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Until the nineteenth century, the investigation of natural phenomena, plants and animals was considered either the preserve of elite scholars or a pastime for the leisured upper classes. As increasing academic rigour and systematisation was brought to the study of 'natural history', its subdisciplines were adopted into university curricula, and learned societies (such as the London Zoological Society, founded in 1826) were established to support research in these areas. These developments are reflected in the books reissued in this series, which describe the anatomy and characteristics of animals ranging from invertebrates to polar bears, fish to birds, in habitats from Arctic North America to the tropical forests of Malaysia. By the middle of the nineteenth century, this work and developments in research on fossils had resulted in the formulation of the theory of evolution.

Animal Chemistry

At the age of thirteen, chemistry enthusiast Justus von Liebig (1803–73) witnessed the devastation caused by a summer of crop failure. Three decades later, Liebig had become a leading German chemist based at the University of Giessen and had made significant contributions to agriculture and medicine in addition to his pioneering work in organic chemistry. This 1842 study in animal metabolism includes detailed analysis of the chemical transformation undergone in healthy and diseased organisms. Although Liebig considers that chemical analysis alone is not sufficient to explain physiological processes driven by 'vital forces', he argues that it offers quantitative research methods that are superior to mere observation. Several of his works, including this one, were translated into English by his colleague, Scottish chemist William Gregory (1803–58). Liebig's laboratory-based teaching methods quickly gained popularity among British researchers and contributed to the founding of the Royal College of Chemistry in 1845.

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Or, Organic Chemistry in Its Applications to Physiology and Pathology

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the beliefs, practices and terminology of their time, and have not been updated.

ANIMAL CHEMISTRY,

OR

ORGANIC CHEMISTRY

IN ITS APPLICATIONS TO

PHYSIOLOGY AND PATHOLOGY.

BY

JUSTUS LIEBIG, M.D., PH.D., F.R.S., M.R.I.A.
PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF GIESSEN.

EDITED FROM THE AUTHOR'S MANUSCRIPT

BY WILLIAM GREGORY, M.D., F.R.S.E., M.R.I.A.
PROFESSOR OF MEDICINE AND CHEMISTRY IN THE UNIVERSITY
AND KING'S COLLEGE, ABERDEEN.

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1842.

TO

THE BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

AT the meeting of the British Association in Glasgow, in 1840, I had the honour to present the first part of a report on the then present state of Organic Chemistry, in which I endeavoured to develope the doctrines of this science in their bearing on Agriculture and Physiology.

It affords me now much gratification to be able to communicate to the meeting of the Association for the present year the second part of my labours; in which I have attempted to trace the application of Organic Chemistry to Animal Physiology and Pathology.

In the present work an extensive series of phenomena have been treated in their chemical relations; and although it would be presumptuous to consider the questions here raised as being definitely resolved, yet those who are familiar with chemistry will perceive that the only method which can lead to their final resolution, namely, the *quantitative* method, has been employed.

The formulæ and equations in the second part, therefore, although they are not to be viewed as ascertained truths, and as furnishing a complete, or the only explanation of the vital processes there treated of, are yet true in this sense: that being deduced from facts by logical induction, they must stand as long as no new facts shall be opposed to them.

When the chemist shews, for example, that the elements of the bile, added to those of the urate of ammonia, correspond exactly to those of blood, he presents to us a fact which is independent of all hypothesis. It remains for the physiologist to determine, by experiment, whether the conclusions drawn by the chemist from such a fact be accurate or erroneous. And whether this question be answered in the affirmative or in the negative, the fact remains, and will some day find its true explanation.

I have now to perform the agreeable duty of expressing my sense of the services rendered to me in the preparation of the English edition by my friend Dr. Gregory. The distinguished station he occupies as a chemist; the regular education which he has received in the various branches of medicine; and his intimate acquaintance with the German language—all these, taken together, are the best securities that the translation is such as to convey the exact sense of the original; securities, such as are not often united in the same individual.

It is my intention to follow this second part with a third, the completion of which, however, cannot be looked for before the lapse of two years. This third part will contain an investigation of the food of man and animals, the analysis of all articles of diet, and the study of the changes which the raw food undergoes in its preparation; as, for example, in fermentation (bread), baking, roasting, boiling, &c. Already, it is true, many analyses have been made for the proposed work; but the number of objects of investigation is exceedingly large, and in order to determine with accuracy the absolute value of seed, or of flour, or of a species of fodder, &c., as food, the ultimate analysis alone is not sufficient; there are required comparative investigations, which present very great difficulties.

Dr. JUSTUS LIEBIG.

Giessen,
3rd June, 1842.

NOTE.

I would beg leave to refer the chemical as well as the physiological reader particularly to the analyses (in Note (27), Appendix) of the animal tissues, which ought to have been referred to on pages 43 and 126, and which at present are only referred to in Note (7). Since the work was printed, moreover, there has been added, at the end of the Appendix, an interesting paper by Keller (see page 325), confirming the very important observation of A. Ure, junior, as to the conversion of benzoic acid into hippuric acid in the human body; a fact which I perceive, by the Philosophical Magazine for June, has also been confirmed by Mr. Garrod, probably at an earlier period than by M. Keller. The reader will perceive that this fact strengthens materially the argument of the Author on the action of remedies.

W. G.

PREFACE.

By the application to Chemistry of the methods which had for centuries been followed by philosophers in ascertaining the causes of natural phenomena in physics—by the observation of weight and measure—Lavoisier laid the foundation of a new science, which, having been cultivated by a host of distinguished men, has, in a singularly short period, reached a high degree of perfection.

It was the investigation and determination of all the conditions which are essential to an observation or an experiment, and the discovery of the true principles of scientific research, that protected chemists from error, and conducted them, by a way equally simple and secure, to discoveries which have shed a brilliant light on those natural phenomena which were previously the most obscure and incomprehensible.

The most useful applications to the arts, to industry, and to all branches of knowledge related to chemistry, sprung from the laws thus established; and this influence was not delayed till chemistry had attained its highest perfection, but came into action with each new observation.

All existing experience and observation in other departments of science reacted, in like manner, on the improvement and developement of chemistry; so that chemistry received from metallurgy and from other industrial arts as much benefit as she had conferred on them. While they simultaneously increased in wealth, they mutually contributed to the developement of each other.

After mineral chemistry had gradually attained its present state of developement, the labours of chemists took a new direction. From the study of the constituent parts of vegetables and animals, new and altered views have arisen; and the present work is an attempt to apply these views to physiology and pathology.

In earlier times the attempt has been made, and often with great success, to apply to the objects of the medical art the views derived from an acquaintance with chemical observations. Indeed, the great physicians, who lived towards the end of the seventeenth century, were the founders of chemistry, and in those days the only philosophers acquainted with it. The phlogistic system was the dawn of a new day; it was the victory of philosophy over the rudest empiricism.

With all its discoveries, modern chemistry has performed but slender services to physiology and pathology; and we cannot be deceived as to the cause of this failure, if we reflect that it was found impossible to trace any sort of relation between the observations made in inorganic chemistry, the knowledge of the characters of the elementary bodies and of such of their compounds as could be formed in the laboratory, on the one hand, and the living body, with the characters of its constituents, on the other.

Physiology took no share in the advancement of chemistry, because for a long period she received from the latter science no assistance in her own developement. This state of matters has been entirely changed within five-and-twenty years. But during this period physiology has also acquired new ways and methods of investigation within her own province; and it is only the exhaustion of these sources of discovery which has enabled us to look forward to a change in the direction of the labours of physiologists. The time for such a change is now at hand; and a perseverance in the methods lately followed in physiology would now, from the want, which must soon be felt, of fresh points of departure for researches, render physiology more extensive, but neither more profound nor more solid.

No one will venture to maintain, that the knowledge of the forms and of the phenomena of motion in organized beings is either unnecessary or unprofitable. On the contrary, this knowledge must be considered as altogether indispensable to that of the vital processes. But it embraces only one class of the conditions necessary for the acquisition of that knowledge, and is not of itself sufficient to enable us to attain it.

The study of the uses and functions of the different organs, and of their mutual connection in the animal body, was formerly the chief object of physiological researches; but lately this study has fallen into the back-ground. The greater part of all the modern discoveries has served to enrich comparative anatomy far more than physiology.

These researches have yielded the most valuable results in relation to the recognition of the dissimilar forms and conditions to be found in the healthy and in the diseased organism; but they have yielded no conclusions calculated to give us a more profound insight into the essence of the vital processes.

The most exact anatomical knowledge of the structure of the tissues cannot teach us their uses; and from the microscopical examination of the most minute reticulations of the vessels we can learn no more as to their functions than we have learned concerning vision from counting the surfaces on the eye of the fly. The most beautiful and elevated problem for the human intellect, the discovery of the laws of vitality, cannot be resolved, nay, cannot even be imagined, without an accurate knowledge of chemical forces; of those forces which do not act at sensible distances; which are manifested in the same way as those ultimate causes by which the vital phenomena are determined; and which are invariably found active, whenever dissimilar substances come into contact.

Physiology, even in the present day, still endeavours, but always after the fashion of the phlogistic chemists (that is, by the *qualitative* method), to apply chemical experience to the removal of diseased conditions; but with all these countless experiments we are not one step nearer to the causes and the essence of disease.

Without proposing well-defined questions, experimenters have placed blood, urine, and all the constituents of the healthy or diseased frame, in contact with acids, alkalies, and all sorts of chemical reagents; and have drawn, from observation of the changes thus produced, conclusions as to their behaviour in the body.

By pursuing this method, useful remedies or modes of treatment might by accident be discovered; but a rational physiology cannot be founded on mere re-actions, and the living body cannot be viewed as a chemical laboratory.

In certain diseased conditions, in which the blood acquires a viscid consistence, this state cannot be permanently removed by a chemical action on the fluid circulating in the blood-vessels. The deposit of a sediment from the urine may, perhaps, be prevented by alkalies, while their action has not the remotest tendency to remove the cause of disease. Again, when we observe, in typhus, insoluble salts of ammonia in the fæces, and a change in the globules of the blood similar to that which may be artificially produced by ammonia, we are not, on that account, entitled to consider the presence of ammonia in the body as the cause, but only as the effect of a cause.

Thus medicine, after the fashion of the Aristotelian philosophy, has formed certain conceptions in regard to nutrition and sanguification; articles of diet have been divided into nutritious and non-nutritious; but these theories, being founded on observations destitute of the conditions most essential to the drawing of just conclusions, could not be received as expressions of the truth.

How clear are now to us the relations of the different articles of food to the objects which they serve in the body, since organic chemistry has applied to the investigation her *quantitative method* of research!

When a lean goose, weighing 4 lbs., gains, in thirty-six days, during which it has been fed with 24 lbs. of maize, 5 lbs. in weight, and yields 3½ lbs. of pure fat, this fat cannot have been contained in the food, ready formed, because maize does not contain the thousandth part of its weight of fat, or of any substance resembling fat. And when a certain number of bees, the weight of which is exactly known, being fed with pure honey, devoid of wax, yield one part of wax for every twenty parts of honey consumed, without any change being perceptible in their health or in their weight, it is impossible any longer to entertain doubt as to the formation of fat from sugar in the animal body.

We must adopt the method which has thus led to the discovery of the origin of fat, in the investigation of the origin and alteration of the secretions, as well as in the study of all the other phenomena of the animal body. From the moment that we begin to look earnestly and conscientiously for the true answers to our questions, that we take the trouble, by means of weight and measure, to fix our observations, and express them in the form of equations, these answers are obtained without difficulty.

However numerous our observations may be, yet, if they only bear on one side of a question, they will never enable us to penetrate the essence of a natural phenomenon in its full significance. If we are to derive any advantage from them, they must be directed to a well-defined object; and there must be an organized connection between them.

Mechanical philosophers and chemists justly ascribe to their methods of research the greater part of the success which has attended their labours. The result of every such investigation, if it bear in any degree the stamp of perfection, may always be given in few words; but these few words are eternal truths, to the discovery of which numberless experiments and questions were essential. The researches themselves, the laborious experiments and complicated apparatus, are forgotten as soon as the truth is ascertained. They were the ladders, the shafts, the tools, which were indispensable to enable us to attain to the rich vein of ore; they were the pillars and air passages which protected the mine from water and from foul air.

Every chemical or physical investigation, however insignificant, which lays claim to attention, must in the present day possess this character. From a certain number of observations it must enable us to draw some conclusion, whether it be extended or limited.

The imperfection of the method or system of research adopted by physiologists can alone explain the fact, that for the last fifty years they have established so few new and solid truths in regard to a more profound knowledge of the functions of the most important organs, of the spleen, of the liver, and of the numerous glands of the body; and the limited acquaintance of physiologists with the methods of research employed in chemistry will continue to be the chief impediment to the progress of physiology, as well as a reproach which that science cannot escape.

Before the time of Lavoisier, Scheele, and Priestley, chemistry was not more closely related to physics than she is now to physiology. At the present day chemistry is so fused, as it were, into physics, that it would be a difficult matter to draw the line between them distinctly. The connection between chemistry and physiology is the same, and in another half-century it will be found impossible to separate them.

Our questions and our experiments intersect in numberless curved lines the straight line that leads to truth. It is the points of intersection that indicate to us the true direction; but, owing to the imperfection of the human intellect, these curve lines must be pursued. Observers in chemistry and physics have the eye ever fixed on the object which they seek to attain. One may succeed, for a space, in following the direct line; but all are prepared for circuitous paths. Never doubting of the ultimate success of their efforts, provided they exhibit constancy and perseverance, their eagerness and courage are only exalted by difficulties.

Detached observations, without connection, are points scattered over the plain, which do not allow us to choose a decided path. For centuries chemistry presented nothing but these points, and sufficient means were available to fill up the intervals between them. But permanent discoveries and real progress were only made when chemists ceased to make use of fancy to connect them.

My object in the present work has been to direct attention to the points of intersection of chemistry with physiology, and to point out those parts in which the sciences become, as it were, mixed up together. It contains a collection of problems, such as chemistry at present requires to be resolved; and a number of conclusions drawn according to the rules of that science from such observations as have been made.

These questions and problems will be resolved: and we cannot doubt that we shall have in that case a new physiology and a rational pathology. Our sounding line, indeed, is not long enough to measure the depths of the sea, but is not on that account less valuable to us: if it assist us, in the mean time, to avoid rocks and shoals, its use is sufficiently obvious. In the hands of the physiologist, organic chemistry must become an intellectual instrument, by means of which he will be enabled to trace the causes of phenomena invisible to the bodily sight; and if among the results which I have developed or indicated in this work, one alone shall admit of a useful application, I shall consider the object for which it was written as fully attained. The path which has led to it will open up other paths; and this I consider as the most important object to be gained.

JUSTUS LIEBIG.

GIESSEN, *April*, 1842.

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