

ON THE

**RELATION OF THE NATURAL SCIENCES**

TO THE

**TOTALITY OF THE SCIENCES.**

AN ADDRESS

DELIVERED BEFORE THE UNIVERSITY OF HEIDELBERG,

BY

PROFESSOR HELMHOLTZ.

TRANSLATED BY

C. H. SCHAIBLE, M.D., PH.D., F.C.P.,

OF THE R.M. ACADEMY, WOOLWICH.

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THE present Address was delivered in the year 1862, by the eminent German scholar, Professor Helmholtz, whose name and works are familiar to every student of science. The occasion was the Annual Distribution of Prizes for the best Essays on subjects proposed by the four Faculties of the University.

The Address is excellent, both in form and substance, and bears especially on a question often discussed in this country, viz., the comparative value of scientific and literary instruction.

The Translator has obtained the kind permission of Professor Helmholtz for its publication, and is convinced it will prove a welcome contribution to the Educational Essays of the present day.

C. H. S.

## ON THE RELATION OF THE NATURAL SCIENCES TO THE TOTALITY OF THE SCIENCES.

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It would seem, at the present day, as if the relations of the various sciences to one another, in respect of which relationship we have been accustomed to group them together under the name of a *universitas litterarum*, had become looser than ever. We see the learned men of our day absorbed in studies of detail of such vast extent, that not even the most versatile dare any longer think of storing up in his head the varied knowledge pertaining to more than some small district of the domain of modern science. To the philologist of the past three centuries, the study of the Greek and Latin languages alone afforded sufficient occupation, and only for immediate practical purposes were perhaps one or two European languages added to his store. But now, Comparative Philology has proposed to itself no less a task than to become acquainted with *all* the languages of *all* branches of the human family, in order to discover from them the laws of the formation of language itself; and to this Herculean task it has set itself with astonishing industry and perseverance. Even in the domain of Classical Philology study is no longer confined to those writings which, on account of their artistic perfection, acuteness of thought, or the importance of their subject-matter, have been accepted as models of poetry and prose for all time. It is now acknowledged that every lost fragment of an ancient author, every remark of pedantic grammarian or Byzantine court-poet, every broken tombstone of a Roman official, that the antiquarian has discovered in some remote corner of Hungary, Spain, or Africa, may contain a piece of intelligence or of evidence, that may be important in its place. And thus again another band of scholars is devoting itself to the interminable work of collecting and cataloguing *all* remains of classic antiquity, of whatever kind, so as to have them all arranged and ready for use. Add to this the study of the sources of history, the examination of parchments and papers accumulated in the archives of states and cities, the collecting together of detached scraps of information scattered through memoirs, correspondence, and biographies; together with the decyphering of hieroglyphic and arrow-head documents and inscriptions;—add to this the systematic ever-extending classification of mine-

rals, plants, and animals, living and fossil; and there is unfolded before our view a mass of ordered materials of science which may well cause the brain to swim. In all these departments of science the circle of research continues to expand, as the aids to observation are improved, the limits of inquiry ever receding as we advance. The Zoologist was formerly content to confine himself to a description of the external characteristics of an animal—the teeth, the fur, the formation of the feet, &c. The Anatomist, on his part, confined himself to the anatomy of the human subject alone, so far as he was able to discover it with the help of his dissecting knife, saw, and chisel, by injection into the vessels, &c. The study of human anatomy was deemed to be then in itself a department of vast extent and difficulty. Now-a-days science is no longer satisfied with the so-called cruder *human anatomy*, which has almost come to be regarded, though erroneously, as an exhausted subject; *comparative anatomy* (*i. e.* the anatomy of *all* species of animals) and *microscopic anatomy*, sciences of an immensely wider range, have been added, and now absorb the attention of the observer.

The four “elements” of the ancients, and of the alchemists of the middle ages, have grown, in our modern chemistry, to sixty-four\* ; the three last found of them have been discovered by a method invented at our own University, which promises many more similar discoveries. But not only has the number of the elementary bodies so surprisingly increased; the methods of effecting complex combinations of these have made such advances, that the so-called *organic chemistry*, which takes cognizance only of combinations of carbon with hydrogen, oxygen, nitrogen, and a few other elements, has already been raised to the rank of a special science.

“As are the stars of heaven for multitude,” was once the natural expression for a number which exceeded our faculty of comprehension. Pliny considers it an undertaking bordering on presumption in Hipparchus (*rem etiam Deo improbam*), to have undertaken to count the number of the stars, and to fix their several positions. Yet the catalogues of stars, registered down to the 17th century, without the aid of the telescope, comprises only from 1000 to 1500 stars, of between the first and fifth magnitudes. At the present time, astronomers are employed, in several observatories, in extending these catalogues to stars of the *tenth* magnitude; which will give for the visible heavens a total number of about 200,000 fixed stars, all of which are to be registered, and of which the places are to be determined by exact measurement. The immediate result of these researches has, moreover, been the discovery of a number of new planets, of which, before the year 1781, only six were known, while at present their number has increased to seventy-five\*.

In contemplating this amazing activity in all branches of science, the daring enterprises of men may well excite in us a feeling of astonishment mingled with terror, as in the chorus of Antigone, exclaiming:

πολλά τὰ δεινὰ, κούδὲν ἀνθρώπου δεινότερον πέλει.

“Much is wonderful, but nothing is more wonderful than man.”

Who shall be able to overlook the whole?—who may hold in his hand

\* This was the number at the time (1862) the Address was delivered.

the connecting thread, and find his way through the labyrinth? The natural result of all this we first perceive in the fact, that each individual explorer is necessitated to choose for himself a continually narrowing field of inquiry, and can attain but to an imperfect knowledge of the adjacent departments of science. We are now inclined to smile on hearing, that in the seventeenth century Kepler was called to fill the post of Professor of Mathematics and Moral Philosophy at Grätz; or that, at the commencement of the eighteenth century, Boerhave occupied, at Leyden, at one and the same time, the chairs of Botany, Chemistry, and Clinical Medicine, in which latter, of course, at that time, was included Pharmacy. We now require at least four, and, at completely equipped Universities, as many as seven or eight Professors, to represent all these branches. And similarly with the other Faculties.

I am the rather drawn to take up the question of the connection of the various sciences, as I myself belong to the department of the natural sciences; and this department has been charged, of late, with having, more than any other of the sciences, struck out for itself an independent path, and become estranged from the rest, which, by common philological and historical studies, are connected with one another. A certain estrangement did indeed for a time manifest itself; and it appears to me to have been more especially developed under the influence of the Hegelian philosophy, or at least by means of it to have been brought into stronger relief. For at the end of the last century, under the influence of the teaching of Kant, such a division had not yet declared itself. On the contrary, the philosophy of Kant took its stand on a precisely common ground with natural science, as is evidenced by Kant's own works on natural science, more particularly his "Hypothesis of the Universe," based upon Newton's law of gravitation, and which latterly, under Laplace's name, has obtained general recognition. The one aim of Kant's critical philosophy was to test the sources and evidence of our knowledge, and to set up a standard for the intellectual work of the different sciences. A proposition invented *à priori*, by direct process of reasoning, could, according to Kant's doctrine, only furnish a rule for the *method* of reasoning, but could have no positive and real value in itself. The "Philosophy of Identity" was bolder. It started with the hypothesis, that the actual world—the phenomena of nature and the life of man—is also the expression of the thought of a creative mind,—a mind which must be regarded as in its essence one with the mind of man. The human mind seemed thus to assume to itself the power (without being guided by experience from without) of thinking again the thoughts of the Creator, and discovering these by its own innate powers. In this sense, the "Philosophy of Identity" proposed to itself to build up, *à priori*, the essential structure of the other sciences. This method might perhaps, with more or less success, be applied to religion, law, government, language, art, history—in short, to all sciences the subject-matter of which is developed from a psychological basis, and which therefore have aptly been classed under the common denomination of "mental sciences." Government, religion, art, language, have been developed for the satisfaction of certain spiritual wants of man. In spite of the disturbing influence

of external elements, as the forces of nature, chance, rivalry of man with man, still must the constant strivings of the human spirit, directed to one end, prevail at last over the aimless workings of these opposing forces. Under these conditions, the attempt were not altogether chimerical, by aid of an exact understanding of the workings of the human mind, to sketch out a course of development in regard to these relations, provided that the philosopher had already accumulated a sufficient store of observed facts wherewith to clothe his abstractions. Hegel, in his efforts to solve this problem, was materially aided by the deep insight into history and science which the philosophers and poets of the times immediately preceding had acquired, and the results of whose labours he had but to bring together and arrange, to lay the foundation of a system imposing by the surprising and far-reaching character of its deductions. Thus it was that his system was received by the majority of cultivated men of his time with enthusiastic applause, and extravagant hopes were excited that many of the deepest problems of human existence were now about to receive their solution ; the more so, as the exposition of the system was wrapped up in a language singularly abstruse, and which was perhaps really understood by but few of Hegel's disciples.

That by the system of Hegel it was found possible, more or less satisfactorily, to deduce the fundamental propositions of the "mental sciences," was yet no proof of the validity of the Hypothesis of Identity, on which that system was based. On the contrary, the *facts of Nature* ought to have been the decisive touchstone of that philosophy. That in mental science traces of the activity and successive stages of development of the mind of man were to be found, was to be expected. But if Nature reflected the result of the thought of a similar creative spirit, then the comparatively simpler forms and processes of nature must be more easily capable of being brought under that system. But here we may affirm that the efforts of the Philosophy of Identity suffered complete shipwreck. The natural philosophy of Hegel appeared, to natural philosophers at least, absolutely without meaning. There was not one of the many distinguished natural philosophers of that time who could find any satisfaction in the Hegelian ideas. As, however, it was of especial importance for Hegel to gain for his system in this particular field a recognition which had been so fully accorded to it elsewhere, there began on his side an unusually passionate and embittered contest, directed chiefly against Newton, as the first and greatest representative of scientific inquiry. The physicists were attacked by the philosophers on the score of narrow-mindedness ; the latter by the former for their want of common sense. The physicists now began to attach a certain importance to keeping their works entirely free from all philosophic theories ; and things soon came to this pass, that many of them, and among them men of the first rank, condemned all philosophy, not only as being useless in itself, but even as mischievous dreaming. We cannot deny that here, along with the unjustifiable claims which the Philosophy of Identity made to subordinate the other Faculties to itself, the legitimate claims of philosophy, more particularly to examine the sources of our knowledge and to set up a standard of mental work of its own, were thrown overboard.

In the mental sciences the process was different, although it actually led to the same result. In all branches of science there rose up enthusiastic disciples of the Hegelian philosophy in its application to religion, government, law, art, language; each of whom sought to reconstruct his own particular domain in accordance with this system, and in the paths of speculation to gather fruits which they had hitherto been content to rear slowly by patient and long-continued application. Thus for a time there was established a sharp and definite opposition between the natural sciences on the one hand, and the mental sciences on the other; and it was not seldom that the claims of the former department to the very name of science were disputed.

It is true this state of opposition did not long endure in its original force. The natural sciences proved to the eyes of every one, by a rapid succession of brilliant discoveries and applications, that there lay in them a germ of unusual fertility; and it was impossible to refuse to them both respect and recognition. In the other regions of knowledge, also, conscientious inquirers soon raised their voice against the too bold flights of speculation. Nevertheless, a certain amount of beneficial influence attaching to these philosophic systems cannot be ignored. It is impossible to deny, that since the appearance of Hegel and Schelling, the attention of inquirers in the various branches of mental science has been directed with greater intentness and persistency to the essence and aim of those sciences than had been the case in former times; and the great work of that philosophy has therefore not been entirely in vain.

In proportion as the empirical examination of facts came also, in the case of the mental sciences, into the foreground, the opposition between them and the natural sciences has been mitigated. At the same time, if this opposition had been brought into exaggerated prominence by the influence of the before-mentioned philosophical opinions and theories, it is still not to be overlooked that such an opposition is actually founded in the nature of things, and must make itself felt. The reason of this lies partly in the nature of the workings of the mind, partly in the subject-matter with which the separate departments have to do, as is already expressed in the terms themselves—Natural and Mental Science. The physicist will find some difficulty in imparting to the philologist and jurist a clear view of a complicated process of nature. He requires in them a power of abstracting from visible phenomena, and a readiness in the application of geometrical and mechanical principles, which they cannot reasonably be expected to possess. On the other hand, the moralist and theologian will probably find the physicist too much inclined to mere mechanical and material explanations, which to them appear trivial, and by which a restraint is imposed on their ardour and enthusiasm. The philologist and the historian, with whom the jurist and theologian are closely connected by common philological and theological studies, will find the physicist surprisingly indifferent to literary treasures; perhaps even more indifferent than is good for the history of his own science. Finally, it is not to be disputed that mental science has to do directly with the dearest interests of man, and with the social ordinances which he has established;

whilst natural science, on the other hand, has to do with matter, which is external and in itself indifferent to him ; which, by reason of its practical use, cannot, indeed, be entirely dispensed with, but which may have very little immediate influence on his mental and moral development.

In this state of the case, when the main trunk of the sciences had spread out into an infinity of branches,—when marked contrasts have been developed between the different compartments,—when it is patent that no individual mind can hope to grasp the whole, or even any considerable portion of that whole,—the question arises, Is it any longer desirable to keep all the sciences together as it were under the same roof? Is not the union of the four Faculties in one “University” merely a relic of the Middle Ages? Many practical advantages have been secured by sending the student of medicine to the hospitals of our great towns, the future physicist to the polytechnic schools, and by the establishment of special seminaries and training schools for the students of law and theology. We trust that the German Universities may long be preserved from such dismemberment! Thus would, indeed, be completely severed the bond of union between the different sciences. And how essential such a connexion is, not only in its formal relation for the conservation and sustentation of scientific working-power, but how essential a bond of union between the different sciences is, not only in its formal relation for the conservation and sustentation of scientific working-power, but also in its material relation for the furthering and development of the results of that work, we propose now briefly to take into consideration.

And first, in its formal relation. I believe that the union of the different sciences is necessary in order to preserve a state of healthy equilibrium between the different faculties of the mind. Each particular science calls into play particular faculties, which by constant practice become strengthened for the work they are called upon to perform. But every form of one-sided development is in itself detrimental, in that it tends to unfit the mind for less practised forms of activity, confines the range of vision of the observer, and hinders him from obtaining comprehensive views of a subject ; and in particular because it too easily inclines to an overweening self-esteem. The man who perceives that he can perform a certain kind of mental work better than other men, is tempted to forget that there are also many things which others are much more proficient in than himself ; and self-conceit—let no man forget—is the worst possible enemy to activity of mind, and to progress in all branches of knowledge. How many men have there been, of more than ordinary capacity, who have been intellectually maimed, as it were, by a neglect of that self-criticism so especially necessary for the student—who have come to look with contempt on dry plodding work, as unworthy of their more finely strung faculties, looking forward rather to grand combinations of ideas and startling discoveries to make their names famous! How many such there have been, who have brought to a close a gloomy and disappointed existence, embittered against mankind because that appreciation and honour has not been accorded to them which men are wont to bestow in recognition of the results of hard and unremitting labour, and not in answer to the confident asser-



tions of self-complacent genius! And the greater the isolation in which the individual wraps himself, the greater the danger of his incurring such a fate; while, on the other hand, nothing tends more to nourish a vigorous intellectual life than that we should be compelled, with the exertion of all our faculties, to win for ourselves the appreciation of men whom we are wont to honour.

When we compare the method of working of the mind in the separate departments of science, we observe certain pervading differences, according to the nature of the sciences themselves; while, at the same time, we must not overlook the fact, that every specially-gifted mind has its own particular bent, by which it is pre-eminently adapted for some special sphere of activity. We need only compare the work of two contemporary explorers in closely related departments of science, to be convinced that the more distinguished the men, the more distinctly will their mental individuality manifest itself, and the less fitted would the one be to take upon himself the work of the other. On the present occasion, I cannot of course attempt to do more than characterize the most marked and general traits of difference which intellectual work exhibits in different fields of study.

I have referred to the immense extent of the accumulated material of modern science. It is clear that the greater this accumulation of material, the more need will there be of a better organisation and more exact classification of it, that the student may not be in danger of hopelessly losing his way in this labyrinth of learning. And the more complete the systematizing of the knowledge acquired, the better the classification and arrangement of facts, the more may the mass of details be augmented, without impairing the unity and connexion of the whole. At the present day the man of science is able to effect the more in detail, because his predecessors have taught him how the ordering of the material of knowledge is to be effected.

This organisation consists, in the first place, in merely outward and mechanical arrangement; such as is exhibited in our catalogues, lexicons, indexes, sketches of literary history, calendars, legal digests, the systems of classification of natural history, &c. In this way, it has at the outset been secured, that all that varied mass of knowledge, which it would be impossible to store up in the memory, is brought together, ready to the hand of the inquirer, in a form in which it may the most easily be turned to account. By means of a good lexicon, many a schoolboy is now in a position to attain to an understanding of the ancient classics, which even an Erasmus, with all his life-long study of the writers of antiquity, might have found no easy task. Works of this nature form, as it were, the principal-fund of the science-property of mankind, the *interest* of which we may turn to further profit. We might compare them to a capital invested in land. Like the soil, of which landed property consists, the knowledge stored up in these catalogues, lexicons, &c., may have but slender attractions for the vulgar; the man unacquainted with the subject can have little idea of the labour and cost at which that soil has been prepared; the work of the husbandman appears to him terribly toilsome, tedious, and clumsy. But although the work of the lexicographer and physical-science cataloguer calls for the same painful and persevering industry as the labour of the husbandman, we must not

therefore hastily assume that the work itself is of an inferior character, or that it is as dry and mechanical as it at first appears when we have the catalogue or lexicon ready printed before us. For it is necessary, in such compilations, that all the isolated facts should first be selected by careful observation, and afterwards tested and compared with one another,—the essential sifted from the unessential,—and all this, it is plain, he only can efficiently accomplish who has clearly conceived the end and aim of his work, and the scope and method of the branch of science which it concerns; but for such an one each minute detail will have its own particular interest, from its position in relation to the whole science of which it is a part. Were it not so, such work would indeed be the worst kind of mental drudgery it were possible to conceive. That also in works like these the progressive development of the principles and methods of science can be traced, is sufficiently evidenced in the constant demand there exists for new lexicons, new systems of classification, new digests of laws, new star-catalogues, &c.; and in these new compilations is exhibited the progress that is taking place, in the arts themselves of method and organisation.

But our knowledge is not to remain as it were petrified in the form of lexicons and catalogues; for the very fact that we are thus obliged to carry it about with us under our arm, shows that we have not yet thoroughly assimilated it, and made it a part of our being. It is not enough that we know *facts* alone: *true science* cannot properly be said to exist until the laws and primal causes of the facts have disclosed themselves to our view. The logical elaboration of scientific material consists, in the first place, in the detection and selection of similarities from amongst the mass of isolated facts, and the formation of general notions that will embrace these. A conception of this kind comprehends a multitude of details, and represents these in our mental operations. We give it the name of a *general notion*, when it embraces a number of *things*; we call it a *law*, when it comprehends a chain of phenomena or events. When we have ascertained by observation that all sucking-animals (*i. e.*, all warm-blooded animals,) which bring forth their young alive, are also found to breathe by means of lungs, and to have a double heart and not less than three auditory ossicles, we have no occasion further to consider these anatomical peculiarities as belonging separately to monkeys, horses, dogs, whales, &c. The general rule comprehends here a vast number of individual cases, and replaces them in the memory. So again, when we have formulated the law of the refraction of light, not only does this law include the cases where rays fall at different angles upon the even surface of water, and inform us what phenomena to expect under such circumstances; but it embraces all cases in which rays of light, of whatever colour, fall upon the surface, however variously formed, of any transparent material whatever. This law therefore embraces literally an infinite number of cases, which it would have been altogether impossible to retain singly in the memory. And further we may remark, that this law embraces not only the cases which we ourselves, and others before us, have observed, but we will not hesitate to apply it to cases as yet unobserved, to deduce the consequences of refraction under these new conditions; and

we shall not find ourselves deceived in our expectations. So also, should we chance to meet with a new species of sucking-animal, we would be able to affirm, with a confidence bordering on certainty, that the animal possesses lungs, a double heart, and not less than three auditory ossicles. By thus collecting and ranging together in thought the facts of experience, and deducing from them general notions and laws, we not only bring our knowledge into a form in which it can readily be handled and stored, but we are also able to extend and add to it, by the application of the newly discovered rules and laws to all analogous cases, as they may arise.

The examples we have adduced are cases in which we find no difficulty in combining the isolated facts, and the method of the whole process lies clear before our eyes. But in more complex cases we are not always able so readily to separate the like from the unlike, and to comprehend the former under some clearly defined generalisation. For instance, we know a certain man to be ambitious; we may be able, with tolerable certainty, to predict that if the man is called upon to act under certain conditions, he will, in obedience to his ruling passion, adopt a certain course of action. But we would not, for all that, be able to define the marks by which an ambitious man may be recognized, nor by what standard the degree of his ambition may be measured; neither can we say with certainty what amount of ambition must be present in him, in order that, in the supposed case, it may give to his course of action that particular direction. We thus make our comparisons between the previously observed actions of the individual and the actions of the generality of men when placed in similar circumstances; and we draw a conclusion as to what will be the consequence of similar conditions on subsequent occasions, without, nevertheless, being able to express either the major or minor premiss as a definite and distinctly formulated proposition; nay, it may be, without having first come to a clear understanding with ourselves, that our conclusion rests on the before mentioned comparison. Our judgment in such a case rests, in fact, only on a certain psychological intuition, and is not the result of a conscious process of reasoning, although, in reality, the mental operation has been the same as in the case where we attribute to the newly-discovered sucking-animal the possession of lungs.

This latter kind of induction, which cannot be carried out to a strict logical conclusion, nor to the establishment of a universal law, plays a very extensive rôle in the intercourse of every-day life. On it rests the entire development of the perceptions of our senses, as may be seen when we examine into the so-called fallacies of sensation. When, for instance, the fibres of the optic nerve are irritated by a blow, we immediately perceive the sensation of light; because we have, all our life long, been accustomed to experience this sensation on the entrance of light into the eye, and have, therefore, been led to associate any irritation of the optic nerve with the presence and action of light; and we continue to do so in cases where no such connexion exists. The same kind of induction plays a chief part in relation to psychological phenomena, on account of the extreme complexity of the influences which govern the formation of character, and the passing phases of feeling and passion in the heart of man.

Nay more, seeing that we claim for ourselves the possession of free will,—*i. e.*, the power of acting independently in our own right, not as being bound by some inevitable law of causality,—we utterly deny the possibility of attributing even some part of the manifestations of the activity of our spirit to the action of a strictly binding law.

To this kind of induction, as distinguished from the *logical*, which issues in the establishment of clearly defined general propositions, we might not inaptly apply the name *artistic induction*, because its working may be discerned pre-eminently in the more celebrated productions of art. It is of the essence of the artist's peculiar talent, that, by the medium whether of language, of form and colour, or of the tones of music, he is able (without being consciously led by any definable rule) to represent the outward phenomena of character, and by a sort of intuitive perception to realize the way in which the varying phases of mind and heart must manifest themselves under varying conditions. Where, on the contrary, we perceive that the artist has only been working according to certain general abstract principles, we deem his work poor and trivial, and withhold from it our admiration. The works of the greatest masters, on the other hand, place before us characters and emotions with a vividness, a fulness of individual traits, and a convincing power of faithful representation, which even seems to us (paradoxical as that may sound) to surpass the reality itself, because we have here no distracting circumstances of time and place to mar the unity of impression.

If we now take a review of the circle of the sciences with regard to the manner of deriving from them practical results, we shall perceive at once a marked and all-pervading difference between the natural and mental sciences. The natural sciences are for the most part capable of carrying out their inductions to the formulating of general rules and laws; the mental sciences, on the other hand, have to do more especially with judgments derived from a process of psychological intuitions. Thus the historian has, first of all, to decide upon the credibility of the accounts whence he derives his facts; the facts being established, there begins for him the difficult and important task of tracing out the frequently very involved and complicated motives of action of nations and individuals; and both these points can only be decided by the light of psychological intuition. The philologist, in so far as he has to do with the elucidation and correction of texts, and the history of literature and art, must seek to bring out the sense of his author, together with the relations and allusions conveyed in his words and forms of expression; and to this end, he must have attained to a correct view both of the individual characteristics of the writer, and of the genius of the language in which he wrote. All these are cases of artistic, and not of proper logical, induction. A judgment can here only be formed, when a very large number of similar facts have been stored up in the memory, so that they may be brought directly into comparative relationship with the matter in hand. One of the primary requisites, therefore, for studies of this nature, is a retentive and ready memory. In fact, the singular strength of memory of many celebrated historians and philologists has been the wonder of their contemporaries. Of course memory alone is not sufficient, without the faculty of quickly dis-

cerning essential similarity in every variety of connexion, and without a fine and cultivated sense for the emotions of the human heart ; which latter again is not to be attained without the possession of warmth of feeling and sympathy, on the part of the observer, of emotional states in others. Whilst constant and sympathetic intercourse with our fellow men in every-day life lies at the foundation of these psychological intuitions, the study of history and art serves to supplement and enrich the acquired power, by bringing before our view men acting under unusual conjunctions of circumstances, and allowing us, in their case, to witness, in its whole breadth and force, the action of forces which lie hidden within our own breasts.

The above named departments of science do not, as a rule, issue in the formulating of strictly general laws, with the exception of language. The laws of language have been established by the human will ; though they may not have been laid down with definite design and according to any fixed plan, but rather have been gradually evolved as they were needed. They therefore present themselves to the student as arbitrary injunctions, or laws imposed by authority from without.

Closely related to historical and philological studies are the sciences of *Theology* and *Jurisprudence*, the preliminary and auxiliary studies to which are actually comprehended in the circle of the former sciences. The general laws, which we find to lie at the foundation of these sciences, are likewise *injunctions*—laws imposed, by an authority external to man, for belief and action in moral and social relations ; not laws which, like the laws of nature, have been evolved by generalisation from a large body of facts. But, as in the application of a law of nature to a particular case, so deduction from these grammatical, judicial, moral, and dogmatic injunctions takes the form of the familiar logical syllogism. The injunction forms the major premiss, the minor determines whether the case in point can be classed among those in relation to which the command was given. The performance of this latter task, whether by way of grammatical analysis, which aims at eliciting the exact meaning of a proposition, or by the judicial investigation of the credibility of the facts themselves, the motives of the actors, or the true sense of the documents left by them,—must again, for the most part, be merely a matter of psychological intuition. On the other hand, it must not be overlooked, that both the grammar of the cultivated languages, and our judicial system, gradually developed and perfected by the practice of more than 2000 years, have now attained to a high degree of logical completeness and consistency, so that, on the whole, the cases which do not admit of being brought with certainty under one of the given laws form but rare exceptions ; though it is inevitable that such exceptions should occasionally occur, as laws of man's making can never have the completeness and universality of authority of the laws of nature. In such cases, we have no alternative but to endeavour to supply the missing links in the sense of the lawgiver, according to the analogy and sequence of the judgments laid down for similar cases.

Grammatical and legal studies have a certain advantage as a means of developing the powers of the mind, in that by their instrumentality the different kinds of mental activity are brought pretty equally into

play. It is to this end that the higher school education of the modern European nations is mainly based on the study, through their grammar, of foreign languages, and especially of the languages of antiquity. The mother-tongue, and those foreign languages which are learnt by practice alone, do not sufficiently call into play the logical faculty; though we may find in them efficient instruments for cultivating a sense of delicacy and artistic beauty of expression. The two "classic" languages, Greek and Latin, have, in addition to their wonderfully delicate artistic and logical development, the further advantage, which they appear to share in common with most of the ancient and original tongues, that they mark with precision, by an extremely copious and distinct scheme of inflections, the grammatical relations of words and sentences to one another. It is the tendency of languages in the course of time to become as it were worn down by use, the inflections being reduced, for the sake of brevity and the saving of time, to the smallest possible compass, and with a proportionate loss in variety and completeness of grammatical relations. This difference may easily be discerned, on a comparison of Latin with the modern European languages; though none of them has gone so far as the English in this process of attrition. And in this, as it appears to me, consists the reason why the modern languages are so much less efficient a means of *education* than the ancient tongues.\*

As we apply the study of grammar to the education of youth, so, for similar reasons, we rightly make use of legal studies as an instrument of culture for those of riper years, even in cases where such special study is not required for the practical end of a professional career.

Now, in regard to the kind of mental work involved, the *Natural Sciences* stand at the opposite extreme to the philologico-historical sciences. Not that there is not also, in many departments of the former sciences, room for the display of the same intuitive perception of analogies, and for a certain artistic discrimination. On the contrary, in the department of natural history, the determination of what distinguishing generic marks are important and what unimportant in their systemic relation,—of what divisions of the fauna and flora are more natural than others,—is left to be determined by the same intuitive faculty, irrespective of strictly defined rules. It is, moreover, not

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\* With regard to the above opinion, the *translator* cannot quite agree with the *author*. As a means of training the intellect, the science of inflections is no doubt important, and here the classical languages offer more advantages than some of the principal modern languages. But the study of inflections is not the only useful part of *grammatical* training. Besides this, the grammatical study of a language comprises other useful elements, such as the development, combination, and construction of sentences, metre, synonyms, etymology, &c., in respect to which the leading modern languages are not inferior to the classics. Moreover, so-called *grammatical* instruction is not the only advantage the study of a language affords. There is, further, the *technical part*, comprehending the reading, writing, and speaking of a language, and the study of its literature. In the latter respect, the leading living languages yield in no way to classics, which they even excel in clearness of expression, as well as in the range and variety of information.

a little remarkable, that it was an "artist" (viz. Goethe) who actually gave the cue for the inquiries of comparative anatomy into the analogy of corresponding organs in different classes of animals, as well as to the analogous doctrine of the metamorphosis of leaves in the vegetable kingdom; and that through him was marked out the precise direction which comparative anatomy has taken since his time. But even in these departments, where we have to do with the least understood workings of the phenomena of life, it is in general much easier to discover and define general comprehensive notions and propositions, than where we have to ground our judgment on an analysis of mental and moral phenomena. The peculiar character of the natural sciences exhibits itself in fullest measure, and with greatest distinctness, in the experimental and mathematically-treated departments, but chiefly in the department of pure mathematics.

The distinguishing characteristic of these latter sciences consists, as it appears to me, in this, that in their case it is comparatively easy to combine the detached results of observation and experiment, into general laws of universal application and extraordinarily comprehensive in extent, whilst in the case of the first-mentioned sciences this task is wont to present insuperable difficulties. Indeed, in the case of mathematics, the general propositions laid down at the outset in the form of axioms are so small in number, of such indefinite extent, and of such immediate evidence, that it is unnecessary to adduce any proof at all for them. Consider merely the fact, that the whole of pure mathematics (the science of numbers) is developed from these three axioms:

- (1) If two magnitudes are equal to a third, they are equal to one another;
- (2) If equals be added to equals, the result is equality;
- (3) If equals be added to unequals, the result is inequality.

Not more numerous are the axioms of geometry and of theoretical mechanics. These sciences are developed entirely from a few main propositions, from which we deduce consequences in cases ever more and more complicated. The science of numbers does not confine itself to the manipulation of the most complex aggregations of an infinite variety of quantities; it teaches us, in the higher analysis, to deal with any number of quantities, whose magnitude increases or diminishes according to the most varied laws, and thus enables us to solve problems that never would have yielded to direct processes of calculation. Here we discern the conscious logical activity of our minds in its purest and most complete form; we may here learn the difficulties with which it has to contend,—the great precaution with which it must make its advances,—the accuracy that is necessary, in order to determine the extent of the propositions that have been elaborated,—the difficulty of forming and of comprehending abstract notions,—but in an equal proportion do we learn to place confidence in the certainty, range, and fecundity of such mental work.

The latter is still more conspicuous in the department of applied mathematics, and especially in mathematical physics, in which branch also physical astronomy is to be reckoned. When Newton had once ascertained, from the mechanical analysis of the planetary motions, that all ponderable matter attracts all other matter remote from it,

with a force inversely proportional to the square of the distance, this one simple law suffices to enable us to calculate completely and with the greatest exactness the motions of the planets, even to the remotest periods of the past and future, if only there be given for any one moment of time the position, rate of velocity, and mass of all the separate bodies of our system; nay, we recognize the effect of the same force even in the motions of the double stars, the distance of which is such, that their light takes years to reach our planet; indeed, in some cases, is so great that the attempt to measure it has hitherto been in vain.

The discovery of the law of gravitation, and its consequences, is the most striking performance of which the human mind has ever shown itself capable. I will not say that there have not lived men with equally great, or even greater, powers of abstraction than Newton and the other astronomers, who in part paved the way for his discovery, or have further developed it after him; but there has never been offered to the explorers so rich a field as was presented by those confused and complicated planetary motions, which hitherto had but nourished astrological superstitions in the minds of ignorant observers, but now were brought under a law able to account for their smallest aberrations.

Following up the track marked out by this illustrious pioneer, and on methods indicated by him, a number of other branches of physics have been developed, and among them particularly the theory of optics, and of electricity and magnetism. The experimental sciences have, in the search after natural laws, one great advantage over the "contemplative" sciences, in that it is possible in their case to vary at will the conditions under which a certain result is produced; and the observation, therefore, of a comparatively small number of characteristic cases will suffice to establish the law. The validity of the law must, of course, be afterwards tested by its application to more complicated cases. Thus it is that the physical sciences, when once the right methods were discovered, have advanced with comparatively rapid strides. Not only have they given us the power of casting our eyes back, through a vast vista of ages, into that primeval period when the nebulous cosmical matter was compacted into stars, becoming fused by the force of impact of its particles; not only have we been enabled to discover the chemical constituents of the sun's atmosphere—(the chemistry of the remotest fixed stars will probably not long remain a secret,)—but they have also taught us to subjugate and turn to our material uses the blind natural forces that surround us.

It will be manifest, from what I have said, how different, for the most part, is the kind of mental activity developed in the pursuit of the latter range of sciences from that called into play by the former. The physicist requires no powerful memory for isolated facts; the mathematician can even dispense with it altogether. Presumptions, based upon the recollection of a number of similar cases, may be useful sometimes in putting the inquirer upon a right track; but they only obtain real importance when they have issued in a clearly formulated and strictly defined law. In dealing with nature, there can be no doubt that we have to do with a complete chain of causes, which



admits of no exceptions ; whence the call that summons us not to relax in our endeavours until we have arrived at the discovery of *universal* laws ; no rest till this task is achieved ; only in this form will science attain to complete victorious dominion over time and space, and the forces of nature.

The severe labour of conscious ratiocination demands great persistence and great foresight ; it proceeds in general only by slow degrees, and is but rarely aided by the quick flashes of inspiration. There is to be found in it little of that ready alacrity with which the most varied experiences must crowd together in the memory of the historian and the philologist. On the contrary, it is an essential condition of the methodical progress of thought, that the mind remain concentrated on one point, not distracted by secondary matters, nor disturbed by desires and hopes ; proceeding only in obedience to its own volition. A celebrated logician, John Stuart Mill, declares it to be his conviction that the inductive sciences have done more, in modern times, for the advancement of logical method than has been done by professed philosophers. A chief reason for this lies surely in the circumstance, that in no department of knowledge can a flaw in the reasoning be so easily detected by the manifest falsity of the result, than in those sciences where the results of our reasoning can, for the most part, be compared directly with real phenomena.

In expressing here my opinion that in the mathematically-developed branches of the natural sciences, the solution of the problems of nature has offered for the most part fewer difficulties than in the case of the mental sciences, I hope you will not suppose that I for a moment intended to depreciate the latter in comparison with the former. If to the natural sciences may not be denied the advantage of greater completeness in scientific form, the mental sciences on their part may justly claim that they have to do with a richer subject-matter, and one lying nearer to the interests and feelings of man, (namely, the human mind in all its varied tendencies and relations). Without doubt, their's is the higher and more difficult task ; but the example of those branches of knowledge should not be lost upon them, which, on account of their more accessible subject-matter, have made greater progress from a *formal* point of view. They may well learn of the latter, in regard to method, and derive encouragement from the fecundity of their results. I believe, too, that our age *has* learnt much from the development of the natural sciences. Unqualified respect for facts, and diligence in collecting them, a certain mistrust of outward appearances, the tendency in all cases to seek after a chain of causes, and presuppose such to exist where it does not lie on the surface, are characteristics which distinguish the present age from those that have gone before, and seem to point to the working of such an influence.

I do not propose here to enter upon the question, how far a more prominent place should be accorded to mathematical studies, as the representatives of conscious logical thinking, in the curriculum of school education. This is really only a question of time. In proportion as the domain of science extends, so must its systematisation and organisation be improved, and it cannot fail that individuals will find themselves compelled to pass through some more stringent course of mental discipline than the study of language is capable

of affording. What my own experience has led me to remark, in the case of students proceeding directly from our grammar schools to the special study of natural science and medicine, has been, in the first place, a certain laxity in the application of strict general laws. The grammatical rules on which they have been trained are in fact clogged, for the most part, with long lists of exceptions; they are, therefore, not accustomed to rely implicitly on the certainty of legitimate deductions from general laws. In the second place, I find them for the most part too much inclined to lean on authorities, even in cases where they might very easily have formed their own opinion. In philological studies, the student will, in fact, even under the best teachers, require to be directed to authorities, because he is seldom able to overlook the whole of the material, and decision will often depend on æsthetic feeling for the beauty of expression and the genius of the language. Both these defects proceed from a certain indolence and uncertainty of thought, the injurious effects of which will not be confined to want of success in the prosecution of subsequent science studies. But, for both, mathematical studies are certainly the best remedy; here there is absolute certainty in our conclusions, and there avails no authority but that of our own understanding.

So much for the various mutually complementary tendencies of mental work in the different branches of science.

But knowledge alone is not the end and aim of man in this world. Though scientific studies do indeed awaken and bring out the finest powers of the human mind, yet he will attain to no proper accomplishment of his destiny on earth, who would study merely in order that he may know. We often see highly gifted men, whose fortune, or misfortune rather, it has been to have allotted to them a comfortable material existence, but, without ambition or native energy, dragging on a tedious and discontented existence, in the belief that they are carrying out the noblest ends of life, by unremitting attention to the increase of their knowledge and the further cultivation of their minds. It is *action* alone that affords to man a worthy object of life; either the practical application of his knowledge, or the augmentation of science itself, must be his aim; for the latter is action for furthering the progress of the race. And we now pass on to the second connecting link, which brings together the work of the various sciences, namely, the relation between the substance and essence of the sciences.

Knowledge is power. No period of the world's history could illustrate this maxim more strikingly than the present. We have compelled the forces of the inorganic world to supply the wants of human life and to further the ends of man's mental activity. The application of steam has increased a thousand and a million fold his bodily strength. The mutual intercourse of men, with its mighty material and spiritual consequences, has been advanced to a degree that the older among us would not have dared to dream of when they entered upon the career of life. But it is not by machines alone that the powers of man are multiplied; it is not alone on rifled canon and iron-clad ships, the accumulated stores of money and of the means of existence, that the real strength of a nation depends; albeit that the influence of these

things has in fact so made itself felt, that even the proudest and the most absolute governments of our time have been compelled to remove the restrictions that fettered industry, and to give to the interests of the producing classes a place in their counsels. It is, moreover, on the political and social organisation of the state, the moral discipline of the individual, that the superiority of the cultivated over the uncultivated nations depends; and the latter, if they show themselves incapable of such culture, are doomed to inevitable extinction. Here all the wheels of life work into one another. Where society rests on no firm basis of law—where the interests of the majority of the nation cannot in due and regular manner find their expression—there the development of the national wealth, and the power that rests upon it, is impossible; and he only will make a proper soldier, in whom, under the influence of just and equal laws, the feeling of honour and independence has been developed, not the slave who does the bidding of a self-willed task-master.

For these reasons, then, every nation, as a nation, is interested, for the most direct and material of all objects—that of self-preservation—without regard to demands of a higher and more ideal character, not only in the development of the natural sciences and their technical applications, but equally in the development of the political and moral sciences, and of their handmaids, the historical and philological departments. No nation that would preserve its independence and its influence, dare lag behind; and this necessity is not left unrecognized by the cultivated nations of Europe. The public funds which are now applied to the maintenance of universities, schools, and scientific institutions far exceed anything that was done in former times for the advancement of learning. I spoke, in my introduction, of the ever increasing subdivision and organisation of scientific work. In fact, men of science do actually compose an organised army, that for the good of the whole nation, and for the most part in its direct service and at its cost, is employed in augmenting the knowledge which may aid in raising the industry, in adding to the wealth, the refinement of life and manners, and in improving the political organisation and moral development of the mass of the population. We must not indeed look, first and chiefly, for immediate advantage, as the ignorant are wont to do. Everything is of value that helps us to a knowledge of the powers of nature and of the human mind, and may prove of material use in its own time and place, and frequently when least expected. Who would have imagined, when Galvani was watching the legs of frogs twitching at the contact of certain kinds of metals, that eighty years later Europe would be threaded with wires which would carry news with lightning speed from Madrid to St. Petersburg, by means of the very same process, the first indications of which the anatomist was then observing. The electric currents were, in the hands of Galvani, and at first in those of Volta, phenomena which exerted but the very weakest of forces, and were only to be detected by the most delicate means of observation. Had experiment, however, been allowed to rest there, because the inquiry seemed to promise no practical advantage, physical science would still have been without the most important and interesting connecting link between the varied forces of nature.

When the young Galileo, a student at Pisa, was watching, during the service, the lamp swinging from the roof of the church, and discovered, by counting the beating of his pulse, that the duration of the vibrations was directly dependent on the magnitude of the arc of vibration, who could know then, that this discovery would lead, by means of the pendulum, to an accuracy in the measurement of intervals of time then deemed impossible; and that the storm-tossed sailor would be able to determine at any moment, by means of his chronometer, in the remotest oceans of the globe, on what parallel of longitude his vessel was then rocking.

He who, in the pursuit of science, strives merely after practical utility, may pretty securely reckon on being disappointed. Complete knowledge, and a full understanding of the operations of the forces of nature and of mind, are all that science may seek after. The individual inquirer must look for his reward in the delight of new discoveries, as so many fresh victories of mind over obstructing matter, and in the æsthetic beauty which the prospect of a well-ordered domain of knowledge affords, where intimate connexion subsists between all the separate parts, one developing itself from the other, and all exhibiting traces of the dominion of mind. He must be satisfied with the consciousness that he also is contributing his quota to the growing capital of knowledge, on which rests the dominion of man over the powers that war against the spirit. He will not, indeed, expect to receive from the world recognition and reward equal to the value of his labour. Too true it is, that many a one, to whom a monument has been erected after his death, would have been fortunate had but the tenth part of the money so expended been bestowed upon him during his lifetime. Still it must be allowed, that the value of scientific discoveries is much more readily acknowledged at the present day by public opinion, than was formerly the case; and that instances in which the originators of great advances in science have been left to starve, have become more and more rare,—that, on the contrary, the governments and nations of Europe have not failed to recognize their obligation to reward distinguished services in the cause of science, in the bestowal of posts of honour and dignity, as well as by special national rewards.

Thus the sciences have this one end in common,—to assert the predominance of mind over the world of matter. Whilst the mental and moral sciences work directly to enrich and beautify our intellectual life,—to separate the pure from the impure,—the natural sciences, on their part, are also working indirectly to the same end, in tending more and more to release man from his state of dependence on the material world. Each individual explorer works in his place, choosing for himself those tasks for which he is best fitted by the bent of his mind, and the direction of his education. But, at the same time, the individual must bear in mind that it is only in combination with others that he is enabled effectually to push forward the great work, and that he is therefore also in duty bound to make the results of his own labours as completely and easily accessible as possible to others. Thus will he derive support from others, and be enabled to lend them his assistance in return. The annals of science are rich in examples, how such “solidarity” has been established between departments

seemingly the farthest removed from one another. Historical chronology rests for support mainly on astronomical calculations of eclipses of the sun and moon, of which the record has been preserved in ancient chronicles; while, on the other hand, many important facts of astronomy—for instance, the uniform length of the day, and the periods of many of the comets—rest upon ancient historical data. Latterly, physiologists, and among them in particular Brücke, have been able to undertake the drawing up of a complete scheme of written characters for every sound capable of being formed by the human vocal organs, and on this to ground proposals for an universal alphabet. Here then we see physiology enrolled in the service of comparative philology, and already able to give the explanation of many apparently singular changes of sound, referring these not, as it has been the fashion to do, to the laws of euphony, but to similarity in the position of the mouth in articulating these sounds. Again, comparative philology gives indication of the ancient relationships, divisions, and migrations of nations in prehistoric times, and of the degree of culture which they had attained at the time of such separation. For the names of the objects which they already at that time were acquainted with, are common to the later languages. And thus does the study of language inform us of times on which no extant historic document throws any light. I may further call to mind the help which the anatomist may afford to the sculptor, as well as to the archæologist engaged in the investigation of ancient statuary. If I might be allowed here to speak of my own latest inquiries, I might add, that it is quite possible, by means of the theory and the physiology of the sensations of sound, to lay down the elements of the construction of our musical system, a task properly belonging to the department of æsthetics. The physiology of the senses, indeed, stands in most intimate relation to psychology, discerning, as it does, in the perceptions of the senses, the results of psychical processes, which do not fall within the range of self-conscious introspection, and must therefore necessarily remain hidden from psychological investigation.

I have been obliged to confine myself here to merely the most conspicuous examples of such intercommunion, and such as could most easily be set before you in few words, and have had to select my illustrations from among the most widely separated sciences. How much more widely extended must be the influence which each science exercises on the one most nearly related to it, I need not attempt to explain.

Let, then, each one of us regard himself as a labourer in the same great work, a work which concerns the noblest interests of humanity, not as one careful merely for the gratification of his own private curiosity or his own individual advantage, or desirous of showing off his talents before the world; and there will not be wanting to us the reward of an approving conscience and the recognition of our fellow men. And to maintain this relation of all inquirers and of all branches of science to one another, and to keep them all working together for the same common end,—this is the great object of our universities; for this it is necessary that in them the four faculties should go on continually hand in hand; and in this sense will we ourselves endeavour, as far as in us lies, to further the great enterprise.