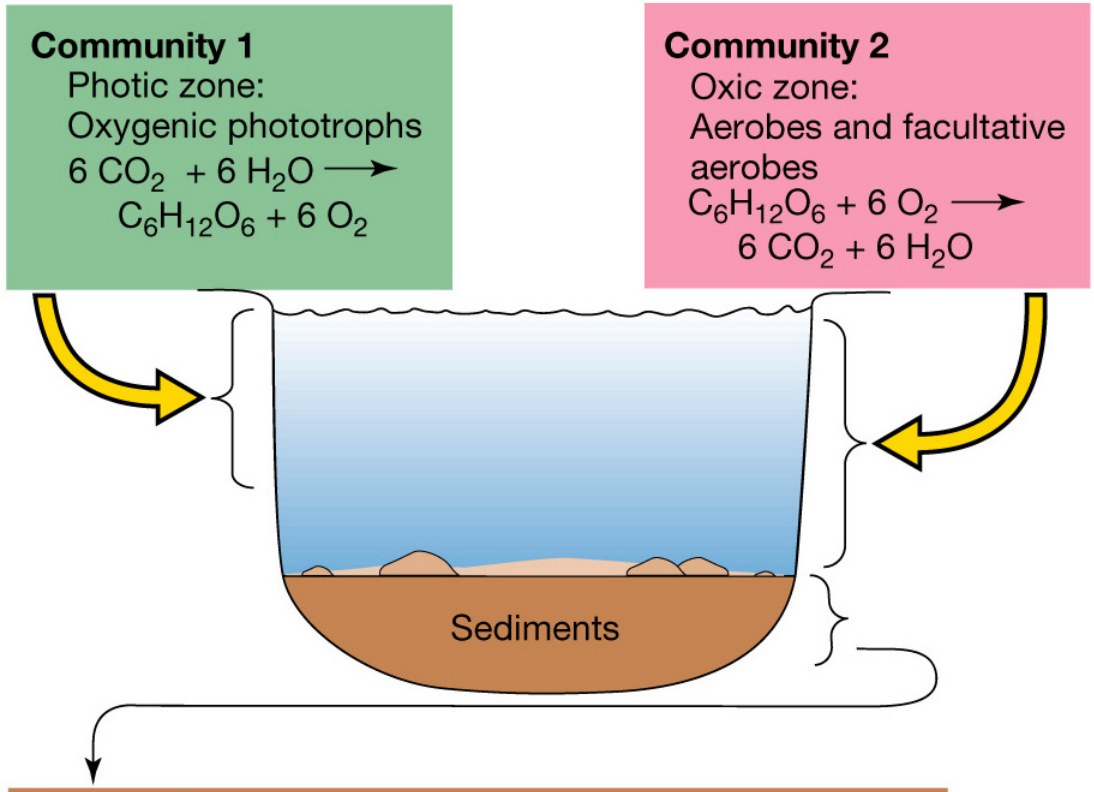
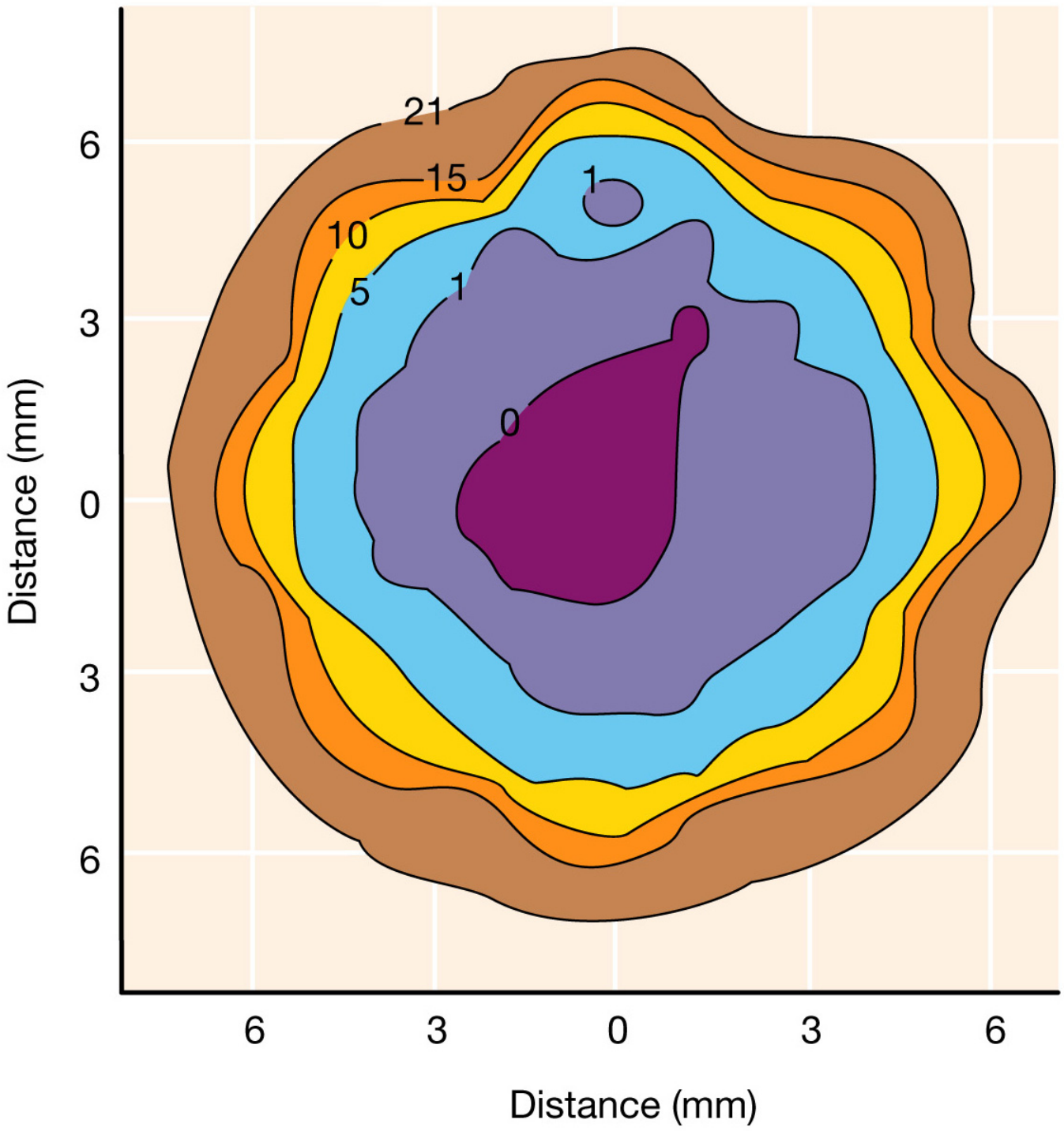
Ecología Microbiana

Dra. Mónica Vásquez

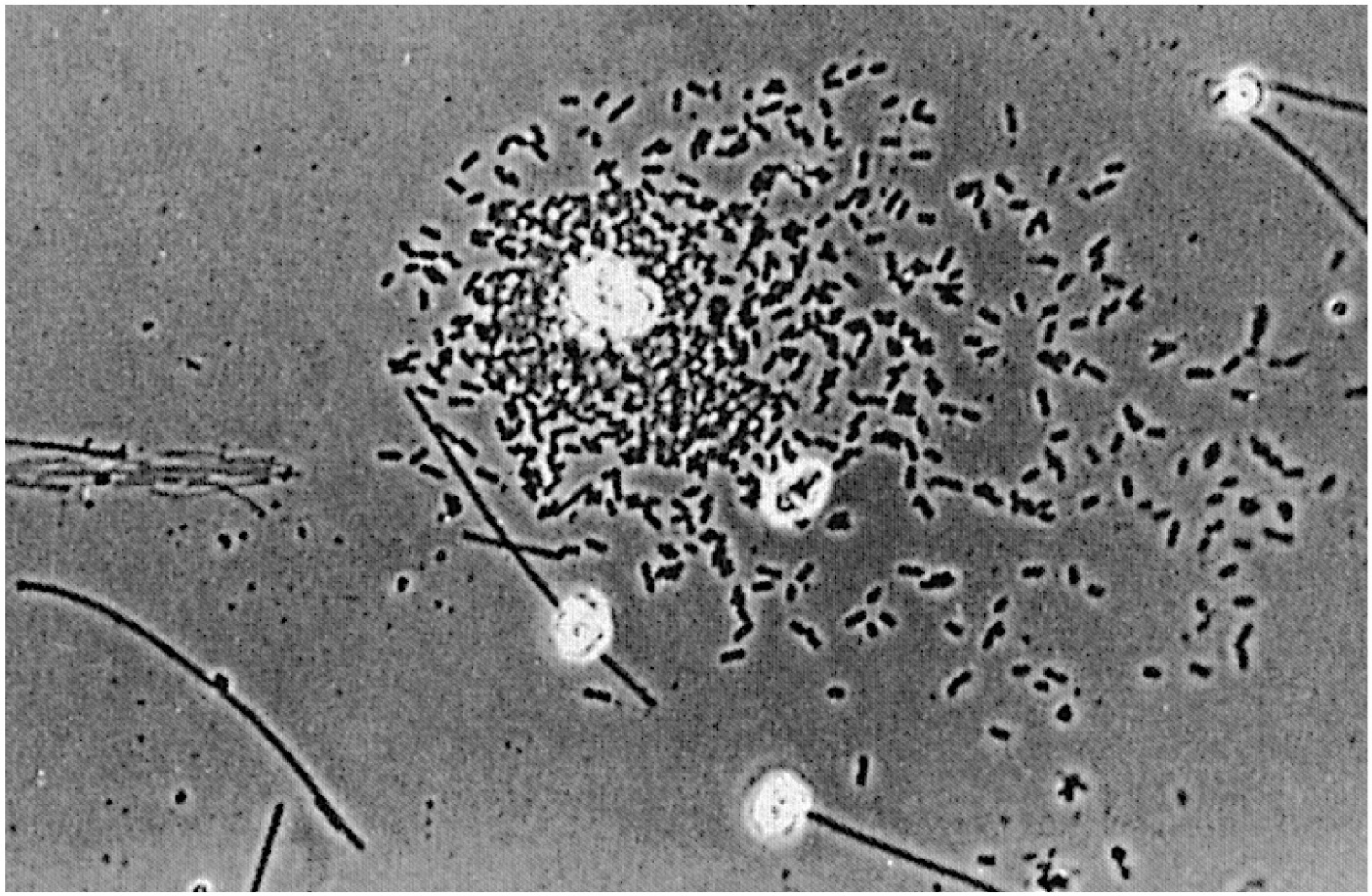
Figures from Brock Biology of Microorganisms



Populations, guilds, and communities—an example of microbial community structure in a lake ecosystem. Microbial communities consist of populations of cells of various species. In a lake ecosystem various communities would exist as shown here. For the sediment community, major guilds are indicated.

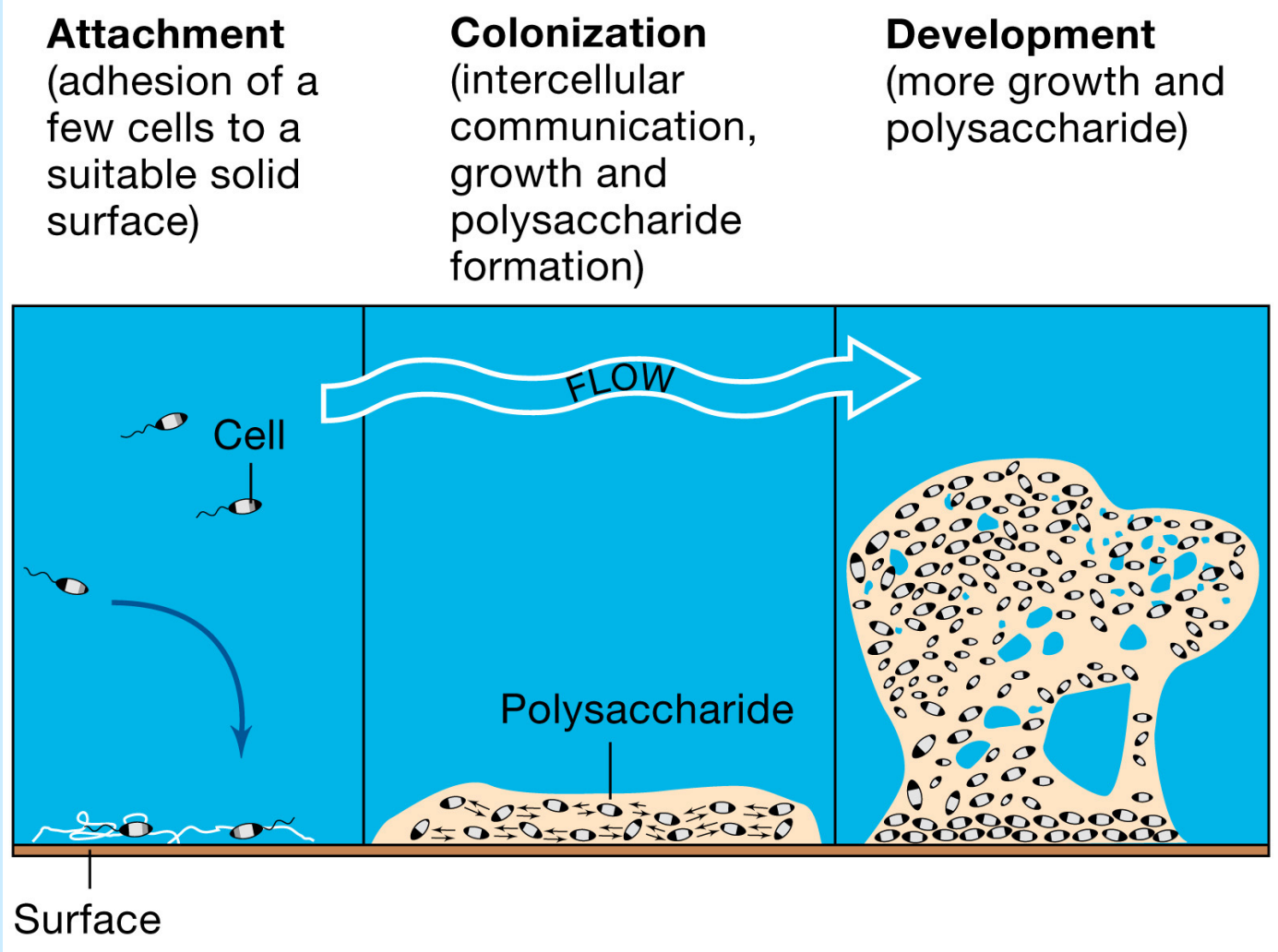


Contour map of O2 concentrations in a soil particle. The axes show the dimensions of the particle. The numbers on the contours are concentrations (in percent; air is 21%). In terms of oxygen relationships for microorganisms, each zone can be considered a different microenvironment.

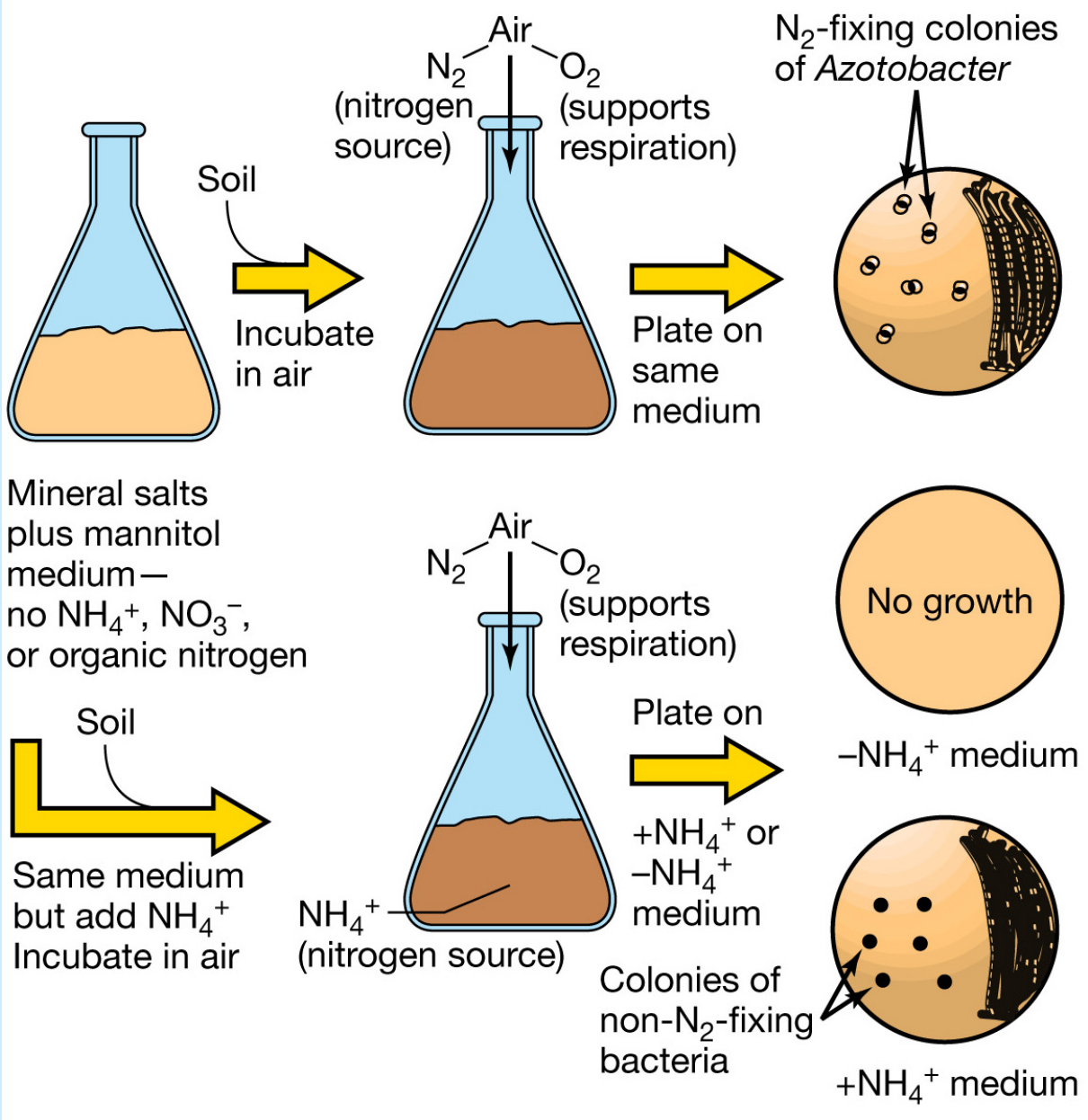


(a)

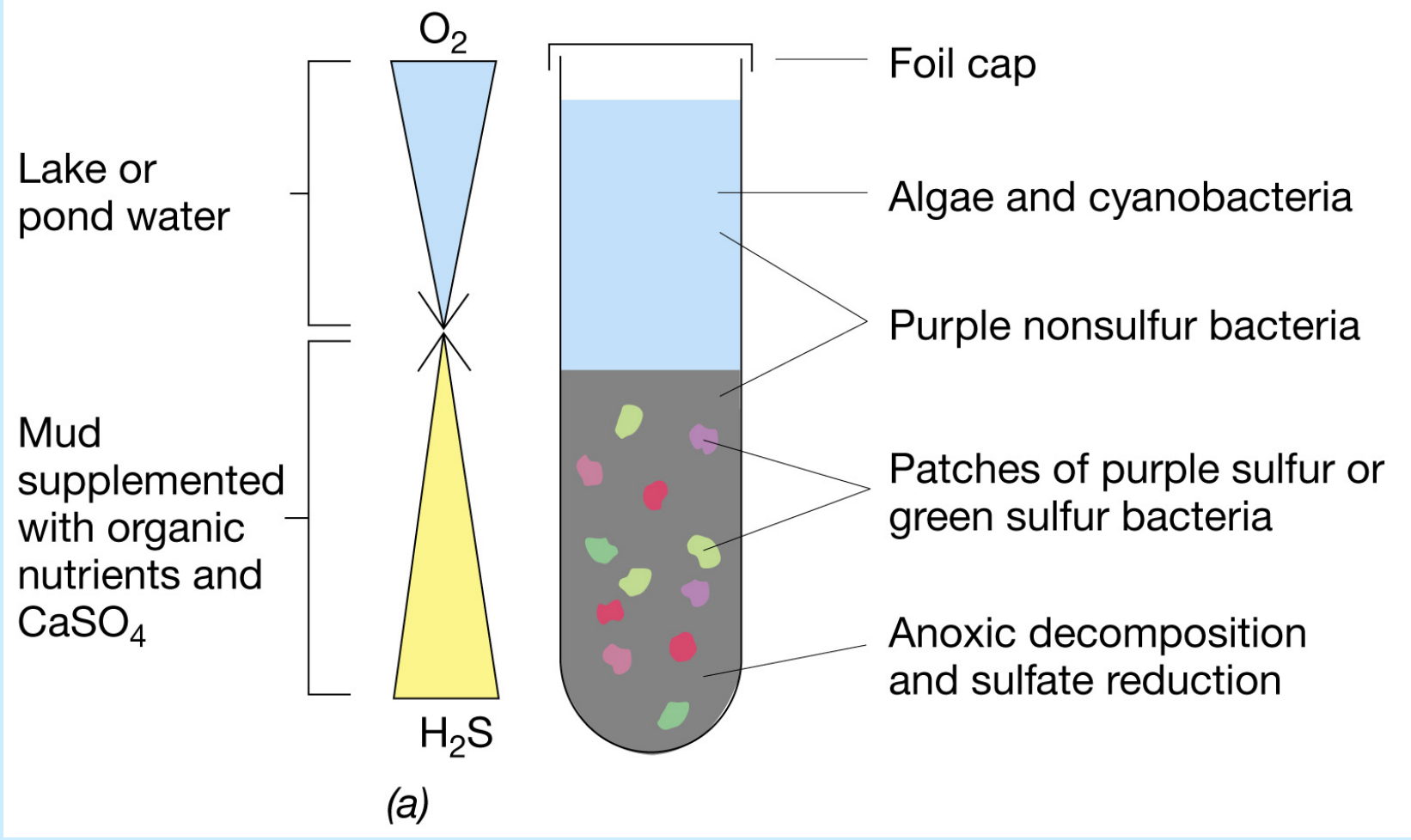
Microorganisms on surfaces. (a) Bacterial microcolonies developing on a microscope slide immersed in a small river. The bright particles are mineral matter. The short, rod-shaped cells are about 3 µm long. (b) Fluorescence photomicrograph of a natural microbial community colonizing plant roots in soil. Note microcolony development. The preparation has been stained with acridine orange.



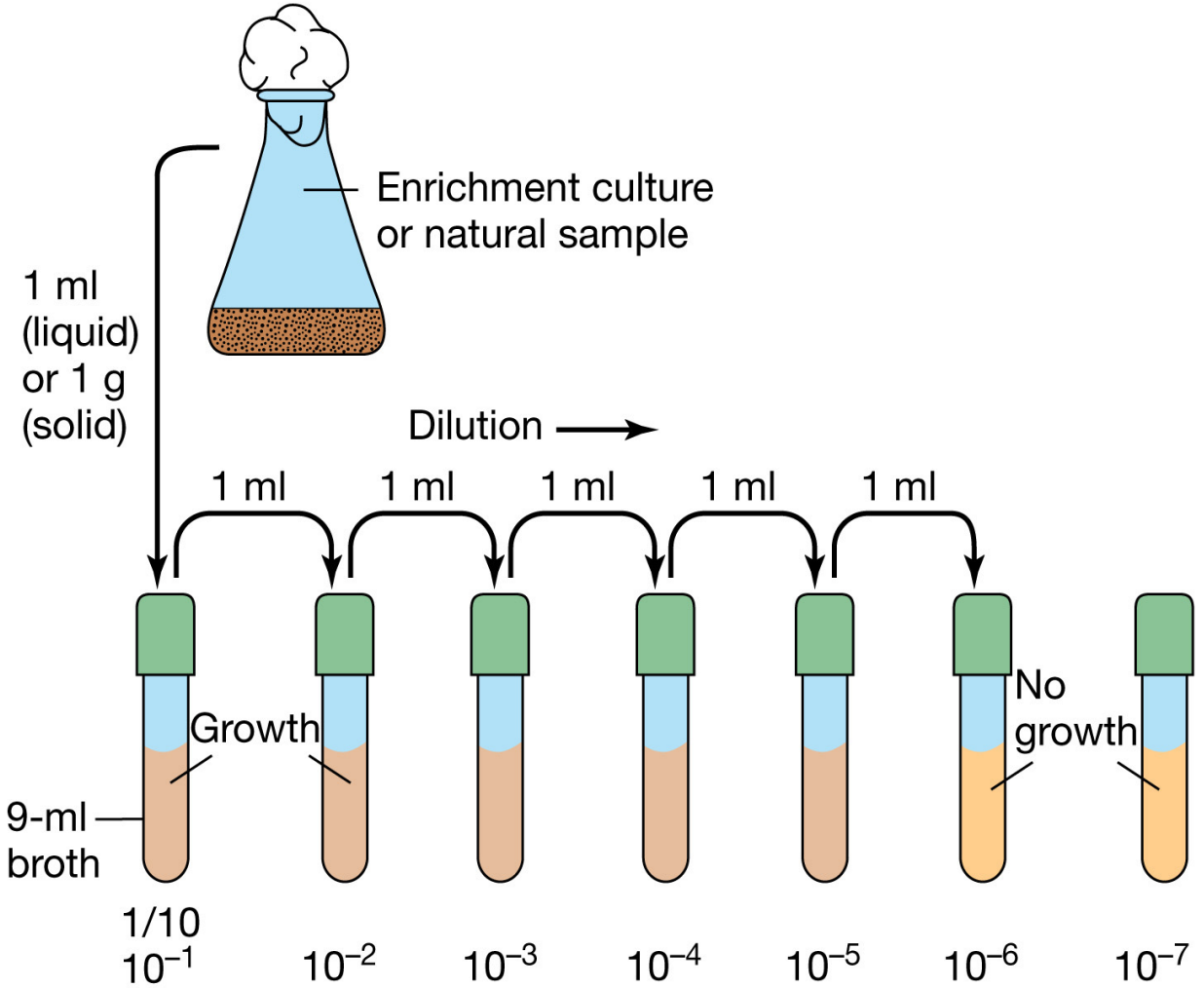
Formation of a bacterial biofilm. The biofilm begins with attachment of a few cells, after which growth and intercellular communication occurs. Polysaccharide formation occurs and becomes more extensive as the biofilm grows.



The isolation of Azotobacter. Selection for aerobic N2-fixing bacteria usually results in Azotobacter or its relatives. By contrast, enrichment with fixed forms of nitrogen such as NH4+ rarely results in N2 -fixing bacteria.

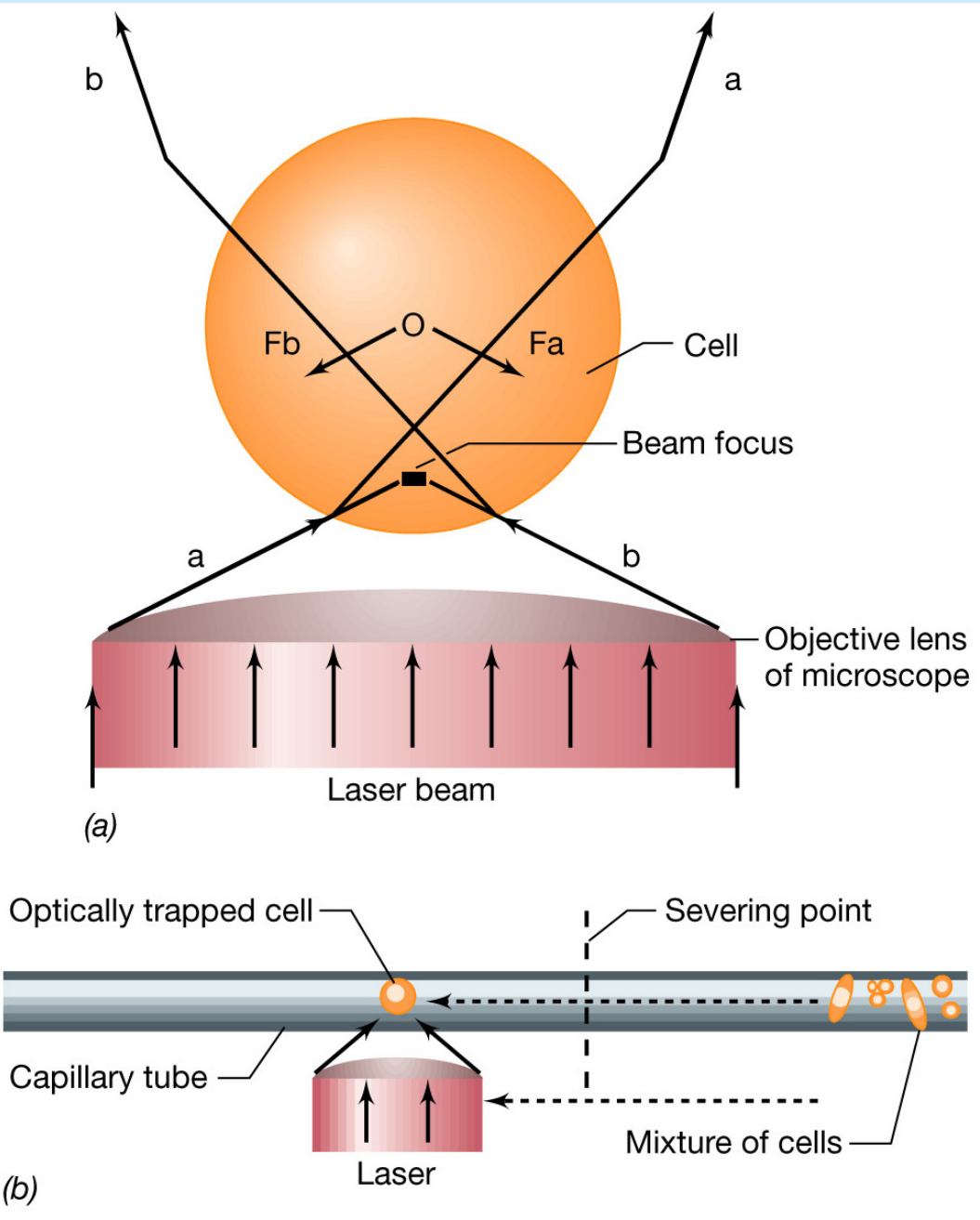


The Winogradsky column. (a) Schematic view of a typical column. The column is placed to receive subdued sunlight. Chemoorganotrophic bacteria grow throughout the column, aerobes and microaerophiles in the upper regions, anaerobes in the zones containing H2S. Anoxic decomposition leading to sulfate reduction creates the gradient of H2S. Green and purple sulfur bacteria stratify according to their tolerance for H2S.

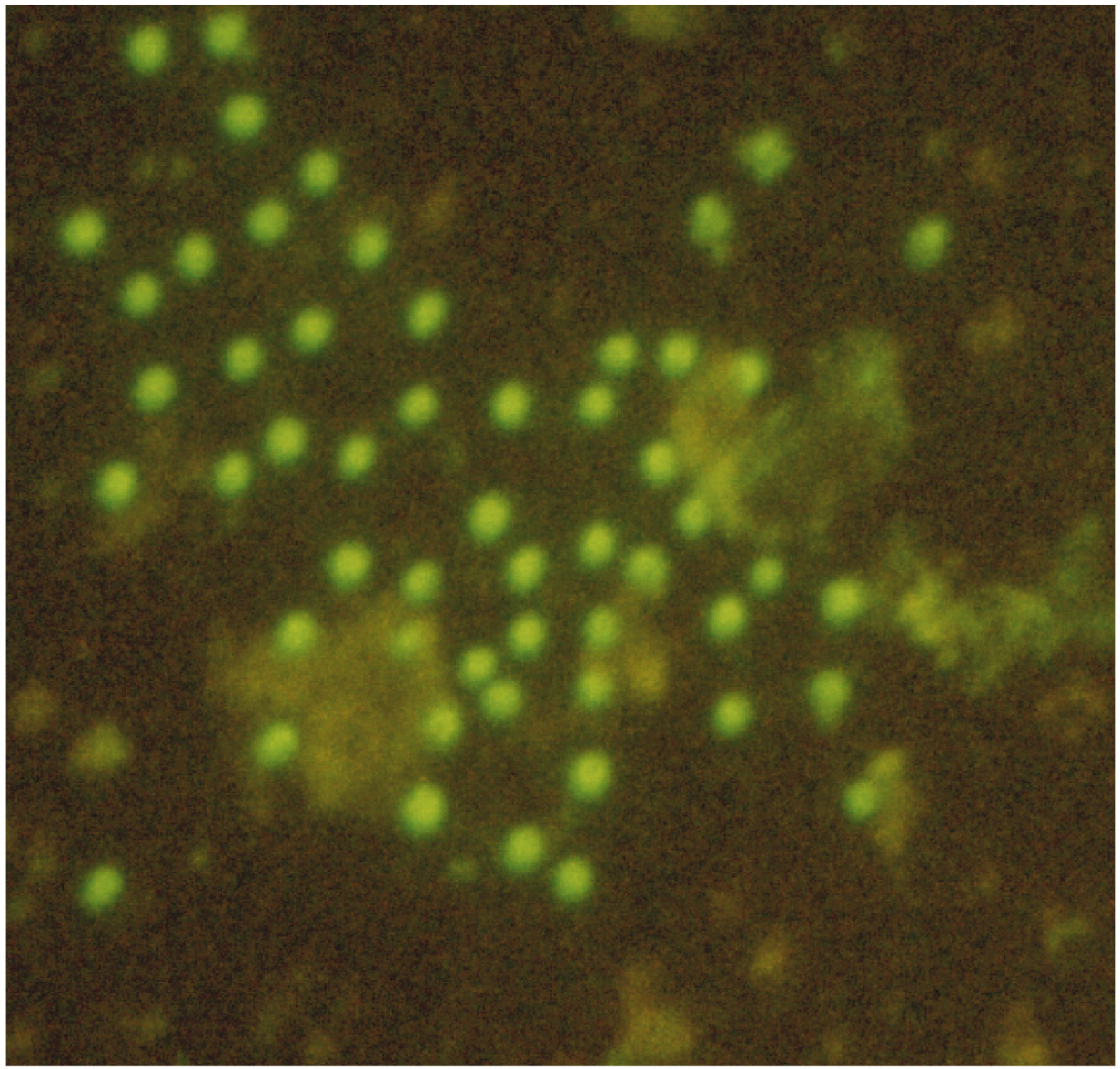


Procedure for an "extincting dilution" enrichment or a most-probable number (MPN) analysis. An existing enrichment culture or a natural sample of water, soil, etc., is added to a selective culture medium, and serial dilutions are made from them. The last tube showing growth (in the example shown it is the 10-5 dilution) should have developed from 10 or fewer cells.

As a means of obtaining pure cultures, the highest dilution showing growth is used as inoculum, and the procedure is repeated. As a means of estimating the numbers of a particular type of bacteria in a sample, the MPN is defined as the highest dilution showing growth. If the medium used in this case were highly selective for sulfate-reducing bacteria, for example, one could conclude that 105-106 recoverable cells of such organisms were present per gram of sample. Use of several replicate tubes at each dilution improves accuracy of the final MPN obtained.

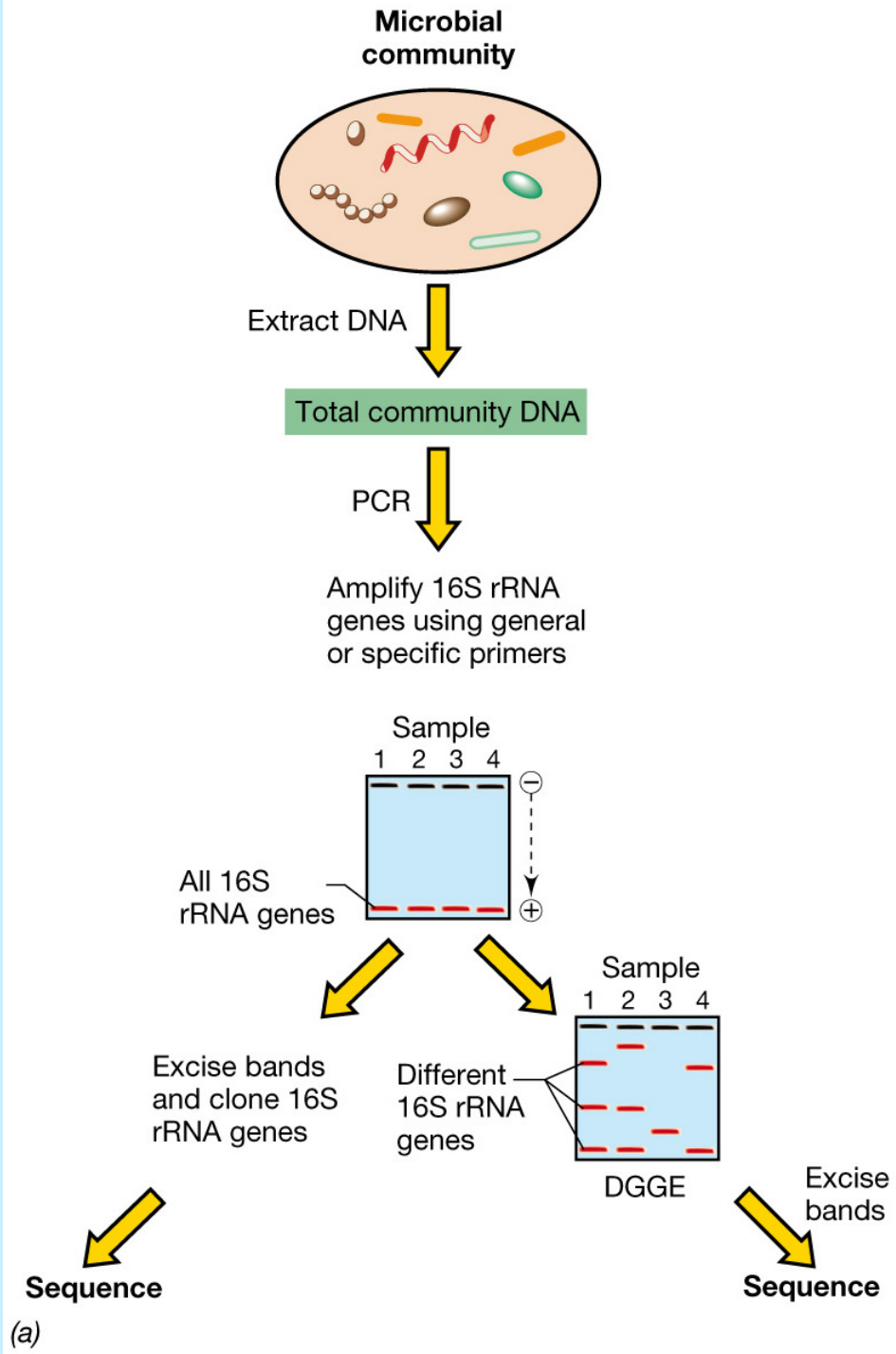


The laser tweezers for the isolation of bacteria. (a) Principle of the optical tweezers. A strongly focused laser beam on an object as small as a bacterial cell creates downward radiation forces Fa, Fb on the cell that allows the cell to be dragged in any direction as long as the beam force remains on it. (b) Isolation. The laser beam can lock onto a single cell present in a mixture in a capillary tube and drag the optically trapped cell (in the example here, the desired cell is dragged from right to left) away from the other cells. Once the desired cell is far enough away from the other cells, the capillary is severed, the laser turned off, and the cell flushed into a tube of sterile medium.

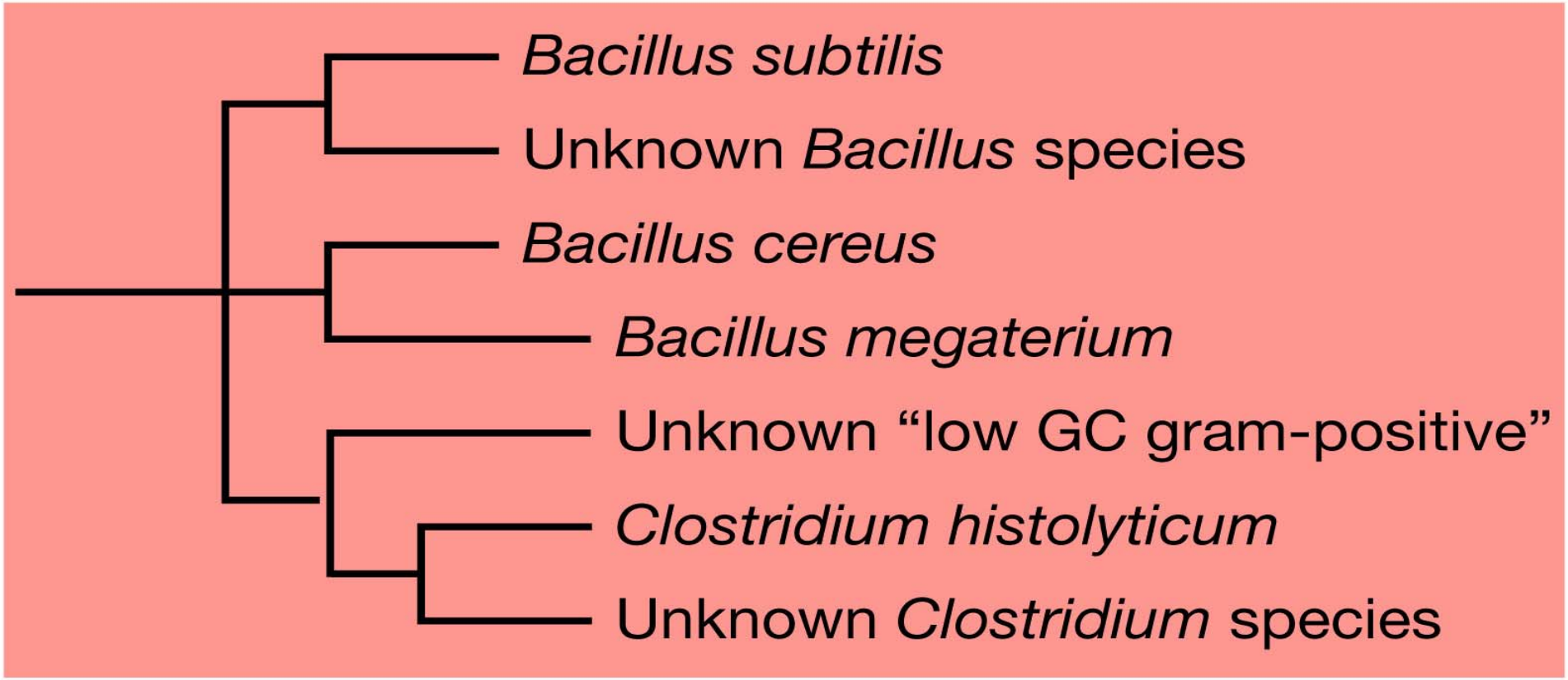


T. D. Brock

Fluorescent antibodies as a cell tag. Visualization of bacterial microcolonies (bacterial cells appear as greenish-yellow dots) of the hyperthermophilic archaeon, Sulfolobus acidocaldarius on the surface of solfatara soil particles by use of the fluorescent antibody technique. Cells are about 1 µm in diameter.

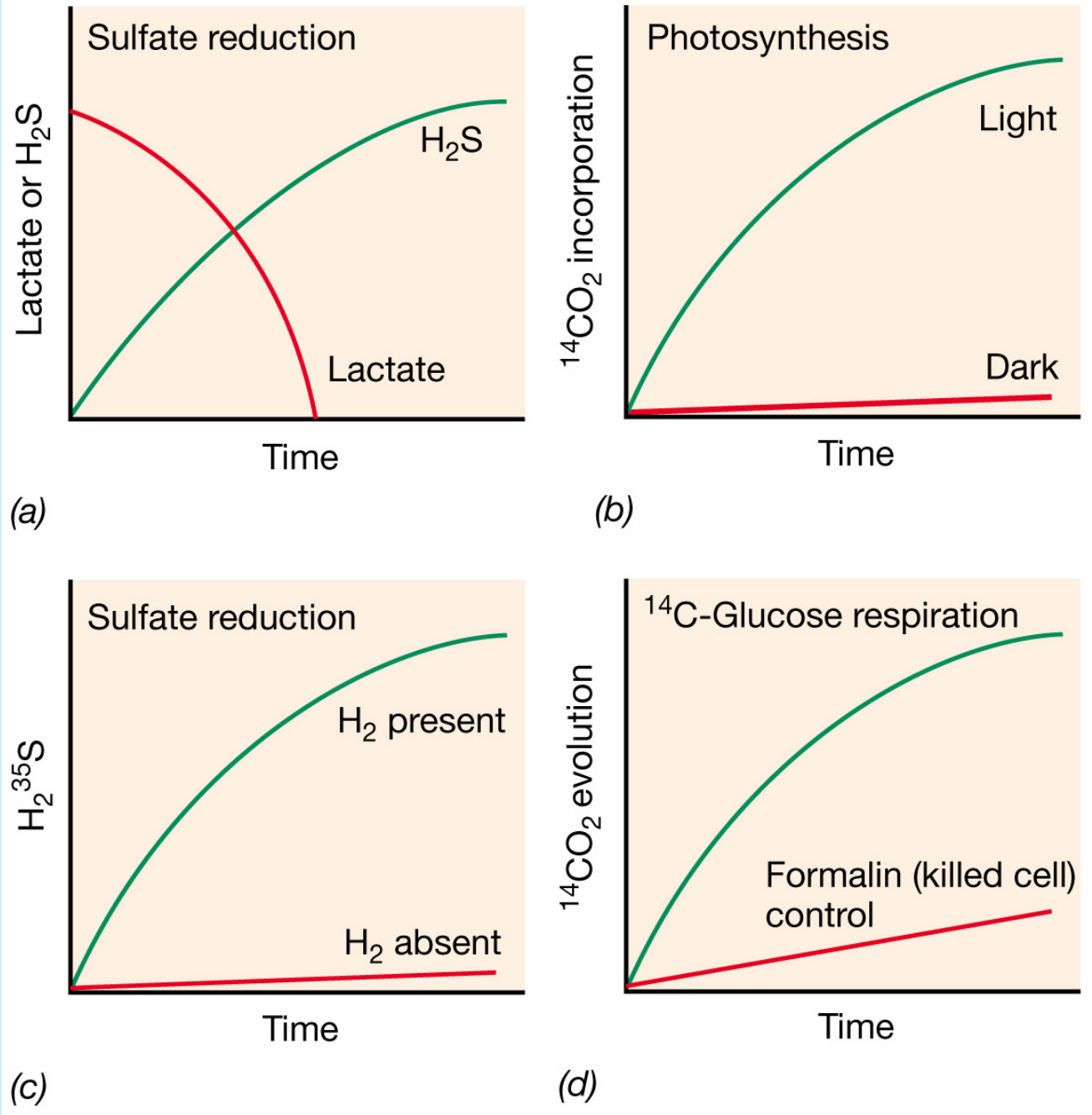


Steps in biodiversity analysis of a microbial community using phylogenetic probes. (a) Total community DNA is used with PCR to amplify 16S rRNA genes using universally conserved primers for Bacteria or primers that will target only a particular phylum of Bacteria. The PCR bands are excised and the different 16S genes separated by either cloning or by DGGE (see Figure 18.15). Note how in the DGGE gel, samples 1, 2, and 4 share a common band (gene), whereas samples 2 and 3 each contain one unique band. Following sequencing, a phylogenetic tree is generated.

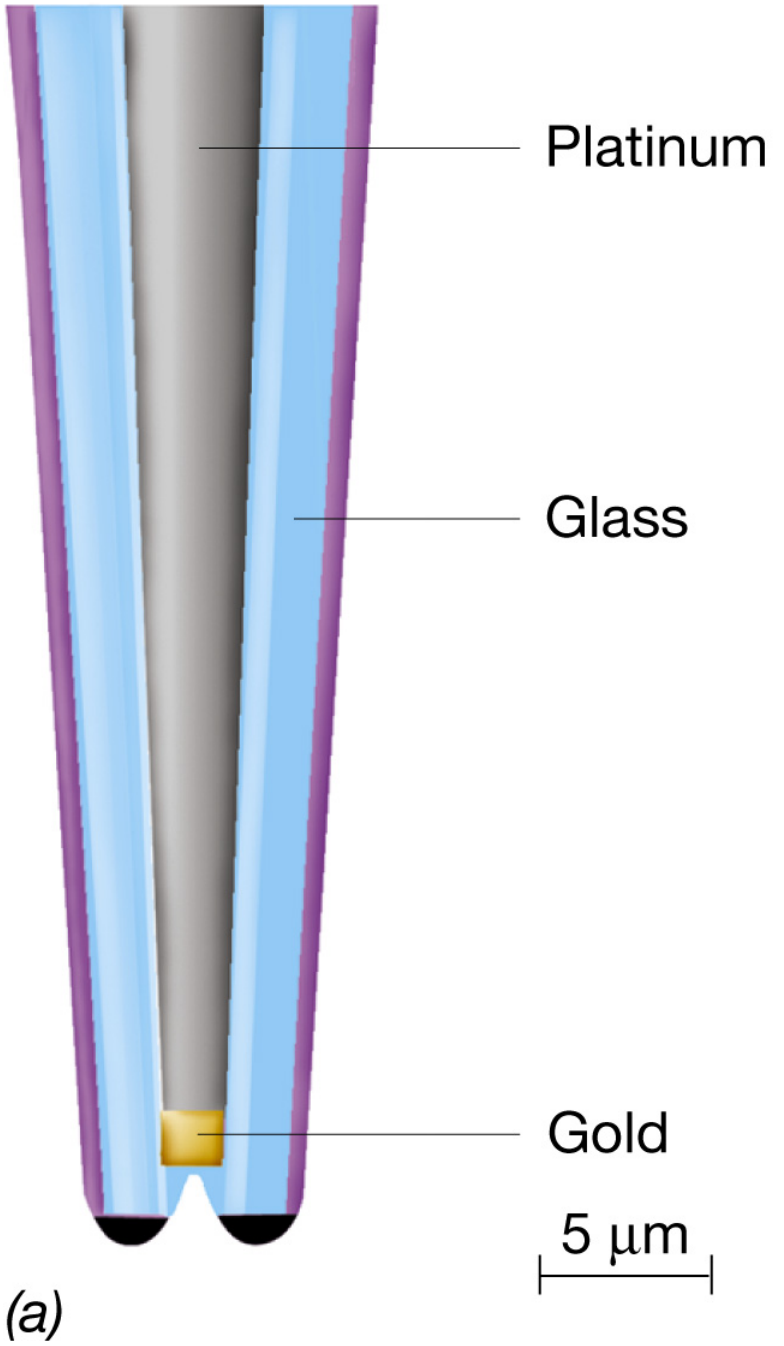


(b)

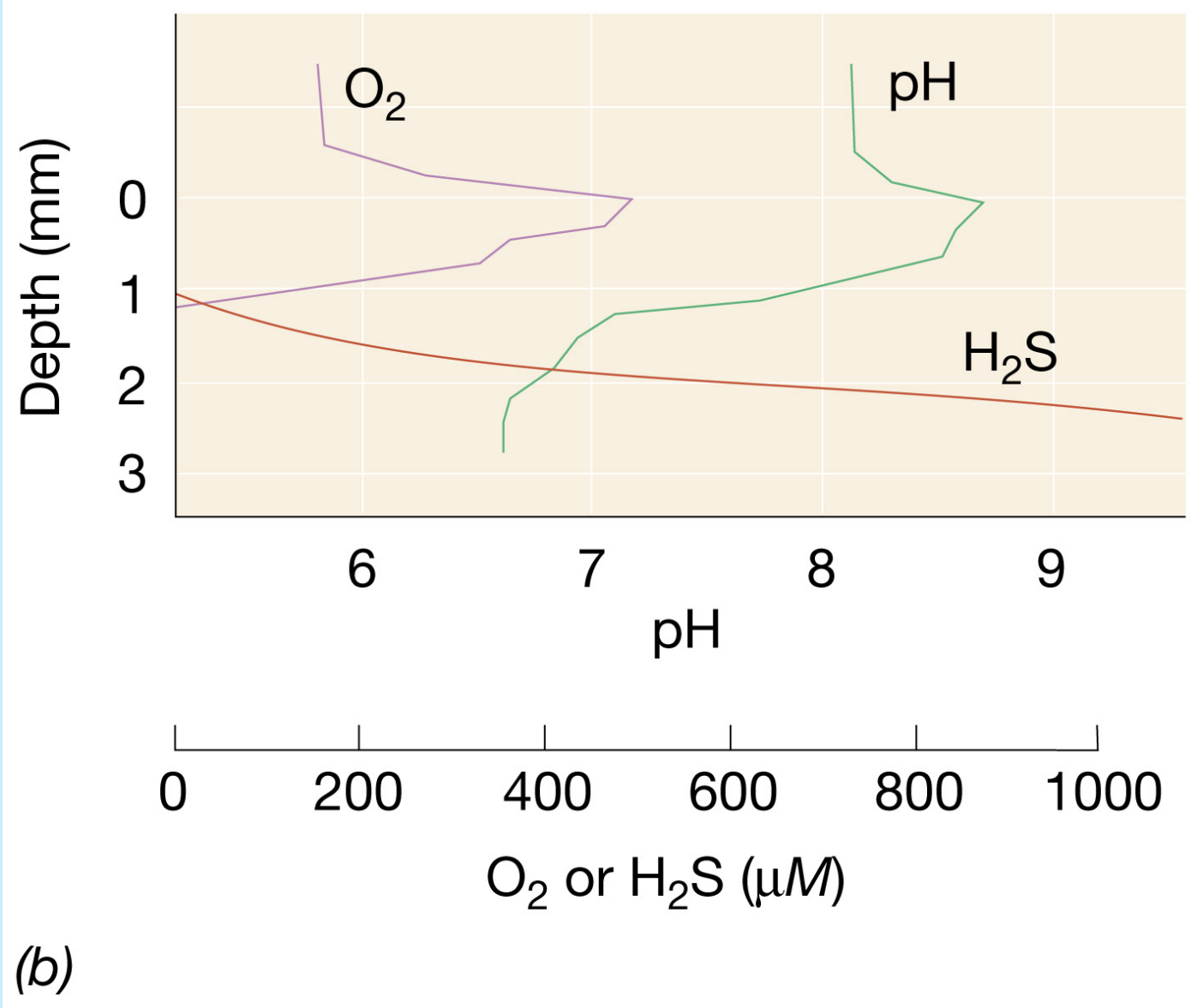
Steps in biodiversity analysis of a microbial community using phylogenetic probes. (b) Example of a phylogenetic tree that might be generated if primers used were specific for the "low GC gram-positive" lineage of the phylogenetic domain Bacteria, which includes species of Bacillus and Clostridium (Section 12.21). Note that many of the sequences do not match the 16S rRNA sequence of any recognized species and therefore are "new" species that await isolation.



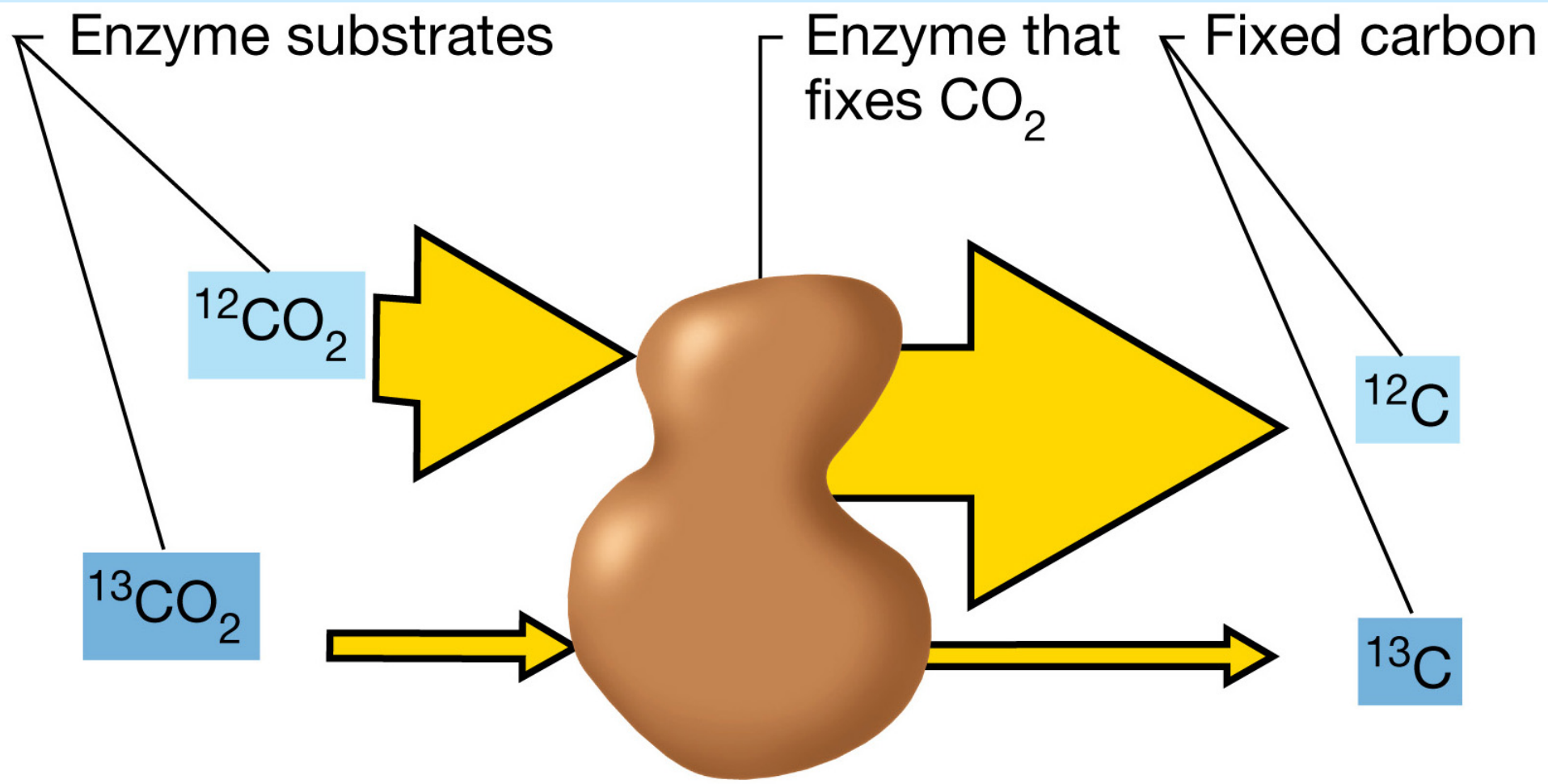
Microbial activity measurements. (a) Chemical assay for lactate and H2S during sulfate reduction. (b–d) Use of radioisotopes. (b) Photosynthesis measured in natural seawater with 14CO2. (c) Sulfate reduction in mud measured with 35SO42- . (d) Production of 14CO2 from 14C-glucose.



Microelectrodes. (a) Schematic drawing of an oxygen microelectrode. Note the scale of the electrode.



Microbial mats and the use of microelectrodes to study them. (b) Oxygen, sulfide, and pH microprofiles in a hot spring microbial mat. Note the millimeter scale on the ordinate.



Mechanism of isotopic fractionation using carbon as an example. Although the ratio of natural abundance of 12CO2 to 13CO2 is about 19:1, enzymes that fix CO2 preferentially fix the lighter isotope 12C2. This results in fixed carbon being enriched in 12C and depleted in 13C relative to the starting substrate. The degree of 13C depletion is calculated as an isotopic fractionation (see legend to Figure 18.20 for calculation). The size of the arrows indicates the relative abundance of each isotope of carbon.

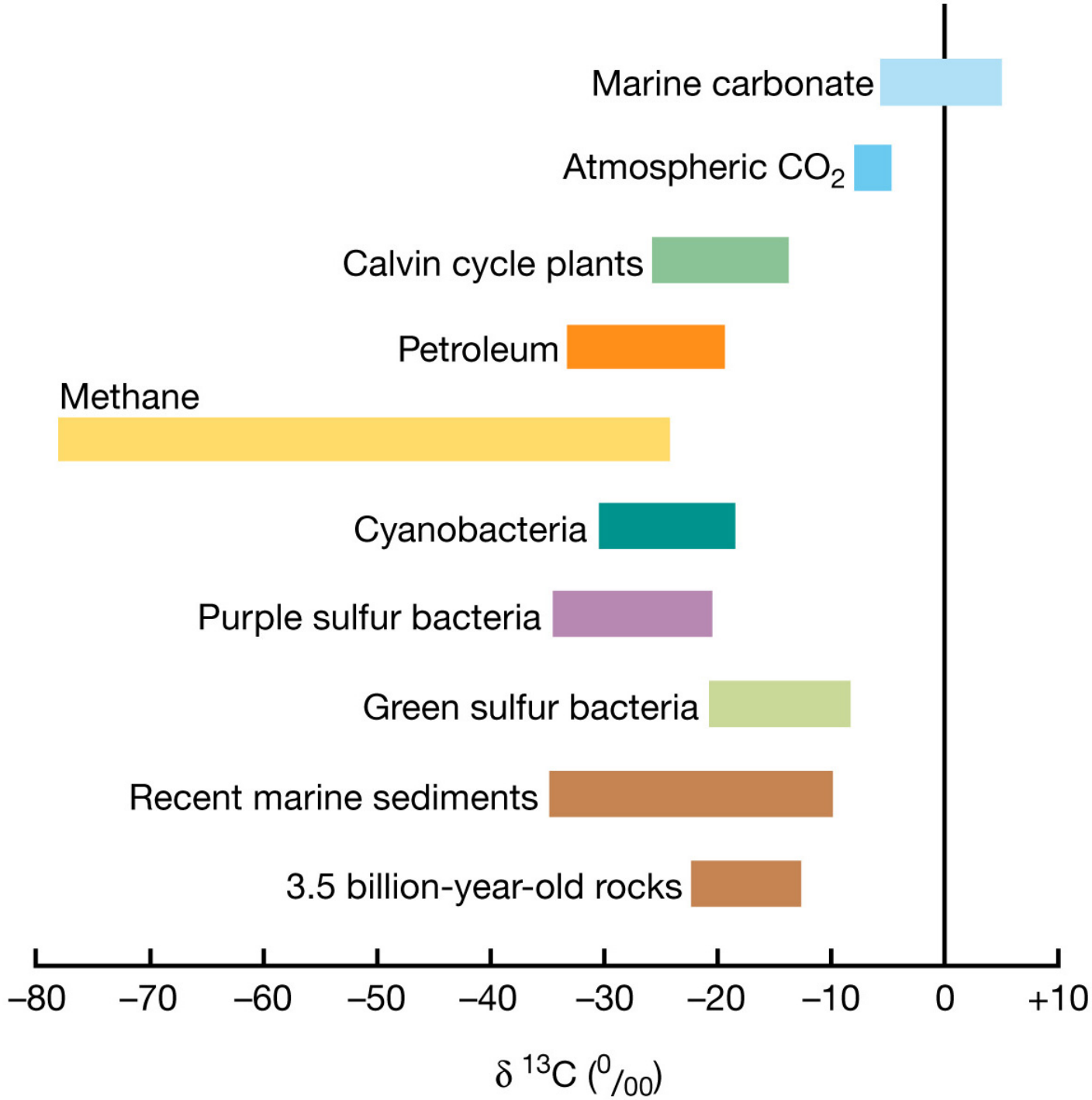
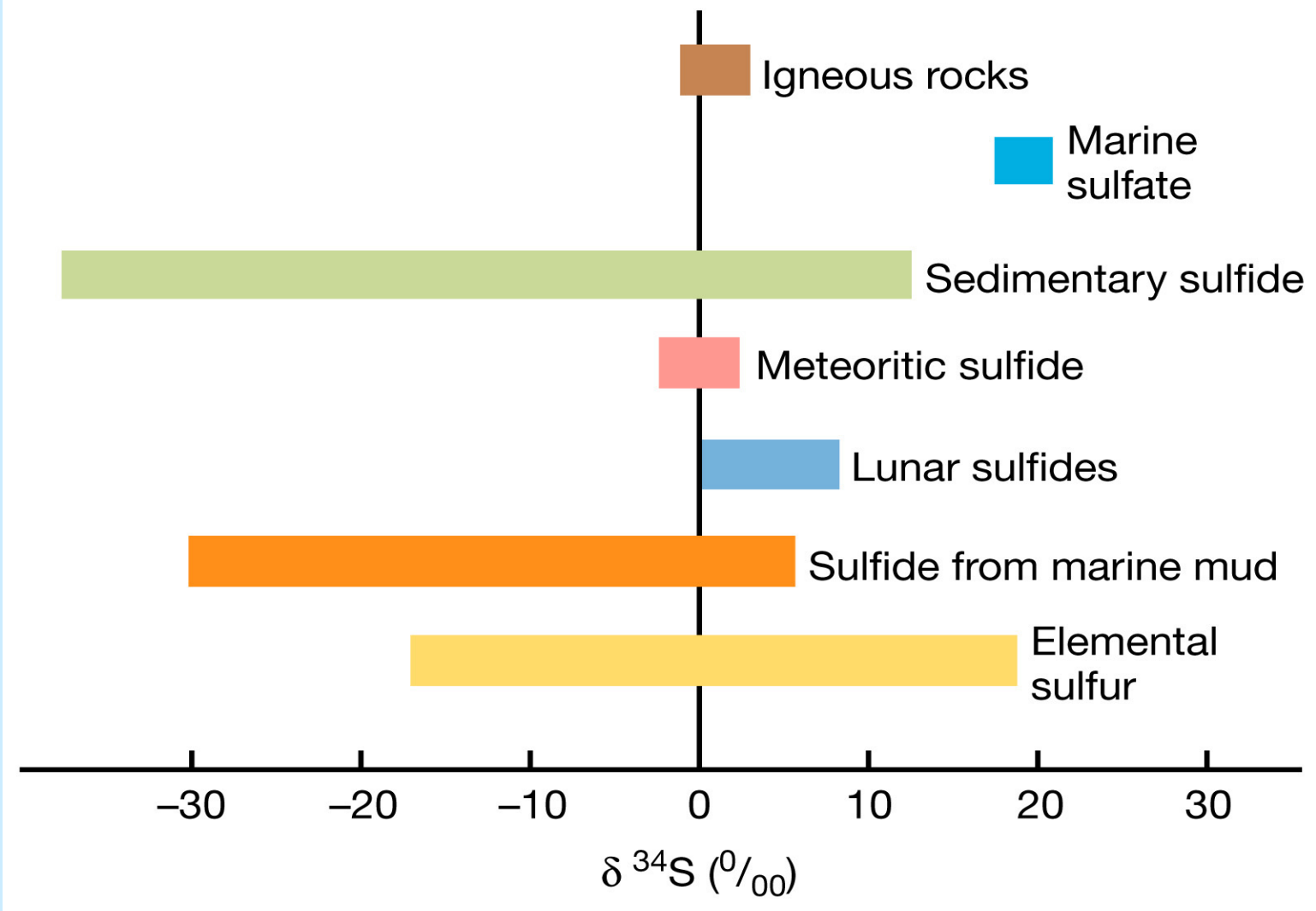


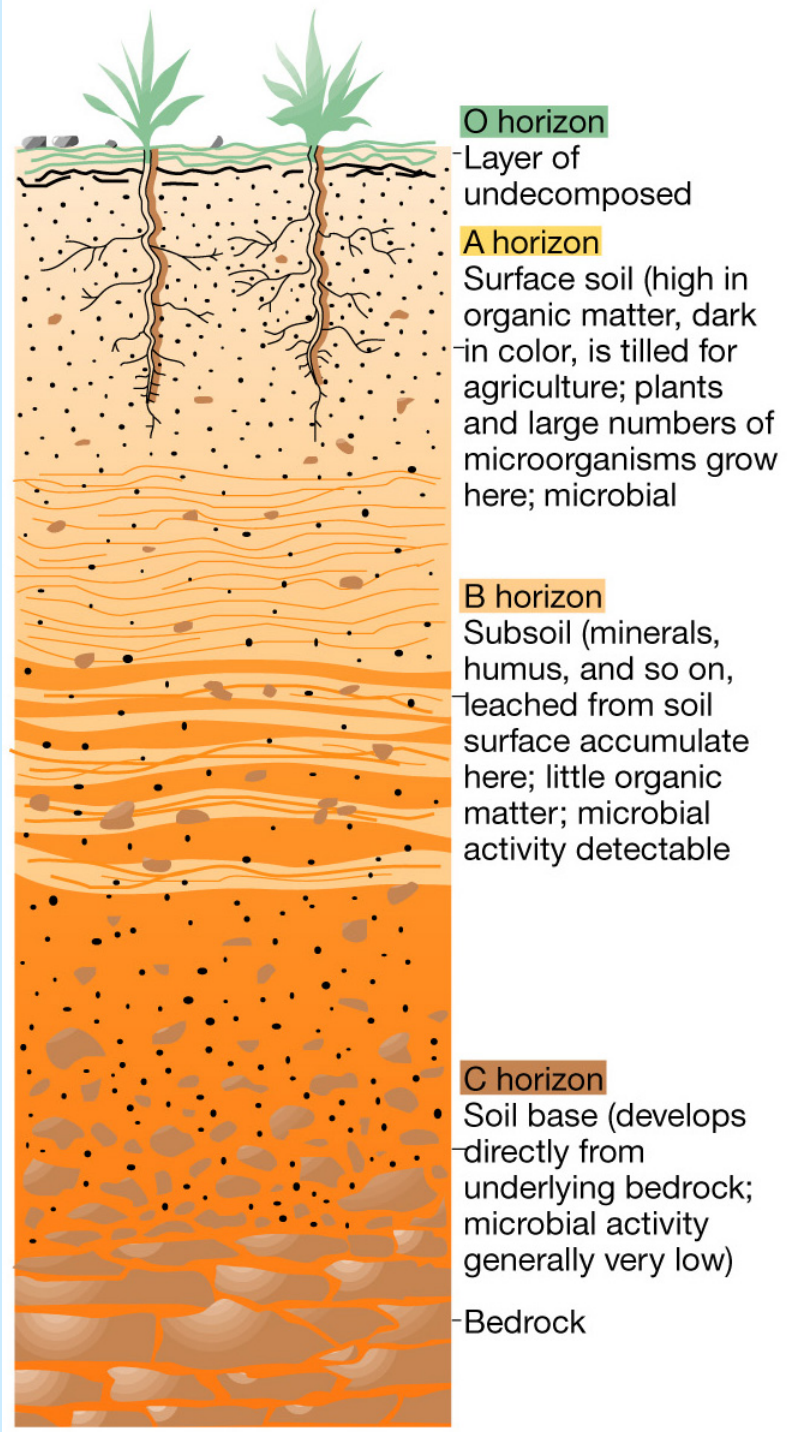
Figure 18.20 Carbon isotopic compositions of various substances. The values are given in parts per thousand (o/oo) and were calculated using the formula (13C/12C sample)-(13C/12C standard) (over) (13C/12C standard) = 1000

The standard is a belemnite sample from the PeeDee rock formation. Note that carbon fixed by autotrophic organisms is enriched in 12C.

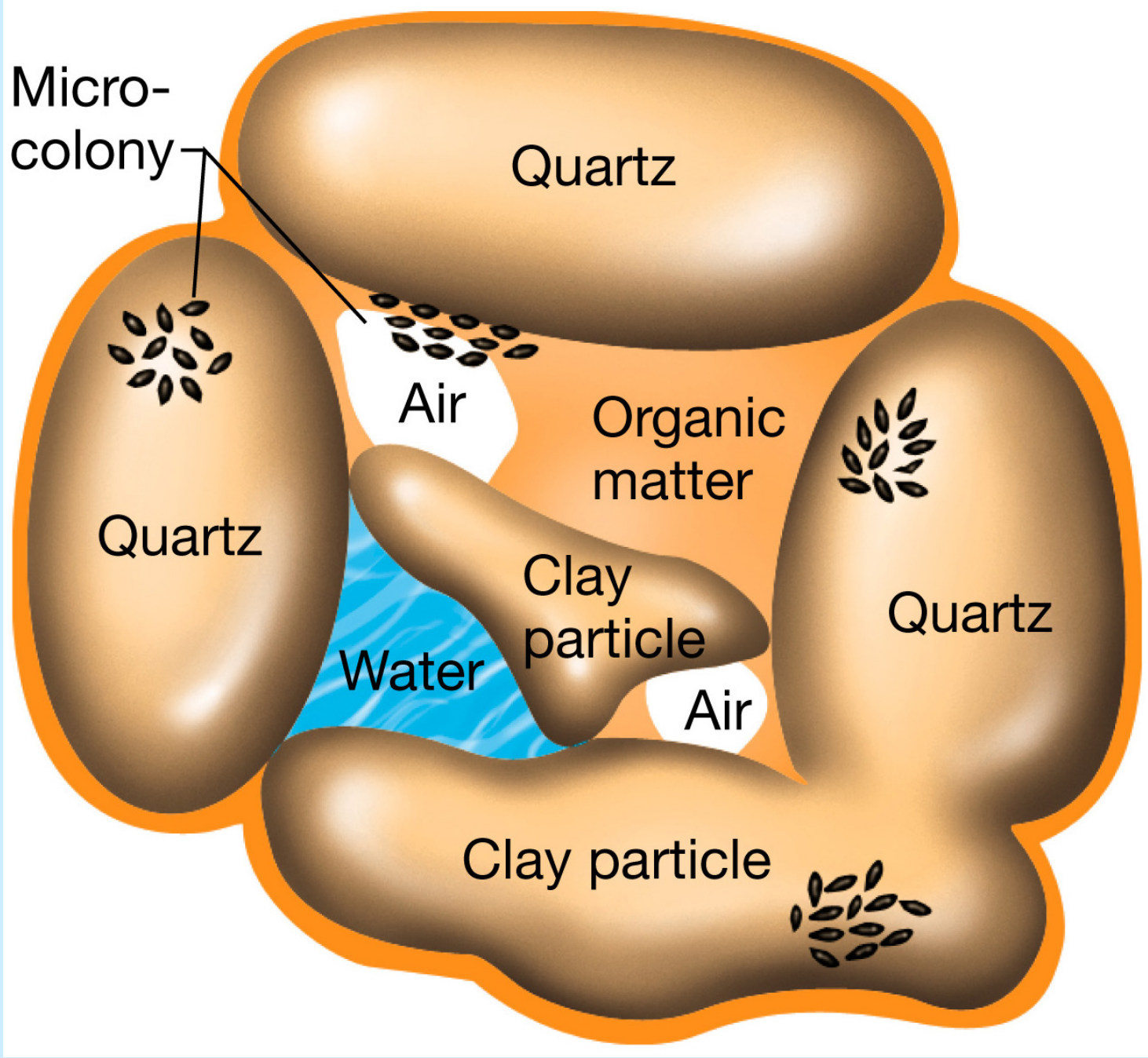


Summary of the isotope geochemistry of sulfur, indicating the range of values for 34S and 32S in various sulfur-containing substances. The values are given in parts per thousand (o/oo and were calculated using the formula (34S/32S sample)-(34S/32S standard) (over) (34S/32S standard) = 100 The standard is an iron sulfide mineral from the Canyon Diablo meteorite. Note that sulfide and sulfur of biogenic origin tend to be depleted in 34S (enriched in 32S).

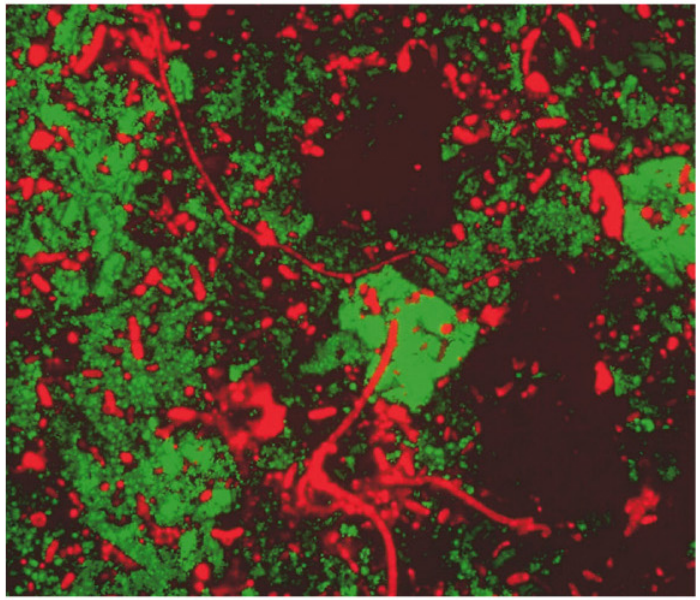
Microorganismos en la naturaleza y ciclos biogeoquímicos



Profile of a mature soil. The soil horizons are soil zones as defined by soil scientists.



A soil aggregate composed of mineral and organic components, showing the localization of soil microorganisms. Very few microorganisms are found free in the soil solution; most of them occur as microcolonies attached to the soil particles.



Todd O. Stevens

(a)

Methanogenesis: $4\ H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O$

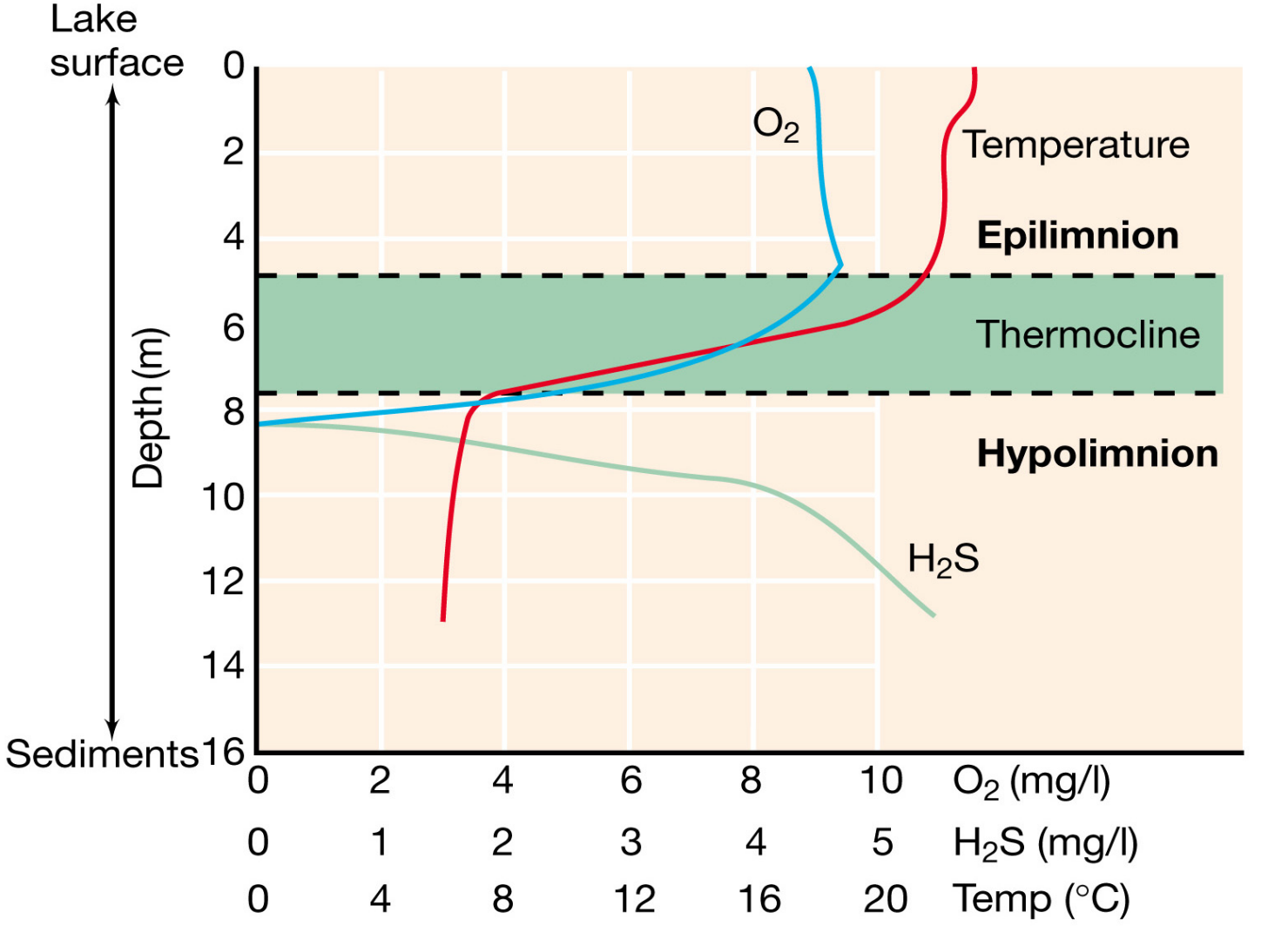
Acetogenesis: $4\ H_2 + 2\ HCO_3^- + H^+ \rightarrow CH_3COO^- + 4\ H_2O$

Sulfate reduction: $4\ H_2 + SO_4^{2-} + H^+ \rightarrow HS^- + 4\ H_2O$

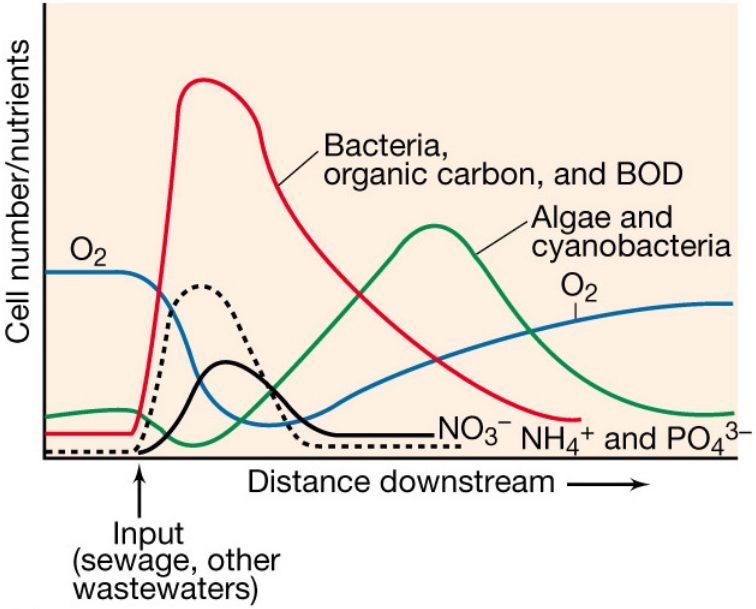
Proposed inorganic H_2 production: $FeO + H_2O \rightarrow H_2 + FeO_2$

(b)

(a) Laser confocal photomicrograph of a microbial biofilm attached to the surface of basalt chips. Green is reflected light from the basalt surface while the red color is from Nile-red stained bacterial cells. The cells in the biofilm were grown on from basalt as depicted in the bottom reaction of Fig. 1b. (b) Key metabolic reactions of anaerobic prokaryotes growing in anoxic deep basalt aquifers.



Development of anoxic conditions in the depths of a temperate climate lake as a result of summer stratification. The colder bottom waters are more dense and contain H2S from bacterial sulfate reduction. The zone of rapid temperature change is referred to as the thermocline. Typically, as surface waters cool in the fall and early winter they reach the temperature and density of hypolimnetic waters and sink, displacing bottom waters and effecting “lake turnover.”



(a)

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(b)

Effect of input of sewage or other organic-rich waste-waters into aquatic systems. (a) In a river, an increase in heterotrophic bacterial numbers and a decrease in O2 levels occur immediately upon a spike of organic matter. If is present in the input, for example, from sewage, is oxidized to by nitrifying bacteria (Sections 12.3, 17.12, and 19.12). Note how the rise in NH4+ is followed shortly by the rise in NO3-, as the two-stage process of nitrification proceeds. The rise in numbers of algae and cyanobacteria is primarily a response to inorganic nutrients, especially PO43- Oxygen levels return to their pre-input levels once most of the oxidizable organic and inorganic compounds are depleted.

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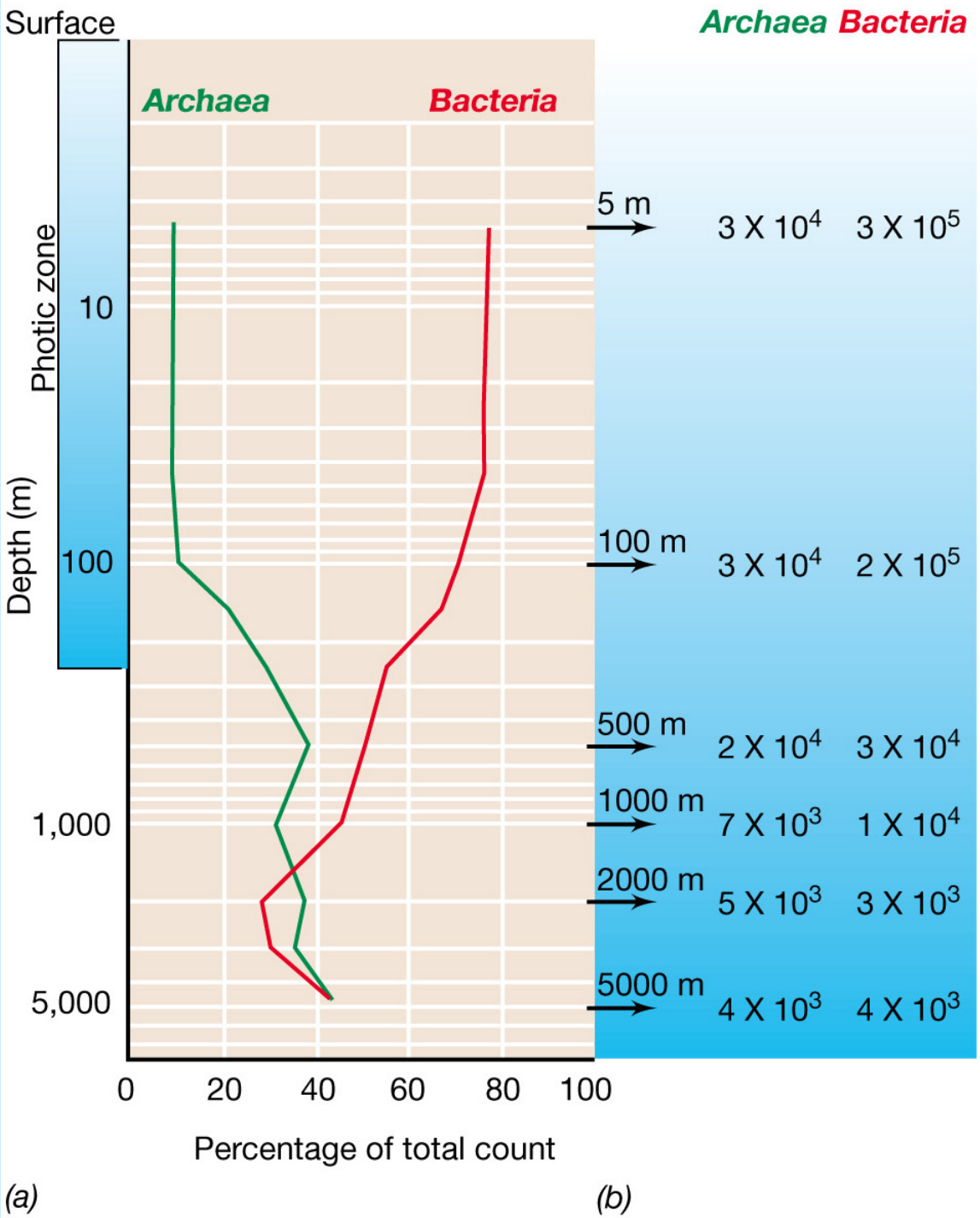
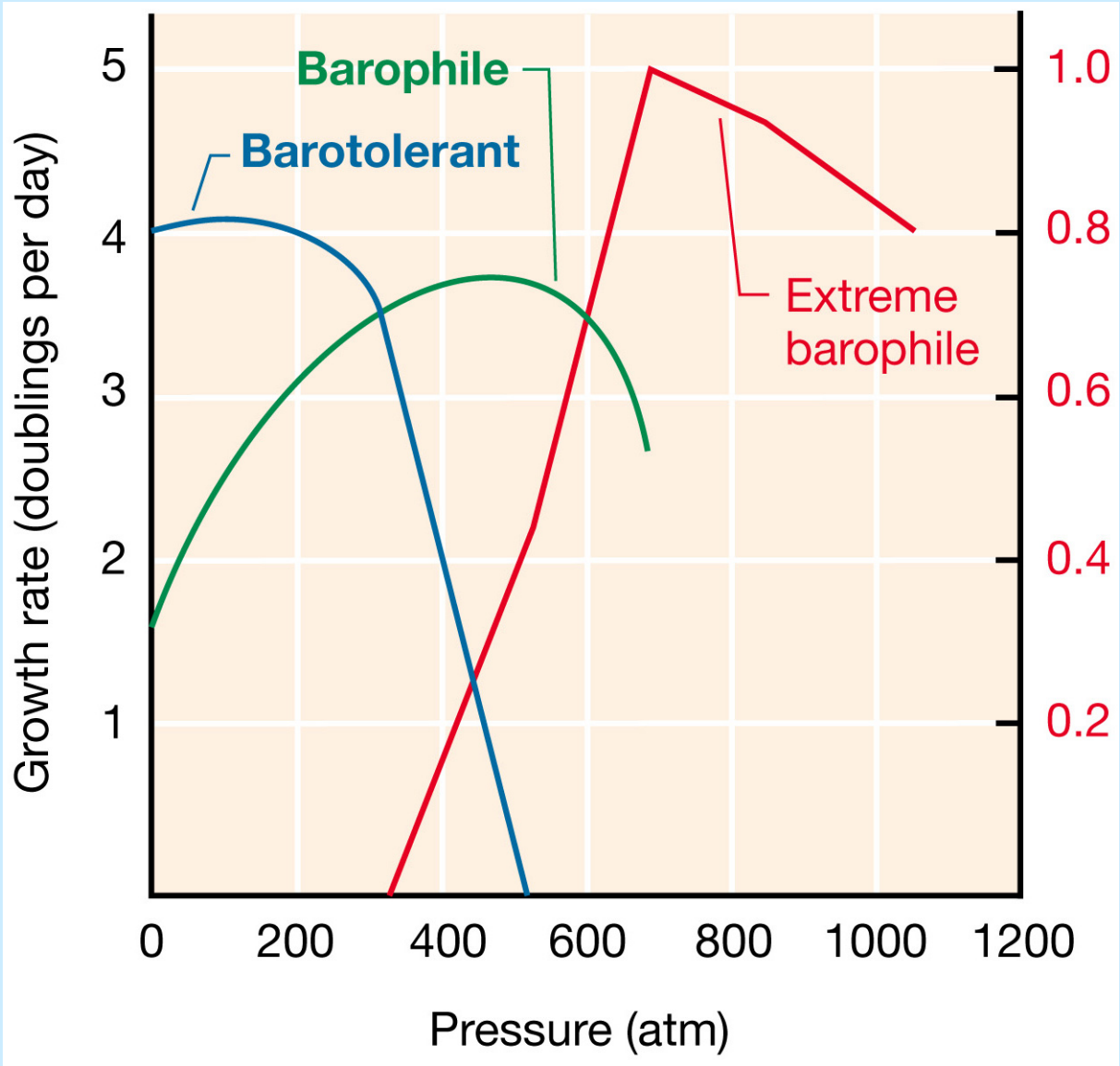
(b)

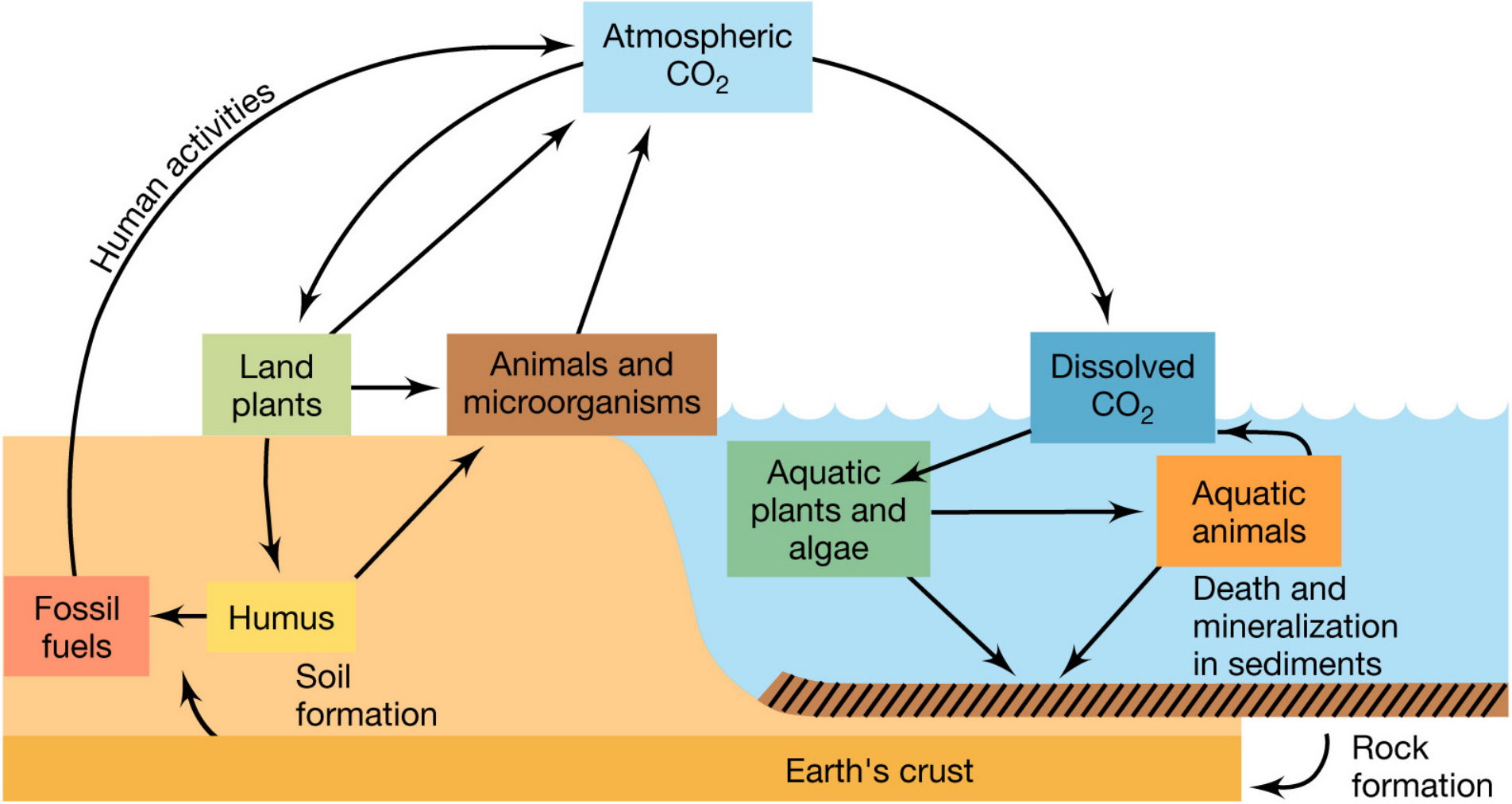
Effect of input of sewage or other organic-rich wastewaters into aquatic systems. (b) A eutrophic (nutrient-rich) lake, Lake Mendota, Madison, Wisconsin, showing algae, cyanobacteria, and macrophytes (aquatic weeds) that develop in response to pollution by inorganic nutrients, much of which results from agricultural runoff into the lake watershed. Dead plant and algal material contains a very large BOD, such that although these phototrophs contribute oxygen by photosynthesis, their degradation results in large-scale O2 depletion.



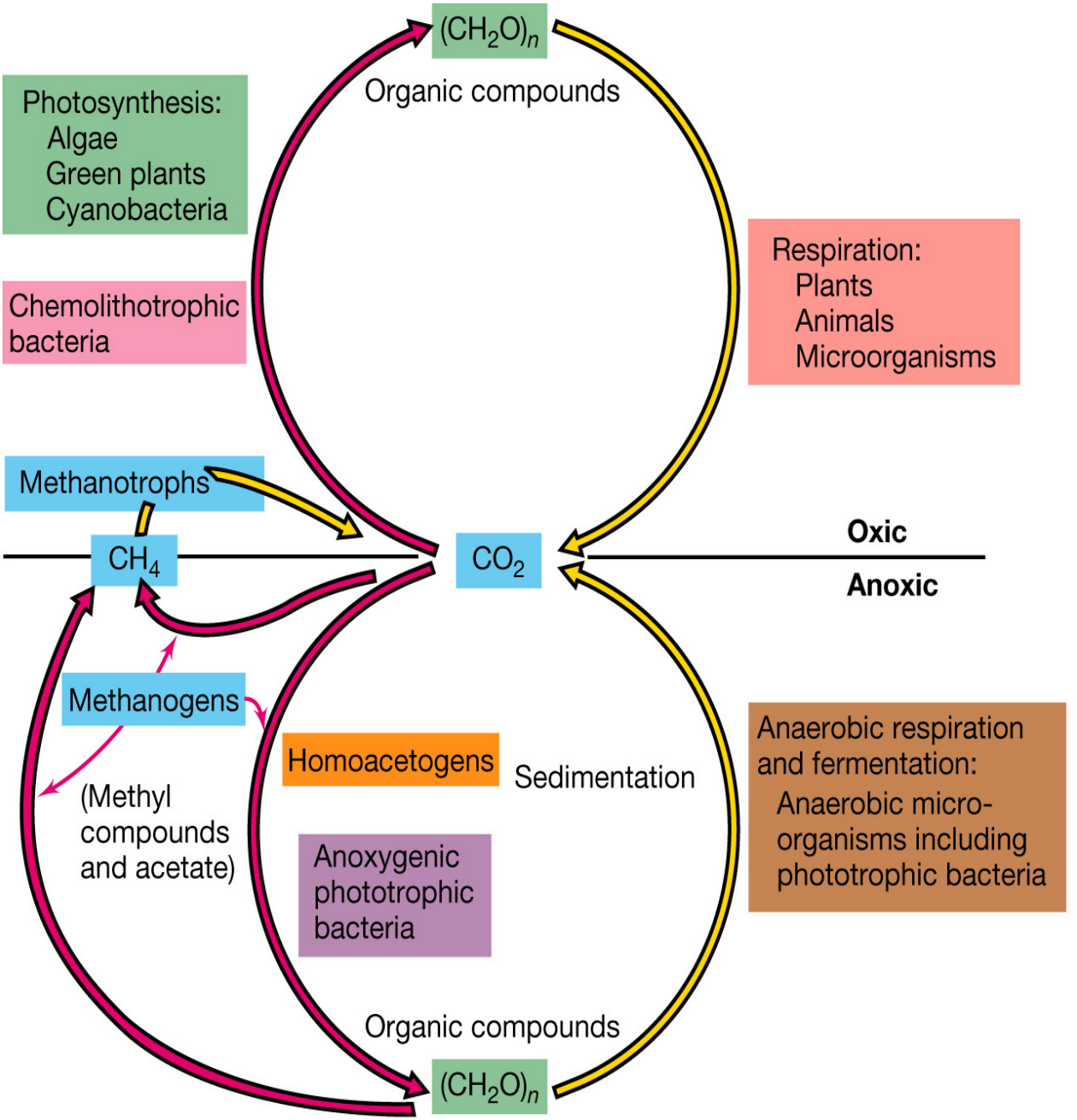
Percentage of total prokaryotes belonging to either the Archaea or the Bacteria in North Pacific ocean water. (a) Distribution of Archaeaand Bacteria with depth. (b) Absolute numbers of Archaea and Bacteria with depth (per milliliter). Adapted from Nature 409:507–510 (2000).



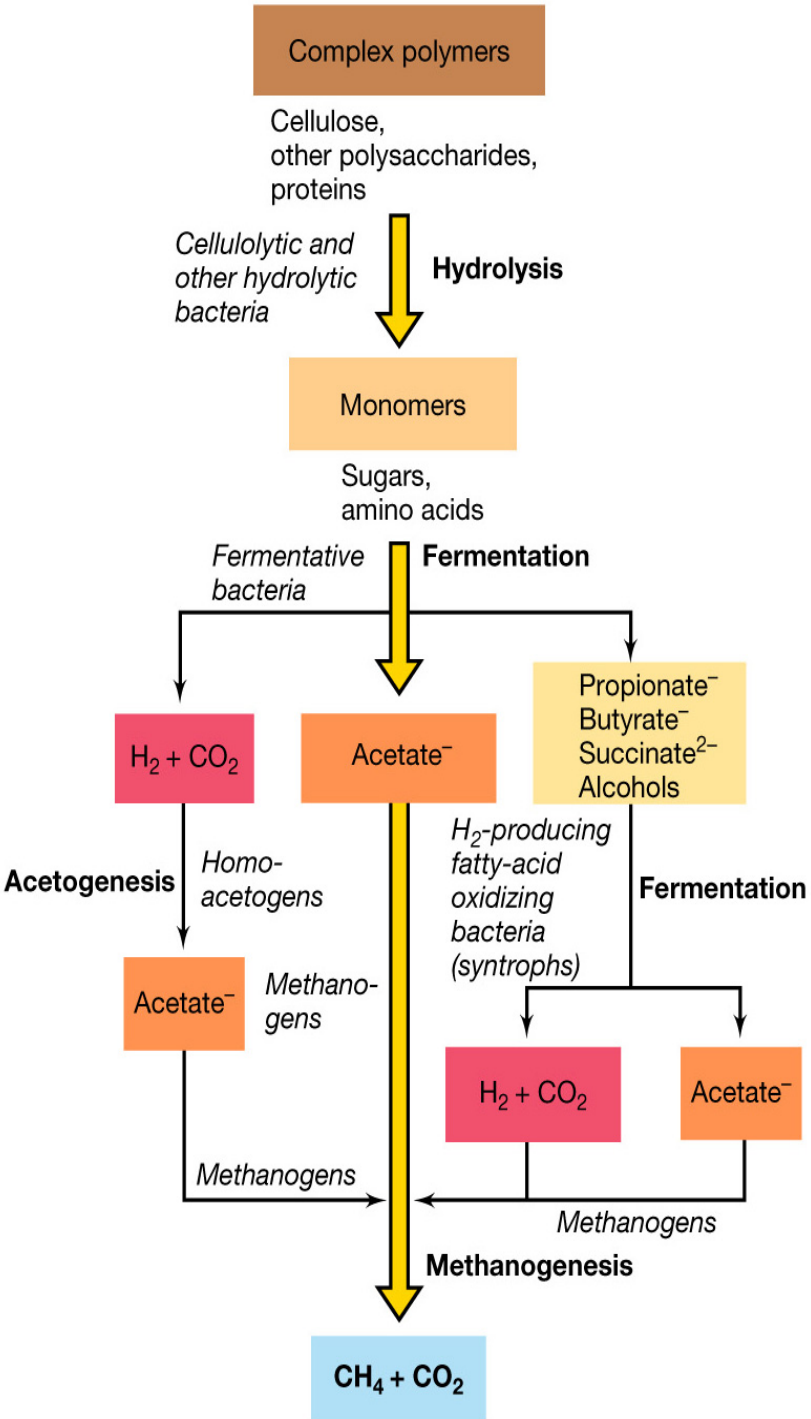
Growth of barotolerant, barophilic, and extremely barophilic bacteria. The extreme barophile was isolated from the Mariana Trench (see Figure 19.15). Note the much slower growth rate (at any pressure) of the extreme barophile (right ordinate) as compared to the barotolerant and barophilic bacteria (left ordinate). Note also the inability of the extreme barophile to grow at low pressures.



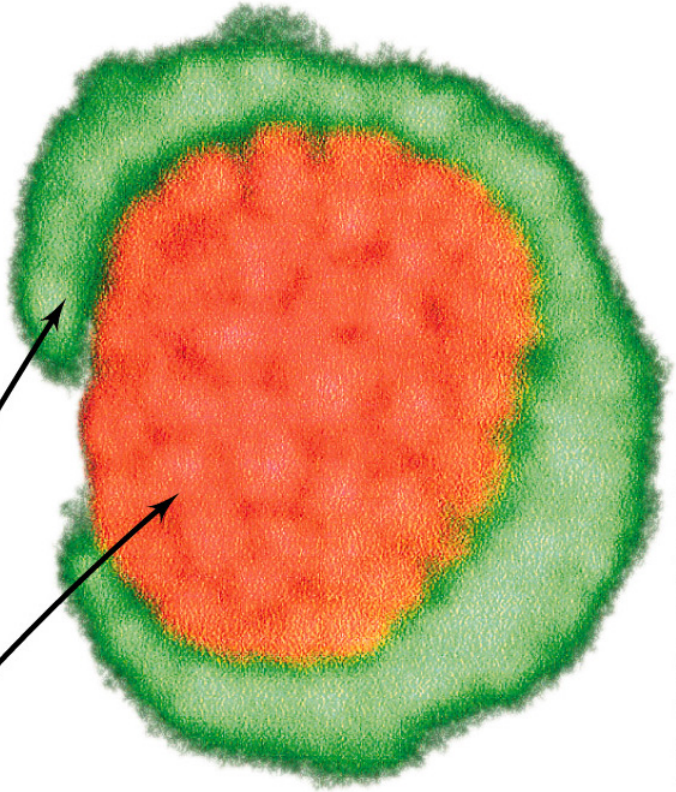
The carbon cycle. The carbon and oxygen cycles are closely connected, as oxygenic photosynthesis both removes CO2 and produces O2 while respiratory processes both produce CO2 and remove O2 (see also Section 19.5). Carbon cycling in the deep subsurface may be as significant as carbon cycling on the Earth's surface (see the box, Microbial Life Deep Underground), but no reliable estimates of this are available.



Redox cycle for carbon; note in particular the contrasts between autotrophic (CO2 organic compounds) and heterotrophic processes. Yellow arrows indicate oxidations; red arrows indicate reductions. Photosynthesis in oxic habitats is mainly oxygenic, whereas in anoxic environments it is mainly anoxygenic from the activities of purple and green bacteria. Under anoxic conditions, besides homoacetogens and methanogens, certain sulfate-reducing and nitrate-reducing bacteria are also autotrophic. Methanogens make methane, whereas methanotrophs consume methane.



Overall process of anoxic decomposition, showing the manner in which various groups of fermentative anaerobes cooperate in the conversion of complex organic materials ultimately to methane 1CH42 and CO2. Acetate and H2 + CO2 from primary fermentations can be directly converted to methane, although H2 + CO2 can also be consumed by homoacetogens. But note how the syntrophs play a key role in anoxic decomposition by consuming highly reduced fermentation products in a secondary fermentation. By activities of the syntrophs, fatty acids and alcohols are converted to the substrates for methanogenesis and acetogenesis. This picture holds for environments in which sulfate-reducing bacteria play only a minor role, for example, in freshwater lake sediments, sewage sludge bioreactors, or the rumen. If alternative electron acceptors are abundant, as for example, sulfate in marine sediments, anaerobic respiration prevails, as syntrophs cannot compete for fatty acids/alcohols with sulfate-reducing bacteria or bacteria carrying out other forms of anaerobic respiration.



Antje Boetius and Armin Gieseke

(a)

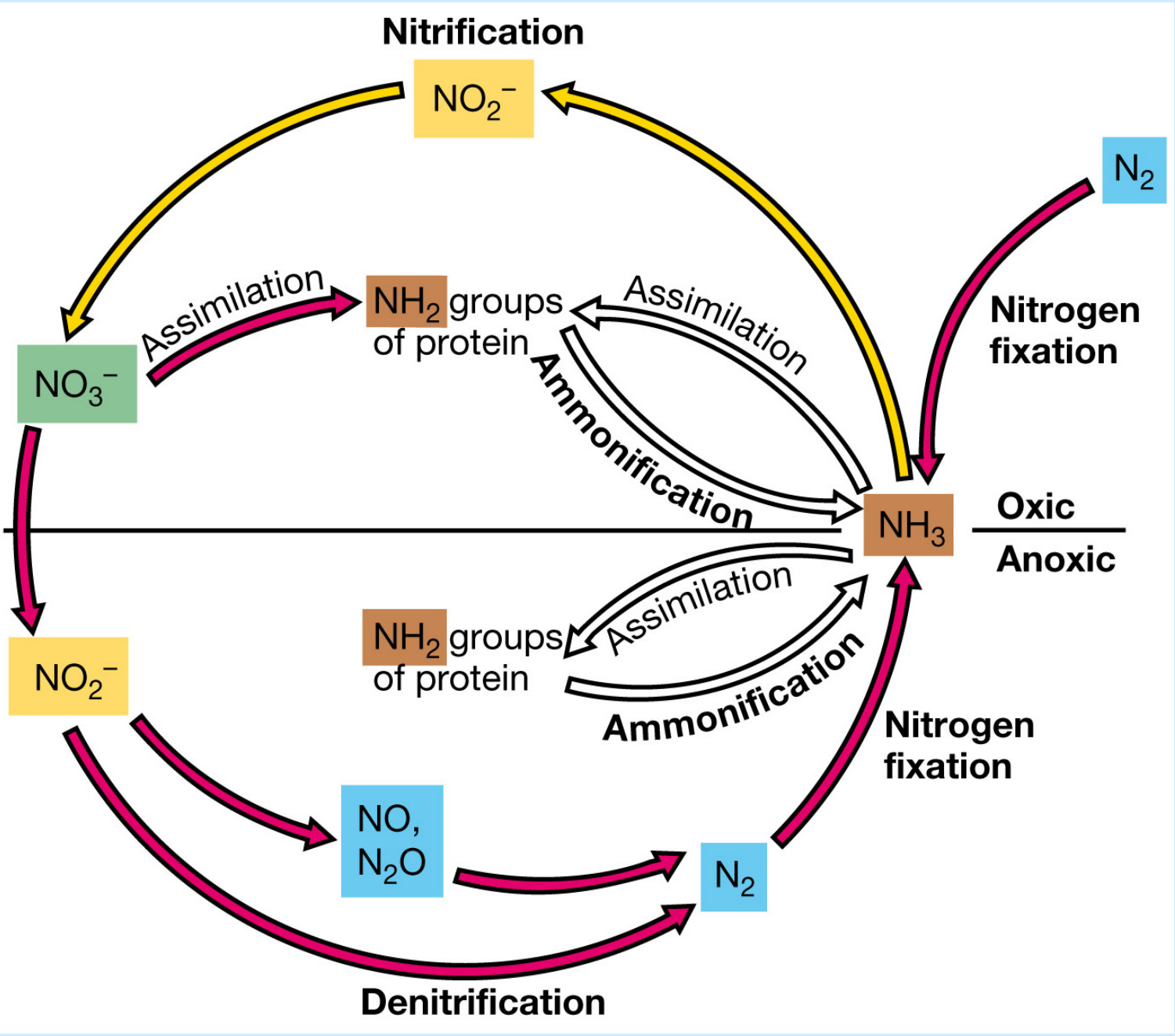
Reaction	Organism	$\Delta G^{0\prime}$ (kJ)
$CH_4 + 2\ H_2O \longrightarrow CO_2 + 4\ H_2$	Methanogen	+131
$SO_4^{2-} + 4\ H_2 + H^+ \longrightarrow HS^- + 4\ H_2O$	Sulfate-reducer	−156
Sum: $SO_4^{2-} + CH_4 \longrightarrow HCO_3^- + HS^- + H_2O$	Syntrophic reaction	−25

(b)

Anoxic methane oxidation. (a) Methane-oxidizing cell aggregates from marine sediments. The aggregates contain methanogenic bacteria (red) surrounded by sulfate-reducing bacteria (green). Each cell type is stained by a different phylogenetic FISH stain (Section 18.4). (b) Possible mechanism for syntrophic anoxic methane oxidation in the cell aggregates.

Key Processes and Prokaryotes in the Nitrogen Cycle

Processes	Example organisms
Nitrification ($NH_4^+ \rightarrow NO_3^-$)	
$NH_4^+ \rightarrow NO_2^-$	*Nitrosomonas*
$NO_2^- \rightarrow NO_3^-$	*Nitrobacter*
Denitrification ($NO_3^- \rightarrow N_2$)	*Bacillus*, *Paracoccus*, *Pseudomonas*
N_2 Fixation ($N_2 + 8H \rightarrow NH_3 + H_2$)	
Free-living	
Aerobic	*Azotobacter* Cyanobacteria
Anaerobic	*Clostridium*, purple and green bacteria
Symbiotic	*Rhizobium* *Bradyrhizobium* *Frankia*
Ammonification (organic-N $\rightarrow NH_4^+$)	
	Many organisms can do this

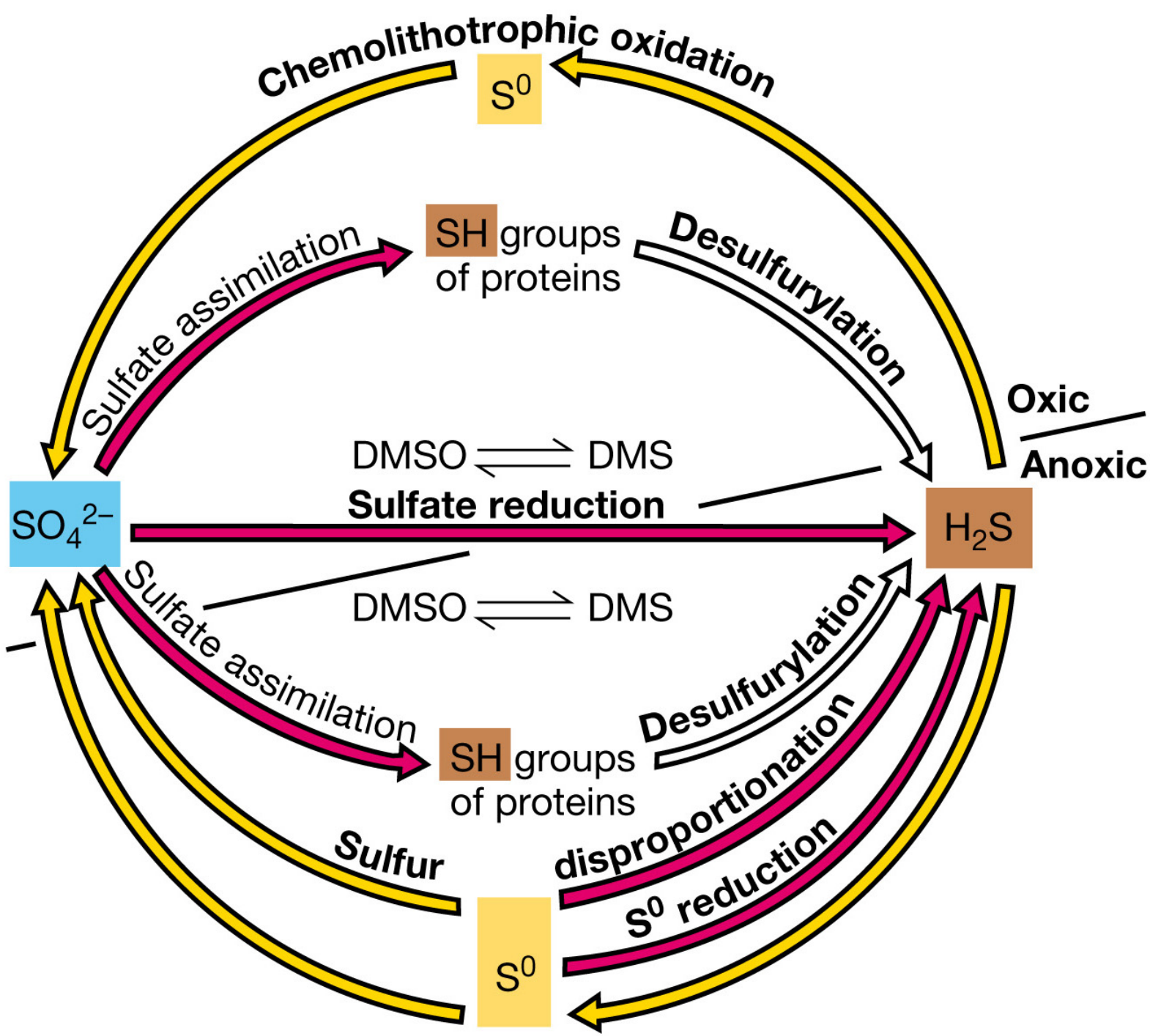


Redox cycle for nitrogen. Oxidation reactions are represented by yellow arrows and reductions in red.

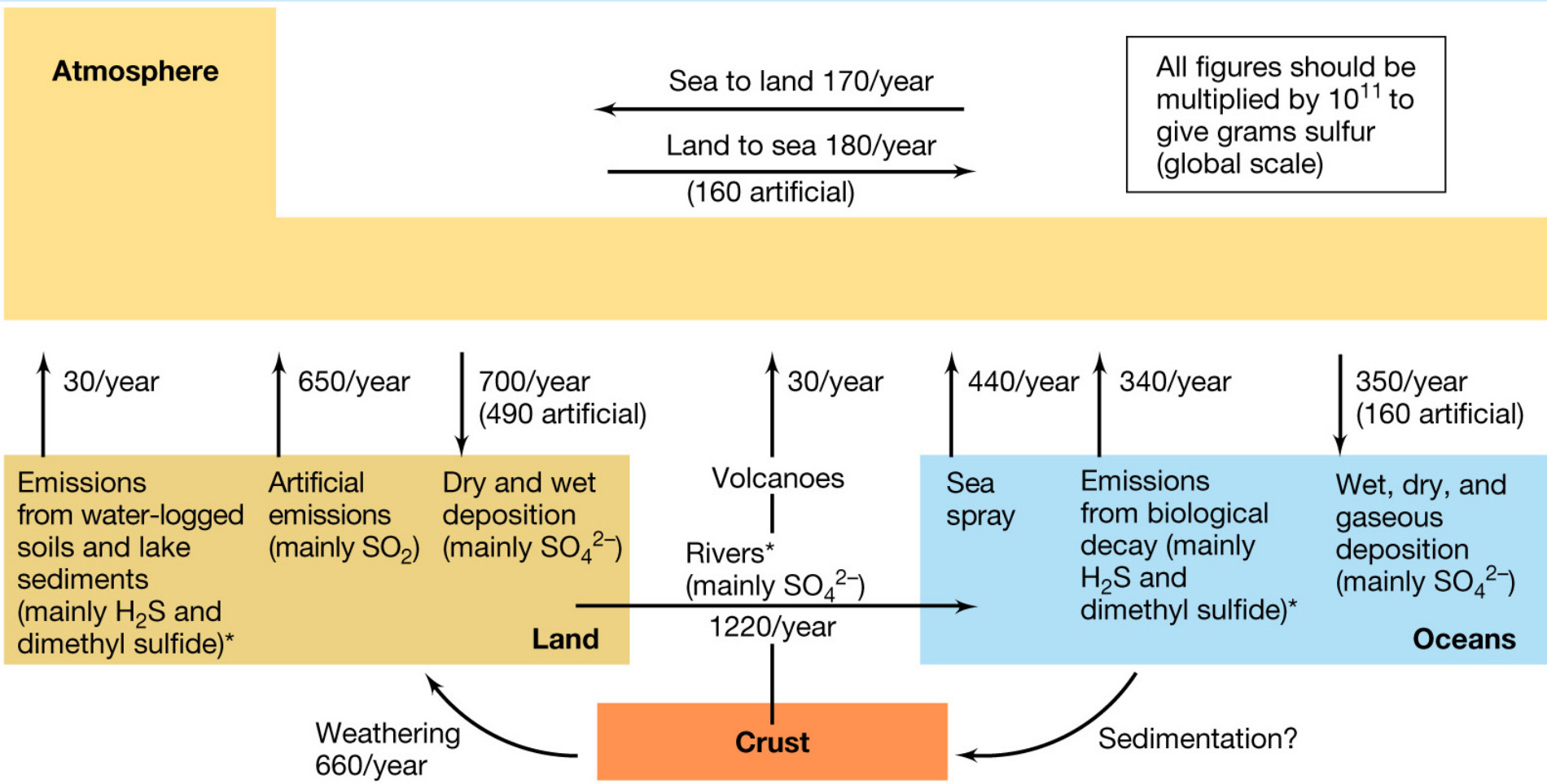
Key Processes and Prokaryotes in the Sulfur Cycle

Process	Organisms
Sulfide/sulfur oxidation ($H_2S \rightarrow S^0 \rightarrow SO_4^{2-}$)	
Aerobic	Sulfur chemolithotrophs (*Thiobacillus*, *Beggiatoa*, many others)
Anaerobic	Purple and green phototrophic bacteria, some chemolithotrophs
Sulfate reduction (anaerobic) ($SO_4^{2-} \rightarrow H_2S$)	*Desulfovibrio*, *Desulfobacter*,
Sulfur reduction (anaerobic) ($S^0 \rightarrow H_2S$)	*Desulfuromonas*, many hyperthermophilic *Archaea*
Sulfur disproportionation ($S_2O_3^{2-} \rightarrow H_2S + SO_4^{2-}$)	*Desulfovibrio*, and others
Organic sulfur compound oxidation or reduction	($CH_3SH \rightarrow CO_2 + H_2S$) ($DMSO \rightarrow DMS$)
Desulfurylation (organic–S $\rightarrow H_2S$)	Many organisms can do this

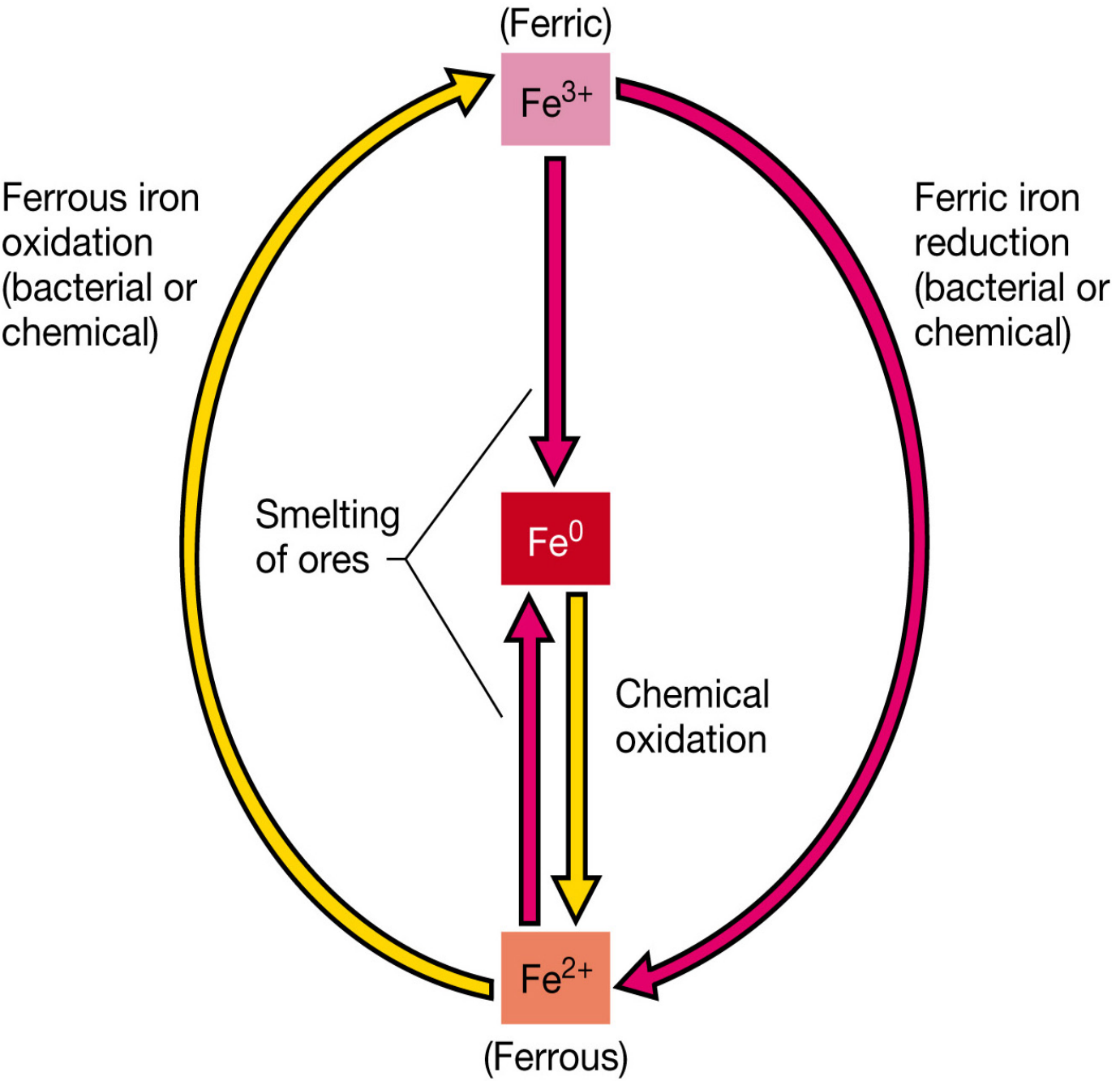
Redox cycle for sulfur. DMSO, dimethylsulfoxide; DMS, dimethylsulfide.



Redox cycle for sulfur. Oxidations are shown in yellow arrows and reductions in red. DMSO, dimethylsulfoxide; DMS, dimethylsulfide.



The global balance of sulfur. Artificial emissions are derived from human activities. An asterisk indicates a process that is partially or solely due to microbial action.



The redox cycle of iron. The major forms of iron in nature are Fe2+ and Fe3+ , Fe0 is primarily a product of human activities in the smelting of iron ores. Ferrous iron oxidation occurs aerobically by the iron chemolithotrophs (or chemically at neutral pH) and anaerobically by certain anoxygenic phototrophic bacteria and denitrifying bacteria. Oxidations are shown with yellow arrows and reductions with red.

T. D. Brock

(a)

Pyrite-rich microbial habitats in bituminous coal- and copper-mining environments. (a) Bituminous coal-mining operation in a strip mine. The shovel is removing the soil (overburden) to reach the coal seam.