Microbiology of Biological Nutrient Removal

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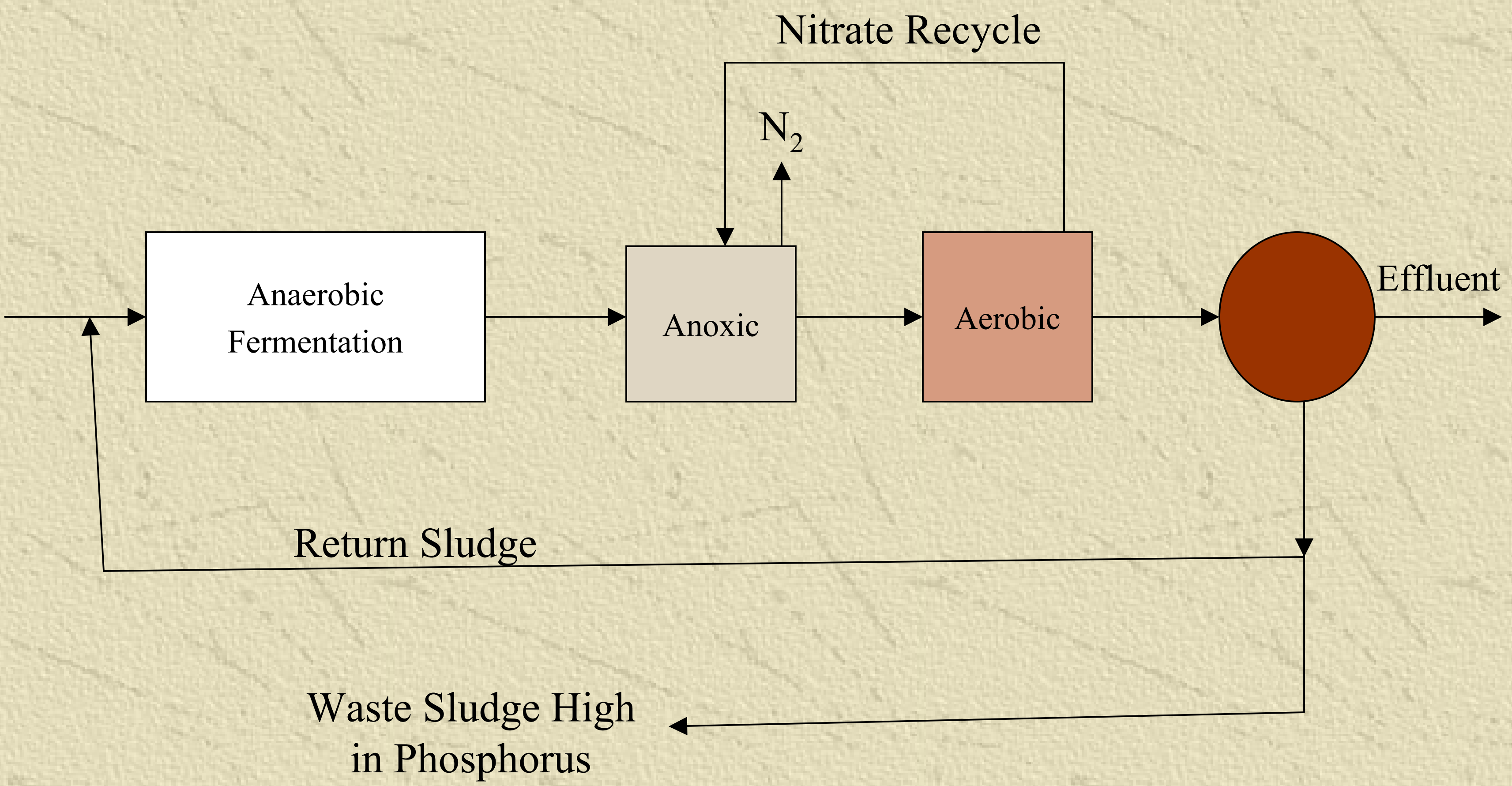
Outline

- Overview of BNR Systems
- Oxidation of Organic Compounds
- Carbon, Nitrogen & Phosphorus Cycles
- Polyphosphate Production and Breakdown
- Anaerobic, Anoxic & Aerobic Microbiological Processes
- Summary

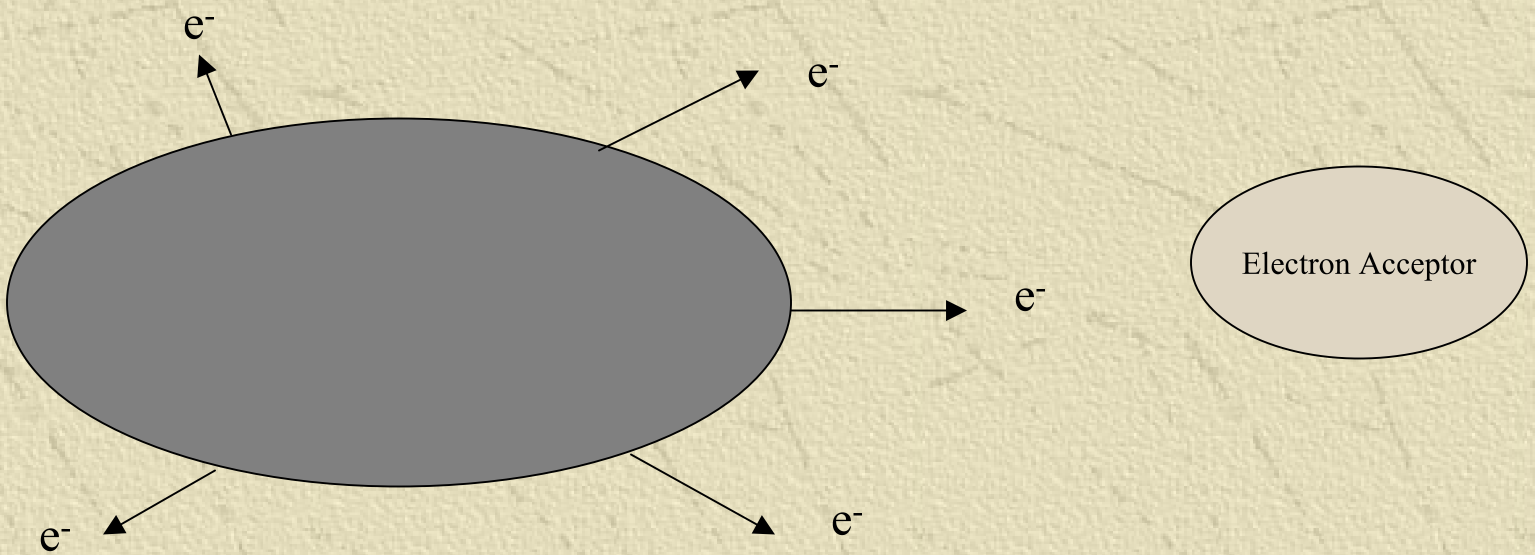
Biological Nutrient Removal (BNR) Systems

- Remove nitrogen and/or phosphorus
- Reduce oxygen requirements (denitrification)
- Reduce alkalinity requirements (denitrification)
- “Strange” microbiology
  - Obligate aerobes live in anaerobic conditions
- “Usually” controls sludge settleability
  - Floc-formers store food better than filaments
  - Upstream BOD_5 uptake “starves” filaments

Typical BNR System



Oxidation of Organic Compounds

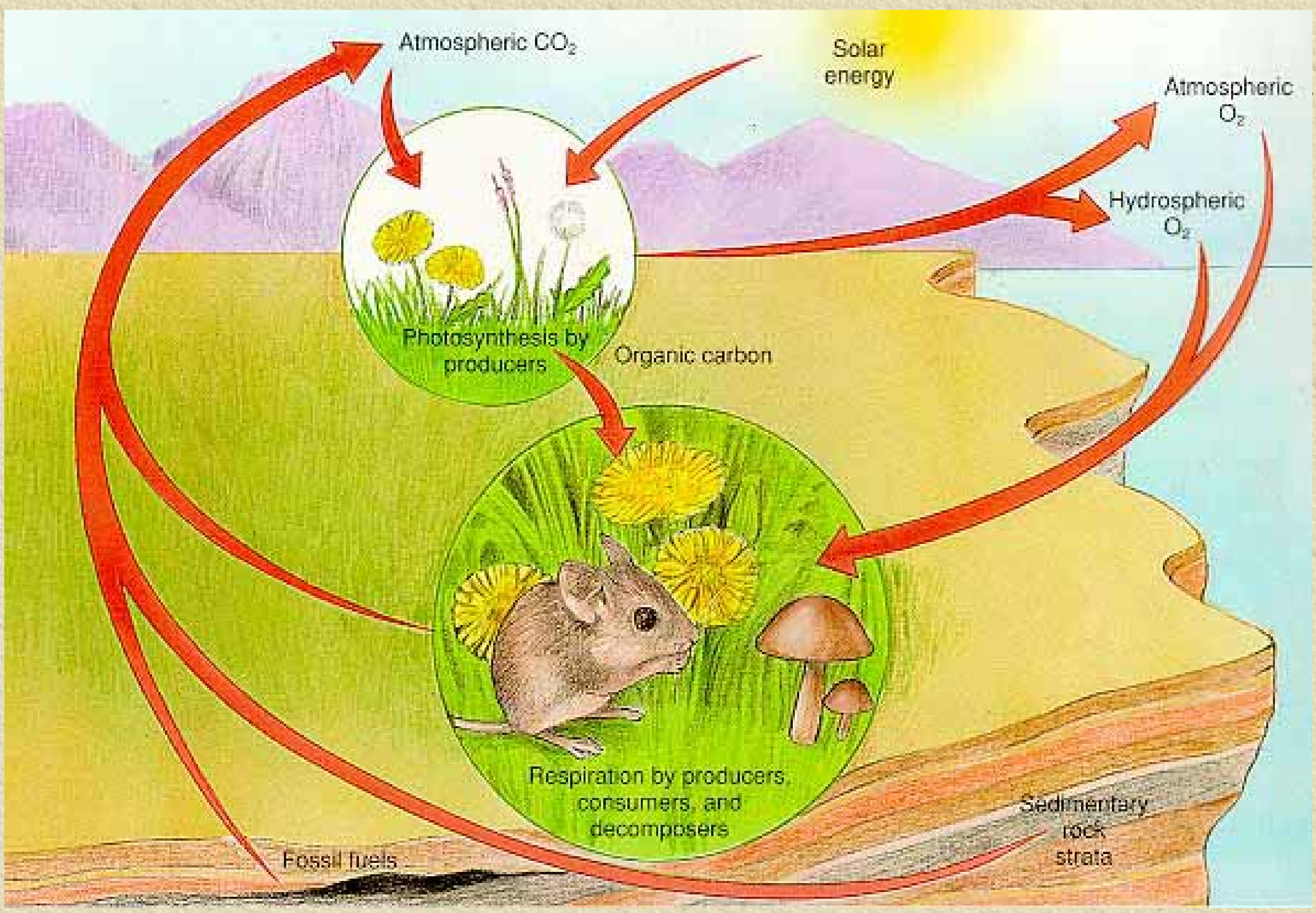


- Oxidation is loss of electrons
- Organics are oxidized
- Electron acceptor is reduced

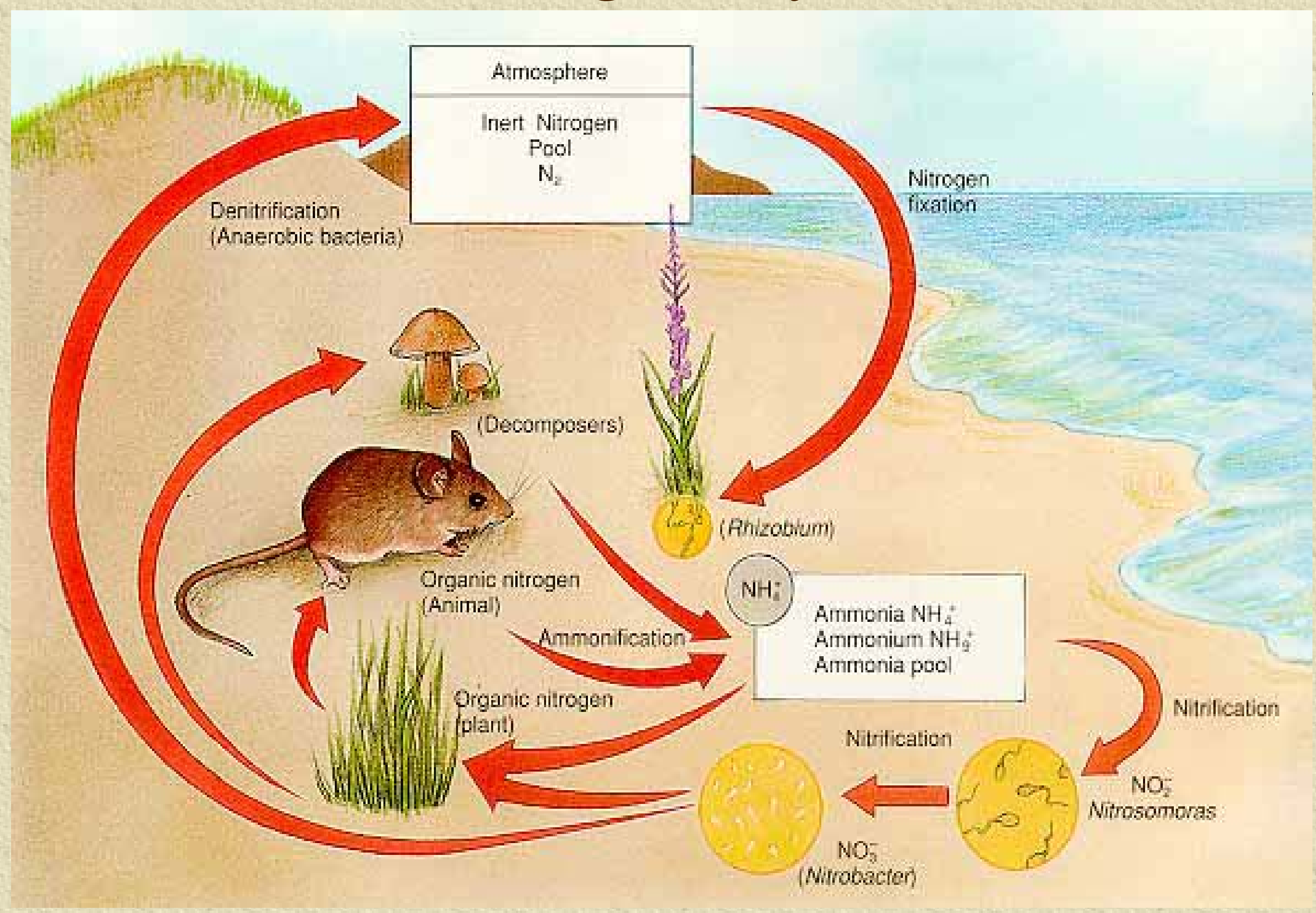
Electron Acceptors

- Aerobic respiration - O_2
- Anaerobic respiration - NO_3^-,SO_4^{-2},CO_3^{-2}
- Anoxic - NO_3^-
- Anaerobic fermentation - Alcohols and organic acids

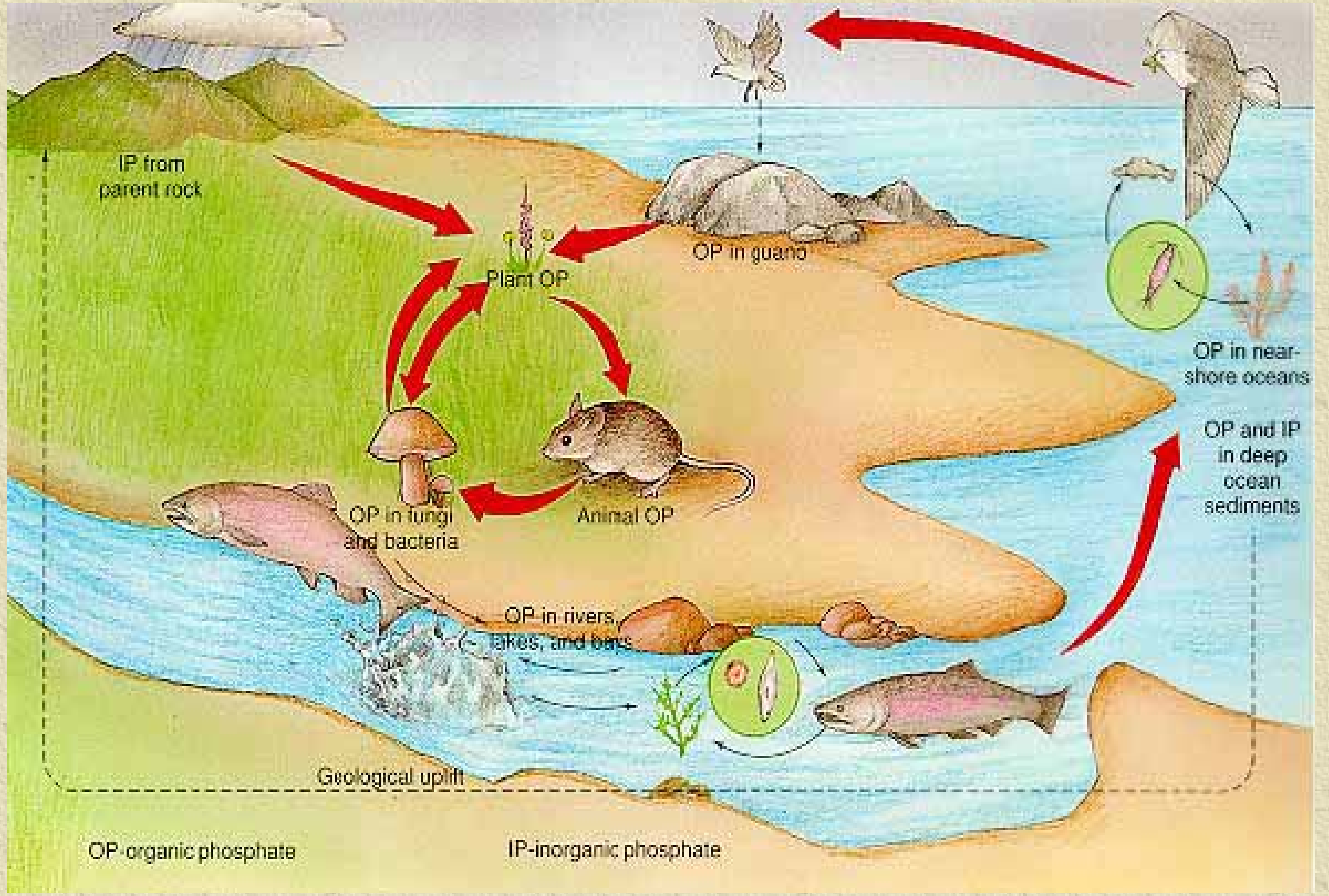
Carbon Cycle



Nitrogen Cycle



Phosphorus Cycle



Polyphosphate

Production

Polyphosphate + Energy $\Rightarrow$ Longer polyphosphate chain

PO_4^{-3}

Breakdown

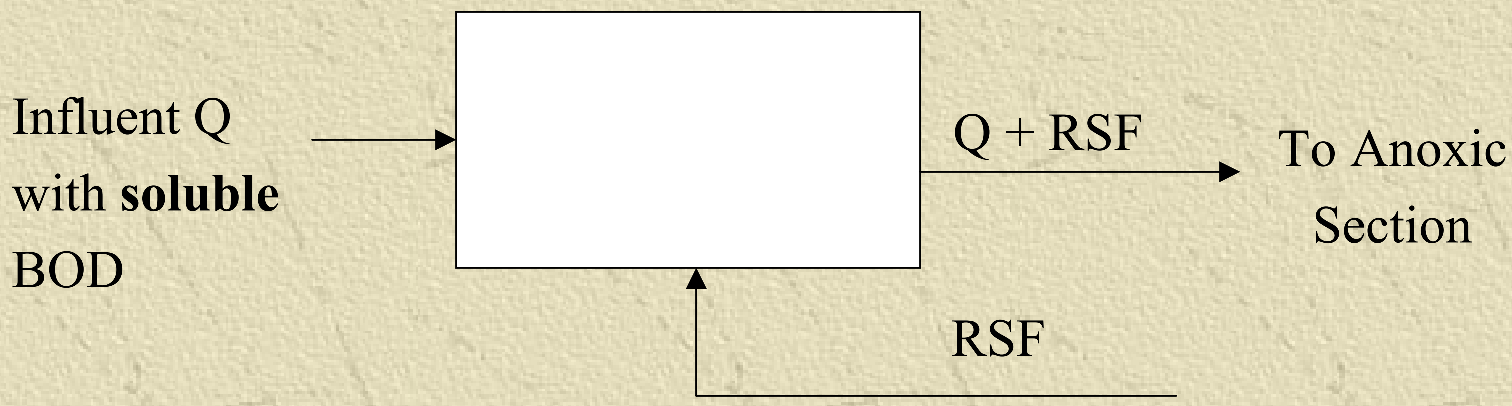
Energy

PO_4- PO_4- PO_4---PO_4 | PO_4 $\Rightarrow$

cleave

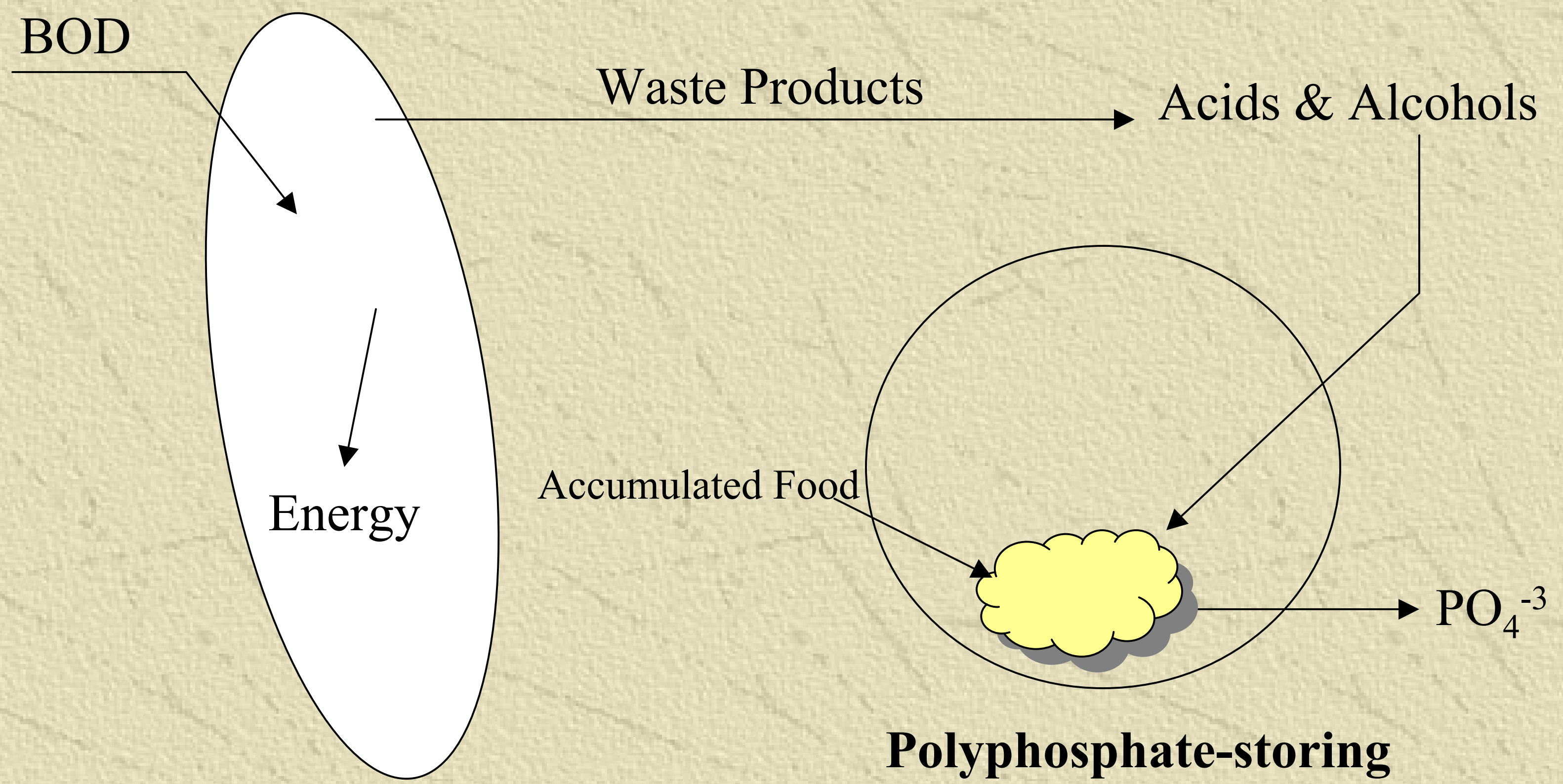
PO_4- PO_4- PO_4- PO_4---PO_4 + PO_4^{-3}

Anaerobic Section
(Anaerobic Fermentation)



Return sludge with facultative fermentation bacteria and obligate aerobic polyphosphate bacteria or phosphate accumulating organisms (PAOs)

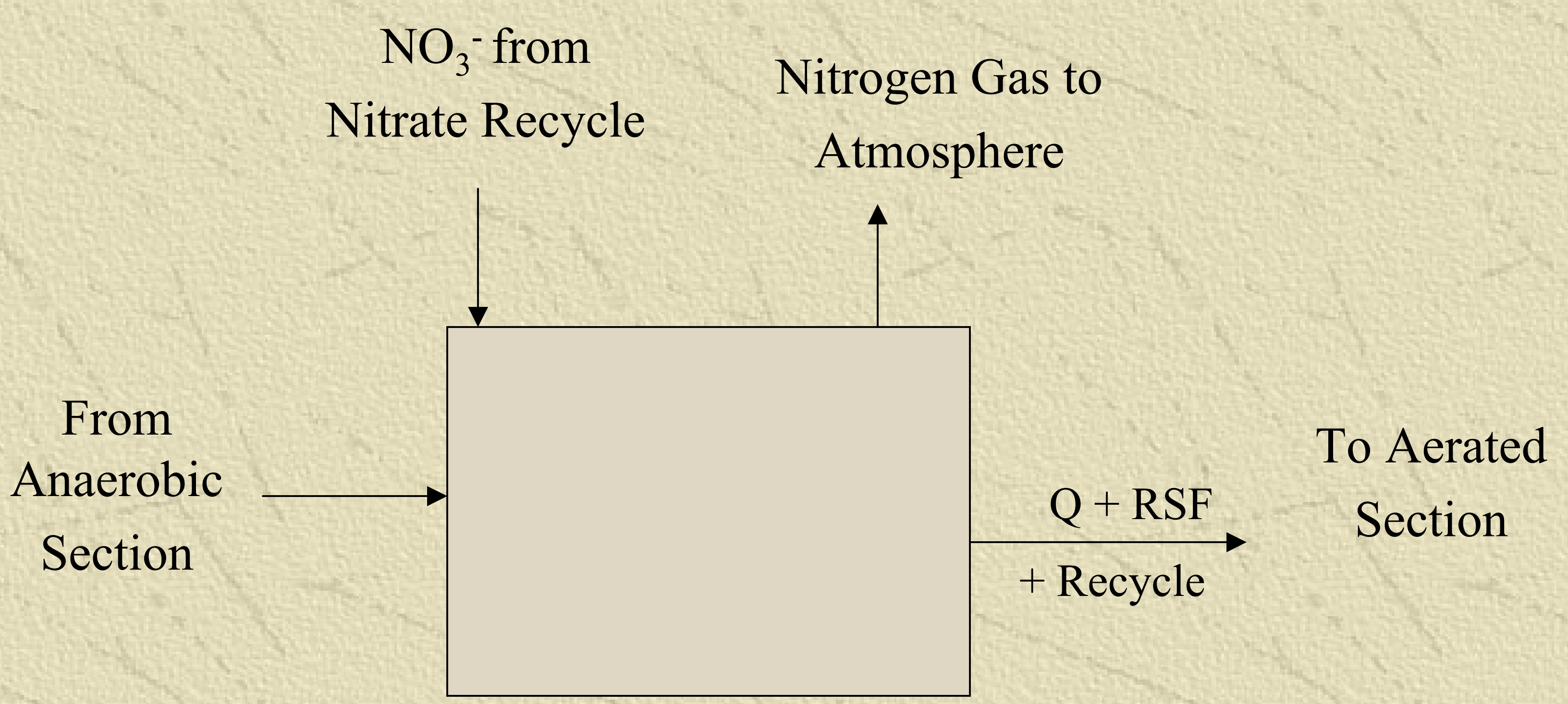
Anaerobic Section Microbiology



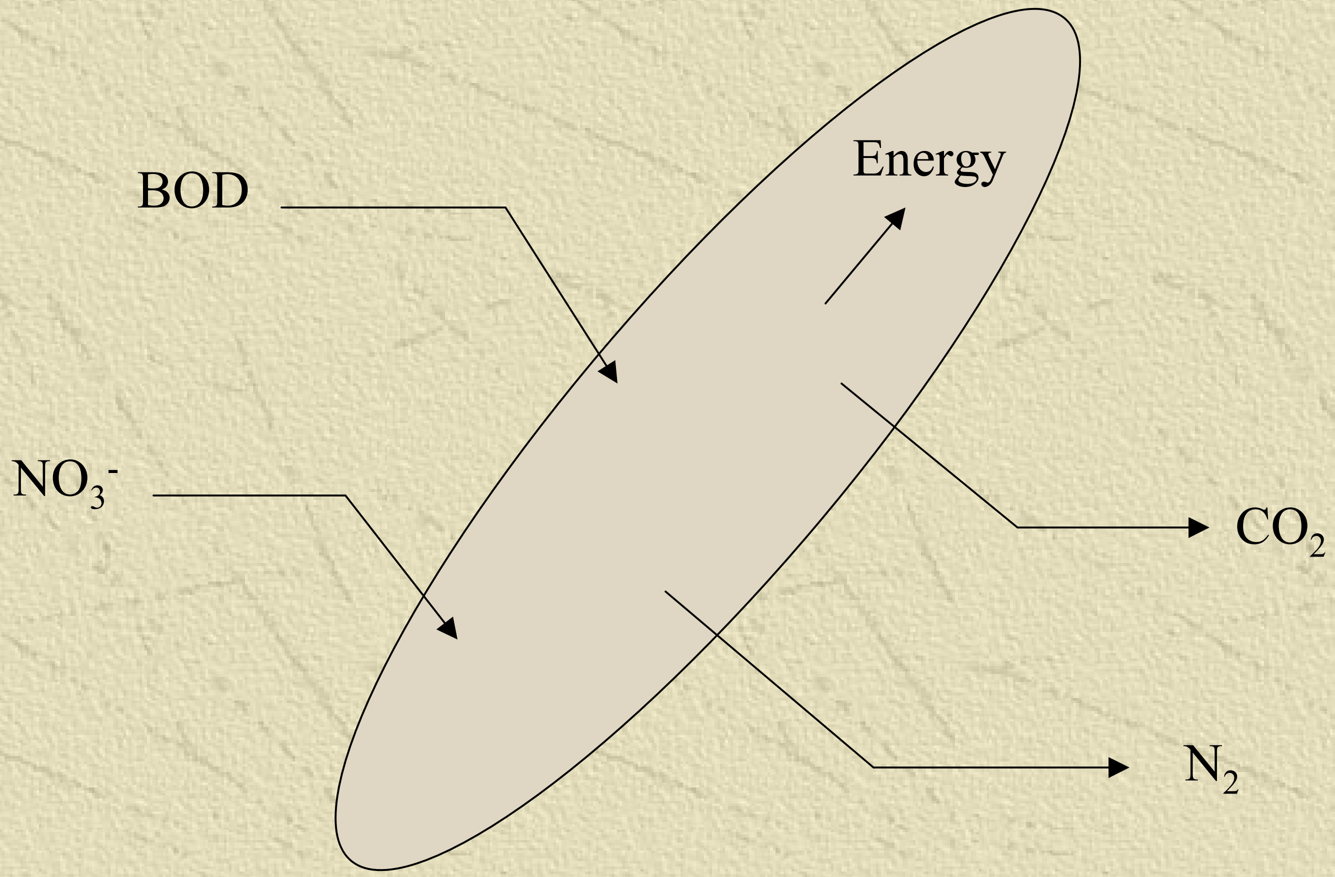
Facultative Fermentation Bacteria

Polyphosphate-storing
Obligate Aerobic Bacteria
(*Acinetobacter* & *Pseudomonas spp.*)

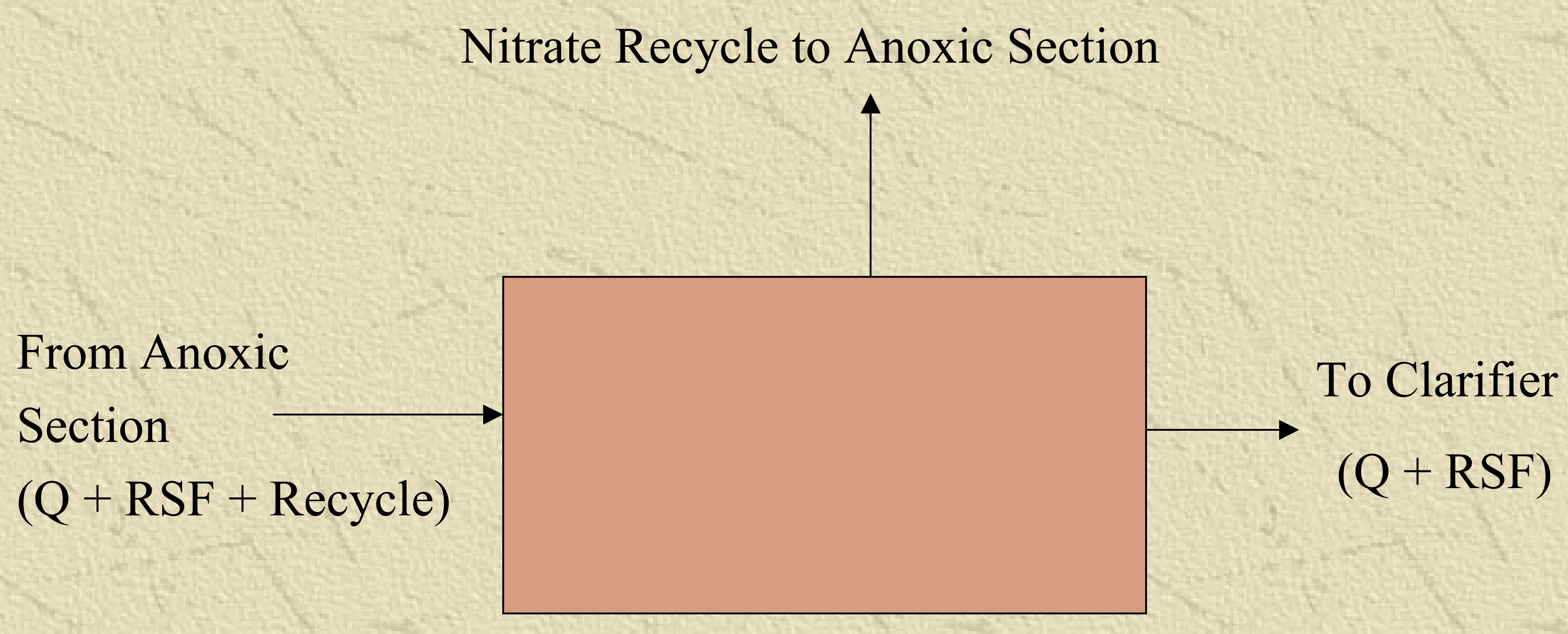
Anoxic Section



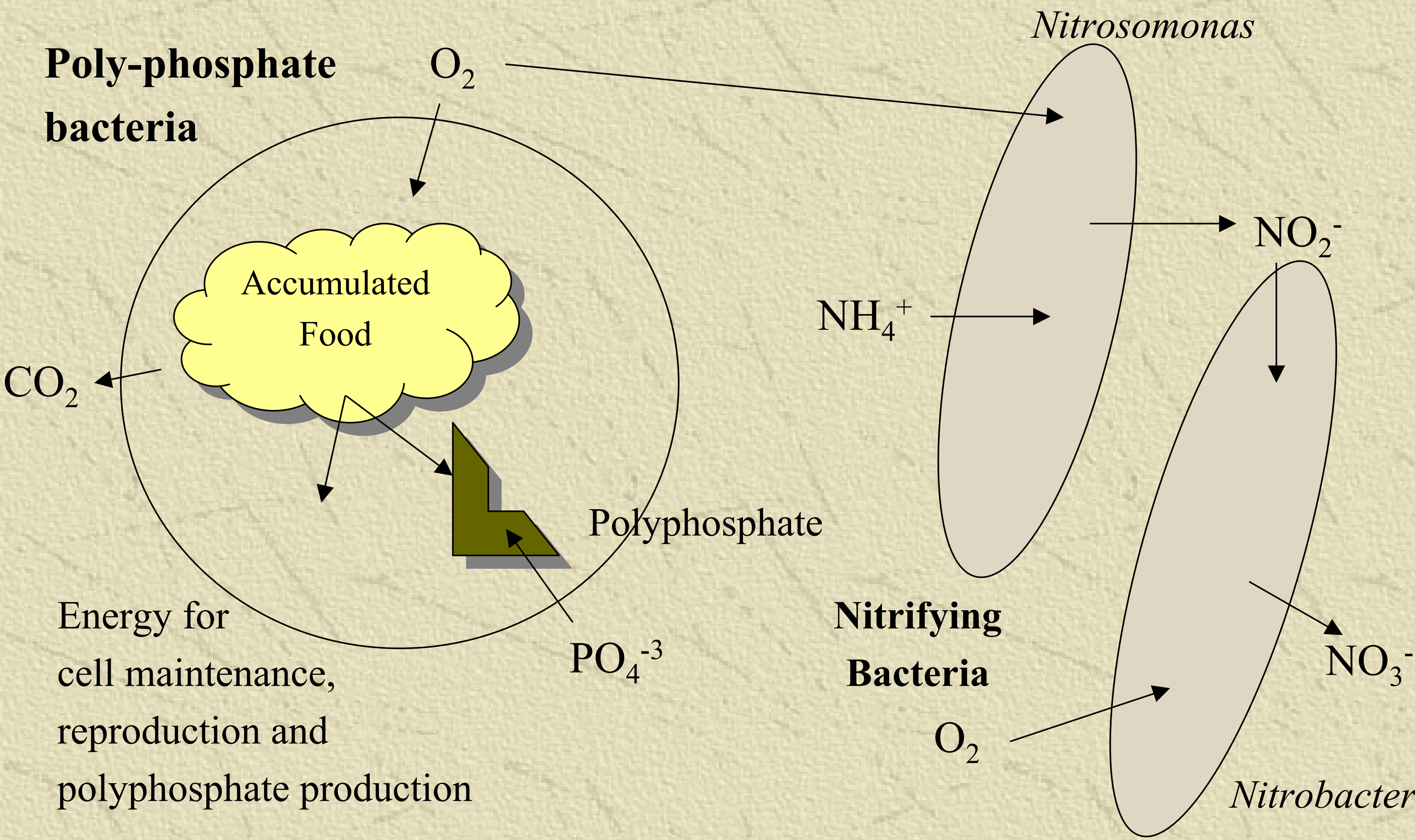
Anoxic Section Microbiology



Aerobic Section
(Aerobic Respiration)

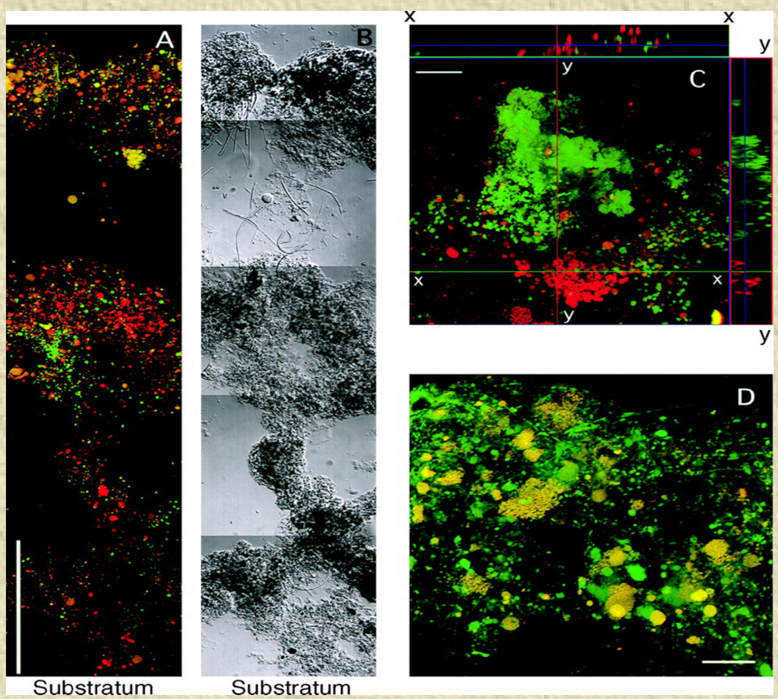


Aerobic Section Microbiology



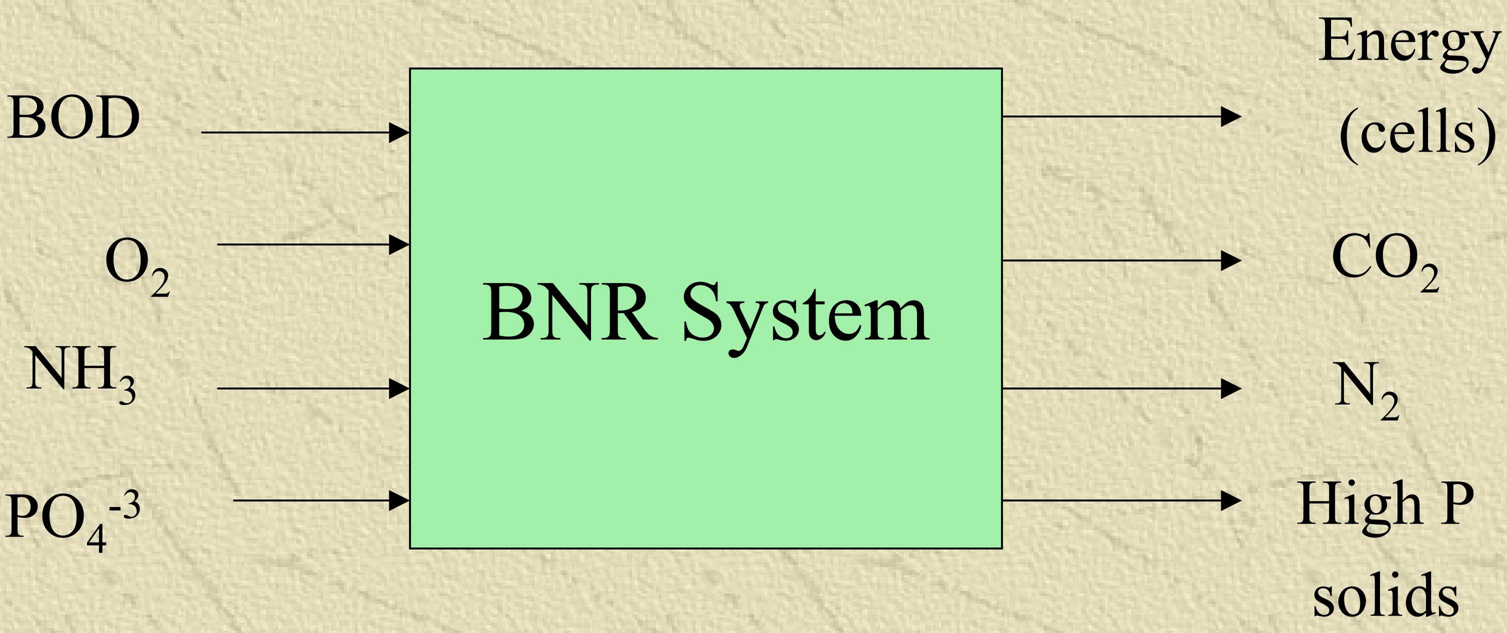
Genera of Nitrifying Bacteria

- Ammonia Oxidizers
  - Nitrosomonas
  - Nitrosococcus
  - Nitrosospira
  - Nitrosorbio
- Nitrite Oxidizers
  - Nitrobacter
  - Nitrospira
  - Nitrococcus
  - Nitrospina



C- Ammonia oxidizers appear red and Nitrospira appear green

Microbiological Summary



Anoxic Polyphosphate Accumulation

- Not as efficient as anaerobic process
- Can be accomplished using altered operational strategies
  - On/Off aeration
  - Oxidation ditch operated with anoxic sections

Protozoa

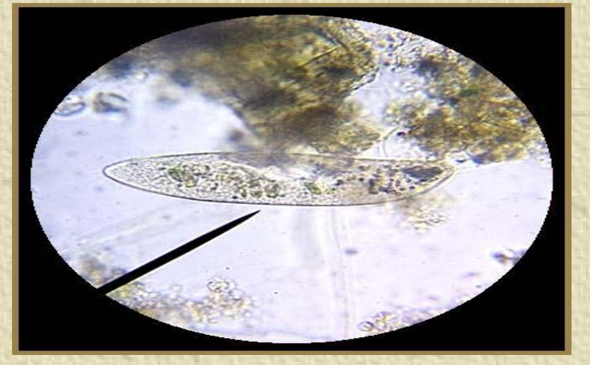
- Aerobic organisms
- Do not like anaerobic conditions

  - Extended time

  - Degree of anaerobic, very low oxidation reduction potential (ORP)

  - Fermentation and anoxic sections

  - "Off" period of "off/on"



Oxidation Reduction Potential

- Allows evaluation of biological conditions with or without DO available
- Simple and cheap
  - Portable pH meter
  - ORP probe
  - Immerse probe in tank and read
- Responds to chemical ion concentrations

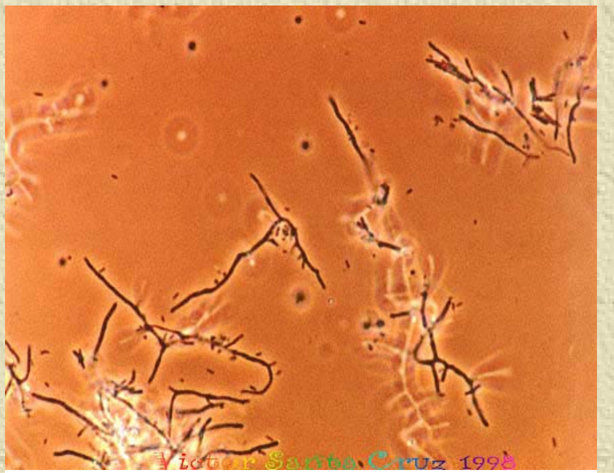
ORP Control

(Goronzy, 1992)

Process	Range, mV	e^- Acceptor
cBOD oxidation	+50 to +200	O_2
Poly-P production	+40 to +250	O_2
Nitrification	+150 to +350	O_2
Denitrification	-50 to +50	NO_3^-
Poly-P breakdown	-40 to -175	NO_3^-, $SO_4^=$
Sulfide formation	-50 to -250	$SO_4^=$
Acid formation	-40 to –200	Organics
Methane formation	-200 to -350	Organics

Summary

S. natans (1000X)



Nocardia (1000X)

- An/Ax/Ar conditions
- High RAS rate
- High recycle rate
- Remove N
- Remove P
- Reduce most filament growth
- Can occur with modified operation
- Monitor with ORP