Biological Wastewater Treatment

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Wastewater Treatment

Why Treat ?

- Environmental Effects
- Image
- Reuse Implications
- Potable
- Industrial
- Regulatory Requirements

Types of Pollutants

1) **Suspended Solids**
2) **Dissolved Solids**
3) **Colloidal Solids**

□ Solids may be

organic (eg. Phenol, oil, bacteria)

or

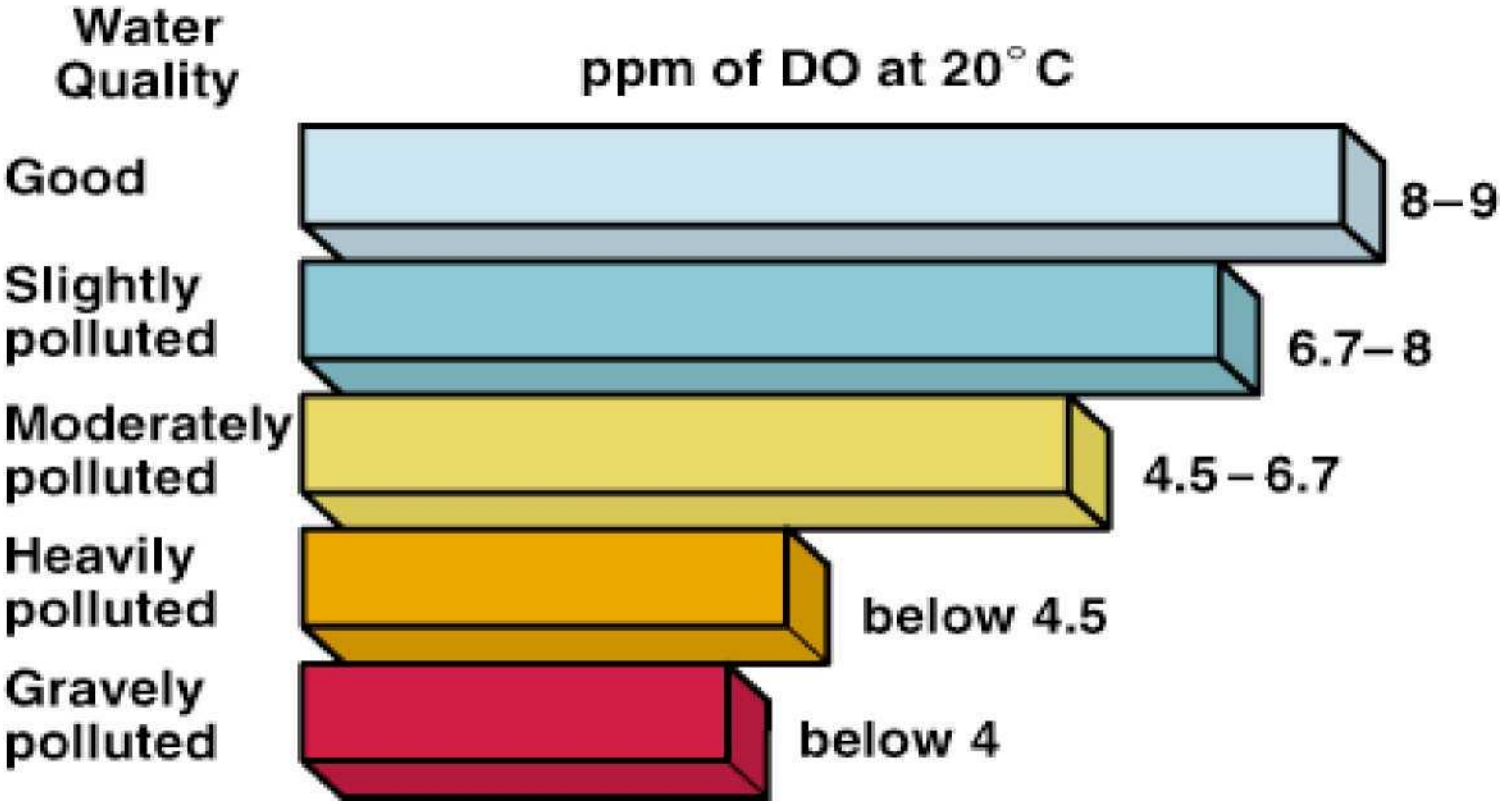
inorganic (eg. Salts, Ca, Mg, silt) in nature

The "Conventional" Pollutant Measures:

- Oxygen (BOD, COD, DO)
- Solids content (TS)
- Nutrients (phosphorus, nitrogen)
- Acidity (pH)
- Bacteria (e.g., fecal coliform)
- Temperature

Measurements of Gross Organic Content

- Dissolved Oxygen (DO)
- Biochemical oxygen demand (BOD)
- Chemical oxygen demand (COD)
- Total organic carbon (TOC)
- Theoretical oxygen demand (ThOD)


Water Quality
ppm of DO at 20° C
Good
8–9
Slightly polluted
6.7–8
Moderately polluted
4.5–6.7
Heavily polluted
below 4.5
Gravely polluted
below 4

Biological Oxygen Demand (BOD)

- BOD: Oxygen is removed from water when organic matter is consumed by bacteria
- Low oxygen conditions may kill fish and other organisms

Chemical Oxygen Demand

- The quantity of oxygen used in biological and non-biological oxidation of materials in wastewater

- The determination of chemical oxygen demand (COD) is used in municipal and industrial laboratories to measure the overall level of organic contamination in wastewater. The contamination level is determined by measuring the equivalent amount of oxygen required to oxidize organic matter in the sample

- BOD/COD ratio - the greater the ratio, the more oxidizable (biologically treatable) the waste. Ratios rarely exceed 0.8-0.9.

Total Organic Carbon (TOC)

- Measure of WW pollution characteristics
- Based on the chemical formula
- Test methods use heat and oxygen, UV radiation, and/or chemical oxidants to convert organic carbon to carbon dioxide, which can then be measured
- Can be assessed in 5 to 10 minutes
- Theoretical > Measured

Theoretical Oxygen Demand (ThOD)

- WW generally contains a mixture of carbon, hydrogen, oxygen, and nitrogen
- Calculated using stoichiometric equations
- Considers both carbonaceous and nitrogenous oxygen demand
  - Main difference from COD

Methods of Treatment

1) Clarification, Sedimentation, Flocculation are used for suspended and/ or colloidal pollutants

2) Evaporation, Reverse Osmosis etc, are used for dissolved inorganic pollutants

3) Oxidation/ Synthesis by Micro-organisms is carried out (Biological Treatment) for Dissolved Organic Pollutant

Biological Processes…

□ cell: derives energy from oxidation of reduced food sources (carbohydrate, protein & fats)

Requires…..

□ microbes with the ability to degrade the waste organics
□ contact time with the organics
□ favorable conditions for growth

Objective of Biological Wastewater Treatment

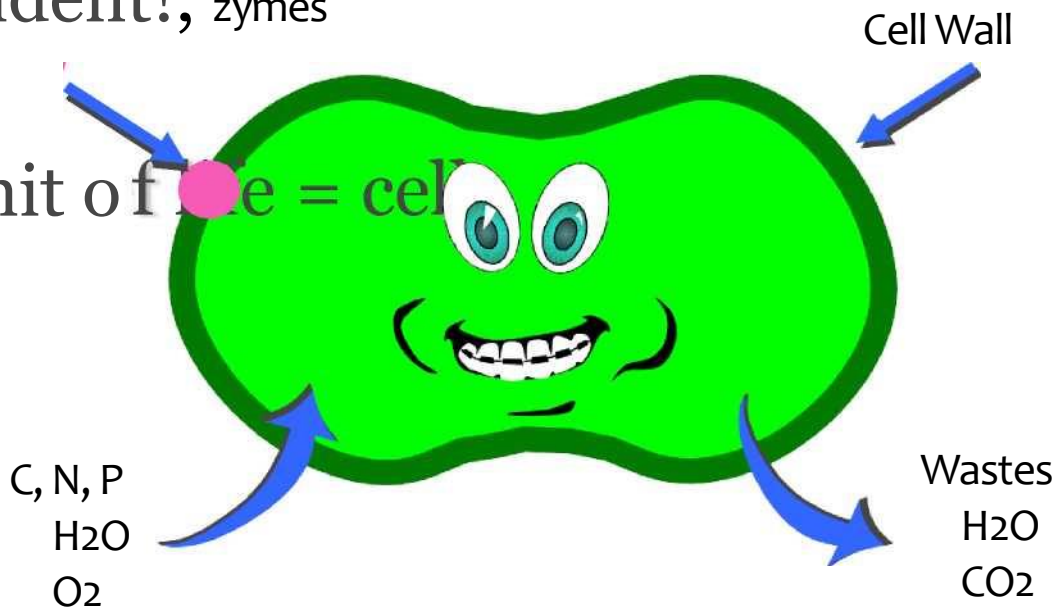
- To stabilize the organic matter (Soluble and non settlable)

- To reduce the amount of dissolved phosphorus and nitrogen in the final effluent

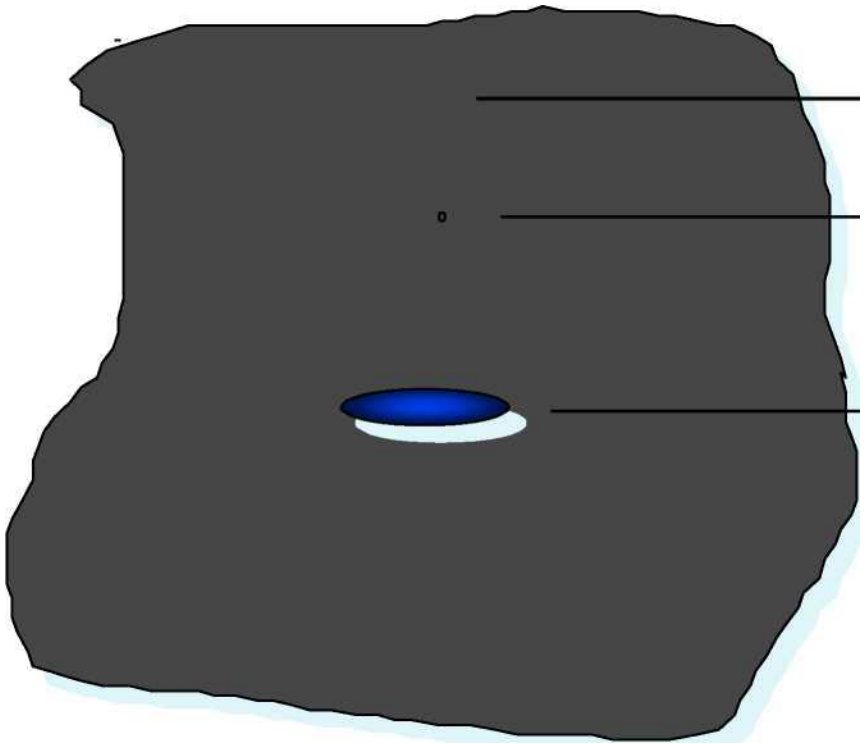
Microorganisms

Microorganisms = single-celled organism capable of performing all life functions independent!, zymes

- Basic unit of life = cell



Typical animal cell:

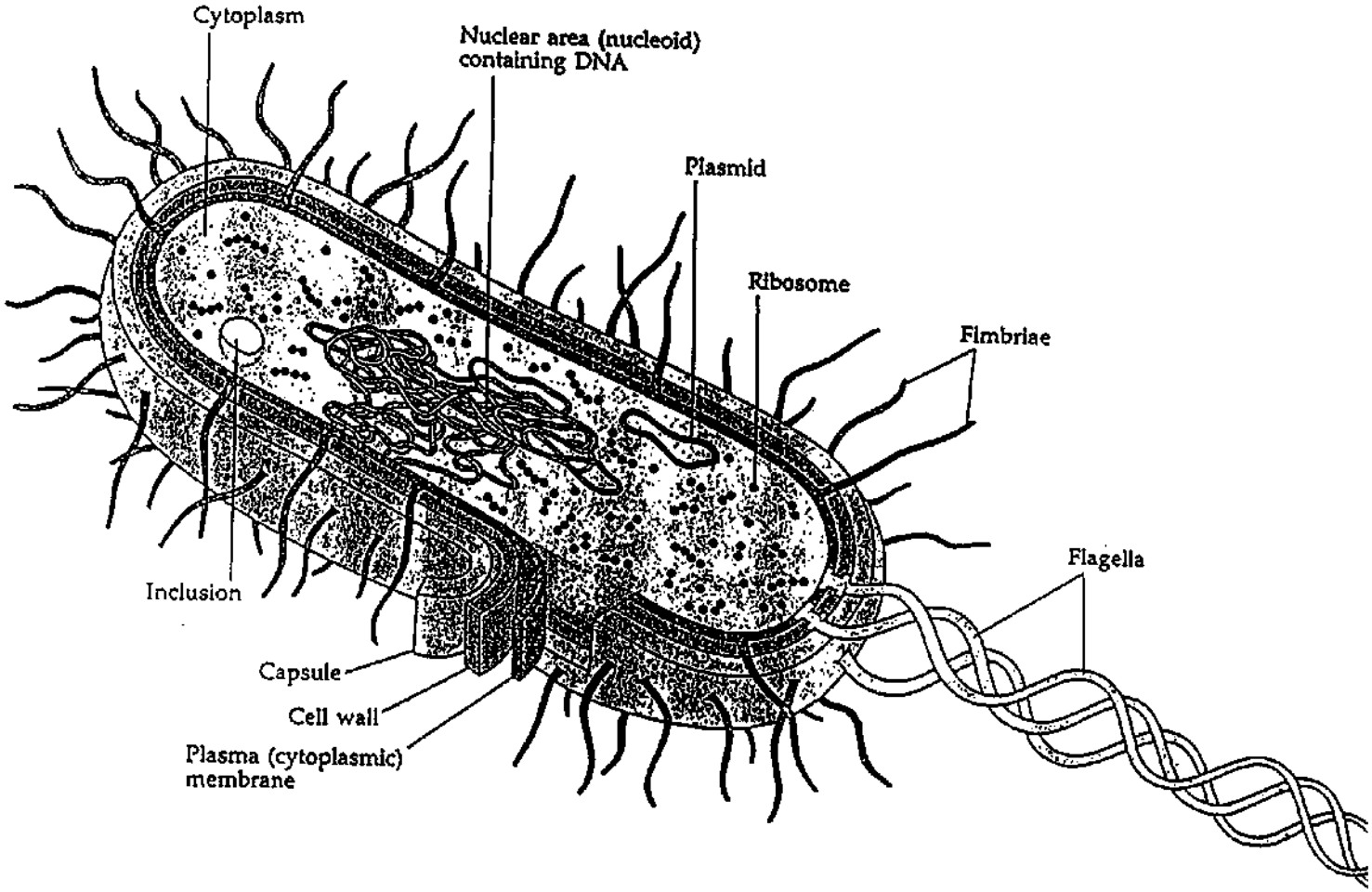


* animal cell

—► virus

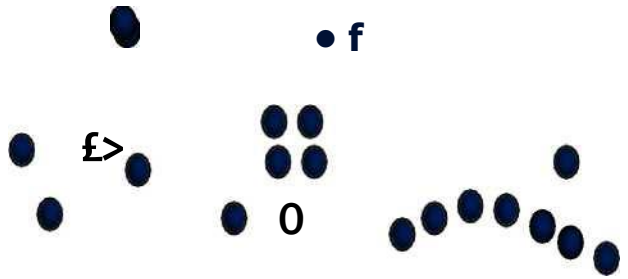
* bacterial cell

Bacterial Cell

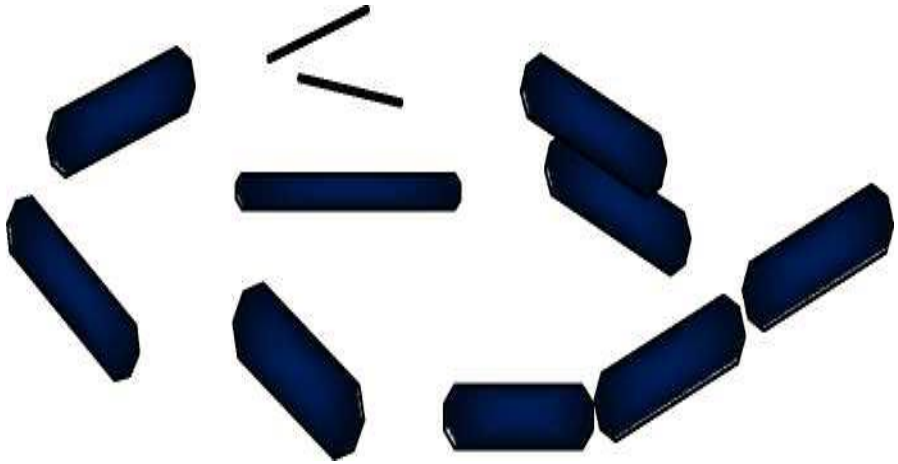


Shape of Bacteria

- **Cocci**
  - spherical cells, often in chains or tetrad^



- **Rods**
  - most common shape
  - vary in shape & size



- **Spiral Rod**
  - curved rods

Growth

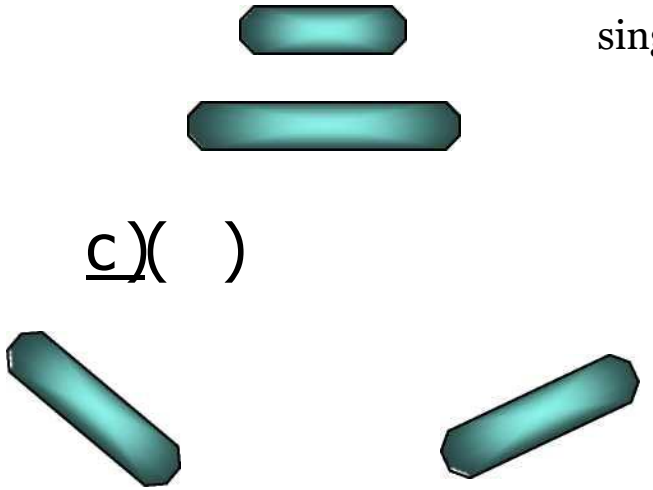
- **Growth = cell division**

  one cell divides to produce two equal daughter cells

- **Generation time**

  length of time required for bacterial population to double

Bacterial Growth: cell division



single cell

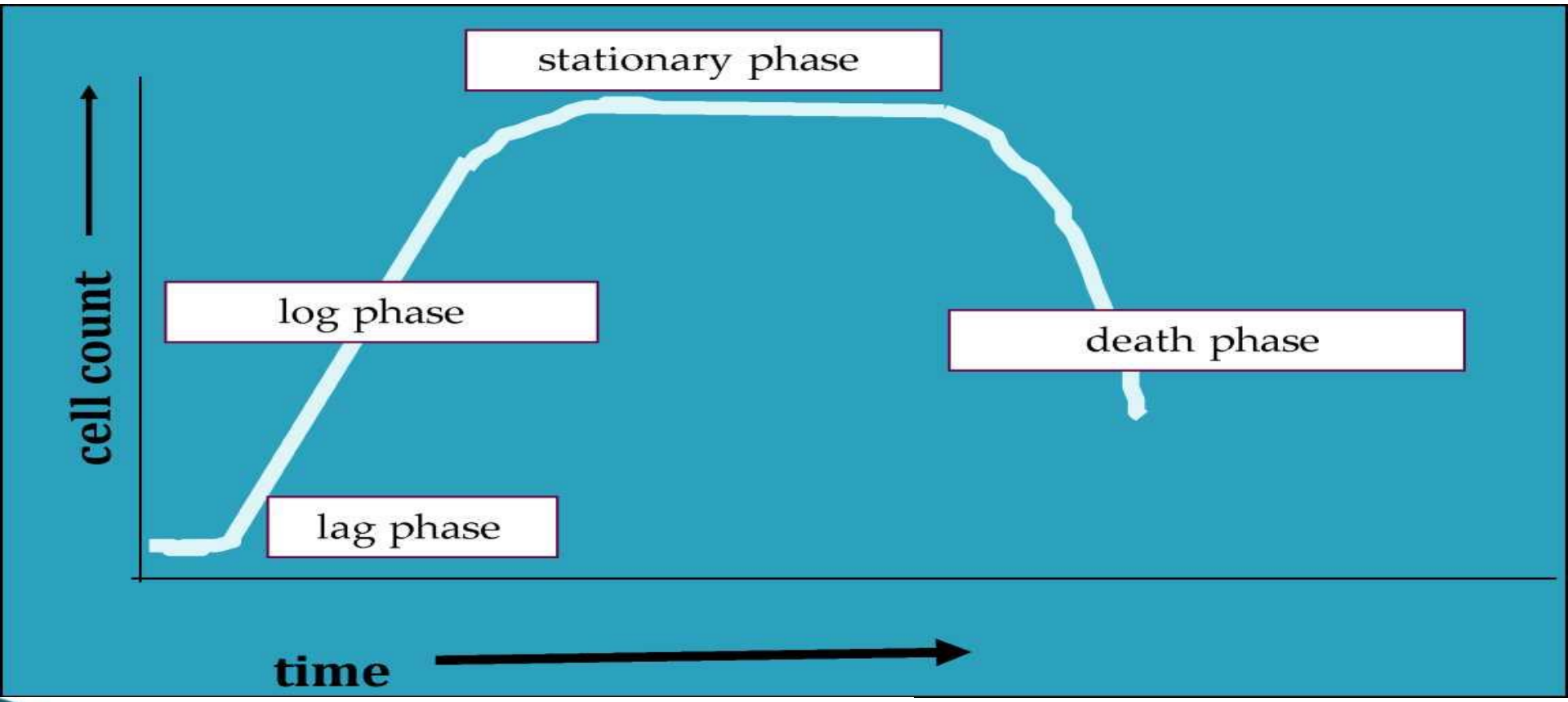
cell elongates

cell produces cell wall

two daughter cells produced

The cell replicates all its components, reorganizes it into two cells, forms a cell wall, and separates.

Growth curve (typical phases of growth)



Composition of bacterial cell:

	Percentage by weight
Carbon	50
Oxygen	20
Nitrogen	14
Hydrogen	8
Phosphorus	3
Sulfur	1

- Potassium 1
- Sodium 1
- Calcium 0.5
- Magnesium 0.5
- Iron 0.2
- All other elements 0.3

Cell Formula $C_{60}H_{84}N_{12}O_{24}P$

Requirements for Bacterial Growth

- **Nutritional**
  - Carbon source (waste to be degraded)
  - N & P (IOO:5:I;C:N:P)
  - Trace minerals
- **Environmental**
  - Oxygen (terminal electron acceptor)
  - Temperature
  - Water
  - pH
  - Non-toxic

Microorganisms

Classification:

- Heterotrophic- obtain energy from oxidation of organic matter (organic Carbon)
- Autotrophic- obtain energy from oxidation of inorganic matter (CO_2, NH_4, H_+)
- Phototrophic- obtain energy from sunlight

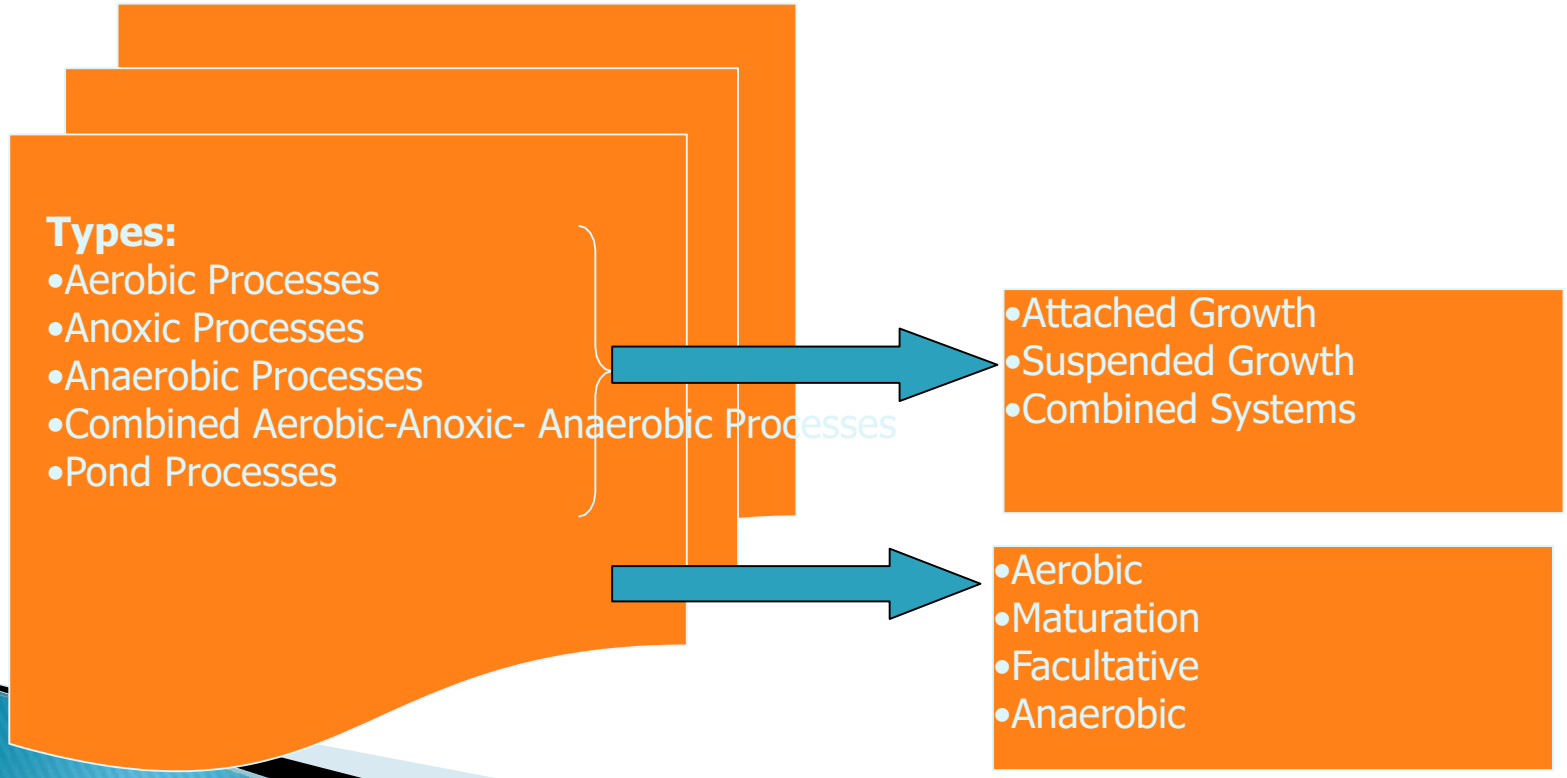
Biochemical Environments

Three Major Ones

- Aerobic - oxygen
- Anoxic - nitrate
- Anaerobic - strict and facultative

Biological Treatment

- In the case of domestic wastewater treatment, the objective of biological treatment is:
  - ❑ To stabilize the organic content
  - ❑ To remove nutrients such as nitrogen and phosphorus



Major Aerobic Biological Processes

Type of Growth	Common Name	Use
Suspended Growth	Activated Sludge (AS)	Carbonaceous BOD removal (nitrification)
	Aerated Lagoons	Carbonaceous BOD removal (nitrification)
Attached Growth	Trickling Filters	Carbonaceous BOD removal. nitrification
	Roughing Filters (trickling filters with high hydraulic loading rates)	Carbonaceous BOD removal
	Rotating Biological Contactors	Carbonaceous BOD removal (nitrification)
	Packed-bed reactors	Carbonaceous BOD removal (nitrification)
Combined Suspended & Attached Growth	Activated Biofilter Process s Trickling filter-solids contact process s Biofilter-AS process s Series trickling filter-AS process	Carbonaceous BOD removal (nitrification)

Biological Carbonaceous Removal

aerobic

A - oxidation

bacteria

CHONS + O_2 + Nutrients --------►CO_2 + NH, + C_5HNO_2

(organic matter) (new bacterial cells

+ other end products)

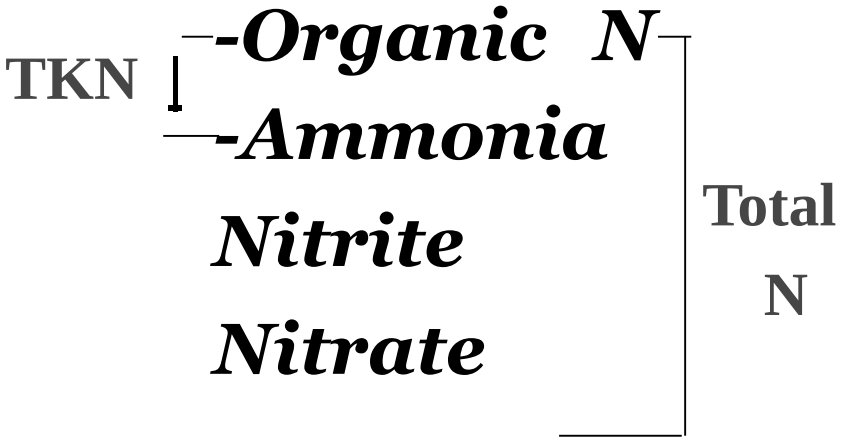
B- endogenous respiration

bacteria

OHNO, + 5O2 + $5CO_2$ -------► + 2H2O + NH3 + energy (cells)

What are the forms of nitrogen found in wastewater?

- Forms of nitrogen:



Why is it necessary to treat the forms of nitrogen?

- **Improve receiving stream quality**
- **Increase chlorination efficiency**
- **Minimize pH changes in plant**
- **Increase suitability for reuse**
- **Prevent NH_4 toxicity**
- **Protect groundwater from nitrate contamination**
- **Increases aquatic growth (algae)**
- **Increases DO depletion**

Nitrification

- NH_4^+ -> ***Nitrosomonas*** NO_2^-
- NO_2^- ^ ***Nitrobacter*** ^ NO_3^-

Denitrification

- **NO_3^- ^ denitrifiers (facultative bacteria) ^ N gas + CO_2 gas**
  - Nitrate is used instead of oxygen as terminal electron acceptor
  - Denitrifiers require reduced carbon source for energy and cell synthesis
  - Denitrifiers can use variety of organic carbon source - methanol, ethanol and acetic acid

Biological Nitrogen Removal

- factors affecting nitrification

- temperature
- substrate concentration
- dissolved oxygen
- pH
- toxic and inhibitory substances

Biological Nitrogen Removal

- factors affecting denitrification
  - temperature
  - dissolved oxygen
  - pH

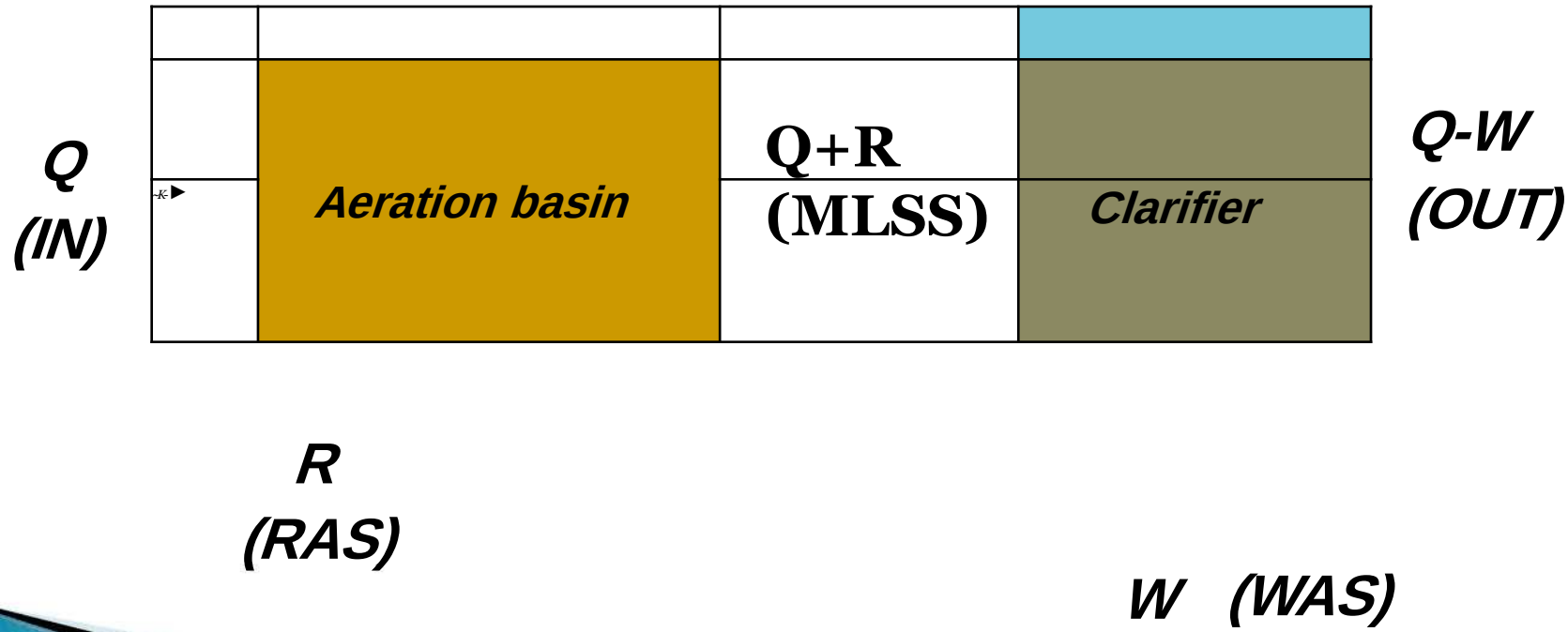
Activated Sludge Process

Activated Sludge Process

- There are two phases to biological treatment

- "Mineralization" of the waste organics producing $CO_2 + H_2O$ + microbes
- Separation of the microbes and water

Activated Sludge Process



MLSS

Mixed Liquor Suspended Solids

The suspended solids in the totally mixed aeration basin liquid

MLVSS

Mixed Liquor Volatile Suspended Solids □ The part

of MLSS which will combust.

- A good approximation of the active biological portion of the MLSS (75 - 85%)
- In a well oxidised sample,

MLVSS = biomass

Operational Parameters in Activated Sludge Process

- Nature of substrate
- F/M ratio
- Dissolved Oxygen
- RAS
- Reactor Configuration
- pH
- Reaction kinetics
- Reactor Hydraulics
- Nutrients

Activated Sludge Process

- **Monitoring**
  - **Flows**
  - **Organic Concentrations and Loadings**
  - **Solids concentrations**
  - **Settleability data**
  - **Oxygen**
    - **Dissolved oxygen (DO) in aeration basin**
    - **DOUR (Dissolved oxygen uptake rate (mg/L/hr)**

Thank You