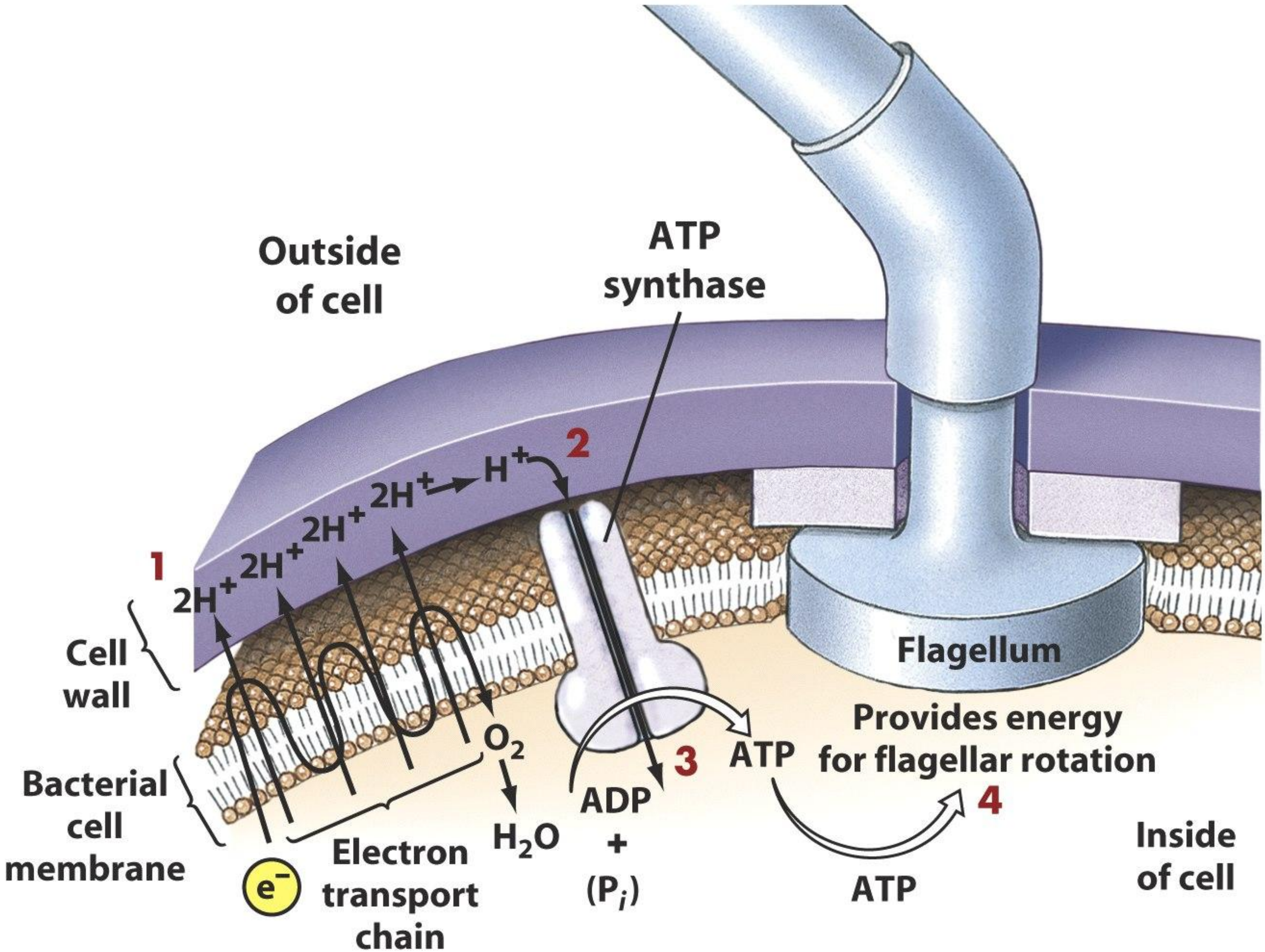
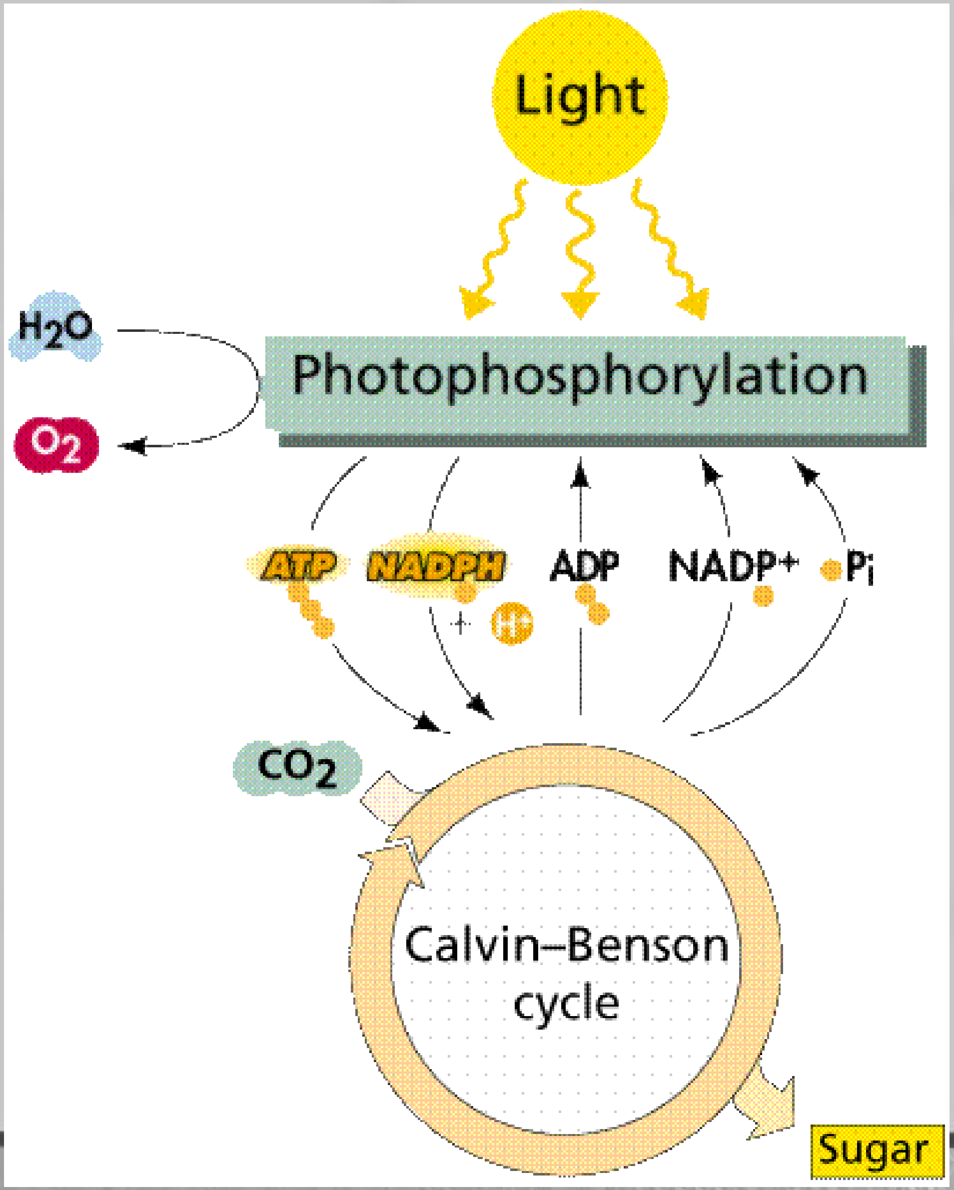


Figure 5-20 Microbiology, 6/e

Photosynthesis

- *Terjadi pada algae, tumbuhan dan bbrp procaryotes*

- *Terdiri atas 2 reaksi utama:* *photophosphorylation* *reaksi terang) dan fiksasi Carbon dioksida reaksi gelap)*



Photosynthesis

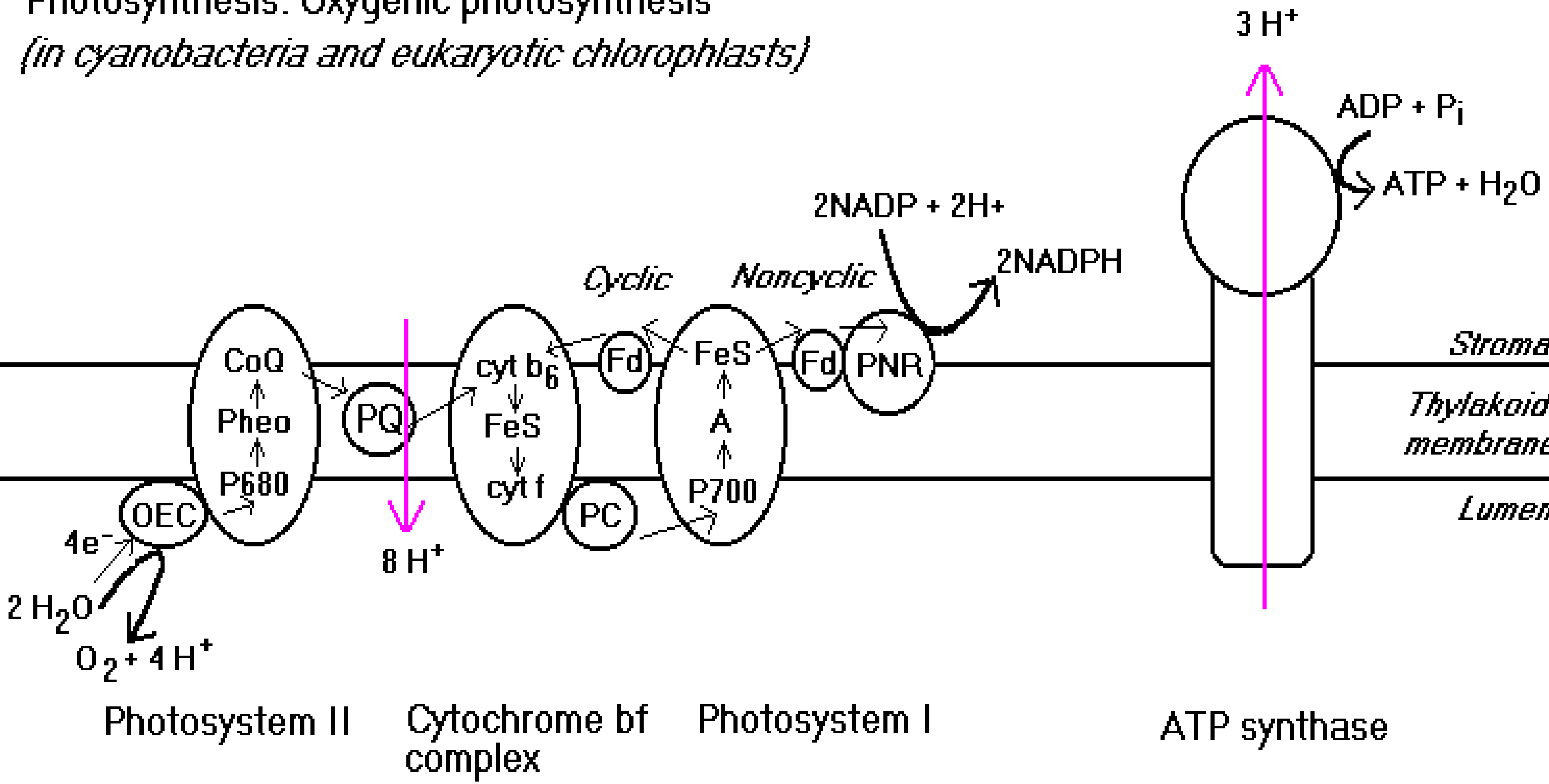
- Pada kelompok bakteri dapat dibedakan atas : anoxygenic dan oxygenic photosynthesis
- Anoxygenic photosynthesis : proses fotosintesis yang tidak menghasilkan O2 dan H2S berperan sebagai donor elektron.
- Anoxygenic photosynthesis
  - Ditemukan pada:
    - Green sulfur bacteria (e.g. *Chlorobium*)
    - Green nonsulfur bacteria (e.g. *Chloroflexus*)
    - Purple sulfur bacteria (e.g. *Chromatium*)
    - Purple nonsulfur bacteria (e.g. *Rhodobacter*)
- Oxygenic photosynthesis
  - Ditemukan pada Cyanobacteria (blue-green algae) dan organisme eukaryotic yang memiliki chloroplast
  - Donor electron adalah H_2O: teroksidasi membentuk O_2
  - Melalui 2 photosystems: PSI dan PSII
  - Fungsi umum menghasilkan NADPH dan ATP untuk fiksasi karbon

Photosynthesis

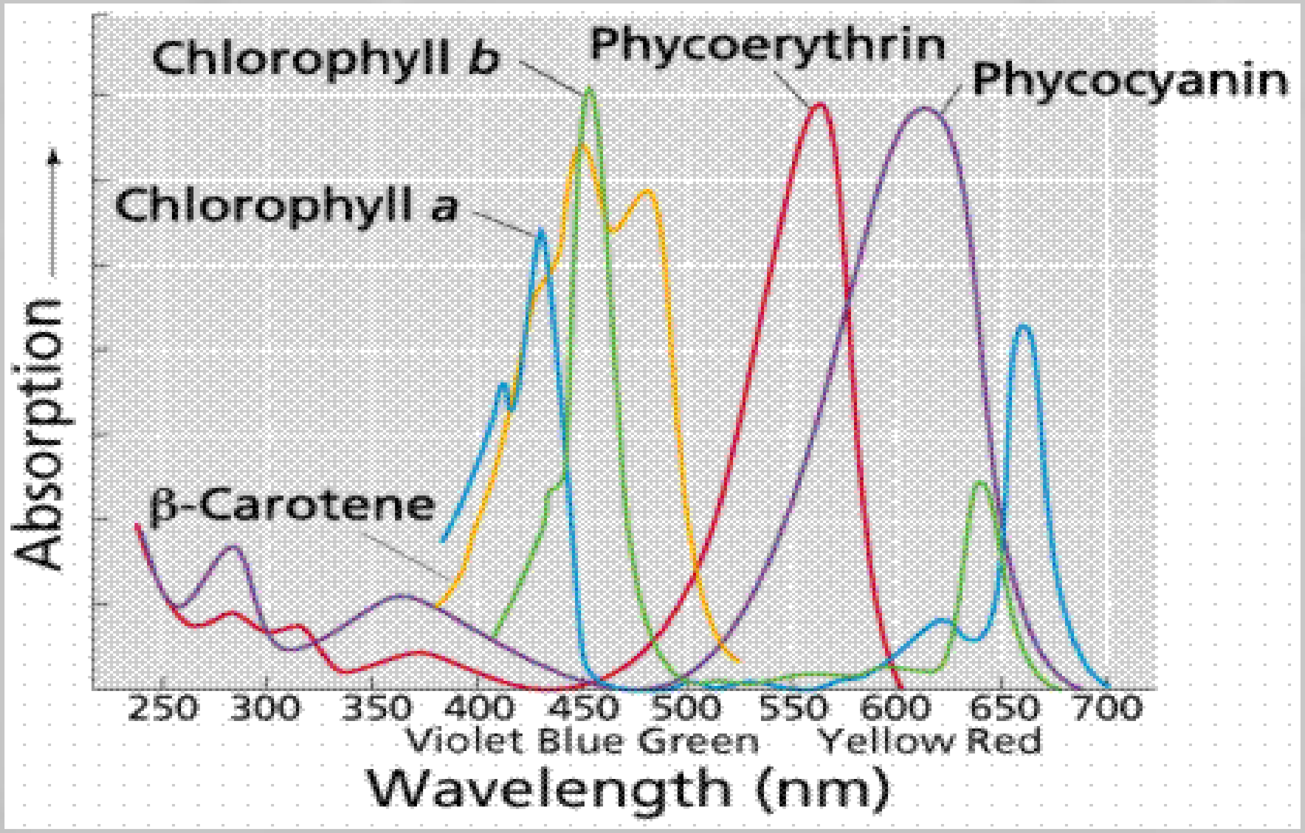
- Anoxygenic photosynthesis
  - Donor Electron bervariasi:
    - H_2S atau S_o pada green dan purple sulfur bacteria
    - H_2 atau senyawa organik pada green and purple nonsulfur bacteria
  - Hanya memiliki ssatu photosystem
    - Pada green bacteria, photosystem sama dengan PSI
    - Pada purple bacteria, photosystem sama dengan PSII
  - Fungsi utama adalah menghasilkan ATP melalui cyclic photophosphorylation

Photosynthesis: Oxygenic photosynthesis

(in cyanobacteria and eukaryotic chloroplasts)

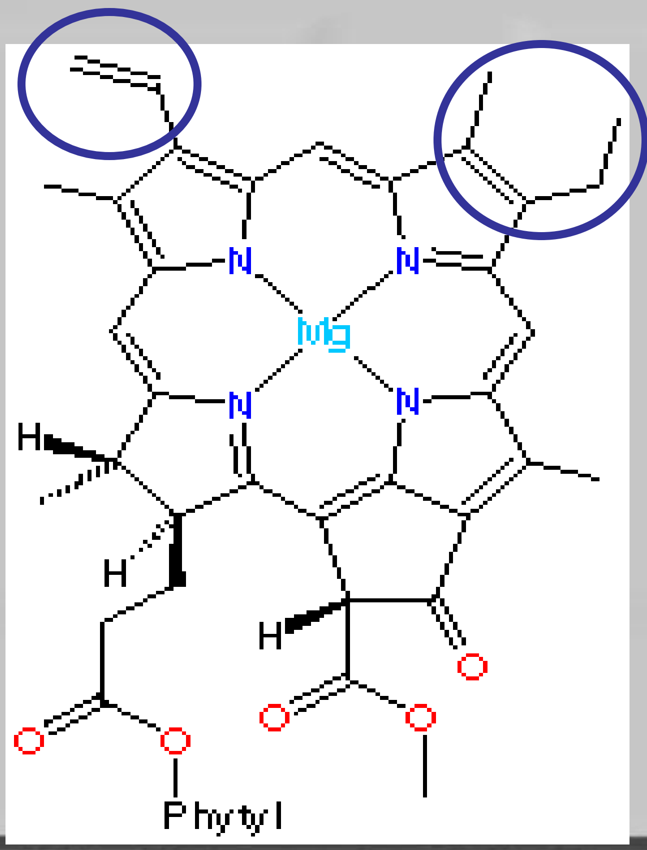


- *Macam Klorofil pada eukaryot dan prokaryot*

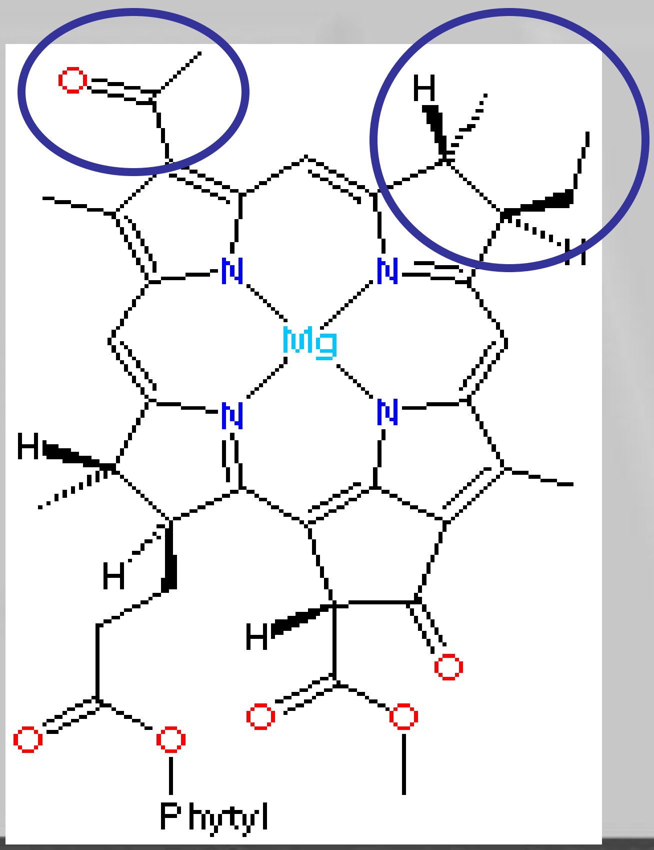


- Chlorophylls are photosynthetic pigments in phototrophic eucaryotes and cyanobacteria

- bacteriochlorophylls adalah pigmen fotosintesis yang ditemukan pada bakteri
- Panjang gelombang berkisar dari - nm

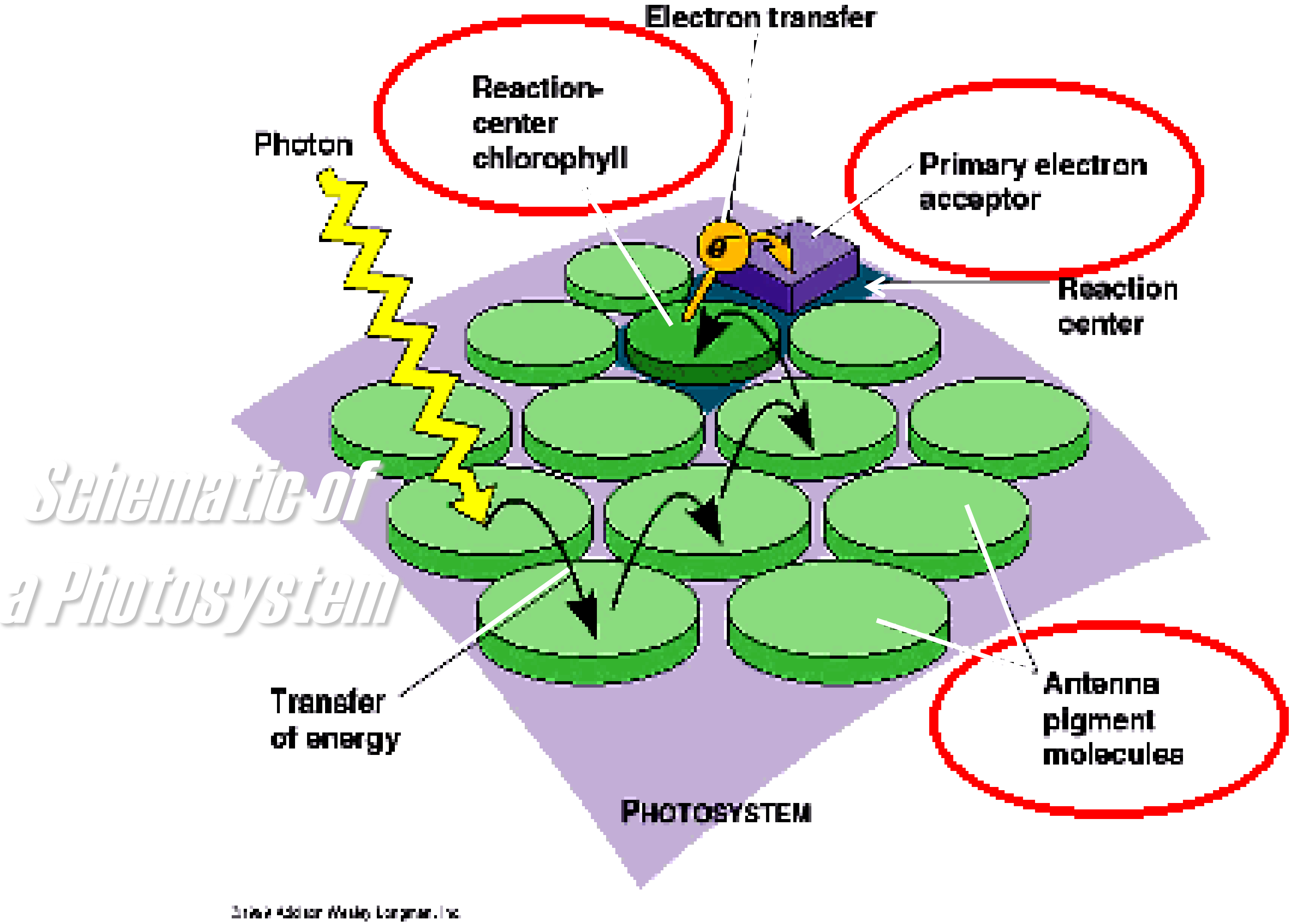


Chlorophyll a

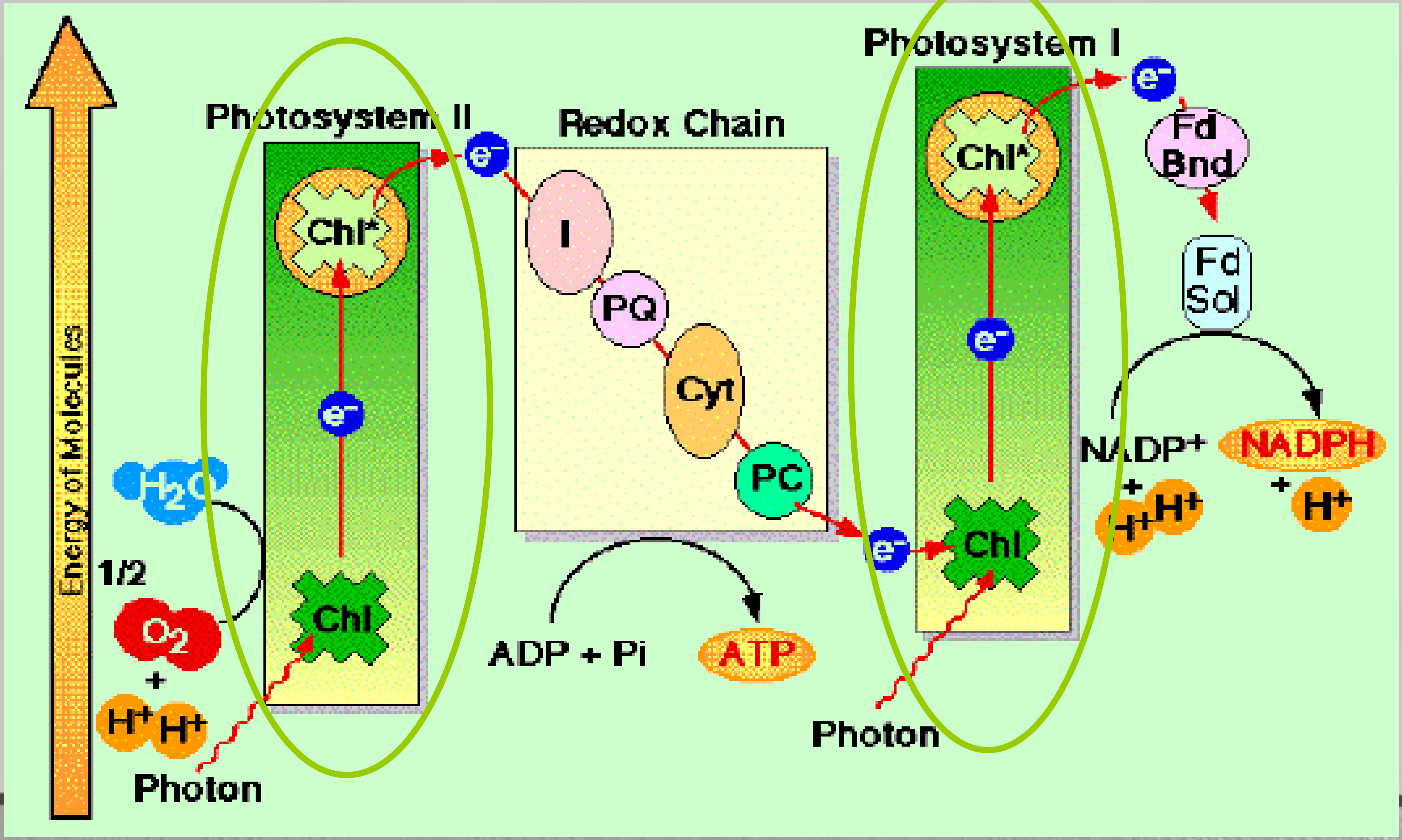


Bacteriochlorophyll a

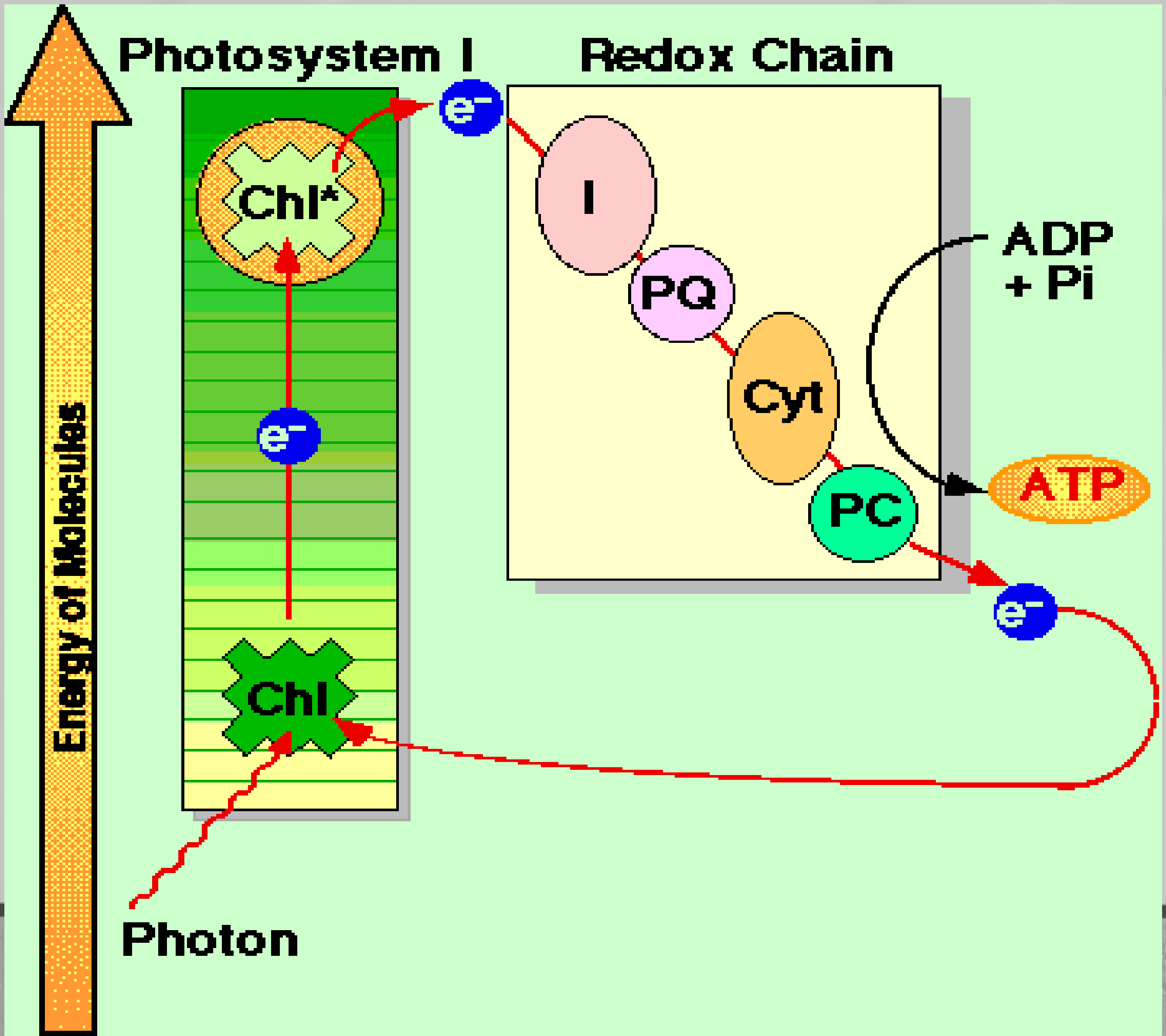
The Light Reactions

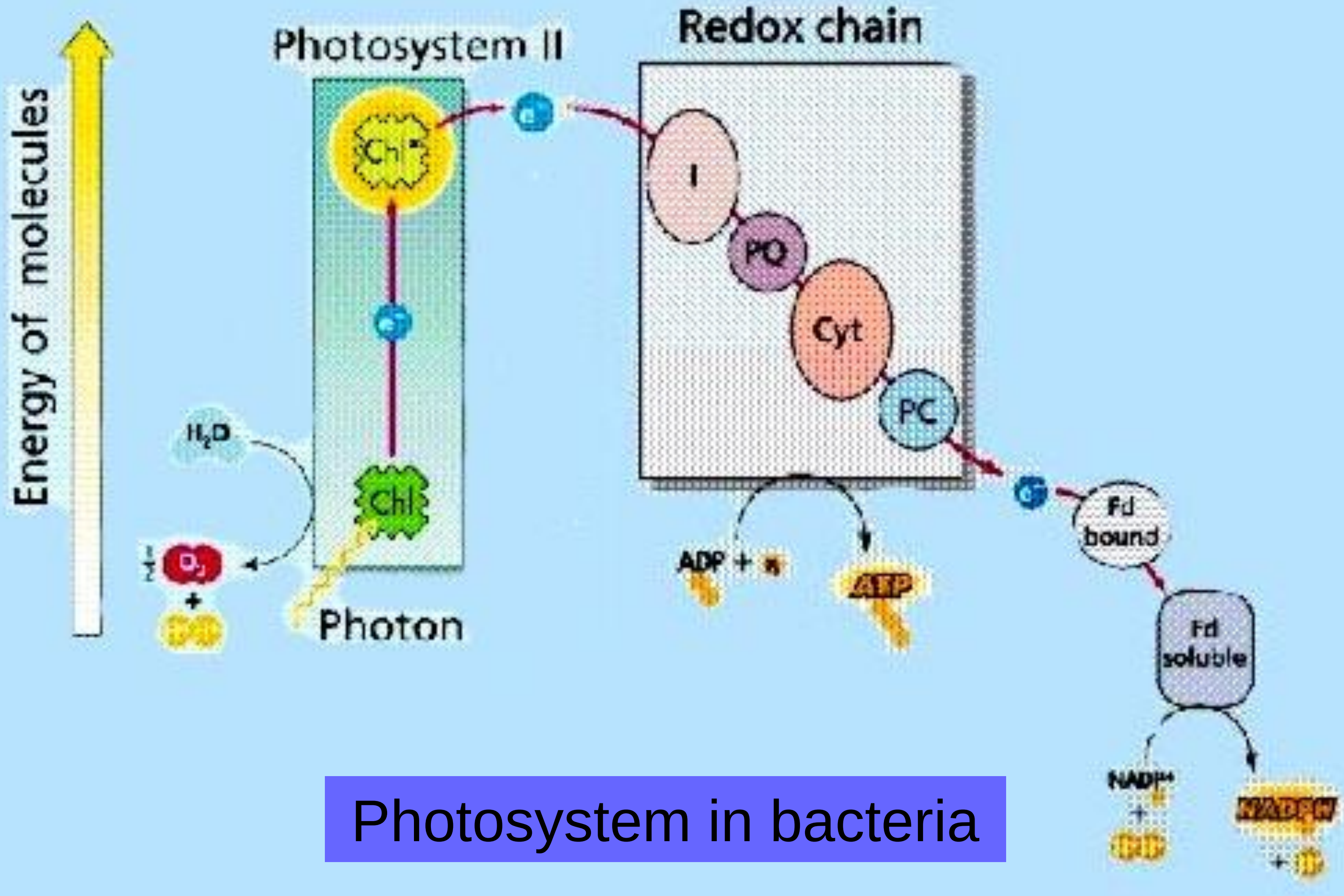


Non-Cyclic Electron Flow (Z-scheme)



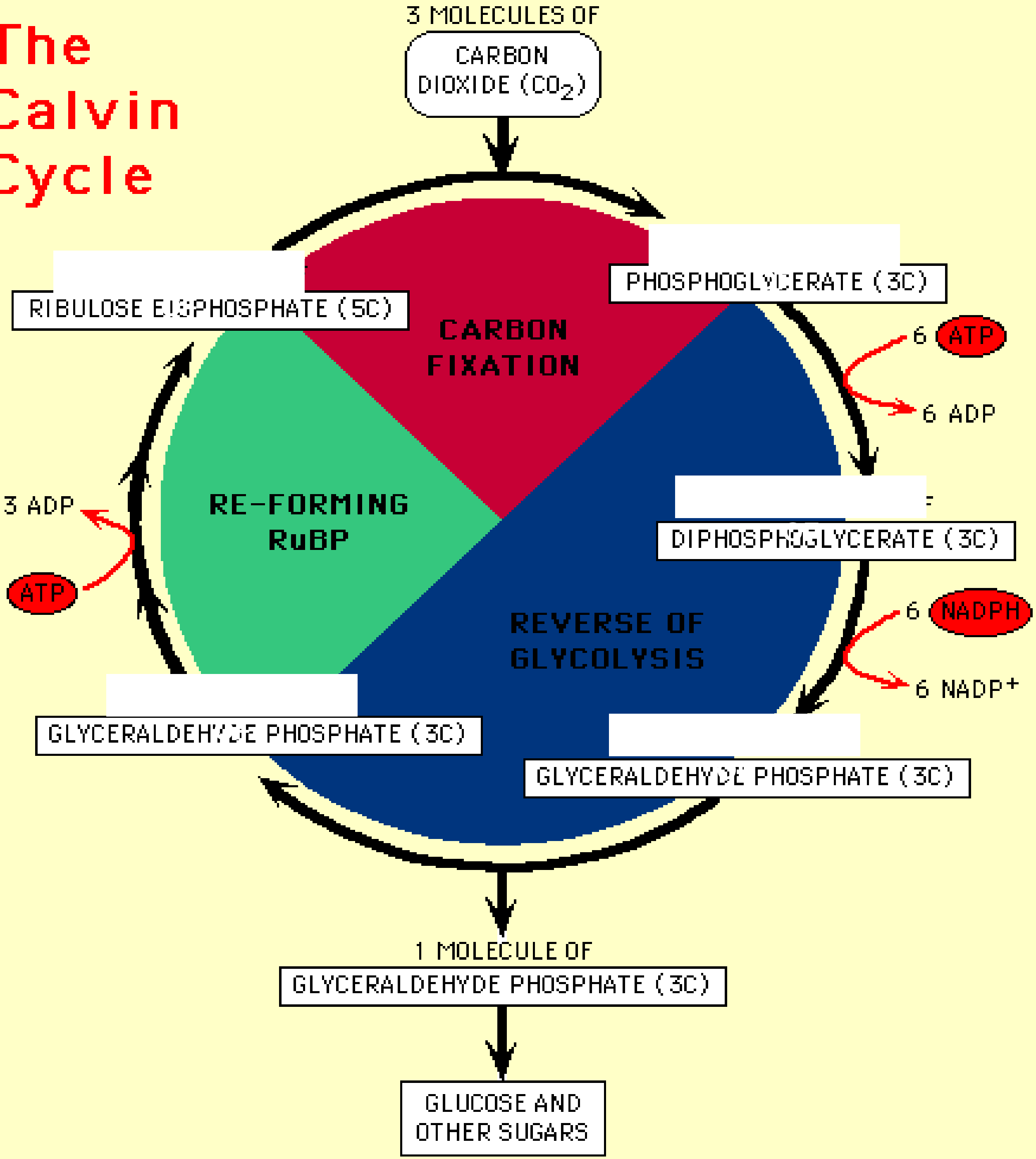
Cyclic Electron Flow





Photosystem in bacteria

The Calvin Cycle



PERBEDAAN FOTOSINTESIS PADA TUMBUHAN DAN BAKTERI

Kriteria pembeda	**plant photosynthesis**	**bacterial photosynthesis**
organisms	plants, algae, cyanobacteria	purple and green bacteria
type of chlorophyll	chlorophyll a absorbs 650-750nm	bacteriochlorophyll absorbs 800-1000nm
Photosystem I (cyclic photophosphorylation)	present	present
Photosystem I (noncyclic photophosphorylation)	present	absent
Produces O_2	yes	no
Photosynthetic electron donor	H_2O	H_2S, other sulfur compounds or certain organic compounds

Perbedaan fotosintesis pada prokariot dan eukariot

Photosynthesis as we know it on Earth

	Eukaryotes	**Prokaryotes**		
		Cyanobacteria	**Purple bacteria**	**Green bacteria**
Electron donors	H_2O	H_2O, some use H_2S	H_2S, S^0, H_2, S_2O_3, organic compounds	H_2S, S^0, H_2, S_2O_3, organic compounds
Site of photosynthesis	Thylakoids	Thylakoids	Cell membrane	Cytochromes
Oxygenic	Yes	Yes	No	No
Chlorophyll type	Chlorophyll a	Chlorophyll a	Bacteria-chlorophyll a and b	Bacteria-chlorophyll a and c, d, or e
Photosystem I	Present	Present	Present	Present
Photosystem II	Present	Present	Absent	Absent

BIOSINTESIS KOMPONEN SEL BAKTERI

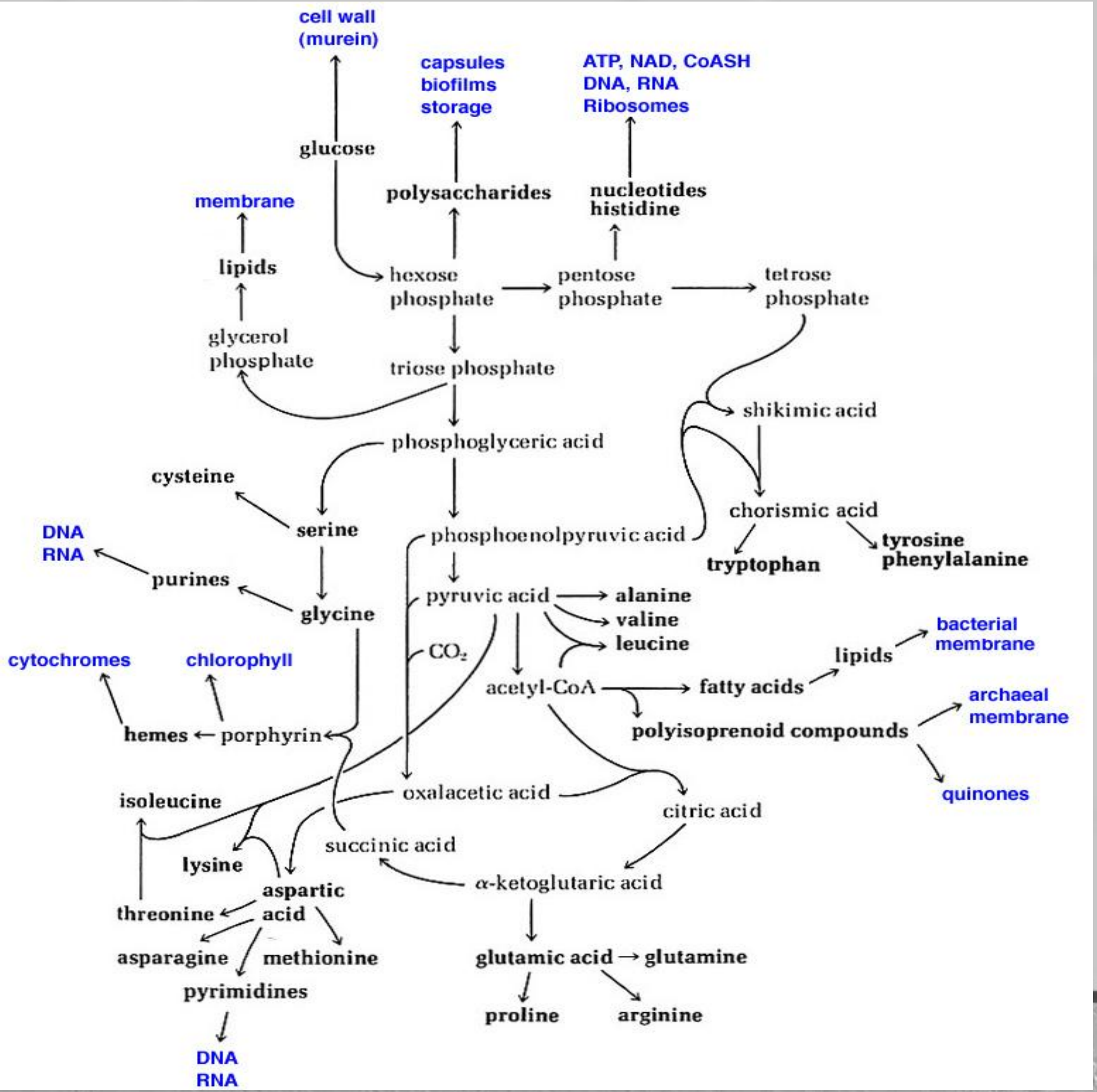


Table 5.6 The Twelve Precursor Metabolites

	Pathway that Generates the Metabolite	Examples of Macromolecule Synthesized from Metabolite[a]	Examples of Functional Use
Glucose 6-phosphate	Glycolysis	Lipopolysaccharide	Outer membrane of cell wall
Fructose 6-phosphate	Glycolysis	Peptidoglycan	Cell wall
Glyceraldehyde 3-phosphate (G3P)	Glycolysis	Glycerol portion of lipids	Fats–energy storage
Phosphoglyceric acid	Glycolysis	Amino acids: cysteine, selenocysteine, glycine, and serine	Enzymes
Phosphoenolpyruvic acid (PEP)	Glycolysis	Amino acids: phenylalanine, tryptophan, and tyrosine	Enzymes
Pyruvic acid	Glycolysis	Amino acids: alanine, leucine, and valine	Enzymes
Ribose 5-phosphate	Pentose phosphate pathway	DNA, RNA, amino acid, and histidine	Genome, enzymes
Erythrose 4-phosphate	Pentose phosphate pathway	Amino acids: phenylalanine, tryptophan, and tyrosine	Enzymes
Acetyl-CoA	Krebs cycle	Fatty acid portion of lipids	Cytoplasmic membrane
α-Ketogluteric acid	Krebs cycle	Amino acids: arginine, glutamic acid, glutamine, and proline	Enzymes
Succinyl-CoA	Krebs cycle	Heme	Cytochrome electron carrier
Oxaloacetate	Krebs cycle	Amino acids: aspartic acid, asparagine, isoleucine, lysine, methionine, and threonine	Enzymes

[a]Examples given apply to the bacterium *E. coli*.

Chemolithotrophy

- Gambaran metabolisme Chemolithotrophy
  - Electron dipindahkan dari suatu donor elektron yang tereduksi
  - Elektron melewati membran terikat transpor elektron berhubungan dengan sistesis ATP dan NADH
  - ATP dan NADH digunakan untuk mengubah CO_2 menjadi karbohydrat

Chemolithotrophy

- Contoh donor elektron
  - Ammonia (NH_4^+) $\rightarrow$ Nitrite (NO_2^-) in *Nitrosomonas*
  - Nitrite (NO_2^-) $\rightarrow$ Nitrate (NO_3^{2-}) in *Nitrobacter*
  - Hydrogen sulfide (H_2S) $\rightarrow$ Sulfur (S_o) in *Thiobacillus* and *Beggiatoa*
  - Sulfur (S_o) $\rightarrow$ Sulfate (SO_4^{2-}) in *Thiobacillus*
  - Hydrogen (H_2) $\rightarrow$ Water (H_2O) in *Alcaligenes*

Chemolithotrophy

- Contoh akseptor electron
  - Oxygen (O_2) $\rightarrow$ air (H_2O) pada kebanyakan organisme
  - Carbon dioxide (CO_2) $\rightarrow$ Methane (CH_4) pada methanogenic bacteria

Chemolithotrophy

siological groups of lithotrophs

physiological group	energy source	oxidized end product	organism
hydrogen bacteria	H_2	H_2O	*Alcaligenes*, *Pseudomonas*
methanogens	H_2	H_2O	*Methanobacterium*
carboxydobacteria	CO	CO_2	*Rhodospirillum*, *Azotobacter*
nitrifying bacteria*	NH_3	NO_2	*Nitrosomonas*
nitrifying bacteria*	NO_2	NO_3	*Nitrobacter*
sulfur oxidizers	H_2S or S	SO_4	*Thiobacillus*, *Sulfolobus*
iron bacteria	Fe^{++}	Fe^{+++}	*Gallionella*, *Thiobacillus*

Terima kasih...