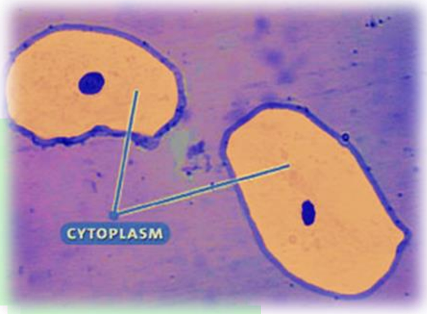
# LEC. 2 | COMPONENTS OF THE CELL (Pt.I)

### The Structure and Function of the
## Cytoplasm, Mitochondria VS Chloroplast and Lysosome

## INTRODUCTION

### The Cytoplasm




Basically, all animal cells can be divided into two major compartments, the **Nucleus** and the **Cytoplasm**. The term **Protoplasm** refers to the entire contents of the cell. The nucleus resides within the interior of the cell, is surrounded by a **Nuclear Envelope**, and contains **Nucleoplasm**. It is from the nucleus that genetic instructions are conveyed to the rest of the cell. The cytoplasm is the region outside the nucleus. It is divided into a deep **Endoplasm**, surrounding the nucleus, and a thin superficial **Ectoplasm**, just beneath the cell membrane. There is no sharp boundary between the two. It is within the cytoplasm that the genetic instructions from the nucleus are implemented to maintain essential cellular processes.

The cytoplasm contains many cell organelles of which we shall learn about:

1. Those that trap and release energy e.g. **Mitochondria** and **Chloroplasts**.
2. Those that are secretory or involved in synthesis and transport e.g. **Golgi**, **ribosomes** and **endoplasmic reticulum**
3. The organelles for motility (**Cilia** and **Flagella**).
4. The suicidal bags i.e. **Lysosomes**.
5. The **Nucleus** which controls all activities of the cell, and carries the hereditary material

### Functions of the Cytoplasm

- Regulates exchange of material outside the cell
- Biosynthesis of macromolecules
- Generation of energy
- Cell movement

### Components of the Cytoplasm

- Cytoplasmic organelles
- Cytoplasmic inclusions
- Cytoplasmic matrix or cytosol

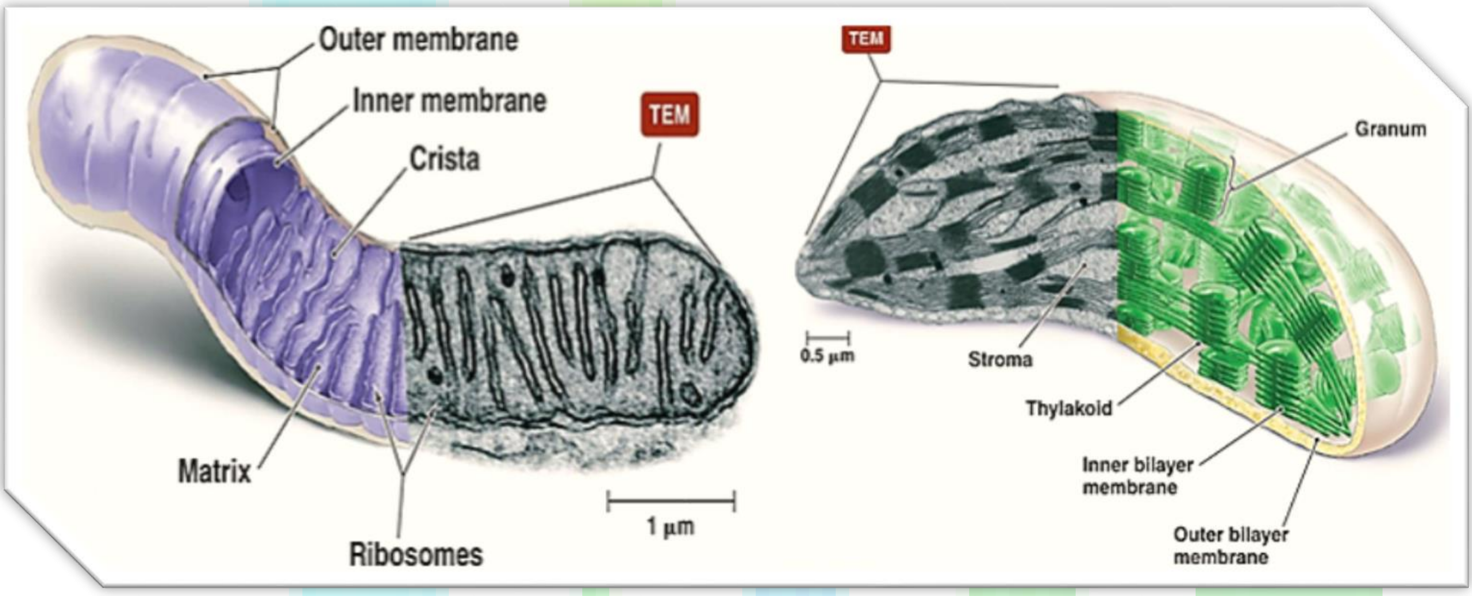
# Cytoplasm, Mitochondria VS Chloroplast and Lysosome

## Cytosol vs Cytoplasm

1. Cytosol is the intra-cellular fluid that is present inside the cells. On the other hand, cytoplasm is that part of the cell which is contained within the entire cell membrane.
2. Cytosol comprises of a lot of water, dissolved ions, large water soluble molecules, smaller minute molecules and proteins. Cytoplasm on the other hand is made of water up to 80% nucleic acids, enzymes, lipids, non-organic ions, amino acids, carbohydrates, and lightweight molecular compounds.
3. It is in the cytosol that all the metabolic chemical reactions of prokaryotes take place. On the contrary large scale cellular activities including glycolis, cell division and other metabolic paths take place in the cytoplasm.

# LEC. 3 | COMPONENTS OF THE CELL (Pt.I)

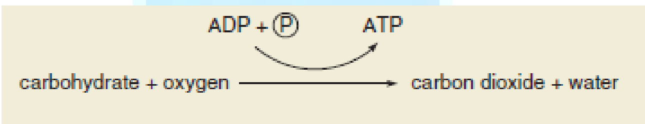
## The Structure and Function of the Mitochondria VS Chloroplast

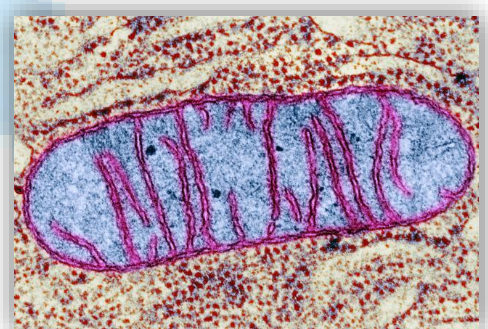



## INTRODUCTION

### The Mitochondria

Bounded by a double membrane. The inner membrane is folded to form little shelves called cristae, which project into the matrix, an inner space filled with a gel-like fluid. Mitochondria are the site of ATP (adenosine triphosphate) production involving complex metabolic pathways. As you know, ATP molecules are the common carrier of energy in cells. A shorthand way to indicate the chemical transformation that involves mitochondria is as follows:



Mitochondria are often called the powerhouses of the cell: Just as a powerhouse burns fuel to produce electricity, the mitochondria convert the chemical energy of carbohydrate molecules into the chemical energy of ATP molecules. In the process, mitochondria use up oxygen and give off carbon dioxide and water. The oxygen you breathe in enters cells and

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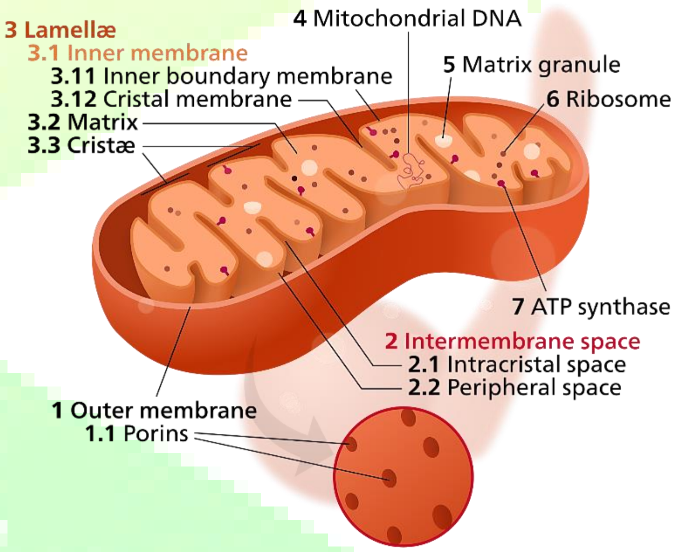



then mitochondria; the carbon dioxide you breathe out is released by mitochondria. Because oxygen is used up and carbon dioxide is released, we say that mitochondria carry on **Cellular Respiration**. Fragments of digested carbohydrate, protein, and lipid enter the mitochondrial matrix from the cytoplasm. The matrix contains enzymes for metabolizing these fragments to carbon dioxide and water. Energy released from metabolism is used for ATP production, which occurs at the cristae. The protein complexes that aid in the conversion of energy are located in an assembly-line fashion on these membranous shelves. Every cell uses a certain amount of ATP energy to synthesize molecules, but many cells use ATP to carry out their specialized functions. For example, muscle cells use ATP for muscle contraction, which produces movement, and nerve cells use it for the conduction of nerve impulses, which make us aware of our environment.

## Eukaryotic Cells Possess a Nucleus and Membrane-Bound Organelles

The specialized compartments called organelles exist within eukaryotic cells for this purpose. Different organelles play different roles in the cell for instance, mitochondria generate energy from food molecules; lysosomes break down and recycle organelles and **Macromolecules**; and the endoplasmic reticulum helps build membranes and transport proteins throughout the cell. But what characteristics do all organelles have in common? And why was the development of three particular organelles the nucleus, the **Mitochondrion**, and the **Chloroplast** so essential to the evolution of present-day eukaryotes

## Why Are Mitochondria and Chloroplasts Special?

Besides the nucleus, two other organelles the mitochondrion and the chloroplast play an especially important role in eukaryotic cells. These specialized structures are enclosed by double membranes, and they are believed to have originated back when all living things on Earth were single-celled organisms. At that time, some larger eukaryotic cells with flexible membranes "ate" by engulfing molecules and smaller cells and scientists believe that mitochondria and chloroplasts arose as a result of this process. In particular, researchers think that some of these "eater" eukaryotes engulfed smaller prokaryotes, and a symbiotic relationship subsequently developed. Once kidnapped, the "eaten" prokaryotes continued to generate energy and carry out other

necessary cellular functions, and the host eukaryotes came to rely on the contribution of the "eaten" cells. Over many generations, the descendants of the eukaryotes developed mechanisms to further support this system, and concurrently, the descendants of the engulfed prokaryotes lost the ability to survive on their own, evolving into present-day mitochondria and chloroplasts. This proposed origin of mitochondria and chloroplasts is known as the **Endosymbiotic Hypothesis** (Lec. 1).

In addition to double membranes, mitochondria and chloroplasts also retain small genomes with some resemblance to those found in modern prokaryotes. This finding provides yet additional evidence that these organelles probably originated as self-sufficient single-celled organisms. Today, mitochondria are found in fungi, plants, and animals, and they use oxygen to produce energy in the form of ATP molecules, which cells then employ to drive many processes. Scientists believe that mitochondria evolved from **Aerobic**, or oxygen-consuming, prokaryotes. In comparison, chloroplasts are found in plant cells and some algae, and they convert solar energy into energy-storing sugars such as glucose. Chloroplasts also produce oxygen, which makes them necessary for all life as we know it. Scientists think chloroplasts evolved from **Photosynthetic** prokaryotes similar to modern-day **Cyanobacteria**. Today, we classify prokaryotes and eukaryotes based on differences in their cellular contents. In prokaryotes, the DNA (chromosome) is in contact with the cellular cytoplasm and is not in a housed membrane-bound nucleus. In eukaryotes, however, the DNA takes the form of compact chromosomes separated from the rest of the cell by a nuclear membrane (also called a nuclear envelope). Eukaryotic cells also contain a variety of structures and organelles not present in prokaryotic cells. Throughout the course of evolution, organelles such as mitochondria and chloroplasts (a form of plastid) may have arisen from engulfed prokaryotes.

## How Do Eukaryotic Cells Handle Energy?

Mitochondria often called the powerhouses of the cell enable eukaryotes to make more efficient use of food sources than their prokaryotic counterparts. That's because these organelles greatly expand the amount of membrane used for energy generating electron transport chains. In addition, mitochondria use a process called **Oxidative Metabolism** to convert food into energy, and oxidative metabolism yields more energy per food molecule than non-oxygen-using, or **Anaerobic**, methods. Energy wise, cells with mitochondria can therefore afford to be bigger than cells without mitochondria. Within eukaryotic cells, mitochondria function somewhat like batteries, because they convert energy from one form to another: food nutrients to ATP. Accordingly, cells with high metabolic needs can meet their higher energy demands by increasing the number of mitochondria they contain. For example, muscle cells in people who exercise

regularly possess more mitochondria than muscle cells in sedentary people. Prokaryotes, on the other hand, don't have mitochondria for energy production, so they must rely on their immediate environment to obtain usable energy. Prokaryotes generally use electron transport chains in their plasma membranes to provide much of their energy. The actual energy donors and acceptors for these electron transport chains are quite variable, reflecting the diverse range of habitats where prokaryotes live. (In aerobic prokaryotes, electrons are transferred to oxygen, much as in the mitochondria.) The challenges associated with energy generation limit the size of prokaryotes. As these cells grow larger in volume, their energy needs increase proportionally. However, as they increase in size, their surface area and thus their ability to both take in nutrients and transport electrons does not increase to the same degree as their volume. As a result, prokaryotic cells tend to be small so that they can effectively manage the balancing act between energy supply and demand.

## SUMMERY

### Mitochondria and chloroplast - the energy transformers

Mitochondria (found in plant and animal cells) are the energy releasers and the chloroplasts (found only in green plant cells) are the energy trappers.

## Mitochondria (Singular = mitochondrion)

Appear as tiny thread like structure under light microscope. Approximately 0.5 - 1.00 µm (micrometer) Number usually a few hundred to a few thousand per cell (smallest number is just one as in an alga (**Micromonas**)).

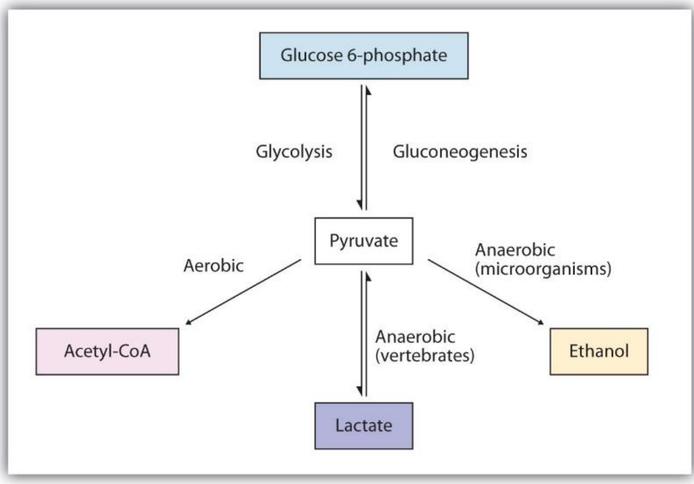
### Structure:

The general plan of the internal structure of a mitochondria observed by means of electron microscope. Note the following parts.

- Wall made of double membrane
- The inner membrane is folded inside to form projections called cristae which project into the inner compartment called matrix.

### Function:

Oxidises pyruvic acid (breakdown product of glucose) to release energy which gets stored in the form of ATP for ready use. This process is also called **cellular respiration**.



# Cytoplasm, Mitochondria VS Chloroplast and Lysosome

A highly simplified flow-chart of the fate of glucose to in the release energy is shown in the right.

## The Mitochondrion

The next membranous organelle we will consider is the mitochondrion. The principal means by which the cell obtains energy for its metabolic processes is through the oxidation of nutrients to form energy-rich molecules of **adenosine triphosphate (ATP)**. This process is called **oxidative phosphorylation** and it occurs in the mitochondria: Mitochondria are 5-10 µm long and 0.5-1 µm in diameter.

They are found in almost all cells, though the number of mitochondria per cell, as well as their individual size and shape, are characteristic of each cell type. In general, the number of mitochondria reflects the energy requirements of a given cell. For example, heart muscle contains many mitochondria, whereas lymphocytes contain few.

Ultra-structurally, the mitochondrion is surrounded by two unit membranes separated by an **intermembranous space**. The **outer mitochondrial membrane** is fairly permeable, but the **inner mitochondrial membrane** is more selective. The inner membrane is convoluted into a series of self-like **cristae** that project into the **mitochondrial matrix**. On the surface of the cristae are numerous spherical projections, about 9 nm in diameter, supported on short stalks. These are called **elementary particles** and are thought to contain the enzyme complex that couples electron transport to oxidative phosphorylation.

During the enzymatic conversion of food to products of the citric acid cycle, numerous electrons are liberated and passed down the electron transport chain of proteins. This is accompanied by a flow of protons from the matrix into the intermembranous space, resulting in an **electrochemical proton gradient** across the inner mitochondrial membrane. These accumulated protons then flow in the reverse direction back down the electrochemical gradient and into the matrix by passing through channels in the enzyme complex of **ATP synthase**.

The energy inherent in this proton motive force drives the phosphorylation of ADP to ATP. The ultrastructural appearance of mitochondria is indicative of their functional state. For example, the **orthodox form** (prominent cristae and large matrix) is seen during low oxidative phosphorylation, and the **condensed form** (non-distinct cristae and large intermembranous space) is seen during high oxidative phosphorylation. Mitochondrial morphology is also a very sensitive indicator of cell injury. During cell stress, **cytochrome C** is released from the intermembranous space into the cytoplasm, initiating a cascade of events leading to cell death via **apoptosis**.

## Contents of the mitochondrial matrix

- **Matrix granules**, which are thought to represent accumulations of divalent cations, mostly **calcium**. This suggests that the mitochondria help regulate calcium levels in the cytoplasm.
- **Various enzymes**, including those of the **citric acid cycle**
- **DNA, RNA, and ribosomes**, which are similar to those found in bacteria. This suggests that mitochondria may have evolved from aerobic bacteria that somehow became incorporated into animal cells. In fact, mitochondria divide independently of cell division, further evidence for a once autonomous existence.

## Plastids

Plastids are found only in a plant cell. They may be colorless or with color. Based on this fact, there are three types of plastids.
(i) Leucoplast-white or colorless
(ii) Chromoplast blue, red, yellow etc.
(iii) Chloroplast – green

# Chloroplast

- Found in all green plant cells in the cytoplasm.
- Number 1 to 1008
- Shape: Usually disc-shaped or spherical as in most plants around you. In some ribbon

Note the following parts:

- Wall made of double membrane i.e. outer membrane and inner membrane numerous stack-like (piles) groups or *grana* (singular = granum) are interconnected by *lamellae*.
- Sac like structures called thylakoids placed one above the other constitute granum.
- Inside of the chloroplast is filled with a fluid medium called stoma.
- Function: chloroplasts are the seat of photosynthesis (production of sugar, from carbon dioxide and water in the presence of sunlight).

**Chloroplast versus mitochondria**

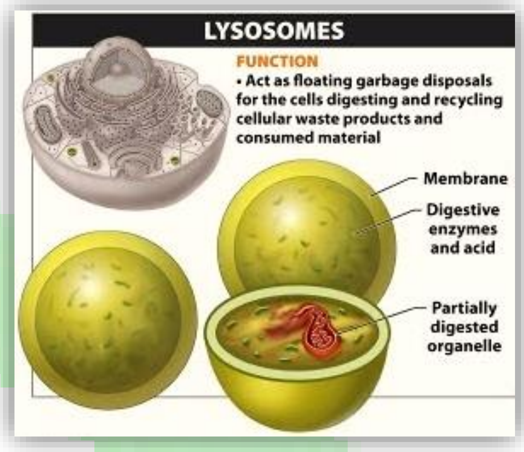
Can you now visualize how these two organelles are opposite to each other, one traps the solar energy locking it in a complex molecule (by photosynthesis), and the other releases the energy by breaking the complex molecule (by respiration).

**Similarities between mitochondria and chloroplasts**

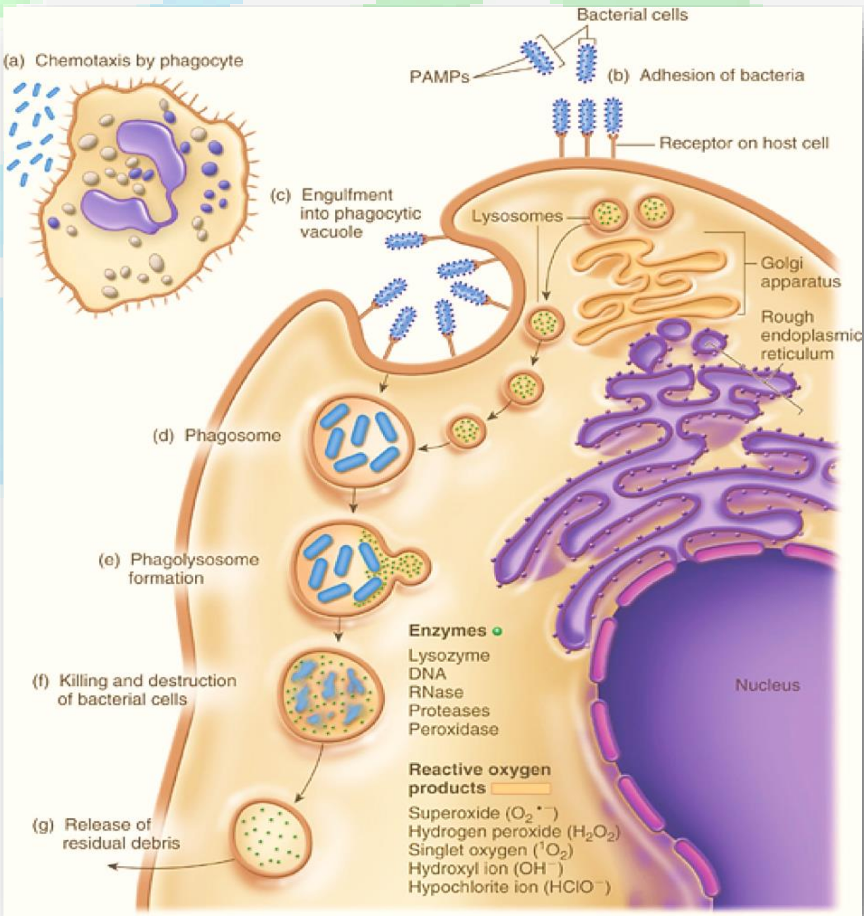
Both contain their own DNA (the genetic material) as well as their own RNA (for protein synthesis). Thus, they can self-duplicate to produce more of their own kind without the

help of nucleus. Since chloroplasts and mitochondria contain their own DNA the hereditary molecule and also their own ribosomes, they are termed semi-autonomous only because they are incapable of independent existence though they have ribosomes and DNA.

## Lysosome




Lysosome, subcellular organelle that is found in nearly all types of eukaryotic cells (cells with a clearly defined nucleus) and that is responsible for the digestion of macromolecules, old cell parts, and microorganisms. Each lysosome is surrounded by a membrane that maintains an acidic environment within the interior via a proton pump. Lysosomes contain a wide variety of hydrolytic enzymes (acid hydrolases) that break down macromolecules such as nucleic acids, proteins, and polysaccharides. These enzymes are active only in the lysosome's acidic interior; their acid-dependent activity protects the cell from self-degradation in case of lysosomal leakage or rupture, since the pH of the cell is neutral to slightly alkaline. Lysosomes were discovered by the Belgian cytologist Christian René de Duve in the 1950s. (De Duve was awarded a share of the 1974 Nobel Prize for Physiology or Medicine for his discovery of lysosomes and other organelles known as peroxisomes).




Lysosomes originate by budding off from the membrane of the trans-Golgi network, a region of the Golgi complex responsible for sorting newly synthesized proteins, which may be designated for use in

lysosomes, endosomes, or the plasma membrane. The lysosomes then fuse with membrane vesicles that derive from one of three pathways: endocytosis, autophagocytosis, and phagocytosis. In endocytosis, extracellular macromolecules are taken up into the cell to form membrane-bound vesicles called endosomes that fuse with lysosomes. Autophagocytosis is the process by which old organelles and malfunctioning cellular parts are removed from a cell; they are enveloped by internal membranes that then fuse with lysosomes. Phagocytosis is carried out by specialized cells (e.g., macrophages) that engulf large extracellular particles, such as dead cells or foreign invaders (e.g., bacteria), and target them for lysosomal degradation. Many of the products of lysosomal digestion, such as amino acids and nucleotides, are recycled back to the cell for use in the synthesis of new cellular components.

Lysosomal storage diseases are genetic disorders in which a genetic mutation affects the activity of one or more of the acid hydrolases. In such diseases, the normal metabolism of specific macromolecules is blocked and the macromolecules accumulate inside the lysosomes, causing severe physiological damage or deformity. Hurler syndrome, which involves a defect in the metabolism of mucopolysaccharides, is a lysosomal storage disease.