Subject Name: Microbiology

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Name of topic: Chemoheterotrophic Metabolism- Anaerobic respiration and fermentation

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Unit-4: Anaerobic Respiration

CC-6 ; SEM-3

Respiration:

The sequence of enzymes and carriers responsible for the transport of reducing equivalents (electrons) from substrates to molecular O_2, is known as respiratory chain (electron transport chain). This fact is known as respiration. The respiratory chain is localised within the inner mitochondrial membrane (in case of eukaryotic system), But the respiratory chain is localised within the cell membrane (in case of prokaryotic system).

Anaerobic respiration:

In the process of aerobic respiration, it has been observed that O_2 of air acts as the terminal electron acceptor whereby O_2 is reduced to H_2O.
Some bacteria possess the facility of transferring electrons to some inorganic compounds, specially nitrate or sulfate as ~~the~~ terminal electron acceptor in absence of O_2. This type of respiration is called anaerobic respiration.
When the organisms use nitrate as terminal electron acceptor, the respiration is known as nitrate respiration.
When ~~sulfate~~ the organisms use sulfate as terminal electron acceptor, the respiration is known as sulfate respiration.

Nitrate (NO_3^-) respiration:

It is typically carried out by some facultative ~~anaerobes~~ anaerobic bacteria though they grow well aerobically.

@ Plants, fungi and many bacteria are able to use nitrate as a N_2 source for protein synthesis. They carry out the process of assimilatory nitrate reduction whereby nitrate is reduced in a step wise ~~manner~~ manner to ammonia.

(a) Assimilation of Nitrate or Ammonia (Assimilatory nitrate reduction)

Step 1:

In the first step, nitrate (NO_3^-) is reduced to nitrite (NO_2^-) by the enzyme nitrate reductase. This reaction takes place in cytosol. Nitrate reductase contains NADH or NADPH as prosthetic group.

$$\overset{+5}{N}O_3^- \xrightarrow[\text{Nitrate reductase}]{NADH + H^+ \;\rightarrow\; NAD^+} \overset{+3}{N}O_2^-$$

Step-2:

In the second step, nitrite is reduced to ammonia by the enzyme nitrite reductase. Nitrite reductase contains ferredoxin as prosthetic group.

$$\overset{+3}{N}O_2^- \xrightarrow[\text{Nitrate reductase}]{Fd(Fe^{2+}) \;\rightarrow\; Fd(Fe^{3+})} \overset{-3}{N}H_4^+$$

Step-3:

Plant avoids ammonium ion (NH_4^+) toxicity by rapidly converting the ammonium ion generated from nitrate assimilation into amino acids involves the sequential action of two enzyme glutamine synthetase and glutamate synthetase.

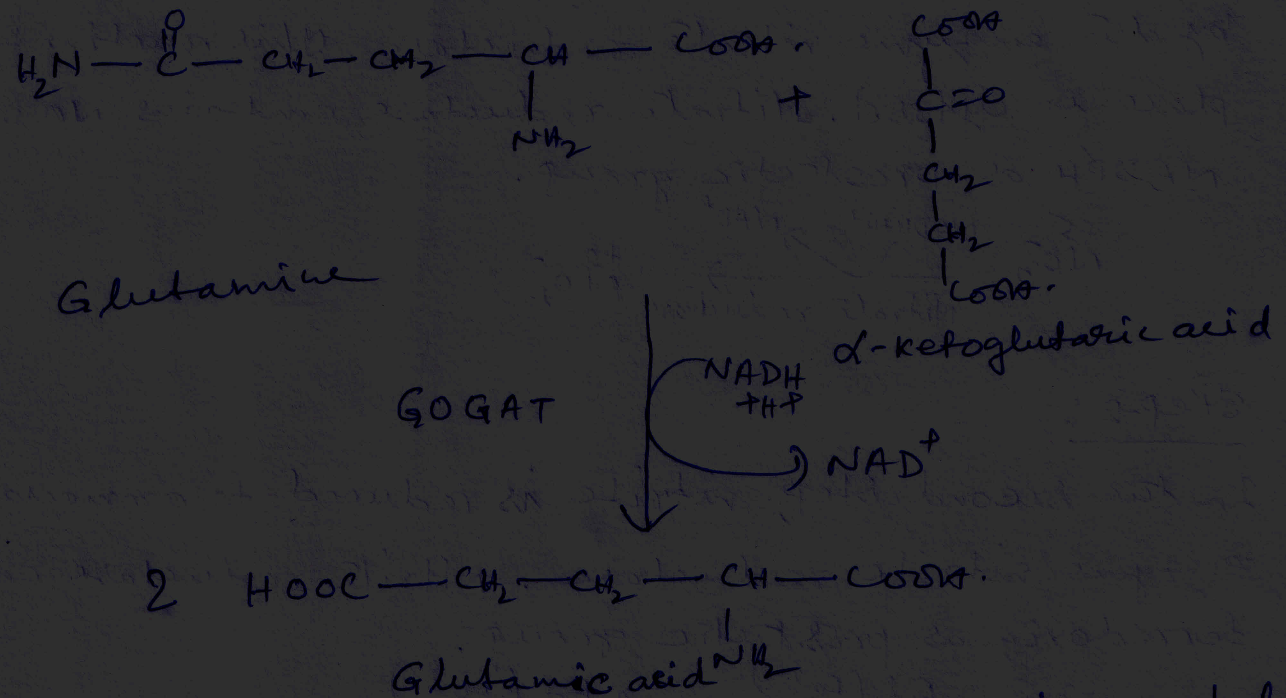
(i). Glutamine synthetase combines ammonium ions (NH_4^+) with glutamate to form glutamine. This reaction required ATP.

$$\underset{\text{Ammonia}}{NH_3} + \underset{\text{Glutamic acid}}{HO-\overset{O}{\overset{\|}{C}}-CH_2-CH_2-\underset{NH_2}{\underset{|}{CH}}-COOH} + ATP$$

$$\downarrow \text{Glutamine synthetare}$$

$$\underset{\text{Glutamine.}}{H_2N-\overset{O}{\overset{\|}{C}}-CH_2-CH_2-\underset{NH_2}{\underset{|}{CH}}-COOH} + ADP + P_i$$

(ii). Glutamine then converted to glutamic acid. It is catalysis by glutamate synthetase. Glutamine-2-oxoglu-tarate amino transferase (GOGAT). This enzyme required NADH as prosthetic group.



Assimilated nitrate or amonia into glutamine and glutamate, N_2 is incorporated into other amino acid via trans-amination reaction.

(6) Dissimilatory nitrate reduction {Denitrification}:

Denitrification is the bio-chemical process in which nitrogenous oxides, principally NO_3^- and NO_2^- are used as terminal electron acceptor in absence of O_2 and are released as dinitrogen gases (N_2) during respiratory metabolism.

Denitrification occures in absence of O_2, hence denitrifiers are technically facultative anaerobes though they grow well aerobically.

Denitrification is linked to bacteria. No fungi or actinomycetes denitrify if we think of denitrification as an energy yielding version or respiratory metabolism.

Some denitrifiers are:

(i) Pseudomonas fluorescens — Aerobes
(ii) P. aeruginosa — Aerobic
(iii). Bacillus cereus — Fermentors
(iv) B. licheniformis — Fermentors.
(v)

Process of denitrification:

The simplest path of denitrification can be represented as:

$$\underset{\text{(Nitrate)}}{NO_3^-} \longrightarrow \underset{\text{(Nitrite)}}{NO_2^-} \longrightarrow \underset{\text{(Nitric oxide)}}{NO} \longrightarrow \underset{\text{(Nitrous oxide)}}{N_2O} \longrightarrow \underset{\text{(Nitrogen)}}{N_2}.$$

Denitrification is a respiratory mechanism exactly like the aerobic respiration. Nitrogen oxides (NO, N_2O) takes the place of O_2 as the terminal electron acceptor. The electron donor does not have to be organic carbon (C); Thiobacillus denitrificans is an example of autotrophic denitrifier. Each step in denitrification is catalized by a distinct enzyme.

(5)

1. $\overset{(+5)}{NO_3^-}$ $\xrightarrow[\text{Dissimilatory nitrate reductase.}]{2e^- + 2H^+ \rightarrow H_2O}$ $\overset{(+3)}{NO_2^-}$

2. $\overset{(+3)}{NO_2^-}$ $\xrightarrow[\text{Dissimilatory nitrate reductase}]{e^- + 2H^+ \rightarrow H_2O}$ $\overset{(+2)}{NO}$ $\xrightarrow{\text{diffusion from cell.}}$ g ↑

3. $\overset{(+2)}{2NO}$ $\xrightarrow[\text{Nitric oxide reductase}]{2e^- + 2H^+ \rightarrow H_2O}$ $\overset{(+1)}{N_2O}$ $\xrightarrow{\text{diffusion}}$ g ↑

4. $\overset{(+1)}{N_2O}$ $\xrightarrow[\text{Dissimilatory nitrous oxide reductase}]{2e^- + 2H^+ \rightarrow H_2O}$ $\overset{0}{N_2}$ $\xrightarrow{\text{diffusion}}$ g ↑

So the total equation is:

$$\overset{(+5)}{2NO_3^-} + 10e + 12H^+ \longrightarrow \overset{0}{N_2} + 6H_2O$$