structure suggests some interesting queries as to the mode of occurrence of this mineral matter. Some of it might be an inherent constituent of the polymer, and this is indeed probably the case for some of the rarer mineral atoms. On the other hand, it might be disposed either on the surface of the polymers or in the interstices. The importance of the possible catalytic action of the mineral matter in pyrolysis is obvious and should be studied.

It should also be possible to assess the part played by mineral matter in the constitution of coal by suitable experiments on the original coal and its extracts in solvents.

We can therefore build up a picture of the coal substance that is correct on broad lines. This picture provides a basis for and gives direction to further research. We need a rational plan for ordering the mass of knowledge that already exists about coals. The hypothesis is here put forward that a coal can be described in terms of four types of data: inner pore structure, size of the polymers, chemical composition of the polymers, and type and location of the mineral matter. Each of these types of data can be investigated independently of the others and by experiments which can be objectively interpreted. These quantities can be measured for any coal, and it may be that a knowledge of them is necessary and sufficient to determine all the properties of the coal. What is now required is to measure these properties for a representative range of coals and to find out by experiment the extent to which this system of classification does order our knowledge in a simple way. We need a plan by which the efforts of many different groups can be co-ordinated and their results combined and assessed.

MORPHOLOGY AND FINE STRUCTURE OF ORGANISMS

A DISCUSSION on "Morphology and Fine Structure" was held at the Linnean Society on February 23, 1950.

In introducing the discussion, Dr. C. F. A. Pantin spoke about those similarities of structure in organisms that are caused not by community of descent, but by the use of particular chemical substances as constructional units, with a resulting necessary resemblance in form. He traced briefly the growth of ideas about the causes of structural resemblances. At first, a system of classification appeared as the expression of an underlying plan or divine idea. This appearance was to a large extent replaced by evolutionary doctrines: classification and homology began to be explained in terms of common descent. Physiologists, however, tended to regard the 'lower' animals not as representatives of separate stocks, but almost as stages in the evolution of man. They examined the functioning of parts of these lower animals in the belief that light would thus be thrown on human physiology, despite the absence of what a zoologist would regard as homology. It is, indeed, very strange that the relation between learning and the structure of the nervous system in cephalopods can throw any light on the corresponding relation in man, since the two stocks are completely separate in evolution; yet the fact is that the one relation does help to clarify the other. Similarly there are biochemical parallels between the metabolic processes of unrelated forms. These resemblances cannot be examples of homology, as that word was ordinarily

understood when the doctrine of evolution was established.

On the old evolutionary view, organisms were like putty, to be moulded in any way whatever by the natural selection of small random variations. Dr. Pantin remarked that the materials of which organisms are, in fact, built are not so much comparable to putty as to the standard parts of a child's constructional set, each with the limitations imposed by its own structure. The number of kinds of more complex forms that can emerge is limited. When similar complex forms emerge in unrelated organisms, parallelisms appear that do not fall into the category of ordinary homology.

When the biologist arranges organisms in a classificatory system, he may be using structural characters of two distinct kinds: those that are due to inheritance from a common ancestor, and those that are controlled by the possibilities latent in the chemical and physical properties of the materials used. A study of fine structure and of the laws that govern chemical morphology are interesting to both physiologist and systematist.

Dr. John R. Baker said that the subject of his remarks lay only on the fringe of fine structure, as he was concerned with the realm that lay near the limit of visibility with the light-microscope. He sketched briefly the history of the invention of the process of microtomy, and showed how the enormous success of this technique in the fields of micro-anatomy and chromosome-cytology gave rise to a belief in its general reliability. This belief was accompanied by a tacit understanding that discoveries in cellular morphology could not be made while the cell was still alive. Dr. Baker said that this idea had always been wrong, but that phase-contrast microscopy had now made the morphological study of the living cell particularly easy. He stressed the serious damage done by fixatives to certain parts of the cell, and doubted whether the degree of shrinkage involved in the routine techniques of microtomy was generally appreciated.

Dr. Baker related the history of Golgi's work on the bodies that bear his name, and told how subsequent workers had striven to reproduce his network by inventing techniques adapted to that end. The first to break away from the use of these methods and make a comprehensive study of the Golgi zone of the living cell was Parat, who disclosed the presence of spherical 'vacuoles'. Those who had been studying the Golgi bodies at Oxford had followed Parat in basing their conclusions on what could be seen in the living cell. Their object had been to define the form of the bodies in this region and to determine their chemical composition by rigorous histochemical tests. They had concluded that the bodies were separate lipid spheres or spheroids, and the presence of phospholipine in them had been proved in certain cases. Their conclusions had been supported by the recent work of Palade and Claude, who had watched the growth of these spheres into interlacing myelin forms under the influence of the routine Golgi fixatives. Palade and Claude, however, had made the mistake of denying the connexion between the Golgi bodies and the processes of cellular secretion.

Dr. Baker suggested that it was undesirable to continue to apply the name of the great Italian neurologist to an artefact. He proposed the name "lipochondria" for the lipid spheres or spheroids. The name was useful for its contrast with mito-

chondria. The latter differ from lipochondria in their tendency to appear as rods or threads, in their uniform diameter in any one cell, and in their high content of ribonucleoprotein.

Lipochondria had been described and figured in the nerve-cells of vertebrates by Valentin in 1836.

Dr. L. E. R. Picken began by defining the expression "fine structure", which had first been used with a particular meaning in the English language by himself, to describe the realm of organisation that lies between molecules on one hand and what is visible with the light-microscope on the other. He took the term to cover the same range of objects as sub-microscopic morphology, and he therefore objected to its use by Dr. Baker to include what can be seen by ordinary microscopy.

About fifteen years ago an important change in outlook had occurred in biology. At that time it began to be generally recognized that the constituent sub-microscopic particles of organisms are not arranged at random—that biological objects have an oriented fine structure. When these objects were regarded as amorphous, they were necessarily considered as fundamentally different from crystals, and thus there seemed to be a lack of contact between the living and non-living worlds. If we consider the component *parts* of cells, we find that the same forces are at work in animate as in inanimate Nature: the growth of a protein chain partakes of the nature of crystal growth.

Dr. Picken discussed the relation between fine structure and visible morphological change. The chain-molecules of cell-walls are often oriented in relation to the axes of symmetry of the cell. When does orientation start, in the transformation of a spherical cell into an object of a particular shape? Does the cell assume its shape first and the molecules become oriented later; or does the orientation precede and perhaps control the assumption of the final shape? Dr. Picken described his own studies of the morphology and fine structure of the scales of certain Lepidoptera. These originate as tubular outgrowths of cells; later they take on various shapes, some becoming hair-like, others paddle-shaped, others flattened into the conventional form of a scale, sometimes with patterned ridges. The tubular outgrowths—so he finds—are birefringent throughout from the start: it is not the case that an oriented fine structure is imprinted upon an outgrowth that was submicroscopically amorphous when it was first formed. In curiously shaped cells the fine structure is related to the visible pattern. Dr. Picken regarded changes of shape in growth, in the cases he had studied, as the result rather than the cause of the orientation of the constituent particles. The origin of the orientation itself is not yet explained, but the cell seems to be constrained by the properties of the available molecules to take on a particular form.

Mr. J. R. G. Bradfield's address was concerned with what he called the "chemical geography" of cells and tissues. He said that he would extend Dr. Picken's definition of fine structure at both ends of the scale. He began by considering the visible organisation of the nucleus. He remarked on evidences of the passage of nucleolar material into the cytoplasm, and on the irregular shapes of nuclei in spinning glands and the nurse-cells of insect ovaries: these shapes are characteristic of the nuclei of cells that are synthesizing proteins particularly rapidly. Examples of this kind showed a simple relation between cellular chemistry and morphology, but it

was not to be supposed that any simple relation would be found between the genes on the chromosomes and the products of their activity.

Turning to the mechanical separation of cellular constituents, Mr. Bradfield considered it probable that the small particles or microsomes obtained by differential centrifuging are to be regarded as sites of protein-synthesis. They are richer in ribonucleic acid than any other cytoplasmic constituent. They are more abundant in the cells of tumours than in normal cells. The larger microsomes contain a higher proportion of protein than the smaller, as though they synthesized protein in growing. Microsomes show only slight enzyme activity. Mr. Bradfield considered that there is strong evidence that the "large particles" obtained by centrifuging are mitochondria. These are constituents containing the greater part of the cell's enzyme-mechanism necessary for obtaining energy from sugars and lipids. That the microsomes and mitochondria represent different categories of cytoplasmic inclusions, despite their resemblances in chemical composition (lipoid and ribonucleoprotein content), is suggested by the fact that radioactive phosphorus introduced into an animal is found in different proportions in the particles of different size thrown down by the centrifuge.

Mr. Bradfield dealt lastly with the chemistry of the fibres of connective tissue. He pointed out that it is advantageous to an embryo that these fibres should show plasticity, while in adults mechanical strength is the requirement. In correspondence with these needs one finds reticulin in embryonic and collagen in adult connective tissue. The same sequence occurs in tissue-cultures of connective tissue cells: the first-formed fibres show the reactions of reticulin, the later-formed ones those of collagen. Mr. Bradfield suggested that the muco-polysaccharide component of reticulin might provide the necessary chemical structure for the plasticity of the embryonic fibres.

In the discussion that followed the set addresses, Dr. Geoffrey Bourne emphasized the variety of structure that had been attributed by different observers to the Golgi bodies. He mentioned his own work on the disintegration of cells by shaking. In these studies he had never found anything resembling the classical Golgi network and he had come rather reluctantly to the conclusion that such a net does not exist in life. Dr. Helen Brown gave an account of the various kinds of cross-linkages that bind polypeptide chains together during the hardening of proteins into skeletal structures. She referred particularly to the widespread use of quinone-bonding for this purpose in invertebrates. The method is found to exist also in the egg-cases of selachians. Dr. M. G. M. Pryor remarked that a particular arrangement of collagen fibres that is found in certain animals and provides maximal torsional stiffness is found also in the fibres of the plywood of the Mosquito aircraft; but the evident functional suitability of the arrangement provides no explanation of the mechanism by which the collagen fibres were oriented in development. He thought no causal explanation was yet possible of the orientation in fine structure shown by the scales of the Lepidoptera studied by Dr. Picken.

In his concluding remarks Dr. Pantin envisaged the development of a new science of fine structure—a new kind of morphology in which the rules would be found to differ from those in the old.

JOHN R. BAKER