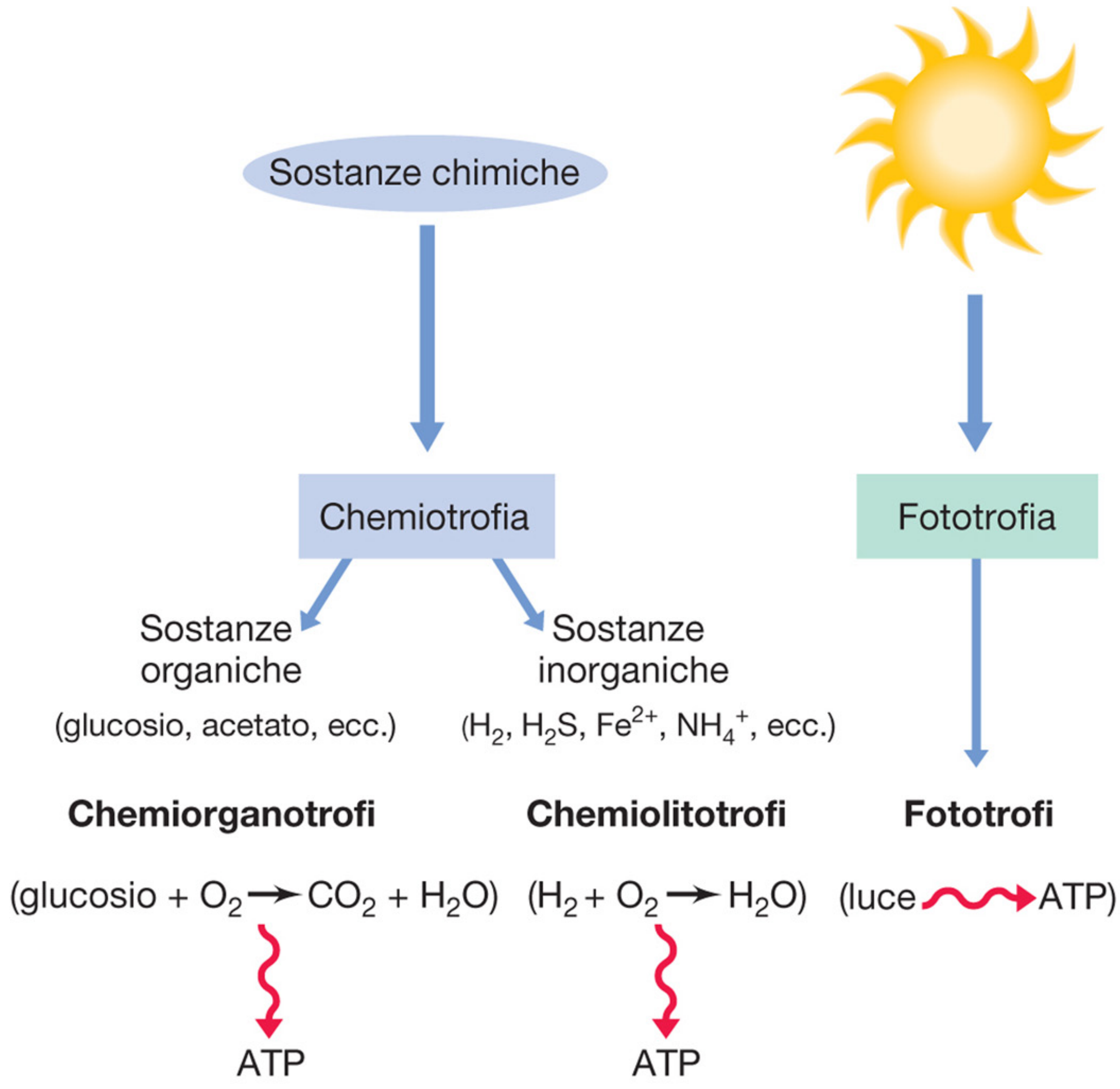
13. APPLIED BIOCHEMISTRY

Energy source

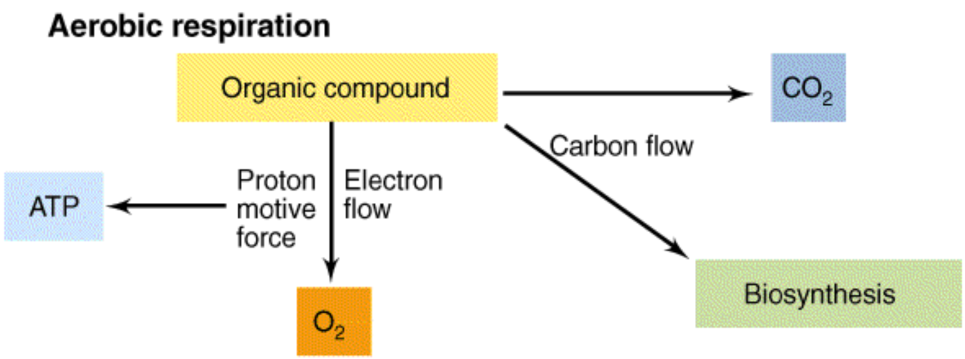


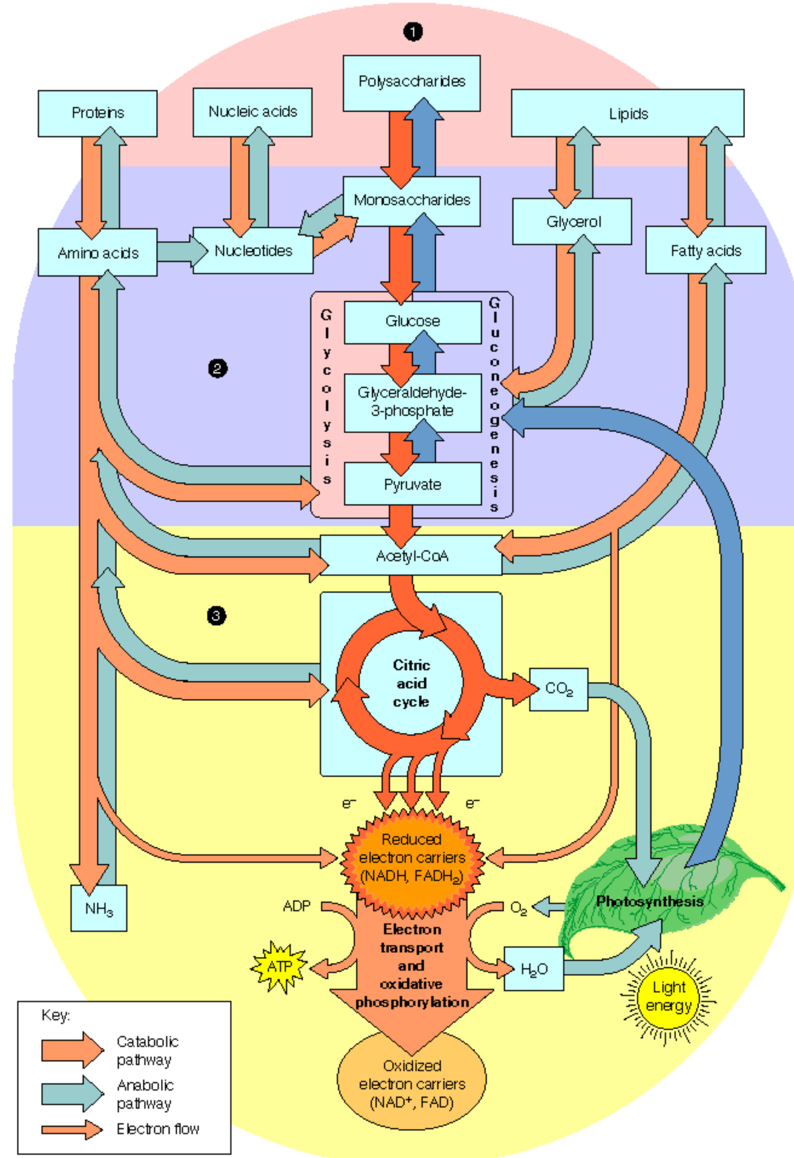
M.T. Madigan, J.M. Martinko **Brock, Biologia dei Microrganismi**

Energy and carbon source

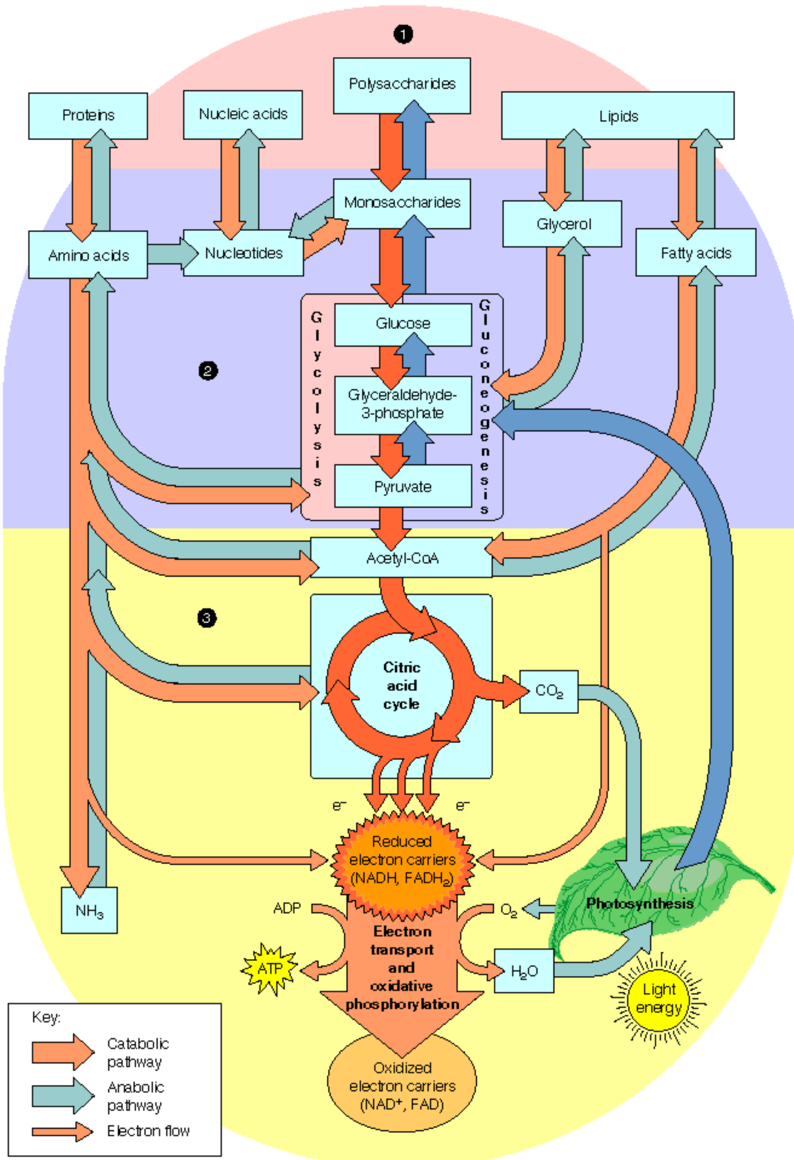
Carbon Source	Energy Source: Light (*photo-*)	Energy Source: Chemical compounds (*chemo-*)
Carbon dioxide (*auto-*)	***Photoautotrophs*** • Plants, algae, and cyanobacteria use H_2O to reduce CO_2, producing O_2 as a byproduct • Photosynthetic green sulfur and purple sulfur bacteria do not use H_2O nor produce O_2	***Chemoautotrophs*** • Hydrogen, sulfur, and nitrifying bacteria
Organic compounds (*hetero-*)	***Photoheterotrophs*** • Green nonsulfur and purple nonsulfur bacteria	***Chemoheterotrophs*** • Aerobic respiration: most animals, fungi, and protozoa, and many bacteria • Anaerobic respiration: some animals and bacteria • Fermentation: some bacteria and yeasts

Alternative energy generating patterns

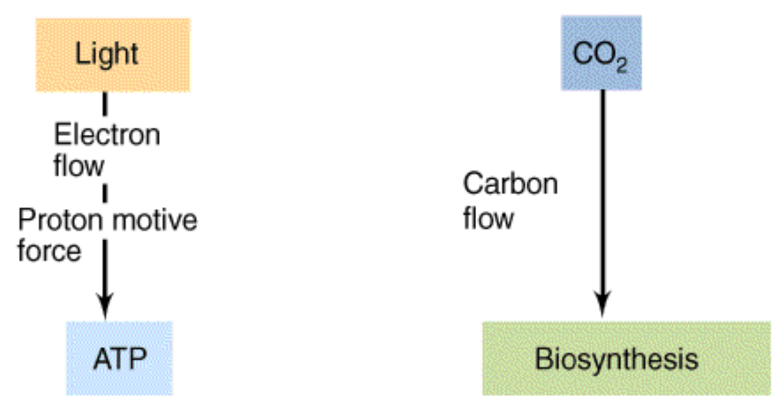




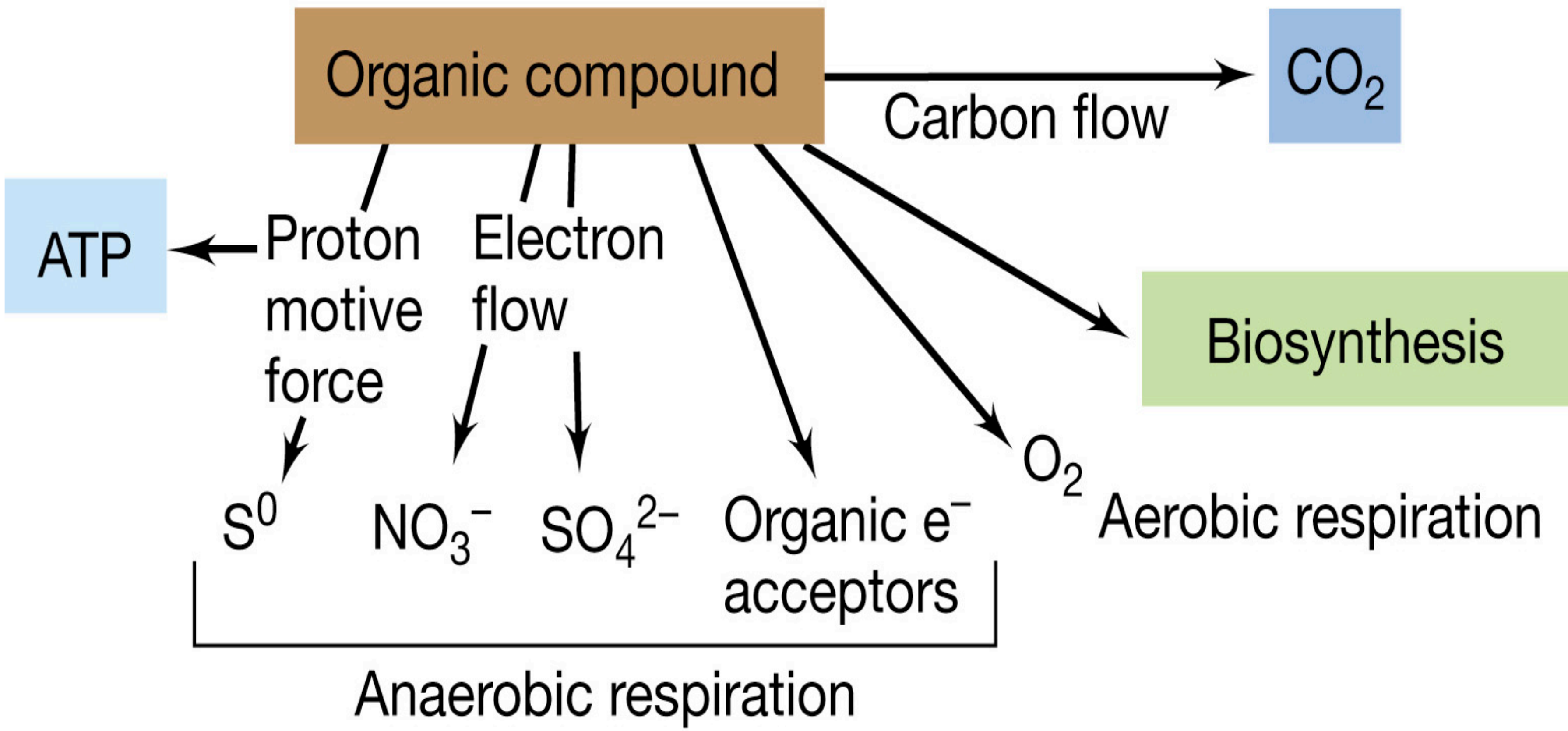
Alternative energy generating patterns



Phototrophic metabolism



Chemoorganotrophic metabolism

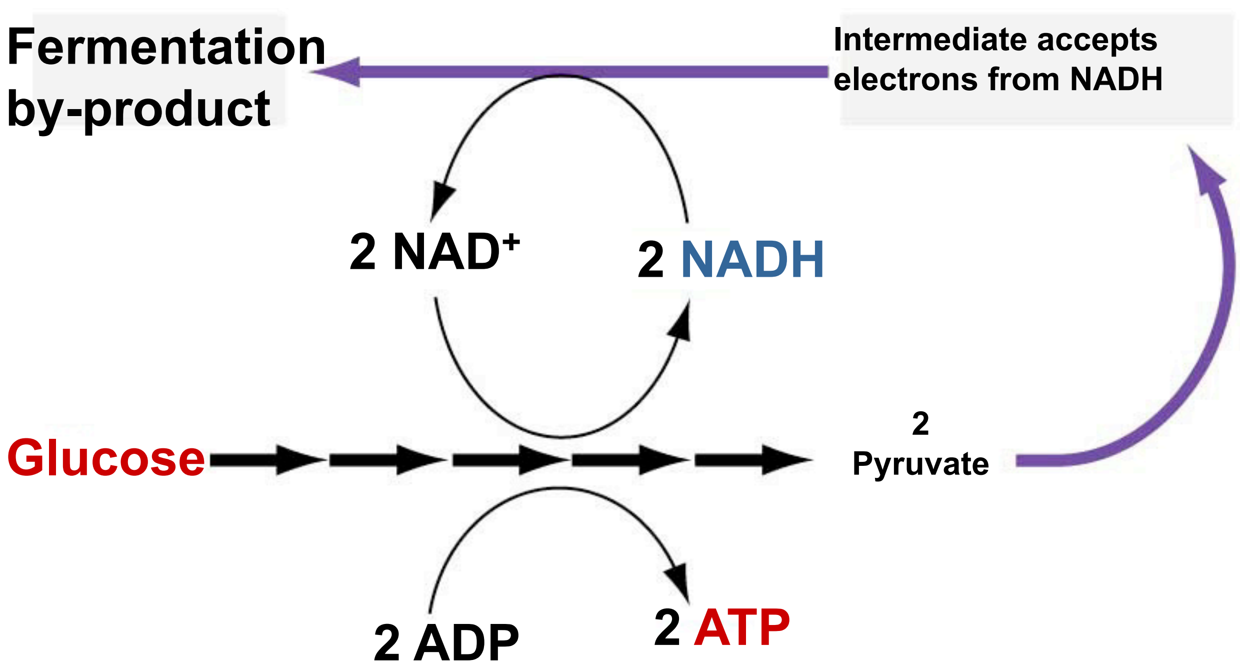


Chemoorganotrophic metabolism

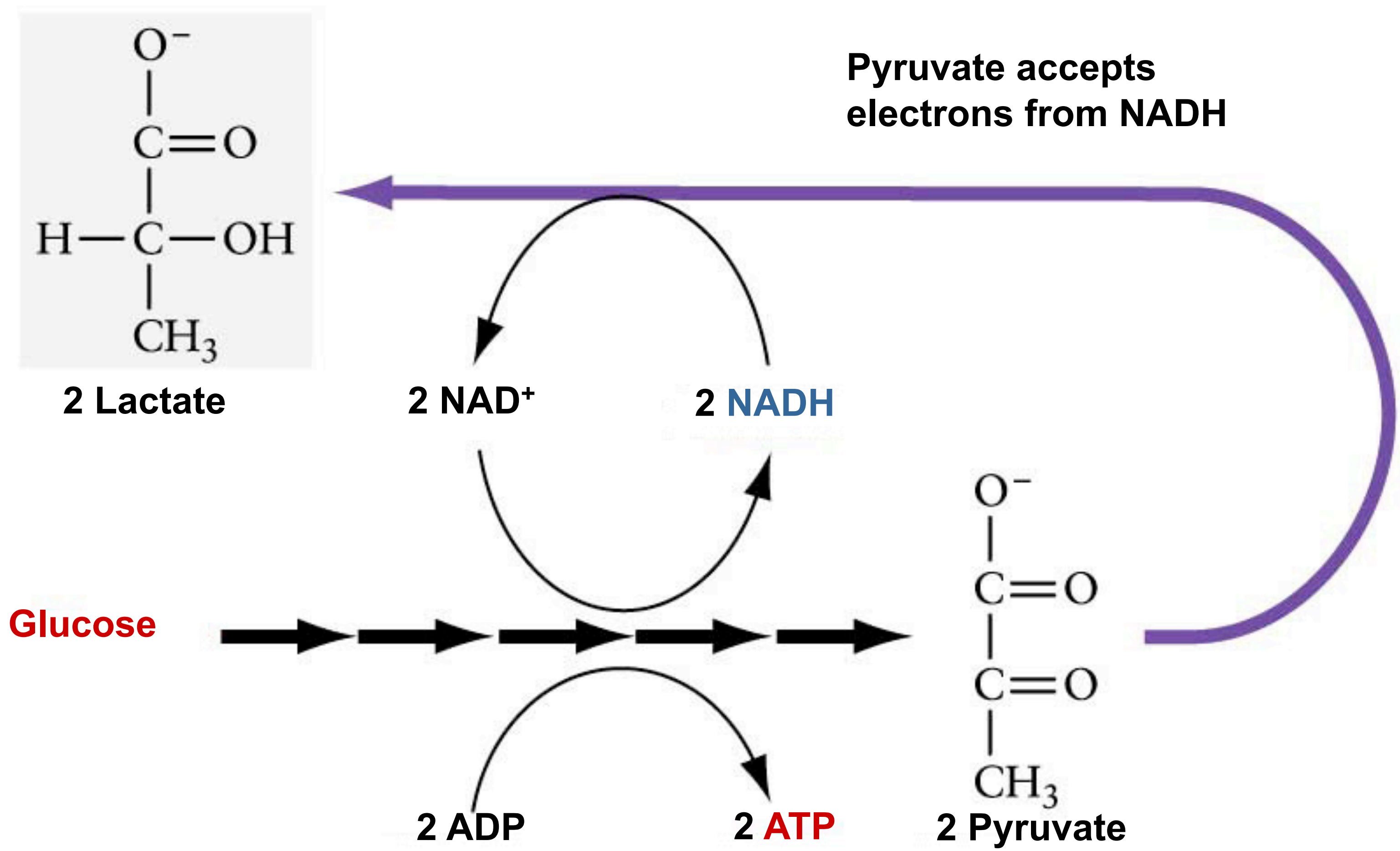
Electron acceptor	Final product	Name of the process
O_2	H_2O	Aerobic respiration
NO_3	NO_2, NH_3 or N_2	Anaerobic respiration: denitrification *Bacillus, Pseudomonas*
SO_4	S or H_2S	Anaerobic respiration: sulphates reduction *Desulfovibrio*
fumarato	succinato	Anaerobic respiration: Organic e^- acceptor *E.coli*
CO_2	CH_4	Metanogenesis (Archea)

Chemoorganotrophic metabolism

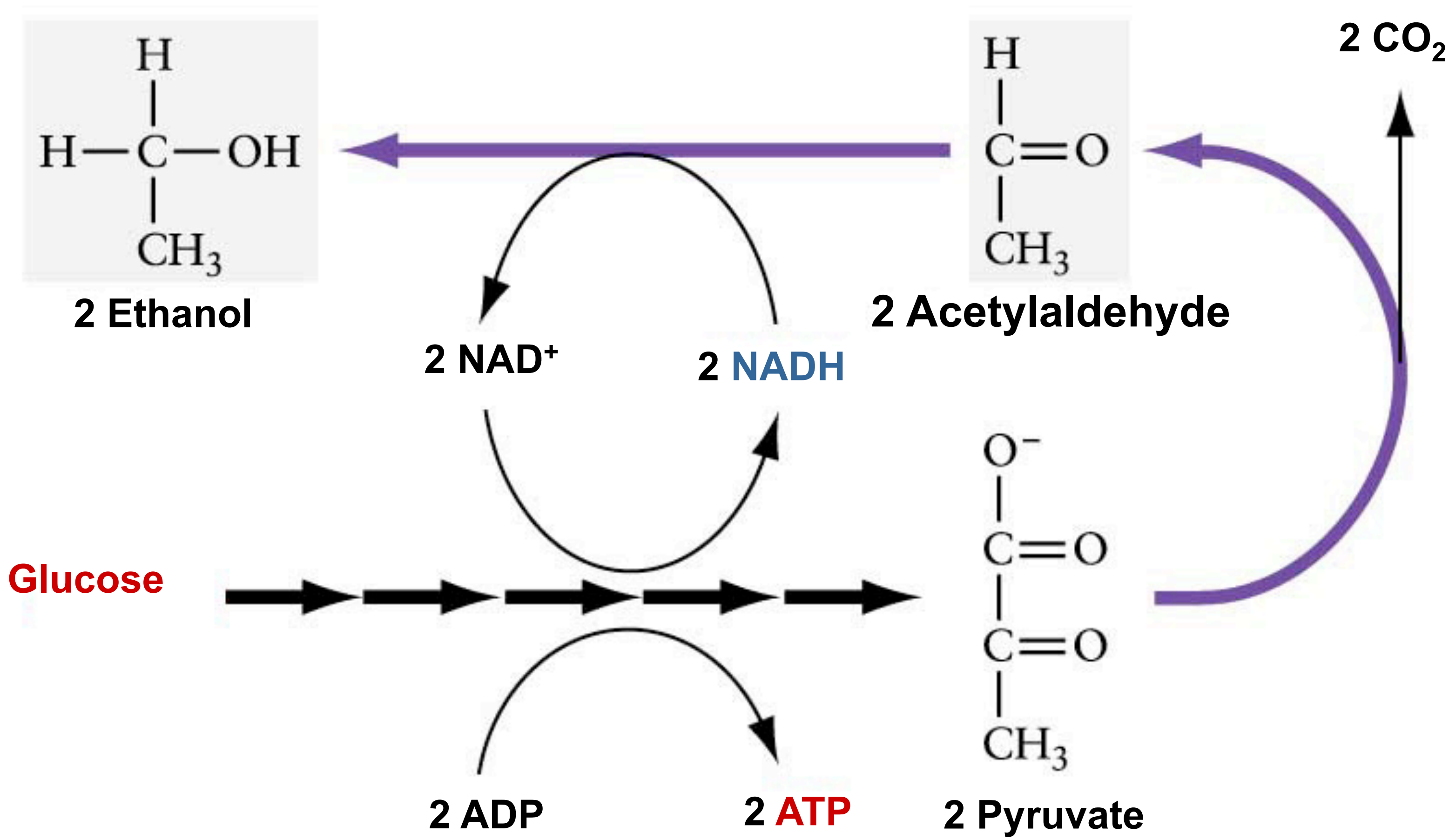
Fermentation pathways allows cells to regenerate NAD^+ for glycolsis



Chemoorganotrophic metabolism

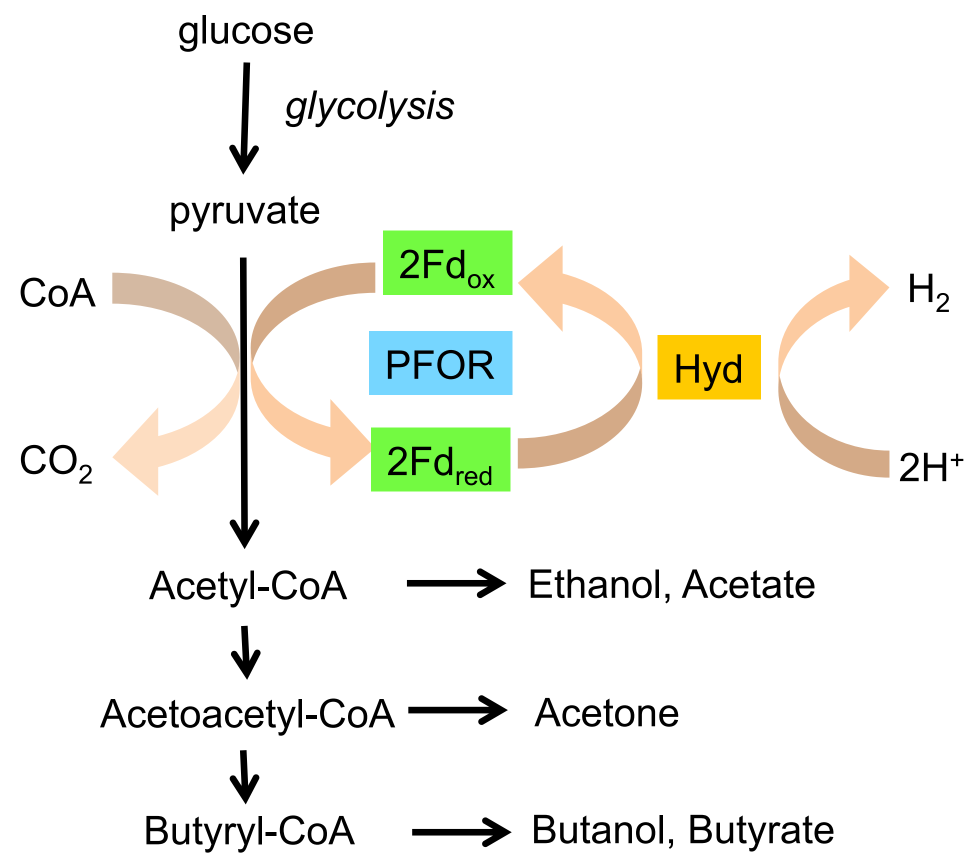


Chemoorganotrophic metabolism



Anaerobic Chemoorganotrophs: -Fermentors

- Genus *Clostridium*
  - Gram-positive rods found in soil
  - Endospores
- Ferment wide variety of compounds
- Representitives:
  - *C. tetani,*
  - *C. perfringens,*
  - *C. botulinum*

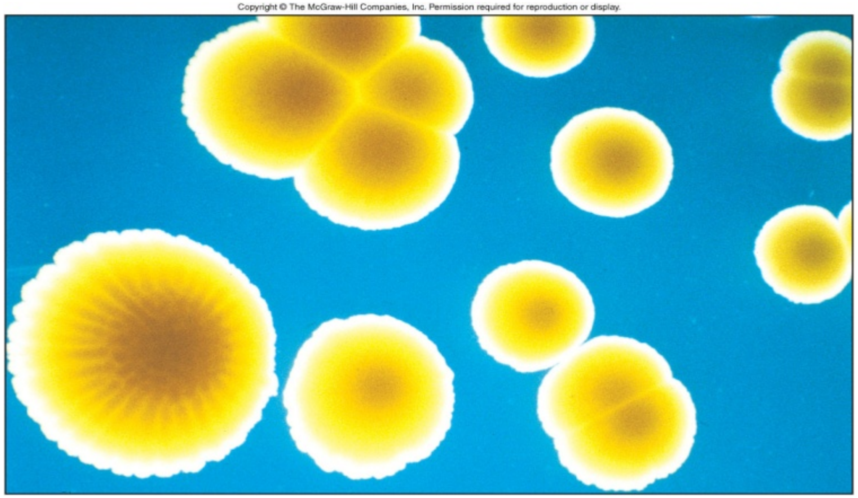


Anaerobic Chemotrophs

- *Propionibacterium* species are Gram-positive rods
- Organisms produce propionic acid as end product of fermentation
  - Found in anaerobic micro environments
  - Essential in the production of Swiss cheese
  - Also ferment lactic acid

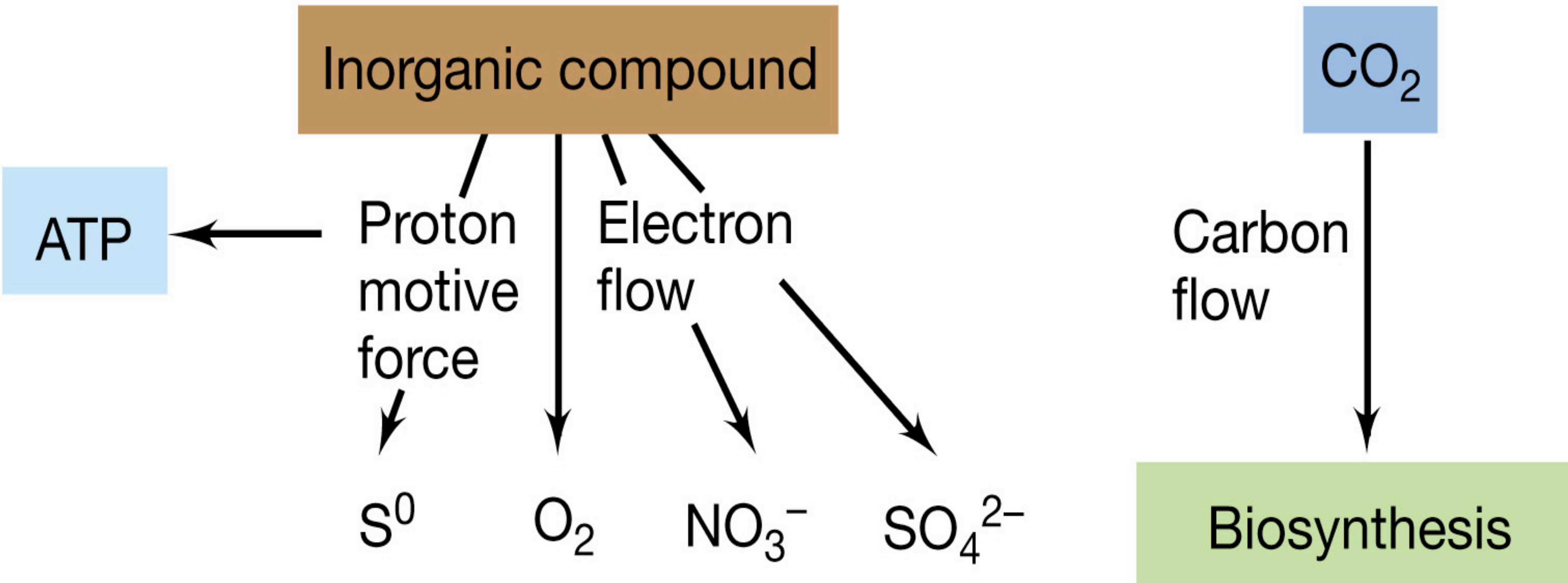
Aerobic Chemoorganotrophs: Obligate Aerobes

- Obligate aerobes obtain energy using aerobic respiration exclusively
- Characteristic genera include
  - *Micrococcus*
    - Gram-positive cocci found in soil and dust
    - Produce yellow pigmented colonies



- *Mycobacterium*
  - Gram-positive bacterium
  - Live on dead and decaying matter
- *Pseudomonas*
  - Gram-negative rods
  - Motile and often pigmented
  - Common opportunistic pathogen
- *Thermus* and *Deinococcus*
  - Both have scientific and commercial uses
    - *Thermus* produces *Taq polymerase*
    - *Dinococcus* used to clean up radioactive contamination

Chemolitotrophic metabolism



Chemolithotrophs

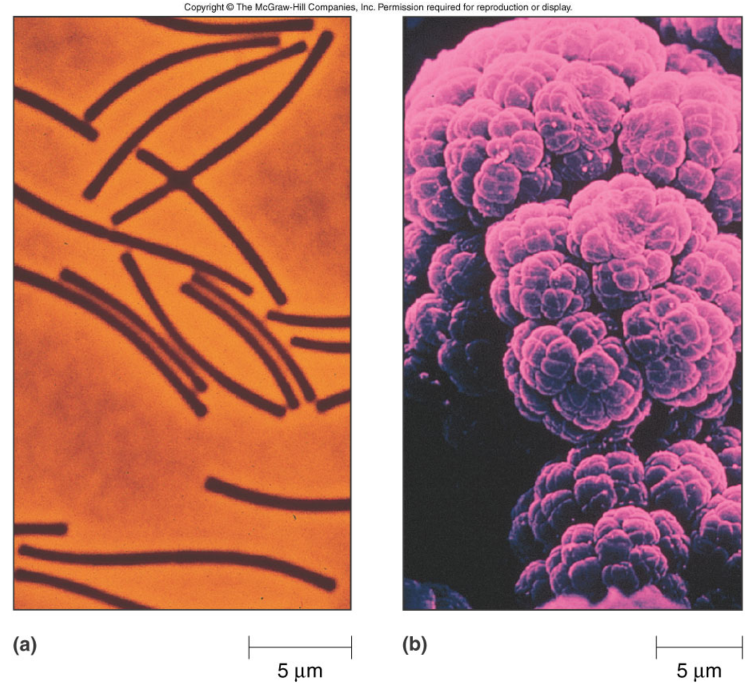
- Chemolithotrophs oxidize reduced inorganic chemicals (e.g. H_2) to produce energy
  - Rare organisms
  - Not O_2 tolerant
  - Terminal electron acceptor usually carbon dioxide or sulfur
  - Members of the domain *Archaea*

Group	Energy source	Final products	Microrganism
Hydrogen bacteria	H_2	H_2O	*Alcaligenes*, *Pseudomonas*
Metanogenes	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*
S-oxidizing bacteria	H_2S or S	SO_4	*Thiobacillus*, *Sulfolobus*
Fe-bacteria	Fe^{++}	Fe^{+++}	*Gallionella*, *Thiobacillus*

Chemolithotroph: Methanogens

- Members of Domain *Archaea*
- Found in sewage, swamps, marine sediments and digestive tract of mammals
- Highly sensitive to oxygen
- Produce energy (ATP) the reaction:

$4H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O$



Aerobic Chemolithotrophs: Hydrogen-Oxidizing Bacteria

- Gram-negative bacteria
- Tend to be thermophilic
  - Found in hot springs, up to 95°C

$$\underset{\text{(energy source)}}{H_2} + \tfrac{1}{2}O_2 \longrightarrow \underset{\text{(terminal electron acceptor)}}{H_2O}$$

Metabolic versatility

Rodospirillum rubrum

(Negative Gram, Proteobacteria)

- Aerobic respiration
- Anaerobic respiration
- Photosynthesis
- Chemoautothroph

BIOREMEDIATION

BIOREMEDIATION

"use of living organisms (e.g., bacteria) to clean up oil spills or remove other pollutants from soil, water, and wastewater.“

Source: United States Environmental Protection Agency, Office of Compliance and Assurance

“clean-up of pollution from soil, groundwater, surface water and air, using biological, usually microbiological processes”

Source: Philp et al., 2001

BIOREMEDIATION

Bioremediation relies largely on the enzymatic activities of living organisms, usually microbes, to catalyze the destruction of pollutants or their transformation to less harmful forms.

Why are microorganisms so important in this process?
They have extraordinary metabolic diversity!

A complex process depending on many factors including:

- ambient environmental conditions (pH, temperature, lack of nutrients & molecular oxygen
- composition of the microbial community
- nature and amount of pollution present

BIOREMEDIATION

Types of pollutants

Organic pollutants → catabolized

- Naturally occurring
- Xenobiotics - substances foreign to an entire biological system, i.e. artificial substances, which did not exist in nature before their synthesis by humans
- Metals from ore extraction and manufacturing

CONTAMINANTS FOR BIODEGRADATION

Readily degradable	Somewhat degradable	Difficult to degrade	Generally recalcitrant
fuel oils, gasoline	creosote, coal tars	chlorinated solvents (TCE)	dioxins
ketones and alcohols	pentachloro-phenol (PCP)	some pesticides and herbicides	polychlorinated biphenyls (PCB)
monocyclic aromatics			
bicyclic aromatics (naphthalene)			

How Microbes Use the Contaminant

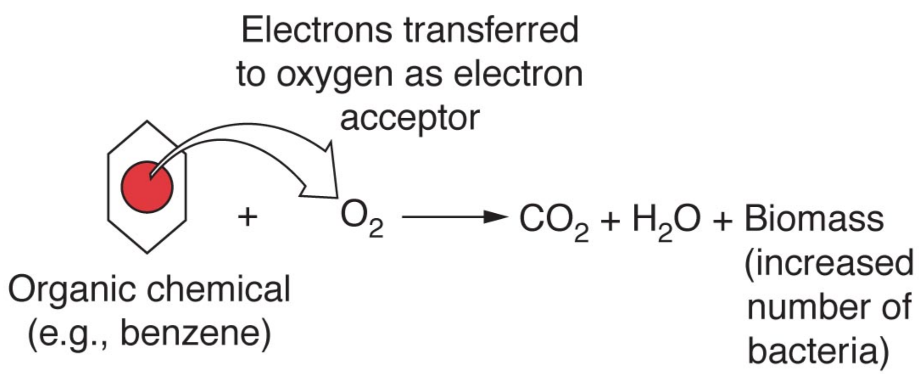
- Contaminants may serve as:
  - Primary substrate
    - enough available to be the sole energy source
  - Secondary substrate
    - provides energy, not available in high enough concentration
  - Cometabolic substrate
    - fortuitous transformation of a compound by a microbe relying on some other primary substrate

USE OF CONTAMINANTS AS PRIMARY SUBSTRATE

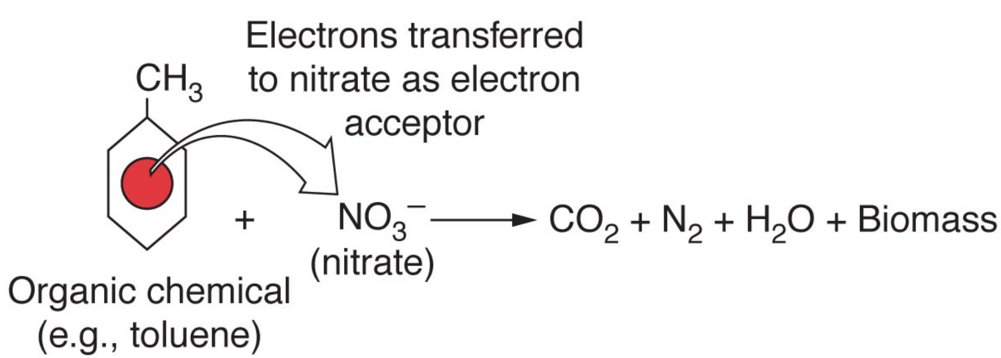
- Aerobic metabolism
  - Microbes use O_2 in their metabolism to degrade contaminants

- Anaerobic metabolism
  - Microbes substitute another chemical for O_2 to degrade contaminants
    - Nitrate, iron, sulfate, carbon dioxide, uranium, technicium, perchlorate

Aerobic biodegradation

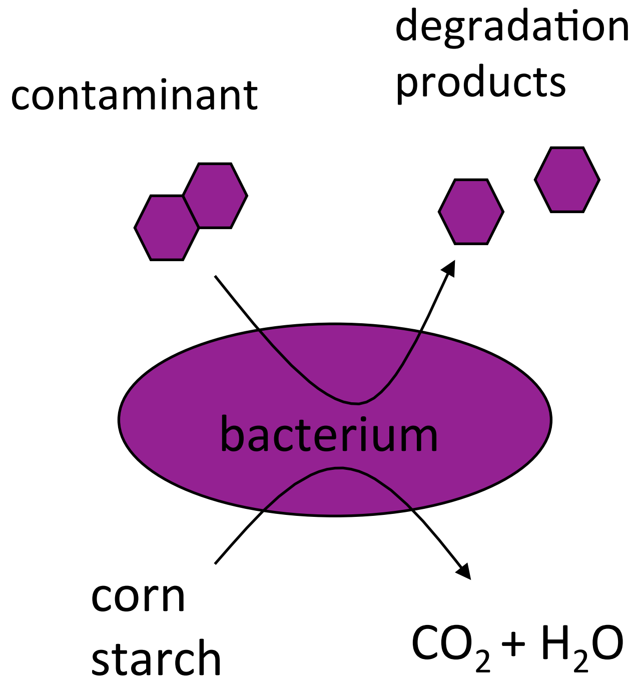


Anaerobic biodegradation

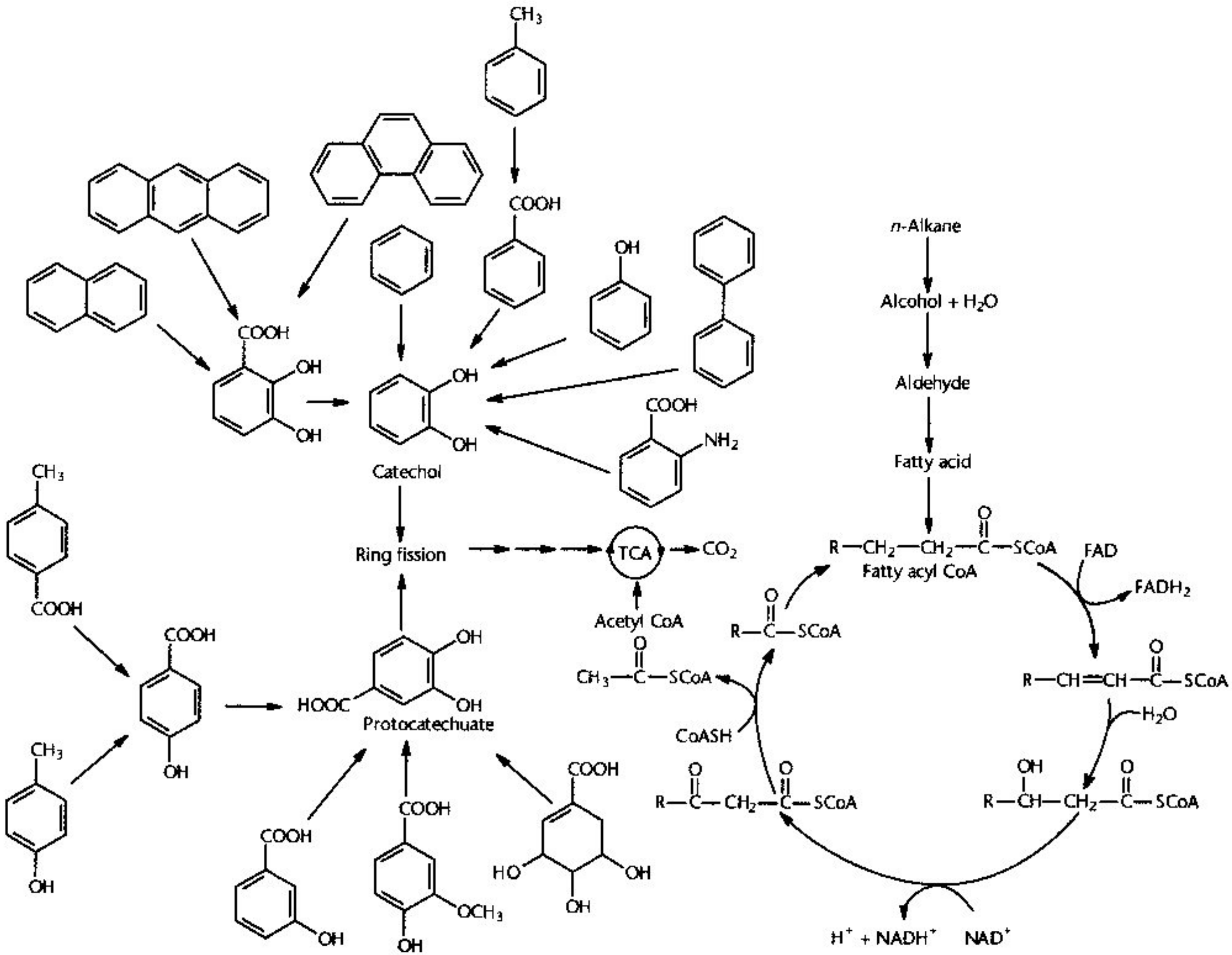


Cometabolism

Bacterium uses some other carbon and energy source to partially degrade contaminant (organic aromatic ring compound)



Cometabolism



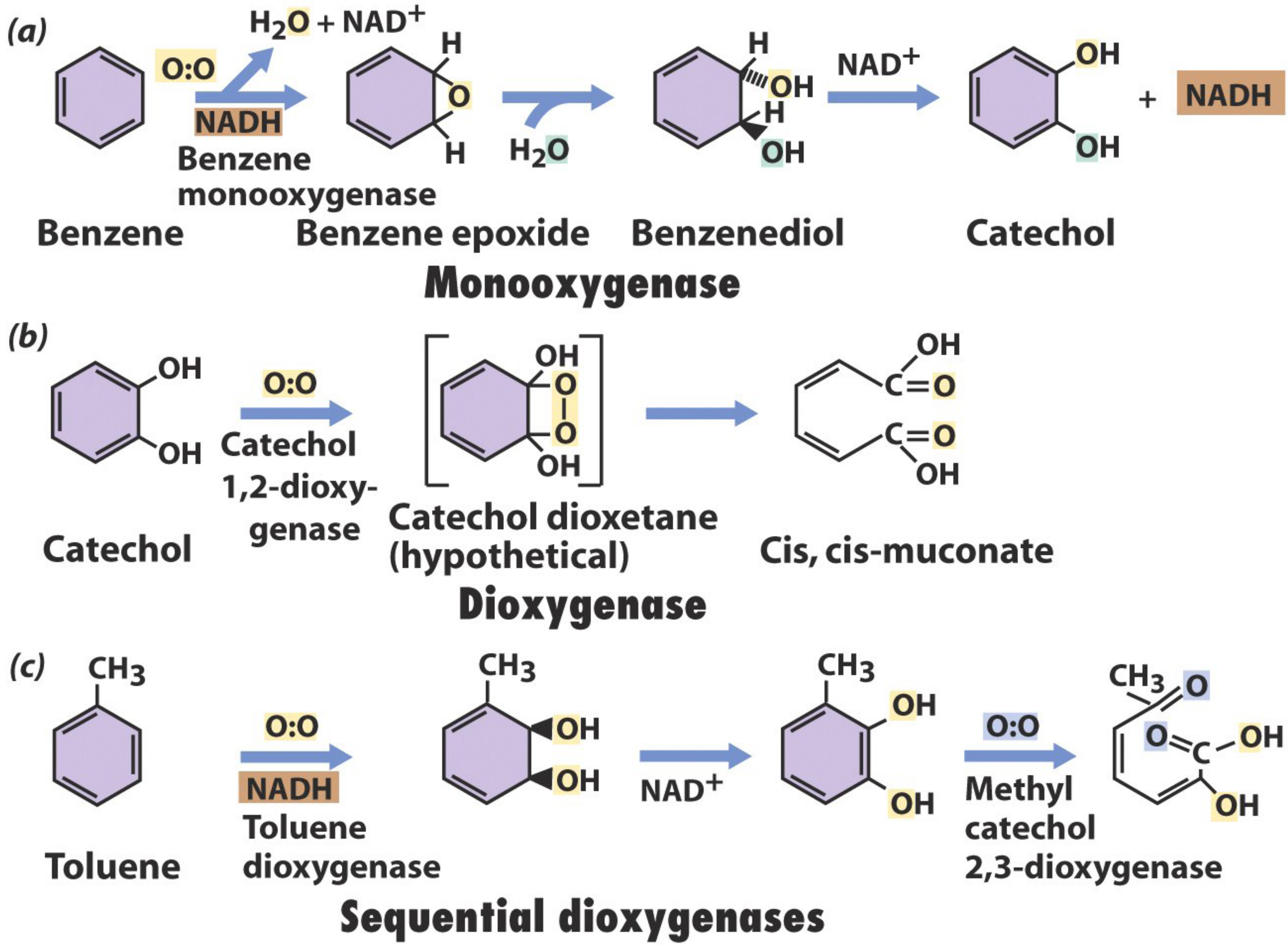


Figure 17-56 Brock Biology of Microorganisms 11/e

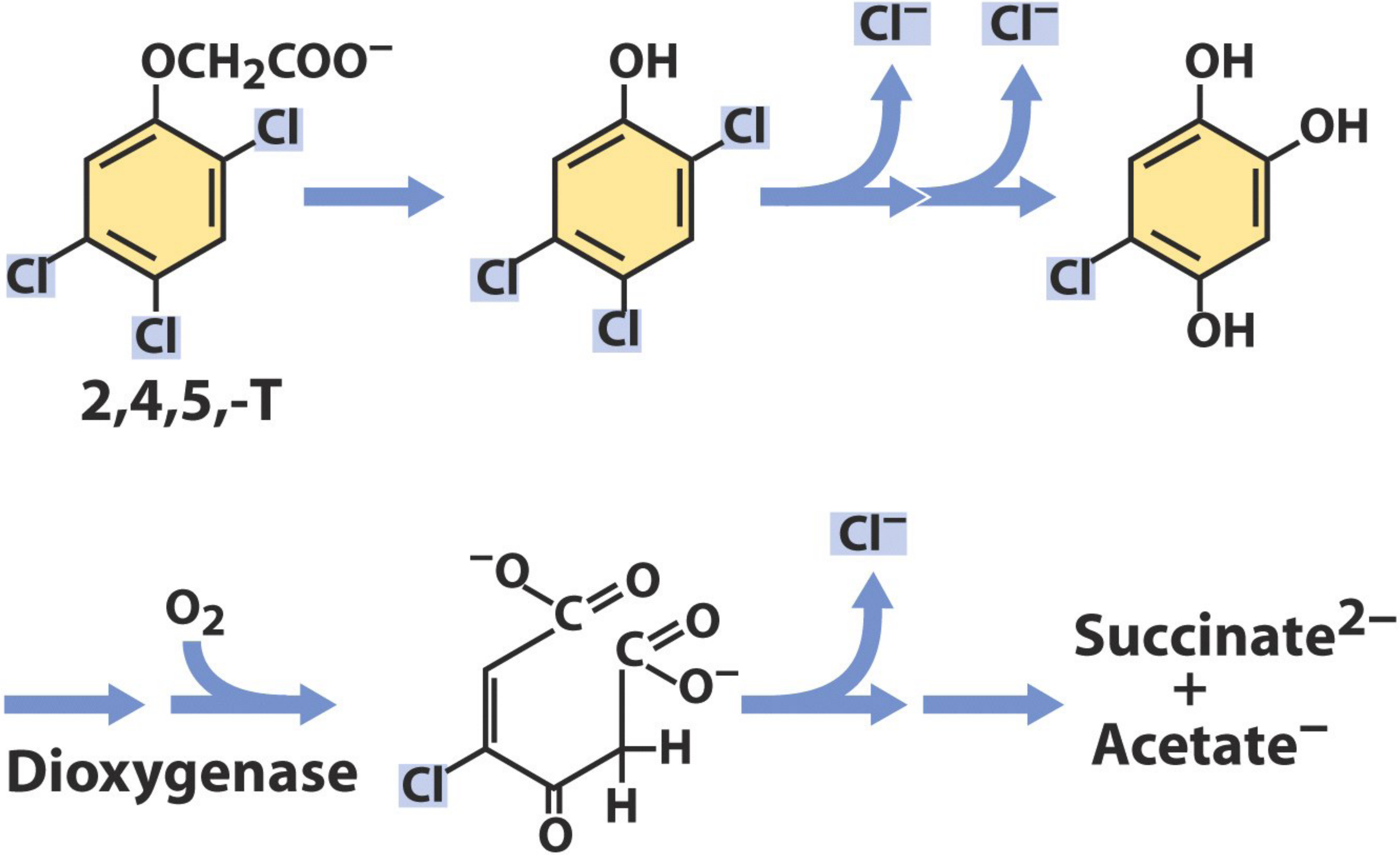


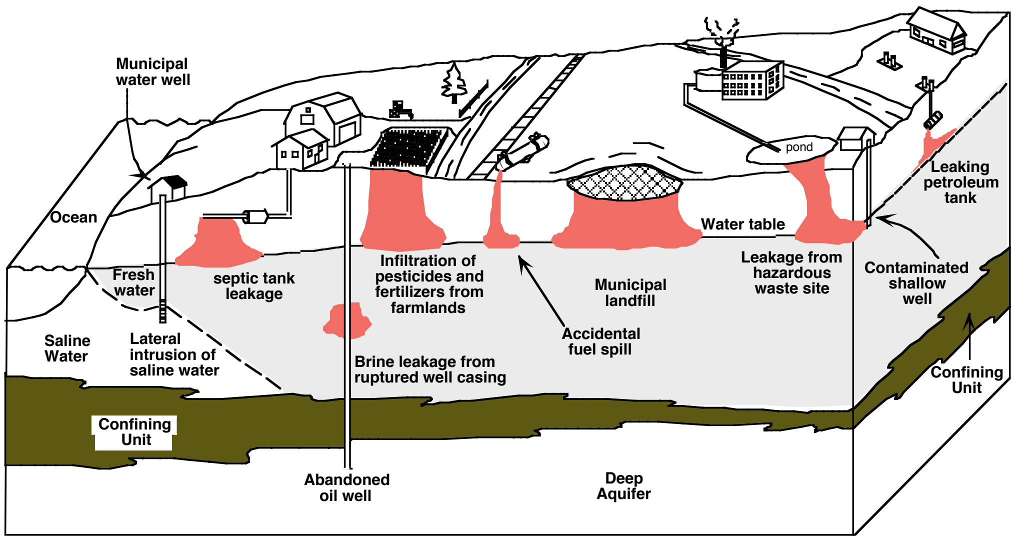
Figure 19-47b Brock Biology of Microorganisms 11/e

Soil and Subsurface Contaminants

- Benzene and related fuel components (BTEX)
- Pyrene and other polynuclear aromatics
- Chlorinated aromatics and solvents
- Herbicides and pesticides
- Nitroaromatic explosives and plasticizers

Sources of Contamination

- Industrial spills and leaks
- Surface impoundments
- Storage tanks and pipes
- Landfills
- Burial areas and dumps
- Injection wells



Biotic Transformations

- Result of metabolic activity of microbes
- Aerobic and anaerobic biodegradation
- Reduces aqueous concentrations of contaminant
- Reduction of contaminant mass
- Most significant process resulting in reduction of contaminant mass in a system

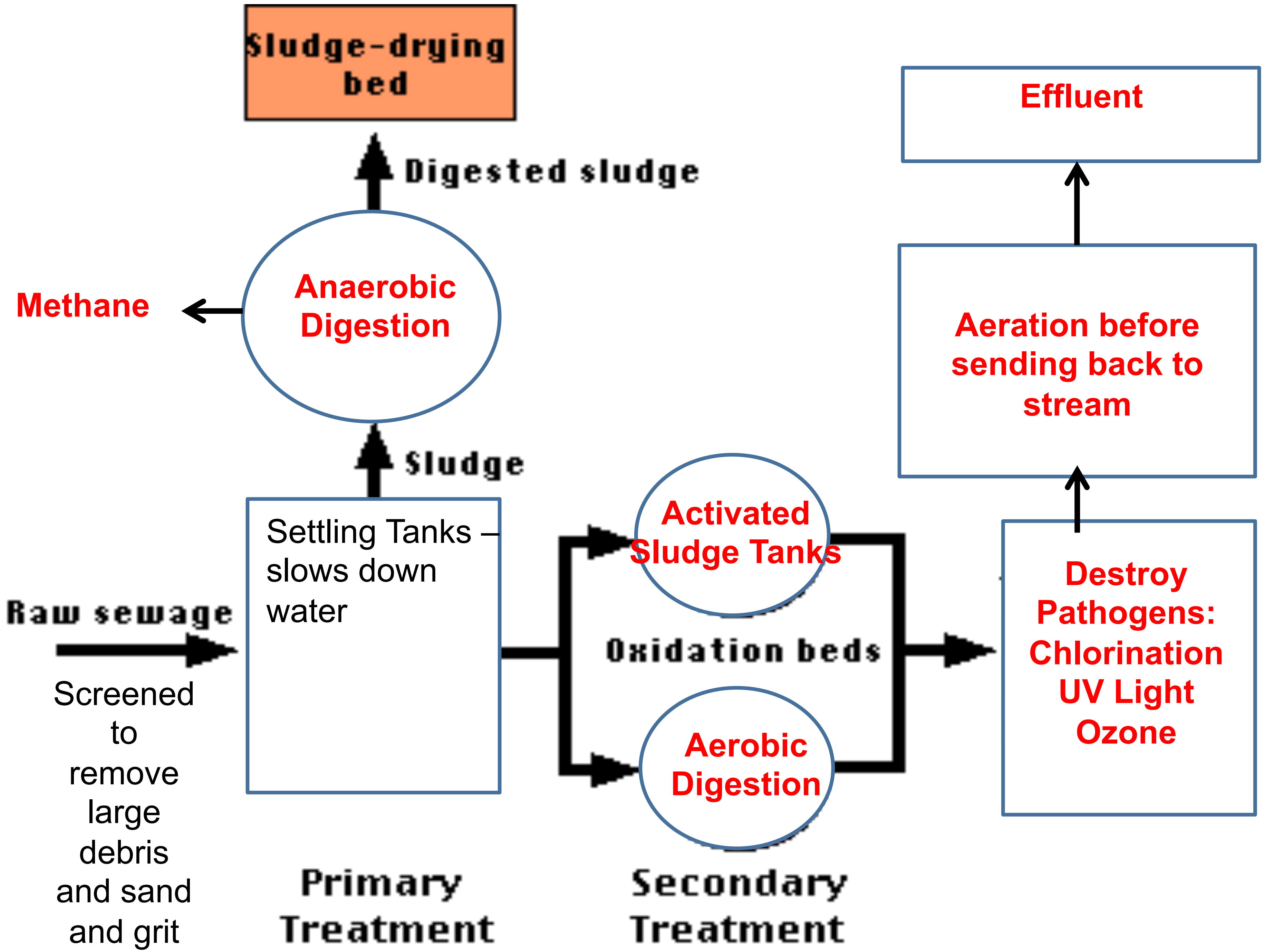
Wastewater Treatment

Treatment depends on three factors:

1) Slow water down - removes larger particles

2) Aerobic decomposition of organic material: natural bacteria decompose organic material IF enough dissolved oxygen is present in the water

3) Destroy pathogens (disease causing bacteria)


Sludge-drying bed
Digested sludge
Effluent
Methane
Anaerobic Digestion
Aeration before sending back to stream
Sludge
Activated Sludge Tanks
Settling Tanks – slows down water
Raw sewage
Oxidation beds
Destroy Pathogens: Chlorination UV Light Ozone
Aerobic Digestion
Screened to remove large debris and sand and grit
Primary Treatment
Secondary Treatment

Wastewater Treatment

Secondary Treatment

- Secondary treatment is a biological process
- Utilizes bacteria and algae to metabolize organic matter in the wastewater