years, though for no small part of that time the so-called "practical man" was accustomed to make light of it. By the middle of last century the importance of some knowledge of stratigraphy was beginning to be generally realised in regard to coal-mining; yet cases sometimes occurred such as making boreholes in search of that material in hopeless places, or carrying a shaft down into the Wenlock Limestone in the hope of striking a valuable seam, which, as the result of an unconformity, had never been deposited. Much information, however, has been obtained about underground stratigraphy by some of these borings for minerals or for water, even when they proved fruitless in themselves. Shafts also for coal and for metals have been carried to much greater depths than formerly, one or two even going down to as much as 5000 ft. below the surface. But the late war repeatedly proved the practical value of a good knowledge of geology, in the cutting of deep trenches, in driving tunnels, mines, and counter-mines, and in constructing underground shell-proof shelters, so that we may now reasonably hope that our military and political authorities will recognise the importance of geology as a subject of education.

This increase of knowledge is not without its attendant drawbacks. The microscopic study of rocks and minerals, the minute observance of the variations in closely allied species, the distinction of geological areas, tend to foster specialism. In the present age the emergence of men like Darwin, Hooker, and Huxley, men with far-reaching views and wide outlook, who make great forward steps, has become increasingly difficult, while the literature of all the subjects, though it aids, also lays a heavy burden on the student. Much time has often to be spent in searching through many volumes, for fear of overlooking some fact which may have an important bearing on a special investigation; in short, there is sometimes a great danger in being unable to "see the wood for the trees." But we may hope that these obstacles will in due time be overcome, and details be regarded in their right relation to principles.

THE NEW BIRTH OF MEDICINE.[1]

BY SIR T. CLIFFORD ALLBUTT, K.C.B., F.R.S.

WITHIN the period of fifty years during which NATURE has been published, medicine has undergone a revolution. It has become enlarged from an art of observation and empiricism to an applied science founded upon research; from a craft of tradition and sagacity to an applied science of analysis and law; from a descriptive code of surface phenomena to the discovery of deeper affinities; from a set of rules and axioms of quality to measurements of quantity. When I turn back to the medical text-books of my pupilage, to the wise and scholarly Watson or the respectable Alison, and contrast them with the text-books of to-day, I marvel that a change so vast, so profound, so revolutionary, should have come about in one lifetime! Many a generation had to pass before Harvey's researches established animal mechanics; many again before the half-lights on animal heat of Willis, Mayow, and Boyle were brought to quantitative verifications.

In medicine, observation cannot carry very far—not so far, let us say, as in astronomy; while skill and sagacity, if they do not die with the individual, keep in the axioms and exercises of the school but a transitory life. No observation of a thunderstorm could unravel its affinities to the action of a loadstone on a scrap of iron; no observation on diet could reveal the relation of food protein, by way of the amino-acids, to the tissues; no observation bestowed on scurvy or beri-beri could detect the occult and elusive but all-potent influence of the vitamines; no observation of secretory and muscular action could reveal the play of surface-tension in muscular contraction, or its relations to lactic acid and oxygen. By what sagacity could the shrewdest observer, let us say of heart disease, perceive the likeness of the formations of a soap bubble, or a raindrop, to the contraction of a muscle-fibre in terms of its length; or that muscular contraction is not so much a chemical as a physical system with a negative temperature coefficient? Again, the relation of sexual hormones to the development of men and women, and to the phases of their respective organs of reproduction, is an issue of the academic laboratory. The prodigious harvest medicine has reaped in the recent operations of war was derived from the original researches of a chemist into the occult causes and laws of fermentation by microbes, and from a field apparently so alien as of the silkworm disease.

One of the main lessons of our history has been that, in neglect of research into truths below the surface, medicine, for lack of a deeper anchorage, has always sunk back into empiricism and routine.

Research is the salt of the most practical training; it cannot begin too soon; it is the light of the wisdom of the man, of the mind of the boy, of the heart of the child. Education has lingered on Hellenistic and scholastic ways, on the systems of abstract notions unvexed by verification, so long that the hard-shell practical man is still occupied by the notions of antiquated theory and the phrases of a dead or moribund nosology. The

[1] Abstracted from an address by the author to the Scientific Meeting of the British Medical Association in April, 1919.

majority of medical men have to work upon the store of scientific ideas and facts with which they set out in practice; onwards they may gain in adaptiveness and technical facility, but can dig little deeper into the strata of knowledge; but for the modern academic spirit this would spell, as in our history it has spelled, stagnation.

Physics and Medicine.

Let us glance, however hastily, towards some of the fields in which new knowledge has been gained. In the venerable study of anatomy in its static aspects the student has long been taught the value of precision; but the recent tide of anatomical study towards its dynamic aspects, as by the work of Sherrington and Head, is bringing in new currents, not of theory only, but also of practice. Of other casements opening upon new visions of medicine that from the chambers of physics is perhaps the most arresting, at any rate at present. How fascinating, in their application to pathology, are the principles of osmosis with its curious reversals, of surface action and adsorption, of electrolytic differentials and electric methods of taking quantitative measurements, of mechanical pressures in the circulation of body fluids and, in the heart, as measured and graphically delineated by Hales, Ludwig, Gaskell, and Mackenzie, of the behaviour of fluid veins, and of the relative diameters, normal or variable, of the cardiac chambers and their main outlets. I need not do more than allude to the recent work on the CO_2 tension in the pulmonary alveoli, and to its immediately practical bearing on so-called acidosis, on the treatment of persons gassed in military or civil operations, and so forth.

By physics again we are shown, especially in plants, how in life the less complex molecules, working not only in planes below those in which the higher functions are developed, but also upwards by pacific penetration, moderate where they do not command. How instantly such researches as these must govern the practice of medicine we perceive, for example, in the gum-saline treatment of surgical shock. It would seem indeed that some of the most mysterious phases of immunity and anaphylaxis, of phagocytosis, as also of narcotism, may depend, at any rate in great part, on surface action; and that the behaviour of lipoids released from disintegrating proteins may lower surface energy, as in the retention of water in renal dropsy; or again in a different field may determine the touch or the permeability of synaptic neurons. These, and such physical laws, as they are revealed to us, teach that the multiplication and co-ordination of surfaces, let alone their chemistry, are operations which do not arise in mere mixtures of the same ingredients. So far it seems as if all biological reactions were determined by physico-chemical laws—that is, by molecular structure. The laws of selective absorption, as revealed in incandescent vapours, might throw some light upon those of biology; for in both fields we have to study vibration of molecular systems in unison, harmony, or discord.

When we rise from physics into systems of biological activity two conceptions especially strike us as new and marvellous; namely, those of the colloids and the cell. But throughout these systems we shall find the physical phases, if no longer constructively dominant, yet still active and effectual. We cannot even guess at the links of these chains where physics recedes and biochemistry takes the lead. The mere size of the molecules now concerned alters their relation to the spaces in or about which they move; not only so, but in organic compounds a mere change of position of a radical profoundly alters the properties of the compound and leads to manifold changes of function.

Often, moreover, these changes, as in the cases of immunity and susceptibility, do not vary gradually, but by leaps and bounds, as flames respond to musical scales of vibration. Thus great diversities, contrasts, and strange conjunctions of morbid phenomena do not necessarily signify great divergence of nature in the morbific agents; so that again we cannot get very far by grouping phenomena by direct observation. Processes outwardly disparate may be alike at the core. A small and latent change of chemical constitution may turn a benignant into a virulent substance, and conversely; as we may see in such substances as cacodylic acid and the cyanides, or as saliva, serpent's poison, and trypsin; and so forth. On a small deviation in a secretion we may be destroyed by those of our own household.

How far are hormones a particular category, how far universals? Do they differ in nature from other secretions, enzymes, antisubstances, and so on? Do they by their interactions, compensations, and inhibitions cover the ground of concerted chemical action in kind, as the nervous system does in time; or are they few and peculiar to certain limited needs? Whether inhibitory or stimulatory may often depend rather upon the term of the series to which the hormone is applied than to a difference in quality. Merely to glance at such questions as these reveals to us how vast is the realm of knowledge yet unconquered, nay undiscovered—

mazes intricate,
Eccentric, intervolved, yet regular
Then most when most irregular they seem.

A very interesting transition from physics to chemical biology is found in the phenomena of catalysis. By some elusive property certain inorganic substances—spongy platinum, for example, or manganese dioxide—themselves unaltered, exercise an accelerating influence upon chemical change; properties which are utilised to-day on an enormous scale in industrial processes. Now by our increasing knowledge of biochemistry we perceive that the function of which the inorganic catalyst is a simple case is manifested also in more complex orders by certain enzymes, or colloidal catalysts, upon which depends in great part the sweep of our health and of our diseases. In these enzymes which accelerate metabolism we may admire again, as in the simpler catalysts, the exquisite economy of energy in vital processes; how small the energy transactions may be, and these often reversible, which may compass great ends. A striking example of such economy is now being demonstrated to us in the calculated balances of voluntary muscular activity. The minute quantities of vitamine suggest that they, too, are catalysts, and function without much waste.

Diet and Nutrition.

During the last half-century the subject of dietetics has been strictly analysed on quantitative lines, and its energies calculated in caloric and other units. Yet even herein our attainment is far from complete. About this well-worn, almost hackneyed subject a breeze of new and far-reaching ideas is gathering. Our balances, as in the children's milk, and in the analysis of the diseases of deficiency, are eluded by imponderables, by the infinitely little; our quantities are set at naught. For health and disease the new vitamines to which I have alluded, like some other hormonic and enzymic imponderables, are as potent as they are intangible. Hormones work in infinitesimal ranks; and I believe no antibody has as yet been isolated. Once more we find that Nature laughs at our formal categories, at our several compartments of protein as such, of carbohydrates as such; a straitlaced reckoning. No one class of foods, it appears, will build or burn without another; carbohydrate metabolism leans on that of protein, the protein on carbohydrates, and all these on the fats, in mutual function; each of these is engaged in the totality of the chemical changes. For instance, deficient carbohydrate means deficient oxygenation of fats, and imperfect protein distribution.

Nor is this all; some of our great ancestors, likewise having penetrating ideas of the infinitely little, supposed that the sources of nutrition must contain a supply to each and every living tissue of its own form of minute identical elements; be they of bone, of muscle, of blood, of "nerve," and so forth, each being proper to its particular tissue, to which it attaches itself (Homœomerism). This crude notion, it is true, made no great way; still until lately we have all of us supposed some, if a more general, congruity of form between the nutritive elements and the qualities of their various destinations. But the study of the reduction of foods to amino-acids, and issues of like researches, are telling us to-day that there is no necessity even for the food proteins to be of similar constitution to the tissues which they subserve. To the almost magical part played by certain elements, such as calcium, as stabilisers, or of the alkali-metals as labilisers of equilibrium I need but allude. The bearings of these dietetic researches upon practice, for example in the treatment of diabetes, are too obvious for reiteration.

If we turn now to the cell, as described to us by Virchow, we realise that our knowledge of this tiny microcosm is as yet only beginning. The infinity of extension is not strange to us, for some of it we can see; but the infinity of the universe of the little, which far escapes even our microscopes, does not so strike the imagination. Still, even of this inward universe and its intense activities, as by present research they emerge into the field of the mathematical physicist, of the spectroscopist, of the radiologist, of the physical chemist, we are beginning to conceive something. The microcosm is no longer Man, but the cell of which he is built. To our wonder we see that, even within such tiny spheres, some of them filtrable, are multiple systems moving in relative independence of each other. The cell membrane is formed chiefly perhaps by the physical processes we have considered. Yet puzzling and intricate as these reactions are, they are all-important to the physician; as, for instance, in the relations of the glomerular epithelium to sugars; its unerring discrimination between substances, even isomeric, in the blood, as between glucose and lactose; or again in the constant and subtle opposition of the normal intestinal epithelium to the entrance of poisonous elements, or foreign proteins, into the vessels and tissues.

For the Future?

This rapid glance over a small part of the field of the medical sciences may serve to reinforce the lesson of their profound and instant bearing upon practice, and the need for linking up the laboratory with the wards. Only by disinterested research on the large patient and prophetic lines of the pure sciences can progress be made. The isolated academic worker, as well as the practitioner, loses by this isolation; he loses the spontaneous outcrops of problems and crucial instances which so often spring up in practice, but fail to show themselves in the laboratory. So complete and mischievous, however, has been the barrier between research and the industry of medicine that a reaction from "laboratorism" to symptomatology has set in, because there are no intermediary workers—no engineers—between the knowledge getters and the knowledge dealers. Thus we have laboratory investigators completely out of touch with practice, and practitioners faithless of theoretical principles—just "Philistines."

As the engineer is something of a mathematician, something of a physicist, so the professor of medicine must be something of a physicist, something of a biochemist. Through these middlemen the man of science and the practitioner should mutually feed each other. In every adequate clinical school, then, there must be a *professoriate*; whole time—or nearly whole time—professors, each with his technical laboratory, biochemical and pathological, who with their assistant staffs shall be engaged continually in irrigating our profession from the springs of the pure sciences.