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Bio. Sci. 4 - Microbiology
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Eukaryotic Cell Structure and Function:
(Part 1)

The science or study of cell structure and function is called **cytology**; but courses dealing with this topic frequently come under the heading of cell and molecular biology. Cytology has undergone extensive change over time.

The term **cell** (cella = a small room) was first used by **Robert Hooke** (1665) with reference to an empty space or chamber (like a prison cell). Hooke was observing the cell walls of dead cork cells from the bark of cork oaks, and not living cells. We now know cells are far from empty spaces.

According to the **cell theory**, as articulated by **Matthias Schleiden** and **Theodor Schwann** (1839), the cell is the basic unit of structure and function in all, living organisms. When first written, the cell theory indicated that living cells could arise spontaneously through abiogenesis, but experiments conducted by **Louis Pasteur** and others invalidated this concept. Instead, it is now recognized that all cells arise from preexisting cells, and that they carry hereditary information (DNA) that is passed from one generation to the next through cell division.

Cells are currently divided into two types, **Prokaryotic** and **Eukaryotic**. The term **karyon** (karyon = nucleus) appears in both names, and is preceded by either pro, meaning before or eu meaning well or truly. Fossil and molecular evidence indicates that prokaryotic cells evolved first, and that the larger, nucleated cells evolved later. Some of the distinguishing features of these two cell types are outlined below.

A typical prokaryotic cell (Before a nucleus):
Does not contain a nucleus surrounded by a nuclear membrane or envelope.
Contains one or more loops of covalently-closed circular DNA (ccc-DNA).
Is not compartmentalized by membranous organelles.
Contains 70S ribosomes.
Is surrounded by a membrane lacking cholesterol and involved in ATP synthesis, wall synthesis, taxis and other physiological activities.
Is usually smaller than a typical eukaryotic cell.

Bacteria and Archaea are prokaryotic organisms; however, the Archaea have membranes unlike other cells.

A typical eukaryotic cell (Well or truly nucleated):
Contains one or more true nuclei, each surrounded by a nuclear envelope.
Contains two or more linear chromosomes.
Is compartmentalized by many membranous organelles.
Contains 80S ribosomes.
Is surrounded by a membrane with cholesterol and not involved in the synthesis of ATP.
Is usually larger than a typical prokaryotic cell.

Microorganisms categorized as Protozoa, Algae and Fungi are made up of eukaryotic cells, as are all plants and animals including humans.

Since eukaryotic cells are more familiar to many students than are prokaryotic cells, these will be covered first. Each eukaryotic cell is surrounded by a cell membrane, and most have one or more true nuclei (though there are some exceptions). The region of protoplasm between the cell membrane and the nucleus is referred to as **cytoplasm**, while the protoplasm inside the nuclear membrane or envelope is called **nucleoplasm** (all is living substance). The cytoplasm is often highly compartmentalized by internal structures called **organelles** (organelles = little organs), and makes up the bulk of the cell. Organelles occur in a variety of shapes and sizes, and typically carry out specific functions (like the organs found within the human body). A number of the structures found within eukaryotic cells are outlined in the lecture syllabus. Keep in mind that not all of the structures listed are found within all types of eukaryotic cells.

1. **Cell membrane** – The cell membrane surrounds and limits the cell and has the structure and functions covered in an earlier section.

2. **Endoplasmic reticulum** – The endoplasmic reticulum (endo = inside, plasmic = cytoplasm, reticulum = network) is a membranous organelle extending from the nuclear envelope into the cytoplasm, and occasionally connecting to the cell membrane. In composition it is like the cell membrane, but includes two membrane layers separated by a thin space. In some cells, the endoplasmic reticulum is highly folded and takes up most of the cytoplasm.

   Functions associated with the smooth endoplasmic reticulum include storage, transport and the synthesis of lipids. Materials can be moved from place to place between the membrane layers, and portions of membrane can be transferred from the E.R. to other structures. Some regions of endoplasmic reticulum are covered with small, granular bodies called ribosomes This is called **rough endoplasmic reticulum** and **is involved in protein synthesis.**

3. **Ribosomes** – Ribosomes are small granular bodies composed of ribosomal-RNA and protein (ribo = ribose, the pentose monosaccharide found in RNA, soma = body). Eukaryotic ribosomes are 80S (the S referring to Svedburg units, a measure of density), and include two subunits of 60S and 40S. **Ribosomes are the site of protein synthesis**, so are essential to cell function. The two subunits come together only when proteins are being made, and those ribosomes associated with the rough endoplasmic reticulum are attached to the membranes by the proteins they are forming. Proteins formed by ribosomes bound to the rough E.R. are usually exported from the cell, while those formed by ribosomes free in the cytoplasm stay inside the cell. Protein synthesis will be described in detail later.

4. **Golgi complex** (apparatus or body) – The Golgi complex is an organelle composed of flat membranous sacs arranged in a stack and is essentially modified smooth endoplasmic reticulum. Like the E.R., the Golgi is involved in **transport** and **storage**, but is also the primary site of **polysaccharide synthesi**s. Membranous components and other materials passing from the E.R. (both smooth and rough) to the Golgi provide raw-materials for the **assembly of complex organic compounds** such as lipopolysaccharides, lipoproteins and glycoproteins. The Golgi is also involved in

packaging and secretion as segments of it can be pinched off to form vesicles, and these can move to the cell surface where their membranes fuse with the cell membrane. The materials contained within these vesicles can then exit the cell through **exocytosis.**

5. **Vacuoles and vesicles –** Vacuoles and vesicles are membranous organelles containing a variety of materials and formed in various ways. The term vacuole suggests an empty space (a vacuum) and in some cells (plants and algae) refers to a large, centrally located region filled with what appears to be clear fluid (the central vacuole). This structure helps maintain tugor pressure within cells and stores toxins that might interfere with metabolism. Vesicles are generally smaller than vacuoles, but the terminology associated with these membranous "bubbles" is inconsistent. Protozoa taking in food materials through endocytosis form **food vacuoles** or **pinocytic vesicles** depending on what was ingested. Both types of structures essentially store nutrients until they can be digested. The membranous fragments "pinched" from the Golgi are most commonly referred to as vesicles, and these carry various materials (waste products, digestive enzymes, etc.) toward the cell surface where they can be released through exocytosis. Lysosomes are formed by the Golgi complex.

6. **Contractile vacuoles** – Contractile vacuoles are organelles found commonly in fresh-water protozoa. They vary considerably in size and complexity, but often appear as circular structures that swell and shrink in a repeating pattern. The swelling occurs when the contractile vacuole is relaxed and filling (diastole), while the shrinking occurs when it contracts, pumping water out of the cell (systole). Contractile vacuoles pump excess water out, so function as **osmoregulatory structures**, preventing cells from bursting due to osmosis. They are connected to the smooth endoplasmic reticulum, so also **aid fluid circulation** within the cell. Since liquid wastes may be eliminated along with the water, contractile vacuoles may also have an **excretory function.**

7. **Lysosomes** – Lysosomes (lysis = to split, soma = body) are membranous organelles containing a variety of digestive enzymes (**hydrolases**) involved in the **hydrolysis** (catabolism) of organic compounds. Their primary function within microorganisms is the **digestion of food materials** taken in through endocytosis; however, they also degrade worn out organelles and help the cell recycle membrane components. The hydrolase enzymes carried within lysosomes are activated after the lysosome membrane binds with that of a food vacuole, and hydrogen ions are pumped in lowering the pH. Bacteria able to prevent this acidification can avoid digestion and may take up residence within the phagocytic cell. Lysosomes are formed and released by the Golgi complex.

8. **Peroxisomes** – Peroxisomes are membranous organelles containing enzymes involved in hydrogen peroxide metabolism. Some of these generate hydrogen peroxide by oxidizing organic compounds while others called **catalase enzymes** break down the hydrogen peroxide produced. Since hydrogen peroxide is toxic, the overall function of catalase enzymes is neutralizing toxins. Peroxisomes are not formed by the golgi complex, but are apparently self-replicating.

9. **Mitochondria** – Mitochondria (singular mitochondrion) are self-replicating organelles surrounded by double layers of membrane. Each mitochondrion has an outer membrane typical of eukaryotic cells and an inner membrane lacking cholesterol and carrying enzymes involved in ATP synthesis. The surface area of the inner membrane

is greatly increased by folds called **cristae**, and these are the site of oxidative phosphorylation (ATP synthesis involving the oxidation of coenzymes). Since quantities of ATP are produced by mitochondria, they are sometimes referred to as the "powerhouses of the cell".

In addition to their unique inner membranes, mitochondria have a number of other interesting features; they carry 70S ribosomes, have closed loops of DNA (ccc-DNA) and are damaged by antibacterial drugs. These features provide strong evidence that mitochondria evolved from prokaryotic cells taken in by larger eukaryotic organisms through endocytosis. Having avoided digestion (possibly by the mechanism mentioned above), they formed a permanent symbiotic relationship, beneficial to both them and their host organisms.

10. **Chloroplasts** – Chloroplasts, like mitochondria, are self-replicating organelles surrounded by double layers of membrane. Within each chloroplast, the inner membrane is folded into numerous sack-like structures called **thylakoids** containing light-trapping pigments and enzymes involved in ATP synthesis through photophosphorylation, a process dependent on light energy. Chloroplasts are only found in certain types of cells such as algae and green plants.

    Like mitochondria, chloroplasts carry 70S ribosomes, have ccc-DNA and are damaged by antibacterial drugs. They apparently evolved from several different types of cyanobacteria ingested by eukaryotes on more than one occasion, because not all chloroplasts carry the same types of light-trapping pigments. Chloroplasts represent another fine example of mutually beneficial symbiosis.

(end of Part 1)