Ecology and Fungal Physiology

LECTURE- 4 **Dr. Hebba Al-Lami**

3- Fungal Metabolism

3.1 Carbon Catabolism

Being chemo-organotrophs, fungi derive their energy from the breakdown of organic compounds. Generally speaking, fungi, but few yeast species, extracellularly break down polymeric compounds by secreted enzymes prior to utilization of monomers as carbon and energy sources. Due to their relatively large size (20–60 KDa), enzymes assembled by the Golgi are transported in vesicles to be secreted from sites of cell growth, essentially from extending hyphal tips. Enzymes may either become linked to the cell wall as wall-bound enzymes, or may diffuse externally to decay substrates within the local environment. Some examples follow of hydrolytic, oxidative, peroxidative, and free radical generating enzyme systems produced by fungi for the degradation of polymeric compounds:

Pectin —(Pectin lyase, polygalactorunase)→ Galacturonic acid

Starch —(Amylases, glucoamylase)→ Glucose

Inulin —(Inulinase)→ Fructose

Cellulose —(Cellulases)→ Glucose

Hemicellulose —(Hemicellulases, xylanase)→ Xylose, Glucose

Lipids —(Lipases)→ Fatty acids

Proteins —(Proteinases)→ Amino acids

Ecology and Fungal Physiology

LECTURE- 4 **Dr. Hebba Al-Lami**

Chitin $\xrightarrow{\text{Chitinase}}$ N-acetylglucosamine

Lignin $\xrightarrow{\text{Ligninase; manganese peroxidase; laccase; glucose}}$ Variety of largely phenolic products

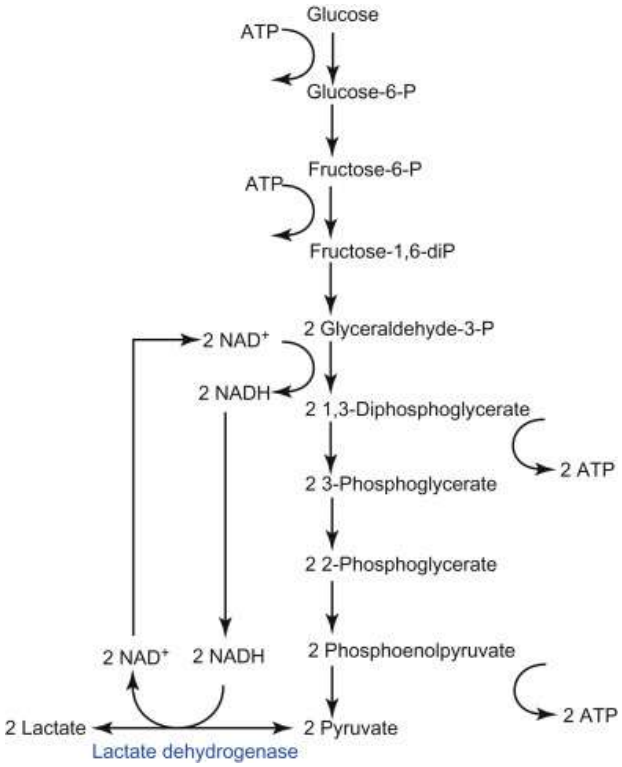
Catabolic pathways are oxidative processes which remove electrons from intermediate carbon compounds and use these to generate energy in the form of ATP. The catabolic sequence of enzyme-catalyzed reactions that convert glucose to pyruvic acid is known as **glycolysis** (Figure 1), and this pathway provides fungal cells with energy, together with precursor molecules and reducing power (in the form of NADH) for biosynthetic pathways. Therefore, in serving both catabolic and anabolic functions, glycolysis is sometimes referred to as an amphibolic pathway. Glycolysis may be summarized as follows:

$$\text{Glucose} + 2\text{ADP} + 2\text{Pi} + 2\text{NAD} \longrightarrow 2\text{Pyruvate} + 2\text{ATP} + 2\text{NADH}^{+} + 2\text{H}^{+}$$

- **During glycolysis**, glucose is phosphorylated using ATP to produce fructose 1,6-biphosphate, which is then split by aldolase to form two glyceraldehyde 3-phosphate. Further phosphorylation occurs, forming two diphosphoglycerate from which four H atoms are accepted by two molecules of NAD+. In the latter stages of glycolysis, four molecules of ATP are formed [by transfer of phosphate from the diphosphoglycerate to Adenosine diphosphate (ADP)] and this results in the formation of two molecules of pyruvic acid. ATP production (two molecules net) during glycolysis is referred to as substrate-level phosphorylation.

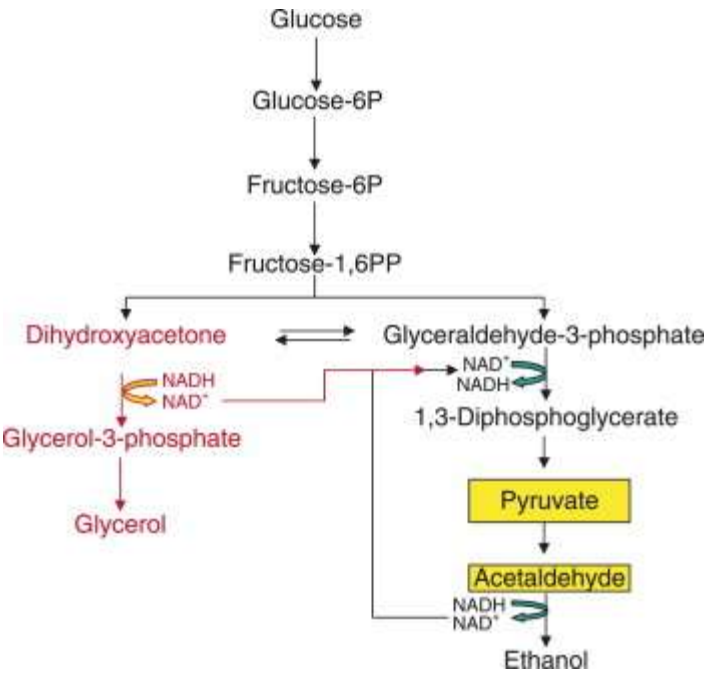
Adenosine diphosphate (ADP) = Adenosine pyrophosphate (APP)

Figure 1 Glycolysis



- In yeast cells undergoing alcoholic fermentation of sugars under anaerobic conditions, NAD+ is regenerated in terminal step reactions from pyruvate. In the first of these, pyruvate is decarboxylated (by pyruvate decarboxylase) before a final reduction, catalyzed by alcohol dehydrogenase (ADH) to ethanol (Figure 2). Such regeneration of NAD+ prevents glycolysis from stalling and maintains the cell's oxidation–reduction balance and ATP production. Additional minor fermentation metabolites are produced by fermenting yeast cells, including glycerol, fusel alcohols (e.g. isoamyl alcohol), esters, (e.g. ethyl acetate), organic acids (e.g. citrate, succinate, acetate), and aldehydes (e.g. acetaldehyde). Such compounds are important in flavor development in alcoholic beverages such as beer, wine, and whisky.

Figure 2 Glycolysis and anaerobic fermentation



- Fungal respiration, is the major energy-yielding metabolic route and involves glycolysis, the citric acid cycle [also known as tricarboxylic acid (TCA) cycle, Krebs cycle], the electron transport chain, and oxidative phosphorylation (Figure 3). In addition to glucose, many carbon substrates can be respired by fungi including: pentose sugars (e.g. xylose), sugar alcohols (e.g. glycerol), organic acids (e.g. acetic acid), aliphatic alcohols (e.g. methanol, ethanol), hydrocarbons (e.g. n-alkanes), and aromatic compounds (e.g. phenol). Fatty acids are made available for fungal catabolism following extracellular lipolysis of fats and are metabolized by β-oxidation in mitochondria (figure 4)
- TCA cycle is a series of chemical reactions to release stored energy through the oxidation of acetyl-CoA derived from carbohydrates, fats, and proteins (Figure 3).

Ecology and Fungal Physiology

LECTURE- 4 **Dr. Hebba Al-Lami**

- The electron transport chain is a series of four protein complexes that couple redox reactions, creating an electrochemical gradient that leads to the creation of ATP in a complete system named oxidative phosphorylation (Figure 3,4).
- Oxidative phosphorylation is the process in which ATP is formed as a result of the transfer of electrons from NADH or FADH $_2$ to O $_2$ by a series of electron carriers (Figure 3,4).

Figure 3 Aerobic dissimilation of glucose by fungi (respiration)

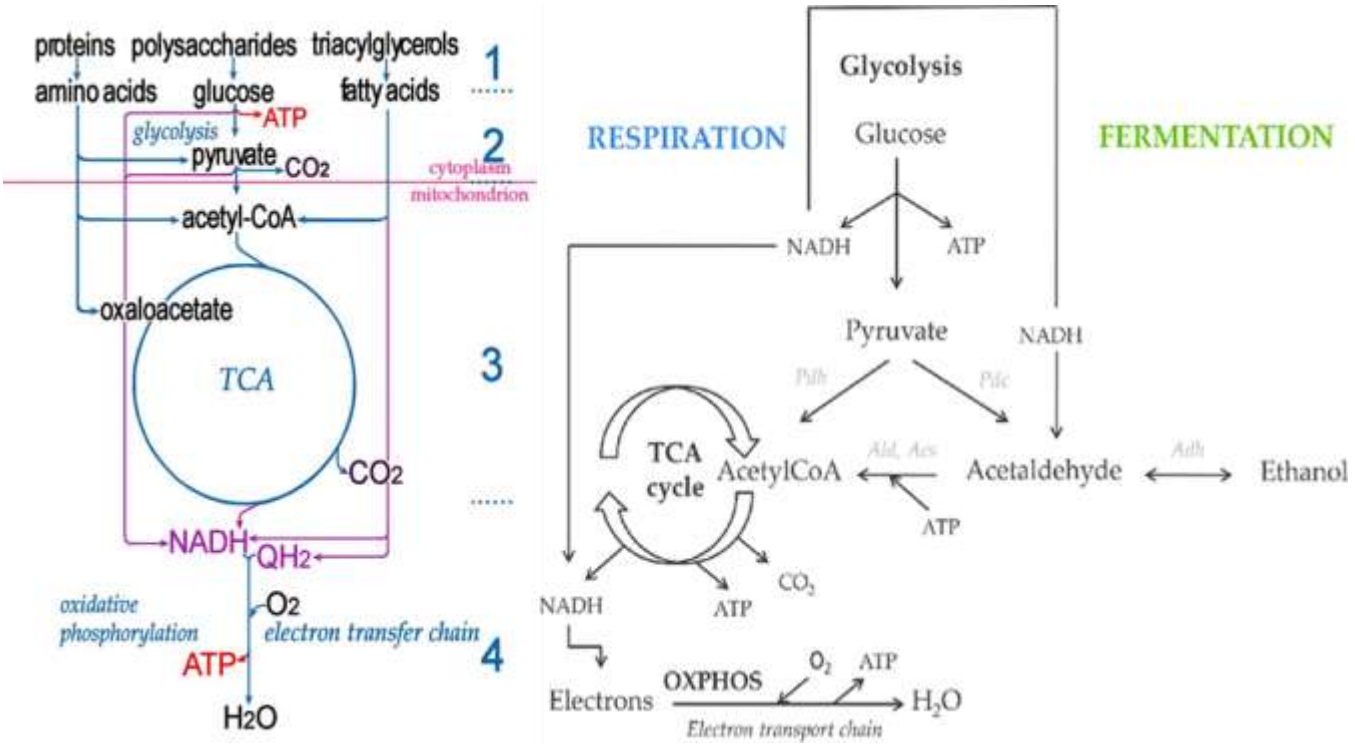
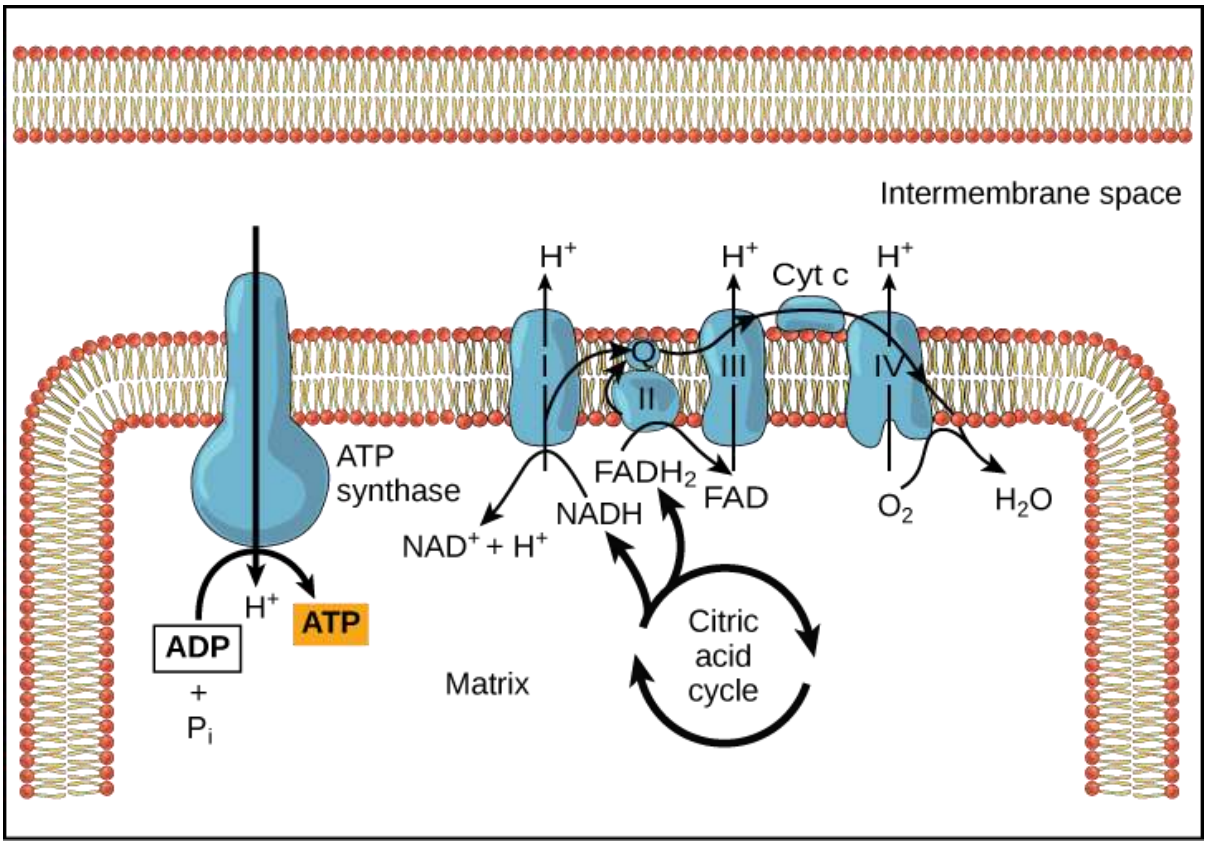


Figure 4 electron transport chain and Oxidative phosphorylation



3.2 Nitrogen Metabolism

Fungi assimilate simple nitrogenous sources for the biosynthesis of amino acids and proteins. For example, ammonium ions are readily utilized and can be directly assimilated into the amino acids glutamate and glutamine that serve as precursors for the biosynthesis of other amino acids. Proteins, urea, ammonia and nitrate can also be utilized nitrogenous sources. Some examples of enzyme systems produced by fungi for the degradation of nitrogenous sources:

Ecology and Fungal Physiology

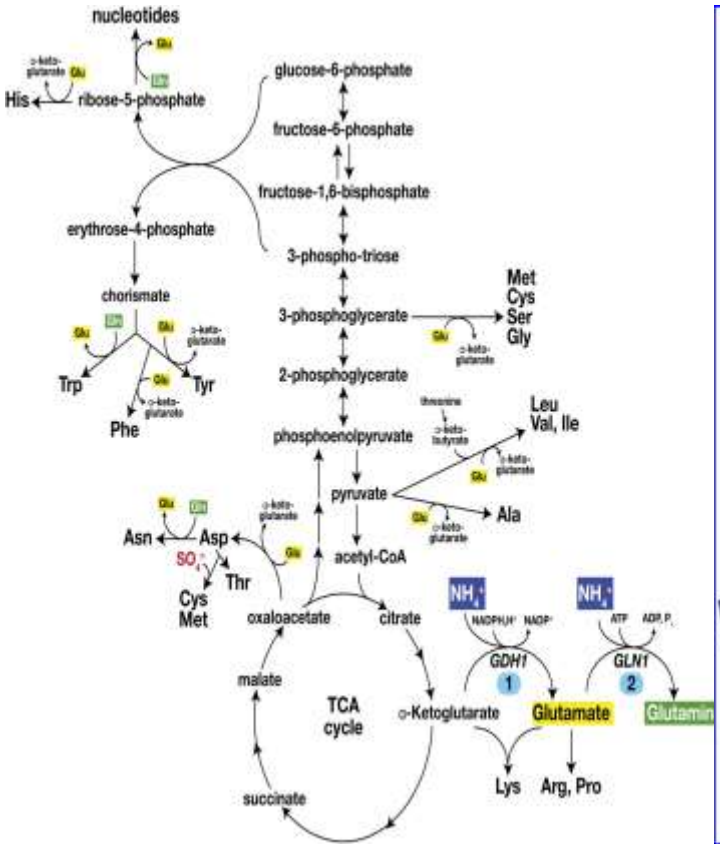
LECTURE- 4 **Dr. Hebba Al-Lami**

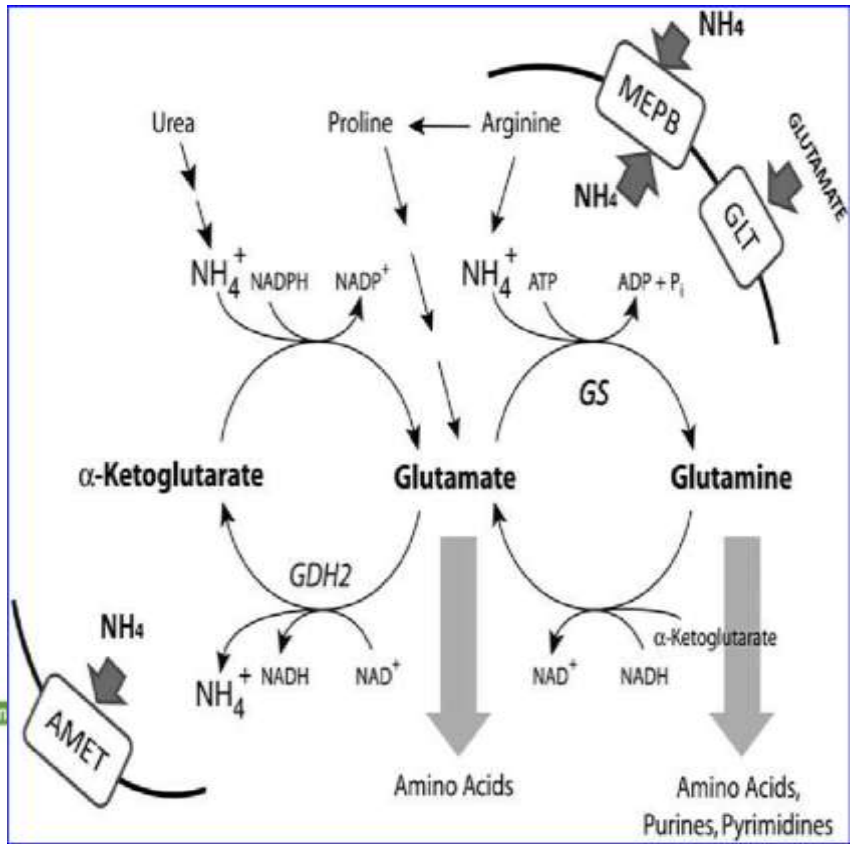
Protein —(Extracellular protease)→ smaller peptides and amino acids

Glutamate —(Glutamate dehydrogenase (GDH))→ α-ketoglutarate and ammonia

Ammonia —(glutamine synthetase + glutamate synthase)→ amino acids + TCA cycle intermediates

Figure 5 Nitrogen Metabolism pathway





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