Evolution and how microbes see it

Dr. Jan Kuever
kuever@mpa-bremen.de

Department of Microbiology

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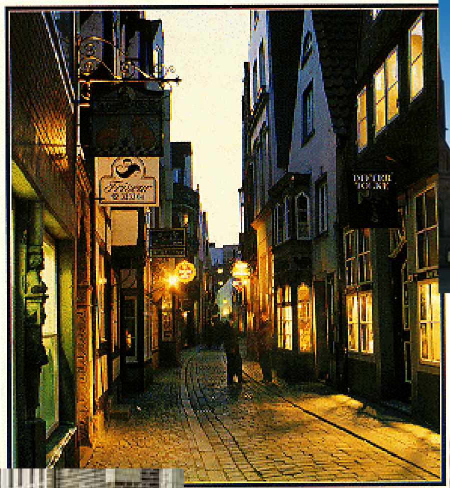
Free Hanseatic City of Bremen

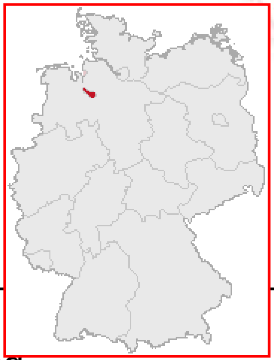


The town-hall

Drop tower

Schnoor-Quarter

SV Werder Bremen



The town musicians

Universum Science Center

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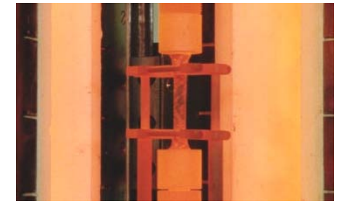
Metallic Materials and Components - Dept. 1



- Analysis of material data
- Examination and testing of metallic parts
- Damage analysis
- Investigation of synergistic effects of matrices for material characteristics

DAP Deutsches Akkreditierungssystem Prüfwesen GmbH

Deutschen AkkreditierungsRat

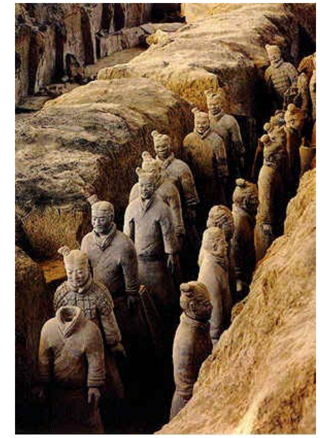
Accreditation

Civil Engineering - Dept. 2

- Testing of building materials
- Surveillance and certification
- Research and development of building materials
- Damage analysis at buildings

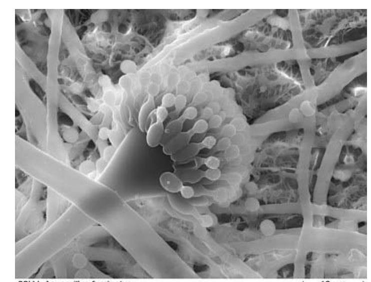
Accreditation
acc. to DIN EN ISO/IEC
17025 since 2001

Analytic Microscopy for Constructional Materials - Dept. 3



- Microscopic damage research
- Development of new matrices for concrete
- Research in the conservation of historical objects
- Analysis of asbestos

Microbiology - Dept. 4



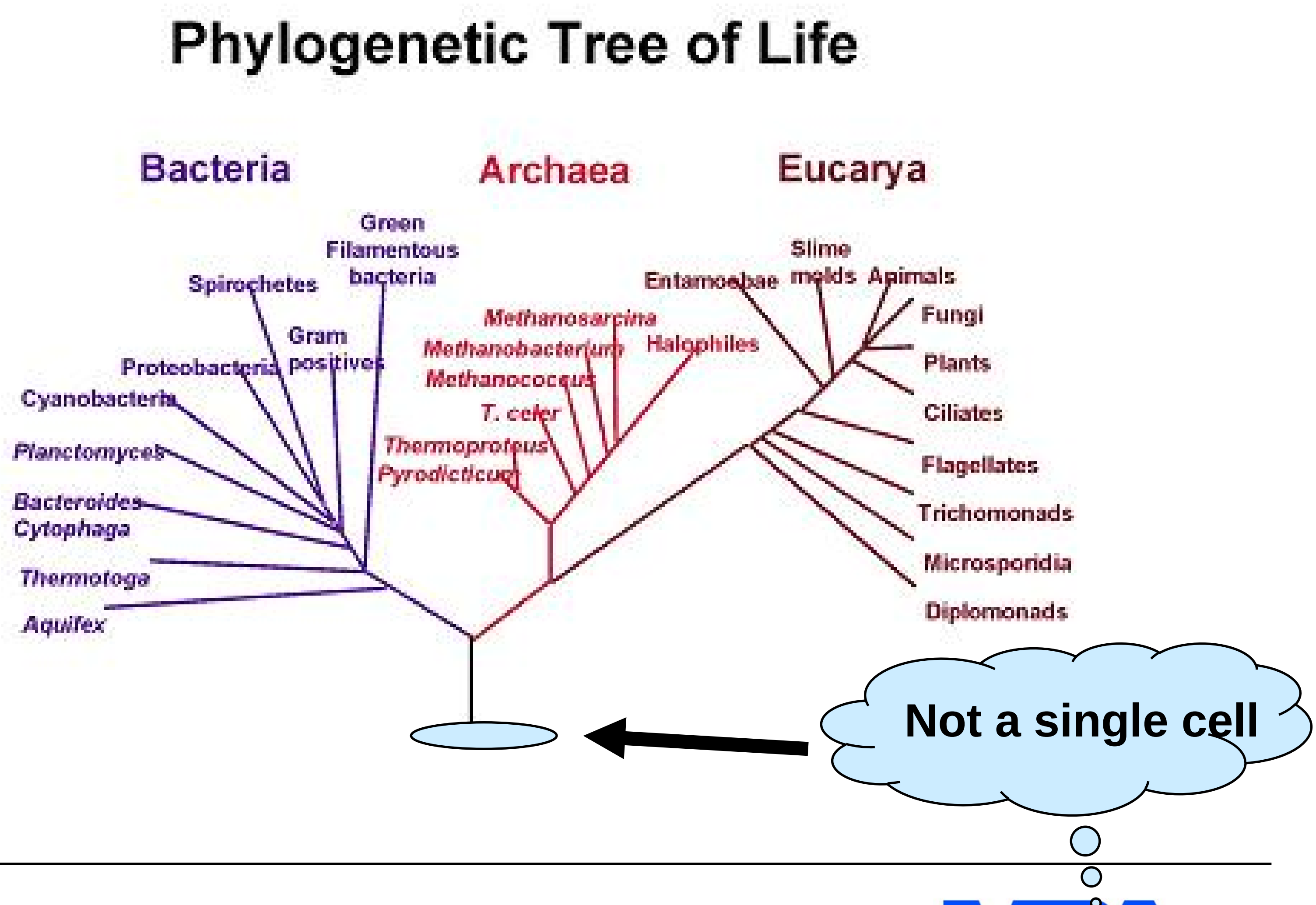
- Microbiological damage analysis
- Identification of damage-relevant microorganisms
- Development of conservation concepts
- Research and development in material resistance also tests acc. to ISO, ASTM, AITM, VdL etc.
- Investigations and research in microbial contamination of technical fluids

Service and Research Topics

- Testing of materials and coatings
- Developments of testing methods
- Isolation, cultivation and identification of microorganisms (fungi, bacteria, archaea, algae)
- Development of biocidic coatings (together with partners)
- Molecular identification and detection
- Rapid identification of microorganisms using MALDI BioTyper™ system
- Systematic of bacteria and fungi
- Functional gene analysis

Microorganisms (MO)

- Prokaryotes: bacteria and archaea
- Eukaryotes: fungi (yeasts), algae



Phylogenetic Tree of Life
Bacteria
Archaea
Eucarya
Green Filamentous bacteria
Spirochetes
Gram positives
Proteobacteria
Cyanobacteria
Planctomyces
Bacteroides Cytophaga
Thermotoga
Aquifex
Methanosarcina
Methanobacterium
Methanococcus
T. celer
Thermoproteus
Pyrodicticum
Halophiles
Entamoebae
Slime molds
Animals
Fungi
Plants
Ciliates
Flagellates
Trichomonads
Microsporidia
Diplomonads
Not a single cell

Early earth conditions

- High temperature (cold-hot changes?)
- Nearly no organic material present
- High UV-light (no ozone layer present)
- Reduced atmosphere (H_2, H_2S, CO, NH_4^+, N_2, CO_2, CH_4, H_2O)

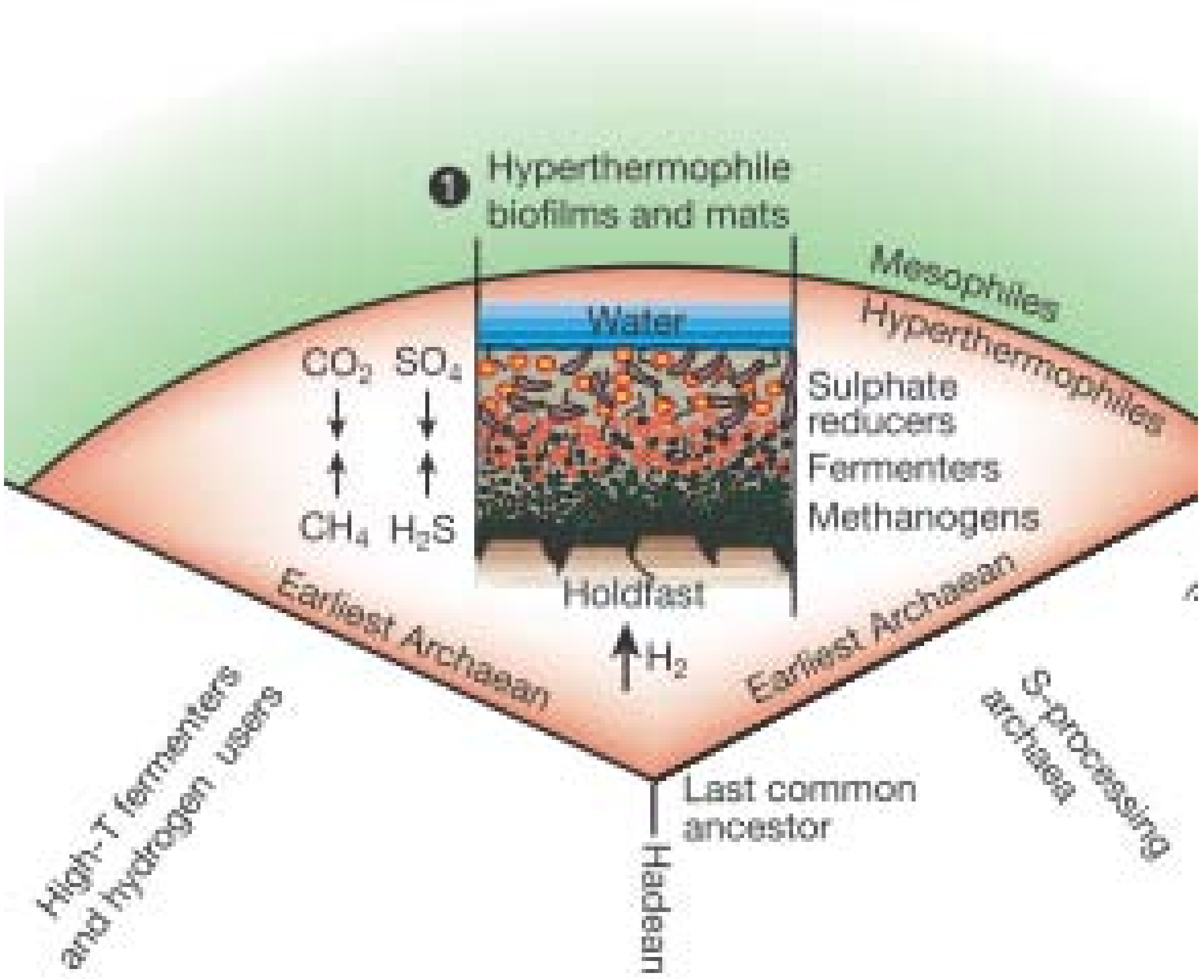
Early pathways

- Carbon fixation pathways for cell synthesis (Assimilation)
  - **Actetyl-CoA pathway (Wood-Ljungdahl pathway) or**
  - **Reverse TCA cycle**

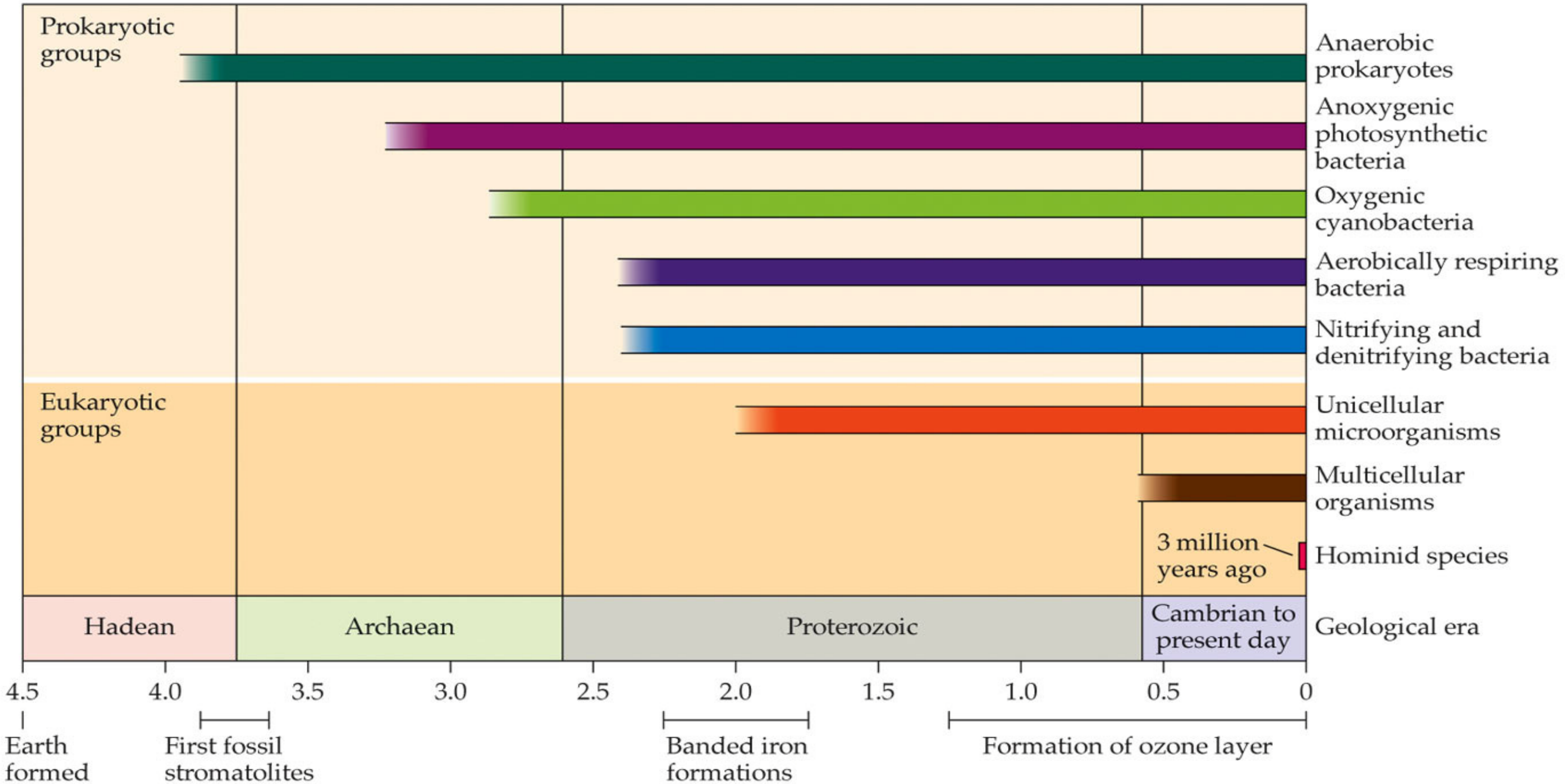
- ATP synthesis, energy production (Dissimilation)
  - **Sulfur (sulfite) reduction: $H_2 + S \rightarrow H_2S$**
  - **Methanogenesis: $4H_2 + HCO_3^- \rightarrow CH_4 + H_2O$**
  - **Homoacteogenesis: $4H_2 + 2HCO_3^- \rightarrow H_3CCOO^- + OH^- + 3H_2O$**

Problems

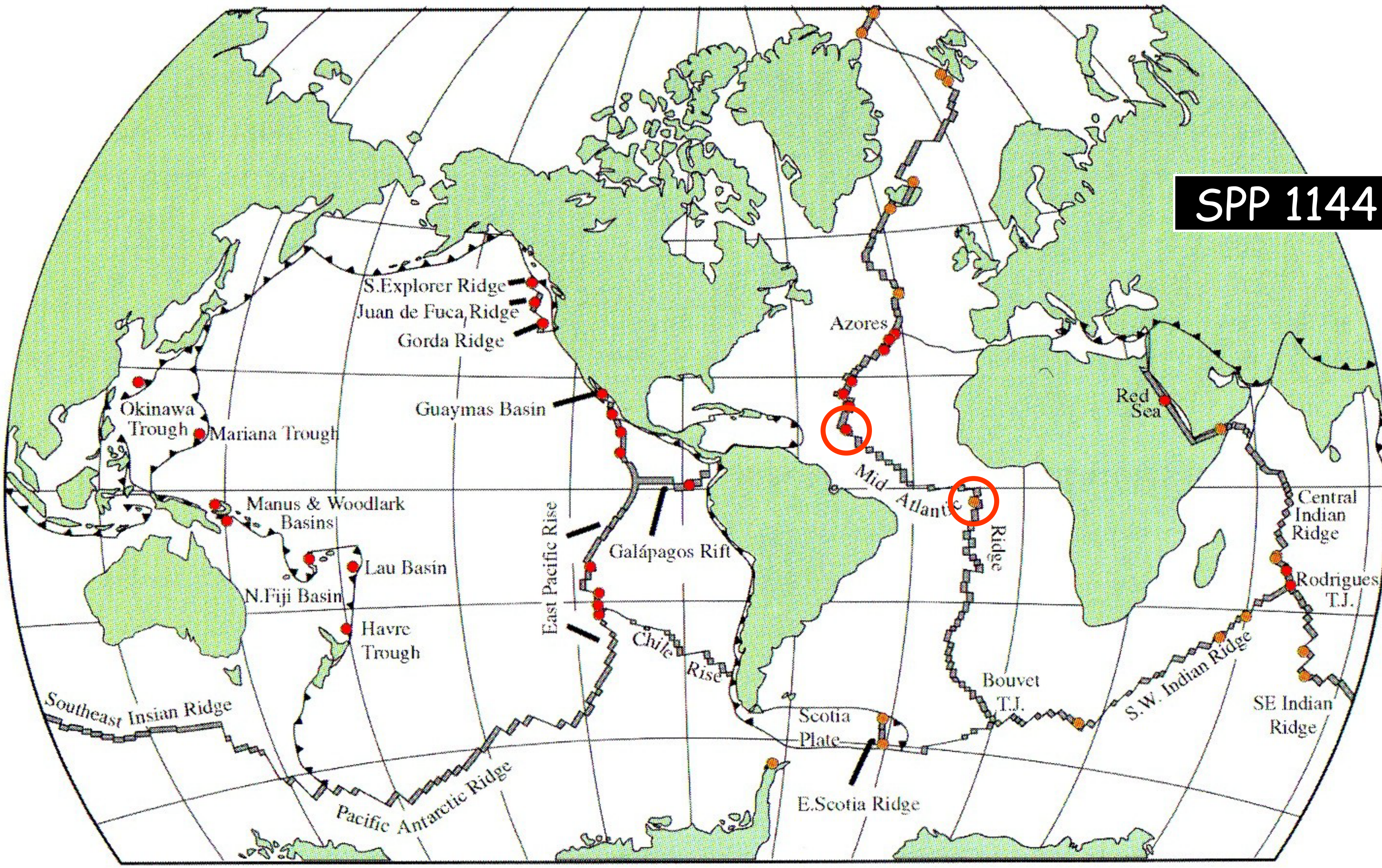
- Purely chemosynthesis
- Low amount of energy generation
- Limited to energy efficient carbon fixation pathways
- Probably dependent on hydrogen



From Nisbet & Sleep, 2001, Nature vol 409



Prokaryotic groups
Anaerobic prokaryotes
Anoxygenic photosynthetic bacteria
Oxygenic cyanobacteria
Aerobically respiring bacteria
Nitrifying and denitrifying bacteria
Eukaryotic groups
Unicellular microorganisms
Multicellular organisms
3 million years ago
Hominid species
Hadean
Archaean
Proterozoic
Cambrian to present day
Geological era
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Earth formed
First fossil stromatolites
Banded iron formations
Formation of ozone layer



Locations of known hydrothermal activity along the global mid-ocean ridge system

● = known active sites ● = active sites indicated by midwater chemical anomalies

aus: German and von Damm (2004)

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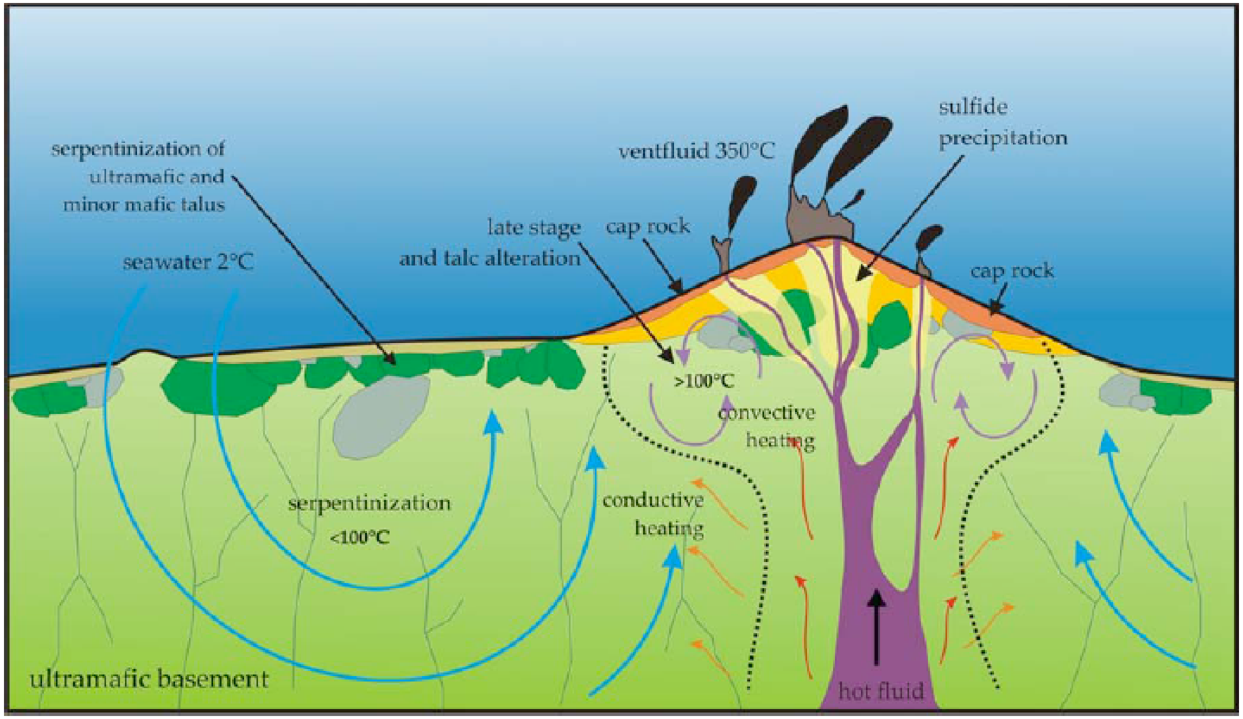
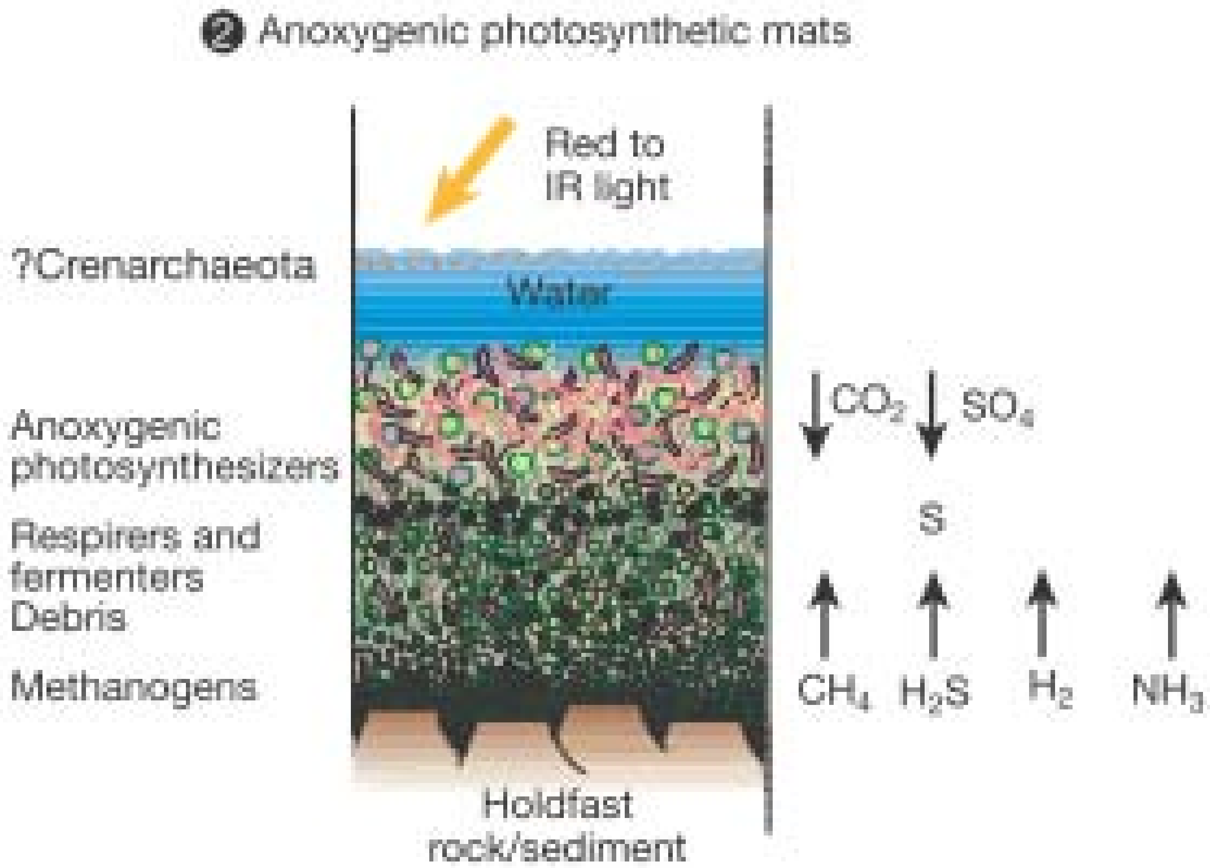


Fig. 4: Schematic model of fluid flow based on geochemical, petrological, and isotopic investigations of altered rocks, sulfides and hydrothermal fluids. Low-T serpentinization of ultramafic rocks takes place well away from the high-T vent sites. Close to the vent sites already serpentinized rocks are overprinted by either high-T hydrothermal fluids or by convectively heated, seawater-derived fluids to form late stage and talc alteration.

What still needs to be done, how and when?

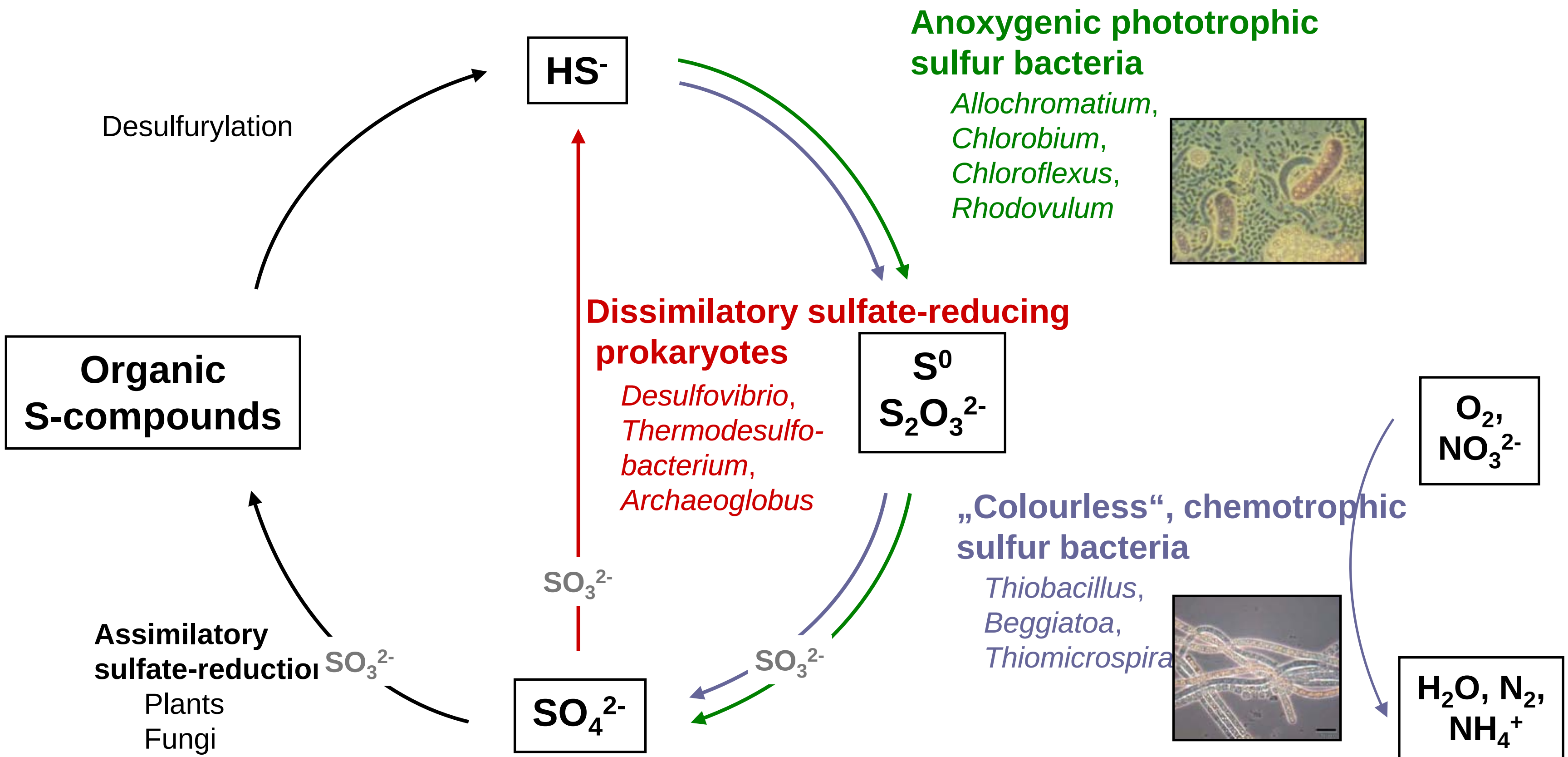
Next steps I:

- Use of light as energy source (anoxygenic photosynthesis)
- Formation of syntrophic interactions (cooperation between different physiological types)
- Establishment of primitive element cycling
- Energy was not limited for phototrophs (blooms?)
- First filamentious cyanobacteria-like organisms



From Nisbet & Sleep, 2001,
Nature vol 409

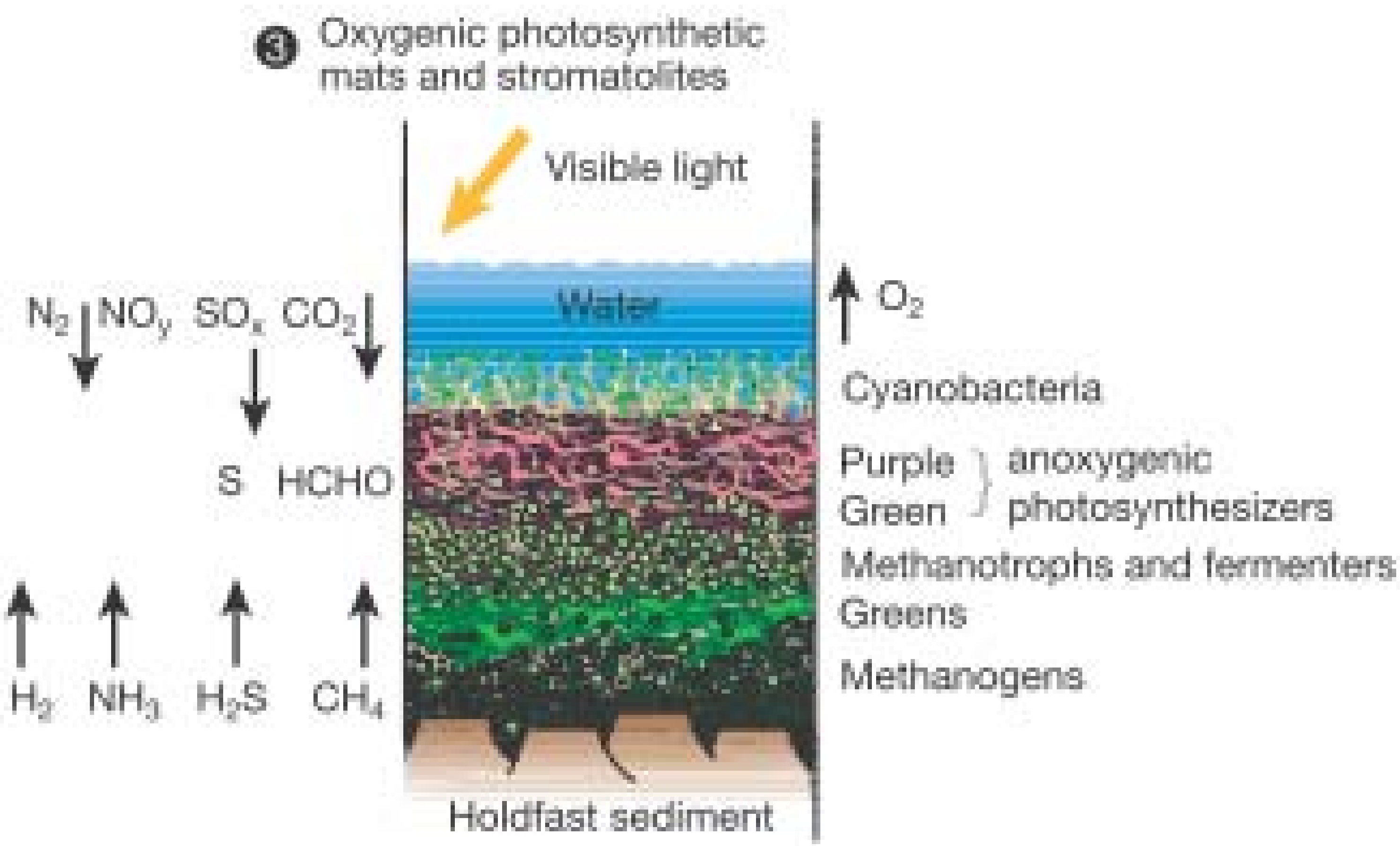
Microorganisms of the sulfur cycle: sulfate-reducing prokaryotes (SRP) and sulfur-oxidizing prokaryotes (SOP)



[Brock. © Pearson education international]

Next steps II:

- Invention of oxygenic photosynthesis
- Reduced atmosphere changed into todays atmosphere
- Oxygen became important electron acceptor
- Due to use of oxygen no energy limitation, development of multicellular life forms and eukaryotes



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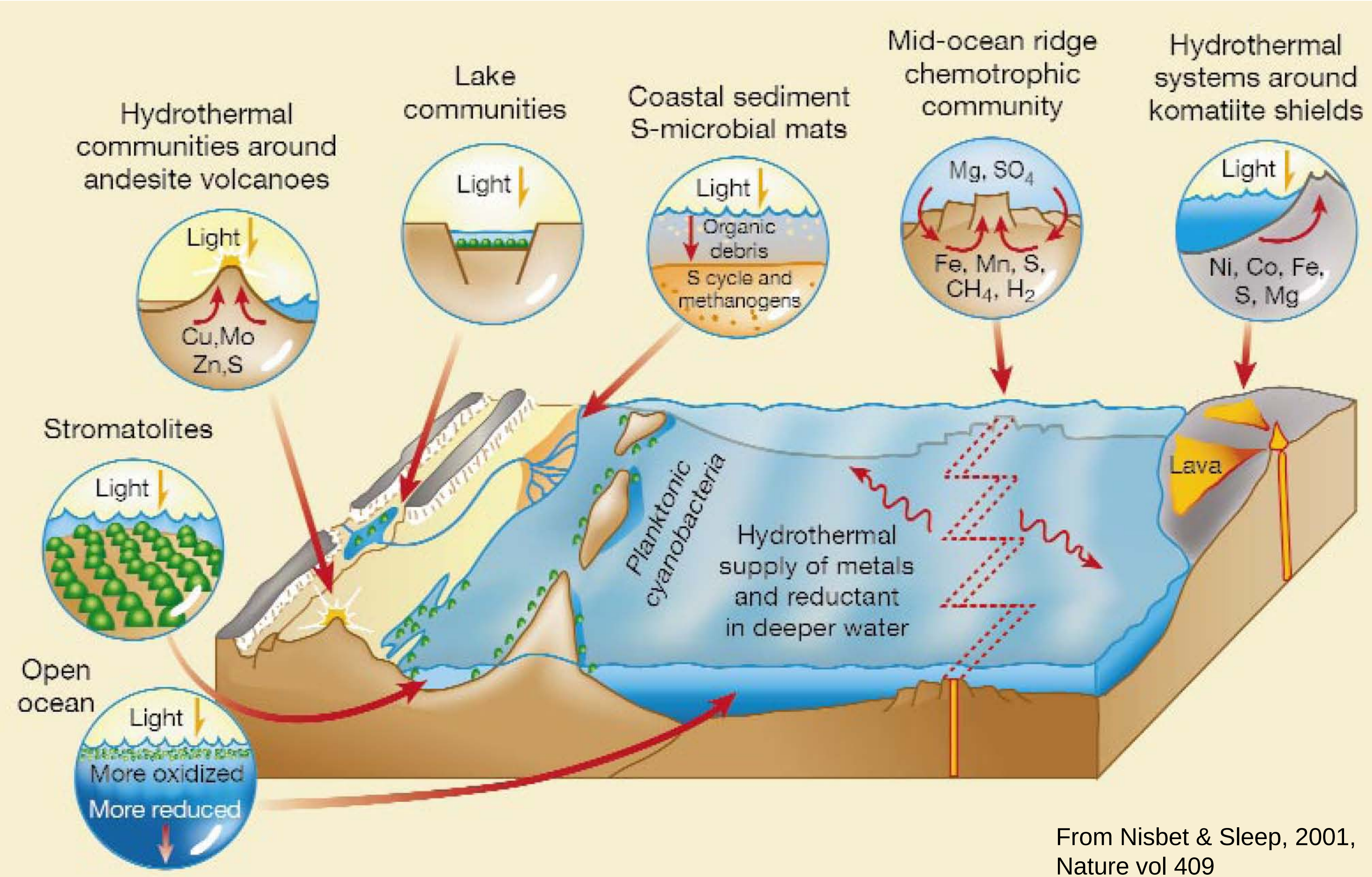

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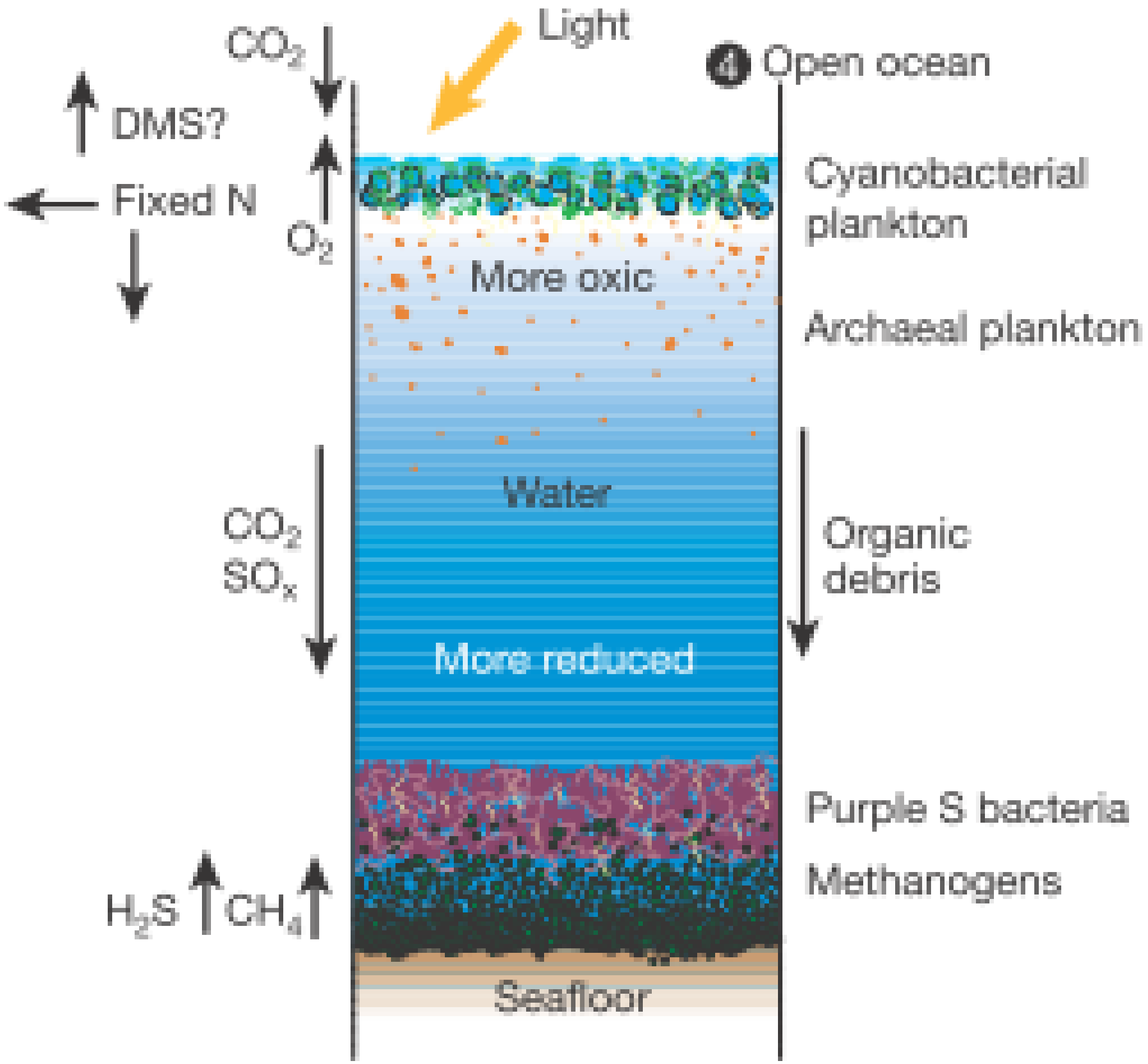


From Nisbet & Sleep, 2001, Nature vol 409

What you should know about MO part I

- Growth at:
  - -12 to ca. 120^{o}C
  - pH 0 bis 13
  - Hydrostatic pressure 0 to 1000 bar
  - Salinity: 0 to saturated
  - Redox potential: -450 to 850 mV

What you should know about MO part II

- Growth on inorganic materials alone
- High tolerance against UV light and radioactive radiation
- High resistance against chlorine and biocides, especially in biofilms
- Surfaces are favored substrates to settle and to develop
- Molecules can be transported against chemical gradients
- MO are working together

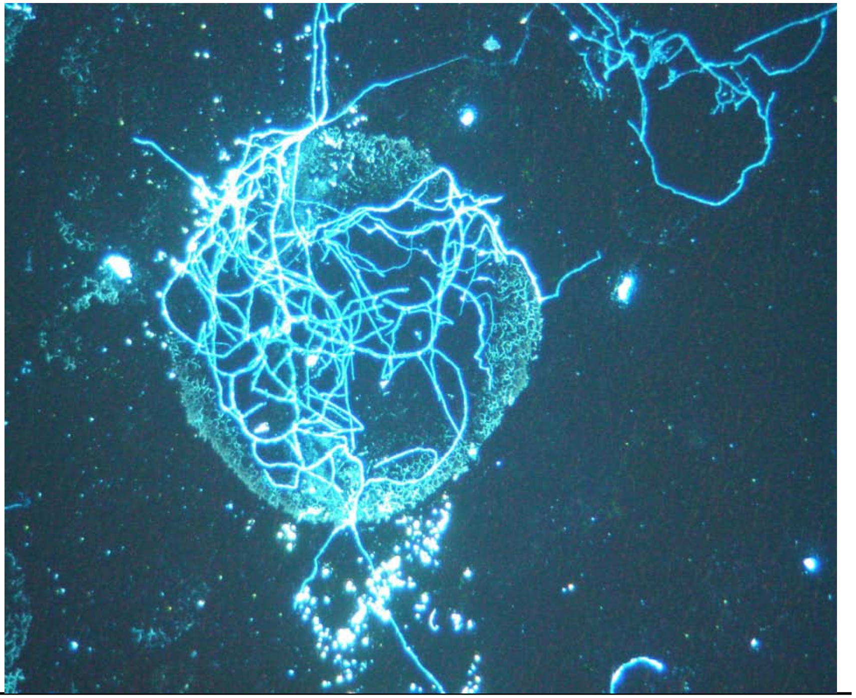
Where can you find microorganisms (MO) and why are they so successful?

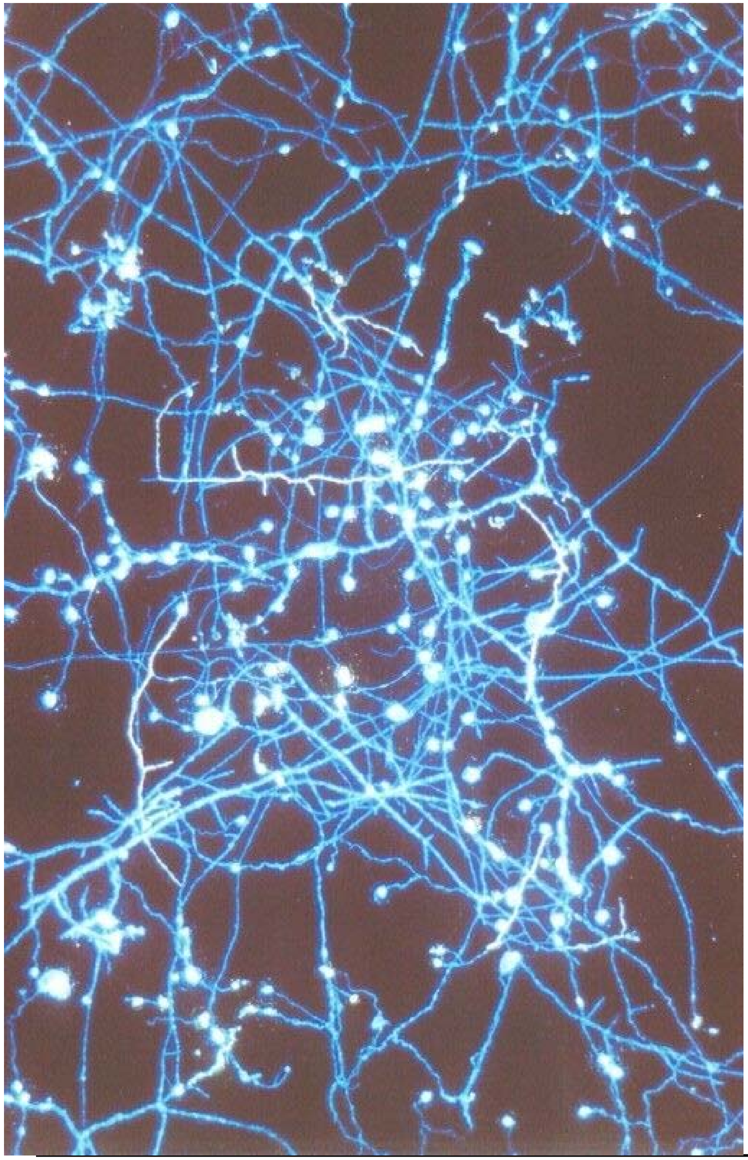
- Nearly everywhere
- They have a large diversity of physiological pathways
- They can adapt to new situations, new food sources, new chemicals
- Rapid growth
- They can take up DNA (genes) from other cells (lateral gene transfer) or from the environment

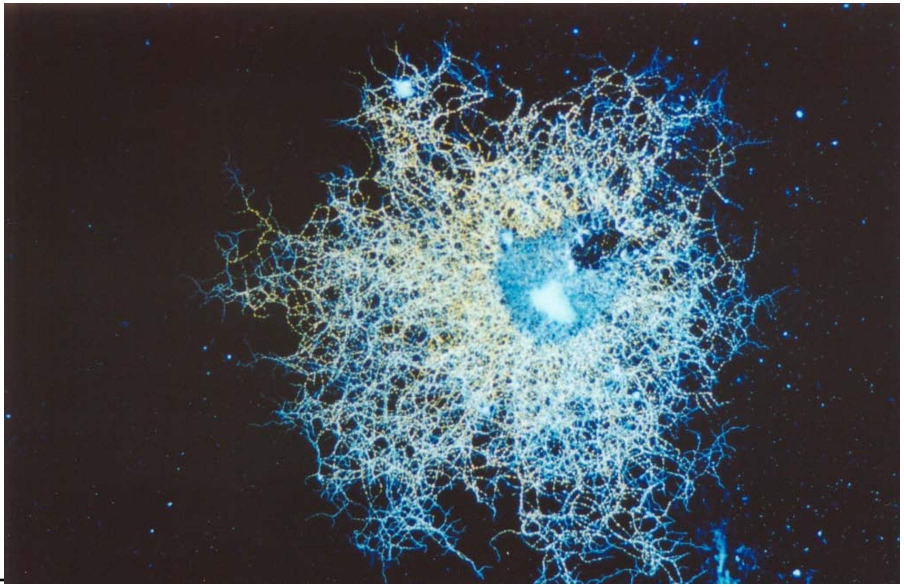
Why are surfaces attractive for MO?

- Surface material itself can be used as food source or provides important nutrients
- Build up of colonies is much easier
- Interaction between cells is possible (cooperation)
- Protection against enemies
- Modification of the surrounding area is possible

MO in space station







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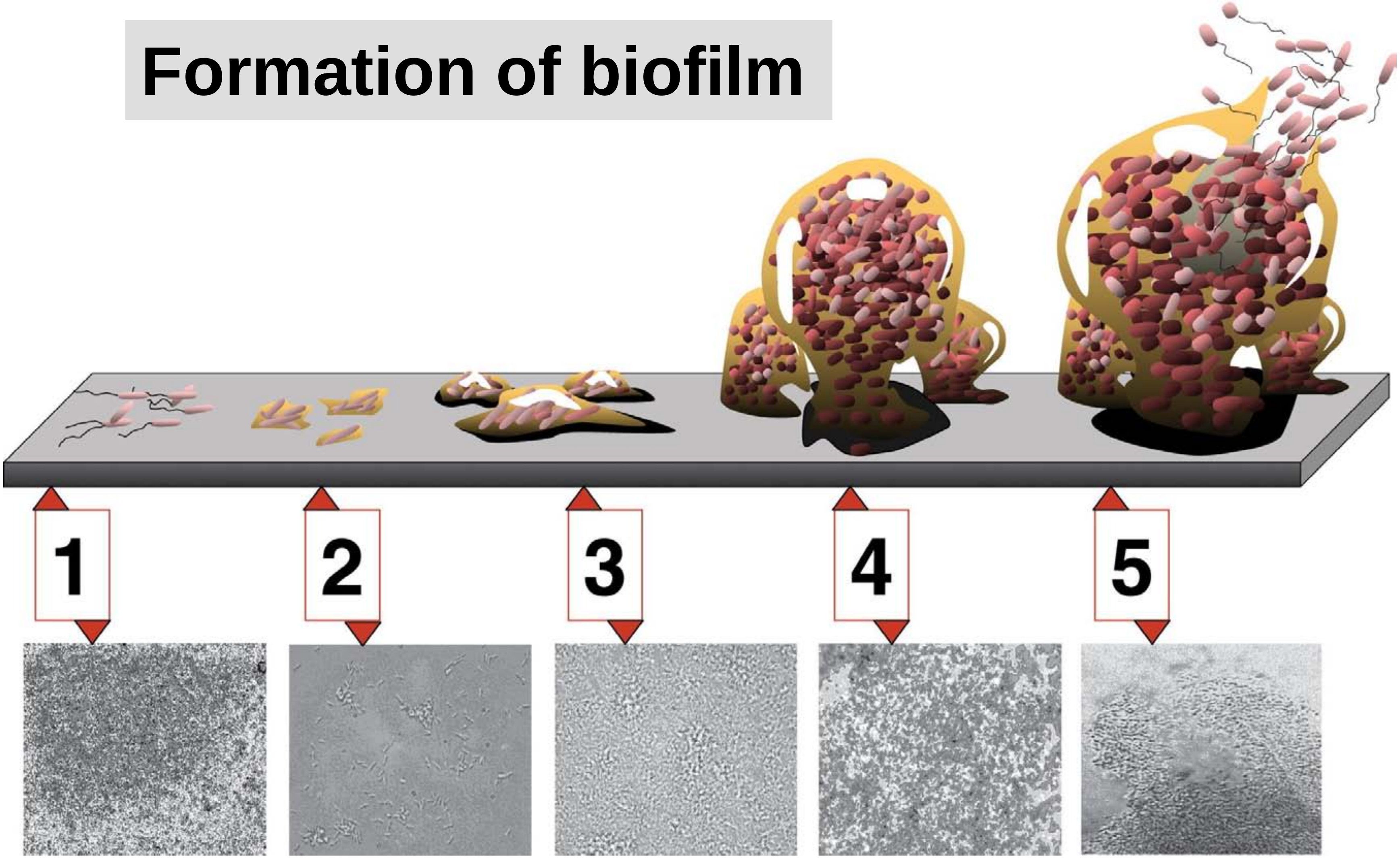
Formation of biofilm

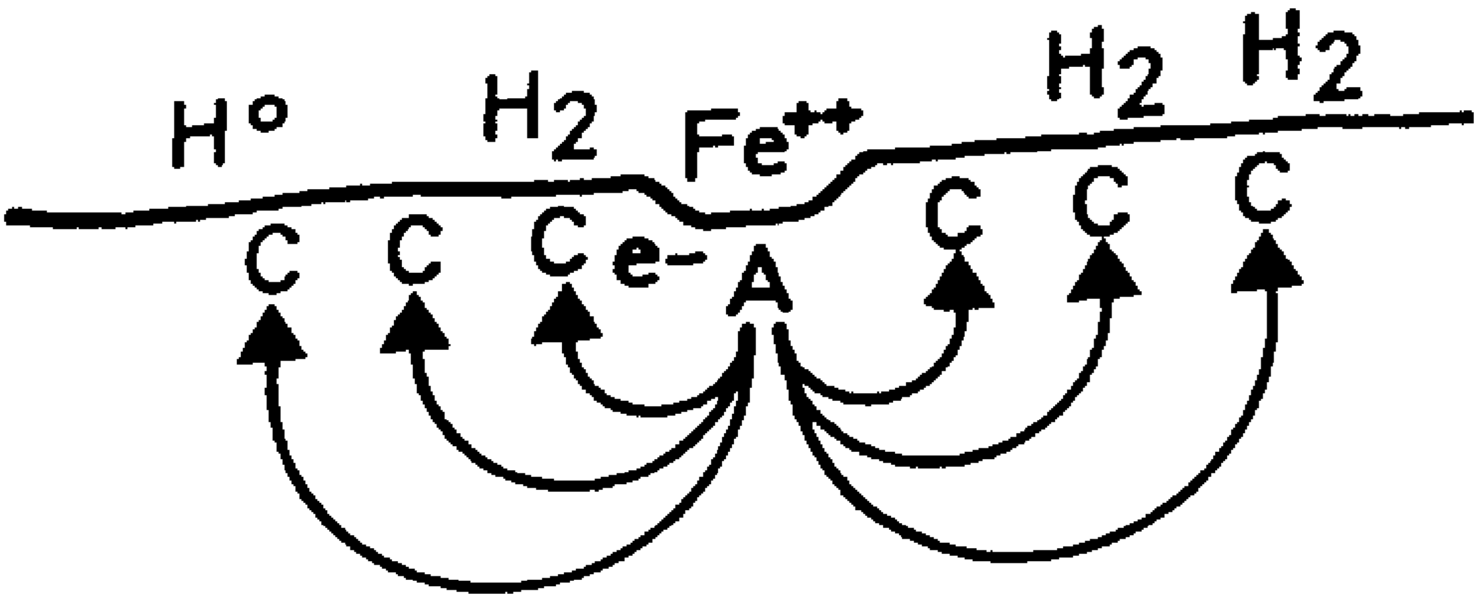


From: Looking for Chinks in the Armor of Bacterial Biofilms Monroe D PLoS Biology Vol. 5, No. 11, e307 doi:10.1371/journal.pbio.0050307

MIC by sulfate-reducing bacteria (SRB)

- No oxygen present, in general oxygen is toxic
- Reduction of sulfate (or other oxidized sulfur compounds) to sulfide
- Most important MIC process

Traditional model: corrosion in the absence of oxygen



Traditional model

- cathodic depolarization
- Formation of H_2 which is then removed by SRB

Direct mechanism: removal of hydrogen

classical depolarization theory:

$4Fe + SO_4^{2-} + 4H_2O \rightarrow FeS + 3Fe^{2+} + 8HO^-$

Dissolution of Fe:

$2Fe \leftrightarrow 2Fe^{2+} + 4e^-$

Cleavage of water:

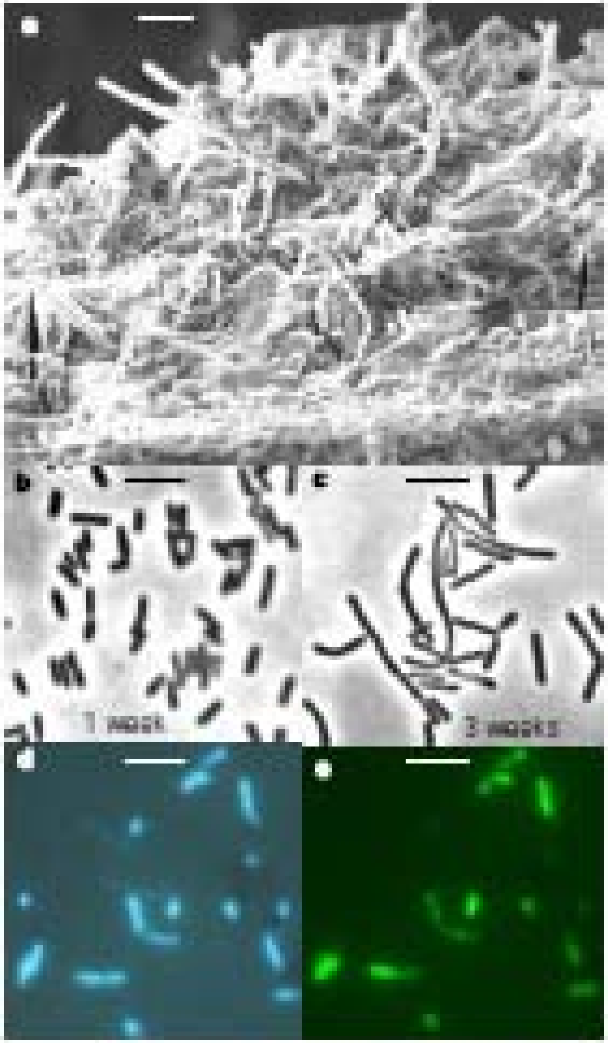
$2H_2O \leftrightarrow 4H^+ + 2HO^-$

Indirect mechanism: attack by sulfide produced by SRB

Overall reaction:

$$2Fe + 2H_2S \rightarrow 2FeS + 2H_2$$

- $2e^- + 2H_2S \rightarrow H_2 + 2HS^-$
- $2e^- + 2HS^- \rightarrow H_2 + 2S^{2-}$
- $2Fe^{2+} + 2S^{2-} \rightarrow 2FeS$
- Sulfide produces more hydrogen
- Massive hydrogen embrittlement



New corrosive sulfate-reducing bacterium „Desulfobacterium corrodens“

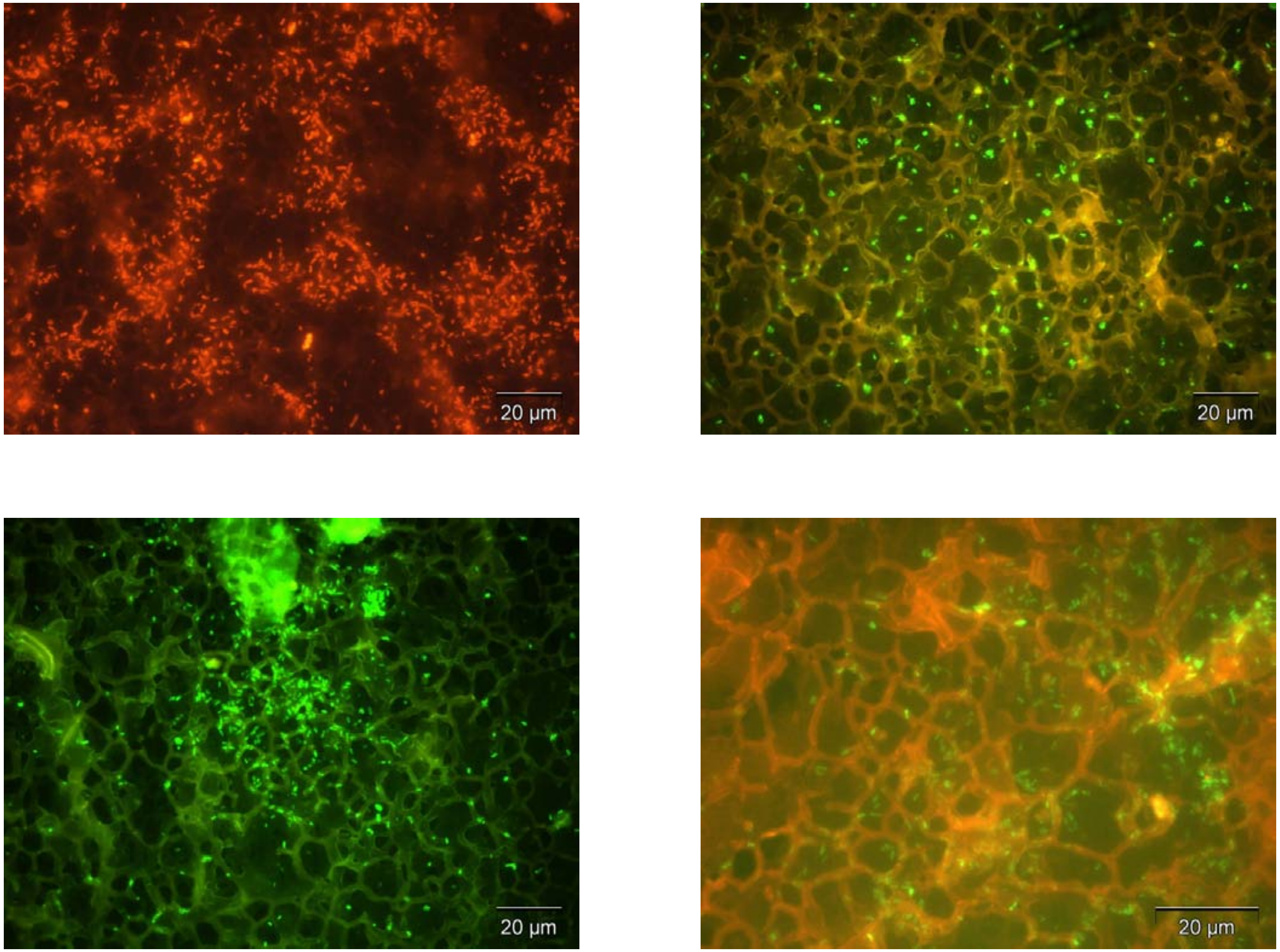
e-donor: Fe

carbon soruce: CO_2

New results

- Widespread at marine habitats
- Growth faster on Fe than on H_2
- Growth only on inorganic compounds
- Produced additional H_2
- Direct contact to metal surface needed
- Cathodic depolarization only side reaction?

Fluorescence-labeled bacteria cells on metal surfaces



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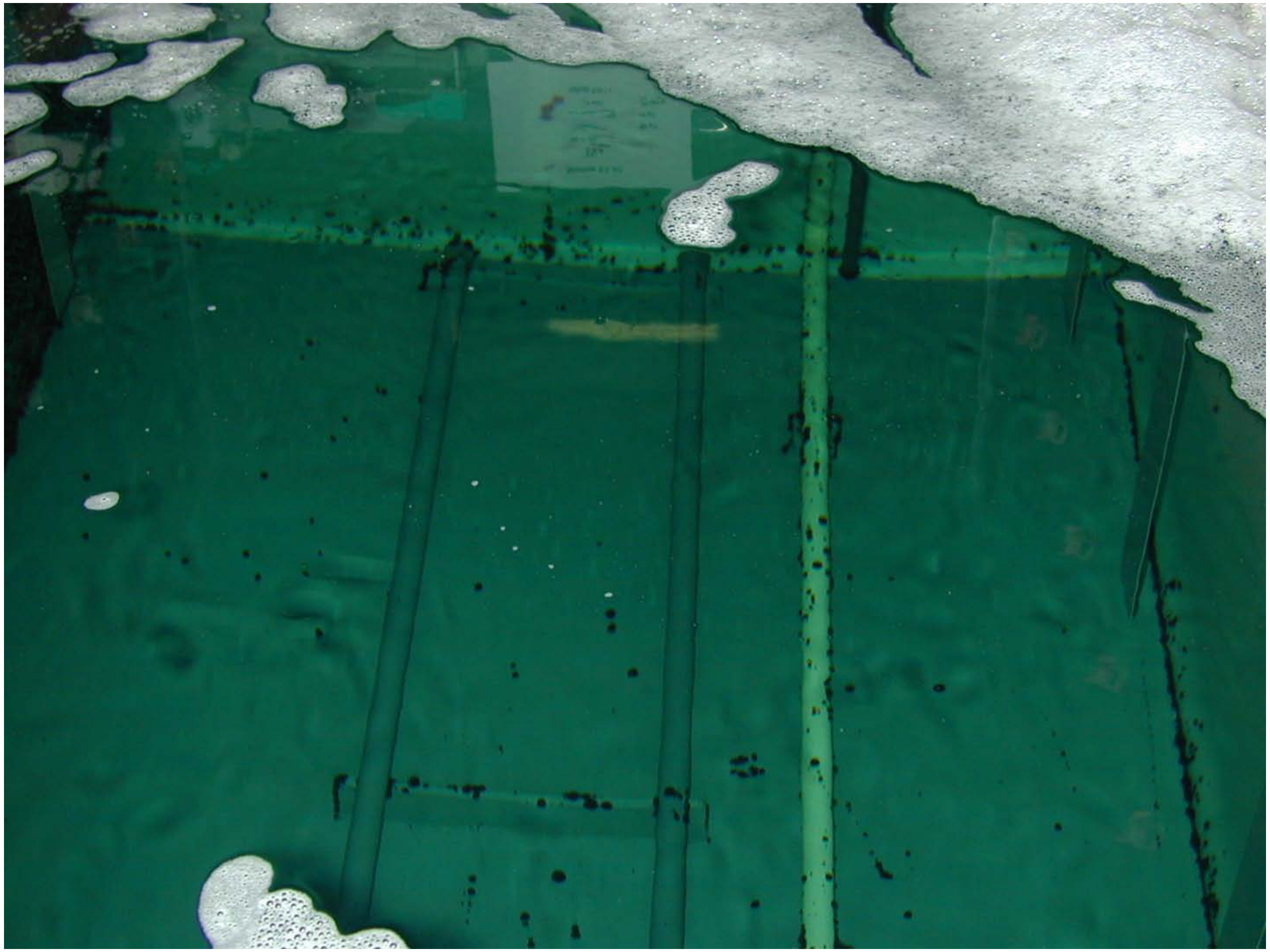
Fungi in an anodizing bath



Fungi in a metalworking fluid system

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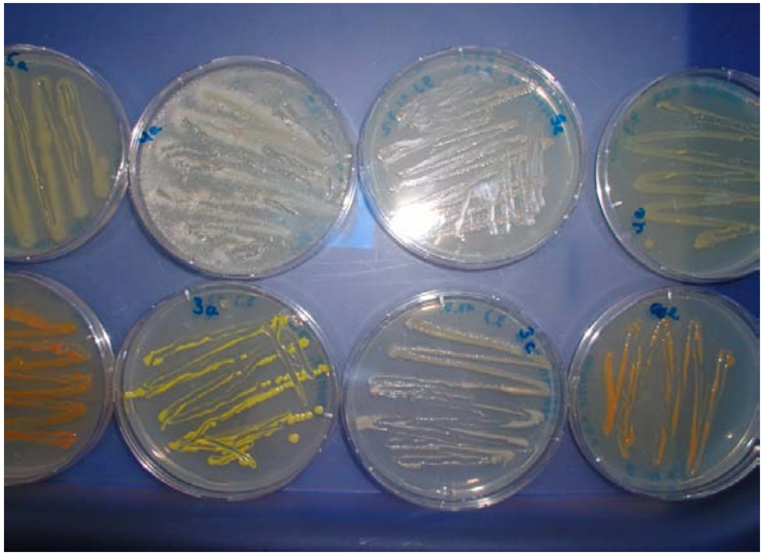
Important:

- MO are extremely important for our world
- Most of them are not at all dangerous for human beings
- You should never underestimate MO
- They can adapt very fast to new situations
- Even modern genome analysis data are only snapshots not more!!!!!!
- One gene ---- encodes one protein is much to simple
- Heterotrophs have advantages in taking up genes
- Often a complete gene cluster has to be taken up, otherwise it would be useless



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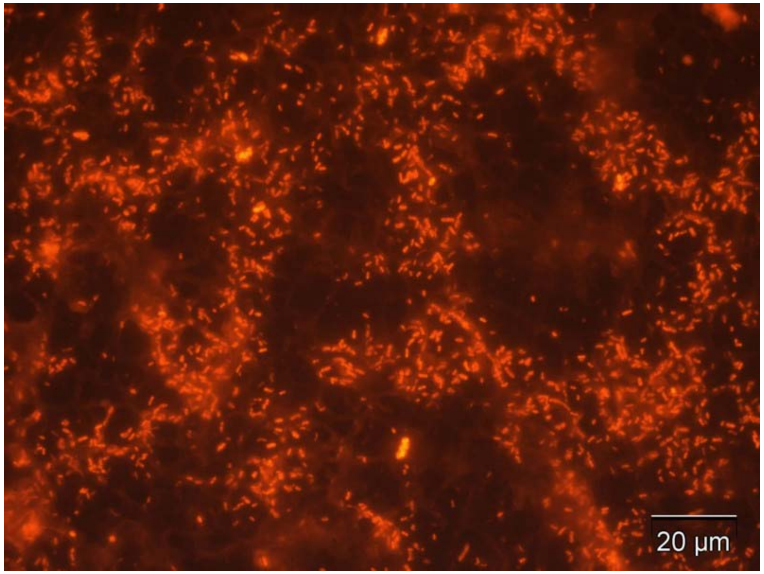

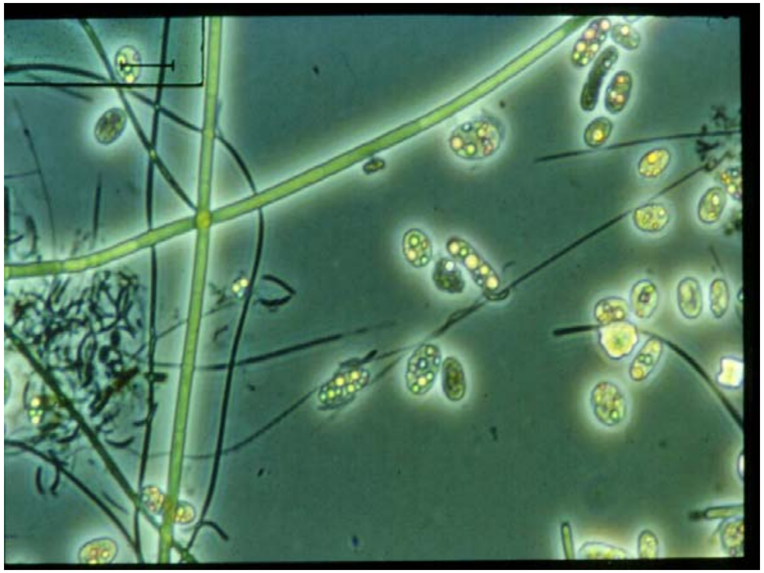

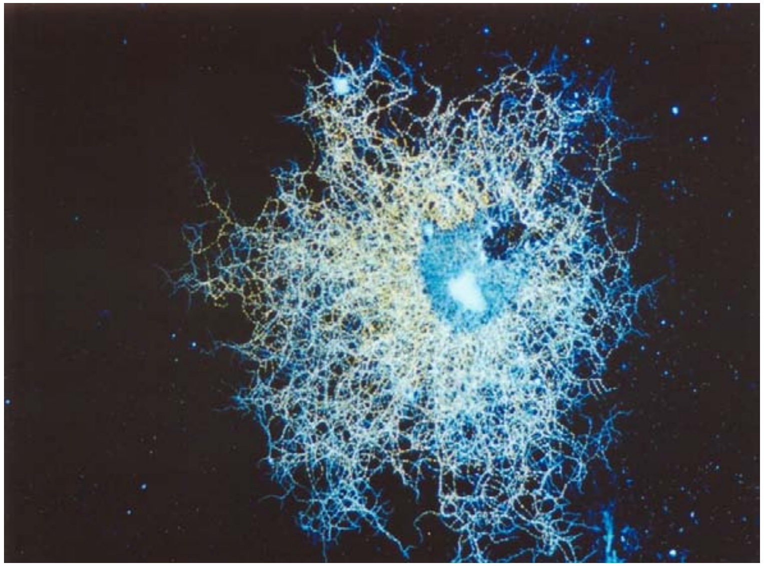

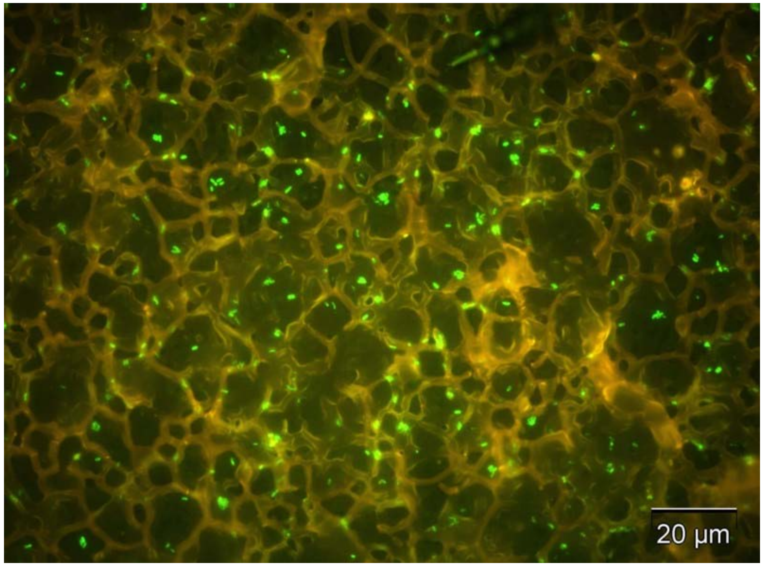

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