Metabolism

Metabolism - the sum of all chemical processes carried out by living cells .
Microbial metabolism : all chemical changes occurring in a microbe during its growth and development for healthy and stable maintenance occurring for activities such as :
• Movement
• Growth
• Synthesis
• Foodstuff
• Reproduction

- **Catabolism** - the chemical reactions that break larger molecules into smaller molecules. It is usually an exergonic process.
- **Anabolism** - the chemical reactions that form larger molecules from smaller molecules. It is usually an endergonic process.

Autotroph - an organism that obtains its energy from sunlight or inorganic chemicals. Plants, photosynthetic protists, and photosynthetic prokaryotes are autotrophs.
Heterotroph - an organism that obtains its energy by consuming and degrading organic molecules. Some eat other organisms, some parasitize, and some degrade the remains of once living organisms. Animals, Fungi, many protests and most prokaryotes are heterotrophs.

- Glucose is the preferred energy source of all organisms and it is the principal product of photosynthesis. Glucose breakdown can be aerobic (using oxygen) or anaerobic (without oxygen). Anaerobic metabolism of glucose is also known as **anaerobic glycolysis** or **fermentation**.

Aerobic metabolism of glucose is known as **glycolysis and respiration**.
Complete aerobic metabolism of glucose produces water and carbon dioxide as products.

- $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

  Energy is released in this process. The overall ΔG of glucose breakdown in cells is -720 kcal/mole. Normally about 32% of the energy released is captured through the formation of ATP. The remainder is released as heat

  All microbial metabolisms can be arranged according to three principles:

  1. How the organism obtains carbon for synthesizing cell mass:
  • autotrophic – carbon is obtained from carbon dioxide (CO_2)

• heterotrophic – carbon is obtained from organic compounds
• mixotrophic – carbon is obtained from both organic compounds and by fixing carbon dioxide
2. How the organism obtains reducing equivalents used either in energy conservation or in biosynthetic reactions:
• lithotrophic – reducing equivalents are obtained from inorganic compounds
• organotrophic – reducing equivalents are obtained from organic compounds
3. How the organism obtains energy for living and growing:
• chemotrophic – energy is obtained from external chemical compounds
• phototrophic – energy is obtained from light

Respiration

Respiration is a type of heterotrophic metabolism that uses oxygen and in which 38 moles of ATP are derived from the oxidation of 1 mole of glucose, yielding 380,000 cal.

Fermentation

In fermentation, another type of heterotrophic metabolism, an organic compound rather than oxygen is the terminal electron (or hydrogen) acceptor.

Less energy is generated from this incomplete form of glucose oxidation, but the process supports anaerobic growth.

Krebs Cycle

The Krebs cycle is the oxidative process in respiration by which pyruvate (via acetyl coenzyme A) is completely decarboxylated to CO2. The pathway yields 15 moles of ATP (150,000 calories).

• **Glyoxylate Cycle**

The glyoxylate cycle, which occurs in some bacteria, is a modification of the Krebs cycle. Acetyl coenzyme A is generated directly from oxidation of fatty acids or other lipid compounds.

Acetyl CoA Formation

• Pyruvic acid is decarboxylated by the removal of CO2 into a two carbon acetyl group
• Occurs in the mitochondria of the cell

Electron Transport

• Involves electron carrier molecules that will release energy in a controlled way
• This energy is used to generate ATP
• Occurs inner mitochondrial membrane

• Chemiosmosis

Glucose Anabolism
• Glycogenesis - conversion of glucose to glycogen; stimulated by insulin
• Glycogenolysis - hydrolysis of glycogen to form glucose; stimulated by glucagon
• Gluconeogenesis - synthesis of glucose from non-carbohydrates such as fats and amino acids

Lipid Catabolism - Lipolysis
• Hydrolysis of triglycerides into glycerol and fatty acids

Glycerol converted to G 3-P and then into pyruvic acid, then into the Kreb's cycle

Beta -oxidation of fatty acids occurs forming two-carbon fragments which is then attached to coenzyme A, forming acetyl CoA

Protein Metabolism
• Proteins are converted into substances that can enter the Kreb's cycle by
• deamination - loss of (NH2) from amino group
• decarboxylation - loss of CO2 molecule
• dehydrogenation - loss of hydrogen atom
• Protein synthesis involves transcription and translation

Bacterial growth
Bacteria multiply by simple processing unlike eukaryotic cells. They reproduce by binary fission, a process by which one parent cell divides to form two progeny cells.
The time required to give two daughter cells is called generation time (doubling time); which is different according to bacterial species, nutrition, temperature, pH and other nutritional factors. For example, generation time of *Escherichia coli* is 20 minutes, *Mycobacterium tuberculosis* is more than 20 hours, and *Mycobacterium leprae* is 20 days.

Phases of bacterial growth cycle:
A- Lag phase (adaptation phase):
During this phase metabolic activity occurs but cells do not divide. It is characterized by:
1. Increase in metabolic rate.

2. Increase in size of cell, but not increase in number of cells (zero growth).

B- Log phase (logarithmic phase):

Rapid cell division occur in this phase, that characterize by

1. Bacteria have high rate of metabolism activity.
2. High rate of growth, and increase number of cells (positive growth).

The β-lactam drugs such as penicillin act during this phase because the drugs are effective when cells are making peptidoglycan for cell wall.

C- Stationary phase:

The number of new cells produced balance the number of cells that die leading to steady state.

Because multiplication and death of cells almost equal in this phase, so called (zero growth). It may be due to depletion of nutrients, or accumulation of toxic products.

D- Decline phase:

During the final stage of bacteria, decrease in number of viable bacteria (negative growth) due to death of cells .

The factors responsible for this phase are:

1. Nutritional exhaustion.
2. End products are increased (toxic accumulation).
3. Autolytic enzymes are common in this phase.
4. Decrease in O2 concentration, and increase in CO2 concentration.
5. Unfavorable ion equilibrium develops (e.g. unflavored pH).

Aerobic and anaerobic growth:

The organisms may inhabit at different ecosystems depending on their requirement of oxygen and other growth factors to obtain energy. However, they are classified into one of three categories :

Obligate aerobes:

- They require oxygen to grow because their ATP- generating system in respiratory pathway is depending on oxygen as hydrogen acceptor (final electron acceptor) in final steps of energy production catalyzed by flavoprotein and cytochrome.
- Because the use of oxygen generates two toxic molecules : hydrogen peroxide (H_2O_2) and free radical superoxide (O_2-). The toxicity of oxygen result from its reduction by enzymes in the cell such as flavoprotein, to hydrogen peroxide and even more toxic free radical superoxide. Accumulation of hydrogen peroxide can cause damage of DNA.
- Aerobes are protected from these products by produce catalase and superoxide dismutase. They require two enzymes to utilize oxygen.

First is superoxide dismutase (SOD), which catalyzes the combination of two molecules of O_2- to form H_2O_2.

$O_2^- + O_2^- \longrightarrow 2H^+ H_2O_2 + O_2$

Second is catalase which catalyzes the reaction

$2\ H_2O_2 \longrightarrow 2H_2O + O_2$

Obligate anaerobes:

- They cannot grow in presence of oxygen because they lack either superoxide dismutase or catalase or both. However, they can use only fermentation pathway to obtain energy. They use variety of small organic molecules such as pyruvate as final electron acceptors.
- Because lack catalase they inability to utilize oxygen and result in accumulation of H2O2 in toxic concentration. They also lack superoxide dismutase that permits accumulation of toxic free radical superoxide.

Facultative organisms:

- They can grow in presence or absence of oxygen.
- They utilize oxygen to generate energy by respiration if it is present, but they can use the fermentation pathway to synthesize ATP in absence of oxygen.