I. THE CELL AND ITS PLACE IN THE BIOLOGICAL SYSTEMS

I.1. THE EVOLUTION OF THE CELL

Once Earth cooled sufficiently, molecules that would later form parts of living beings appeared on our planet. Over millions of years, these molecules slowly joined into units able to reproduce themselves, and the first cells were born. Today there are millions of types of cells in the organisms on Earth that involved from those early beginnings. Scientists are trying to unravel the complexity they pose, hoping to understand how surprisingly small constellation of molecules can produce such variety of structure and function.

Living systems, including the human body, consist of such closely interrelated elements that no single element can be fully appreciated in isolation from the others. Organisms contain organs; organs are composed of tissues; tissues consist of cells; and cells are formed from molecules, the most versatile of which are the proteins. At the top of this hierarchy of biological organization lie the genes. Genes do not only specify the structure of proteins, but they define the organization of cells, direct cells to form tissues and organs, and maintain the integration of function that gives the organism its unity. Genes are nothing more than a coded representation of the elements of life, a code written in four chemical letters and displayed as a continually varying sequence in the DNA molecule.

The unity of living systems is coordinated by many levels of interrelationships: molecules carry messages from organ to organ and cell to cell; tissues are delineated and integrated with other tissues by non-cellular membranes secreted by cells; cells gain identity from contact with other cells- generally all the levels into which we fragment biological systems interconnect. To learn about biological systems, we must take a segment at a time. A logical partition is to present the biology of cells as a unit, because an organism can be viewed as consisting of interacting cells, with cells being the closest thing to an autonomous biological unit we can define. Their autonomy is shown by our ability to grow dissociated cells in the laboratory in the absence of any of the normal organization in the living organism. The integration of cellular activity into tissues, the development of organisms by growth and specialization of cells, and the metabolic events fuelling the dynamics of living systems are all topics on which we will touch, but they are all topics that fall within the province of other branch in the tapestry of biological science.

The notion of cell as a central unit of biological organization is not just a didactic convenience. All organisms are made from cells and small organisms consisting of single cells. Cells can live in the absence of the rest of the organism from which they are taken and thus are truly alive. Organisms only grow by the growth and division of cells. This was all realised first by Matthias Schleiden, working with plants in 1838, and a year later by Theodor Schwann, who was studying animals. Rudolf Virchow, a German pathologist enunciated the cell theory, in all its glory, in 1858: ***"Every animal appears as the sum of vital units, each of which bears in itself the complete characteristics of life".***

Note that Virchow still clung to the idea inherited from the past that cells are "vital units", by which he meant that cells had a special property that endowed them with life. Today we know that living systems are composed of individual chemical constituents that work closely together to allow cells to function, grow and divide and we no longer need to think that life is a property separate from the constituent parts of cells.

Cells were seen earlier than the nineteenth century, but it was not realized how fundamental they were. In the last half of the seventeenth century, the Dutch naturalist Antonie van Leeuwenhoek, using a simple magnifying lens, first saw that pond water contained a wide array of what he called "animalcules". About the same time, Robert Hooke used the word "cells" to describe the units he saw in dead samples of cork, but it took almost two century of technical development of microscopes, tissue preservation, and tissue slicing before Scheiden and Schwann realised the generality of cellular organization.

I.2. SYSTEMIC THEORY

I.2.1. GENERAL CONSIDERATIONS

The basic idea of the systemic method is that matter, both lifeless and living is organised in hierarchical systems. According to L. von Bertalanffy's definition (1960), a system is "an assembly of interacting elements". Depending on the exchanges they have with the environment, the systems are classified in three categories: isolated, closed and open systems.

Isolated systems: are those systems which don't interact in any way with the environment (neither materially nor energetically). Such systems don't exist in nature.

Closed systems: are systems where only energetic exchanges take place and no material exchanges are carried out. For example, an hermetically sealed vessel with water will have only energetic and no material exchanges with the environment. From the systemic point of view, the cell is a biological, open system.

Open systems: are those systems which establish both material and energetic exchanges with the environment. From the systemic point of view, the cell is a biological, open system.

I.2.2. THE FEATURES OF THE SYSTEM

1. Historical Character

The first cells, archebacterium, appeared 3.5 billion years ago, and the eukaryotes appeared 1.5 billion years ago. The diversification of the living world began 600 billion years ago, the last philogenetic appearance as a species being ***homo sapiens sapiens*.**

2. Informational Character

Having an historical character, the biological systems inherit from the ancestor systems an important informational package, to which own information is added, gained from the relation between each system and the environment. The informational unit of the cell is inscribed in the genetic code and is represented by the codon (a codon signifies an amino acid).

3. Programme Character

This feature is to the structural and functional capacities of the system. These internal factors determine the reaction of the system to external stimuli that is the way the system will respond to the environment. The fact that any system has more possible states means that it also has more programs. In any system there can be recognized three categories of programs:

- programs for oneself, which are structural, functional programs, ensuring the self-preservation of the given system;
- inferior programs, meaning the programs of the component subsystems of the body;
- superior programs, for an organism, this category includes the programs which ensure the reproduction and the multiplying of the organisms, therefore, the fulfilling of their function in the life of the species.

4. The Character of the Dynamic Equilibrium

The dynamic equilibrium represents the state of continuous joining of stability and change; every moment the system is different because of the exchanges with the environment. When dynamic equilibrium ceases to exist, the system dies.

5. Integrality Character

Consists of the sum of the characteristics, owned by the components, to which new structural and functional features are added, resulting from the interaction of the component parts of the system.

6. Self-regulating Character

Self-regulation is the capacity of the system for controlling its internal process while interacting with the environment, in order to maintain the homeostasis, the integrality and the dynamic equilibrium.

Self-regulation can be accomplished in 2 ways:

- **the direct connection**: the environmental stimuli act on the receptor; this sends the message to the control and processing centre on the afferent path ; from here, on the efferent path the message is carried away to the effecter which makes the response.

- **reverse connection**: for the self regulation to become possible, the system's responses must be compared on either one path or the other with the command. This is realised by reverse connection or feedback.

At cellular level self regulation is being performed in 3 ways:

-direct connection

-reverse connection

-structural control: is being realising based on the cellular membranes (ectomembrane and endomembrane) which divide the cell into compartments.

The efflux and influx of matter and energy can be held under control because of the selective permeability of the membranes

In other words, the cell could be compared with a big "processing unit" and each organelle with a reaction vessel in which specific reactions take place due to specific enzymes; the reactions are maintained at this level because of the division realized by the membranes.

7. **The Heterogeneity Character**

Heterogeneity represents the fact that systems can consist of more components, that is they can be more or less heterogeneous.

I.3. THE MOLECULES OF LIFE

The life of a cell is a complicated orchestration of many events. These include a multitude of specific chemical transformations, provision of sufficient energy, formation of organelles, and movement of materials to their appointed place in the cell, and growth and division when new cells are needed. Many life-threatening diseases result from apparently small mistakes in these processes: phenylketonuria when a dietary constituent cannot be digested; cystic fibrosis when an ion channel made in the cytoplasm is unable to make its way to the cell surface; sickle cell disease when haemoglobin precipitates inside red cells rather than being soluble; muscular dystrophy when a molecule that should help organize the interior of muscle cells is not functional. To keep all cells in the body in appropriate condition so that the whole organism can function requires complex and precise directions.

To appreciate how evolution has provided the directions that allow the cell to carry out its myriad activities, we need first to consider the implications of a central dichotomy of cellular life: there are two fundamentally different types of molecules in cells, small molecules and macromolecules, and they are formed in cells by two different types of synthetic processes. Small molecules are made and altered by individual steps of chemical transformation; these can be so extensive that a vegetarian diet can support the growth of an animal. Macromolecules, in contrast, are linear polymers made by linking a defined set of small molecules (monomers) together through repetitive use of a single chemical linkage step.

Small molecules and macromolecules play fundamentally different roles in the cell. The key function of small molecules is to be the substrates for making macromolecules, and cell is careful to provide the mix of small molecules needed for macromolecular synthesis. Small molecules also do things in their own right; for instance, they store and distribute the energy for all cellular processes, and they are broken down to extract chemical energy, as when sugar is degraded to CO_2 and H_2O with the release of the energy bound up in the molecule. Small molecules can act as signals to cells; nerve cells communicate with each other by releasing and sensing small molecules, and the powerful effect on our body of a frightening event comes from the instantaneous flooding of the body with a small molecule hormone that mobilizes the "fight or flight response".

Macromolecules, though, are the most interesting and characteristic molecules of living systems; in a true sense the evolution of life as we know it is the evolution of macromolecular structures. The chief macromolecules in the cell, in terms of variety of function, are the proteins. Proteins are the doers of the cell; they catalyze small molecule transformations, allow cells to move and do work, and maintain internal cell rigidity. Moreover, proteins control the genes that determine cell constitution and function, move molecules across membranes, and even direct synthesis of themselves and other macromolecules. They come in many shapes and size, and the elucidation of their structure remains one of the most active areas of scientific investigation. Proteins are actually polymerized from only 20 types of monomers (amino acids). That such a limited set of building blocks can do so much is a continual marvel, even to those who work daily with proteins. They are the true glory of the biological world.

The macromolecule about which we most often read in the news is not protein but DNA. This molecule is extraordinary on many counts and thus easily captures the imagination of writers and even artists. Not only does its double-helical structure make it one of nature's most magnificent constructions, but its functional properties also make it the cell's master molecule. It contains a coded representation of all of the cell's proteins; other molecules like sugars or fats are made by proteins, so their structures are indirectly coded in DNA. It also contains a coded set of instructions about when the proteins are to be made and in what quantities. DNA does all of this using only four types of monomers (nucleotides) arrayed in one to 50 or more strings called chromosomes, each containing many millions of nucleotide units.

I.4. CELLS HAVE BOTH A FIXED IDENTITY AND AN ABILITY

A cell in an adult organism can be viewed as a steady-state system. The DNA is constantly being read out into a particular constellation of RNA, and these are specifying a particular set of proteins. As these proteins function, they are also being degraded and replaced by new ones, and the system is balanced so that the cell neither grows, shrinks, nor changes its functions. This static view of the cell, however, misses three important perspectives on cellular life. One is that cells do change their functions over time. For instance, when you eat a meal, the cells in your liver modify themselves to deal with the particular chemical constituents of the food you have ingested. When a pathway in the brain is strongly stimulated, those brain cells respond by making specific new RNA encoding proteins that modify the cells, probably as part of the consolidation of a memory trace.

A second aspect of cellular dynamics is that the no growing cell can begin to grow, preparatory to its division into two cells. Cell growth and division may be a response to an external regulatory signal, or it may come from relief of an internal cellular inhibitor. The growth process of a cell is organised into a cycle of events that has many check points used to determine if the various parts of the cells are duplicating in an orderly fashion. Whether a given cell will grow and divide is a highly regulated decision of the body, assuring that the adult replaces worn out cells or makes more cells in response to a new need. Examples are the growth of muscle in response to exercise or damage, and the proliferation of red blood cells when a person ascends to a higher altitude and needs more capacity to capture oxygen. There is, however, one major and devastating disease of cells, cancer, where cells multiply even though they are not needed by the body.

The third type of cellular change is most dramatic and complicated: the cellular growth and differentiation that occurs during the development of an organism from a fertilized egg. This is a process of extensive cell multiplication and cellular change. A mammal that starts as one cell becomes an organism with hundred of diverse cell types such as muscle, nerve, skin and hair. Here we see at its most dramatic the power of DNA to control cellular behaviour because development is an orchestrated of easily tens of thousands of cellular changes that occurs virtually without fail.

Nowhere is the variety of cellular activities and responses better illustrated than in the body's immune system. It is there that many cell types come together in organized tissues specifically designed to allow the body to distinguish its own cells from those of foreign invaders. Within the immune system we see specialized cells develop that can recognize invading cells; we see the formation of tissue from cells that originate in various parts of the body; we see cells actively surveying their environment with surface receptor proteins like antibodies, and we see cells change their properties as a consequence of their reaction to a foreign substance, allowing the body to rid itself of invaders.

I.5. THE BIOLOGICAL WORLD HAS TWO TYPES OF CELLS

There are actually two different types of cells in biological world (Table I):

- cell with a nucleus-**eukaryotic** cell (karyon in Greek means nucleus);
- cell without nucleus-**prokaryotic** cell.

TABLE I: COMPARISON OF PROKARYOTIC AND EUKARYOTIC ORGANISMS

	PROKARYOTES	EUKARYOTES
Organisms	bacteria and cyanobacteria	Protists, fungi, plants and animals
Cell size	generally 1 to 10 μm in linear dimension	generally 10 to 100 μm in linear dimension
Cell wall	is located immediately outside the plasma	-is relative a rigid structure at plants -is absent to animals

	membrane	
Plasma membrane	selectively permeable for proteins and little molecules; unidirectional transport	movement of materials into the cell is referred to endocytosis; movement out of the cells termed exocytosis
Metabolism	anaerobic and aerobic	aerobic
Cytoplasm and streaming	no cytoskeleton, no cytoplasmic streaming - endocytosis or exocytosis	cytoskeleton composed of protein filaments, cytoplasmic streaming; endo and exocytosis
Organelles	few or none ribosomes	ribosomes, endoplasmic reticulum Golgi apparatus, lysosomes, peroxisomes mitochondria
Nucleus	nucleoid, without membrane and any nucleoli present	nucleus with nuclear envelope and nuclear pores; inside it has nuclear sap and nucleoli
Genetic material	Circular DNA in cytoplasm, organized in 2 chromosomes	very long DNA containing many noncoding regions; organized into chromosomes and bounded by nuclear envelope; also in mitochondria and chloroplasts
RNA and protein	RNA and protein synthesized in same compartment	RNA synthesized and processed in nucleus; proteins synthesized in cytoplasm
Cell division	by binary fission	by mitosis and meiosis
Cellular organization	mainly unicellular	mainly multicellular, with differentiation of cells