(Shchipansky et al. 2004). Greenstone belts in the central parts of the Karelian Province are younger (2.75–2.73 Ga) than in its western and eastern parts.

See also

- ► Amphibolite Facies
- ► Archean Eon
- ► Banded Iron Formation
- ► Craton
- ► Earth, Formation and Early Evolution
- ► Greenstone Belts
- ► Igneous Rock
- ► Metamorphic Rock
- ► Metasediments
- ► Ophiolite
- ► Shield
- ► Tonalite–Trondhjemite–Granodiorite

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Fennoscandian Shield

► Fennoscandia

Ferment (obsolete)

► Enzyme

Fermentation

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Definition

Fermentation is an ► anaerobic ► catabolism of a reduced carbon source (e.g., glucose) to generate ► ATP within a strict internal ► oxidation-► reduction balance. In many cases, the same substrate is used both as reductant and oxidant. The hallmark of fermentation is the accumulation of partially oxidized end products. Only a part of the chemical energy stored in the initial substrate is conserved during the synthesis of ATP, usually by a mechanism of substrate level phosphorylation. Nevertheless, there are some examples of the involvement of an electrochemical ion gradient in the synthesis of ATP (e.g., citrate fermentation).

History

Antoine Laurent Lavoisier (1743–1794) collected the first quantitative data on alcoholic fermentation. Louis Pasteur (1822–1895) studied in depth the fermentation by intact living cells and defined this physiological process as "life without oxygen". In 1897, Eduard Buchner (1860–1917) showed that fermentation could occur in cell-free extracts, inaugurating the genuine biochemical in vitro approach to living phenomena. Parallel studies on yeast alcoholic fermentation and anaerobic muscle glycolysis during the first half of the twentieth century contributed to the development of biochemistry as a science (Barnett 2003).

Overview

Many microorganisms, obligate or facultative anaerobic, are able to degrade extracellular polymers (e.g., polysaccharides, proteins, nucleic acids) and use the monomers (e.g., hexoses, pentoses, amino acids, purines, pyrimidines) as fermentable substrates. There are other substrates of fermentations such as organic acids (e.g., citrate, succinate, or malonate) or even aromatic hydrocarbons. In this latter case, fermentation appears as a metabolic task of several microbial species working together. Regarding amino acid fermentations, many anaerobic bacteria can catabolize single amino acids but grow better with amino acid mixtures (the Stickland reaction). In this case, some amino acids of the mixture act as reductants whereas others are the oxidants.

The stoichiometric yield of ATP in a fermentation depends on the particular pathway used and can range from less than one up to 4 mol of ATP per mol of fermentable substrate. Microorganisms are capable of generating a wide array of end products during fermentation, including carbon dioxide, ethanol, lactate, butyrate, acetate, and propionate. In comparison to respiration (i.e., electron transport chain–dependent processes), fermentations are less energetically efficient because a lot of potential chemical energy is still retained in most of the end products. Thus, to compensate this relatively low-energy yield, large amounts of fermentable substrate are used and most carbon from this can be recovered in the form of end products. Other anaerobic bacteria use the excreted end products of fermentations, building an anaerobic food chain with methanogens at the bottom. From a biotechnological point of view, however, since very ancient times, fermentations are widely used for the processing of food products, such as yogurt, cheese, beer, wine, or bread.

In a few cases, some ATP synthesis during fermentation is associated with the dissipation of an electrochemical potential gradient either of protons or sodium ions. These ion gradients can be generated by electron transport (e.g., fumarate reduction in *Propionibacterium*), membrane decarboxylases (e.g., sodium-pumping succinate decarboxylase of *Propionigenium modestum*), or electrogenic substrate translocation through membranes (e.g., lactic acid bacteria like *Lactococcus cremoris*).

When compared to the other energy-generating systems (such as respiration and photosynthesis), fermentation seems simpler at the structural and enzymatic levels. For this reason, in 1924, Oparin (Oparin 1924) postulated that fermentation was the earliest metabolic mode.

See also

- ► Anaerobe
- ► ATP
- ► Catabolism
- ► Chemoorganotroph
- ► Embden-Meyerhof-Parnas Pathway
- ► Glycolysis
- ► Origin of Life
- ► Oxidation
- ► Reduction

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Fermi Paradox

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Keywords

Extraterrestrial civilizations

Definition

The Fermi paradox, attributed to Italian physicist Enrico Fermi, concerns the apparent contradiction between the lack of any evidence for the presence of extraterrestrials on Earth and the view that extraterrestrial civilizations should be rather common in the Galaxy.

History

Fermi formulated his paradox in 1950, during a casual conversation in Los Alamos Laboratory with E. Teller and colleagues, with the famous phrase "where are they?" (or "where is everybody?"). His point was that, if there are many extraterrestrial civilizations, Earth should have been visited by one or more of them, long ago and many times over. The discussion went completely unnoticed for many years. The phrase "where are they?", attributed to Fermi but without comments, is first encountered in a paper published in 1963 by American astronomer Carl Sagan. Sagan referred to this problem as "Fermi's paradox" after American astronomer Michael Hart independently rediscovered Fermi's arguments in 1975.

Overview

As all paradoxes, the Fermi paradox is better understood if its premises are explicitly stated:

(a) There are many extraterrestrial civilizations in the Milky Way.
(b) Our civilization is a typical one (not the first to have appeared, neither the most technologically advanced, nor the only one seeking to explore the cosmos and communicate with others).
(c) Interstellar travel is not too difficult for civilizations slightly more advanced than ours.