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OBJECTIVE

- Raise awareness of the role microbio plays in the overall the technical success of treatment programs.

OBJECTIVE

- Develop a practical understanding of the science in order to identify problems, determine root causes, understand the impact of problems, and determine appropriate corrective action.

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Water Treatment Model

[The 4 Building Blocks]

Water Treatment Model

[The 4 Building Blocks]

Corrosion

Ferrous, Non-ferrous

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Water Treatment Model

[The 4 Building Blocks]

Corrosion

Ferrous, Non-ferrous

Scale

Carbonate, Sulfate, Phosphate

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Water Treatment Model
[The 4 Building Blocks]

Corrosion

Ferrous, Non-ferrous

Scale

Carbonate, Sulfate, Phosphate

Fouling

Silt, iron

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Water Treatment Model
[The 4 Building Blocks]

Corrosion

Ferrous, Non-ferrous

Scale

Carbonate, Sulfate, Phosphate

Fouling

Silt, iron

Microbio

Bacteria, Molds, Algae, Amoeba

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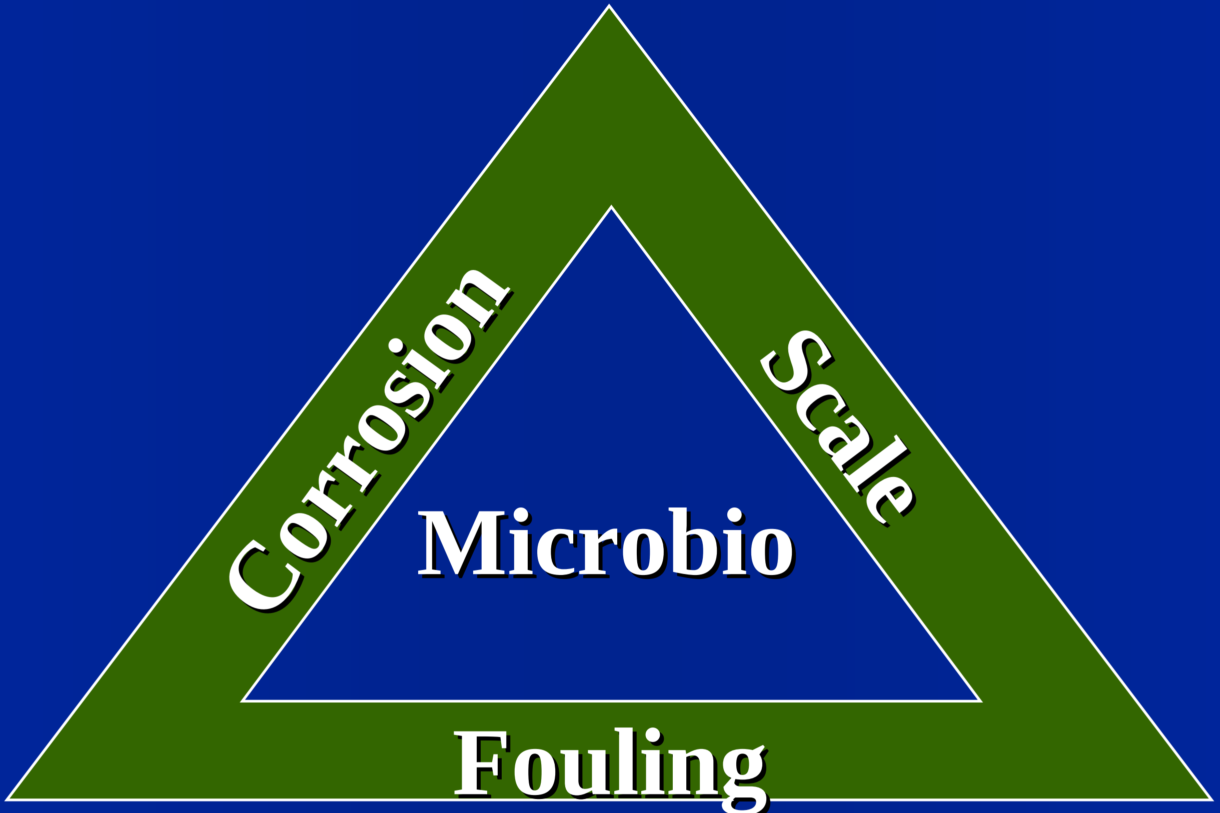
Water Treatment Model

[The 4 Variables]



OVERVIEW

- The Microbial World
- Legionella Update
- Biocide Review
- STABREX Review

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The Microbial World

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Outline

- Microbial Size, Number and Diversity
- Bio-films and Microbial Fouling
- Microbial Metabolic Cycles
- Differential Microbiological Analysis

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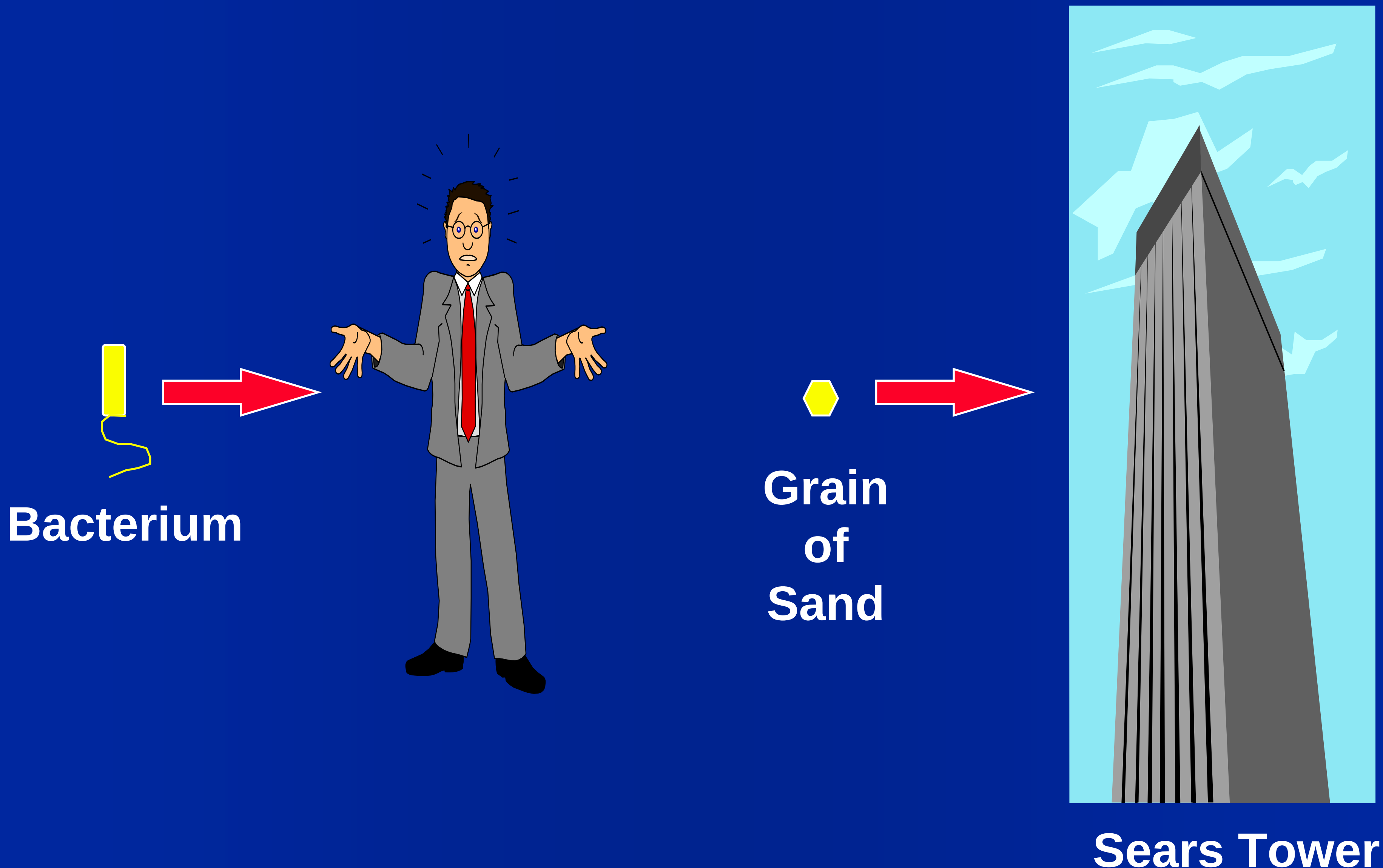
Size, Number,

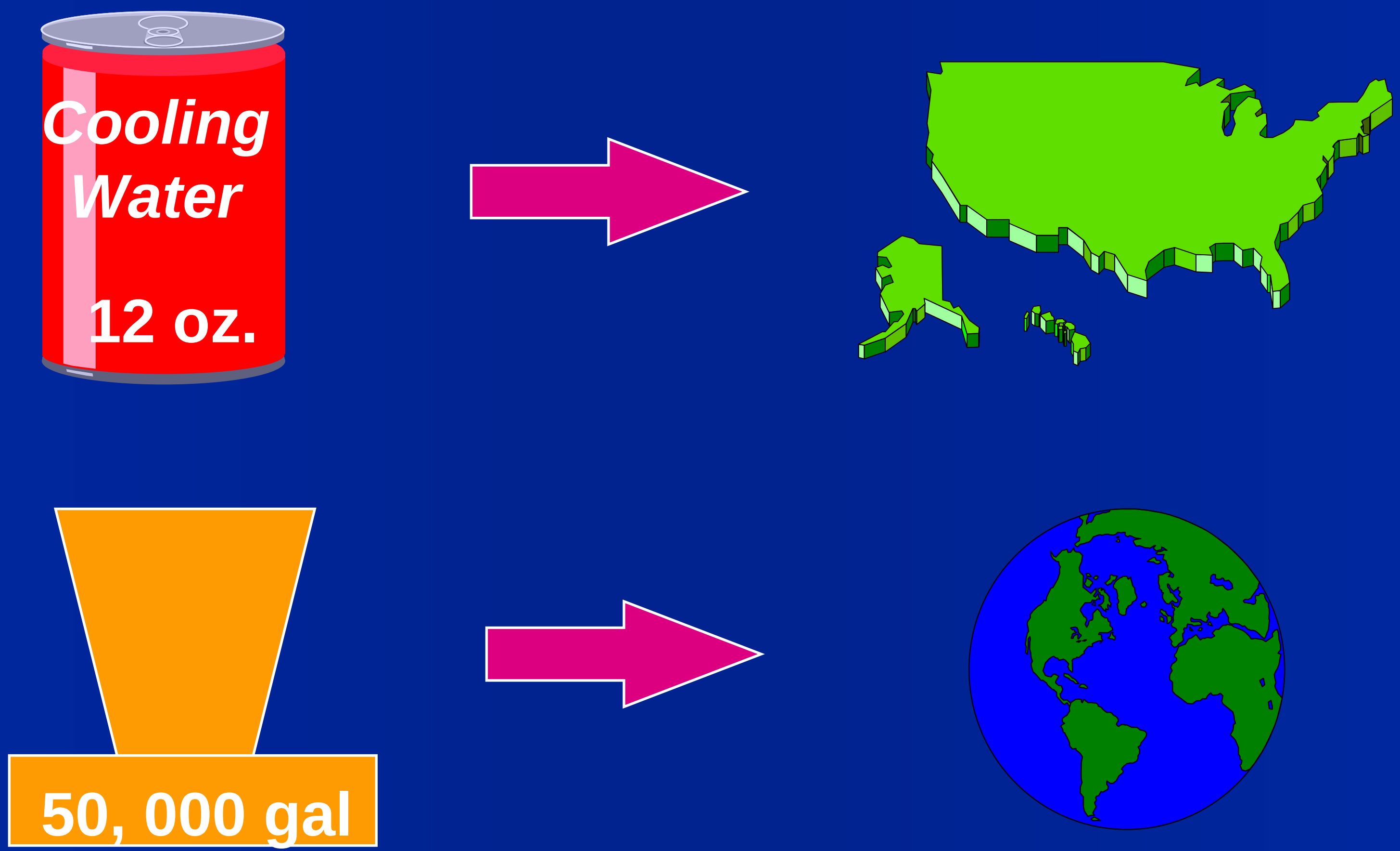
and

Diversity

Size of Bacteria



Population of Bacteria in a Cooling Tower



40,000 X

Diversity

Di-ver-si-ty - the condition of being different

Diversity

Microbiological Diversity of a System

- A high diversity of microorganisms within a system indicates low control
- If the diversity is low there is typically better microbiological control

Diversity

Aerobic Bacteria
- require oxygen for growth

Anaerobic Bacteria
- grow in the absence of oxygen

Algae
- can grow in masses on surfaces exposed to sunlight

Fungi
- can reinforce microbial deposits

Higher Life Forms
- indicate an older deposit with established microbial population

Diversity

Sessile vs Planktonic

Outline

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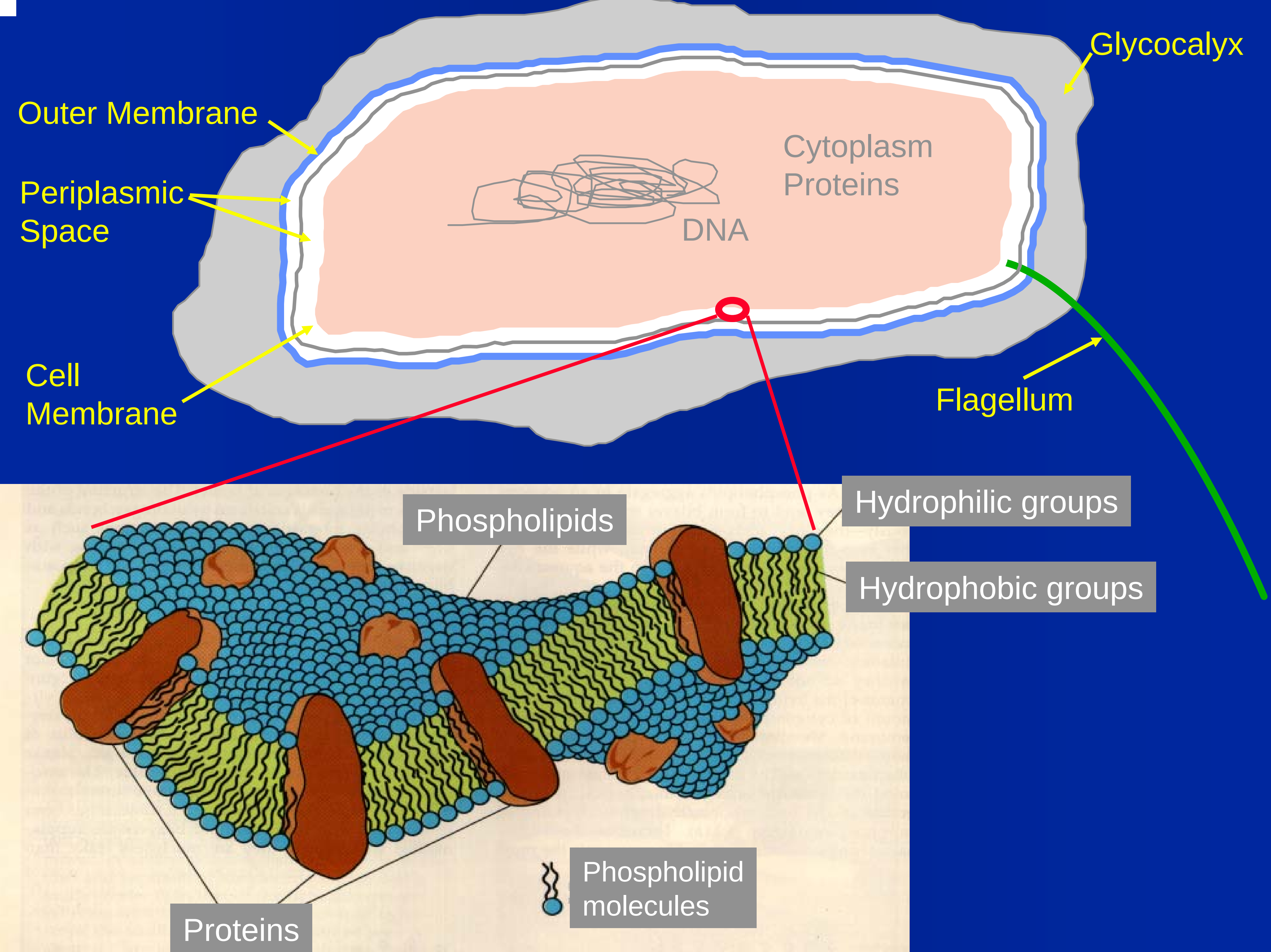
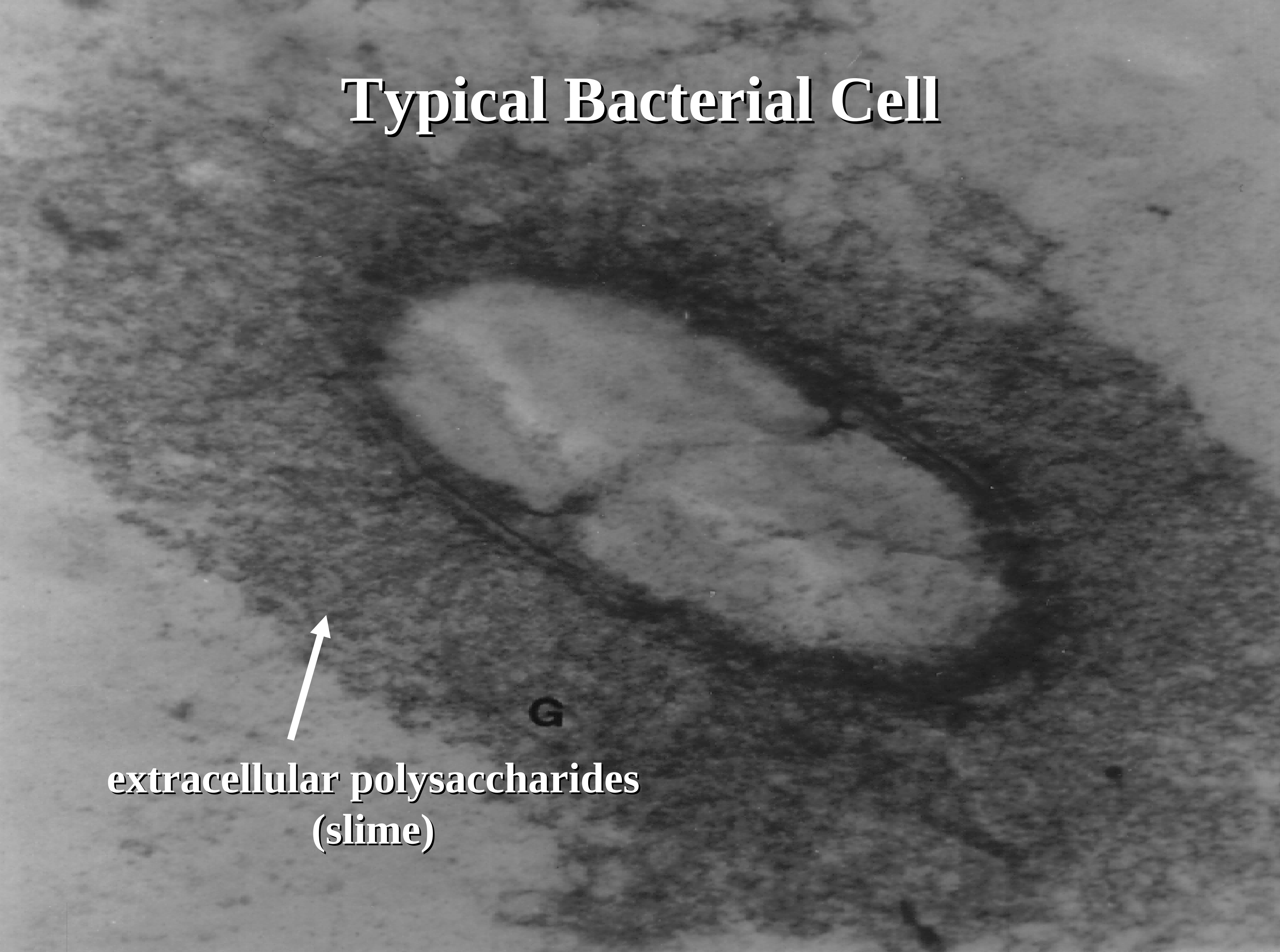
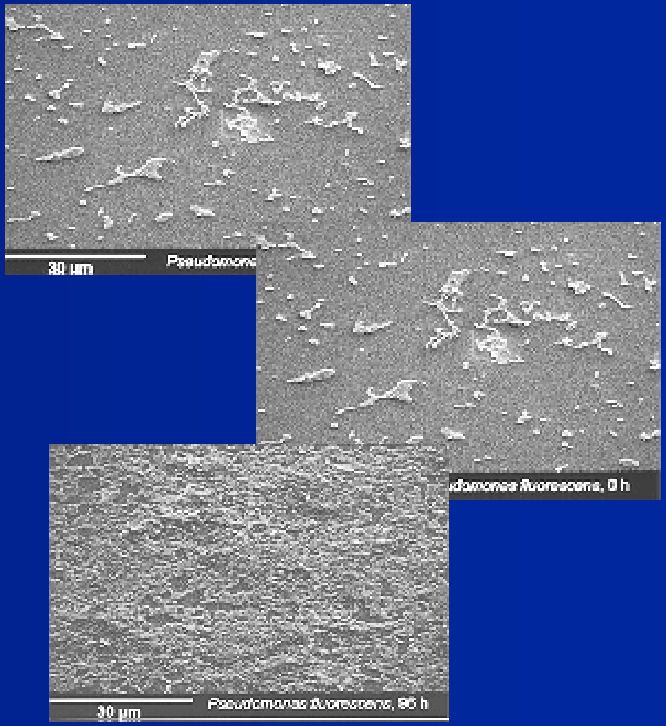

Glycocalyx
Outer Membrane
Periplasmic Space
Cytoplasm Proteins
DNA
Cell Membrane
Flagellum
Phospholipids
Hydrophilic groups
Hydrophobic groups
Phospholipid molecules
Proteins

Typical Bacterial Cell

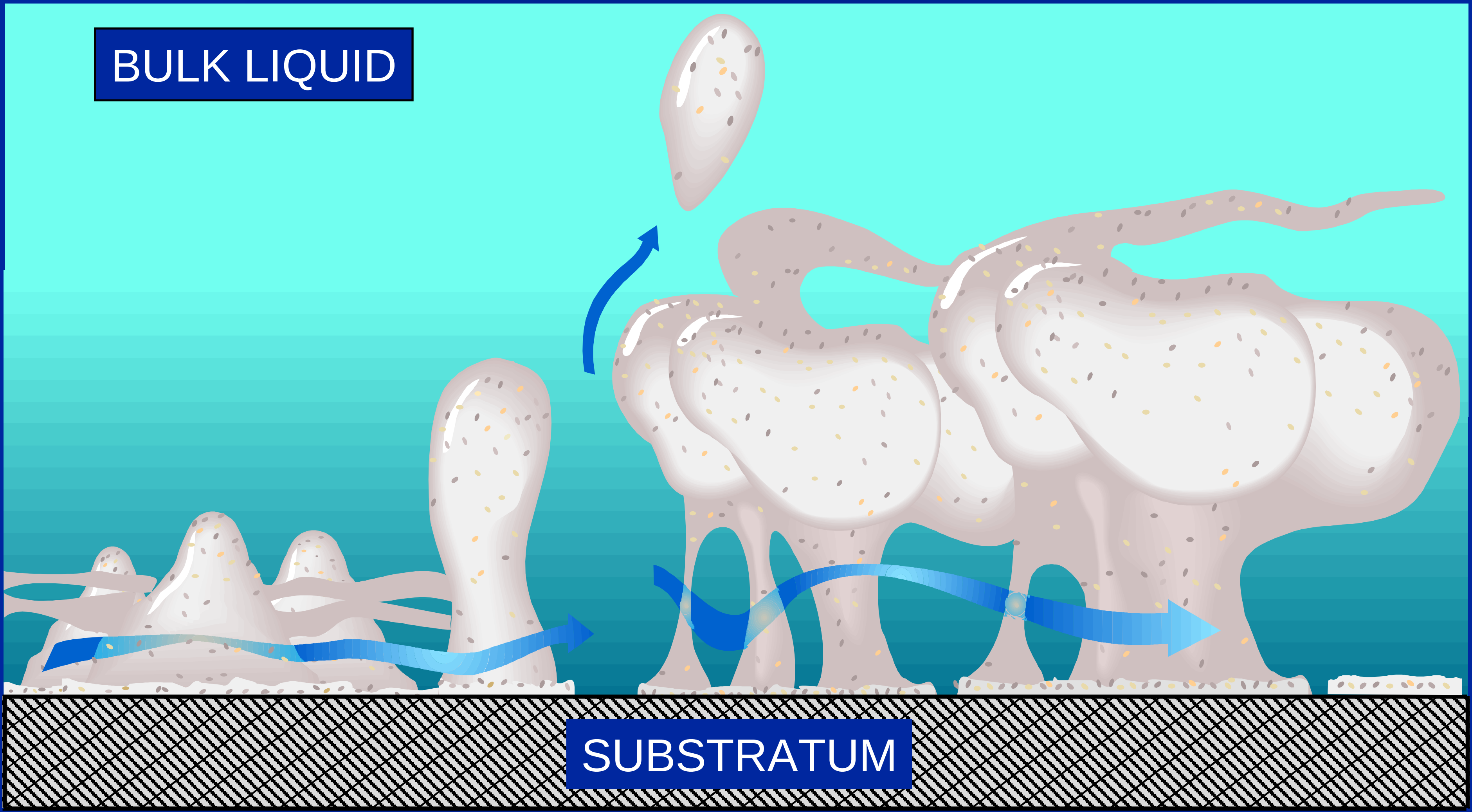


Bacteria Grow Exponentially

- Initial population
- 2 Days later
- 4 Days later
  - A protective slime is formed
  - Film thickness can be 100 microns



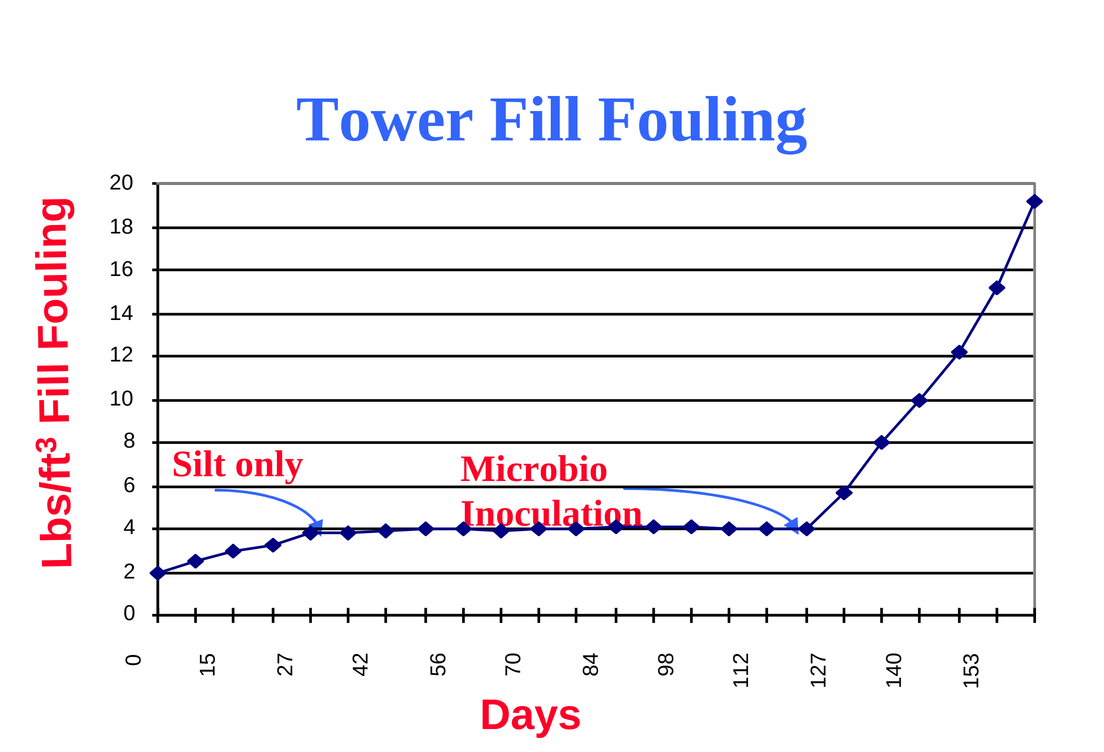
Bio-Film



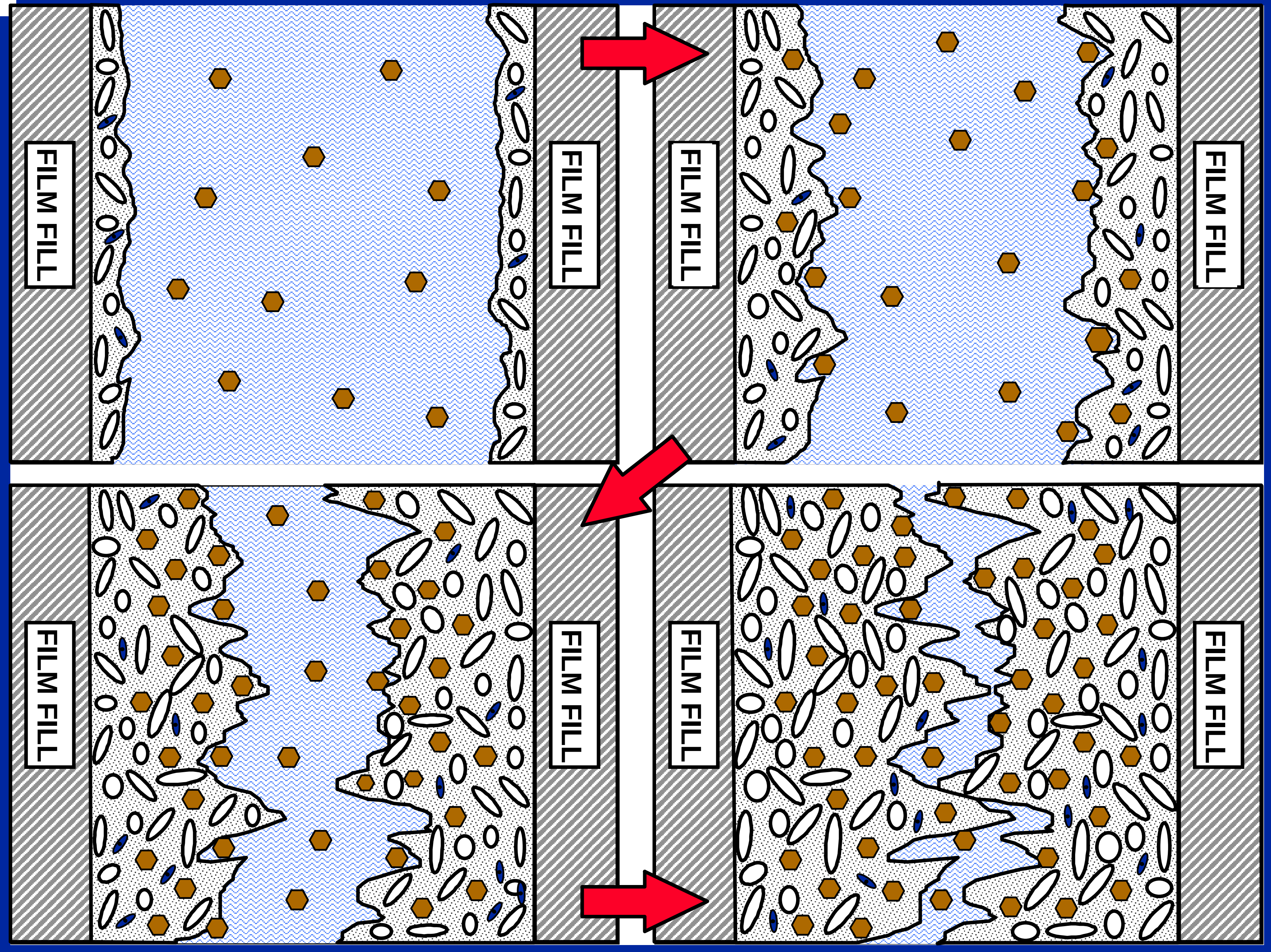
Tower Fill Norms
Deposit Analysis

Fouling	*Weight %*
Biological	37 %
Mud/Silt	41 %
Calcium Scales	15 %
Corrosion Products	7 %
Total	100 %

Marley Study on Fill Fouling



Film Fill Fouling in Counterflow Cooling Towers: Mechanism and Design
1994 Cooling Tower Institute Annual Meeting; Paper #TP94-05


FILM FILL
FILM FILL
FILM FILL
FILM FILL
FILM FILL
FILM FILL
FILM FILL
FILM FILL

Consider this:

- With fouling, cooling towers can lose 5 degrees in approach to ambient wet-bulb temperature within 18-24 months.
- For every 2 degree increase in ambient wet bulb, the cooling water increases 1 degree.
- A tower water temperature increase of 1 degree equals a 2% increase in energy use.
- A loss of five degrees in approach to wet-bulb will result in a 10-15% loss in cooling load.

Microbio Energy Norms

Thermal Conductivity

A biofilm is actually a better insulator than calcium carbonate scale

Scale	Thermal Conductivity (W/MK°)
Calcium carbonate	2.26 - 2.93
Calcium sulfate	2.31
Calcium phosphate	2.60
Magnesium phosphate	2.16
Magnetic iron oxide	2.88
Biofilm	0.63

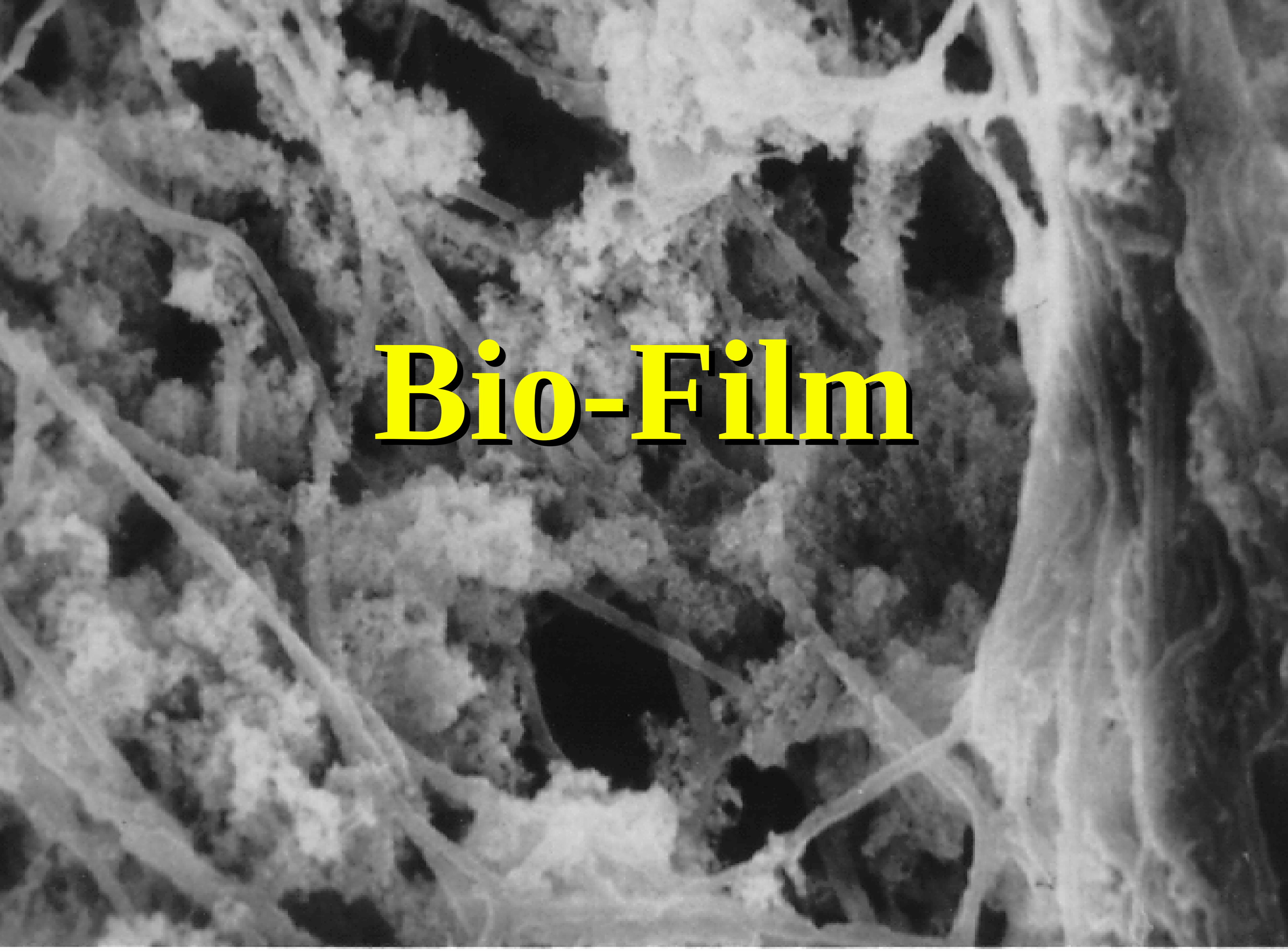
N. Zelver et al., CTI Paper No. TP239A

ROI Example

Condenser Fouling in HVAC

Biofilm thickness on condenser tubes	Increase in energy	Added energy cost
0.006 inch	5.3 %	$ 13,500
0.012 inch	10.8 %	$ 27,000
0.024 inch	21.5 %	$ 59,000
0.036 inch	32.2 %	$ 83,000

*Based on a 1,000 Ton chiller operated 350 days/yr, 16 hours/day @$0.07/KWH


Bio-Film

Factors Affecting Microbial Fouling

- Inoculation sources
- Nutrient Sources
- Flow Rate
- pH
- Temperature
- Physical/Mechanical Design

Inoculation Sources

- Make-up water
- Dust and other airborne contaminants
- Side-stream filters
- Dead legs
- Low flow areas

Nutrient Sources

- Oil including greases or other extractions from oil
- Dirt, dust, and silt
- Leaves and other debris
- Suspended solids
- Phosphates, Nitrates, Sulfates

Low/No Flow Rate

- Common source of microbial fouling
- Do not receive lethal concentrations of biocide
- Commonly associated with build-up of solids from other parts of the system
- Perfect conditions for slime to form and develop into biofilms and thick microbio deposits

Physical/Mechanical Design

- Wood Fill vs Plastic Fill
- Mist Eliminators
- Tower Deck Covers
- Good Flow in Tower Basins

Other Factors

- pH
- Temperature
- Seasonal Variations

Outline

- Microbial Size, Number and Diversity
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- Microbial Metabolic Cycles
- Differential Microbiological Analysis

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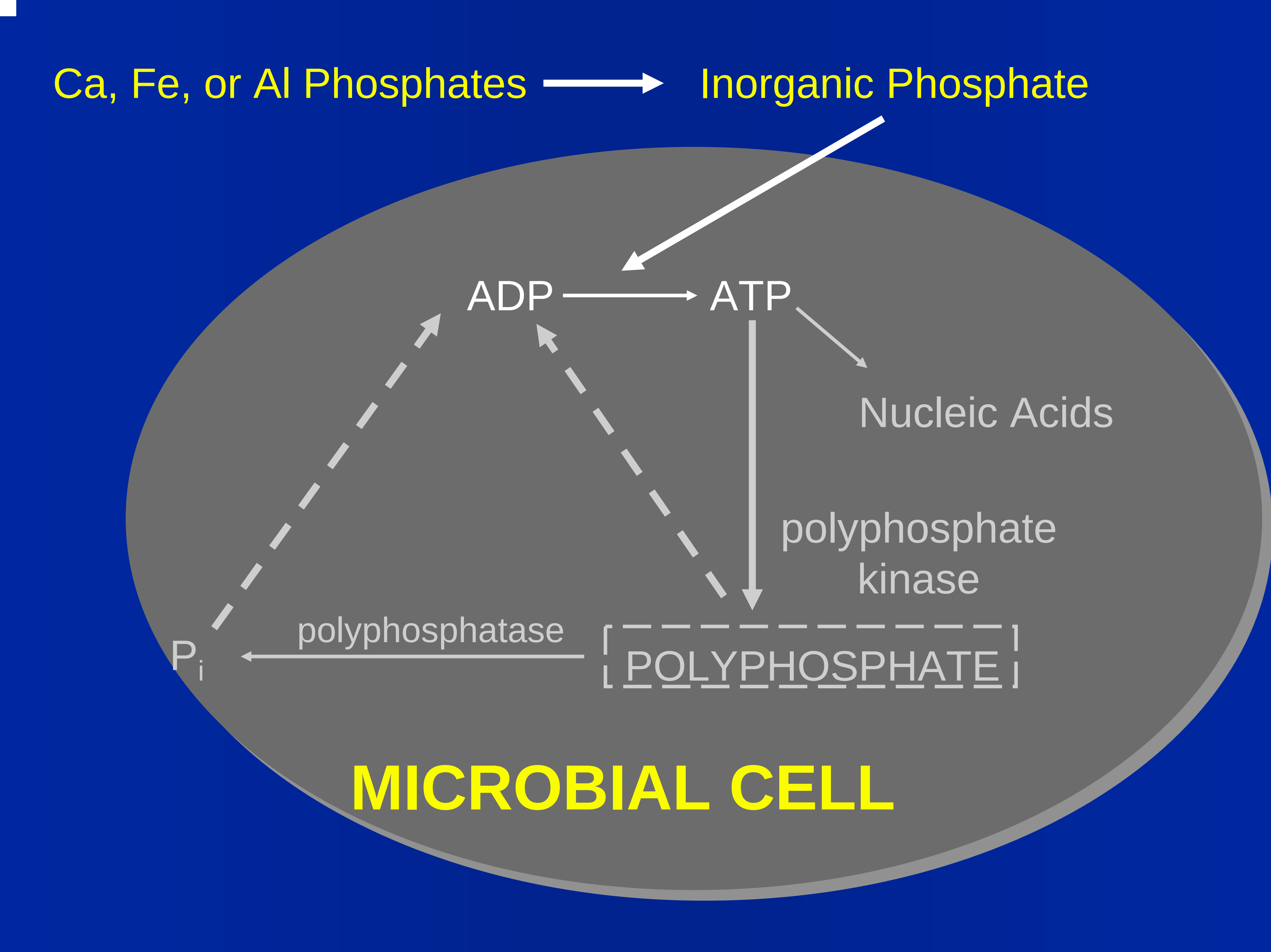
Metabolic Cycles

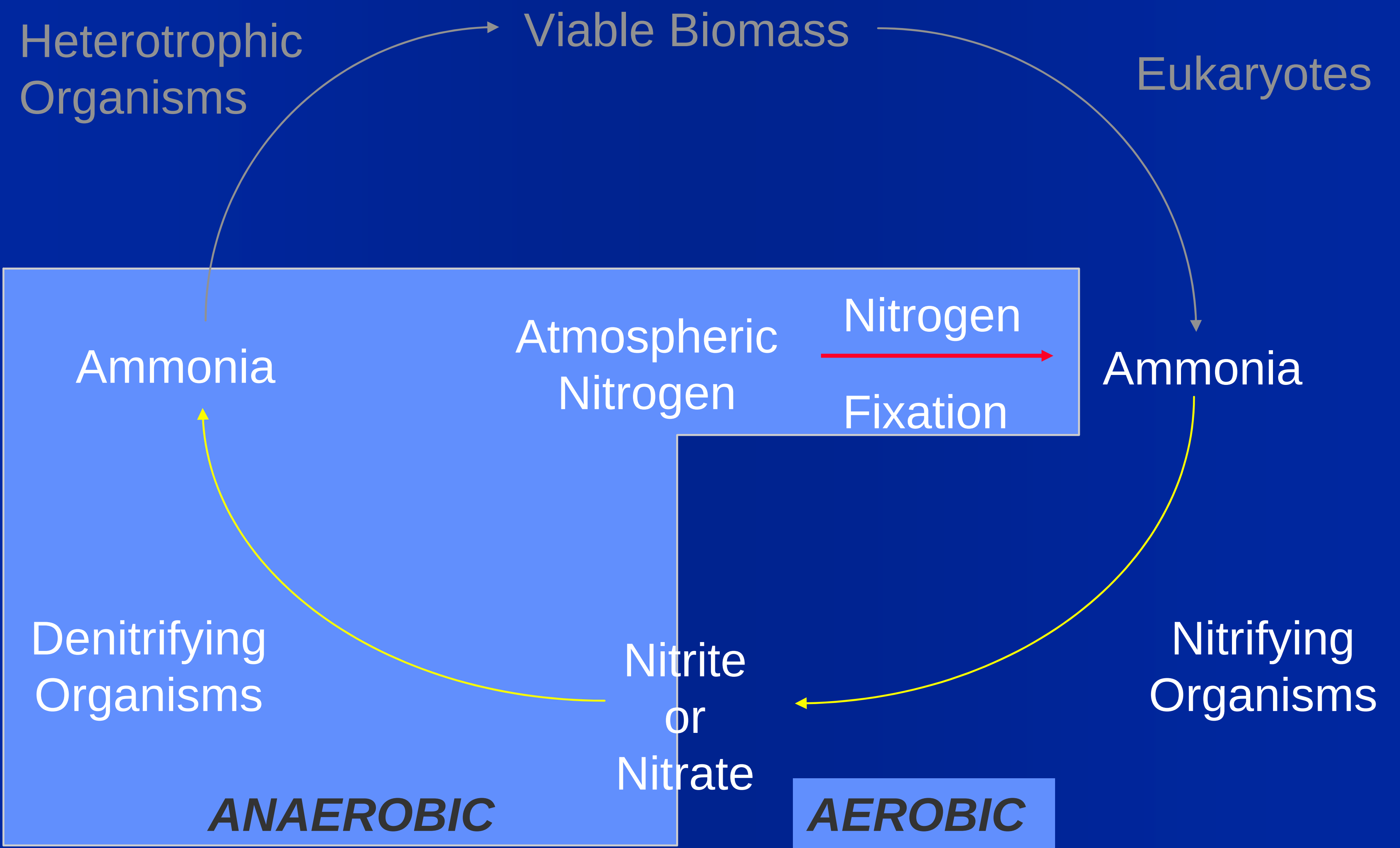
- Phosphorous
- Nitrogen
- Sulfur

Phosphorous

- Limiting nutrient in most aquatic environments
- Leads to eutrophication
- Some cooling water bacteria able to utilize phosphonate as sole phosphorous source


Ca, Fe, or Al Phosphates
Inorganic Phosphate
ADP
ATP
Nucleic Acids
polyphosphate kinase
polyphosphatase
P_i
POLYPHOSPHATE
MICROBIAL CELL

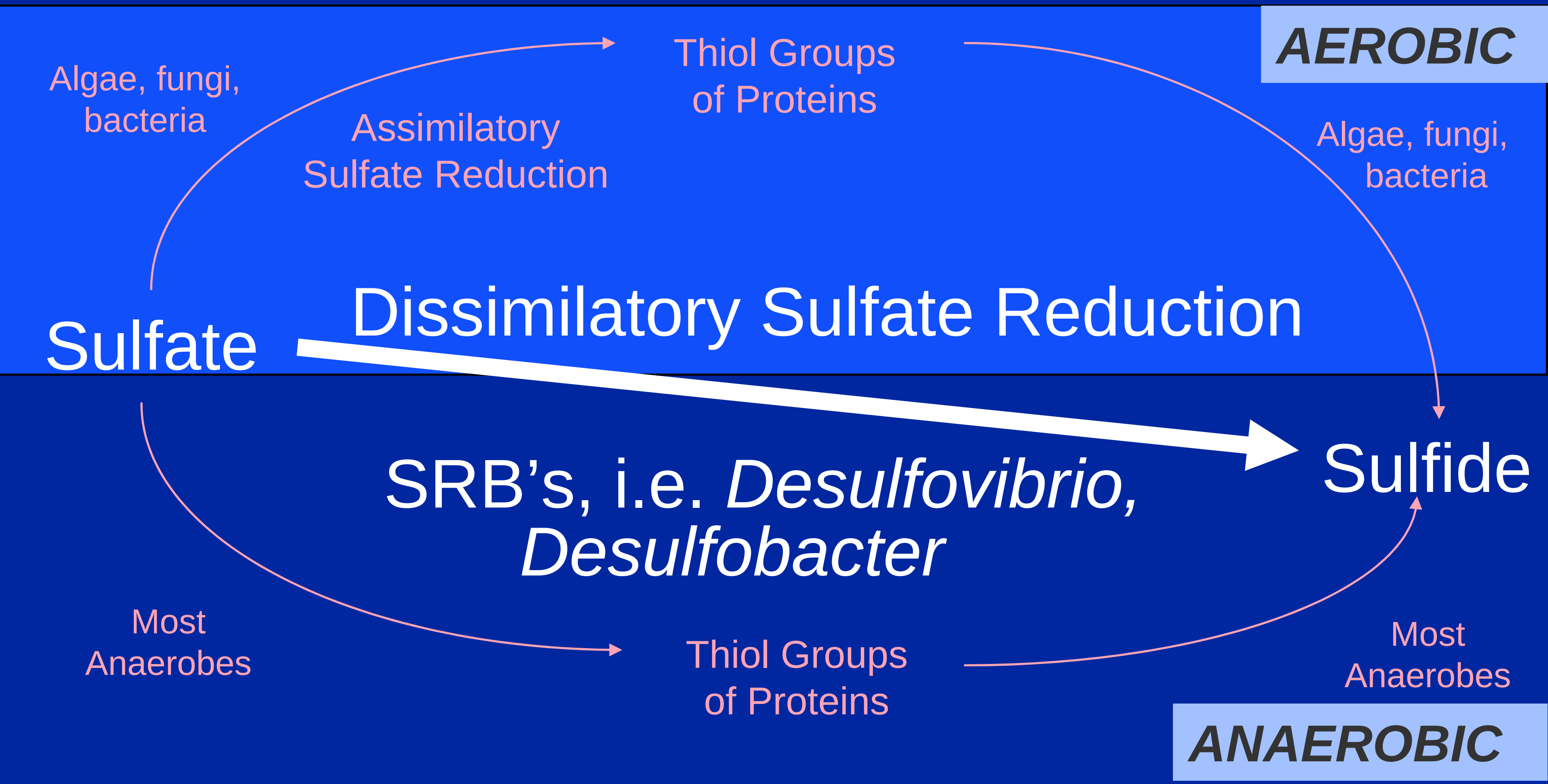
Nitrogen Cycle



Denitrifying Organisms

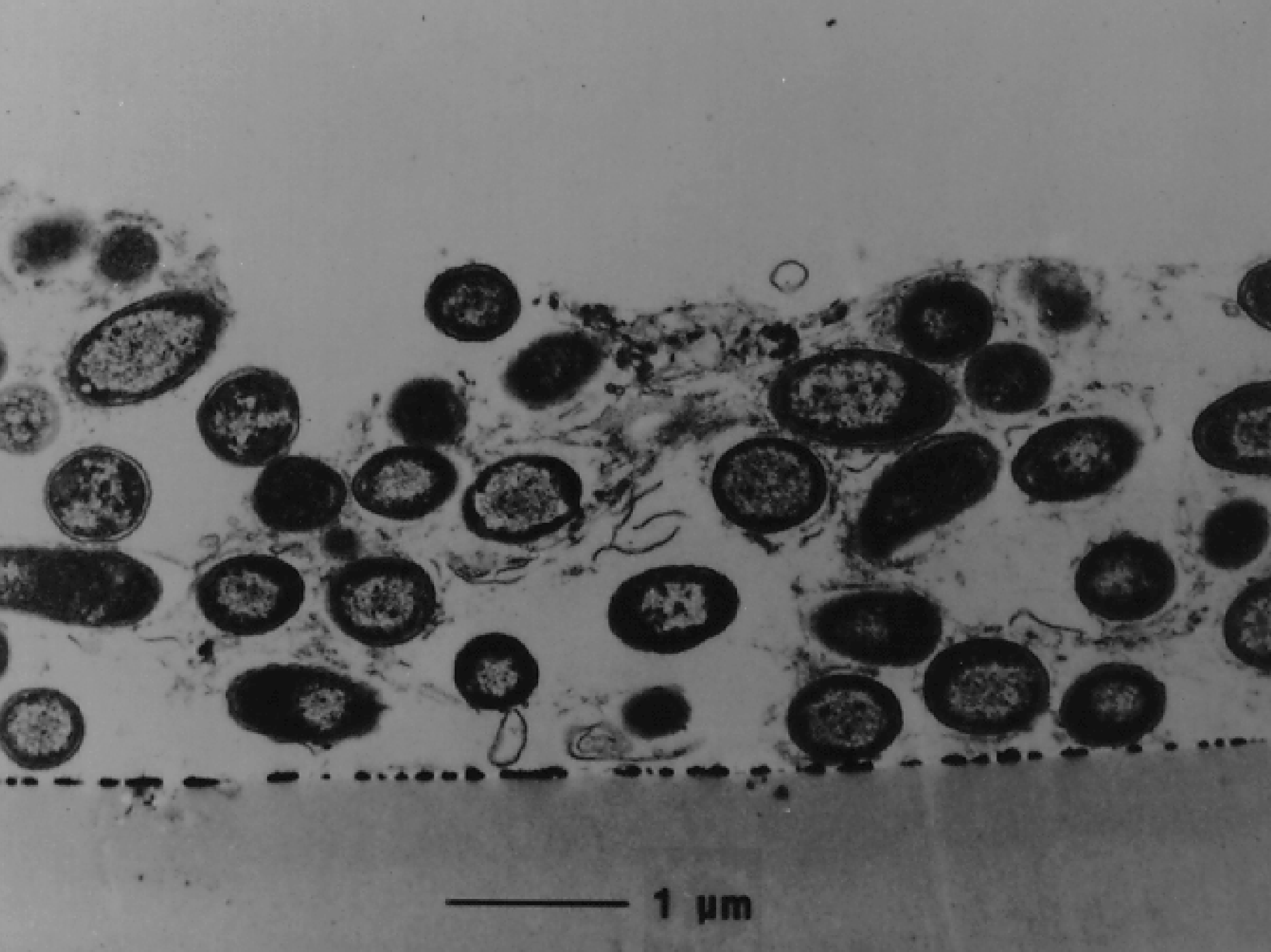
- Convert nitrite or nitrate back to ammonia
- Common in closed loops
- Anaerobic Conditions
  - *Thiobacillus denitrificans*
  - *Serratia*
  - *Pseudomonas*
  - *Enterobacter*

Sulfur Cycle

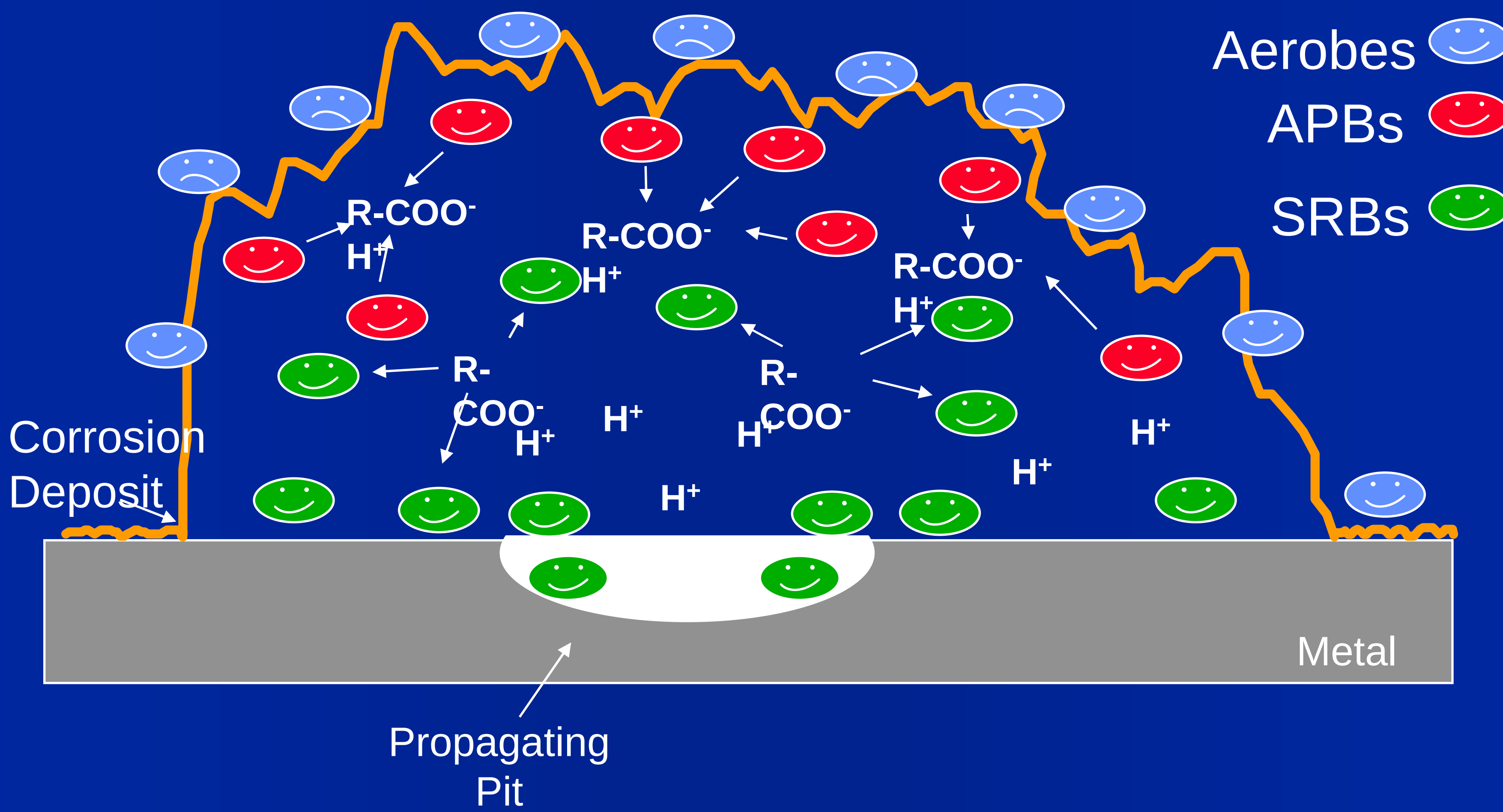


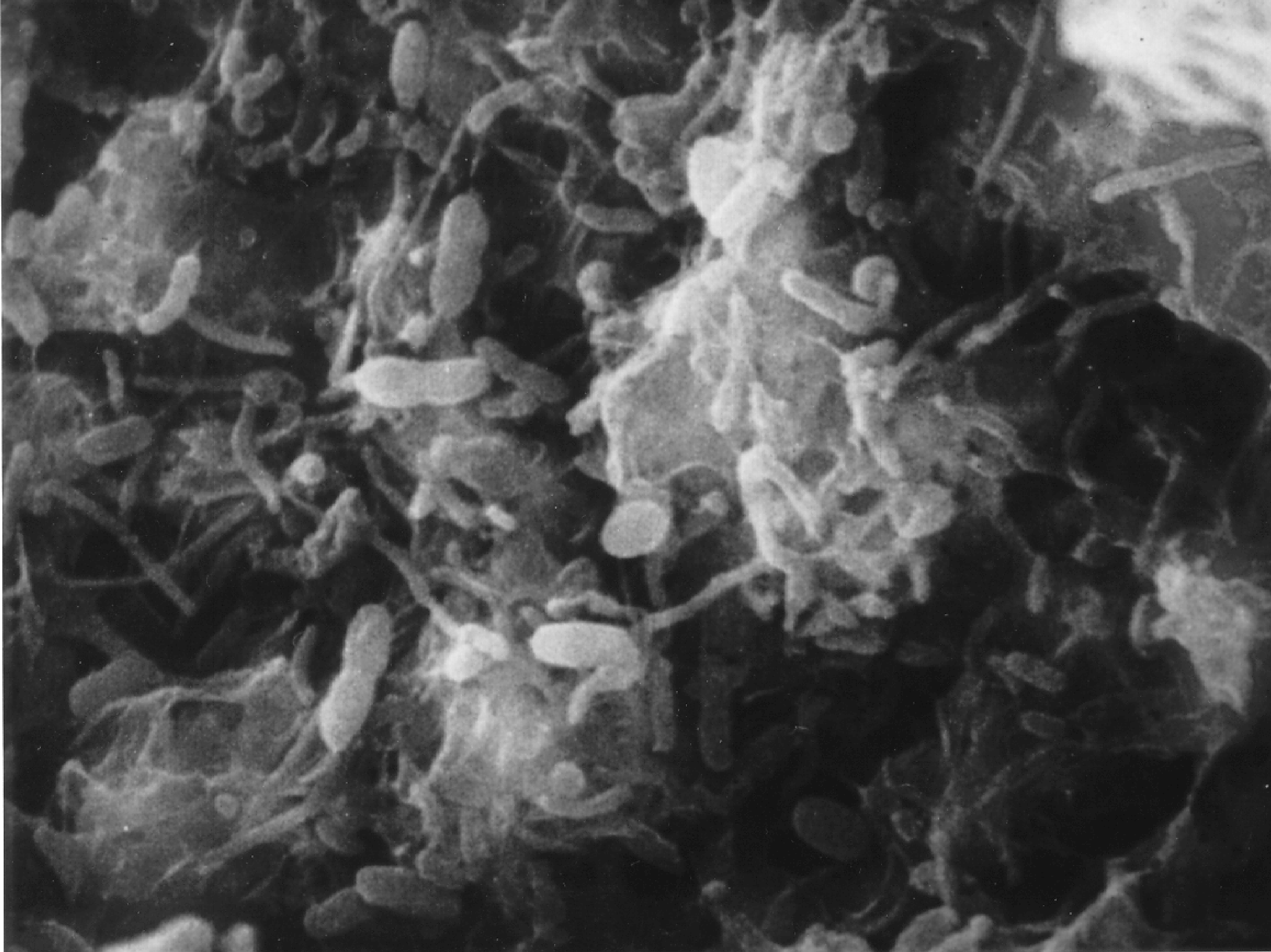
Sulfate Reducing Bacteria

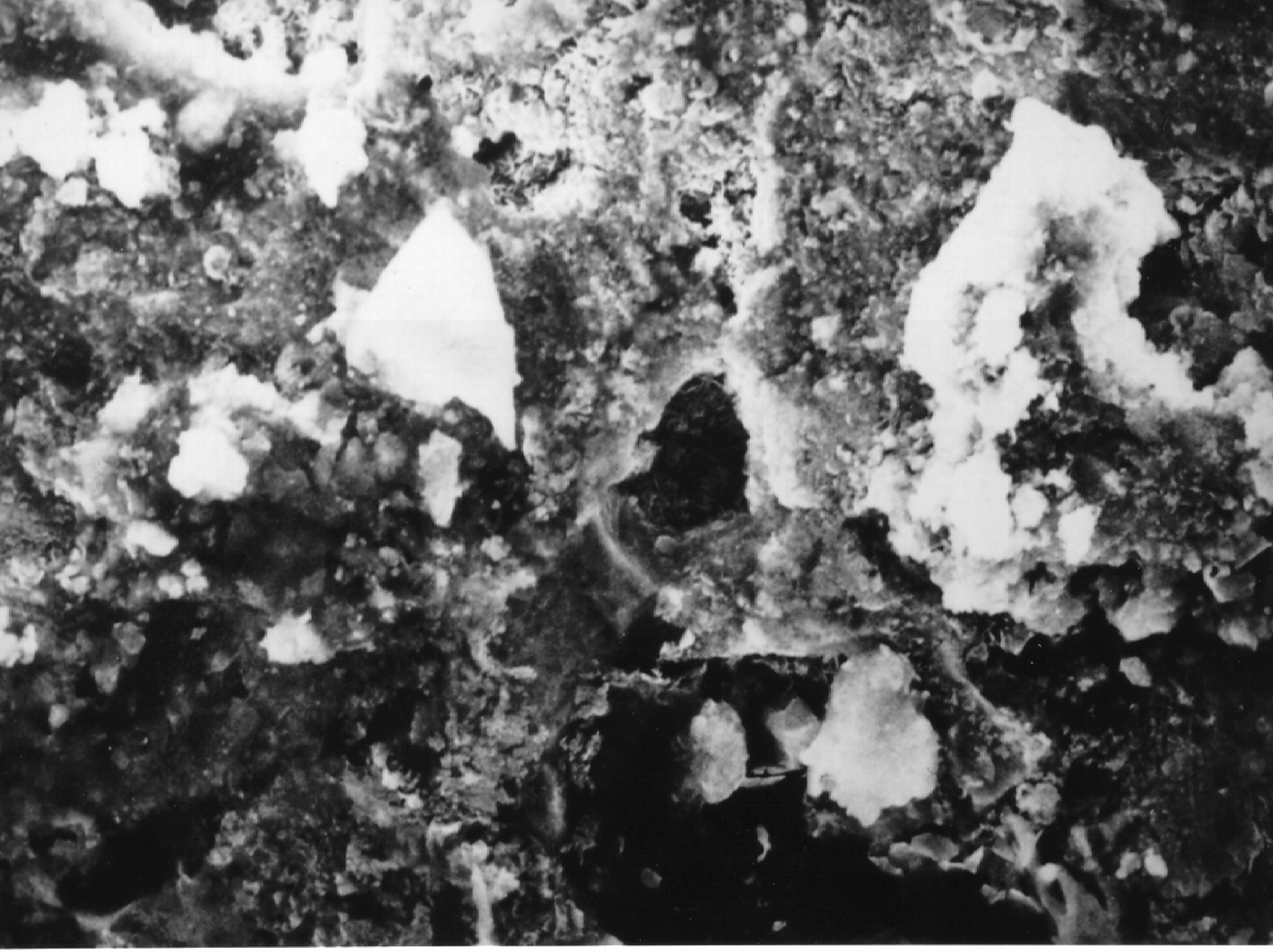
- Anaerobic bacteria which are involved in microbiologically influenced corrosion
- They reduce sulfate to sulfide

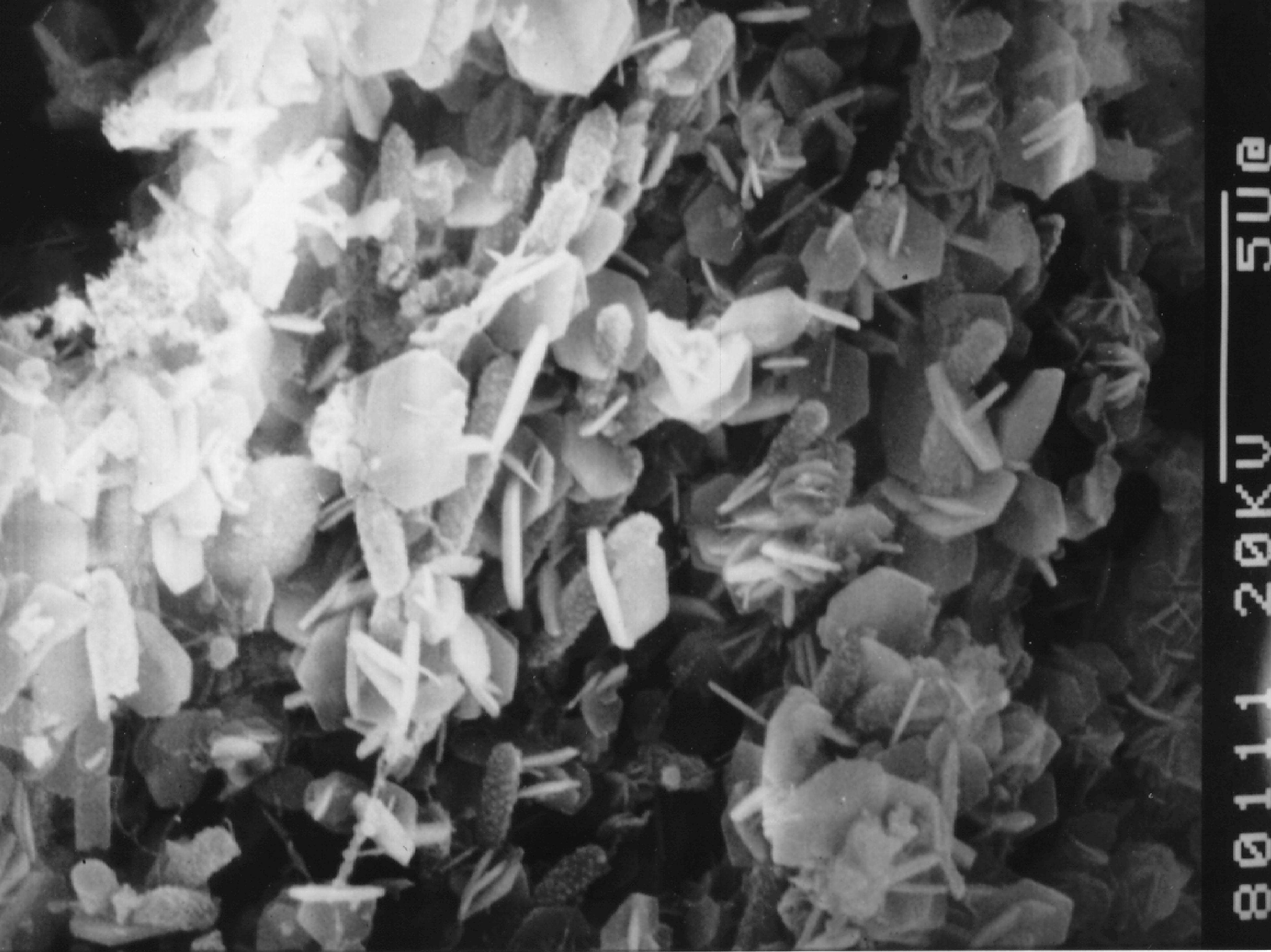

1 µm

Microbio Influenced Corrosion (MIC)








80111 20KV 5U0

Outline

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Differential Microbiological Analysis (DMA)

From:
ABC Plant

Sample Marked:
Cooler Outlet

Analysis No.	MB 207310
Date Sampled	9/ 9/97
Date Received	9/10/97
Date Completed	9/15/97
Date Printed	9/15/97

>>> Microbiological Evaluation <<<

PHYSICAL APPEARANCE	Liquid with Floc
TOTAL AEROBIC BACTERIA	4,000
Enterobacter	<100
Pigmented	<100
Mucoids	<100
Pseudomonas	<100
Spores	<10
TOTAL ANAEROBIC BACTERIA	
Sulfate Reducers	2
Clostridia	<10
TOTAL FUNGI	
Yeasts	<10
Molds	20
IRON-DEPOSITING	
Gallionella	None
Sphaerotilus	None
ALGAE	
Filamentous	None
Nonfilamentous	None
OTHER ORGANISMS	None

Lab Comments:
All counts express colony forming units per ml.

Microscopic examination: few crystals and very few diatoms.

- Testing designed to differentiate the microbiological content within a system.

Aerobic Bacteria

Total Aerobic Bacteria

- Total count of aerobic microbiological population

Enterobacter

- Certain species of *Enterobacter* are considered potential indicators of wastewater contamination

Pigmented and Mucoids

- Indicator of diversity, and Mucoids may be involved in slime formation

Pseudomonas

- common isolates of industrial cooling systems are considered major biofoulers as they can produce copious amounts of extracellular polysaccharides (slime)

Spores

- dormant cells with a protective outer layer that can resist antimicrobials, desiccation, temperature, etc.


PSEUDOMONAS

Anaerobic Bacteria

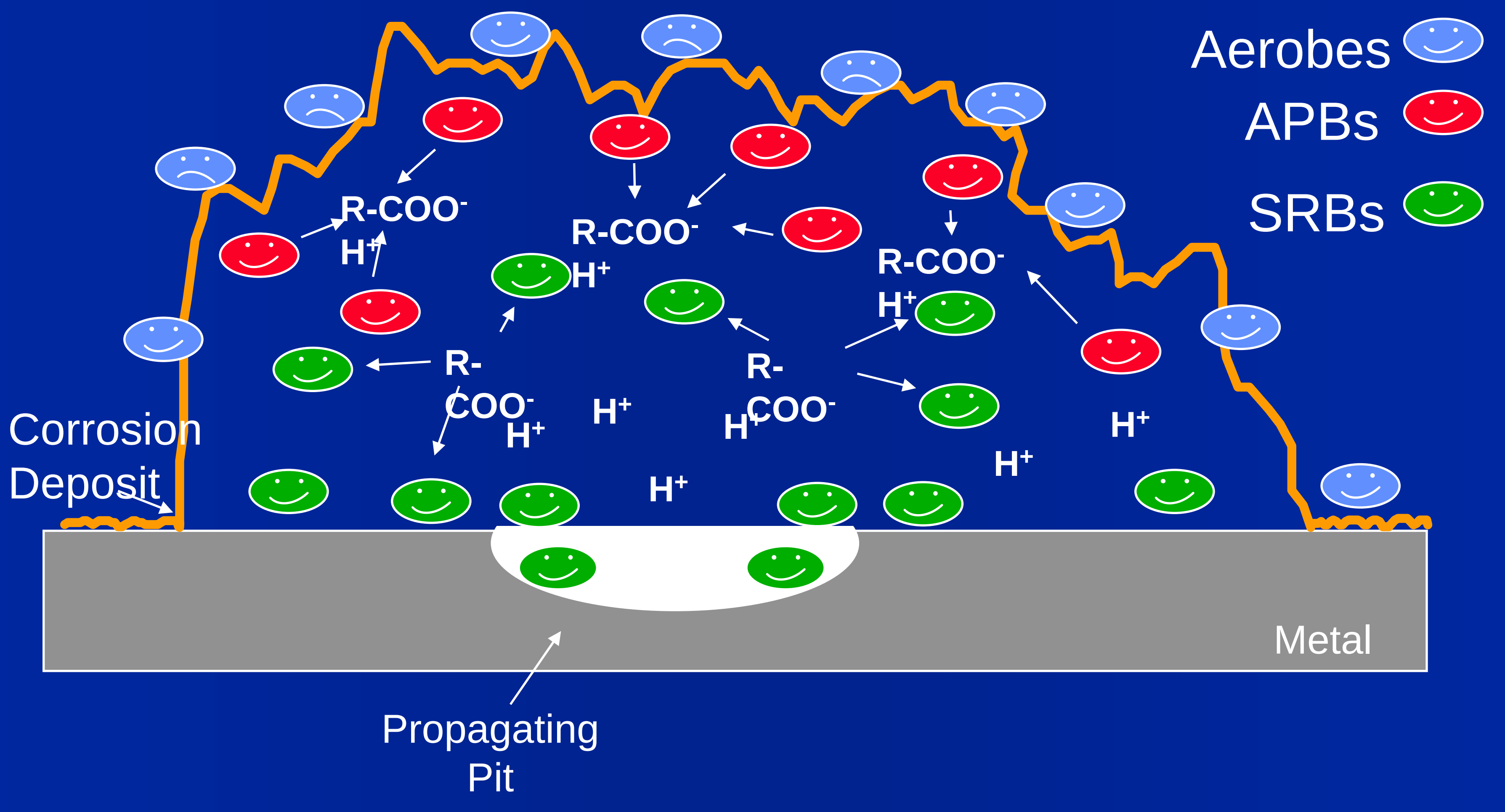
Sulfate Reducers

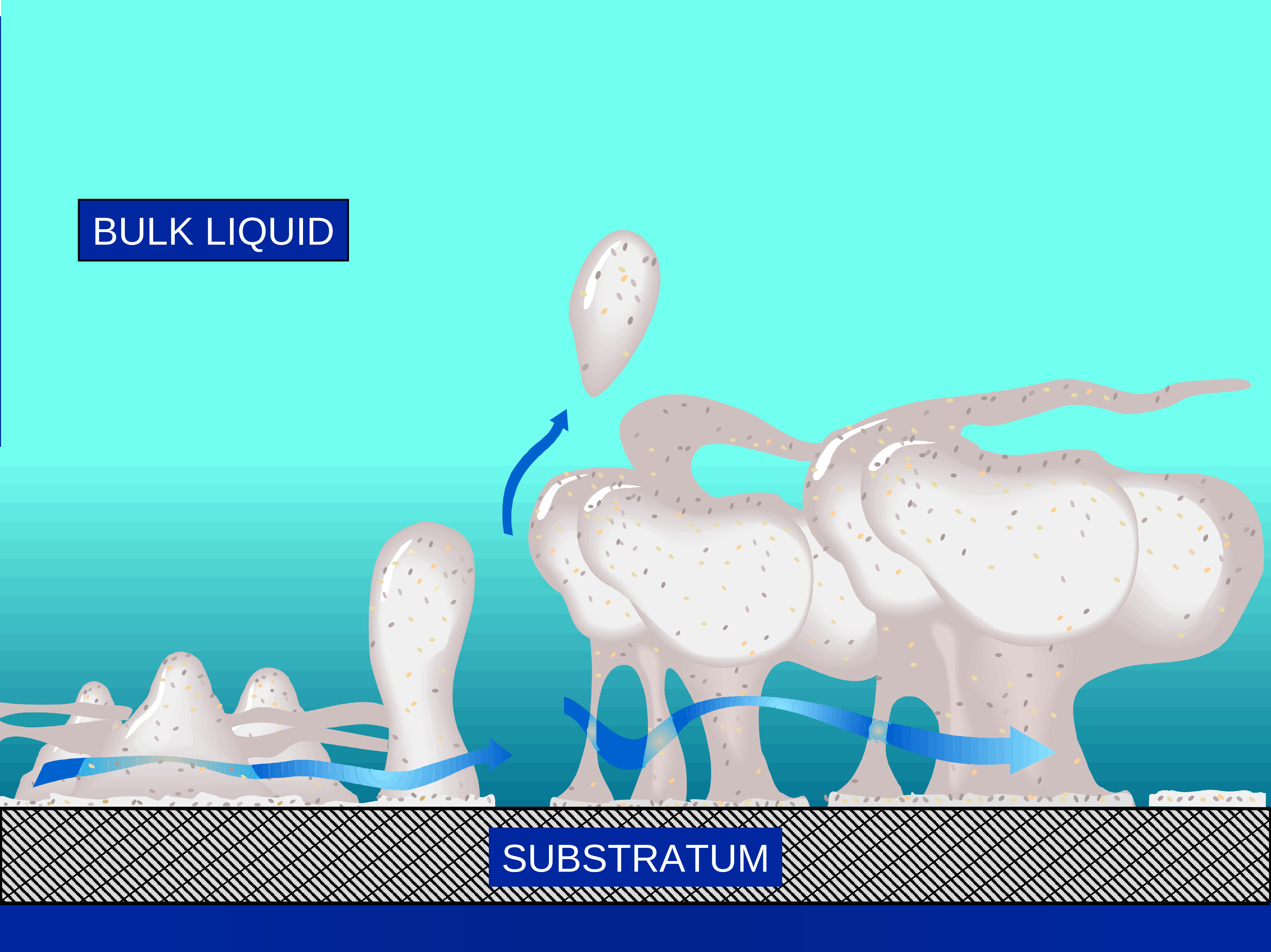
- Anaerobic bacteria which are involved in microbiologically influenced corrosion
- They reduce sulfate to sulfide

Clostridia

- Anaerobic bacteria which can produce acidic end products which may contribute to corrosion or pitting. Can produce spores to resist harsh environmental conditions.

Microbio Influenced Corrosion (MIC)




BULK LIQUID
SUBSTRATUM

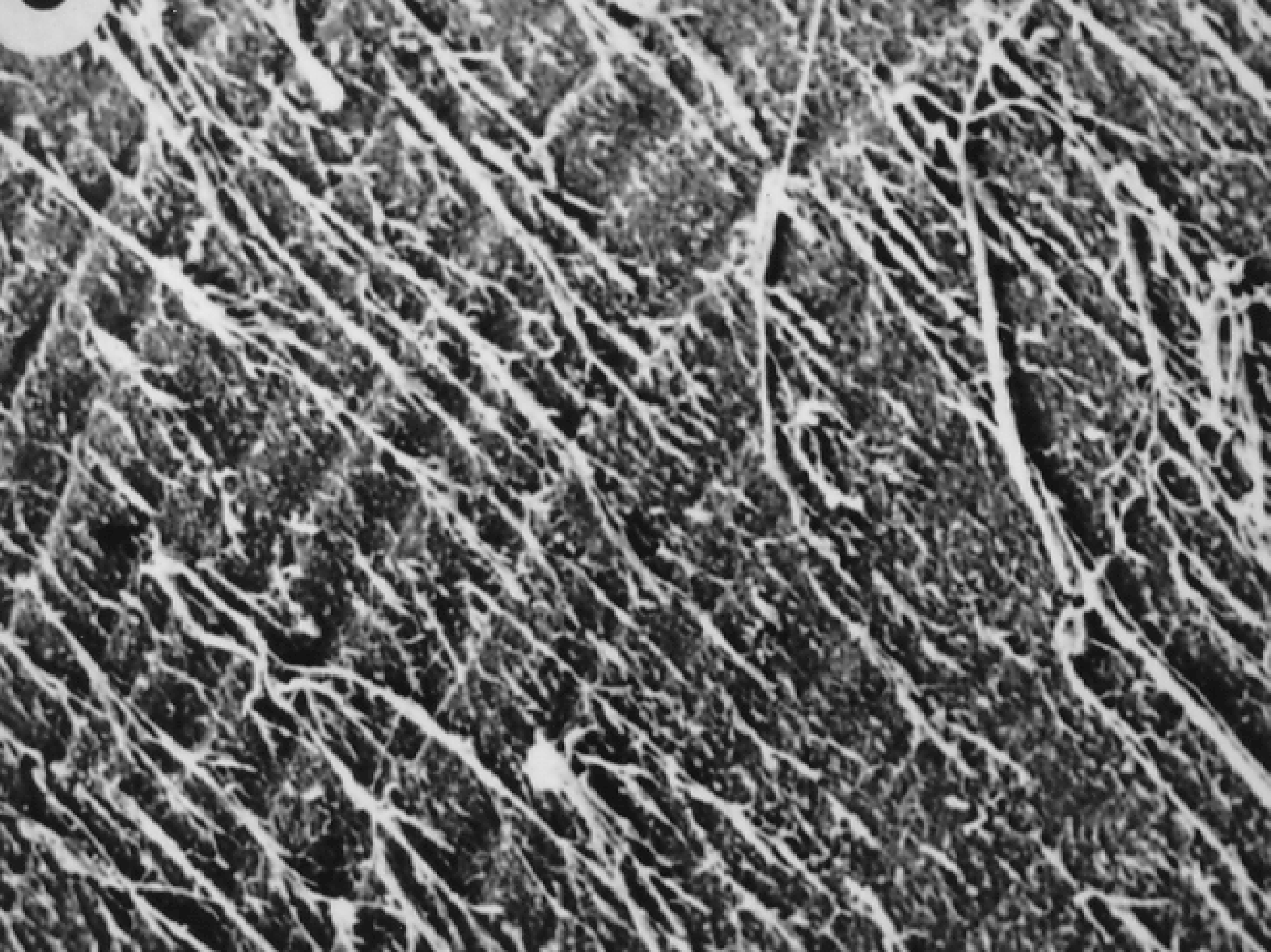
Other Organisms

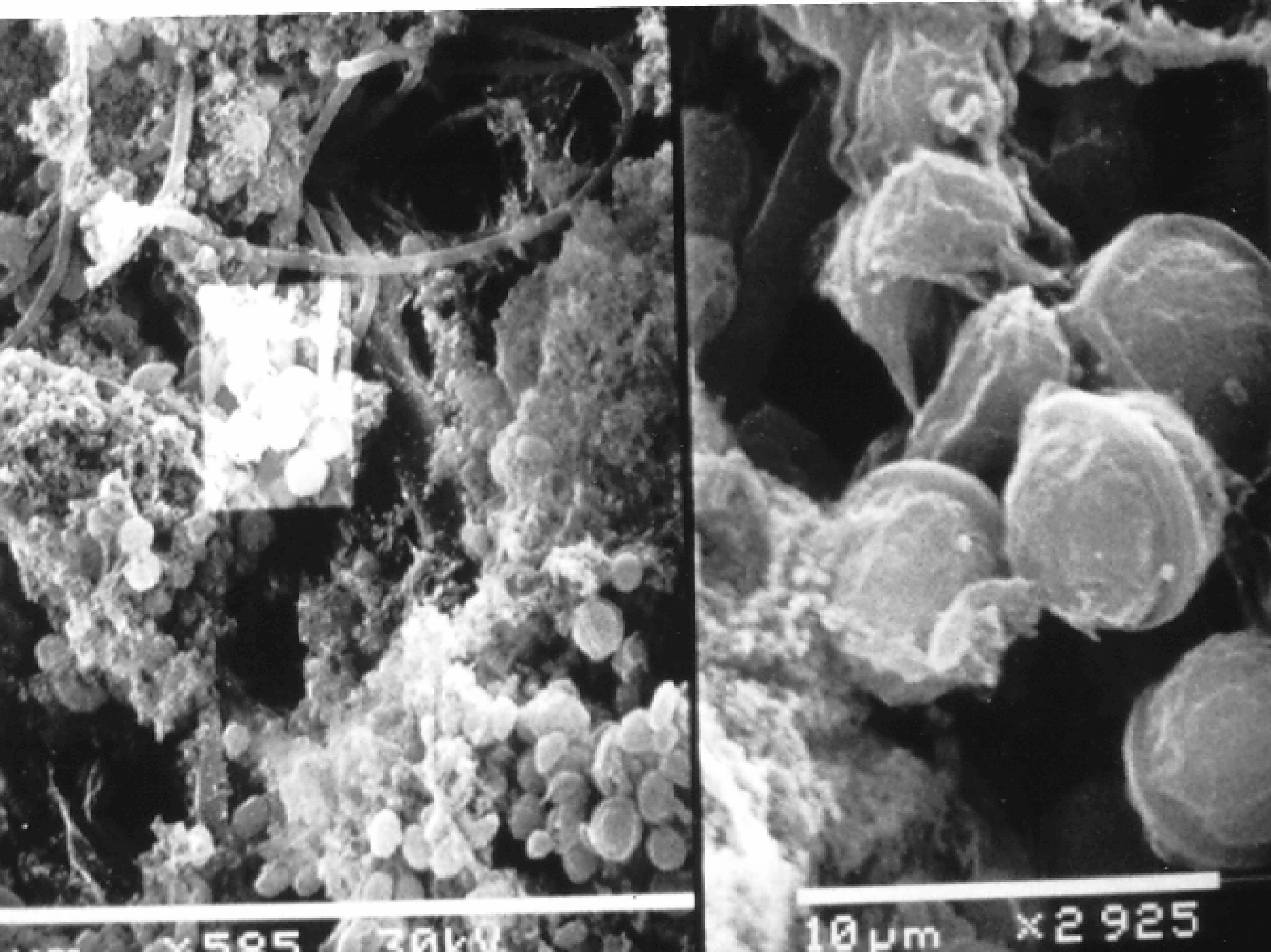
Iron Depositing Bacteria (*Gallionella, Sphaerotilus*)
- Bacteria that will deposit iron on surfaces
- They are often found in well water

Algae
- Can grow in masses on surfaces exposed to sunlight (such as cooling tower decks)

Total Fungi
- Some Fungi have been identified as contributors to microbial influenced corrosion
- Molds can act to "reinforce" microbial deposits with their filamentus structure.

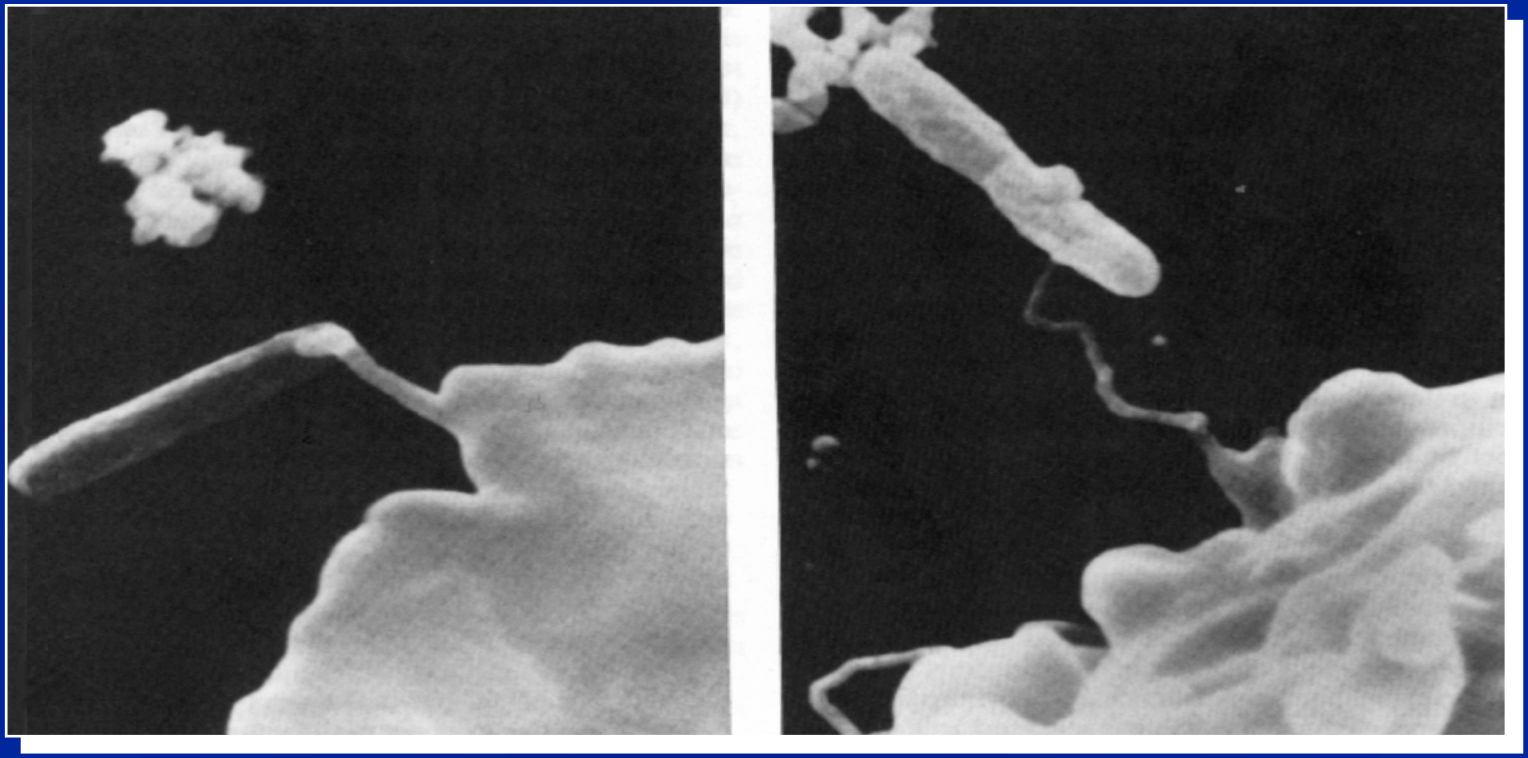
Higher Life Forms (Worms, Protozoa, Insect Larvae etc.)
- Indicates an older deposit with established microbial population
- Not a newly formed deposit




×585
10µm
×2925


80651 20KV
5U

Legionella



Scanning electron micrographs of a virulent *Legionella pneumophila* cell attached to *Hartmannella vermiformis*.