Macromolecules

Increased understanding of natural polymers has made possible the synthesis of many useful new ones.

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Natural polymers such as wood, cotton, wool, silk, lacquers, rubber, and many types of gums have been used for centuries in all kinds of practical applications. Their chemical composition and structure were unknown; improvements made in the course of time were mainly through breeding, through selection of the best raw materials, and through advances in the mechanics of the manufacturing processes. A few very important, though probably accidental, chemical discoveries were made which led to the development of techniques by which the chemical composition and structure of certain natural polymers were changed. Among these techniques were the vulcanization of rubber; the mercerization of cotton, hemp, and flax; the tanning of leather; and the loading of silk. They led to significant technical results and were constantly improved in an empirical fashion.

Early Qualitative Work

Scientific work began around 1880 on the chemical composition, structure, and morphology of cellulose, wool, silk, starch, and rubber; this work was largely descriptive and qualitative, but it provided a very useful background for further, quantitative approaches. During this period the first synthetic polymers were made—in particular, condensation products of formaldehyde with phenol, urea, and proteins (the products were called Bakelite, Pollopas, and Galalit) and derivatives of cellulose (nitrate and acetate); they acquired a considerable commercial importance, but their development was purely empirical and their properties were, in most cases, inferior to those of the corresponding natural products. Hence they were generally considered substitutes or ersatz and were given such names as *Kunstseide, Kunstleder*, and *Kunststoff*. Most of these developments took place in Europe, particularly in Germany, France, and England.

The groundwork for the organic chemistry of polymers, or macromolecules, was laid around 1905 in the Institute of Emil Fischer in Berlin. His work on sugars and amino acids clarified, in a complete manner, the composition, structure, and stereochemistry of these substances and opened the way to a step by step synthesis of progressively larger and larger molecular species. Fischer himself remained strictly in the domain of classical organic chemistry, of which he was the unsurpassed master, and reached only the lower limits of polymer chemistry (molecular weights between 1000 and 1500), but his co-workers pioneered in all fields of true polymer research —Freudenberg, Helferich, and Hess in the field of polysaccharides; Leuchs and Bergmann in the domain of polypeptides; and Harries and Pummerer in the area of polyhydrocarbons, particularly rubber. At the same time Ostwald and Svedberg developed physicochemical methods for investigating colloidal systems by the measurement of diffusion, sedimentation, viscosity, and turbidity and laid the foundation for the quantitative study of polymer solutions. Finally, after the basic discovery of x-ray diffraction by von Laue, Bragg, Debye, and Scherrer showed the way to apply this method for the elucidation of the fine structure of the solid state, even in microcrystalline materials. Their work eventually led to the x-ray investigation of such polymeric materials as cellulose, proteins, and rubber.

The combination of all available methods—organic, physicochemical, and physical—was systematically promoted from 1920 to 1930 and led to the synthesis of many new polymers and to a systematic clarification of a number of basic facts, such as the average molecular weights of the polymers, the way in which they behave in solution, and the details of their structure in the solid state. Most of the results were still qualitative or semiquantitative, but a wide field was opened for further research. Industry began to make use of polymers, and it became evident that valuable properties could be obtained in great variety and at low cost. A few prominent names of this period are W. H. Carothers, K. H. Meyer, E. K. Rideal, and H. Staudinger.

Quantitative Studies

During the next decade there occurred a continuation of the systematic synthesis of many new polymers in the field of fibers, plastics, and rubbers, particularly through the preparation of new monomers, the discovery of new catalytic systems, and the discovery of the principle of copolymerization. The developments of this decade included (i) quantitative formulation of the kinetics of polymerization processes and understanding of the individual steps; (ii) development of the statistical thermodynamics and hydrodynamics of polymer solutions, and thus of a quantitative understanding of osmotic pressure, diffusion, sedimentation, and viscosity; (iii) clarification of the solid-state structure of polymers and development of theories of rubber elasticity, transition phenomena, the crystalline-amorphous system, and relaxation behavior. Some prominent names are P. J. Flory, E. Guth, L. M. Huggins, W. Kuhn, W. H. Melville, and G. V. Schulz.

After 1940 there was a successful extension, amplification, and refinement in all directions—specifically, the following.

1) Many new monomers, many new powerful catalytic systems, many new polymerization techniques.

2) Refinement of the statistical treatment of macromolecules in solution and in the bulk state.

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3) Development of new methods for the characterization of polymers: light scattering, small-angle x-ray diffraction, polarized infrared absorption spectroscopy, rotatory dispersion measurement, nuclear magnetic resonance, differential thermal analysis, and sedimentation and diffusion in a density gradient cell.

4) Clarification of the mechanism of polymerization under various conditions: in solution, under conditions of suspension and emulsion, at high pressures, at high and low temperatures, and in natural polymers.

5) Enormous growth of the industrial uses and production of all polymers.

Predictions

The following important progress can be forecast, without too much risk, for the near future.

1) Lowering of the selling prices of all standard plastics and rubbers into the range between 20 and 30 cents per pound (44 to 66 cents per kilogram), with some priced as low as 15 cents. Lowering of the selling prices of most standard staple fibers into the range between 40 and 60 cents per pound, with some priced as low as 25 to 30 cents.

2) Synthesis of polymers which remain flexible and supple at temperatures as low as −100°C, and of others which can withstand temperatures of 500°C for long periods.

3) Development of adhesives which will make it possible to build houses, cars, and airplanes without nails, screws, or rivets.

4) Polymerization at low temperatures in the liquid or solid state, permitting rapid continuous production of many polymers of high purity, with convenient control of molecular weight.

5) Further improvement of the methods for characterizing polymers—in particular, nuclear magnetic resonance, flow birefringence, optical-activity analysis, and differential thermal analysis.

News and Comment

Lysenko: Attacks on His Theories Renewed in U.S.S.R. in Aftermath of Khrushchev's Removal from Power

The long scientific and ideological struggle involving the Soviet geneticist Trofim D. Lysenko is stirring again in the U.S.S.R., apparently as a consequence of Nikita Khrushchev's removal from power last month.

In the course of Khrushchev's 10-year reign, Lysenko lost the mantle of scientific infallibility that had been conferred upon him by Stalin, and a sort of scientific coexistence developed in the Soviet biological community.

In part, Lysenko's loss of power was probably related to Khrushchev's desire to loosen the ideological bonds on Soviet society; but it appears also to have been related to Khrushchev's determination to promote agricultural research as a means to greater food production. Given a choice between ideological purity and higher food output, Khrushchev seems to have sought a compromise between Lysenko and his opponents.

Lysenko, though no longer possessed of the dictatorial powers that he held under Stalin, held the directorship of the Institute of Genetics of the Soviet Academy of Sciences and served as editor of the journal *Agrobiology*. And his thesis, that heredity is governed by environment rather than by genetic material transmitted from one generation to the next, was frequently reflected in popular articles in the government and party press. At the same time, however, articles reflecting genetic theories held in the West were permitted publication, and it became clear that Soviet scientists were no longer risking their careers by publicly disagreeing with Lysenko.

Khrushchev's ouster as Premier and Party chairman now seems to have accelerated the downgrading of Lysenko. Writing on 2 November in *Pravda*, on the occasion of the 47th anniversary of the October Revolution, M. V. Keldysh, president of the Soviet Academy, included an oblique attack on Lysenko in the course of a lengthy review of Soviet science and technology. "With every year," the Soviet academician stated, "there is a wider development of research on the front line of biological science. . . . It must be said that the development of a number of sectors of modern biology has been impeded because of the dogmatic views of individual groups of scientists. The duty of scientists and agricultural and medical workers is to raise biological science to a high level and employ more broadly the newest achievements of biological science in the national economy and public health."

That was a delicate, though clear, reference to the Lysenko controversy. A few days later, however, according to the New York *Times*, a far less restrained attack was carried in *Pravda*, which not too long ago had served as a medium for Lysenkoist views. The Soviet newspaper noted that the latest issue of *Agrobiology* had disparaged prominent Soviet biologists who disagree with Lysenko by referring to them as "people who are lightheaded when it comes to theory" and as "biologists who try to ignore the [Marxist] dialectic."

Pravda added that, "while pouncing on classical biology and inadmissibly insulting different-minded geneticists, the journal [*Agrobiology*] at the same time constantly and in the most glowing tones talks about T. D. Lysenko." And *Pravda* went on to observe that it found this "all the more strange," since Lysenko is editor of *Agrobiology*.

According to the *Times*, anti-Lysenko views were also carried last week by other Soviet news organs. In a radio broadcast, Nikolai P. Dubinin, one of the scientists who was "insulted" by Lysenko's *Agrobiology*, stated that recent research has demonstrated that it is possible to control heredity through mutations induced by