Role of Microorganisms in Wastewater Treatment

The stabilization of organic matter is accomplished biologically using a variety of microorganisms

$$\underbrace{\text{Carbonaceous organic matter}}_{\text{Colloidal \& dissolved form}} \longrightarrow \text{Gases + cell tissue}$$

Specific gravity of the cell tissue ≥ specific gravity of water ;

Cell tissue removed by gravity settling

Note: Unless the cell tissue is removed from the solution, complete treatment will not be accomplished because the cell tissue will be measured as BOD in the effluent

Classification of bacteria

Kingdoms

- Animals
- Plants
- Protista

Energy and Carbon Source

- Autotrophic
- Heterotrophic

Relationship to Oxygen

- Obligate aerobes
- Obligate anaerobes
- Facultative

Temperature Range

- Psychrophiles
- Mesophiles
- Thermophiles

energy and carbon source

- The relationship between the source of the carbon and the source of the energy for M.O. is important.
- Carbon is the basic building block for cell synthesis.
- Energy must be obtained from outside of the cell to enable synthesis to proceed.
- Our goal in wastewater treatment;
    - to convert both the carbon and the energy in the wastewater into microorganisms
    - remove M.O from the water by settling.
- Different organisms have different ways to obtain carbon and energy:

carbon requirement:	*energy source:*
Autotrophs use CO2;	**Phototrophs** use light;
Heterotrophs use organic carbon	**Chemotrophs** use Glucose, inorganics & S

*All animals belong to **Chemoheterotrophs***
*Plants belong to **Photoautotrophs***

relationship to oxygen

Different organisms have different requirement in O_2 for metabolic reactions;

Those that use O_2 as electron acceptor in energy producing pathways are **aerobes**;

Obligate aerobes have to use O_2 .

Organisms that don’t use O_2 are **anaerobes**;

Facultative anaerobes can adapt to anaeobic conditions.

Those organisms that cannot use O_2 at all and are even poisoned by it are **obligate anaerobes**.

relationship to temperature

Each species of bacteria reproduces best within a limited range of temperatures.

< 20^0C	Psychrophiles
25- 40^0C	Mesophiles
45- 60^0C	Thermophiles

CLASSIFICATION OF MICRORGANISMS BY SOURCES OF ENERGY AND CARBON

Classification	Energy source	Carbon Source
Autotrophic:		
Photoautotrophic	**Light**	**CO_2**
Chemoautotrophic	**Inorganic oxidation-reduction reaction**	**CO_2**
Heterotrophic:		
Chemoheterotrophic	**Organic Oxidation-reduction reaction**	**Organic Carbon**
Photoheterotrophic	**Light**	**Organic Carbon**

BACTERIAL BIOCHEMISTRY

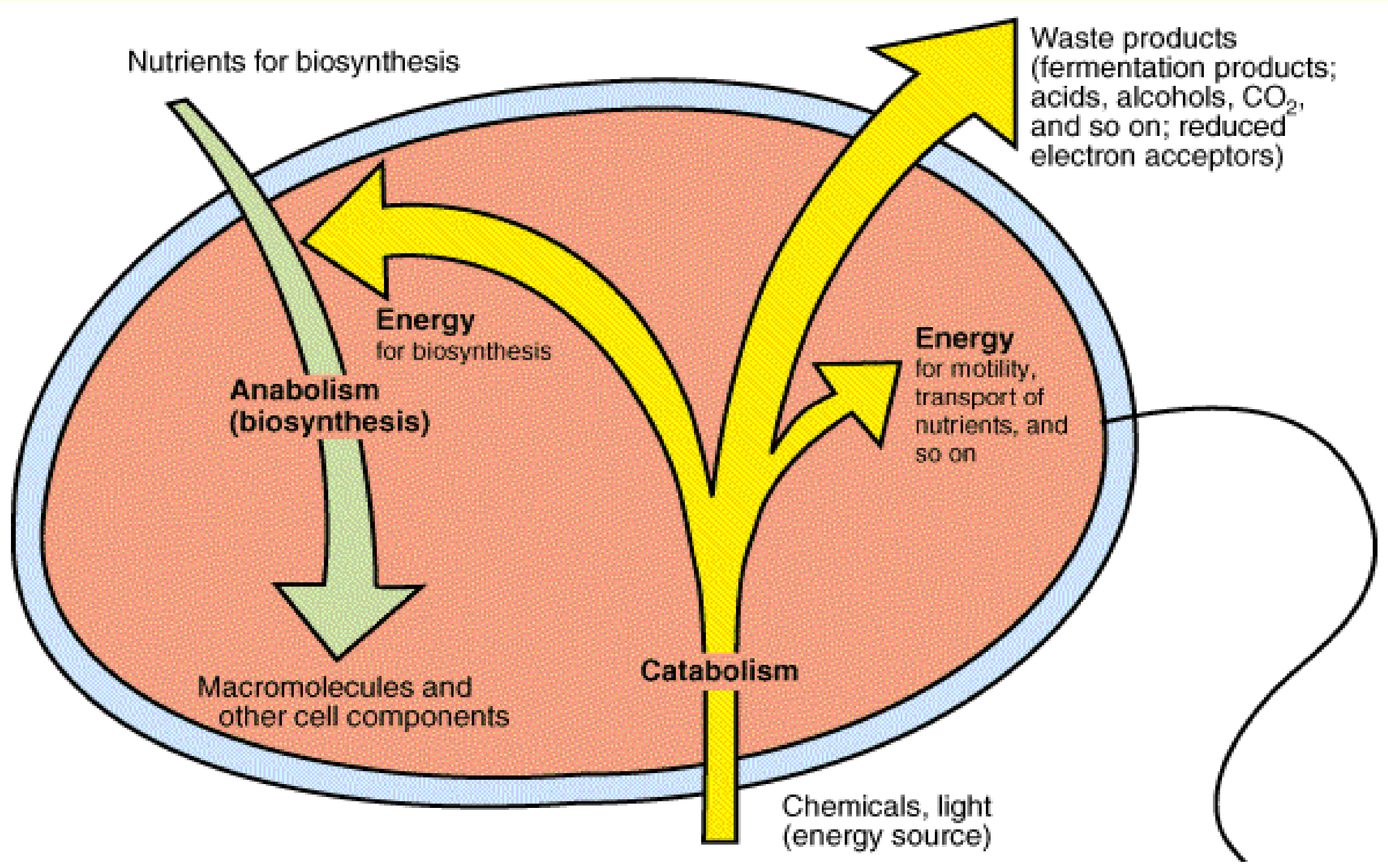
- Many of the chemical reactions involved in the self-purification process must be biologically mediated.

- These chemical reactions are not spontaneous but require an external source of energy for initiation

Metabolism

- Sum up all the chemical processes that occur within a cell
  1. Anabolism: Synthesis of more complex compounds and use of energy
  2. Catabolism: Break down a substrate and capture energy

Overview of cell metabolism



Catabolism & Anabolism

- Catabolic processes convert fuels into cellular energy:

  Fuels (carbohydrates, fats) → CO2 + H2O + energy

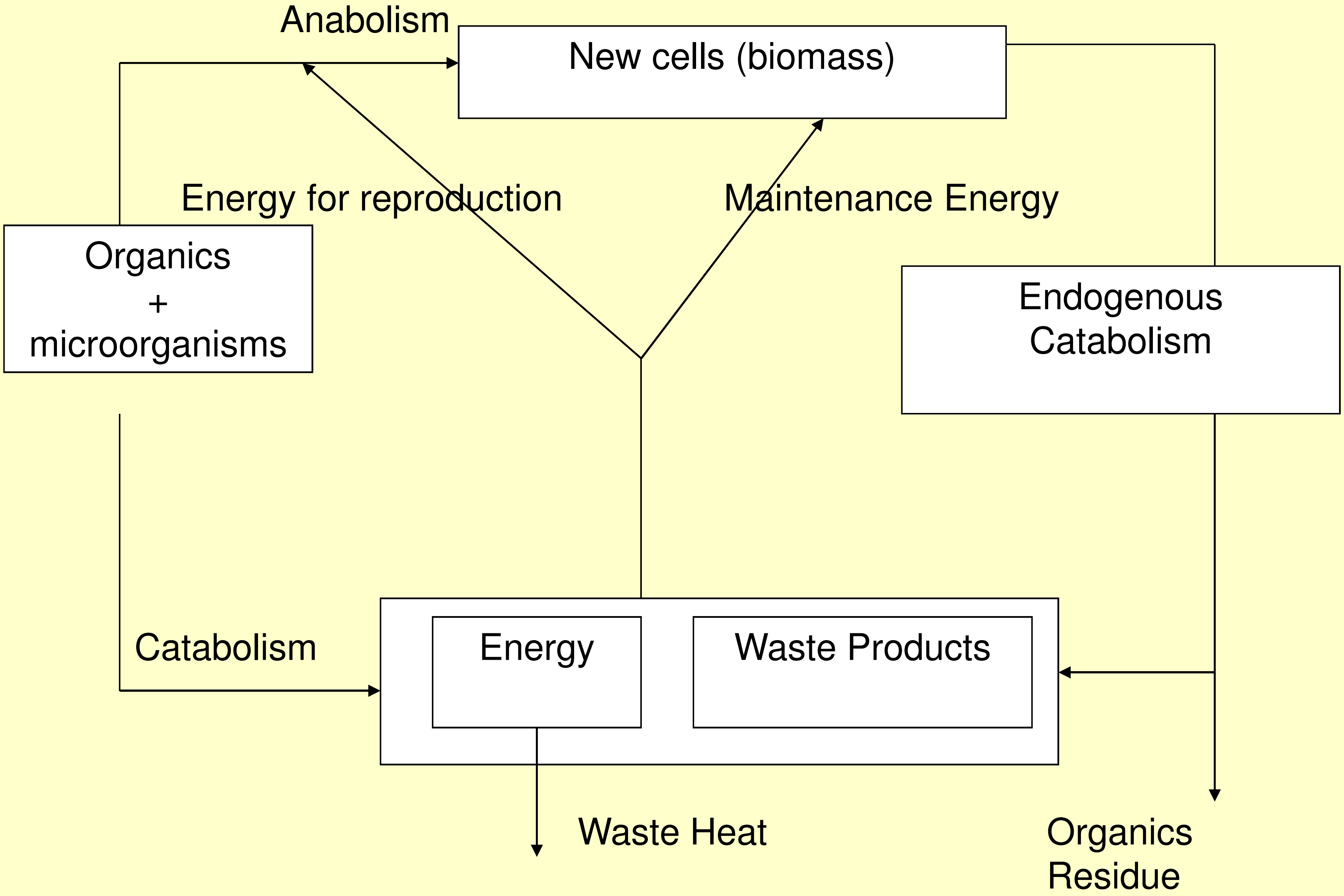
  - provides the energy for the synthesis of new cells, as well as the maintenance of other cell functions.
  - destructive metabolism
  - larger organic molecules are broken down into smaller constituents
  - this usually occurs with the release of energy (usually as ATP).
  - When an external food source is interrupted, the organisms will use stored food for maintenance energy in a process called endogenous catabolism.

Catabolism & Anabolism

- Anabolism: provides the material necessary for cell growth.
- constructive metabolism
- small precursor molecules are assembled into larger organic molecules. This always requires the input of energy (often as ATP).
- generate complex molecules from simple ones by using energy:

Energy + small molecules → Complex molecules

GENERALIZED METABOLIC PATHWAY



Anabolism

New cells (biomass)

Energy for reproduction

Maintenance Energy

Organics
+
microorganisms

Endogenous
Catabolism

Catabolism

Energy

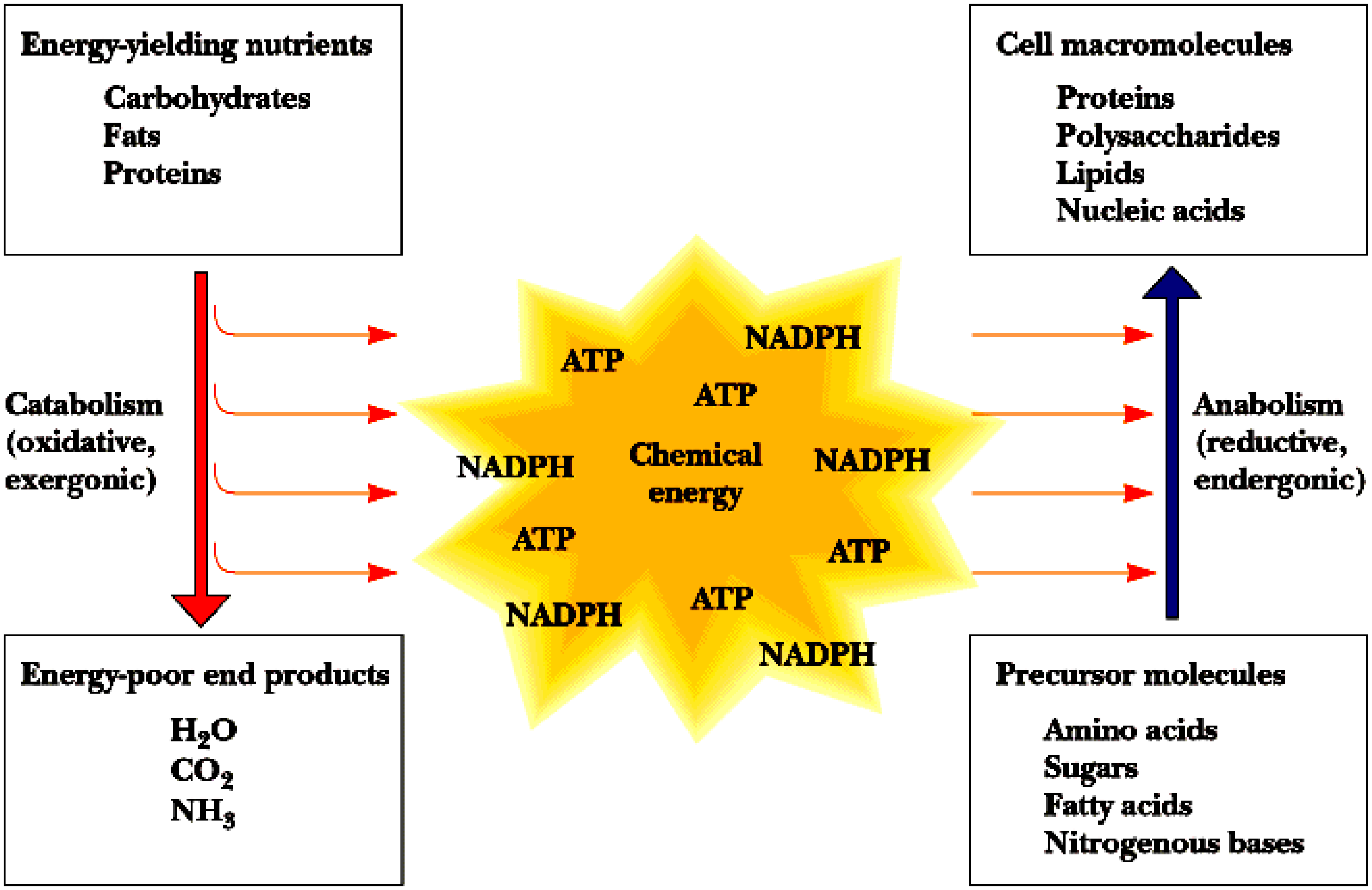
Waste Products

Waste Heat

Organics
Residue

Energy Relationship Between Catabolism And Anabolism

Figure 18.4



Energy-yielding nutrients

Carbohydrates
Fats
Proteins

Catabolism
(oxidative,
exergonic)

Energy-poor end products

H_2O
CO_2
NH_3

ATP
NADPH
ATP
NADPH
Chemical energy
NADPH
ATP
ATP
NADPH
ATP
NADPH

Cell macromolecules

Proteins
Polysaccharides
Lipids
Nucleic acids

Anabolism
(reductive,
endergonic)

Precursor molecules

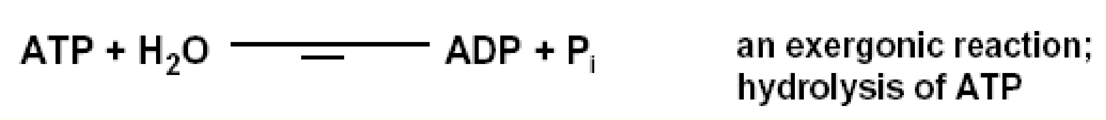
Amino acids
Sugars
Fatty acids
Nitrogenous bases

Saunders College Publishing

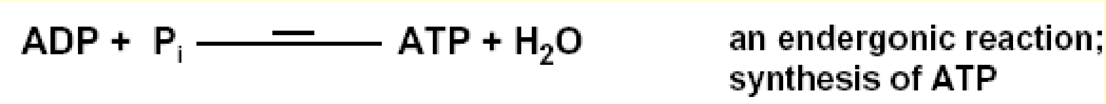
ATP Cycles

- ATP is the energy currency of cells
  - In phototrophs, light energy is transformed into ATP
  - In heterotrophs, catabolism produces ATP

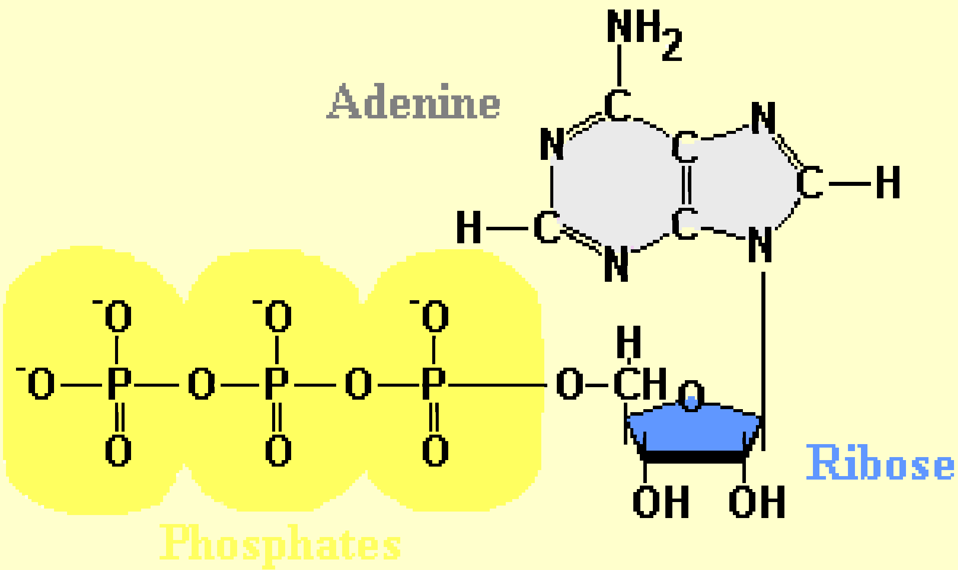
- ATP cycle carries energy from photosynthesis or catabolism to the energy-requiring anabolic processes of cells (protein synthesis, nucleic acid synthesis etc.)



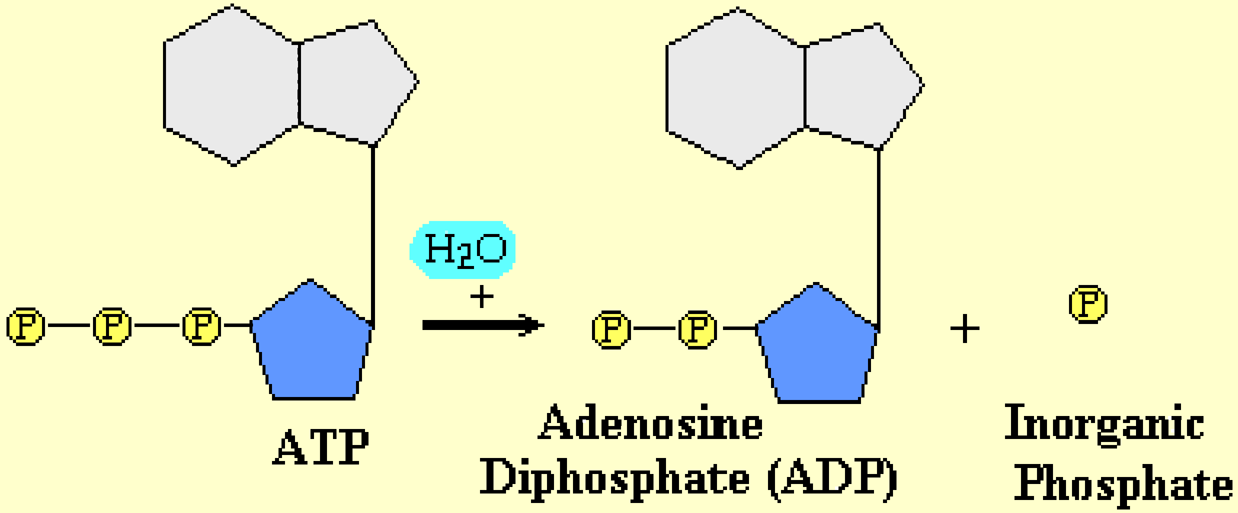
$ATP + H_2O \rightleftharpoons ADP + P_i$ an exergonic reaction; hydrolysis of ATP



$ADP + P_i \rightleftharpoons ATP + H_2O$ an endergonic reaction; synthesis of ATP



Adenosine Triphosphate (ATP)



The Microbiology of Activated Sludge

- Activated sludge can be defined as "a mixture of microorganisms which contact and digest bio-degradable materials (food) from wastewater."
- Activated sludge is *microorganisms*.
- The Activated sludge process is a *biological process*.
- To properly control the activated sludge process, you must properly control the growth of microorganism. This involves controlling the items which may affect those microorganisms.

The Microbiology of Activated Sludge

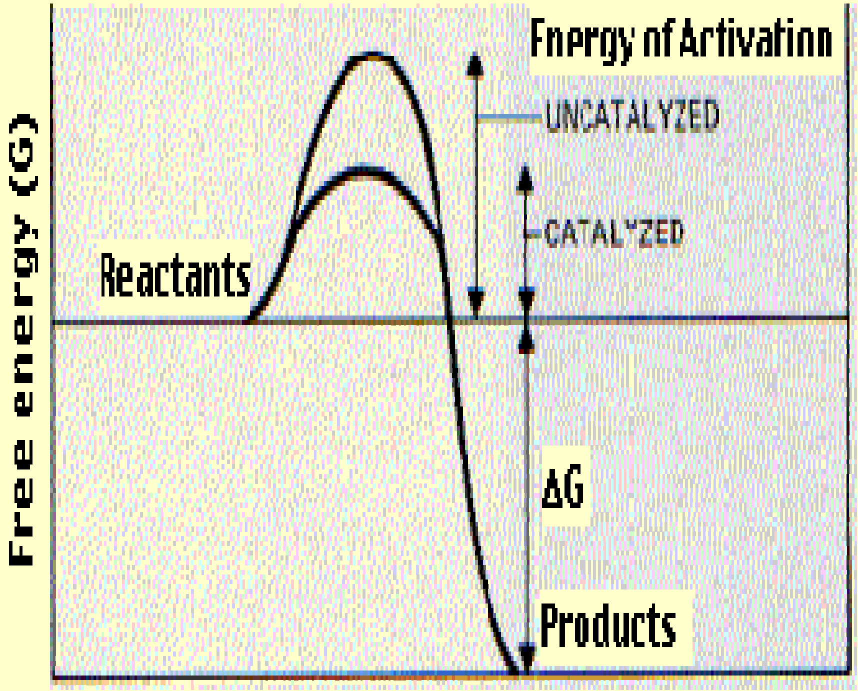
Bacteria:

- Make up about 95% of the activated sludge biomass.
- These single celled organisms grow in the wastewater by consuming (eating) bio-degradable materials such as proteins, carbohydrates, fats and many other compounds.

The Role of Enzymes

- Enzymes are compounds that are made by living organisms. Their purpose is to help biochemical reactions to occur. Almost all biochemical reactions require the presence of enzymes to cause the reaction to occur.
- Enzymes help bacteria in the process of breaking down nutrients, and in rebuilding broken down nutrients into the new compounds that they require for growth and reproduction.
- Enzymes only do what they are supposed to when environmental conditions are right. If the conditions are not right the enzymes will not function properly, thus, the bacteria will not function properly, and they will not survive. If conditions are right the bacteria will live and prosper.

The Role of Enzymes

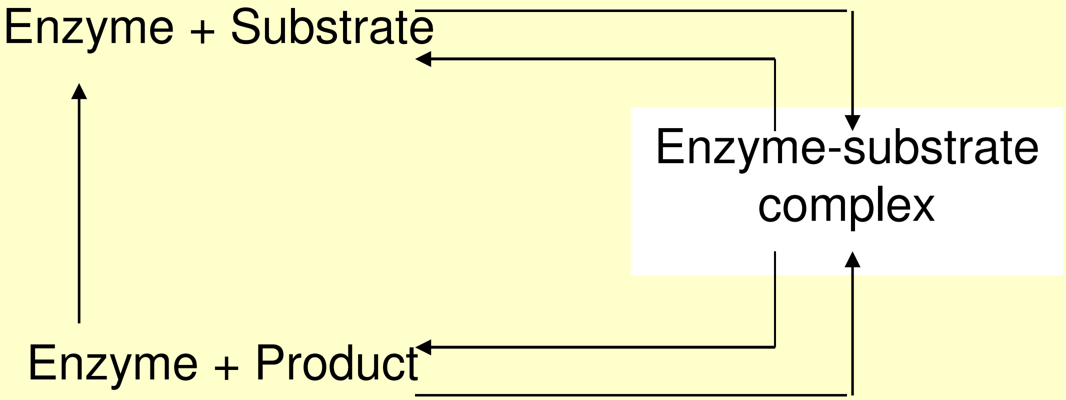


- Enzymes are compounds that are made by living organisms. Their purpose is to help biochemical reactions to occur.

- Almost all biochemical reactions require the presence of enzymes to cause the reaction to occur.

- Enzymes help bacteria in the process of breaking down nutrients, and in rebuilding broken down nutrients into the new compounds that they require for growth and reproduction.

ENZYME REACTION MODEL



Enzyme + Substrate

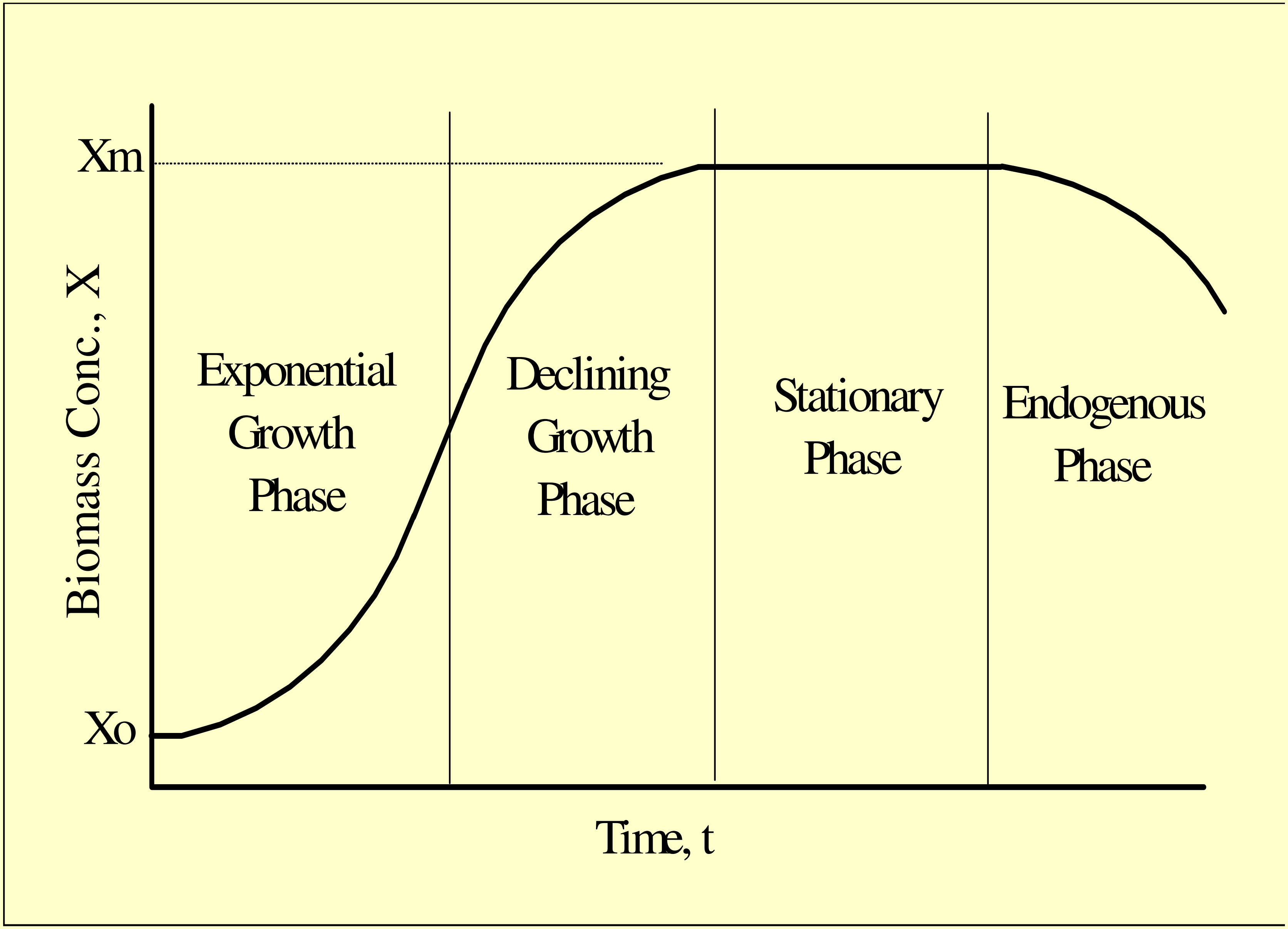
Enzyme-substrate complex

Enzyme + Product

- Enzymes only do what they are supposed to when environmental conditions are right.

- If the conditions are not right the enzymes will not function properly, thus, the bacteria will not function properly, and they will not survive

GROWTH CURVE OF BACTERIA



GROWTH CURVE OF BACTERIA

- *Lag-phase* During this phase bacteria become acclimated to their new surroundings. They are digesting food, developing enzymes and other things required for growth.

- *Accelerated Growth-phase* The bacteria are growing as fast as they can, since there is an excess of food. The cells are mostly dispersed, not sticking together.

- *Declining Growth-phase* Reproduction slows down because there is not an excess of food. A lot of food has been eaten and there are now a large number of bacteria to compete for remaining food, so the bacteria do not have enough remaining food to keep the growth rate at a maximum.

- *Stationary-phase* The number of bacteria is the highest possible, but not much food is left, so the bacteria cannot increase in number. There is some reproduction, but some cells are also dying, so the number of bacteria remain relatively constant.

- *Death-phase* The death rate increases with very little if any growth occurring. Therefore, the total number of living bacteria keeps reducing. The bacteria are just trying to keep alive.

The Effects of Mixing

•Mixing is required to bring organisms, oxygen, and nutrients together, and to remove metabolic waste products.

•If there is not enough mixing, proper treatment will not take place because of lack of contact between the bugs, their food and oxygen.

•If too much mixing is provided, it can cause break up of floc or formation of unstable floc particles.

The Effects of Nutrients

- Microorganisms require certain nutrients for growth.

- The basic nutrients of abundance in normal raw sewage are carbon (C), nitrogen (N), phosphorus (P), with the ratio of C:N:P ratio approximately equal to 100:10:1.

- In addition to C,N,and P, trace amounts of sodium (Na), Potassium (K), magnesium (Mg), iron (Fe), and many others are required.

- In normal municipal sewage, most of these nutrients are provided.
- Most problems with nutrient deficiency occur when there is a lot of industrial wastes present.

- When proper nutrients are not available, the metabolism fails and a kind of bacterial fat (slime) will begin to accumulates around the cell.

- The cell slows down in activity because it cannot produce enough enzymes and because needed nutrients cannot penetrate the slime layer as they should. The sludge will not settle and BOD removal slows down.

Electron Acceptor & Electron Donor in Biological Processes

- Microorganisms such as bacteria obtain energy to grow by transferring electrons from an electron donor to an electron acceptor.

- An electron acceptor is a compound that receives or accepts an electron during cellular respiration.

- The process starts with the transfer of an electron from an electron donor.

- During this process (electron transport chain) the electron acceptor is reduced and the electron donor is oxidized.

- Examples of acceptors include oxygen, nitrate, iron (III), manganese (IV), sulfate, carbon dioxide, or in some cases the chlorinated solvents such as tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride (VC).

Electron acceptor

(a) An electron acceptor is the substance in a chemical reaction that gains an electron (that is, is reduced)

(b) In catabolism, ultimately electrons must be donated from one substance (typically containing carbon) to some other substance (often oxygen)

(c) The last substance receiving the electrons before their elimination from the organism is termed a final electron acceptor (in aerobic organisms the final electron acceptor is usually molecular oxygen, which is converted to water upon reception of these electrons)

(d) Note that the reception of electrons by an electron acceptor in a biological system is typically associated with the gain of a bond to a hydrogen atom (H), e.g., water is H-O-H which represents a replacement of the O=O bond of molecular oxygen with H-O bonds

Electron donor

(a) An electron donor is the substance in a chemical reaction that loses an electron (that is, is oxidized)

(b) The complex, energy-rich substances broken down during catabolism are termed electron donors

(c) Essentially, electrons are removed from these substances and the energy associated with those electrons is used to phosphorylate ADP to produce ATP

(d) For a carbon-containing electron donor, the donation of elections typically is associated with the loss of C-H bonds and the gain of C-O bonds