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T.Y.B.SC.(MICROBIOLOGY)(CBCS)

NEW PROPOSED SYLLABUS -JUNE 2021

MB-502 BACTERIAL METABOLISM (THEORY)

UNIT :4SELECTED ASPECTS OF METABOLISM IN SPECIFIC MICROBIAL SYSTEM

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Content

- Nitrifying bacteria
- Iron bacteria
- Sulfure oxidizer bacteria
- Hydrogen bacteria
- Lactic acid bacteria
- The enteric group and related bacteria
- Archaebacteria

Chemoautotrophs

- What is chemoautotrophs?

Chemoautotrophs are those that make their own food by chemosynthesis.

- Chemosynthesis is a process by which some organisms, such as certain bacteria, use chemical energy to produce carbohydrates.
- Chemoautotrophs first discovered between 1880-1890 by s. winogradsky .
- Chemoautotrophs can use inorganic energy sources such as hydrogen sulfide, elemental sulfur, ferrous iron, molecular hydrogen, and ammonia or organic sources to produce energy.
- Most chemoautotrophs are extremophiles, bacteria or archaea that live in environments (such as deep sea) and are the primary producers in such ecosystems.
- Chemoautotrophs generally fall into several groups: methanogens, sulfur oxidizers and reducers, nitrifiers, anammox bacteria, and thermoacidophiles.

example of chemoautotrophs

- Nitrobacter, Nitrosomonas and Sulphur bacteria.
- Nitrogen-fixing bacteria and iron-oxidizing bacteria are chemoautotrophic.
- Chemoautotrophs are microorganisms such as bacteria and archaea. Some examples are sulfur-oxidizing archaea and bacteria, nitrogen-fixing bacteria, and iron-oxidizing bacteria.

Chemoautotrophic nitrifying bacteria

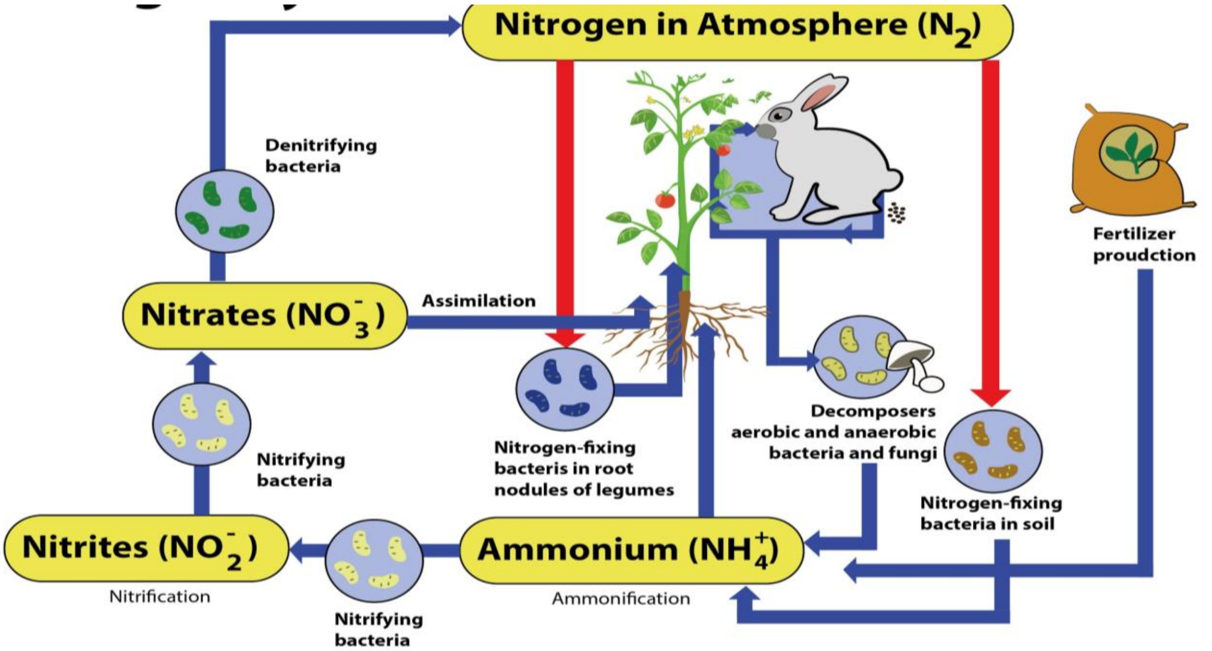
1. Chemoautrops are the organisms that create their energy and biological materials.
2. Chemoautotropic nitrifying bacteria use inorganic compounds as energy sources to get organic compounds.
3. They convert soil ammonia to nitrates which plants use.

- Which was small, gram-negative ,rod shaped bacteria (Nitrosomonas) which oxidize ammonium to nitrite .
- First evidence indicated that oxidation of ammonium to nitrite in natural environment is a microbial process.
- Nitrobacter organism are most importance participants in the nitrogen cycle .hence their activities and relationships to nitrogen metabolism .
- The nitrogen cycle cannot be completed without them .

Nitrifying bacteria

- Nitrosomonas is the most common organism found in soil that oxidized ammonia to nitrite both Nitrosomonas and Nitrobacter.
- The diversity of nitrifying bacteria grow cell structure having vesicular ,lamellar or tubular structure
- some time few organism use acetate as carbon &energy source which slowly grow than with nitrite.

Nitrogen cycle



- Nitrogen Cycle is a biogeochemical process through which nitrogen is converted into many forms, consecutively passing from the atmosphere to the soil to organism and back into the atmosphere.
- It involves several processes such as nitrogen fixation, nitrification, denitrification, decay and putrefaction.

Iron bacteria

- Many microorganisms can oxidize Fe (II) to Fe(III).
- Some of these are known as iron bacteria and use the free energy generated from the oxidation Many heterotrophic bacteria also oxidize Fe(II), but the function of such ferrous iron oxidation is not known and they do not conserve the free energy.
- Certain fresh water ponds & springs have high content of reduce iron salts. The bacterial flora is associated with such habitats. Bacterial colony form when utilize ferrous.

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Iron cycle

- The iron cycle includes several different genera that carry out iron oxidations: transforming ferrous ion (Fe2+) to ferric ion (Fe3+).
- Thiobacillus ferroxidase carries out this process under acidic conditions, Gallionella is active under neutral pH conditions, and Sulfolobus functions under acidic, thermophilic conditions.
- Much of the earlier literature suggested that additional genera could oxidize iron, including Sphaerotilus and Leptothrix.
- These two genera are still termed "iron bacteria" by many non-microbiologists.

- Iron cycle with examples of microorganisms contributing to these oxidation and reduction processes.
- In addition to ferrous ion (Fe2+) oxidation and ferric ion (Fe3+) reduction, magnetite (Fe3O4), a mixed valence iron compound formed by magneto tactic bacteria is important in the iron cycle.
- Different microbial groups carry out the oxidation of ferrous ion depending on environmental conditions.

Hydrogen bacteria

- Many species aerobic bacteria posses the ability to grow chemoautotroph with molecular H. In contrast to other organism H bacteria use a wide range of organic compound as C & energy source.
- Most of bacteria placed in a genus Hydrogen monas'.
- The enzymology of H oxidation has been extensively studied, by H.G.Schlegel and his coworker.
- Most H bacteria have a single hydrogenase which catalyzes the reaction.
- Most of them have a cytochrome-dependent particulate hydrogenase on their cytoplasmic membrane .
- Ralstonia eutropha (Alcaligenes eutrophus) and Nocardia autotrophica possess a NAD+-dependent soluble hydrogenase in addition to the particulate enzyme.
- Only the soluble enzyme is found in the third group which includes Alcaligenes denitrificans, Alcaligenes .
- Hydrogenase :ruhlandii and Rhodococcus opacus The particulate hydrogenase has a high affinity for the substrate enabling the bacterium to use hydrogen at low concentrations.

- Organisms with only the particulate hydrogenase employ reverse electron transport to reduce NAD(P)'.

Sulfur oxidizers

- Chemolithotrophic sulfur bacteria are referred to as colorless sulfur bacteria.
- These are phylogenetically diverse and include bacteria and archaea.
- They are grouped either according to the location of sulfur deposition after sulfide is oxidized Winogradsky examined the properties of the filamentous gliding bacteria .
- Thiothrix group, which characteristically in certain sulfide rich environment.
- Sulfur oxidizer shows that these organisms can oxidize H2S-S.
- This sulfur stored in cells.
- Further it oxidized to sulfide (SO2).Bacteria that oxidize H2S with formation of intra cellular deposits:-→Filamentous gliding organisms-e.g. Beggiatoa, Thiothrix, Thioploca → Very large unicellular gliding organisms e.g.Achromation .

The lactic acid bacteria

- Lactic acid is a chemical compound that plays a role in several biochemical processes.
- That is a carboxylic acid with a chemical formula of CaH6O3.
- Lactic acid is used in the food industry for several aspects Lactic acid bacteria: Gram-positive cocci or rod, Non-spore forming and Non-motile bacteria
- Physiological characteristics : Anaerobes or microaerophiles, strictly fermentation (major end product: lactic acid), Acid-tolerant bacteria
- Lactate is a common fermentation product in many facultative and obligate anaerobes.

- Some bacteria produce lactate as a major fermentation product and these are referred to as lactic acid bacteria (LAB).
- Most LAB have a limited ability to synthesize monomers for biosynthesis and vitamins which are needed as growth factors.
- LAB is regarded as obligate anaerobes but they can use oxygen, synthesizing cytochromes when hem in is provided in the medium.
- Some LAB produce only lactate from sugars while others produce acetate and ethanol in addition to lactate .
- LAB are classified into two groups according to their hexose metabolic pathways:
- (1) homofermentative (HoLAB), where lactic acid is the main end product; and
- (2) heterofermentative (HeLAB), where other end products, such as acetic acid, carbon dioxide, or aroma compounds are produced in addition to lactic acid.

Fermentation pathway for lactic acid bacteria

- **Homo fermentative lactate fermentation**

- Homofermentative Lactic acid production bacteria (LAB) include most species and of Lactobacillus, Sporolactobacillus, Pediococcus, Enterococcus and Lactococcus.
- They use hexoses through the EMP pathway to generate ATP Lactate dehydrogenase reoxidizes the NADH reduced during the EMP pathway using pyruvate as the electron acceptor.
- As fermentation proceeds lactate is accumulated lowering the intracellular pH. Lactate dehydrogenase is active in acidic-conditions producing lactate as the major product.
- Under alkaline conditions, homofermentative LAB produce large quantities of acetate and ethanol .

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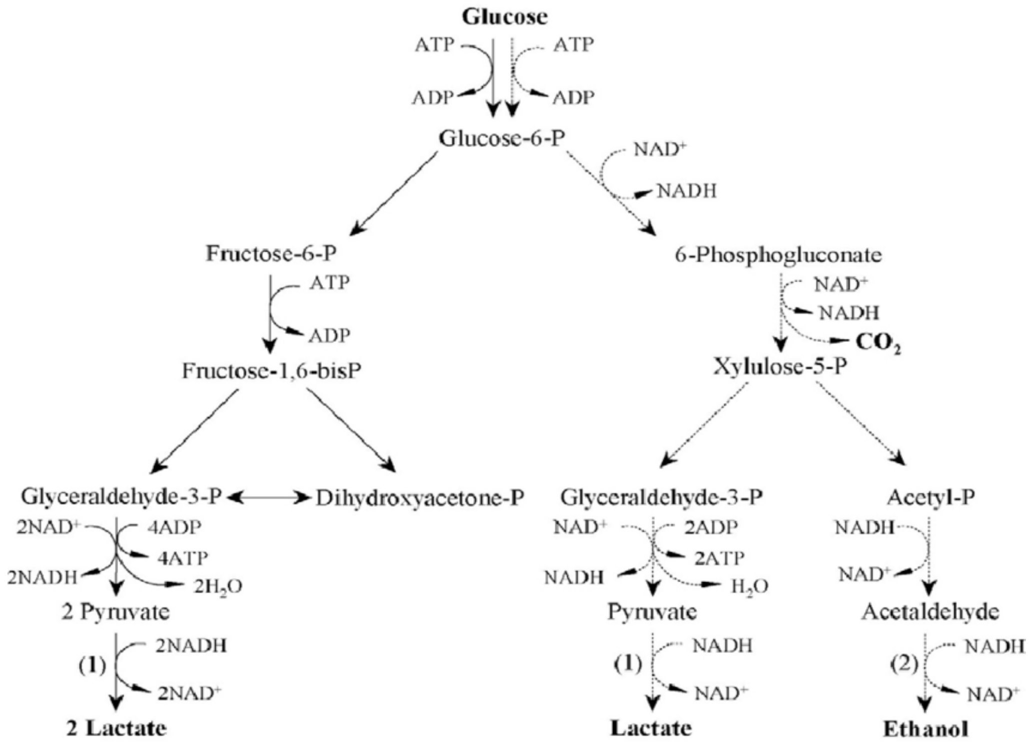


Hetero fermentative lactate fermentation

- Species of Leuconostoc and Bifidobacterium produce ethanol and acetate in addition to lactate.
- They employ a unique glycolytic pathway known as the phosphoketolase pathway. As shown in (Fig. 4.9), heterofermentative LAB like Leuconostoc mesenteroides oxidize glucose-6-phosphate to ribulose-5- phosphate.
- Epimerase converts ribulose-5-phosphate xylulose-5- to phosphate, before cleavage to glyceraldehyde-3-phosphate and acetyl- phosphate by the action of phosphoketolase.
- Glyceraldehyde-3-phosphate is metabolized to lactate as in the homolactate fermentation generating ATP.
- Acetyl-phosphate is reduced to ethanol acting as the electron acceptor to oxidize the NADH reduced in the glucose-6-phosphate oxidation process.

- One ATP per hexose is available from this fermentation. Pentoses are converted to xylulose-5-phosphate without reducing NADP. In this case, acetyl-phosphate is not used as the electron acceptor but is used to synthesize ATP.
- Leuconostoc mesenteroides synthesizes 1 ATP from a molecule of hexose and 2 ATP from a molecule of pentose.

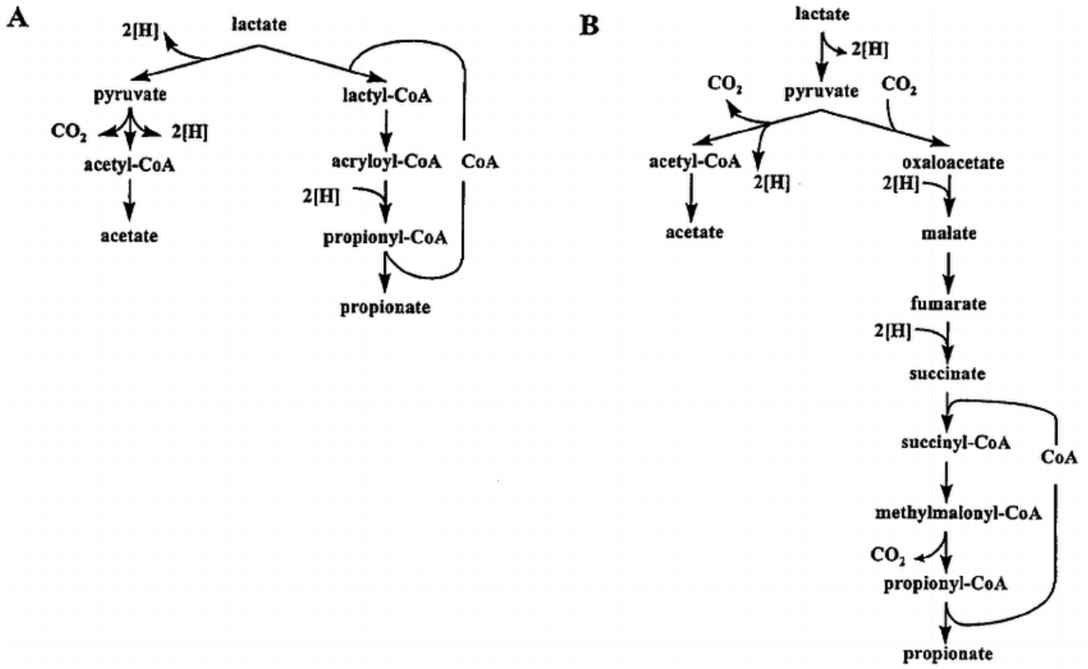
The enteric group and related bacteria

Gram-negative bacteria (GNB) are among the world's most significant public health problems due to their high resistance to antibiotics.

These microorganisms have significant clinical importance in hospitals because they often require patients to be in the intensive care unit (ICU), and patients are at high risk of morbidity and mortality.

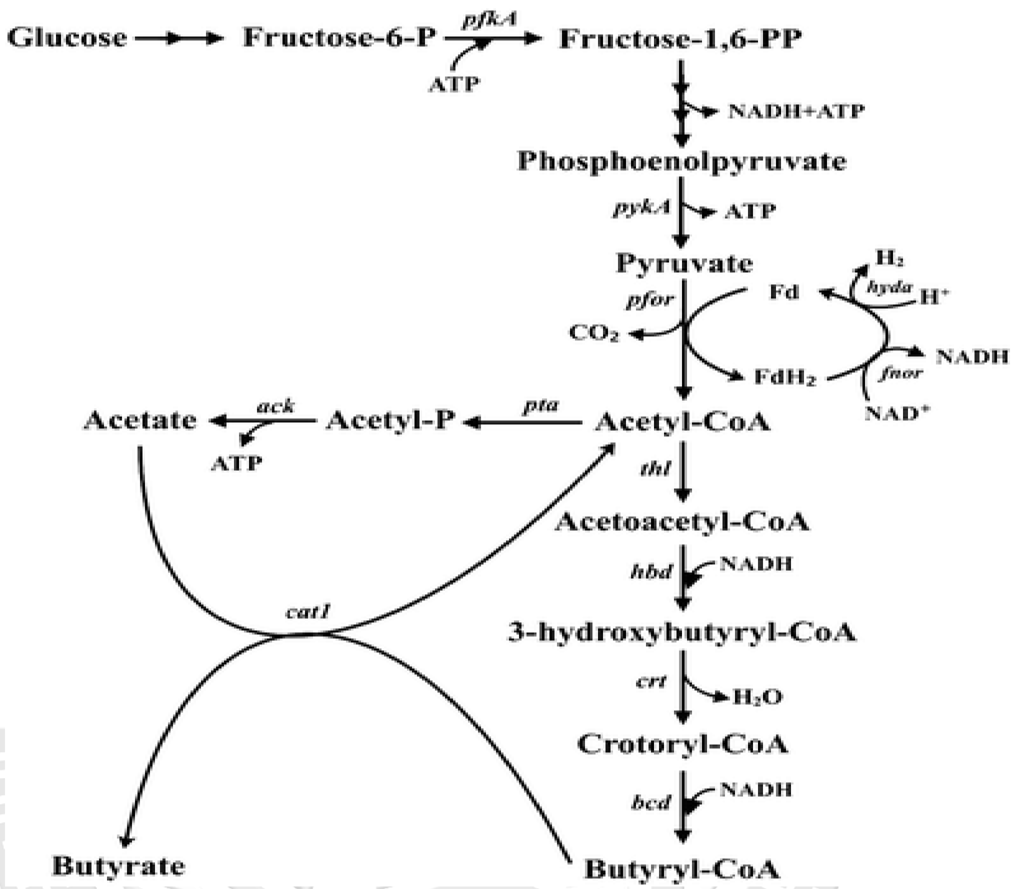
Fermentation patterns of gram-negative bacteria

1) **Propionate fermentations**
   - High propionate concentration has been achieved through fermentation of glycerol by E. coli, which is comparable to anaerobic fermentation by Propionibacterium (73).
   - Veillonella criceti as a Gram-negative bacterium can convert lactate to propionate with high productivity rate of 39 g
   - Propionic acid (propionate) is a commercially valuable carboxylic acid produced through microbial fermentation.
   - Propionic acid is mainly used in the food industry but has recently found applications in the cosmetic, plastics and pharmaceutical industries.



Butyrate fermentation

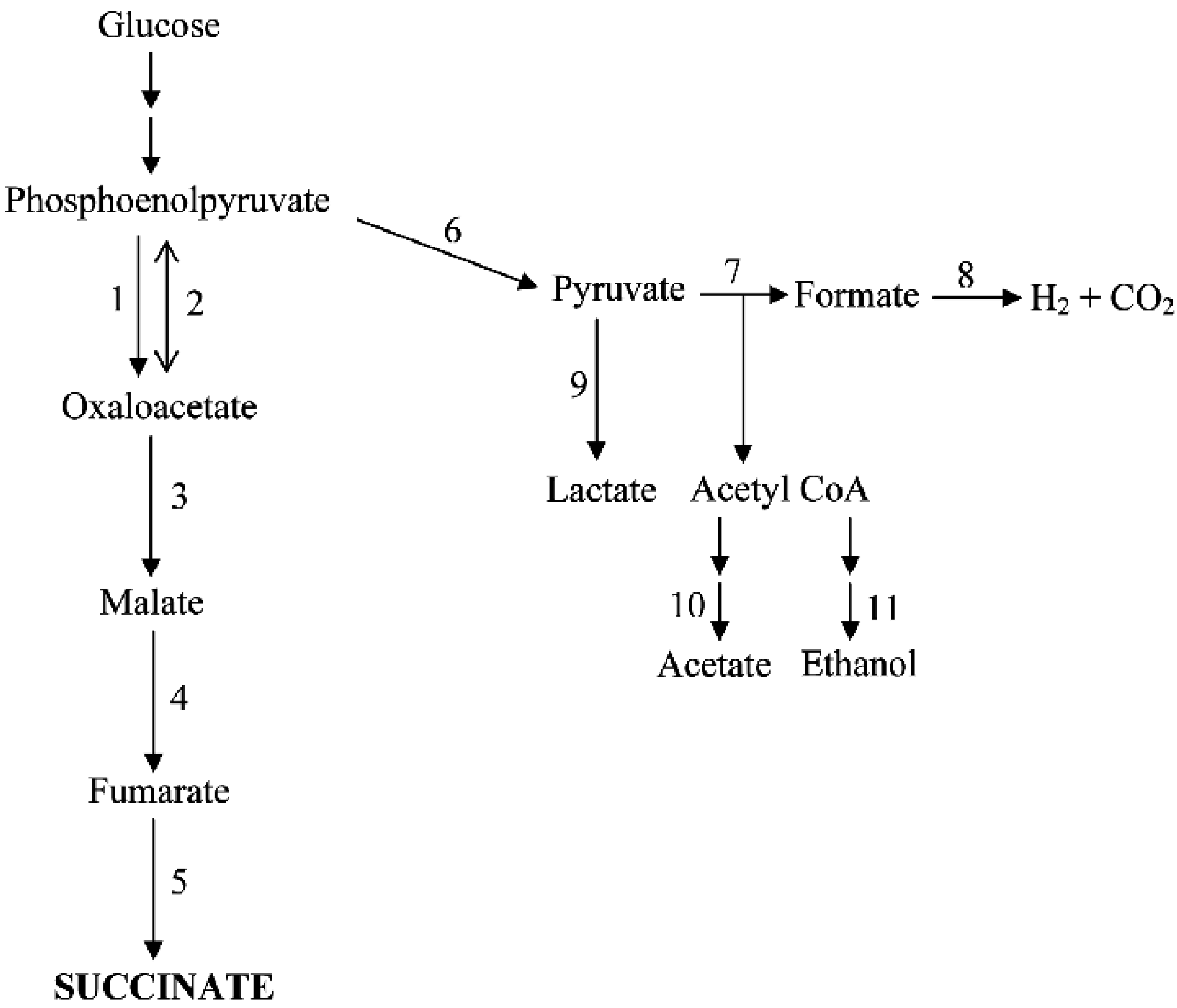
- Butyrate is produced by several fermentation processes performed by obligate anaerobic bacteria.
- This fermentation pathway was discovered by Louis Pasteur in 1861. Examples of butyrate-producing species of bacteria: Clostridium butyricum.
- The end products of fermentation are a spectrum of organic acids, including short chain fatty acids (SCFAs)[3] such as butyrate, succinate, and propionate, as well as other terminal products such as lactate .
- Butyrate (pronounced “byoo-ter-ate”) plays an important role in digestive system health by providing the main energy source for your colon cells; it meets about 70% of their energy needs.



Succinate fermentation

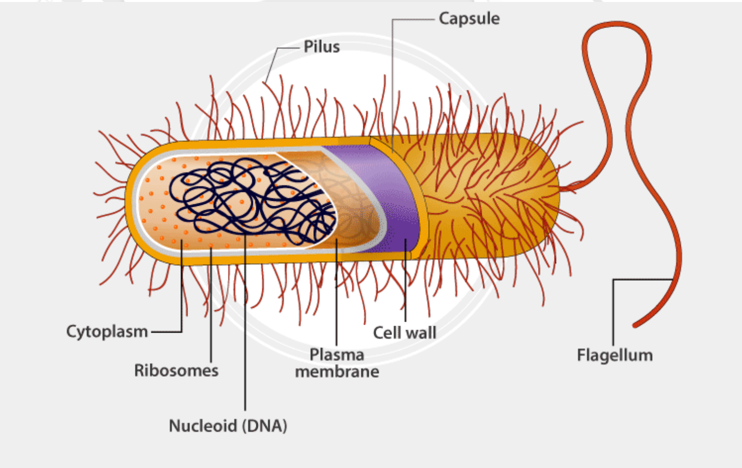
- There are three pathways for succinate formation including the reductive branch of the TCA cycle, the glyoxylate pathway, and the oxidative TCA cycle [5–10].
- The maximum possible succinate yield based solely on a carbon balance is 2 mol mol^{-1} glucose when all the succinate is formed via the anaerobic pathway.
- In addition to the natural producers, many microorganisms can be metabolically engineered to produce succinate as a fermentative end-product.
- These engineered producers are always model microorganisms since they are easy to be genetically modified.12-Dec-2013

- To produce succinate, CO_2 fixation is required, one molecule of CO_2 is incorporated to phosphoenolpyruvate (PEP) to form oxaloacetate (OAA) catalyzed normally by PEP carboxylase (PPC).



Archaebacteria

Archaebacteria are known to be the oldest living organisms on earth. They belong to the kingdom Monera and are classified as bacteria because they resemble bacteria when observed under a microscope.
Apart from this, they are completely distinct from prokaryotes. However, they share slightly common characteristics with the eukaryotes
These can easily survive under very harsh conditions such as the bottom of the sea and the volcanic vents and are thus known as extremophiles.



Characteristics of Archaebacteria

Following are the important characteristics of archaebacteria:

Archaebacteria are obligate or facultative anaerobes, i.e., they flourish in the absence of oxygen and that is why only they can undergo methanogenesis.

The cell membranes of the Archaebacteria are composed of lipids.

The rigid cell wall provides shape and support to the Archaebacteria. It also protects the cell from bursting under hypotonic conditions.

The cell wall is composed of Pseudomurein, which prevents archaebacteria from the effects of Lysozyme. Lysozyme is an enzyme released by the immune system of the host, which dissolves the cell wall of pathogenic bacteria.

Types of Archaebacteria

Archaebacteria are classified on the basis of their phylogenetic relationship. The major types of Archaebacteria are discussed below:

Crenarchaeota

The Crenarchaeota are Archaea, which exist in a broad range of habitats. They are tolerant to extreme heat or high temperatures. They have special proteins that help them to function at temperatures as high as 230 degrees Celsius. They can be found in deep-sea vents and hot springs, regions with superheated water. These include thermophiles, hyperthermophiles, and thermoacidophiles.

Euryarchaeota

These can survive under extremely alkaline conditions and have the ability to produce methane, unlike any other living being on earth. These include methanogens and halophiles.

Korarchaeota

They possess the genes common with *Crenarchaeota* and *Euryarchaeota.* All three are believed to have descended from a common ancestor. These are supposed to be the oldest surviving organism on earth. These include hyperthermophiles.

Thaumarchaeota

These include archaea that oxidize ammonia.

Nanoarchaeota

This is an obligate symbiont of archaea belonging to the genus Ignicoccus.

Importance of Archaebacteria

The importance of archaebacteria can be understood from the following points:

- Archaebacteria have compelled the scientists to reconsider the common definition of species. Species are a group with gene flow within its members. The archaebacteria exhibit gene flow across its species.
- The Archaebacteria are methanogens, i.e., they are capable of producing methane. They act on the organic matter and decompose it to release methane which is then used for cooking and lighting.

Examples of Archaebacteria

Following are the important examples of archaebacteria:

Lokiarcheota

It is a thermophilic archaebacterium found in deep-sea vents known as the *Loki's* castle. It has a unique genome. Some of the genes of the genome are involved in phagocytosis. They also possess the eukaryotic genes that are used by the eukaryotes to control their shapes. It is believed that Lokiarcheota and eukaryotes shared a common ancestor several billion years ago.

Methanobrevibacter smithii