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H.G. Trueper: PHOTOTROPHIC BACTERIA AND THEIR ROLE IN THE BIOGEOCHEMICAL SULFUR CYCLE

An essential step that cannot be bypassed in the biogeochemical cycle of sulfur today is dissimilatory sulfate reduction by anaerobic bacteria. The enormous amounts of sulfides produced by these are oxidized again either anaerobically by phototrophic bacteria or aerobically by thiobacilli and large chemotrophic bacteria (*Beggiatoa, Thiovulum*, etc.) Phototrophic bacteria use sulfide, sulfur, thiosulfate, and sulfite as electron donors for photosynthesis. The most obvious intermediate in their oxidative sulfur metabolism is a long chain polysulfide that appears as so-called sulfur globules either inside (Chromatiaceae) or outside (Ectothiorhodospiraceae, Chlorobiaceae, and some of the Rhodospirillaceae) the cells. The enzymes involved in phototrophic bacterial sulfur metabolism are cytochrome c, flavocytochrome c, reverse siroheme sulfite reductase, thiosulfate sulfur transferase, thiosulfate:acceptor oxidoreductase, adenylylsulfate reductase, ADP sulfurylase, ATP sulfurylase, and sulfite:acceptor oxidoreductase. Molecular oxygen is not involved in any of these steps. The amount of carbon assimilated by phototrophic bacteria per mole sulfide oxidized to sulfate is about 10 fold higher than that assimilated by chemolithotrophic sulfur-oxidizing bacteria. Phototrophic sulfur bacteria therefore are the predominant primary producers in the sulfuretum. During dark periods under anoxic conditions phototrophic bacteria perform a slow fermentative maintenance metabolism, during which they reduce elemental sulfur and polysulfides to H_2S. At low partial pressures of oxygen several species of the Chromatiaceae (e.g., *Chromatium vinosum, Thiocystis violacea*) are also capable of oxidizing reduced sulfur compounds in the dark. They possess an energy metabolism like that of chemolithotrophic bacteria. The assimilation of sulfur compounds in phototrophic bacteria is in principle identical with that of non-phototrophic bacteria. However the Chlorobiaceae and some of the Chromatiaceae and Rhodospirillaceae, unable to reduce sulfate, rely upon reduced sulfur for biosynthetic purposes.

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Metabolic type (all anaerobic)	Mechanisms	Microorganisms
Dissimilatory Sulfate Reduction	Electron acceptors: Sulfate, Thiosulfate, Sulfite Electron donors: Organic compounds or H_2 Product: H_2 Carbon source: organic compounds or CO_2	*Desulfovibrio* *Desulfotomaculum* *Desulfomonas* *Desulfobacter* *Desulfobulbus* *Desulfococcus* *Desulfosarcina* *Desulfonema* *Thermodesulfobacterium*
	Electron acceptors: Sulfur Electron donors: Organic compounds or H_2 Product: H_2S Carbon source: organic compounds or CO_2	*Desulfuromonas* *Desulfovibrio* (some) *Campylobacter* (some) *Wolinella* Chromatiaceae (dark) Chlorobiaceae (dark) *Beggiatoa* *Thermoproteus* *Thermodiscus* *Pyrodictium* *Thermococcus*

For list of references see Trueper, 1984b.

Table I-6. Inorganic sulfur compounds as electron acceptors in bacteria.

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Metabolic type	Mechanism	Microorganisms
Phototrophic Sulfur Oxidation (anaerobic)	Electron donors: Sulfide, Sulfur, Thiosulfate, (Sulfite) Photosynthesis (CO_2 Fixation) Product: Sulfate Carbon source: CO_2 and/or organic compounds	Chlorobiaceae Chromatiaceae *Ectothiorhodospira* Rhodospirillaceae (some) Chloroflexaceae Cyanobacteria (some)
Chemotrophic Sulfur Oxidation (anaerobic)	Electron donors: Sulfide, Sulfur, Thiosulfate, (Sulfite) Electron acceptor: Nitrate Product: Sulfate Carbon source: CO_2	*Thiobacillus denitrificans* *Thiomicrospira denitrificans*
Chemotrophic Sulfur Oxidation (aerobic)	Electron donors: Sulfide, Sulfur, Thiosulfate, (Sulfite) Electron acceptor: O_2 Product: Sulfate Carbon source: CO_2 or organic compounds	*Thiobacillus* *Thiomicrospira* *Sulfolobus* *Thermothrix* *Paracoccus* *Pseudomonas* *Beggiatoa* *Thiothrix* *Thiospira* *Thioploca* *Macromonas* *Achromatium* *Thiobacterium* Chromatiaceae (dark, some species) Many heterotrophs

For list of references see Trueper, 1984b.

Table I-7. Inorganic sulfur compounds as electron donors in bacteria.