Cell and Developmental Biology

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Dr. Karruna Santoshasing Pardeshi
Dr. Ashwani Kumar Dubey

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Dedicated to My beloved Mother
Late Godavari Dubey

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Preface

Developmental biology is the science of explaining how a variety of interacting processes generate an organism's heterogeneous shapes, size, and structural features that arise on the trajectory from embryo to adult, or more generally throughout a life cycle. It represents an exemplary area of contemporary experimental biology that focuses on phenomena that have puzzled natural philosophers and scientists for more than two millennia.

Developmental Biology is an important link between almost all biological sciences, and is assuming more and more importance in fields such as machine and agriculture. Molecular biology has began fulfilling its long anticipated role of linking genetics and embryology and many questions of embryology that had lain dormant for decades have been taken up with new molecular tools and strategies. While our knowledge of the molecular aspects of development has so drastically increased during this time, our applications of developmental phenomenon in evolution and ecology has also expanded. It is becoming impossible to study any area of biology without some background in developmental biology.

The distinction between prokaryotes and eukaryotes is considered to be the most important distinction among groups of organisms. Eukaryotic cells contain membrane-bound organelles, such as the nucleus, while prokaryotic cells do not. Differences in cellular structure of prokaryotes and eukaryotes include the presence of mitochondria and chloroplasts, the cell wall, and the structure of chromosomal DNA.

Regulation of the cell cycle involves processes crucial to the survival of a cell, including the detection and repair of genetic damage as well as the prevention of uncontrolled cell division. The molecular events that control the cell cycle are ordered and directional; that is, each process occurs in a sequential fashion and it is impossible to "reverse" the cycle.

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Spermatogonia are the initial pool of diploid cell that divide by mitosis to give two identical cells. One of these cells will be used to replenish the pool of spermatogonia – these cells are A1 spermatogonia. This replenishment of spermatogonia means that males are fertile throughout their adult life. The other cell – type B spermatogonium – will eventually form mature sperm.

Oogenesis occurs in the outermost layers of the ovaries. As with sperm production, oogenesis starts with a germ cell, called an oogonium (plural: oogonia), but this cell undergoes mitosis to increase in number, eventually resulting in up to one to two million cells in the embryo.

Fertilization is the beginning of the embryo's development. Fertilization is a process of male and female sex cells fusion that is followed by the formation of zygote. Zygote has a basic difference from sex cells – it contains a diploid chromosomal set. Fertilization is merging of the spermatozoon and the secondary oocyte that is followed by the fusion of their nuclei into the single nucleus of the fertilized oocyte, which is called zygote. Spermatozoon has two functions – the first is the activation of the oocyte and stimulation of its development, The oocyte development without the sperm cell's contribution is called parthenogenesis. The other function of spermatozoon is the introduction of new genetic material into the oocyte.

The frog has been historically been used as an amphibian animal model of development due to the ease of observation from the fertilized egg through to tadpole stage. The later metamorphosis of the tadpole to frog has also been studied for hormonal controls and limb development. There have also been many different species used in these developmental studies.

The chick is one of the most satisfactory animals on which student laboratory work in embryology may be based. Chick embryos in a proper state of preservation and of the stages desired can be readily secured and prepared for study. Used as the only laboratory material in a brief course they afford a basis for understanding the early differentiation of the organ systems and the fundamental processes of body formation common to all groups of vertebrates.

An outstanding feature of Cell and Developmental Biology is a wealth of exceptionally clear and vivid illustrations that complement the text, resulting in a succinct yet fully up-to-date treatment of this rapidly changing field.

Dr. Ashwani Kumar Dubey

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1

Introduction to Cell Biology

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HISTORY OF CELL BIOLOGY, CELL THEORY

Cell Biology

Far away in the distant past, when the primeval seas bubbled and steamed, when ultraviolet light of great intensity streamed onto the surface of the earth, molecules of polypeptides, of long-chain fatty acids, steroids of various sorts and purines and pyrimidines ultimately to form part of the nucleic acids, went through the seething pangs of synthesis. Both purines and pyrimidines have recently been found in the interior of meteorites —thus they are not unique to this world and indicate that nucleic acid synthesis may be occurring elsewhere in space.

These compounds, floating free in a warm soup, performed no organized activity. They reacted indiscrim-inately with each other, blindly, with no form or purpose. Then, groups of molecules responding to electrical and surfaceforming forces became orientated in a way which produced a membrane.

Presumably these membranes which were forming on the surface of the water were at first simply flat structures, but "One day" through inter-reaction of the various molecules a membrane formed a little vesicle. Many other vesicles became formed and here we had for the first time the potentialities for the development of living structures, for the membrane cut off the contents of the bag from the environment.

What could have been the composition of such membranes? Perhaps the amino acids were formed into proteins at the time that this happened. Proteins, in general, have a remarkable property of spreading in a very thin film upon the surface of water—even when they are themselves in solution they are capable of forming these thin films. Compounds such as steroids and fats, *i.e.*, compounds which have a preponderance of hydrocarbon groupings which makes them only slightly soluble in water, also have the ability to spread on surfaces and to have a particular orientation so that their polar groups will, in general, be in contact with water or with other polar groups and those parts which have hydrocarbon groups will be out of contact with the water.

Furthermore, lipoprotein films which combine both these two types of compounds, can even be formed artificially, for instance cholesterol and the protein gliadin have been used to produce such a film. These films have considerable elasticity and a good deal of strength.

Within the little vesicles we have mentioned, the reorganization of the molecules went on and eventually a vesicle formed within the parent vesicle which formed a structure similar to the nucleus. Combinations between proteins and nucleic acids formed a basis for inheritance of some of the characters of the cell in a way which we do not yet understand fully. By a slow and gradual process of evolution a complicated structure we now know to be a cell was built up and from it developed the multicellular organisms, animal and plant. At the stage when the multicellular organisms were evolving, it is not even certain that the cell was completely developed in the way we know it at the moment, it probably had a much simpler character than present day cells.

The bags or vesicles contained proteins, fats, phospholipids, carbohydrates, minerals, enzymes, vitamins and water. Now if one normally shook such components up in a little bag not much would happen, although no doubt there would be some linkup of some of the molecules to form structures. For example, if collagen is disaggregated with citrate and then is left to stand after the citrate had been removed, many of these groups of molecules reform into collagen units or even collagen fibres. Something of this sort could occur in the type of vesicle we have described if the right molecules got together. On the other hand, in the beginning very little activity characteristic of the living cell would develop. In the presence of their substrates, for instance, many of the enzymes present would have some action, but for some of the enzymes the pH would be wrong and in such a mixture there would

probably be only one uniform pH and the temperature would not be optimal. There would be no mechanism for removal of reaction products from the site of their formation and the reactions would be rapidly saturated with them and would grind to a stop.

The secret of the complex activity of the living cell lies in the isolation or partial isolation or even the timed isolation of its various activities. This is achieved by the presence of various membranes. The nuclear membrane guards the activity of the nucleus and the Golgi apparatus and the mitochondria have membranes which permit them to carry out activities in partial but not complete seclusion.

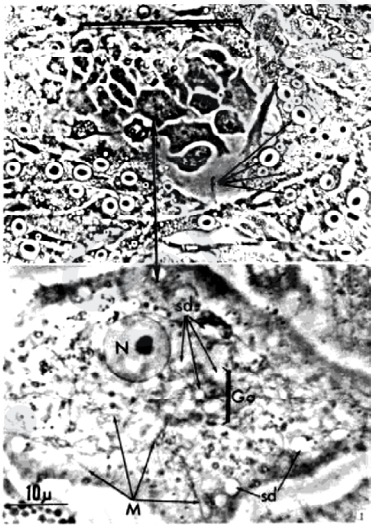


Fig. ***The Living Cells Under the Optical Microscope.***

It is of interest that natural, fresh water frequently contains films and these are probably derived, according to Goldacre, from decomposed biological material. They appear to contain protein or lipoprotein and in many ways possibly resemble the type of film just described from which cells were probably originally formed. It is of further interest that films such is these, upon collapsing, can spontaneously form vesicles or cylinders, *e.g.*, the wind may cause a collapse of the film. In the case of water passing under a floating barrier, for example, when a stream disappears underground, the surface film is carried towards the point of entry and according to Goldacre, may be concentrated.

Compression of this film causes a wrinkling and if the wrinkles become sufficiently pinched the walls finally touch underneath the wrinkles and complete cylinders may be detached which separate from the rest of the film. These cylinders themselves can form vesicles which