Early Studies on Protoplasm

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Introduction

The active living substance of both plant and animal cells, which we now call protoplasm, has interested and baffled man since its discovery three centuries ago. Its importance is recognized in such phrases as the statement that protoplasm is "the physical basis of life" and in present-day definitions which point out that protoplasm is "the essential material of which living creatures are composed."

Current knowledge indicates that every living cell contains a small quantity of protoplasm. The bulk of this protoplasm is usually cytoplasm, which in plant cells, abuts upon the surrounding cell wall. This cytoplasm is believed to function under the control of a directing nucleus which is generally confined within the cell unit. Here the nucleus lies submerged in, or surrounded by, the cytoplasm.

Most cells are vacuolated, that is to say they contain one or more vacuoles, or resevoirs, which are filled with water and various solutes. Mature plant cells, in contrast to those of animals, usually contain one large vacuole which occupies the bulk of the cell. In these cells, the cytoplasm is confined to a thin layer along the wall, plus occasional strands, which may stretch across the vacuole. The nucleus is found either in the sytoplasm adjacent to the wall, or suspended in the vacuole by means of strands of cytoplasm and enclosed in a thin envelope of the same material.

The Pre-protoplasmic Era

In 1665, the English natural philosopher, Robert Hooke, published his "Micrographia" in which he described numerous observations made with a microscope of his own design. Hooke who had broad interests in the field of science, was a mathematician, a physicist, an inventor, a surveyor, an architect, and a doctor of medicine. He served as curator for the Royal Society for over forty years. While not a biologist by training or profession, it was his good fortune to be the first to publicize the cellular structure of plant tissues.

Although his first recorded observations were made upon the structure of non-living cork, Hooke also reports that further observations were made upon thin sections of living plant tissues. These objects he likewise found to possess cellular structure. This was as far as Hooke's curiosity led him, for he turned his attention to other things and left the careful study of plant structure to workers of the next decade.

From the English Hooke we pass to Leeuwenhoek of Holland, a contemporary who outlived Hooke by twenty years. Leeuwenhoek was a master builder of microscopes of original design. Although his were simple microscopes, each containing but a single lens, yet his skillful grinding and choice of materials were such that he obtained magnifications of as high as 270 diameters.

With the aid of these microscopes, Leeuwenhoek made a very great many observations and discoveries of tremendous importance to biology. For example he observed and accurately described one of the smallest of man's cells, the red blood corpuscle. He also observed the cells of yeast plants, the eggs of weevils and of flies, and the spermatozoa of dogs and man. His superior lenses and keen eyesight enabled him to discover the existence of protozoa and finally, to climax his previous work, to see and describe bacteria for the first time. This he did in 1683 at the age of sixty years.

It remained, however, for the Italian physician Malpighi and his English medical contemporary Grew to use the microscope as a tool for the patient, minute study of higher forms of living organisms. Both Malpighi (1679) and Grew (1682) published independently an "Anatomy of Plants" in which the structures of organs and tissues were painstakingly detailed in terms of the tiny cells of which they are built. While the work of Malpighi and Grew stressed the different tissues which were constituent parts of the organisms they studied, yet the smallest unit of structure, the cell, is shown in their drawings in easily recognizable form.

"Sarcode"

As far as known, neither Hooke nor the keen-sighted Leeuwenhoek, nor even the students of plant anatomy-Malphigi and Grew-ever clearly saw living protoplasm. If they did, no importance was apparently attached to such an observation. This can be explained on the grounds that, owing to imperfections in the microscopes of the seventeenth century, accurate observations upon the internal structure of living cells were out of the question. It remained, therefore, to the workers of the 18th century to begin this phase of cellular investigation. According to some authors, it was the Italian "cytologist" Corti, who in 1772 early observed and reported the existence of the slimy substance present in living cells. That Corti followed up this observation is shown by the fact that he discovered currents existing within the cell. This flowing movement we now speak of as protoplasmic streaming. Corti's observation upon protoplasmic streaming was later substantiated by Treviranus, a German botanist and professor at Bonn.

But progress in the field was extremely slow since it waited upon the further development of the microscope. This did not come until early in the nineteenth century, when microscopes with achromatic lenses began to appear in the laboratories of biological institutions. Thus it happened that the eighteenth century was, on the whole, relatively fruitless in the production of new knowledge of the cell.

With the improved microscopes which were put into use during the first half of the nineteenth century, much light was thrown upon the internal structure of cells. The name of Felix Dujardin (1801-1860) stands out among those who contributed most to this new knowledge. Although trained in art and engineering, Dujardin early developed into one of the leading French biologists. In 1835 he published a paper which, according to a modern authority (Seifriz), contains an accurate description of protoplasm that has not been greatly improved upon to this day. This paper was one of a series "Investigations on the lower organisms" and was entitled "On the supposed stomachs of Infusoria and on a substance called 'Sarcode'." A translation of his description is as follows: "Thus I propose to name that which some other observers have called a living jelly, that glutinous, transparent substance, insoluble in water, contracting in globular masses, adhering to the dissecting needles, and allowing itself to be drawn out like mucus; finally, occurring in all lower animals interposed, on the other structural elements."

Dujardin called attention to the ability of "sarcode" droplets, which were caused to emerge from a protozoan parasite of the earthworm, to produce film formation around the droplets, although this was known to occur only in certain cases.

In a later work (1841) the same author pointed out another property of "sarcode," namely that of forming vacuoles. He says: "But the strangest property of sarcode is the spontaneous production, within its mass, of vacuoles or small spherical cavities." This property of vacuolization Dujardin pointed out, distinguished protoplasm from gelatin, mucus, or albumin and was observed to take place in protozoa following injury.

A contemporary of Dujardin was Dutrochet, the discover of osmosis. This worker, 1837, published a note in Comptus Rendus concerning the effect of temperature, mechanical irritation, salts, acids, alkali, narcotics, and alcohol upon protoplasmic streaming in the alga Chara. He found that streaming took place slowly, even at temperatures as low as melting ice, but increased rapidly with a rise in temperature. Dutrochet also stated that mechanical pressure, when exerted on a plant cell can cause the cessation of protoplasmic streaming.

Another contributor to our knowledge of the cell is the Scottish botanist Robert Brown. Brown, who is the discover of the random motion of particles which bears his name, published in 1831 his discovery of the nucleus or "areola" as he also called it. This important protoplasmic structure he discovered in the epidermis of members of the orchid family, and later demonstrated it in a great number of other plant cells.

Protoplasm

We owe the term "protoplasm" to the Czech scientist Purkinje. This term was derived from the Greek "protos" meaning first and "plasma" meaning form. As used by Purkinje, the term was applied to the formative material of animal eggs and embryos, and was introduced in 1839.

In 1864, there appeared one of a long list of important papers from the pen of the German scientist von Mohl. Von Mohl began his career as a doctor of medicine, then he became professor of physiology, and finally professor of botany. Additional traits include those of a modest and reserved man of science who was able to observe and evaluate known facts in a careful and accurate manner.

In his paper Von Mohl applied the term "protoplasm" to the living substance in plant cells and showed that the "sarcode" of animal cells and the protoplasm of plant cells are essentially the same. Von Mohl described protoplasm in a paper entitled "On the fluid movement in the interior of cells" as "never a clear watery cell fluid but a viscous stringy mass."

Further properties of protoplasm were recorded by Carl Nägeli, a Swiss botanist contemporary with Von Mohl. Nägeli verified the membrane formation taking place at the surfaces of exuded drops of protoplasm. He observed the formation of protoplasmic strands in plasmolyzed Spirogyra cells. These strands, when cut, contracted and pulled back into the main mass of protoplasm. Nägeli, also studied the influence of temperature on protoplasmic streaming, the formation of vacuoles in degenerating plant protoplasm, and the killing of algal cells by dilute solutions of copper and mercury salts.

Before going on to the "protoplasm doctrine" of Max Schultze, let us "turn back the clock" some twenty years and touch upon the cell-theory concept. In 1838, Matthais Jacob Schleiden published an essay entitled "Contribution to Phytogenesis" which forms the first installment of what is now known as the "cell theory." Schleiden was the son of a Hamburg physician and studied jurisprudence, then became a doctor of law, and later a barrister in his home town. At this point in his career, matters took a strange turn. Proving to be unsuccessful at law, Schleiden became despondent and shot himself in the head. In this, he was also unsuccessful, and upon recovery resolved to devote his life to natural science. This he did and thereby gained lasting fame.

In discussing the question of how cells arise, Schleiden emphasized the importance in cell division of the recently discovered nucleus and uncovered the fact that the embryo arises from a single cell. He stressed the cell as an independent unit, presenting, at the same time, the plant as a community of cells.

These concepts applied to plants by Schleiden were extended the following year to animals by the German zoologist, anatomist, and discover of pepsin, Theodor Schwann. He states: "The elementary parts of all tissues are formed of cells in an analogous, though very diversified manner, so that it may be stated that there is one universal principle of development for the elementary parts of organisms, however different they may be, and that this principle is the formation of cells." The importance of these conclusions is pointed out by J. A. Thomson in his book "The Great Biologist." He says "To see many things as one, is one of the ends of science, and the cell-theory gave a new unity to the whole range of animate nature."

While Schleiden and Schwann have usually been given the credit for originating and publicizing the "cell theory," earlier work on this subject should not be ignored. According to Raber, Dutrochet had previously (1824) "(1) established the anatomical individuality of cells, (2) described the universal cellular structure of living plant and animal tissues, and (3) stressed the importance of the cell as the physiological unit of the organism."

In spite of the importance of the views presented by the proponents of the cell theory, their concepts were restricted too much to walls or other cell boundaries. Less attention was given to the living content of the cells and its importance in the physiology of living things. This misconception was corrected by Max Schultze in a short essay entitled "On muscle bodies and what one calls a cell" which appeared in 1861. Schultze had devoted himself to the extensive study of microscopic subjects including single celled animals, leuconsites, and nerve and muscle tissues. From these studies he became convinced that the most essential thing in a cell is not, as his predecessors had stated "a vesicle surrounded by a membrane, with a nucleus and fluid contents," but a mass of protoplasm with a nucleus. Thus to Schultze, the word "cell" becomes, illogically perhaps, the vital "element" represented by the nucleus and accompanying protoplasm. The cell envelope, be it wall or membrane, assumes when present a role of lesser importance. This is in keeping with our modern conception of the life and the component parts of the cell.

Conclusion

We have attempted to trace the development of the concept of structural and functional unity of living organisms from early beginnings up to a climatic statement which gives Schultze's viewpoint of nearly 90 years ago, but which even now represents sound physiological views. In other words, we still hold (to quote Raber) "that the important physiological and morphological unit of all organized life is the nucleated mass of protoplasm."

This does not then mean, of course, that no advancement has been made in subsequent study. Microscopes of greater power and refinement, improved techniques in handling the experimental material, and new knowledge in the fields of colloid chemistry and related sciences have all contributed to aid in man's study of protoplasm. At the same time, the protoplasmic system appears to be so complex, the organization so intricate, and the equilibra so sensitive that a complete understanding of the stuff which we all call protoplasm is not by any means "just around the corner."

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