Developments in Food Science

14

MOLECULAR GENETICS

An Outline for Food Chemists and Biotechnologists

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Preface

Dear reader,

We would like to invite you to take part in an adventurous trip to the fantastic microworld of informational molecules which contain the code of life, including your own. We want to lead you nearer to the complicated and incredibly accurate work of a living cell in which these informational molecules are formed and where they control and steer its biological functions through a marvellously ingenious mechanism. We invite you to learn to understand the molecular basis of heredity, the discovery of which rates among the most significant achievements of modern science. We shall guide you along a path beginning with the biosynthesis of informational molecules and the laws governing their structure, all the way to the reproduction and functions of these magnificent natural polymers; in their company you will become acquainted with the recent brave attempts of molecular geneticists to interfere with the heredity of living organisms – genetic engineering.

It is essential to realize at the very beginning how minuscule these informational macromolecules are. If an average man's height were equal to the size of Great Britain the informational macromolecule (a double-stranded deoxyribonucleic acid), which is highly economically located in every somatic cell of the super-giant, would appear as a filament about 1 mm in diameter and several hundred kilometres long! The existence of man and all his faculties – as well as those of all other forms of life – are thus based on an incredibly tenuous matrix.

Even the concept of time is different in this micro-cosmos. The singularly complex molecule of a protein formed by several hundred building blocks of twenty different kinds and associated in a precise sequence can be formed in a living cell within a few seconds. Once it is grasped by what complicated and multiply regulated mechanisms a protein molecule is formed, it is almost beyond human comprehension to appreciate the speed at which these intricate and involved processes take place. You will soon appreciate the fact that the apparent perfection of life on the macro-scale is made possible by a no less perfect and admirable micro-world of macromolecules. You will recognize and accept that life is not based on a simple principle, some "living primeval substance", but that the complexity of the biological macro-cosmos only reflects complicated motion in the micro-cosmos of informational molecules. On the other hand, it is a highly satisfying thought to realize that the fundamental principles of all life on Earth are the same at the level of these informational molecules, being based on the existence of very similar, even identical polymers. This conclusion is unequivocal proof of the origin and evolution of life on Earth from the same principle.

The road from the beginnings of classical genetics to molecular genetics was very long and tortuous, fraught with obstacles. Classical genetics needed a whole century to reach definitive conclusions. Mendel is recognized as its founder, the Mendel who in 1865 formulated his classical laws on the basis of experiments with genetic crosses of the pea (*Pisum sativum*). Mendel's genetics localized the hereditary traits into the so-called alleles which occur in pairs. These paired alleles segregate during the formation of gametes (male and female sexual cells) and are recombined during the fertilization process. The model derived from Mendel's studies has a purely statistical character. The segregating units were called genes in 1911.

Morgan's experiments on the fruit-fly (*Drosophila melanogaster*) extended Mendel's laws of heredity by important facts. Genes were found to be organized in certain groups that show mutual linkage during genetic transfers. Within each linkage group genes are ordered in a sequence that can be expressed by a linear genetic map. In such a map short distances between any two genes will result in a small recombination probability whereas longer distances will lead to more frequent recombination during crossing. Morgan's experiments led to the important conclusion that the number of linkage groups exactly matches the number of chromosome pairs of somatic (body) cells.

Another important factor that enriched and extended classical genetics was the discovery of mutation (de Vries); physical or chemical factors were shown to induce changes in hereditary properties.

The onset of the so-called biochemical genetics was marked by experiments with microorganisms and later with phages. When mutagenic factors are permitted to act on microbial cells mutants may arise that do not contain an enzyme, which is essential for the formation of a substance required for growth. Such mutants will grow only if the requisite substance is added to their growth medium. It is through the use of such deficient mutants that a great many problems in biochemistry and "pure" genetics have been solved.

Results of studies of classical genetics led to the conclusion that living matter can be reproduced only if suitable instructions, located in the chromosomes, are present. These instructions, subject to well-defined rules of genetic transfer, are instrumental in the formation of cell proteins (enzymes) and can be influenced by mutagens. However, the chemical nature and structure of this genetic material remained unresolved.

It was in 1928 that Griffith discovered bacterial transformation. He was able to demonstrate that virulence (infectivity) of pneumococci inactivated by heat can be transferred to a nonvirulent (noninfective) strain. Three years later such a bacterial transformation was accomplished *in vitro* by Alloway. After several years of analysing the transformation process Avery and co-workers could declare that the only cell fraction with transformation activity is the fraction of deoxyribonucleic acids. Identification of deoxyribonucleic acids as genetic material and the elucidation of their double-helical structure by Watson and Crick in 1953 laid the foundation of molecular genetics.

In studies of the molecular genetics of microorganisms, bacteria and fungi have been used. However, bacterial mutants are increasingly being employed in production microbiology. Genetic engineering, permitting transfers of genes to be made between different species, opens fundamentally new perspectives for fermentation processes.

Progress in molecular genetics and molecular biology of the cell provides a new impetus for studies of cell differentiation and of the basis of tumour growth. An excellent and uniquely useful model for such studies was found in viruses and the viral transformation of cells. Even immunology is positively stimulated by molecular genetics.

In preparing this volume, we took upon ourselves a complicated task: to select from the enormous breadth of contemporary molecular genetics of microorganisms only the very fundamental information that is germane to the productive development of food chemistry and biology. We assumed that the reader would have a solid knowledge of basic chemistry but only of the principles of biochemistry and biology – hence we attempted to compile something like basic genetics for food chemists and biotechnologists. We were aided in this work by many years of experience in teaching at the Institute of Chemical Technology in Prague. As we were convinced that graphical clarity is of primary importance for understanding the more complicated relationships and for retaining them in the memory, the text is accompanied by a number of schematic representations and illustrations.

We are indebted to the reviewers of the manuscript, Professor Oldřich Nečas and Dr. Václav Pačes, for many valuable comments, to Mr. František Zemanec for collaboration in the illustrations and last but not least to Dr. Arnošt Kotyk for his professional translation of the book into English.

J. Škoda and H. Škodová