from his friend the author

ON THE

IMPORTANCE OF CHEMISTRY TO MEDICINE.

AN

INTRODUCTORY ADDRESS

TO THE

MEDICAL CLASSES OF KING'S COLLEGE,

DELIVERED OCTOBER 1, 1845;

WITH AN

INAUGURAL LECTURE

AT

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GIVEN OCTOBER 6, 1845.

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ON THE

IMPORTANCE OF CHEMISTRY TO MEDICINE.

Mr. Principal and Gentlemen,

Unexpectedly, and at a time when my leisure has been more than usually occupied, I have been requested, however unworthy of the honour, to deliver the opening address with which it is customary in our College to commence the labours of the Session, and, in the name of my Colleagues and myself, to be the instrument of conveying our welcome collectively to the former Students of this Institution, and of introducing our new friends to the studies which they will have here to prosecute.

The pressure of other business must plead my apology for a part of the imperfections of this address, and will, I trust, induce you to look with a lenient eye upon those defects with which it may be defaced.

Before, however, I proceed with my immediate subject I must revert for a few moments to the irreparable loss which we, as well as the scientific world at large, have sustained in the decease of the distinguished philosopher who scarcely six months ago occupied the Chair of Chemistry in this College.

Although this is not the fitting time or place to pay the tribute due to the moral worth or intellectual eminence of that excellent man, whose unbending integrity, united with sound good sense, commanded respect, while the genuine benevolence of his disposition, the warmth of his feelings, and the real kindness of his heart, endeared him to all who knew him well, it would be impossible for me to appear before you for the first time as his successor in the Chair, without a passing allusion to the void which his sudden and unexpected summons from works to rewards has left in this College, and in the hearts of those who had the best opportunities of appreciating his excellence.

To myself the responsibility of succeeding such a man is of no ordinary kind; but in assuming those duties which devolve upon me in consequence of the high honour I have received in my appointment to the station which he so lately and so ably filled, and to which I of course cannot bring the long experience and matured views which he possessed, I can, to a sincere interest in the science I profess, and a zealous devotion to the service of this

Institution, yet add the advantage of his bright example, and the privilege for many years past of his friendship, instruction, and advice.

In addressing myself to the object directly before us, it would be superfluous for me to attempt the discussion of the general scheme of study which is recommended and adopted in the Medical Department of this College; it has already been ably considered; as the subject of Medical Education was treated *in extenso*, in the opening address delivered at the commencement of the last Winter Session, by our late Dean; an address which lies within the reach of all, and which the Student, who is about to enter upon his professional studies, will do well to consult.

My observations will be restricted to a part only of this field, a part which is yet not unworthy of attentive examination, and which, as bearing upon the subject I more immediately profess to teach, may not be inappropriate either to the occasion of our meeting, or to the individual who now addresses you.

My purpose is to take a brief review of the relation subsisting between Chemistry and Medicine, and to indicate a few of the important bearings which chemical science has upon the study and the practice of the healing art; bearings which it is daily becoming more needful for the student of our profession rightly to appreciate, lest he, from defective knowledge of the point, be led on the one hand to underrate the advantages which Chemistry is capable of conferring, or, on the other, be induced to look to it for extravagant advantages which it is impossible should ever be realized. I design, in short, to show you that in the present day no man can be a physician, unless at the same time he be a chemist. Not indeed a Davy, a Faraday, or a Daniell, but a chemist in so far as to understand not only the general principles of the science, but their particular application to the phenomena of life.

In the remarks I am about to make, my observations will therefore of necessity be principally confined to the study of Chemistry. Yet far be it from me to seek to exalt it beyond its due position, or to undervalue other sciences not less essential to the completion of a medical education, but of which I may have less immediate occasion to speak.

The main object of the medical man is the prevention and cure of disease, and the only rational foundation upon which the practice of medicine can rest is an extensive acquaintance with *Pathology*, the science of diseased structure and function. Now there can be no adequate knowledge of Pathology without an equal familiarity with *Physiology*, or the science of healthy structure and function. Physiology, in its turn, is not less dependent upon two other branches of study, viz., *Anatomy*, whose province it is to examine the arrangement and collocation of the different parts of the body; and upon *Chemistry*, which tells us all we know of the composition of those different parts, scrutinizes the various products of those structures, and traces the successive changes which they undergo in the proper performance of the vital functions, as well as during their morbid aberrations and their return to a state of healthy activity.

Within the last few years the advances made both in Anatomy and Chemistry have been extraordinarily rapid: their influence on the progress of Physiology has been proportionably felt, and through Physiology they are gradually working an important change in the whole science of Medicine. Interesting and useful as it might be to trace the steps by which those advances have been made, and admirably as it might illustrate some parts of the present subject, such a course would lead us into far too wide a field, and one which is in itself well worthy of separate consideration. It will be sufficient for us here to say, that this progress is mainly attributable to the right use of the microscope and the balance, two instruments which have in the present day attained a nicety in their construction, and a facility in their application, unsurpassed by any of the inventions of human ingenuity.

Ever since the systematic application of the balance by the celebrated but unfortunate Lavoisier, Chemistry, which then first assumed the form and accuracy, as well as the character and dignity of a science, has been intimately connected with the study of life; and in proportion as our knowledge of each has become more exact, the more distinctly has the indissoluble nature of the tie that unites them been manifested.

In considering this connection, let us trace first the relations of Chemistry to Physiology; by this means we shall further perceive its importance to Pathology, and in conclusion we will briefly notice the powerful aid it can lend us in the prevention and cure of disease.

The more important functions whose immediate dependence upon chemical principles has been distinctly traced are, *digestion*, or the process which effects the reduction of the food into a state capable of being absorbed into the system; *nutrition*, or the reparation of the frame; and *respiration*, or the changes which the atmosphere produces upon the blood and constituents of the body in general, including as its consequence the production of animal heat; and we shall find further that we are not without indications of an intimate chemical connection between these changes and nervous influence, and through it, with volition.

The complete solution of our inquiries respecting the essential nature of *life*, is an attainment which will probably for ever be beyond our reach as mortals, just as the attempt to ascertain the real nature of electricity, of light, of heat, or of any of the wonderful powers by which the changes of the universe are regulated and maintained, must be looked upon as an inquiry transcending our limited endowments.

But from the day that modern Chemistry was enabled to demonstrate that the numberless varieties of organized beings which constitute the two grand kingdoms of vegetable and animal life, are composed of materials precisely the same as those which occur abundantly amongst the products of inanimate nature, the discovery of the process by which these lifeless matters become parts of a living organism, and therefore for the time endowed with life, has always been a problem of the highest interest and importance: at the same time that it is one of which the partial solution at least, may reasonably be anticipated. Hitherto we are very far from having attained the end proposed, although we have with certainty discovered some of the intermediate steps. Our ideas of the direct subservience of vegetable to animal life have increased much in precision, whilst in the constant supply by the animal creation of those substances peculiarly adapted to the support of vegetable life, and which, unless they were systematically and regularly removed from the atmosphere, would accumulate till they destroyed the beings that produced them, we have a most striking display of the harmonious system of compensation, which everywhere meets us as the grand principle that pervades the stupendous machinery of the universe.

Amongst many striking differences between plants and animals, we may particularly specify two, viz.: First, the absence of volition in plants, and its presence in animals, intimately connected no doubt with the Second, which is the absence in plants of the rapid and continuous waste and reparation so characteristic of animal life. Plants certainly increase in bulk, they have remarkable powers of assimilation, they are continually putting forth fresh branches, these each returning year are clothed with leaves, which in time fade and decay, to be again renewed; but the removal of matters once deposited, though it does occur in some slight and partial measure, is not a change essential to their existence as it is to that of animals, in whom it is evidenced by the large quantities of solid matter they consume as food, whilst their size never increases beyond a limited extent. On the other hand, the consumption of food by plants is of so different a description, and of comparatively so small an extent, that for a long time it was almost overlooked; and their growth appears to have no definite boundary.

There is no doubt that the nourishment of plants is derived directly from things without life, either suspended in the atmosphere that surrounds them, or dissolved in the water that penetrates the soil in which they root; and it appears equally certain that animals cannot directly assimilate these mineral substances; for if we except common salt, there is nothing that is capable of serving as food to animals, unless it has previously formed part of a vegetable organism. The case of those animals which feed on flesh, far from being an exception, is rather a confirmation of the truth of this remark; for they appear to require a diet still more remote from the mineral kingdom; the animals on which they feed, first of all drew their nutriment from plants, and these plants elaborated it as before from the crude materials presented to them by the earth and air.

We are not yet in possession of the first step in the transition of dead matter to the state of matter in which it is fitted to become part of a living organism. Chemistry cannot pronounce upon the link which connects the two. But it shows us that this change is produced under the influence of light, when a healthy plant is supplied with certain well-known inorganic bodies which constitute its food.

Amongst the numerous products of vegetable life, it has however been found that in plants are prepared, almost in a perfect state, the complicated materials of which the muscular parts of animals are composed, and experiment has further shewn, that animals do not appear capable of originally arranging the substances of their food in such a manner as to constitute muscular tissue, unless the aliment supplied, even though of vegetable origin, contain a sufficient quantity of the peculiar flesh-producing matters; for if these be absent the animals languish, and eventually die of starvation. This conclusion is of the highest practical importance; it defines and places in a clearer light the imperfectly understood but all-important function of digestion.

The process of digestion is one which is more liable to temporary derangement than any other, in consequence of our imprudent indulgence both in the quantity and quality of the food which we employ. But it is also the function over which, from our direct access to the organ in which it is performed, we might, had we but the requisite knowledge, possess the most complete control. That control, it is evident, can only be exercised to advantage, after a careful investigation of the nature of the alterations which the food undergoes in the stomach, where digestion is principally carried on. We know that these alterations are in great degree chemical, for up to a certain point they can be imitated out of the body. During true digestion no formation of new and more complicated products appears ever to take place in the stomach; the changes are modifications rather than decompositions, and consist chiefly, so far as we can trace them, in the reduction of solids to the liquid form, in consequence of which they are rendered susceptible of absorption by the vessels destined to that office; those portions which are unfit for reception into the system, whether from their insolubility, or from other less understood causes, are rejected, A certain power of selection appears to be exercised by this absorbent surface, upon which some little light has been thrown by the phenomena of endosmosis, but the explanation attempted is very partial and insufficient; much still remains behind, which neither the chemist nor the physiologist has been enabled to unveil.

Thus, after digestion, the food by absorption passes into the blood; and here again we meet with mysteries which make us bow in adoring wonder of the skill and wisdom of the great Contriver. Here is a fluid from which each one of the various tissues of the body, bone, sinew, ligament, muscle, brain, and nerve is elaborated; each at his appointed place and in his appointed season. Can we be surprised if sometimes the complicated apparatus by which this is effected should receive a strain, or that the balance should be now and then destroyed? Is it not the rather admirable that these interruptions should be of such rare occurrence, and that when they do arise, the equilibrium should ever be again restored? Ill could we spare any knowledge that might serve to throw even but a glimmering light on the intricate and beautiful machine which we are now contemplating; and for the glimpses which we have attained respecting the changes which maintain their ceaseless round, we are indebted almost entirely to the recent progress of organic chemistry.

The great law of the organic creation appears to be that like should produce like. Once in health, if suitable materials be supplied, the tendency is to continue in health, but ofttimes in disease, the tendency of the latter to reproduce itself, in obedience to this law, is the grand difficulty with which we have to contend, Of the causes of nutrition, we can indeed be said to know but little; we watch their effects, and from experience can tell, in most cases, what will be the products of the change, but why muscle, for example, as it is removed is replaced by muscle, nerve by nerve, we know not. This however is certain, that each particle of our frame is deposited from the blood, to become in its turn displaced, and its situation to be occupied by an equally transitory successor. We also know further that when once the fibrin of the blood has assumed its place as a living constituent of muscle, it never again returns as fibrin to the circulating mass, it is never absorbed whilst it retains the form or composition which it had at the moment it was deposited, but it is removed from its situation by a process of decay, the result of a chemical change in the arrangement of its components, and it re-enters the fluid in the form of two or more substances totally distinct from the muscle that it once was. That which is true of fibrin is equally true of every other solid constituent of the body, and hence it is evident that, in the common acceptation of the term, absorption of the solids, or removal of them bodily, possesses nothing more than an ideal existence. The agency in virtue of which certain particles, and only those, are removed, is concealed from our enquiries, but the steps by which that removal is effected have been somewhat more distinctly ascertained.

We have already glanced at the provision made for maintaining the renewal of the blood, and have now to consider the mode of its purification. This fluid, in its passage through the various channels of our frame, must evidently become loaded with the debris of the tissues, which are constantly pouring into it from the process of decay just mentioned, as well as from the complementary products of secretion from certain glands to which we shall presently advert. Its composition must, therefore, be continually changing, unless means be adopted for preventing such an occurrence.

To effect the purification thus rendered needful, it is propelled through various filters in the form of glands, in each of which the blood undergoes changes dependent on the nature of the gland. And although the external configuration and general arrangement of the constituent parts of those organs may vary greatly, yet so closely do the smallest of these secreting parts resemble each other, that, placed side by side, they can hardly be distinguished by the microscope as belonging to glands whose functions may be widely different. The mystery of secretion is still unfathomed, but here again the results of the operation are manifest.

The glands may be divided into two great classes; the first are those which supply the materials required for consumption within the body in the performance of its several functions, and are termed the *secernent glands*, the second those which separate from it useless or noxious ingredients, the *excreting glands;* and the chemistry of these two classes differs greatly. In the secerning glands, the compounds produced appear dependent on the gland for their existence, and, having produced from the blood the materials of the secretion which they separate, the residual ingredients, or complementary portion, is returned into the mass of circulating fluid, and contributes fresh impurity to it: these complementary products furnish a part of the substances separated by the excreting glands, in which, contrary to that which occurs in the secerning ones, the compounds are the result of operations taking place at various distant points of the body, and the glands act simply in effecting their separation.

Three of the excreting glands, from their size and importance, may here be mentioned, viz., the lungs, the kidneys, and the liver. The organ last named appears to be the connecting link between the secernent and excreting glands, as it partakes of the characters of both. The lungs differ from the kidneys and liver in one very remarkable particular, for they do not contain within themselves the agent that effects the transformation and separation of their peculiar secretion. Some texture in the structure of the kidneys and the liver appears to be the immediate agent in producing the changes which the blood undergoes in them, and so long as a free circulation through these glands is maintained their functions may continue undisturbed.

Far different is it with the lungs. The important processes which here occur obviously depend upon the intervention of atmospheric air, which is brought to act upon the blood in the most complete and favourable manner, owing to the minute state of subdivision in which both are presented to each other in the exquisitely delicate interlacement of air-tubes and blood-vessels of which the lungs consist. This minute division of the blood for the purposes of aëration, is the only office which the organ performs. The alterations which the blood undergoes within it are, so far as we can distinguish, producible out of the body, by simply exposing it to the air, and are of a purely chemical nature. No secretion in a liquid form is here separated. The products are entirely gaseous.

The striking nature of the changes thus effected, the sudden alteration of colour from the dark purple which the blood has on its entrance, to the vermilion which it possesses on its exit from the lungs, the removal of a large portion of the oxygen of the air, and its replacement by a bulk of carbonic acid nearly equal to itself, the large amount of aqueous vapour thus constantly exhaled, together with the precision of which the analysis of the expired air is susceptible, not less than the vital importance of the function of respiration, early fixed the attention of chemists. Numerous careful experiments were made by different individuals, though with widely differing results, in order to determine the relative proportion of matter thus removed from the system, the limits within which it varied, and the circumstances under which such variations took place. We have, in consequence been put in possession of more complete information upon this subject than upon any other point of chemical physiology. Yet this completeness is merely comparative, for many enquiries have still to be prosecuted. The influence of climate on the production of carbonic acid, the variations which this substance undergoes in quantity from modifications of diet, both in the arctic and tropical climates, the effect of clothing in accelerating or retarding its formation, its connexion with the exhalation from the skin, and other similar questions, have yet to be investigated. On all these points we are at present acting only upon inference. That inference, it is true, possesses a high degree of probability, but its correctness is not yet demonstrated by experiment.

The remarkable fact that carbonic acid, the chief new product contained in air that has passed through the lungs, is the same compound as that formed so abundantly in all our ordinary processes for obtaining artificial heat, could not long escape the notice of observant men, when once attention had been roused to the existence of different kinds of aëriform bodies. Accordingly we find that the analogy between the combustion of an ordinary fire and the production of heat in the animal body was soon pointed out; and the latter was regarded as arising from a slow and regulated species of combustion. Experiments were devised in order to ascertain the ratio between the amount of heat given out by combustion of a certain weight of charcoal, and its conversion out of the body into carbonic acid, and that of the heat evolved from any animal whilst the same quantity of carbonic acid was being disengaged.

The attainment of accuracy in these experiments, which evidently are extremely delicate and difficult of performance, was hardly to be expected, and we therefore cannot be surprised if some discrepancy was observable between the two amounts, even in the hands of philosophers whose habitual dexterity and caution are unquestioned. It was found in all cases that the animal emitted more heat, generally one-eighth or one-tenth, more than that furnished by the combustion of a corresponding quantity of charcoal.

With the impatience of uncertainty, which too often, by leading us to hasty and incorrect conclusions, has defeated its own object, by retarding instead of assisting the advancement of knowledge, some physiologists, though ascribing the principal part of the heat evolved to the chemical operations by which the vital functions are characterized, were induced by these differences, supported by some striking results obtained by dividing certain nerves, to attribute to the vague action of nervous influence that rise of temperature which remained unaccounted for. A new and hypothetical source was thus introduced, which, far from removing the ambiguity it sought to clear, served by seeming knowledge to obstruct the further prosecution of research after the discovery of a *vera causa* for the phenomenon.

To the masterly way in which Liebig has handled this difficult subject, and to the clear exposition which he has given of its essential points, science is greatly indebted, and there can be little doubt that the subdivision of alimentary matters into materials for nutrition, and materials for respiration, as proposed by him, is, in the main, as correct as it is ingenious. His attempts to reconcile the discrepancies between the comparative experiments on combustion and respiration, by making allowances for an inaccurate result in the quantity of heat given out during the combustion of carbon and hydrogen in a pure state, have been less successful. This is not surprising; for the data which we possess on this subject are very discordant, and cannot be considered as by any means established. They require, and are receiving, careful re-investigation.

Analogy, meanwhile, is entirely in favour of the view which considers the production of animal heat as a true chemical result, dependent upon the combination of oxygen with carbon and hydrogen, two substances which exist in the body in a state of union with other elements, as compounds the exact nature of which is unknown to us. Indirect proofs we have in the kind of food used under varying circumstances of climate. The productions of the earth vary in different parts of the globe in accordance with the temperature of the surface at these respective spots. It cannot be a matter of accident that those substances which serve as food for man, are in each case those which are best adapted to his requirements in those climates; that, in the frozen regions of the north, the whale, the seal, and other monsters of the deep, supply abundance of flesh and fat, which experience has shewn to be requisite in those countries to the maintenance of health, and the due supply of animal heat; they are precisely those which theory would indicate; while under the burning sun of the tropics, a succulent and luxuriant vegetation furnishes that lighter diet which is best adapted to the inhabitants of those thirsty lands.

It might perhaps be thought, that by an examination of the blood before it enters the lungs and after it leaves them, that much light would be thrown on this part of the subject. Few, however, have any idea of the difficulties with which such researches are surrounded. Theoretically, nothing sounds easier than the general prescription—analyse the blood which is collected from the vessels, immediately before they enter the gland and immediately after they quit it. A little consideration will, however, shew us, how all but impossible it is to execute this apparently simple direction. Suppose, at a rough estimate, that the whole of the blood contained in the body amounts to thirty pounds. If, at each beat of the heart, two ounces of blood enter the pulmonary artery, this entire quantity would pass through the lungs in the course of something less than four minutes. During that period a quantity of carbonic acid, equivalent at most to fifteen grains of solid charcoal, is produced; this is at the rate of one half grain of carbon for every pound of blood, or one part in fourteen thousand. Suppose we examined one thousand grains of blood, a quantity at least ten times greater than in such an analysis we could treat with accuracy, there could be but a difference of one fourteenth of a grain of charcoal between the analysis of the blood before and after its passage through the lungs, a quantity on the addition or removal of which it is absolutely impossible that mere analysis could inform us. It may be said, that probably this change in the lungs is carried on at the expense of some particular substance, which may be entirely removed by the act of respiration, and which therefore might be detected before the process had taken place and not after its occurrence. In all probability this supposition is true; even then this substance will be in minute quantity, and the complicated nature of the fluid, as well as the mixture of substances so closely resembling each other that at present we have no exact method of discriminating between them, (much less of effecting their separation from each other,) leads us again to the confines of our power. It appears, however, that the lungs, in common with the excretory glands in general, do not produce the substances they liberate. The carbonic acid and the water are formed in the ultimate ramifications of the vessels through which the blood circulates in all parts of the body; oxygen is taken into the fluid by a process of absorption from the surface of the lungs, and at the same moment, by a simple act of displacement, the carbonic acid, with which the venous blood is loaded, is expelled; the oxygen is carried by the red arterial blood to the capillaries, and there effects those remarkable changes, in virtue of which the effete particles are removed, and the place of these particles is occupied by fresh ones, fitted to perform the functions which they had ceased to fulfil. In consequence of these changes, by steps, of which, though we have many theories, we have no probable explanation, carbonic acid is produced, the blood assumes its dark hue; and regains its scarlet on parting with this gas in its passage through the lungs.

The changes just mentioned are attended by the evolution of heat, which is extricated on the spot where they occur, and thus the great uniformity of temperature subsisting in health between the various parts of the body is maintained; those parts situated in the trunk through which the circulation is more rapid, and which from its mass resists cooling influences the most perfectly, have, as we should expect, a somewhat higher temperature than the extremities.

Further proof of the direct ratio which exists between activity and exertion and the waste and consumption of the components of the body, together with the extrication of heat resulting from these alterations, is afforded by the accelerated rate of the circulation, the elevation of animal temperature, and the increased demand for materials, shewn in the sharpened appetite which results from the use of active exercise, and the reverse of all these circumstances which accompany repose, and particularly sleep. The suitably rapid succession of these changes ensured by sufficient exercise, and the due supply of food, is the main condition upon which the preservation of health depends.

Upon the origin of animal heat in known causes, did time permit, I might enlarge much more; for the daily progress of discovery in all departments of science is tending towards one common'end, viz., the convertibility of force of one description into its equivalent of force of a different kind. Liebig has endeavoured to shew that all vital actions are but the result of certain applications of chemical power,—an idea sufficiently ingenious and plausible, but at present requiring the confirmation of extended experiment. We, however, know experimentally, that a certain amount of heat is produced by the combustion of a given weight of carbon, and that a definite quantity of water is convertible into steam by the heat thus evolved. Further, this steam, properly applied, will exert a given amount of mechanical force. It appears no strained conclusion, that the combustion of carbon in the body should, allowing for certain known causes of diminution in the effect, also give rise to a similar amount of heat, and should enable the animal or individual to execute an amount of physical exertion equally definite.

Other kinds of force are mutually convertible. A given quantity of heat by suitable means will elicit a corresponding definite amount of electricity. Electricity will in its turn produce a certain quantity of magnetism, and magnetism will excite a certain amount of motion. By proper contrivance, each of these may be made to reproduce the corresponding amount of each of the others, and therefore is capable of being represented by quantities of the other forces mutually equivalent to each other. It is not difficult to carry the reasoning a step farther and to suppose, that a given amount of chemical change within the body should produce a definite development of vital energy.

Recent discoveries, by Matteucci, bearing directly on this point, have added still further evidence of the close connection between the phenomena of vitality and the chemical change of particles which is constantly occurring. It has been for many years known, that by suitable arrangements, the chemical action of an acid upon a metal, and of various chemical compounds upon each other, is capable of producing a continuous development or current of electricity; and that the tendency of this current is to cause a magnetic needle, freely suspended, to place itself across the direction in which the current is passing. In many cases the magnetic needle may therefore be employed as the test of chemical actions of a certain order that may be too feeble to be revealed by any other means. Now, Matteucci has found, that during the life of an animal, or that during the period for which vitality continues in a part severed from the body, (a time which, as you well know, varies greatly in duration under different circumstances,) by arranging the parts in succession in such an order, that the deep or cut surface, say of a muscle, shall be in contact with the superficial uncut surface of another portion, and so on repeatedly, if connection be made with the wires of the instrument, a current of electricity will be rendered evident, which gradually becomes more and more feeble until life becomes extinct. No sooner does death ensue, than chemical changes of a different order take place—putrefaction and decay commence, and these are changes incapable of exciting an electric current.

Of the influence exercised by the mind through the nerves upon the chemical changes, and of chemical changes in return upon the nervous system, our proofs, though less direct, are nevertheless indisputable. We know, from personal experience, the effect of mental exertion upon the general circulation, and the consequent distribution of animal heat, in the hot head and flushed face, together with the cold extremities, which are the frequent concomitants of such exertions. Not less marked is the influence of strong emotion on secretion; as is shewn by the dry parched tongue often produced by great anxiety, or the sudden cold and clammy sweats occasioned by an unexpected fright; while the important part played by nervous influence in the phænomena of nutrition is rendered evident, amongst other circumstances, by the diminished power of paralysed limbs to resist injury from external agents—such as pressure, and any considerable elevation or depression of temperature. Nervous power, therefore, though dependent upon, and doubtless proportioned to, the amount of other less mysterious forces, is, it is clear, by the control which it exercises over the circulation, both local and general, the prime agent in distributing the other forces over the different parts of the system.

These are facts respecting which there can hardly be question or dispute, but they would not perhaps warrant us in drawing the conclusion deducible from others, which render it probable that not a motion occurs in our limbs, not even a thought passes through the mind, which is not attended, as a necessary consequence, by a definite and peculiar chemical change. Intense mental anxiety, or over-exertion of the brain, is immediately manifested by a corresponding alteration in the composition and character of the excretions, and consequently of the tissues which remain behind as constituents of the frame. A striking example of this fact is afforded by a case the particulars of which were related to me in conversation a few days ago. It is well known that phosphorus enters largely into the composition of the brain and nervous matter, while it is found but very scantily in any other of the soft parts of the body. An excess of phosphorus in any of the excretions would therefore, *ceteris paribus*, betoken an undue consumption of nervous matter. These facts being premised, their application will be immediately perceived.

A reporter to one of the daily papers applied for advice a short time since to his physician, complaining of languor, depression of spirits, and exhibiting hæmorrhagic spots under the skin, resembling those of purpura, attended with general disorder of the system. He had been working closely for many hours a day, and heavily taxing his mental powers till late at night. His medical man at once conjectured the *fons et origo mali*. On examining his urine, the excessive consumption of nervous substance which the symptoms appeared to indicate was rendered evident by the abundant precipitate produced on applying the ordinary tests for phosphoric acid, the quantity of which in a healthy state is but small—here it was extremely abundant. The brain had undergone rapid alteration, from the extent of the labours imposed upon it, while its reparation did not appear to have been adequately provided for. The phosphorus was oxidized in passing through the system, and had made its appearance in the acid form. This indication at once pointed out the appropriate treatment. Entire abstinence from mental exertion for a few days, country air and scenery, a nutritious diet, a glass or two of sound wine, and a few drops of nitric acid daily, formed almost the entire of the plan prescribed. In four days a marked amendment was perceived, and by perseverance in the simple course laid down, for a few days more, the patient was restored to perfect health. The phosphates in the urine had fallen to their due proportion, and the gentleman was able to resume his ordinary avocations.

Cases like these speak for themselves; they illustrate at once the mutual dependance of mental exertion and organic changes of a chemical nature, while they forcibly show how a judicious application of sound chemical principles may be made subservient to the cure of diseases, which, to an ordinary observer, appear to have sapped the vitals of the constitution.

In proportion as the true nature of the chemistry of life becomes better understood, as the processes of secretion are more thoroughly investigated, and as the mutual dependance of one part and the products to which it gives rise upon the rest, is more correctly appreciated, so will the aid which our science can impart to Pathology be increased and extended. It is not always that, as in the instance just quoted, we can apply our chemical knowledge with such immediate benefit. At present our information on the subject of Pathological Chemistry is more special than general. We do not yet understand the full meaning of the alterations we perceive. The disturbances we observe are in most cases the results of disease, and not the diseases themselves; hence we are liable to the prevailing danger which so constantly besets us in the practice of medicine, the temptation to treat symptoms rather than to attack the root whence they spring.

Still the special services which Pathology receives from Chemistry are scarcely less important than those which are afforded by it to Physiology, and are of a kindred nature. The first safe step towards the cure of a disease is a knowledge of its nature; and the disturbances of function, which are generally the first to attract the patient's attention and to convince him of the derangement of his health, are in very many cases attended with alterations in the products furnished by the organs either primarily or secondarily affected. These alterations possess the same value to the physician as means of diagnosis, that the physical signs afforded by auscultation do in diseases of the heart and lungs. They are independent of the patient's sensations, and therefore possess a positive meaning. It is the province of Chemistry to teach us what these alterations are, and to aid in determining their meaning.

Circumstances apparently trivial, as the undue preponderance, even in very slight degree, of certain substances whose presence is yet in minute quantity always observed in health, may lay the foundation of serious or irremediable disease. A little consideration will render this evident. It has already been mentioned that the great object of digestion is so to modify the food as to bring it into a soluble form of such nature as to be susceptible of absorption from the inner surface of the intestines.

This surface may in fact be looked upon as the root of the animal through which the nutriment enters the system, having previously undergone a certain elaboration in the stomach, an elaboration unnecessary in the case of plants, which absorb their food directly and in a crude state from the soil. Now on the inner surface of the alimentary canal no pores are distinguishable, even by the microscope. Every thing therefore that is absorbed by it must be in the liquid form. The walls of the blood-vessels themselves are also equally devoid of pores. The body may in fact be regarded a tissue of tubes and membranes, permeable to liquids, but not to solids that they may hold in suspension—the whole being supported on a firm bony framework. It is therefore of high importance that all the products of decomposition in the tissues should, like the food, be of a nature to be dissolved in the circulating fluids. Any formation of insoluble matter must be attended with serious inconvenience, and will be productive of disease of greater or less severity, according to the importance of the part affected, or the extent to which the obstruction may have proceeded; the solids must accumulate instead of undergoing removal; and this is particularly observable in cases where masses of fluids of any magnitude collect and are retained, even for short periods; concretions in various parts are the result of these accumulations. In the gall-bladder, for example, the reservoir of the bile, calculi not unfrequently form, arising from the agglomeration of a waxy substance termed cholesterin. This body is soluble in the bile in quantities almost infinitesimally minute; yet, even in these minute proportions, it forms a never-failing constituent of ordinary bile. If from any cause this substance be increased in quantity it remains undissolved, the torpid action of the liver allows it to collect in the gall-bladder, where it concretes into pellets, which, as they are from time to time expelled, occasion paroxysms of a most painful disease.

Similar phenomena are observed in the urine, but in a degree still more marked, as this fluid contains several substances which are soluble in small quantities only, or are capable of solution only through the intervention of substances liable to variation in quantity; hence various deposits are apt to occur. It is of the highest importance to possess a certain and ready means of discriminating between these different forms of sediment or gravel. No secretion is subject to greater variation, both in the quantity and quality of its components, none more certainly indicates the nature and progress of disease, and none has been more attentively examined. As we might expect, the benefits accruing from this scrutiny have been proportionably valuable. The kidneys are the principal outlet for the combined nitrogen of the system after it has done its work in the frame. When the different functions are performed correctly, this element escapes almost entirely in the shape of a very soluble and remarkable compound, which has received the name of urea, at the same time that a small proportion makes its appearance in the form of *uric acid*, a body of very sparing solubility. A slight error in diet causes an increase in the quantity of this insoluble matter, which manifests itself by producing a deposit in the secretion. In gouty or rheumatic persons this alteration proceeds to a still greater extent; chemical analysis has shown that the so-called chalk stones which occasion such inconvenience to gouty patients by their accumulation round the affected joints, consist almost entirely of a combination of uric acid with soda, and a little lime. Now, uric acid, when deposited from the urine, occurs in two distinct forms, first, as an occasional sediment or cloud; and, second, in the more permanent shape of gravel, as a firm granular or crystalline mass. I mention this apparently trivial fact, because it leads to a very important distinction, to a point the chemistry of which is to pathology of the highest interest, and which at present is but slightly understood—I mean the origin of the different substances presented to us by the operations of the economy. In the case before us, the two different varieties proceed from different sources; the light sediment from its transitory nature, evidently arises from the food which has been taken, and disappears with a return to more suitable diet, the more compact form from deeper-seated derangement, in the decomposition of the substance of the body. The different tissues, there is every reason to believe, yield peculiar products of decomposition; thus muscle gives rise to a set of organic compounds of one description, brain to another partially or entirely different, and cartilage to a third series probably different from both, just as out of the body dissimilar substances by the same treatment yield compounds of perfectly dissimilar qualities. The nature of the products peculiar to each tissue is almost unknown, though we cannot doubt from analogy that each may again be broken up in products of a different description under the modifying influence of disease; as in the laboratory we see the same substance capable of yielding different compounds as results of its decomposition if the circumstances of the experiment be accidentally or designedly varied.

Besides these uric acid deposits, which when they accumulate in the bladder, form one variety of calculus, there are others also of frequent occurrence, of which phosphoric acid and magnesia or lime, constitute the principal ingredients. These can easily be discriminated from the former by simple chemical tests. Now it is a matter of no mere idle curiosity to ascertain whether we have to deal with a uric acid or phosphoric acid calculus. In the majority of instances they proceed from two very different states of the system, and therefore require modes of treatment widely dissimilar.

Again, there are other diseases of which the kidneys give evidence by allowing the formation not of solid deposits, but of substances in solution which are absent in a healthy condition of the secretion. Of these, two of the most important are sugar aad albumen, the one a substance which ought not to be produced at all in the system; the other forming the principal constituent of the serum of the blood, and the loss of which therefore drains and speedily exhausts the frame; both by their presence indicate diseases of the most serious description. The symptoms, however, by which they are usually accompanied, may many of them be present in other less dangerous maladies, so that not only is the diagnosis at once established by deciding on their presence or absence, but the prognosis also is founded mainly upon the results of such an examination.

Incidental remarks which I have already had occasion to make, will have rendered it hardly necessary for me now to state that over our curative measures likewise, Chemistry exercises a powerful influence, though at present this most important branch, the practical application of our knowledge, has received less assistance than those divisions of medical science from which our Therapeutics spring—Physiology and Pathology. Further advances in these are still requisite; and as they are gradually attained, our remedial measures will acquire a corresponding certainty and improvement. Much caution is as yet requisite, lest we be inclined to attribute more to Chemistry than in its present condition it is capable of performing, and be tempted, for example, to explain the poisonous action of hydrocyanic acid from its conversion of the iron of the blood into Prussian blue, or to suppose with equal probability that the narcotic effects of half a grain of morphia introduced into the stomach, depend upon its chemical action on the brain. Notions like these, though affording exercise to the imagination, must not be permitted to guide our practice. It is taking but a narrow view of the subject to imagine that medicines introduced into the mouth, will act by direct chemical affinities upon maladies whose existence is displayed in the formation of morbid productions at certain remote parts of the system, or to fancy that we can alter the nature of these products in a manner as simple as that in which we would neutralize an acid by an alkali in one of our test tubes, or that we could by the action of a solvent liquefy a compound in the body, with the same ease with which it would be effected by the operations of the digester.

Therapeutic Chemistry must be based upon more extended grounds than these. It must modify processes not products. Its first object must be to prevent the formation of abnormal compounds, not to neutralize them when formed; to check uncompensated waste; and failing in these primary aims, it may then attempt to palliate symptoms, and to alleviate diseases that it cannot cure.

Valuable researches however have been instituted, which have shown that certain substances when introduced into the stomach, and frequently also when injected into the veins, pass out of the system almost exclusively through particular channels, and the same experiments have also proved that the channel through which they escape is greatly under the control of the physician. Many saline compounds, Rochelle salt for instance, may, by exhibiting them in certain states of dilution with water, undergo a species of digestion, and pass off almost entirely by the kidneys, whilst in a different state of concentration they are evacuated without change, almost wholly by the bowels. Researches of this description, if multiplied and extended, cannot fail to add greatly to the resources of the practitioner, and they are capable of being conducted with much less difficulty than most physiological inquiries.

Thus have I endeavoured to set before you some of the important benefits which Chemistry is capable of rendering to the healing art, when its principles are well understood, and judiciously applied. Of the facilities for acquiring this science within these walls, and the additional means which have been lately placed at our disposal, I shall, on another occasion, have an opportunity to treat more at large*. Brief and imperfect as my sketch has necessarily been, I yet venture to hope that I have succeeded in convincing you, that at least three important divisions of medical science—Physiology, Pathology, and Therapeutics, are under obligations to it of fundamental importance and of daily increasing extent. Let me, in conclusion, offer a few remarks upon the spirit in which all our investigations should be performed, and upon the means best adapted to ensure success.

A real love for our profession is assuredly one of the best foundations on which to build; for the old adage is as true as it trite,—that nothing is a trouble which we do willingly. In such a case, our time, our thoughts, and above all, our attention, the principal requisite in the acquisition of knowledge, will be fully and freely rendered. Few ever rise to eminence in any pursuit without a certain degree of enthusiasm in the prosecution of their object. By its assistance they are carried forward over the difficulties that are inseparable from every study, and which are especially met with in one of so complicated a nature as the science of Medicine. But earnestness in pursuit may be recommended on grounds still higher than the advantages it holds out to us,—it is incumbent upon us as a positive duty; we have the authority of an inspired command for our direction, in the precept, "Whatsoever thine hand findeth to do, do it with thy might:" and we are exhorted to be "not slothful in business," as well as "fervent in spirit."

The advancement of our profession is indeed a noble object, and one which, as it requires, so it may well deserve, a sustained and energetic devotion of our powers. The prize offered to such devotion is one of no mean value; for it has been well and wisely

* See page 30 *et seq.* of the subsequent Lecture.

ordained, that the promotion of true knowledge and the advancement of every branch of human learning, while it benefits our race at large, shall also redound to the advantage of the individual by whom it is effected. But grand and noble as is this aim, we must not forget that it is one which is limited to this present world,—a world in which our being does but commence, where our faculties are but beginning to expand, whilst the great end of our existence here is preparation for another hereafter. It is an object whose nature is special, when considered in relation to the still nobler and more important end for which were created. Special duties arising from our individual positions we all have to perform; and if these be neglected, our general and still more important duties cannot be duly fulfilled. Let us, however, beware that whilst performing the peculiar duties of the medical practitioner, we lose not sight of those still higher ones arising from our membership in the great family of man.

The profession of medicine happily is one which, though its glory is to contribute efficient aid in alleviating the sufferings incident to humanity, is yet one which, far from tying us down to the changing scenes through which we pass, is, beyond most, calculated to carry our thoughts forward, and to raise our views from the creature to the Creator. To no one is the book of nature more fully displayed than to the medical man; and, therefore, none can apply it with greater advantage to the pages of Revelation. At every moment proofs of the unlimited power and the condescending goodness of the great Author of nature are displayed before us. When fatigued with the toils and the cares of an active, and it may be a harassing round of professional duties, it is our refreshment and our privilege, in consequence of the knowledge thus acquired, to "lift up our eyes on high, and behold who hath created these things," and to admire, in the inexhaustible fertility of contrivance, and the varied but complete adaptation of means to the object, the perfection of wisdom and of might in the hands of Him who made them all.

AN INAUGURAL LECTURE.

Mr. Principal and Gentlemen,

Although, from the circumstance of my having had the honour of delivering the Introductory Lecture given on the occasion of our first meeting for the business of this Session, I might perhaps claim exemption from the usual practice of commencing a first Course with the customary Inaugural Lecture, yet as it will afford me the means of touching upon some points which could not otherwise conveniently be discussed, at the same time that it will give me an opportunity of explaining the general principles that I wish to keep in view in my performance of the duties of this Chair, any deviation from the established method appears to be unadvisable on the present occasion.

In the acquisition of knowledge, the easiest method is for the most part the best; and we shall certainly find that the natural method, (by which I do not mean the careless adoption of anything casually presenting itself, but the systematic plan of education which is a secondary and inevitable consequence of the general current of affairs in the world,) the natural method, or the progression from the known to the unknown, is the true and sure foundation of education on which our system must be based.

In the following Lectures my first object will therefore be to assist you in arranging the already considerable mass of information on various subjects connected with Chemistry, which every one with a moderate share of observation and common sense must have acquired, and to enable you to use the facts that you possess after having ascertained that the knowledge which you have of those facts is accurate; and next to put you in the way of reducing them under more general and comprehensive heads termed *laws*. These laws of Natural Philosophy are in truth merely general expressions, including a number of particular cases.

All knowledge, to be useful, must be particular: it must adapt itself to the special case under immediate notice; but it by no means follows that knowledge consists simply in the accumulation of facts. Were this the case, the time allotted to us here, would be wholly insufficient for the attainment of ordinary skill on common subjects. The natural tendency of the mind is to generalize, and to frame laws if it cannot discover them, whilst the use of these laws is to dispense with the burdensome acquisition of particular facts ; the laws, if correct, enabling us to predict what will happen in the special case with which we may be dealing. Take as the simplest instance the action of gravity. It is wholly unnecessary for me to try the experiment whether the ruler I hold in my hand will, when I relax my grasp, fall to the ground. I know that every ruler I have seen does fall under such circumstances ; further, I know that this property is not confined to rulers, but every wooden instrument will do the same ; still further, I know that it signifies nothing, whether iron, wood, stone, any thing else be the material, and the general law is arrived at, that all bodies left unsupported, fall towards the earth. Of course this is all matter of common observation, and thus much must have been known to every individual from the commencement of time: for nearly five thousand years, notwithstanding no one thought of inquiring further. The question What is it that keeps the earth from falling? never presented itself for solution, or if it did, no satisfactory reason, no reference to any known principle, (for all our reasons amount but to this,) could be assigned; until at length Newton suggested the true reason, which once known, is as obvious as it is simple and conclusive, his supposition being not only that all bodies fall towards the earth, but that the earth in return falls towards all those bodies that approach it, or in other words, that action and reaction being equal, the force which draws all bodies to the earth, must in like manner draw the earth towards them; of course to an amount for objects close to its surface, utterly imperceptible to us, because the amount of this drawing together, this *attraction*, will be divided betwixt the two bodies, and the motion produced in each body will be inversely proportioned to the mass of the moving body. The magnitude of the earth, as compared with that of every object upon it, is so enormous, that its own motion in these cases is inappreciable. Newton, however, bounded not his supposition by the limits of our globe, but conceived the bold and happy idea that the same attraction counteracted by an impulse operating at right angles to it, in accordance with the then recently discovered laws of motion, might hold the moon in its place near the earth, account for its motion round our globe, might maintain the earth and other planets in their courses near the sun,—and by *analogy*, that is, by a similar process of reasoning, extended it to all the unnumbered suns and their systems, that fill the illimitable realms of space.

Our knowledge, however, of natural science, that is to say, of created things, must be based in the first instance upon individual facts ; and it is surprising how many of those which fall within the ordinary observation of every one may form essential contributions towards the foundation on which to raise the superstructure of our philosophy. The employment of hard names, and high-sounding words, be it remembered, is no proof of profundity on the part of him who uses them; and no mistake, as Bacon long ago remarked, requires to be more carefully guarded against than that of substituting names for ideas, thus cheating the mind into the belief that the nature of the phenomenon is explained, because we have given it a name. True it is that long words and hard terms are of constant and even necessary occurrence in scientific descriptions. It should, however, be carefully borne in mind, that no authority, however great, can justify the employment of new words for old ideas, when the terms which we already have are adequate to the purpose, and convey without risk of mistake the precise meaning that is intended.

Precision in science is, however, of such vital importance, that the signification of the words it makes use of, requires a far more rigorous definition than is the case in common language; and it therefore often becomes necessary to employ new words for familiar ideas, when the terms by which they are usually expressed are of a vague and general nature, and applicable to more than one object. Further, we constantly have occasion to define new ideas or new combinations of old ones, and then new terms for the purpose are indispensable.

Mere words, however, can never constitute science, which consists simply in the application of common sense exercised upon daily occurrences by a process of induction to the discovery of general principles; and these principles are subsequently applied to the determination of new and previously unsuspected facts of a kindred nature. It will be my endeavour, therefore, in leading you on from things which you already know to others that you do not, not merely to give you facts, but to furnish you with the principles which will enable you hereafter practically to apply them; for, as Sir John Herschel has expressed it, "We must never forget that it is principles, not phenomena, laws, not insulated facts, which are the objects of enquiry to the natural philosopher."

Facts, however, are essential primary requisites, and therefore *observation* of the things presented to us must be our first guide. In observing, we must learn to discriminate between the circumstances which are essential to a given result, and those which are accidental. We shall hence naturally be led to *experiment*, which is merely observation under a more active form, by which nature herself is questioned and cross-examined, so that we are enabled to obtain direct answers to our enquiries. The greater our skill in putting these questions, the more simple yet comprehensive and accurate our experiments, the greater will be our success; the more definite and precise the information we shall acquire. By this union of observation and experiment we are led to the discovery of *particular* laws.

At the lecture-table, however, experiments are frequently performed with an object somewhat different from those undertaken in original research, and they are here often employed as means of demonstration, as proofs of the correctness of previously ascertained principles, and as pegs by the help of which those principles are stored up in the mind. The excellence, therefore, of such a demonstration consists, not simply in the beauty of the experiment, but in its adaptation to the object in view.

I have already alluded to *analogy*, and to the use made of it by Newton, in extending the case of attraction from the substances near the surface of our earth to the moon, the planets, and the heavenly bodies in general. "Design," as Professor Daniell observes, "soon becomes apparent in the order of creation, and this design, as far as our limited faculties can trace it, is uniform, and in the system of the universe every part is doubtless proportioned to the whole. No intelligence but that of Omniscience can comprehend the plan—the *theory* of the universe; but from the plan of such small portions as we have mastered, we are often enabled successfully to anticipate the order of other portions, and thus to obtain a guide to experiment, to which an ultimate appeal must always be made*." This tracing of resemblances is one of the principal instruments employed in the search after truth; but it requires especial care in its use; within proper limits, it is invaluable, and in the facility of wielding it consists the great difference between the successful and the unsuccessful votary of science. Analogy is our main guide in the discovery of *general* laws.

Observation and experiment, and analogy or comparison, being thus the three chief instruments which aid us in the acquisition of knowledge and the extension of its boundaries, it is of the first importance that we learn to use them aright. Of them all, observation is unquestionably the one that is fundamental. It must, however, be minute and accurate, otherwise it is worse than useless, and the art of observing can only be acquired by long-continued care and patient attention. We must know what to look for in order to look to advantage; our *minds* must accompany us in the exercise of our senses, and we must be prepared to mark, not merely general resemblances, but minute differences, which often modify in an important manner, the conclusions to be drawn from them. Another

* *Introd. to Chem. Phil.*, p. 5.

object, therefore, which I intend steadily to keep in view in these Lectures will be to aid you in acquiring the art of observation.

But the acquisition of precise modes of thinking is not less imperative than the possession of accurate materials for its exercise. Confusion of ideas necessarily leads to confusion of purpose, and confusion of purpose to confusion in action. Another of my aims will therefore be, not to spare you the labour of thought, but to furnish you with food for its development. The mere reception of truth is valueless: it must be assimilated, and made a constituent part of the mind; for, just as the body cannot be sustained without material food, and yet this very food if undigested or taken in excess clogs the stomach and impairs its power; so the mere loading of the memory with facts, needful as they are to the mind for its healthy existence and its growth, speedily overpowers it, unless by due reflection they are digested and stored up, so as to contribute to its efficient activity. Thought is the exercise of the mind—an exercise as inseparable from its healthy condition, as corporeal exertion is from the maintenance of a robust state of body.

I must, however, now turn to that branch of science which it is more particularly my province to teach. But whilst endeavouring to impress upon you the value and importance of Chemistry, let it not be for a moment supposed that I wish to underrate the other indispensable branches of science which will form the objects of your study under other Professors of this College. My observations must apply necessarily to my own subject; the motives which should incite you, and the means which you should adopt in its acquisition, must therefore form the principal topics of my present Lecture.

From very humble and unpromising origin, amid the visionary speculations of the Alchemist, in his search for the so-called philosopher's stone, and for the not less chimerical elixir vitæ, Chemistry has at length attained a position, if not foremost, at least amongst the very first of those sciences which minister to the necessities and comforts of man, and which may at the same time occupy his most laborious physical exertions, whilst it opens to him the most exalted views of the wisdom and goodness of the Creator, and supplies materials for the speculations of the most refined and exalted intellect. It would be foreign to my purpose at the present time, as it would be needless in the present day, to expatiate upon the immense importance of this wide-reaching science. The absolute necessity of its study by all who would keep pace with the rapidly advancing progress of professional knowledge, of agricultural improvement or of manufacturing industry, is self-evident; and its high value as a branch of liberal education is forcing itself upon the consideration of those who have hitherto regarded it as a mere technical art, and one which is unable to contribute in any essential degree to the improvement of the mind, or to the development of the intellectual powers. For surely a science which wields the gigantic, though silently-operating forces, by which this material world is made to undergo its ceaseless, but nicely-regulated cycles of alternate decay and renovation,—a science which, with the properties of heat, teaches us to control and distribute a power which is not less essential to our existence than the air we breathe, the water that we drink, or the food that we consume,—a science which teaches us to disarm the tempest of its fiery bolt, which enables us to evoke the subtle influence of magnetism from the feeblest chemical action, or to fix it and store it for our use in the needle that points the way through storms and darkness over the pathless ocean,—a science that can extract from the sunbeam, a force that may be treasured up for centuries, but can in a moment be made to reassert its sway; that can engrave upon the imperishable surface of metal each shifting scene as it passes in quick review before our eyes,—a science which, in addition to all these wonders, can teach us the composition of the atmosphere we inhale, and the nutriment which supports our frame; which guides the husbandman in his toils, which points out the mode of extracting the gold from the dross, of separating the jewel from the earth which surrounds it, and which converts a comparatively useless mass of clay into the iron which stamps upon the age its grand characteristic,—a science of which these are but a few of the multifarious applications and subdivisions, can no longer be looked upon with indifference. It must assert its sway, and it will, ere long, unchallenged, claim the station which of right it occupies among the powers that be; and which are permitted to regulate, direct, and control the destinies of mankind.

But independent of these claims upon our attention, motives beyond those of mere utilitarian advantage press this science on our earnest attention. Considered as a purely mental training, it would not be easy to find one so fascinating to the ardent and vigorous mind. By a happy union of theory with practice, of what Bacon calls "the comfort of imagination with the industry of trial," by the rare combination of intellectual exertion with the bodily exercise which the performance of its manipulations requires, we are enabled almost to realize the ideal of perfection in occupation; it scarcely wearies, for it alternately exercises and refreshes both body and mind; whilst the successful termination of a well-arranged series of experiments in the discovery of truth, affords gratification of the purest description. In Chemistry all the resources of the most ingenious, the patience of the most persevering, the fancy of the most imaginative, and the curiosity of the most enquiring may meet with ample scope, not for the occupation of mere idle moments, but for the energies of sustained and untiring attention. Nay, more, to those ambitious of acquiring honourable distinction among the cultivators of science, what mine opens more boundless treasures or holds out more certain promises of rich reward? Do you fear that such success can be attained only by the man of wealth, of leisure and of influence? Look to the history of some of the brightest names in philosophy, —they are enrolled among the followers of this noble science, and let us trace their origin and view them in their ascent to the eminent position they adorned and dignified. Who was Sir Humphry Davy, the discoverer of the compound nature of the alkalies and earths, the acute investigator of chlorine, the inventor of the safety-lamp, and for thirty years the great luminary of chemical science? He was the son of poor Cornish parents, apprenticed to an apothecary, his laboratory a garret, his apparatus a few glass phials, bladders, and tobacco pipes. Who was Dalton, who has just descended to the tomb full of years and of honours, the man who stamped precision on Chemistry, and who first gave it a claim to the rank of an exact science, by his happy discovery and development of the laws of combination? He was usher in a private school, and subsequently was for many years compelled to earn a scanty subsistence by taking pupils in mathematics. Who was Scheele, the great rival of Lavoisier and Priestley, one of the great founders of Pneumatic Chemistry, and the discoverer of a larger number of elementary substances than any one before or since, a man of whom his patron Bergmann, himself one of the profoundest chemists of his time, said, and said truly, "that his greatest discovery was the discovery of Scheele?" Scheele was the shop-boy, the drudge of a village apothecary.

Think not, however, that none of the great men who adorn the science in our own day could furnish us with similar examples. Faraday, it is well known, was a bookbinder's apprentice. Dumas, the first chemist in France, rose from a station little higher than Scheele; and Liebig, the leader of the German chemists, was the son of a small tradesman in Darmstadt. Is further comment needed to shew, how little rank, or power, or wealth are wanted to achieve triumphs that will endure, when adventitious aids like these shall long have passed away?

But, Gentlemen, interesting as the science of Chemistry is,—important, as you cannot but feel it, from its inseparable connection, not only with so many of our most indispensable arts and manufactures, but even with the commonest actions of our lives, nay, with our very existence itself, it is not by its flowers alone that

I would hope to incite you to its persevering, and its active study. Weak indeed must its hold be on that mind, and feeble indeed the mental energies of him who would study it simply for the beauty of its experiments, or the dazzling effect of its almost magic transformations. No! Chemistry has higher claims than these to your attention. It is capable of developing the loftiest powers of the mind, and of calling into play its noblest faculties. If we except Astronomy, no science, save that which is conversant with things divine, offers so wide a grasp, or embraces within its field so vast a number of collateral sciences; based on the rigid foundations of numerical computation, it admits the application of some of the most abstruse calculations of abstract science; the laws of heat and electricity, the two pillars on which the science rests, have employed, and still continue to occupy, the exertions of the highest human intellects. Hundreds are at this moment engaged in extending our knowledge of the endless variety of chemical compounds, and hundreds more may yet reap an abundant harvest in the same inexhaustible field.

Yet Chemistry, if regarded simply as an arena for the display of intellectual power, or a course for the triumphs of ambition, loses its most solid and universal recommendation. Few, comparatively, of those it numbers among its students can expect to enlarge its domains, or to add new treasures to the stock of human learning; but none, if they rightly pursue it, can fail to have their minds purified and ennobled, their hearts filled with wonder and admiration of that supreme Intelligence which at first devised the complicated, yet harmonious scheme it unfolds to our view; and their souls humbled under a consciousness, in spite of all their boasted knowledge, of their real ignorance and insignificance.

Such being the indisputable importance of this science, adequate provision must evidently be made for enabling the student to acquire a knowledge of it, which may put him in a position to apply its principles to practice. Its immense extent, and the still measureless development of which it is susceptible, render it, however, impossible to convey in a regular course of Lectures more than the general principles on which it rests. These are compressible into a moderate compass, and are therefore attainable by all; the theory of science may therefore be acquired in the Lecture-room; and there, as it admits of illustration by experiment, it must ever be obtained with the greatest advantage, provided the Lectures are followed up by a suitable course of reading.

And I may here *en passant* refer to a disadvantage under which a professor of this science very commonly labours. Chemistry is a subject of such high interest, that its pursuit is apt to be regarded rather as an amusement and recreation, than as a serious study, deserving and demanding vigorous application and sustained attention; but it has its difficulties as well as its pleasures. The consequence is, that so long as the experiments are brilliant and numerous, nothing can exceed the assiduity and diligence of pupil; but when his reasoning powers should be called into exercise, and mental application is required, forgetful that nothing beyond what is cheerfully paid to most other subjects is thus demanded, the student is apt to persuade himself that what is difficult or dry is unimportant, and he comforts himself with the idea that something more interesting will presently occur. By this indolent and superficial method, vague notions and undefined generalities may be acquired, but no information that can be of permanent or solid utility. Let me, then, at the outset, deprecate this habit. It is one by which the greatest injustice is inflicted, both on the student and on his teacher. Let me impress upon you, that if ever the science of Chemistry is to be mastered, it must be by close, persevering, and diligent study: that study, be assured, will reward you in the pursuit, not only by its intrinsic interest, and by the value of the knowledge you will acquire, but, as in all cases of successful application, it will confer upon you additional control over the powers of your own mind, and will enable you to direct them with an increased certainty of success to any other object which you may determine to attain.

But, besides the acquisition of principles, a certain facility in the performance of experiments is desirable. The impression made by witnessing the same experiments at the lecture-table is far less vivid than that acquired by their actual performance at leisure by the pupil himself, and by varying them in different ways as circumstances may suggest. In order to carry this into effect, some training of the hands is necessary, as particular expedients are resorted by the chemist, which are best attained by practising them under direction of one accustomed to execute them; and on this account a Course of Chemical Manipulation has been established in this College, where an opportunity of seeing and performing the most important operations of the Laboratory is afforded to each student who enters the class. An attendance of such a course is rendered imperative by the University of London upon those who graduate in Medicine, and by the Examining Boards of the Army and Navy.

Though this class, however, furnishes the majority of medical students, after due attention to principles as developed in the regular course of Lectures, with a sufficient acquaintance both with theory and practice, certain very important branches of the science are comparatively unprovided for by them. It is to these branches I wish now particularly to direct your attention, as it is for those that increased accommodations have recently been provided in this College. Instruction in the principles of Analytical Chemistry, and the mode of conducting chemical researches, the making of a chemist, in short, is impossible in the Lecture-room. This can only be done in the Laboratory; and formerly, on account of the expense, this opportunity lay within the reach of comparatively few. Now, however, when the demand for instruction of this kind has become so much augmented, means have been taken for facilitating this important object, and by a reduction of the customary fee to one half, and by the increase of accommodation in the Laboratory for students, provision has been made by which all persons, for a trifling expense, and for periods of time varying from a single month to twelve months, or longer, may have the opportunity of acquiring either the processes and principles of Analytical Chemistry and the method of conducting such operations in general, or will be encouraged and assisted in carrying on original research in prosecuting systematic enquiry into any subject which they may wish to investigate. Each business, each branch of manufacture, has a chemistry of its own, which requires special study; and till it has been made the object of searching and well-directed inquiry, it is evident that the limits of improvement in the various arts are neither attained nor even guessed at.

The agriculturist, the calico printer, the dyer, colourman, the soap boiler, the sugar refiner, the glass manufacturer, the brewer, the distiller, the tanner, and even the maker of glue, must ere long, each in his own defence, study scientific chemistry, or that portion of it which bears immediately upon his own business. The necessity of this is recognized abroad, and, as a consequence of its recognition, the manufacturer becomes the patient and laborious student of Chemistry. The effects of this system are rapidly showing themselves, and scarcely a month passes without the introduction into practice of some important improvement directly traceable to this source.

A few illustrations relative to the nature and amount of one or two of the principal forces associated with matter will perhaps place this in a still clearer point of view. The object of the manufacturer is to produce the greatest amount of his article at the least cost, *i. e.*, with the smallest expenditure of time, labour, and material. Now it will not be difficult to perceive that all true economy resolves itself into economy of force, which it is equally easy to show involves and depends upon economy of material.

All of us are familiar with the idea of matter as a something which in its various shapes is capable of being appreciated by the sense of touch from the resistance which it offers to our efforts to crush or displace it. By this property the notion of substance is so impressed upon us, as to be almost inseparable from our minds, and our difficulty becomes, not to conceive of matter associated with substance, but of matter independent of substance. We are not, however, all equally familiar with a further but not less essential characteristic of matter, viz., its association with a definite amount of different kinds of force, so that in addition to the idea of substance, we are led to consider it as an assemblage of points or centres of force, the amount of which force is determined by the quantity and kind of matter which may be present. To explain my meaning more clearly, let us take the example of a piece of iron. This piece of iron we know to be composed of a number of particles separable from each other, which yet individually consist of the same substance, still are pieces of iron. This separation of parts may be carried on to an extent far beyond what our unaided senses can conceive. Still we have reasons to believe that there are limits to this subdivision, reasons which we shall have hereafter to examine in detail, from which we are led to conclude that in the state of minutest subdivision of which it is susceptible, all those particles or atoms have the same size, the same form, the same weight, and in all respects the same properties. Each atom, besides possessing a definite form, and a definite weight, may be regarded as a centre, round which a certain quantity of various forces are grouped, and having associated with it an amount of each force, the same for each individual atom. A certain limited quantity of heat or of electricity, for instance, is associated with each particle of matter, or is capable of being called into action by it under favourable circumstances.

The sum of the forces by which each atom is drawn towards the earth constitutes the weight of the body, which therefore it is evident is strictly proportional to the quantity of matter or number of particles present. But besides this force of gravity, as the tendency of bodies to fall to the earth is termed, each atom has a certain attraction towards its fellows, and that tendency called cohesion is equally definite between all the particles, provided they be constantly at the same distance from each other. It is this force which keeps the particles of bodies together, and prevents an iron bar from possessing as little coherence as a rope of sand. Now, as different bodies, though equal in bulk, have different weights, so dissimilar substances have different amounts of cohesive strength, a force which may be expressed in numbers as accurate and definite as those representing weight itself; and in fact by opposing it to the force of gravity, the amount of which we can easily apportion and estimate, we arrive at a measure of the force of cohesion. This iron wire, for example, is capable of supporting 550lbs. without breaking, an enormous amount of force which lies dormant until opposed to another and equal force; each transverse row of particles resists separation from the adjoining one with a force greater than 550lbs.; and if we know the exact area of such a section, we can immediately determine the cohesive strength, or coefficient of cohesion for iron.

Iron, it is true, varies in toughness with its quality; but perfectly pure iron, provided its texture be absolutely free from flaws, would at the same temperature always possess the same cohesive force; and what holds good in this respect with iron, holds good with all other substances. Now, till we are employing the whole of this cohesive force, we are not economizing our material to the utmost, for a wire of this thickness, provided the strain it has to bear do not exceed 550lbs., is just as efficacious as a rod an inch diameter would have been; and in an economical point of view it is of course superior. Take another substance in illustration of a different force, viz., that of chemical affinity, and we shall find that chemical affinity has its equivalent and corresponding amount of other forces, such as heat, magnetism, and electricity, which it can call into play, and these again are all reducible to a certain, a motive power. Without, however, entering into the wide details that a discussion of this subject would involve, let us content ourselves with a single illustration, and consider the production of heat by the combustion of a given quantity of charcoal. A pound of charcoal is not simply an amount of matter drawn towards the earth with a certain force arbitrarily termed a pound weight. It is an assemblage of a definite number of small particles of charcoal, each capable of exerting an amount of different kinds of force as definite as the weight that each possesses.

When this pound of pure charcoal is burned, when it combines with oxygen from the air, it gives out a certain amount of heat, which, from careful experiment, appears to be sufficient to convert thirteen pounds of water at 60°, the ordinary temperature of the air, into steam at 212°, the boiling-point of water. In other words, it will boil away thirteen pounds of water; and more than the heat sufficient to effect this, no ingenuity can make it furnish. It is evident, however, if it is capable of furnishing this quantity of steam, that unless we actually generate this full amount in our steam boilers,—unless the whole thirteen pounds of water is turned into steam for every pound of charcoal which we consume, that we are incurring a loss greater or less in proportion to the quantity of steam produced. Some waste is almost inevitable; but our exertions cannot be considered to be crowned with the success which is attainable so long as any considerable loss is sustained; we must therefore examine and reflect upon the various circumstances which may produce such loss. The first and most obvious loss arises from the escape of the heated air from the chimney before it has surrendered to the boiler the full amount of heat which it is capable of relinquishing. It is manifest, that the best method of obviating this consists in so arranging the chimney and passages for the products of combustion, that they shall circulate thoroughly around the boiler, and that sufficient time may be allowed for them to part with their high temperature before escaping into the external air. Doubtless this is an extremely difficult thing to effect to the best advantage, and is the part where some loss is inevitable; but it is so striking a point that I need not here dwell longer upon it. Another important source of loss is the cooling down of the pipes and boiler after the steam has been generated, but before it has been used. And here science has rendered most important service; in the Cornish engines especially this point has received attention,—and four times the quantity of work may now be obtained with the same expenditure of fuel from an engine which Mr. Watt considered was doing the full amount of work that could be expected from it. There is, however, another very important but more unsuspected mode in which loss is sustained, and one which is intimately connected with the chemistry of combustion. It depends upon an insufficient supply of air. It is a fact, not less singular than important, that charcoal, or coke, may be dissipated in vapour, and may apparently be wholly consumed, by one half of the amount of air that is usually required in an open fire, under circumstances where the full quantity of heat is given out; and it is to be observed, that in this case one pound of charcoal instead of emitting heat enough to convert thirteen pounds of water into steam, will only give out one-fifth of the heat, and will therefore raise but little more than two pounds and a half of water into steam. This important fact depends upon the property which charcoal has of forming two compounds with oxygen; in the first case, where the most heat is emitted, twice the amount of oxygen is taken up, and carbonic acid gas, or fixed air, is produced; in the second case, a gas is obtained also, called carbonic oxide; it is colourless, and therefore escapes notice; but it is combustible, which carbonic acid is not, and in burning, it gives out a large amount of heat; in short, the other four-fifths of the heat which are deficient when charcoal is burned into this gas.

Now, the way in which this gas is produced is worthy of notice. It is not formed, in the first instance, by the direct union of the coke or charcoal with the oxygen of the air; for carbonic acid is the compound which is invariably obtained; but when this carbonic acid is made to pass over red-hot coals, it dissolves a portion of the coal, becomes dilated to twice the bulk it occupied, and actually, instead of increasing the heat of the furnace by the quantity of coal with which it thus unites, it most materially diminishes it, and carries it off in sheer waste. I can show you this combination of the incombustible carbonic acid with the combustible coal, and the production of a gas which is capable of taking fire on the application of a light, by passing the carbonic acid through a long glass tube filled with charcoal, and heated to redness by passing it across the furnace, and then collecting in separate vessels the gas which escapes from the apparatus. Now let us consider what is actually going on in many of our furnaces: these are usually open to the air at bottom by the bars of the fire-grate,—brisk combustion takes place, and the body of coke above becomes of a bright red heat; but the air is quickly deprived of its oxygen by the lowest layer of coal, the draught carries up the exhausted air, and with it the carbonic acid that has been formed; this gas, as it passes over the intensely ignited coal, dissolves a fresh portion, cools the fire and ascends the chimney; when it reaches the top of the chimney, it has become too much cooled down to take fire as it comes into the air, and passes off unsuspected and to waste; actually carrying with it four-fifths of the heat that it ought to give out if the coal that it takes off had been burned with a due supply of air. I do not mean to say that the whole of the carbonic acid is ever entirely converted into carbonic oxide; the gas is not in contact with the heated coal for a sufficient length of time to produce this effect; but this I do say, that in all furnaces of the common construction, a large loss is sustained in this insidious and unsuspected manner.

In the case where coal and not coke is employed, still greater loss is sustained; all the visible smoke is wasted, a good deal of carbonic oxide in addition passes off in the invisible form, and still more coal gas escapes unnoticed; the coal in the upper part of the furnace becomes coked by the heat of the lower portion, and nearly all that the gas-works obtain by distillation of coal in retorts, here passes unheeded into the air. The question, therefore, of the consumption of smoke, resolves itself not merely into a question of health and public convenience, to which too often a deaf ear is turned by those who are deriving profit at the expense of the sufferers, but it is actually a question of economy on the widest scale—it is a question on which common sense and common humanity are alike agreed,—and it is therefore a point which eventually will demand from self-interest, that attention which mere good feeling would long solicit in vain.

In the case of heat, then, economy of material is manifestly involved in the economy of force. Nor is it less so, in the saving of time or of manual labour. Every individual is capable, in a given period, with a certain allowance of food, of executing a given amount of labour, and whether that labour be beneficially employed or not, the same amount of food must be consumed to maintain the functions of his body; for it is past a doubt that indirectly and ultimately it is the quantity of force associated with the elements of the food he receives which, by means as yet transcending our finite comprehension, are converted into the physical force which he displays in the execution of his task; the amount of force which he can exert being, as all experience shows, confined within certain limits. The operations of the mind, by inscrutable arrangements, influence and direct the exertions of the body, and these are all accompanied by certain chemical changes effected within the frame, and which are as inseparable from the performance of those functions as light is from vision, or nerve and muscle from voluntary motion. Even the brain itself, in the operation of thinking, is undergoing constant change. Nothing, in fact, is more certain, or more beautifully illustrative of the mysterious connexion of mind with matter, than the truths just mentioned, and which Liebig has summed up in the following words.

"Physiology has sufficiently decisive grounds for the opinion that every movement, every manifestation of power, is the consequence of a transformation of the tissues of the materials which compose them, that every imagination, every affection is followed by alterations in the chemical composition of the secreted fluids, —that every thought, and every emotion is accompanied by a change in the constitution of the substance of the brain*."

It would be easy, Gentlemen, to enlarge upon this topic; but the mutual relation of force, the transfer and convertibility of one species of force into another, transformations which maintain the universe in motion, will form one of the most interesting and important branches of our future study. I might, moreover, show, that it is not less necessary to economize mental than physical force,—that mental force, like physical, has its definite amount and strict limitation; and that one great object in education is to teach us to apply that force to the best advantage; but I forbear—time warns me to bring these remarks to a conclusion. My chief object will have been attained, if they have in some degree awakened in your minds an interest in the extensive and beautiful science which we are purposing to study together; and that you may be the better able to follow me as I proceed, I would recommend each of you to procure the excellent *Introduction to Chemical Philosophy*, of our late lamented Professor

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* *Die Organische Chemie in ihrer Anwendung auf Physiologie und Pathologie*, p. 9.

Daniell. And let me earnestly request you to devote a portion of your time and attention, not merely to the Lectures in the Class-room, but to a careful study of the subject daily as we advance; difficulties you of course will meet with: these it will be my pleasure to attempt to remove, if you will give me the opportunity of doing so by stating them after the hour of Lecture is over. If then you will join with me heartily, remembering that we have the highest authority as a sanction of our diligence in all lawful pursuits, if, I say, you will co-operate with me, and really allow us to study our science together, I have no fear for the result of our labours, being well assured that in such a case neither will you have listened, nor shall I have lectured in vain.

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