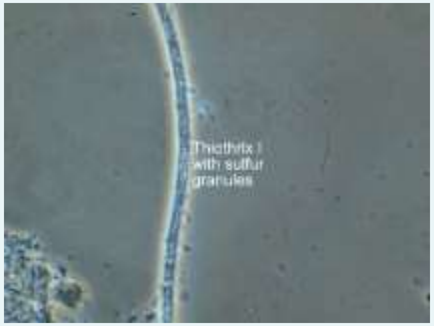
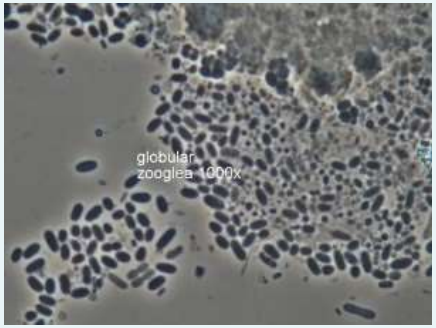
# Septicity

**(Organic Acids/ Sulfide)**

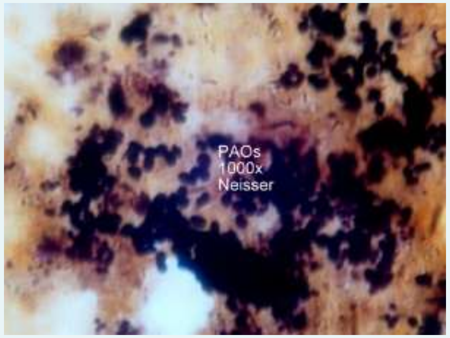
*Presented by: Ryan Hennessy*

**Midwest Contract Operations**



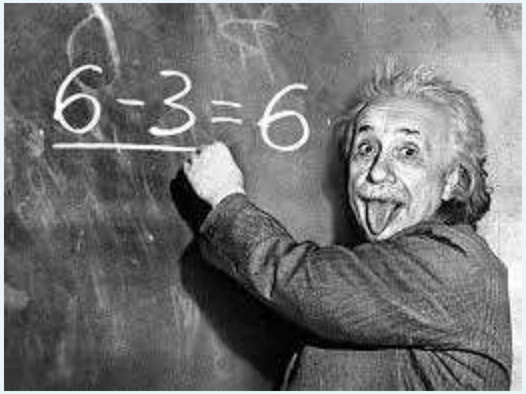







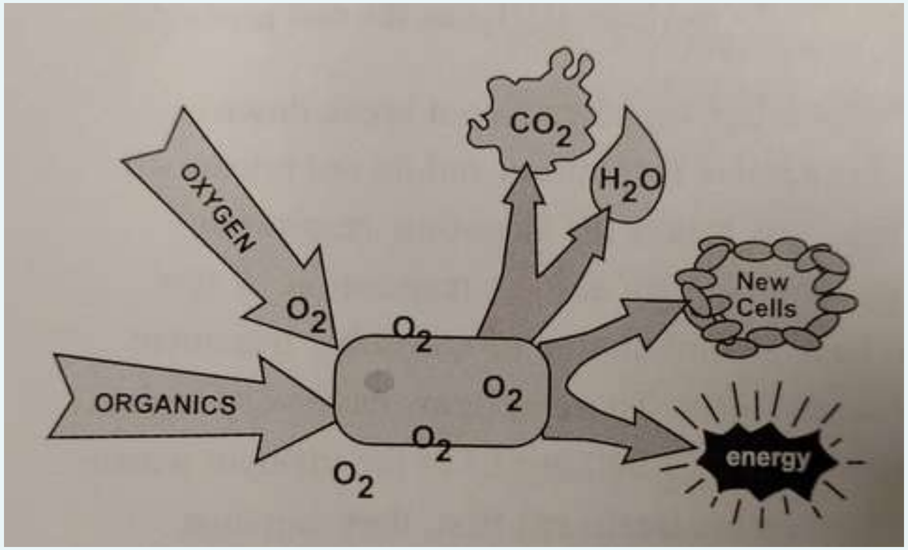
# Types of Organisms

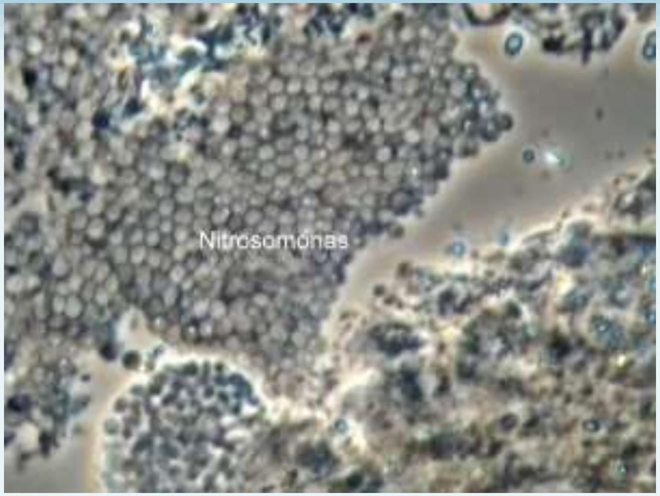
- Microorganisms can be classified by the type of respiration they use
- **Aerobes** use aerobic respiration
- **Anaerobes** have a different metabolism and oxygen (free and combined) is toxic to them
- **Facultative** organisms can possess both enzyme systems, but function aerobically if oxygen is available

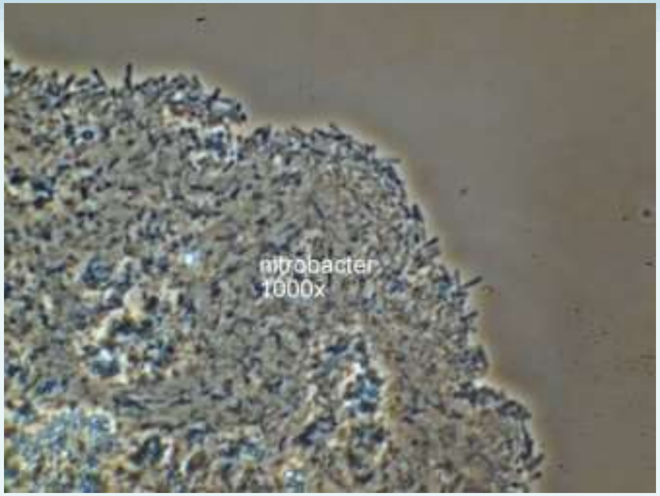


# Types of Respiration

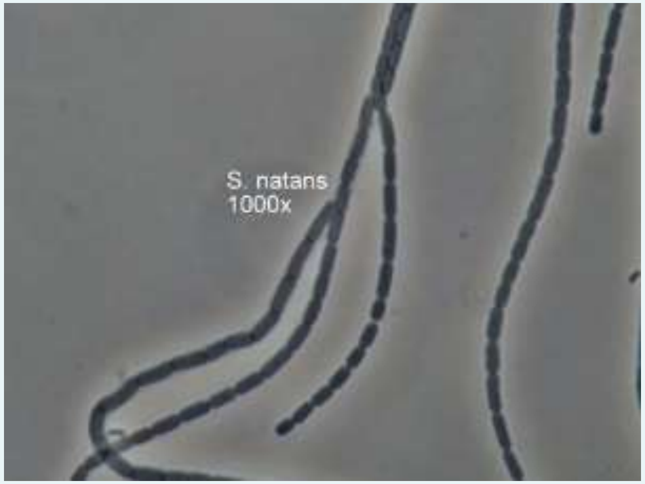
- **Aerobic Respiration**: oxygen is involved in the last step (as an electron acceptor)
- Organics + Oxygen yield carbon dioxide, water, new cells, and energy




Nitrosomonas


nitrobacter
1000x


Suctorian
200x


S. natans
1000x

# Respiration and Enzymes

- Respiration is a process controlled by enzymes that creates usable energy from food molecules

- **Enzymes are critical to the process**
  - These are protein molecules that are manufactured by cells
  - Each reaction sequence needs a certain set of active enzymes
  - The reason extremes in temperature, pH, and the presence of toxic materials disrupt treatment is due to the failure of enzymes

# "Build it and they will come".



- pH
- Alkalinity
- Temperature
- Hydraulic Retention Time
- Sludge Retention Time
- Dissolved Oxygen
- Nutrients

- Additional Variables
  - Fats, Oils, Grease
  - Septicity/ Organic Acids
  - Inhibitory Compounds

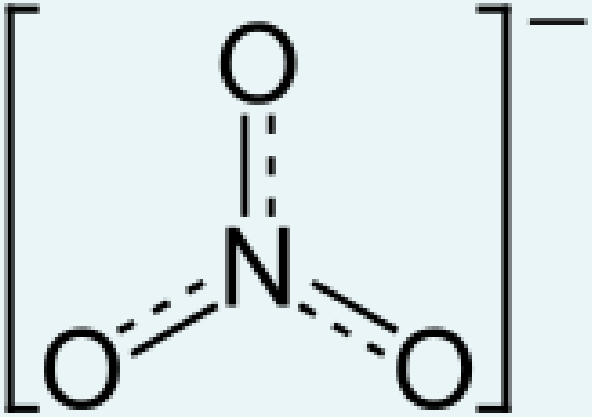
# Anaerobic Respiration

- **Anaerobic Respiration**: no free or dissolved oxygen, but uses oxygen combined in other compounds such as Nitrate and Sulfate.
  - Nitrate will be used before sulfate
    - When nitrate (NO3-) is used, nitrogen gas is the end product
      - Denitrification
    - When sulfate (SO4-2) is used, end products are hydrogen sulfide
      - Sulfide formation
    - When carbonate is used, methane is produced
      - Anaerobic treatment

# Facultative Bacteria Option #1

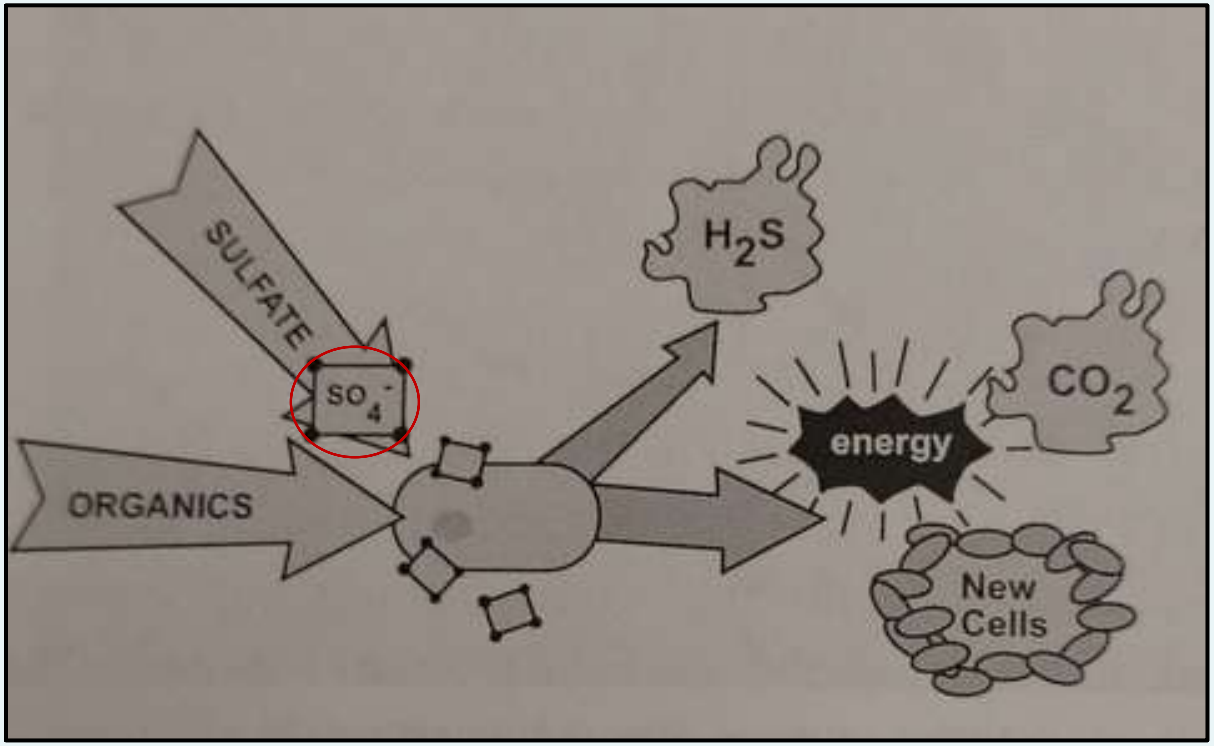
**Dissolved Oxygen (preferred)**

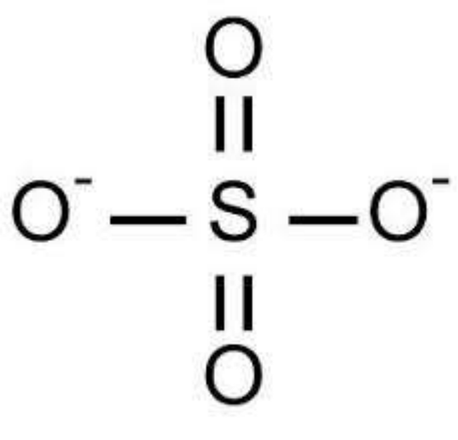
# Option #2 “Nitrate”



Nitrate + **carbon source** + facultative bacteria = Nitrogen gas, carbon dioxide, water, alkalinity, and new bacterial cells

# Option #3 Sulfate as Electron Receptor



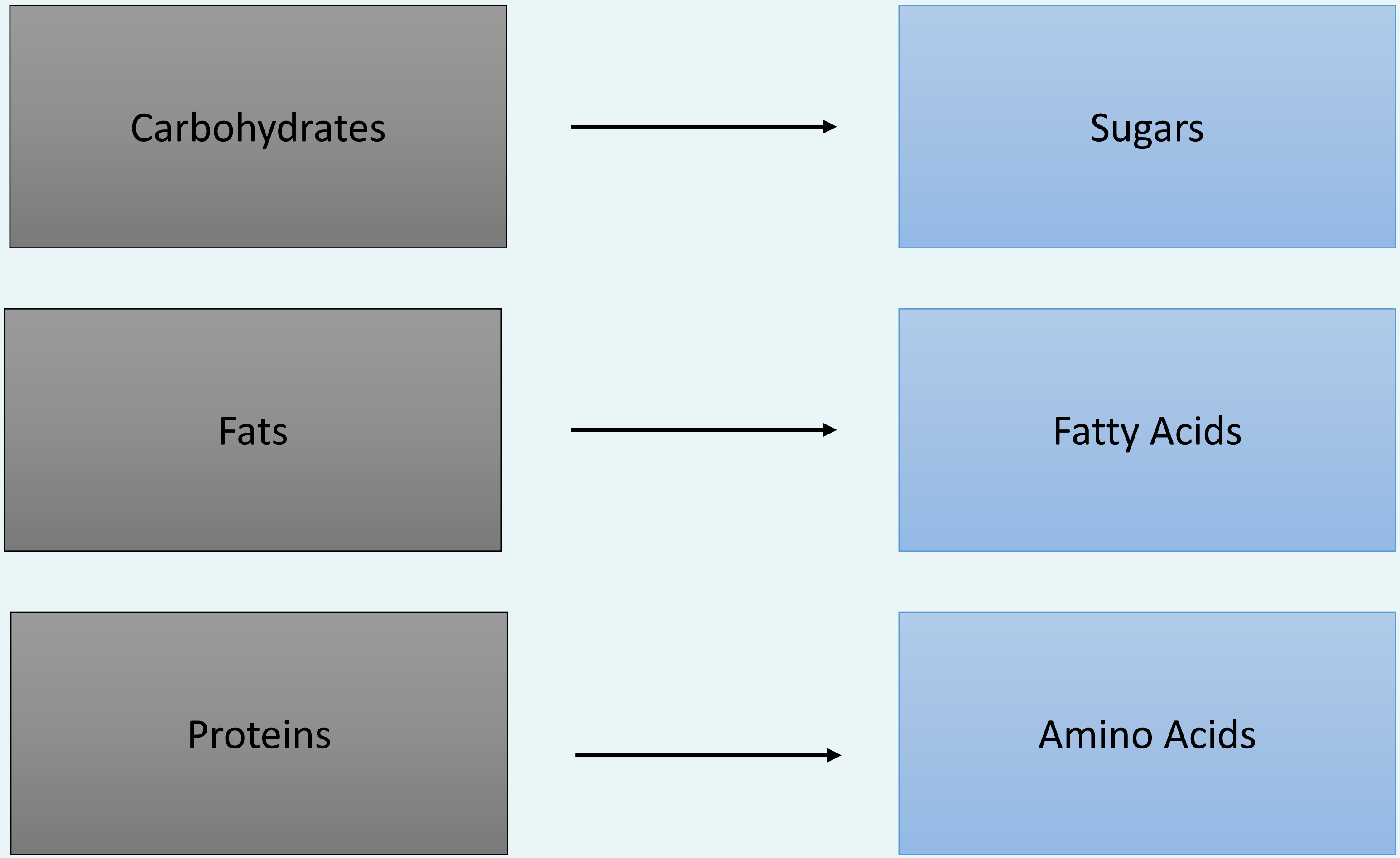
# Four Steps of Anaerobic Digestion

1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis

Egg-shaped gas storage

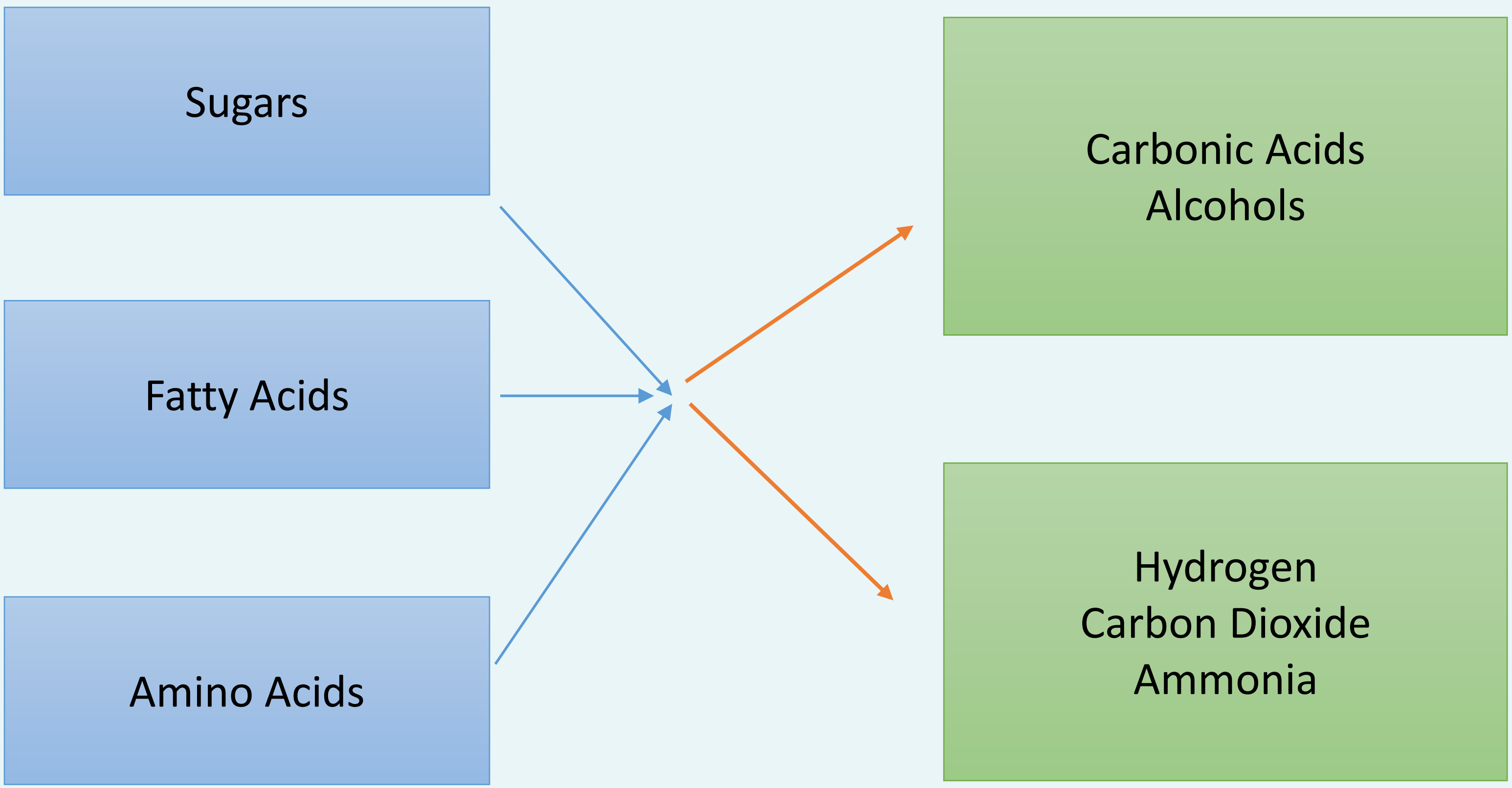
# Hydrolysis-Large Polymers To Smaller Parts

*Performed by bacteria, protozoa, and exocellular enzymes*



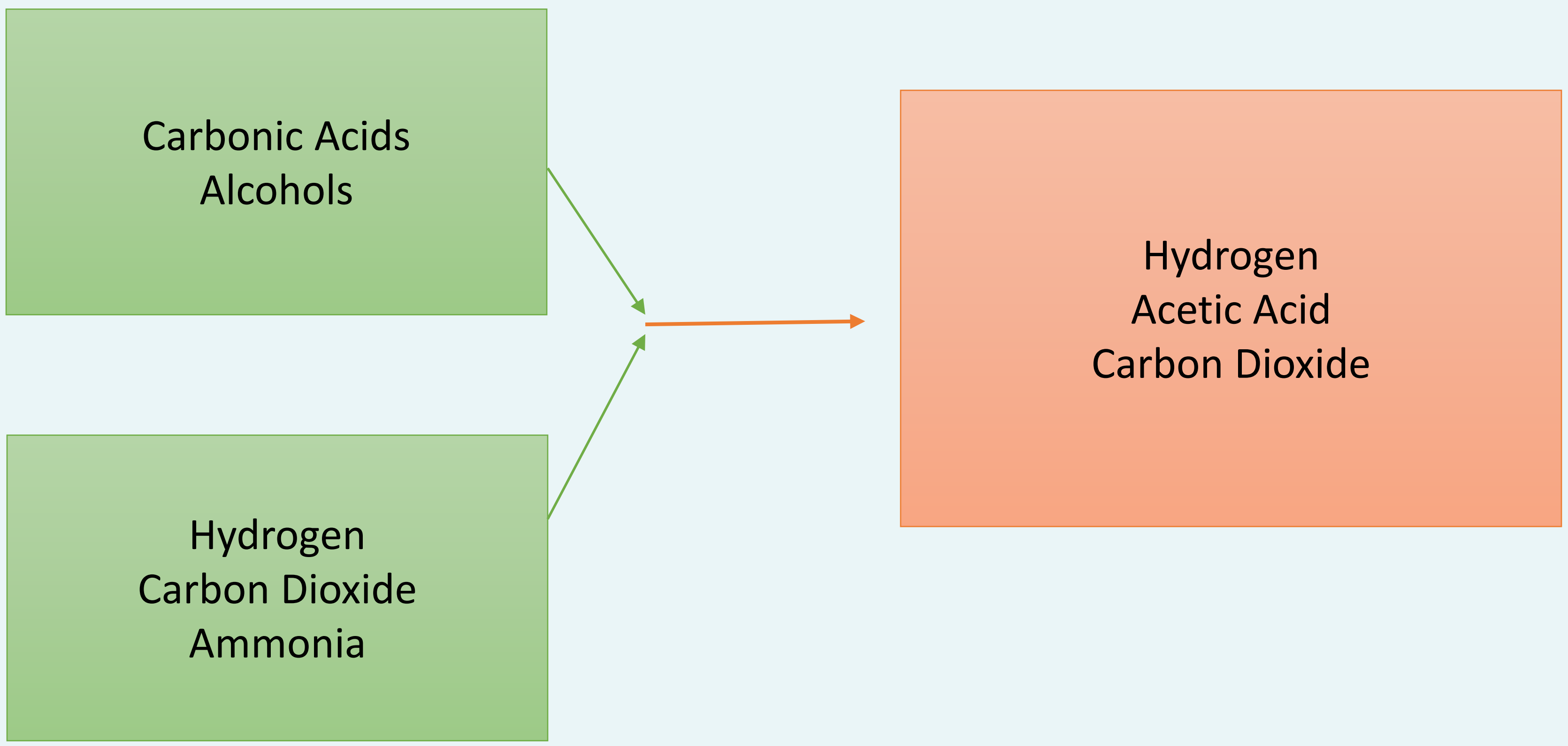
# Acidogenesis

*Done by Acid Forming Bacteria*



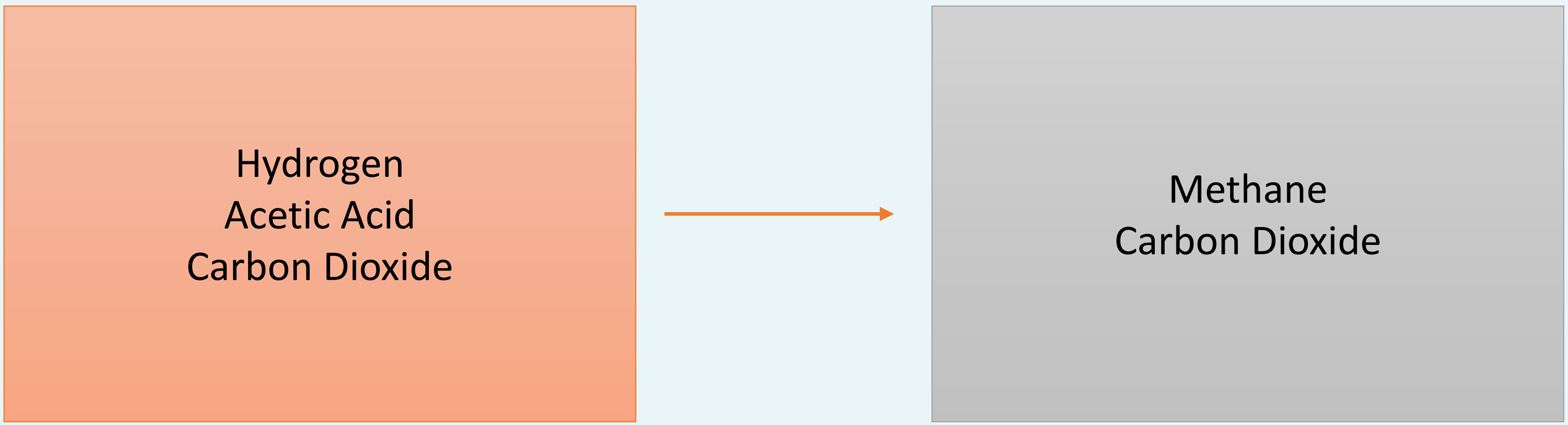
# Acetogenesis

*Done by Acid Forming Bacteria*

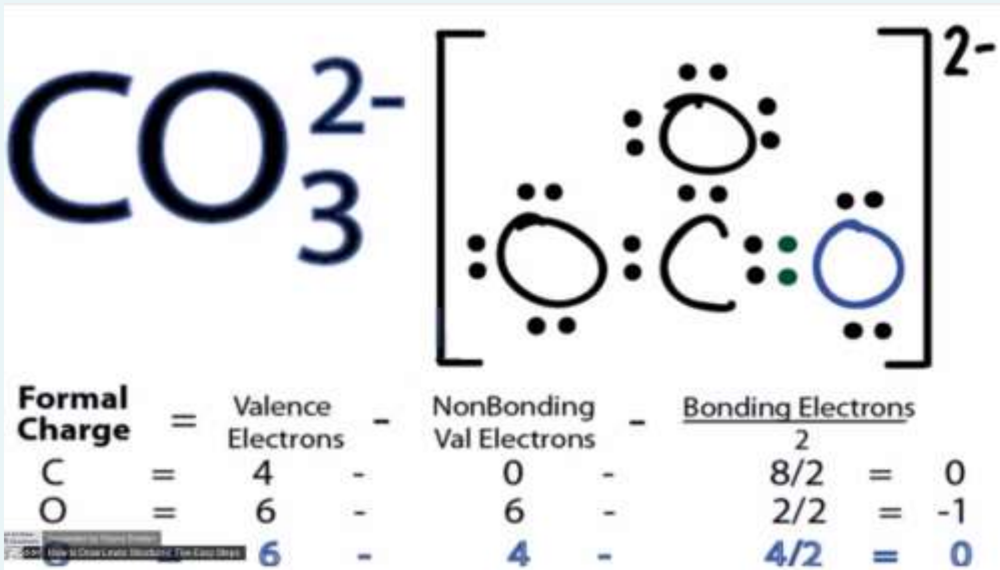


# Methanogenesis

*Done by Methanogens*

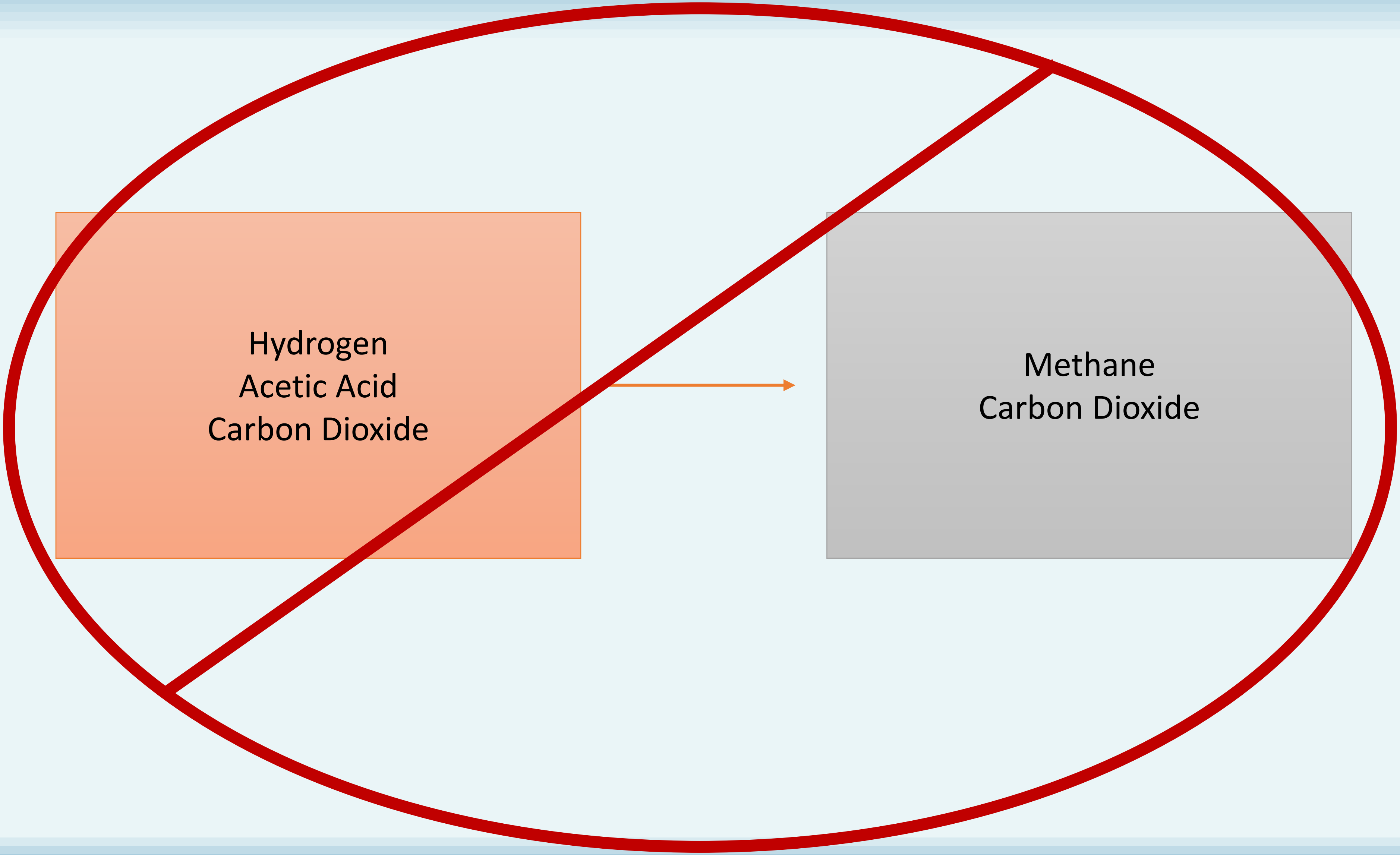


# Anaerobic Treatment: Carbonate Reduction

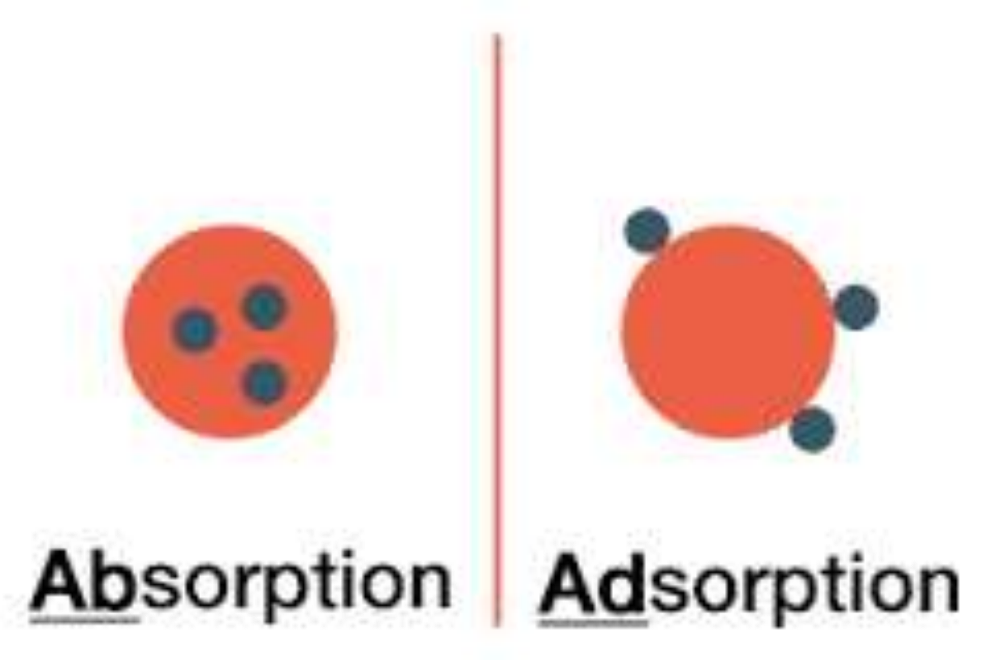



**Carbon Dioxide and Methane as end products**

# Fermentation

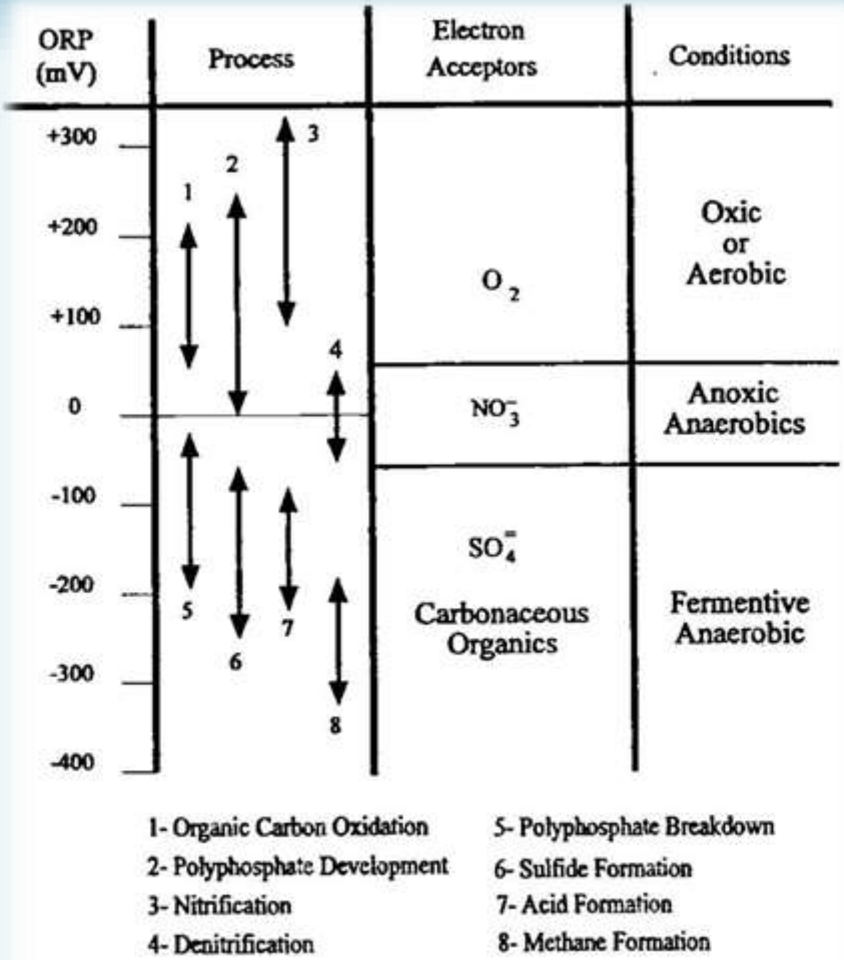


# Absorption vs Adsorption




# What is Septicity?

- Septicity occurs when bacteria ferment organic matter (BOD) to “smaller pieces” in the absence of free dissolved oxygen
  - These “smaller pieces” are known as organic acids

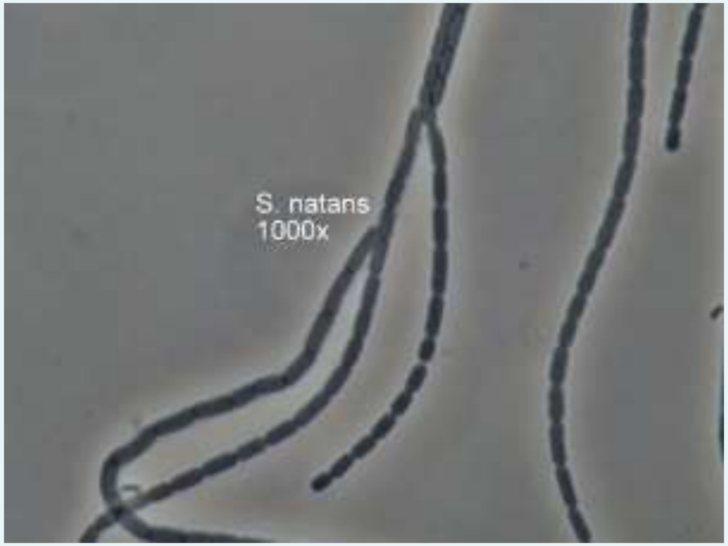



ORP & Metabolic Processes.
Goronszy, M, et al 1992

# Septicity

- Wastewater becomes/ became anaerobic
- Sulfate reducing bacteria reduce sulfate to hydrogen sulfide
- Anaerobic bacteria ferment organic materials to organic acids
  - Acetic
  - Propionic
  - Butyric
  - Valeric

# Septicity Vs. Low DO




# Sources of Septicity

- Can occur ahead of the plant
  - Lift stations
  - Long retention time in collection system

- Industrial wastes
  - Dairy, pickling, textile dyeing operations
- Septage
- Treatment Plant
  - Equalization basins
  - Primary clarifiers
  - Sludge processing side-streams
  - Co thickening WAS sludge can be a common cause

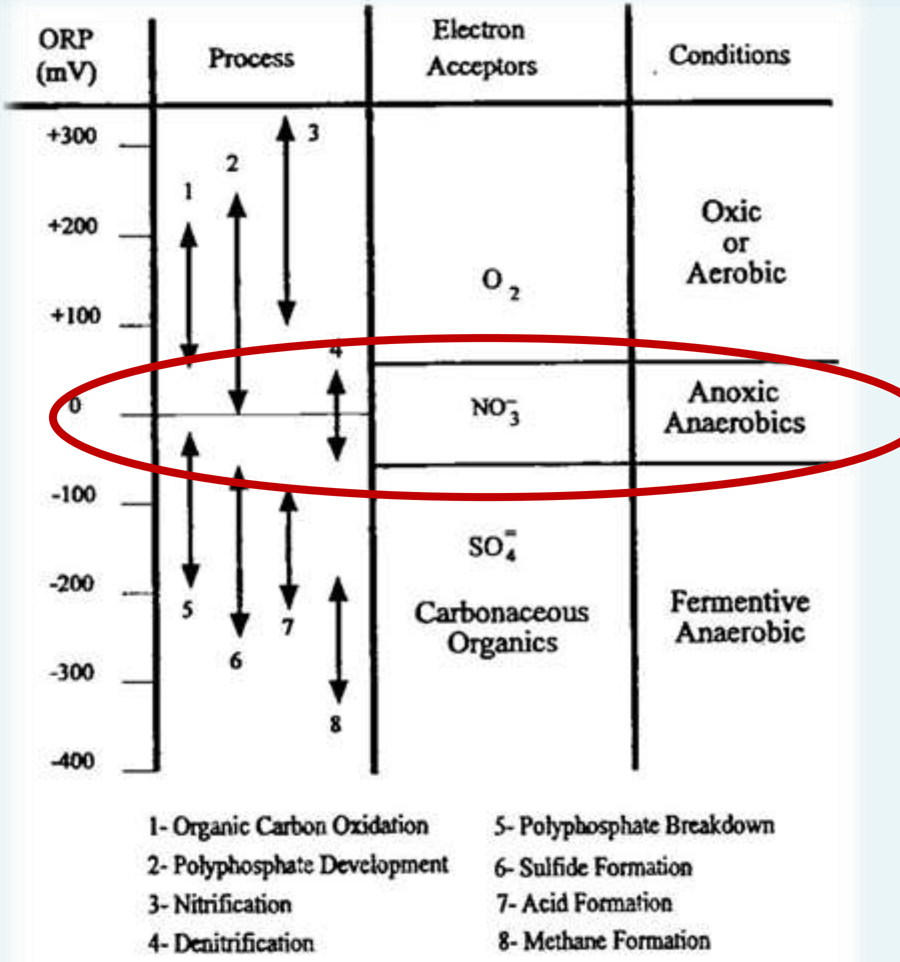
# Double Edged Sword

- **Organic Acids (VFA's) are needed for enhanced biological nutrient removal**
  - Denitrification
  - Biological Phosphorus Removal


- To obtain enhanced biological nutrient removal plant must be designed with selector
  - **If VFAs are too high and pass through selector can cause several issues**
  - Filaments
  - Dispersed growth
  - Zooglea
  - Inhibition of nitrification

# Organic Acids role in Denitrification

- Nitrate + **carbon source** + facultative bacteria = Nitrogen gas, carbon dioxide, water, alkalinity,
  and new bacterial cells
  - In denitrification, bacteria reduce nitrate to nitrogen gas. Nitrogen gas is not very water-soluble so it is released into the atmosphere
- Actual requirements of **soluble COD** to nitrate for denitrification are plant specific and can sometimes be as high as 10 mg COD/mg nitrate to denitrify




ORP & Metabolic Processes.
Goronszy, M, et al 1992

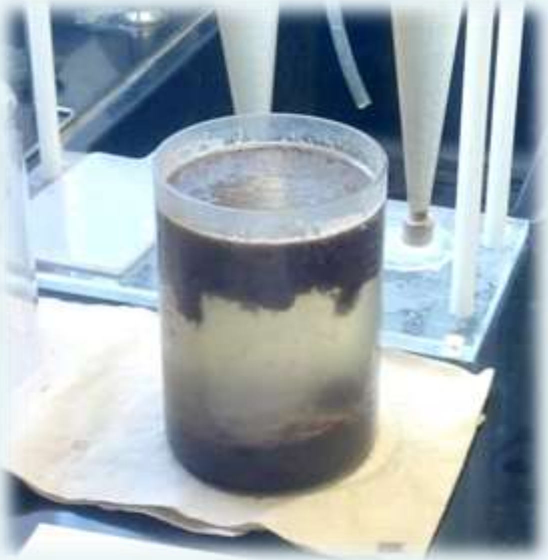
# Causes of Denitrification

1. Lack of DO
2. Presence of Nitrate
   - Through Nitrification
3. A carbon source
   - Soluble BOD
   - Internally stored BOD such as PHB granules

Denitrification in Clarifier

# Denitrification Problems

- Can be diagnosed by seeing the settled sludge rise in the settling test jar within 2 hours or less
- Occurs when nitrogen is batch dosed due to high periods of nitrate build up
- Denitrification and nitrification can occur simultaneously in the floc with no residual nitrate



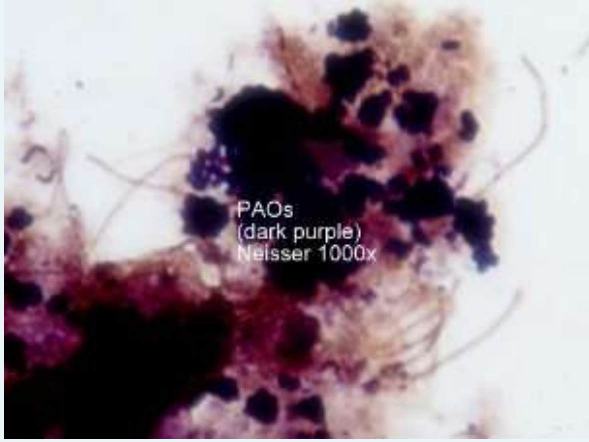
Denitrification

# Control Strategies: Denitrification

- Increase DO at end or aeration basin
- Increase RAS rate to limit sludge retention time in the clarifier to a minimum
- Prevent nitrification
  - Usually not possible/ permit
- Improve sludge quality

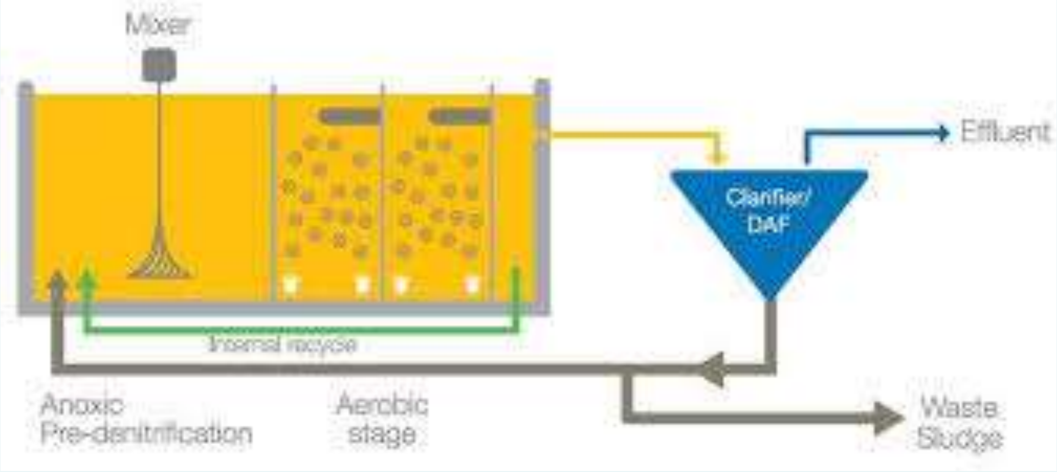
# Biological Phosphorus Removal

- In a conventional activated sludge system microorganisms take up soluble phosphorous as a nutrient to generate new biomass
  - These organisms contain about 2% of phosphorous on a dry weight basis
- Polyphosphate Accumulating Organisms consist of roughly 35% phosphorous
- By creating an environment to select PAOs more phosphorous can be taken up by the bacteria
  - Sludges with high percentage of PAOs can contain up to 6% phosphorous on a dry weight basis

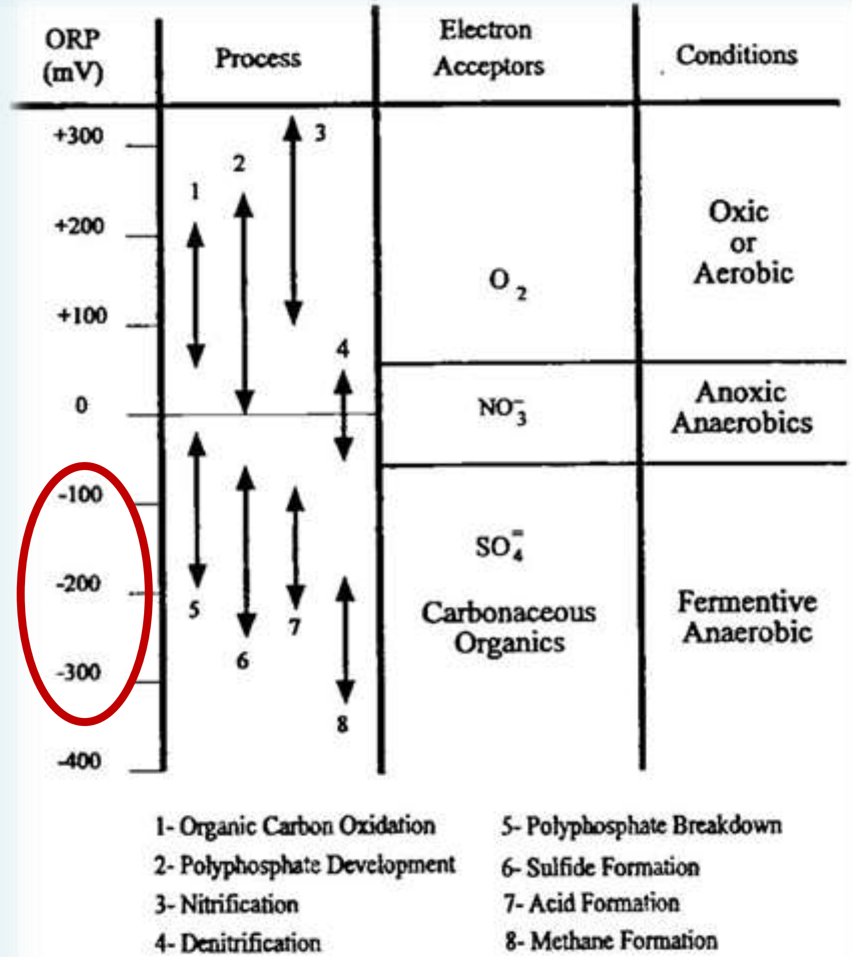


# Bio P removal (summary)

- A two step process in which an anaerobic environment is followed by an aerobic one
- In the anaerobic selector PAOs release orthophosphate to obtain the energy to uptake readily biodegradable organics (soluble BOD)
- In the Aerobic zone PAOs grow new biomass and take up phosphorus, typically more than they released in the anaerobic zone



# OA's role in Bio P removal



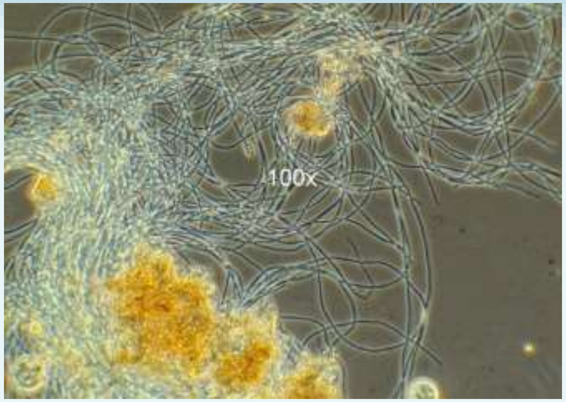

ORP & Metabolic Processes.
Goronszy, M, et al 1992

# Bio P impact Effluent Phos based on TSS

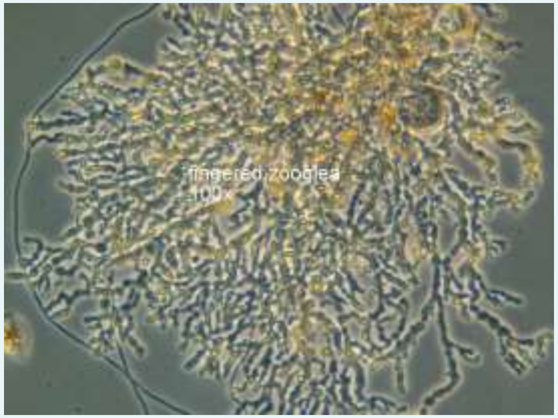
| Mg/L TSS | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|
| 3%P | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 |
| 4%P | 0.40 | 0.60 | 0.80 | 1.00 | 1.20 |
| 5%P | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 |
| 6% | 0.60 | 0.90 | 1.20 | 1.50 | 1.80 |

# If too many OA's pass through…..

- Selector should remove 60-80% of soluble BOD




Filamentous Bulking



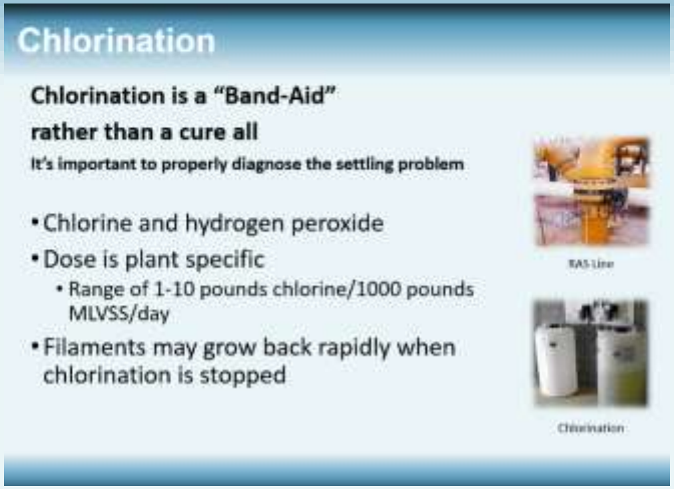
Floc with abundant zooglea

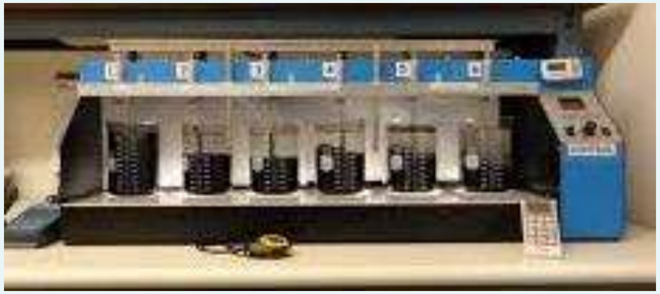
# Control of Septicity/Organic Acids

- Pre-aeration
- Chemical Oxidation
  - Oxidizes sulfide and some organic acids
    - Chlorine, hydrogen peroxide, potassium permanganate
- Chemical Precipitation
  - Ferric Chloride will precipitate sulfide
- Calcium Nitrate
  - An “oxygen source” to raise the redox potential
- Diluting Influent
  - Recirculated % of treated effluent back into head of plant
- Switching modes of Operation
  - Step Feed
  - Complete-mix

# Other Options

- Often it is not possible or economically feasible to treat sources of organic acids
  - Coagulant/polymer addition
  - Chlorination of RAS to selectively destroy filaments



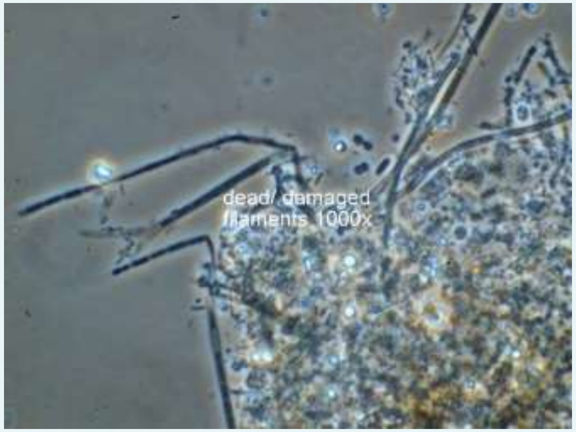
Polymer jar test

MCO Microscope Setup


Healthy filaments

MCO staff at microscope


Damaged filaments




Damaged filaments

# Chlorination

**Chlorination is a "Band-Aid" rather than a cure all**

**It's important to properly diagnose the settling problem**

- Chlorine and hydrogen peroxide
- Dose is plant specific
  - Range of 1-10 pounds chlorine/1000 pounds MLVSS/day
- Filaments may grow back rapidly when chlorination is stopped

RAS Line

Chlorination

# RAS Chlorination Dose

GENERAL GUIDELINES

- **2-3 lbs Chlorine/1000 lbs MLVSS/day**
  - A typical maintenance dose when the SVI is generally under control and chlorination is needed to kill newly growing filaments
- **5-6 lbs Chlorine/1000 lbs MLVSS/day**
  - A typical dose that will reduce SVI over several days and have little impact on effluent quality
- **10-12 lbs Chlorine/1000 lbs MLVSS/day**
  - Usually will destroy excess filaments and reduce the SVI rapidly/ Floc structure is likely to deteriorate at this dose

# Chlorine Dosing Points

Chlorine must be dosed at a point of excellent initial mixing

- Add where the chlorine demand is at a minimum
  - RAS line (application point of choice)
  - Elbow in a pipe
  - Into/below the rising liquid level in the riser tube of airlift RAS pumps

- Areas <u>NOT</u> to dose chlorine
  - Aeration basin (generally causes floc dispersion and system damage)
  - RAS wet wells
  - Mixed liquor channels
  - Any other point of poor mixing

# Contacts of Chlorine/MLSS

- RAS should come into contact with the chlorine 2-3x per day
- In long aeration basins with long hydraulic residence times a second RAS dosing point may be needed to obtain this
- Dose the center well of the clarifier in addition to the RAS line to achieve the necessary contacts between the RAS and the chlorine

# Chlorination (continued)

- A microscopic evaluation is recommended daily when chlorinating
- If the proper dose is reached settling usually improves in 1-3 days
- Sheathed filaments take longer to get rid once a target SVI is reached

# Chlorination Impacts

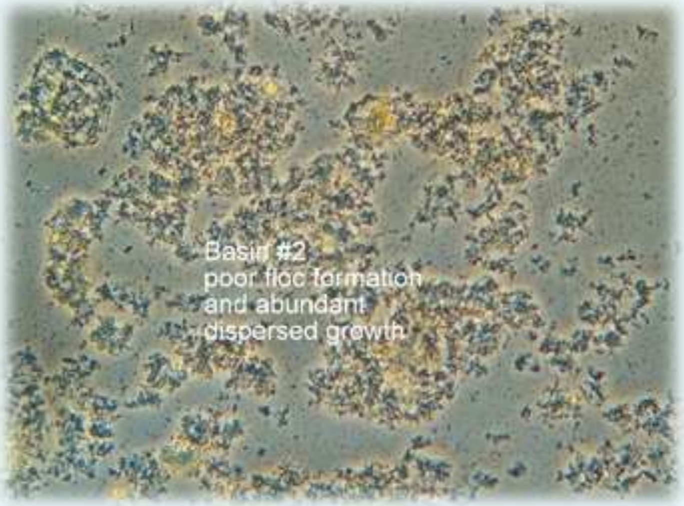

Empty Sheaths- *Thiothrix* I


Dead Filament

- Loss of sulfur granules
- Damaged cells, empty sheaths, and cytoplasm shrinkage
- Filament breakup
  - Ceasing chlorination once about 70% of the cells are damaged or missing a filament

# Signs of Over-Chlorination

- A turbid milky effluent
- Significant increase in effluent TSS
- Loss of higher life forms (protozoa,metazoa)
- Reduction of BOD removal
- Disruption of nitrification
- Small broken up flocs under the microscope




Over- Chlorination

# Take Home Points/ Review

- What are organic acids?
- Where are organic acids formed?
- What is the sequence in which different forms of dissolved oxygen are used?
- What is the main final end product in true anaerobic treatment and what's the difference between true anaerobic treatment and fermentation?
- What are we measuring with negative ORP values?
- Describe denitrification and it's recipe
- Describe biological phosphorus removal principles
- Describe potential ways to reduce septicity or maintain good settling sludge if source reduction is not possible.

# References


- Jenkins, D., M.G. Richard and G.T. Daigger, Manual on the Causes and Control of *Activated Sludge Bulking, Foaming, and Other Solids Separation Problems*, 3rd Edition., Lewis Publishers (CRC PRESS), Boca Raton, FL, 2003
- *Activated Sludge Microbiology Problems and Their Control,* 2010 Michael Richard, Ph.D. Michael Richard Wastewater Microbiology LLC Fort Collins, CO www.mrwwm.com
- Water Environment Federation, *Operation of Municipal Wastewater Treatment Plants Volume II: Liquid Processes, Manual of Practice No.11* McGraw Hill Companies, New York, NY 2008
- Industrial Activated Sludge Operations: METC Group Incorporated, 1999
- All microorganism pictures courtesy of Ryan Hennessy, Midwest Contract Operations, 2015 and 2016

# Q&A Segment

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**http://www.mco-us.com/**

## Thank you!


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