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* Hyperthermus butylicus* gen. nov., sp. nov., a Hyperthermophilic, Anaerobic, Peptide-Fermenting, Facultatively H$_2$S-Generating Archaeabacterium

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We describe a hyperthermophilic archaeabacterium, *Hyperthermus butylicus* gen. nov., sp. nov., that was isolated from flat-sea sediments. This organism is the first extremophilic archaeabacterium for which fermentation products have been identified. The type strain is strain DSM 5456.

![Electron micrographs of *H. butylicus*](image.png)

(a) Intact cell with pili. (b) Ghost of diploform exhibiting S-layer and one vacuole. Negatively stained with uranyl acetate. Bars = 0.5 μm.

The hyperthermophilic archaeabacterium *Hyperthermus butylicus*, which grows at temperatures up to 107°C and survives at 108°C, was isolated from hydrothermally heated flat-sea sediments off the coast of San Miguel, Azores, with source temperatures up to 112°C (2). This organism thrives by fermenting peptides; it produces CO$_2$, butanol, and organic acids as fermentation products and uses H$_2$S production from molecular hydrogen and elemental sulfur as an accessory energy source. Thus, it is the first extremophilic archaeabacterium for which fermentation products have been identified. Phylogenetically, the genus *Hyperthermus* represents a long lineage which branches off in the vicinity of the genera *Desulfurococcus* and *Pyrodictium* but is distinct from both of these extremely thermophilic sulfur archaeabacterial...
genera. The metabolism and phylogeny of this organism have been described in detail elsewhere (2).

**Description of Hyperthermus Zillig, Holz, and Wunderl gen. nov.**

*Hyperthermus* (Hy.per.ther'mus. Gr. prep. hyper, above; Gr. fem. n. therme, heat; N. L. masc. n. Hyperthermus, an organism existing in a very hot environment). Obligately anaerobic, extremely thermophilic, gram-negative, irregular cocci with partially level surfaces and edges. The diameter of cells is about 1.5 μm. Division probably occurs by constriction. The envelope is a highly regular hexagonal S-layer. Only one species is known, the type species; this species is described below.

**Description of Hyperthermus butylicus Zillig, Holz, and Wunderl sp. nov.**

*Hyperthermus butylicus* (bu.ty'li.cus. N. L. masc. adj. butylicus, butylic, referring to production of butanol). Shape and size as described above for the genus (Fig. 1). About 1% diploforms (Fig. 1). Projections, probably pili and not flagella, extend from the whole surface. Often there are short "tails," which are probably remnants from division. About 25% of late-log-phase cells grown at 107 to 108°C have long appendages. Many cells in the late log phase of growth have vacuoles (Fig. 1). The lattice constant of the hexagonal S-layer is 25.9 nm and is distinct from the lattice constants of other archaebacteria.

Obligate anaerobe. Grows by fermentation of proteolysis products (e.g., tryptones and gelatin). The products are CO2 (2.6 mmol/g [dry weight]) and n-butanol, (33 mmol/g [dry weight]), as well as acetic acid, propionic acid, and phenylacetic acid (equal amounts). Growth is stimulated about 10-fold by SO2 plus H2, with massive production of H2S. No stimulation by CO2. No chemolithoautotrophic growth.

Optimal growth occurs with 6 g of tryptone (Difco) per liter, 10 g of SO2 per liter under CO2 or N2 containing 20% (vol/vol) H2, and 17 g of NaCl per liter at pH 7 between 95 and 107°C. The generation times are 2 to 3 h; at 85°C, the generation time is 4.5 h. No growth occurs at 75°C. Slow growth occurs at 108°C.

Cells contain DNA-dependent RNA polymerase which is not sensitive to rifampin and is stable at 102°C. The component pattern is distinct on the basis of the apparent molecular weights of the components but corresponds in principle to the component patterns of other thermophilic sulfur archaebacteria.

The polyisoprenoid tetraether lipids of the membrane consist of only two major components (mainly tetraether lipids with 0 to 2 cyclopentane rings in isoprenoid chains).

The guanine-plus-cytosine content of the DNA is 56 mol%.

Phylogenetically (as determined by DNA-rRNA cross-hybridization experiments [1]), *H. butylicus* forms a long lineage between the genera *Thermoproteus* and *Sulfolobus* and is distinguished from members of the genera *Desulfurococcus* and *Pyrodictium* by its S-layer structure, its RNA polymerase component pattern, its mode of growth, and its morphology.

The type strain is strain DSM 5456.

**REFERENCES**
