ADVANCES IN CHEMICAL PHYSICS

VOLUME VII

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ADVANCES IN CHEMICAL PHYSICS—VOLUME VII

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The Structure and Properties of Biomolecules and Biological Systems

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INTRODUCTION*

Up to the Renaissance, man had no reason to doubt that his senses revealed to him the ultimate nature of the world. He thought his senses and mind were perfect and trusted his reasoning more than any crude experiment. Each of us being the center of his (or her) universe, there could have been no doubt that man was really the center of the universe which was created for his pleasure or temptation, with a "beyond", in which apparent inequities could be amended.

In that great reawakening of the western mind, the Renaissance, here and there men appeared who questioned our perfection. Copernicus pointed out that the apparent motion of the sun around our globe could be equally explained by our globe's moving around the sun, and so our impressions do not necessarily correspond to reality. Maybe our eyes are not perfect either! So, Galileo built his telescope by which he discovered the rings of Saturn and the satellites of Jupiter. These had never been seen by man before, indicating that the universe could not have been created, solely, for man's pleasure. A Dutch greengrocer, Leeuvenhoek, built the first microscope, with which he discovered a whole new world, too small to be seen by the unarmed eye. Kepler replaced crude observation by taking careful notes of measurements while Galileo asked questions of nature and did experiments. Thus began experimental science, which grew exponentially, accelerating its own development. This "classical science", which had reached maturity at the end of the last century, extended man's world, replaced divine whim by natural laws, corrected many of our ideas, but brought nothing into the picture that man could not "understand". What we commonly call "understanding" means correlating our observation with some earlier experience. If I am told that it is gravitation which holds the universe together "I understand", though I do not know what gravitation is. By "understand" I mean that gravitation is the same thing which makes apples fall and I have seen apples fall before. So classical science introduced nothing that man could not

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understand, that was beyond his experience and was based on the impressions mediated by his senses. Nor did it introduce new dimensions into man's life. All this holds true, also, for science's twin brother: technology. Stephenson's "iron horse", the train, could still be outrun by a good live horse. So man could still feel at home in this universe, built of indestructible matter and energy.

A new period of science, and with it a new period in man's history, was ushered in by two mysterious discoveries just before the turn of the century, in 1896. The one was the discovery of radioactivity, by Becquerell, the other the discovery of X-rays, by Röntgen. These were the first steps toward an entirely new world, hidden behind the directly observable one, a world in which no human experience comes to our help in "understanding". In a way, this mysterious world is the real one, while the one in which we live is more or less but a flickering shadow.

We are at the very beginning of the exploration of this new world. Not only can our senses not reveal it, they are made so as not to reveal it. Our senses are given us by Nature to help us to get through the day alive. If they showed the real nature of things they would be useless. If I could see my chair as it is, a queer-shaped vacuum with here and there an atomic nucleus in it with electrons moving around it at a crazy speed in crazy patterns, I could simply not sit on it. I cannot expect ever to "understand" these nuclei and electrons because there is nothing analogous in my everyday experience.

This "modern" science brought new dimensions into man's life, creating a new world in which we are, more or less, strangers ourselves. It replaced the speed of the horse with the speed of light, and replaced the flimsy little terrestrial fires with cosmic energies which we are clever enough to release but not clever enough to grasp, and which threaten us all, now, with extinction.

The penetration into this new world, with its new dimensions, spreading from the infinitely small to the infinitely big, is exceedingly difficult. Our main vehicle is mathematics, which is not linked to any dimension. But even this tool, mathematics, is highly inadequate, its methods clumsy. We need enormous computers to solve the equation of an electron jump, while that electron simply makes that jump without calculation, and never misses.

By the side of the mathematical methods we have also developed sophisticated experimental methods for penetration into this new

world, often equally as clumsy as the mathematical methods, using thousands of tons of hardware to observe the behavior of an elementary particle. The most important of the new tools is the human brain, trained in the new ideas and methods, equipped for participation in this grand expedition into the unknown.

Chemistry has grown up on the shoulders of classical science, and biochemistry on the shoulders of classical chemistry. The newly discovered world of quanta, with its wave mechanics has had, as yet, no real impact on biology. Biochemistry has hardly taken notice of it. Present biochemistry is still "classical", being closely connected with everyday experience. A molecule of sugar is still the same sugar which I know from my breakfast table. It is true, I cannot see its shape and structure, but, all the same, I can describe them with my human ideas, and I can symbolize my ideas with simple figures, drawn on paper. "Molecular biology", which dominates biochemistry, at present uses these human ideas when describing molecules, stating their length, width, charge, and the sequence and relative positions of atoms.

There can be no doubt that this molecular biology is still harvesting the most wonderful successes, such as the "breaking of the code" of DNA, but behind these achievements there are hidden failures, which we tend to forget, being blinded by our successes. The basic phenomena of life, by which we know life from death, like motion (mechanic work), secretion (osmotic work) and reflexes (electric work), we still do not understand. The electron microscope has revealed, in the cell, an unsuspected wealth of structures, dominated by laminar formations. What is the deeper meaning of these formations? One of the most basic principles of Nature is that of organization. When Nature puts two things together in a meaningful way it always generates something entirely new, the qualities of which cannot be described in terms of the qualities of components. Living Nature is not additive. This holds true through the whole gamut of levels of organization, from elementary particles up to complex societies. What, then, is the meaning of these lamellar structures? What is the meaning of the cell, this most basic unit of life? Why are all higher organisms built of such small, more or less uniform units? And what is that mysterious "living state" which needs a constant energy for its maintenance and the preservation of its low entropy, the "negentropy" of Brillouin.

Looking, unbiased, at biology one must come to the conclusion that we have hardly scratched the surface of its central problems and created, with the molecular approach, merely a frame from which the picture is still missing. There is no doubt in the author's mind that the real nature of life will remain a closed book as long as we try to approach it solely with ideas of "classical" chemistry.

Needless to say hopeful beginnings of a new approach are not missing. Suffice it to quote the pioneering work of B. and A. Pullman, who have made an extensive effort to translate molecular biochemistry into the new language of wave mechanics, looking at biomolecules as they really are, not as pieces of matter with a certain anatomy, but as structures of atomic nuclei, surrounded by electronic clouds of varying shape and density, finding the explanation of chemical reactivity and biological function in the changes of these electronic clouds. The writer himself, with his associates, has devoted his last decade to calling the attention of biologists to this new approach, trying to broaden the way leading into this new world.

In the present volume, the Editor is bringing together papers, all leading us one step deeper into this new world. The penetration into such a new domain is exceedingly difficult. It demands both a great deal of knowledge and courage to try to participate in this new epic of man's intellectual ascent. The final goal is far, the ascent difficult, which makes the effort still more laudable and significant.

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PART I

THEORETICAL