SPENCER HERBERT

ESSAYS: SCIENTIFIC, POLITICAL, AND SPECULATIVE, VOLUME II

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Содержание

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THE GENESIS OF SCIENCE

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There still prevails among men a vague notion that scientific knowledge differs in nature from ordinary knowledge. By the Greeks, with whom Mathematics – literally *things learnt* – was alone considered as knowledge proper, the distinction must have been strongly felt; and it has ever since maintained itself in the general mind. Though, considering the contrast between the achievements of science and those of daily unmethodic thinking, it is not surprising that such a distinction has been assumed; yet it needs but to rise a little above the common point of view, to see that it is but a superficial distinction. The same faculties are employed in both cases; and in both cases their mode of operation is fundamentally the same. If we say that science is organized knowledge, we are met by the truth that all knowledge is organized in a greater or less degree – that the commonest actions of the household and the field presuppose facts colligated, inferences drawn, results expected; and that the general success of these actions proves the data by which they were guided to have been correctly put together. If, again, we say that science is prevision – is a seeing beforehand – is a knowing in what times, places, combinations, or sequences, specified phenomena will be found; we are obliged to confess that the definition includes much that is foreign to science in its ordinary acceptation: for example, a child's knowledge of an apple. This, as far as it goes, consists in previsions. When a child sees a certain form and colours, it knows that if it puts out its hand it will have certain impressions of resistance, and roundness, and smoothness; and if it bites, a certain taste. And manifestly its general acquaintance with surrounding objects is of like nature – is made up of facts concerning them, grouped so that any part of a group being perceived, the existence of the other facts included in it is foreseen. If, once more, we say that science is *exact* prevision, we still fail to establish the supposed difference. Not only do we find that much of what we call science is not exact, and that some of it, as physiology, can never become exact; but we find further, that many of the previsions constituting the common stock alike of wise and foolish, *are* exact. That an unsupported body will fall; that a lighted candle will go out when immersed in water; that ice will melt when thrown on the fire – these, and many like predictions relating to the familiar properties of things, have as high a degree of accuracy as predictions are capable of. It is true that the results foreseen are of a very general character; but it is none the less true that they are correct as far as they go: and this is all that is requisite to fulfil the definition. There is perfect accordance between the anticipated phenomena and the actual ones; and no more than this can be said of the highest achievements of the sciences specially characterized as exact.

Seeing thus that the assumed distinction between scientific knowledge and common knowledge cannot be sustained; and yet feeling, as we must, that however impossible it may be to draw a line between them, the two are not practically identical; there arises the question – What is the relationship between them? A partial answer to this question may be drawn from the illustrations just given. On reconsidering them, it will be observed that those portions of ordinary knowledge which are identical in character with scientific knowledge, comprehend only such combinations of phenomena as are directly cognizable by the senses, and are of simple, invariable nature. That the smoke from a fire which she is lighting will ascend, and that the fire will presently boil the water placed over it, are previsions which the servant-girl makes equally well with the most learned physicist; but they are previsions concerning phenomena in constant and direct relation – phenomena that follow visibly and immediately after their antecedents – phenomena of which the causation is neither remote nor obscure – phenomena which may be predicted by the simplest possible act of reasoning. If, now, we pass to the previsions constituting science – that an eclipse of the moon will happen at a specified time; that when a barometer is taken to the top of a mountain of known height, the mercurial column will descend a stated number of inches; that the poles of a galvanic battery immersed in water will give off, the one an inflammable and the other an inflaming gas, in definite ratio – we perceive that the relations involved are not of a kind habitually presented to our senses. They depend, some of them, on special combinations of causes; and in some of them the connexion between antecedents and consequents is established only by an elaborate series of inferences. A broad distinction, therefore, between scientific knowledge and common knowledge is its remoteness from perception. If we regard the cases in their most general aspect, we see that the labourer who, on hearing certain notes in the adjacent hedge, can describe the particular form and colours of the bird making them, and the astronomer who, having calculated a transit of Venus, can delineate the black spot entering on the sun's disc, as it will appear through the telescope, at a specified hour, do essentially the same thing. Each knows that on fulfilling the requisite conditions, he shall have a preconceived impression – that after a definite series of actions will come a group of sensations of a foreknown kind. The difference, then, is neither in the fundamental character of the mental acts; nor in the correctness of the previsions accomplished by them; but in the complexity of the processes required to achieve the previsions. Much of our common knowledge is, as far as it goes, precise. Science does not increase its precision. What then does it do? It reduces other knowledge to the same degree of precision. That certainty which direct perception gives us respecting coexistences and sequences of the simplest and most accessible kind, science gives us respecting coexistences and sequences, complex in their dependencies, or inaccessible to immediate observation. In brief, regarded from this point of view, science may be called *an extension of the perceptions by means of reasoning*.

On further considering the matter, however, it will perhaps be felt that this definition does not express the whole fact – that inseparable as science may be from common knowledge, and completely as we may fill up the gap between the simplest previsions of the child and the most recondite ones of the physicist, by interposing a series of previsions in which the complexity of reasoning involved is greater and greater, there is yet a difference between the two beyond that above described. And this is true. But the difference is still not such as enables us to draw the assumed line of demarcation. It is a difference not between common knowledge and scientific knowledge; but between the successive phases of science itself, or knowledge itself – whichever we choose to call it. In its earlier phases science attains only to *certainty* of foresight; in its later phases it further attains to *completeness*. We begin by discovering *a* relation; we end by discovering *the* relation. Our first achievement is to foretell the *kind* of phenomenon which will occur under specified conditions; our last achievement is to foretell not only the kind but the *amount*. Or, to reduce the proposition to its most definite form – undeveloped science is *qualitative* prevision; developed science is *quantitative* prevision.

This will at once be perceived to express the remaining distinction between the lower and the higher stages of positive knowledge. The prediction that a piece of lead will take more force to lift it than a piece of wood of equal size, exhibits certainty, but not completeness, of foresight. The kind of effect in which the one body will exceed the other is foreseen; but not the amount by which it will exceed. There is qualitative prevision only. On the other hand, the predictions that at a stated time two particular planets will be in conjunction; that by means of a lever having arms in a given ratio, a known force will raise just so many pounds; that to decompose a given quantity of sulphate of iron by carbonate of soda will require so many grains – these predictions show foreknowledge, not only of the nature of the effects to be produced, but of the magnitude, either of the effects themselves, of the agencies producing them, or of the distance in time or space at which they will be produced. There is both qualitative provision and quantitative prevision. And this is the unexpressed difference which leads us to consider certain orders of knowledge as especially scientific when contrasted with knowledge in general. Are the phenomena *measurable*? is the test which we unconsciously employ. Space is measurable: hence Geometry. Force and space are measurable: hence Statics. Time, force, and space are measurable: hence Dynamics. The invention of the barometer enabled men to extend the principles of mechanics to the atmosphere; and Aerostatics existed. When a thermometer was devised there arose a science of heat, which was before impossible. Of such external agents as we have found no measures but our sensations we have no sciences. We have no science of smells; nor have we one of tastes. We have a science of the relations of sounds differing in pitch, because we have discovered a way to measure these relations; but we have no science of sounds in respect to their loudness or their *timbre* , because we have got no measures of loudness and *timbre*. Obviously it is this reduction of the sensible phenomena it presents, to relations of magnitude, which gives to any division of knowledge its specially scientific character. Originally men's knowledge of weights and forces was like their present knowledge of smells and tastes – a knowledge not extending beyond that given by the unaided sensations; and it remained so until weighing instruments and dynamometers were invented. Before there were hour-glasses and clepsydras, most phenomena could be estimated as to their durations and intervals, with no greater precision than degrees of hardness can be estimated by the fingers. Until a thermometric scale was contrived, men's judgments respecting relative amounts of heat stood on the same footing with their present judgments respecting relative amounts of sound. And as in these initial stages, with no aids to observation, only the roughest comparisons of cases could be made, and only the most marked differences perceived, it resulted that only the most simple laws of dependence could be ascertained – only those laws which, being uncomplicated with others, and not disturbed in their manifestations, required no niceties of observation to disentangle them. Whence it appears not only that in proportion as knowledge becomes quantitative do its previsions become complete as well as certain, but that until its assumption of a quantitative character it is necessarily confined to the most elementary relations.

Moreover it is to be remarked that while, on the one hand, we can discover the laws of the greater part of phenomena only by investigating them quantitatively; on the other hand we can extend the range of our quantitative previsions only as fast as we detect the laws of the results we predict. For clearly the ability to specify the magnitude of a result inaccessible to direct measurement, implies knowledge of its mode of dependence on something which can be measured – implies that we know the particular fact dealt with to be an instance of some more general fact. Thus the extent to which our quantitative previsions have been carried in any direction, indicates the depth to which our knowledge reaches in that direction. And here, as another aspect of the same fact, it may be observed that as we pass from qualitative to quantitative prevision, we pass from inductive science to deductive science. Science while purely inductive is purely qualitative; when inaccurately quantitative it usually consists of part induction, part deduction; and it becomes accurately quantitative only when wholly deductive. We do not mean that the deductive and the quantitative are coextensive; for there is manifestly much deduction that is qualitative only. We mean that all quantitative prevision is reached deductively; and that induction can achieve only qualitative prevision.

Still, however, it must not be supposed that these distinctions enable us to separate ordinary knowledge from science; much as they seem to do so. While they show in what consists the broad contrast between the extreme forms of the two, they yet lead us to recognize their essential identity, and once more prove the difference to be one of degree only. For, on the one hand, much of our common knowledge is to some extent quantitative; seeing that the amount of the foreseen result is known within certain wide limits. And, on the other hand, the highest quantitative prevision does not reach the exact truth, but only a near approach to it. Without clocks the savage knows that the day is longer in the summer than in the winter; without scales he knows that stone is heavier than flesh; that is, he can foresee respecting certain results that their amounts will exceed these, and be less than those – he knows *about* what they will be. And, with his most delicate instruments and most elaborate calculations, all that the man of science can do, is to reduce the difference between the foreseen and the actual results to an unimportant quantity. Moreover, it must be borne in mind not only that all the sciences are qualitative in their first stages, – not only that some of them, as Chemistry, have but lately reached the quantitative stage – but that the most advanced sciences have attained to their present power of determining quantities not present to the senses, or not directly measurable, by a slow process of improvement extending through thousands of years. So that science and the knowledge of the uncultured are alike in the nature of their previsions, widely as they differ in range; they possess a common imperfection, though this is immensely greater in the last than in the first; and the transition from the one to the other has been through a series of steps by which the imperfection has been rendered continually less, and the range continually wider.These facts, that science and ordinary knowledge are allied in nature, and that the one is but a perfected and extended form of the other, must necessarily underlie the whole theory of science, its progress, and the relations of its parts to each other. There must be incompleteness in any history of the sciences, which, leaving out of view the first steps of their genesis, commences with them only when they assume definite forms. There must be grave defects, if not a general untruth, in a philosophy of the sciences considered in their interdependence and development, which neglects the inquiry how they came to be distinct sciences, and how they were severally evolved out of the chaos of primitive ideas. Not only a direct consideration of the matter, but all analogy, goes to show that in the earlier and simpler stages must be sought the key to all subsequent intricacies. The time was when the anatomy and physiology of the human being were studied by themselves – when the adult man was analyzed and the relations of parts and of functions investigated, without reference either to the relations exhibited in the embryo or to the homologous relations existing in other creatures. Now, however, it has become manifest that no true conceptions are possible under such conditions. Anatomists and physiologists find that the real natures of organs and tissues can be ascertained only by tracing their early evolution; and that the affinities between existing genera can be satisfactorily made out only by examining the fossil genera to which they are akin. Well, is it not clear that the like must be true concerning all things that undergo development? Is not science a growth? Has not science, too, its embryology? And must not the neglect of its embryology lead to a misunderstanding of the principles of its evolution and of its existing organization?

There are *à priori* reasons, therefore, for doubting the truth of all philosophies of the sciences which tacitly proceed upon the common notion that scientific knowledge and ordinary knowledge are separate; instead of commencing, as they should, by affiliating the one upon the other, and showing how it gradually came to be distinguishable from the other. We may expect to find their generalizations essentially artificial; and we shall not be deceived. Some illustrations of this may here be fitly introduced, by way of preliminary to a brief sketch of the genesis of science from the point of view indicated. And we cannot more readily find such illustrations than by glancing at a few of the various *classifications* of the sciences that have from time to time been proposed. To consider all of them would take too much space: we must content ourselves with some of the latest.

Commencing with those which may be soonest disposed of, let us notice, first, the arrangement propounded by Oken. An abstract of it runs thus: —

> Part I. MATHESIS. —*Pneumatogeny*: Primary Act, Primary Consciousness, God, Primary Rest, Time, Polarity, Motion, Man, Space, Point, Line, Surface,

Globe, Rotation. —*Hylogeny*: Gravity, Matter, Ether, Heavenly Bodies, Light, Heat, Fire.

(He explains that MATHESIS is the doctrine of the whole; *Pneumatogeny* being the doctrine of immaterial totalities, and *Hylogeny* that of material totalities.)

Part II. ONTOLOGY. —*Cosmogeny*: Rest, Centre, Motion, Line, Planets, Form, Planetary System, Comets. —*Stöchiogeny*: Condensation, Simple Matter, Elements, Air, Water, Earth. —*Stöchiology*: Functions of the Elements, &c. &c. —*Kingdoms of Nature*: Individuals.

(He says in explanation that 'ONTOLOGY teaches us the phenomena of matter. The first of these are the heavenly bodies comprehended by *Cosmogeny*. These divide into elements. —*Stöchiogeny*. The earth element divides into minerals —*Mineralogy*. These unite into one collective body —*Geogeny*. The whole in singulars is the living, or *Organic*, which again divides into plants and animals. *Biology*, therefore, divides into *Organogeny*, *Phytosophy*, *Zoosophy*.')

FIRST KINGDOM. – MINERALS. *Mineralogy*, *Geology*.

Part III. BIOLOGY. —*Organosophy*, *Phytogeny*, *Phyto-physiology*, *Phytology*, *Zoogeny*, *Physiology*, *Zoology*, *Psychology*.

A glance over this confused scheme shows that it is an attempt to classify knowledge, not after the order in which it has been, or may be, built up in the human consciousness; but after an assumed order of creation. It is a pseudo-scientific cosmogony, akin to those which men have enunciated from the earliest times downwards; and only a little more respectable. As such it will not be thought worthy of much consideration by those who, like ourselves, hold that experience is the sole origin of knowledge. Otherwise, it might have been needful to dwell on the incongruities of the arrangement – to ask how motion can be treated of before space? how there can be rotation without matter to rotate? how polarity can be dealt with without involving points and lines? But it will serve our present purpose just to indicate a few of the absurdities resulting from the doctrine which Oken seems to hold in common with Hegel, that "to philosophize on Nature is to re-think the great thought of Creation." Here is a sample: —

"Mathematics is the universal science; so also is Physio-philosophy, although it is only a part, or rather but a condition of the universe; both are one, or mutually congruent.

"Mathematics is, however, a science of mere forms without substance. Physio-philosophy is, therefore, *mathematics endowed with substance* ."

From the English point of view it is sufficiently amusing to find such a dogma not only gravely stated, but stated as an unquestionable truth. Here we see the experiences of quantitative relations which men have gathered from surrounding bodies and generalized (experiences which had been scarcely at all generalized at the beginning of the historic period) – we find these generalized experiences, these intellectual abstractions, elevated into concrete actualities, projected back into Nature, and considered as the internal frame-work of things – the skeleton by which matter is sustained. But this new form of the old realism, is by no means the most startling of the physio-philosophic principles. We presently read that,

"The highest mathematical idea, or the fundamental principle of all mathematics is the zero = 0." * * *

"Zero is in itself nothing. Mathematics is based upon nothing, and, *consequently* , arises out of nothing.

"Out of nothing, *therefore* , it is possible for something to arise; for mathematics, consisting of propositions, is a something in relation to 0."

By such "consequentlys" and "therefores" it is, that men philosophize when they "re-think the great thought of creation." By dogmas that pretend to be reasons, nothing is made to generate mathematics; and by clothing mathematics with matter, we have the universe! If now we deny, as we *do* deny, that the highest mathematical idea is the zero – if, on the other hand, we assert, as we *do* assert, that the fundamental idea underlying all mathematics, is that of equality; the whole of Oken's cosmogony disappears. And here, indeed, we may see illustrated, the distinctive peculiarity of the German method of procedure in these matters – the bastard *à priori* method, as it may be termed. The legitimate *à priori* method sets out with propositions of which the negation is inconceivable; the *à priori* method as illegitimately applied, sets out either with propositions of which the negation is *not* inconceivable, or with propositions like Oken's, of which the *affirmation* is inconceivable.

It is needless to proceed further with the analysis; else might we detail the steps by which Oken arrives at the conclusions that "the planets are coagulated colours, for they are coagulated light"; that "the sphere is the expanded nothing;" that gravity is "a weighty nothing, a heavy essence, striving towards a centre;" that "the earth is the identical, water the indifferent, air the different; or the first the centre, the second the radius, the last the periphery of the general globe or of fire." To comment on them would be nearly as absurd as are the propositions themselves. Let us pass on to another of the German systems of knowledge – that of Hegel.

The simple fact that Hegel puts Jacob Bœhme on a par with Bacon, suffices alone to show that his stand-point is far remote from the one usually regarded as scientific: so far remote, indeed, that it is not easy to find any common basis on which to found a criticism. Those who hold that the mind is moulded into conformity with surrounding things by the agency of surrounding things, are necessarily at a loss how to deal with those who, like Schelling and Hegel, assert that surrounding things are solidified mind – that Nature is "petrified intelligence." However, let us briefly glance at Hegel's classification. He divides philosophy into three parts: —

1. *Logic* , or the science of the idea in itself, the pure idea.

2. *The Philosophy of Nature* , or the science of the idea considered under its other form – of the idea as Nature.

3. *The Philosophy of the Mind* , or the science of the idea in its return to itself.

Of these, the second is divided into the natural sciences, commonly so-called; so that in its more detailed form the series runs thus: – Logic, Mechanics, Physics, Organic Physics, Psychology.

Now, if we believe with Hegel, first, that thought is the true essence of man; second, that thought is the essence of the world; and that, therefore, there is nothing but thought; his classification, beginning with the science of pure thought, may be acceptable. But otherwise, it is an obvious objection to his arrangement, that thought implies things thought of – that there can be no logical forms without the substance of experience – that the science of ideas and the science of things must have a simultaneous origin. Hegel, however, anticipates this objection, and, in his obstinate idealism, replies, that the contrary is true. He affirms that all contained in the forms, to become something, requires to be thought; and that logical forms are the foundations of all things.

It is not surprising that, starting from such premises, and reasoning after this fashion, Hegel finds his way to strange conclusions. Out of *space* and *time* he proceeds to build up *motion* , *matter* , *repulsion* , *attraction* , *weight* , and *inertia*. He then goes on to logically evolve the solar system. In doing this he widely diverges from the Newtonian theory; reaches by syllogism the conviction that the planets are the most perfect celestial bodies; and, not being able to bring the stars within his theory, says that they are mere formal existences and not living matter, and that as compared with the solar system they are as little admirable as a cutaneous eruption or a swarm of flies. [1] Results so absurd might be left as self-disproved, were it not that speculators of this class are not alarmed by any amount of incongruity with established beliefs. The only efficient mode of treating systems like this of Hegel, is to show that they are self-destructive – that by their first steps they ignore that authority on which all their subsequent steps depend. If Hegel professes, as he manifestly does, to develop his scheme

[1] It is curious that the author of "The Plurality of Worlds," with quite other aims, should have persuaded himself into similar conclusions.

by reasoning – if he presents successive inferences as *necessarily following* from certain premises; he implies the postulate that a belief which necessarily follows after certain antecedents is a true belief; and did an opponent reply to one of his inferences that, though it was impossible to think the opposite, yet the opposite was true, he would consider the reply irrational. The procedure, however, which he would thus condemn as destructive of all thinking whatever, is just the procedure exhibited in the enunciation of his own first principles. Mankind find themselves unable to conceive that there can be thought without things thought of. Hegel, however, asserts that there *can* be thought without things thought of. That ultimate test of a true proposition – the inability of the human mind to conceive the negation of it – which in all the successive steps of his arguments he considers valid, he considers invalid where it suits his convenience to do so; and yet at the same time denies the right of an opponent to follow his example. If it is competent for him to posit dogmas which are the direct negations of what human consciousness recognizes; then is it also competent for his antagonists to stop him at any moment by saying, that though the particular inference he is drawing seems to his mind, and to all minds, necessarily to follow from the premises, yet it is not true, but the contrary inference is true. Or, to state the dilemma in another form: – If he sets out with inconceivable propositions, then may he with equal propriety make all his succeeding propositions inconceivable ones – may at every step throughout his reasoning draw the opposite conclusion to that which seems involved.

Hegel's mode of procedure being thus essentially suicidal, the Hegelian classification which depends upon it, falls to the ground. Let us consider next that of M. Comte.

As all his readers must admit, M. Comte presents us with a scheme of the sciences which, unlike the foregoing ones, demands respectful consideration. Widely as we differ from him, we cheerfully bear witness to the largeness of his views, the clearness of his reasoning, and the value of his speculations as contributing to intellectual progress. Did we believe a serial arrangement of the sciences to be possible, that of M. Comte would certainly be the one we should adopt. His fundamental propositions are thoroughly intelligible; and, if not true, have a great semblance of truth. His successive steps are logically co-ordinated; and he supports his conclusions by a considerable amount of evidence – evidence which, so long as it is not critically examined, or not met by counter evidence, seems to substantiate his positions. But it only needs to assume that antagonistic attitude which *ought* to be assumed towards new doctrines, in the belief that, if true, they will prosper by conquering objectors – it needs but to test his leading doctrines either by other facts than those he cites, or by his own facts differently applied, to show that they will not stand. We will proceed thus to deal with the general principle on which he bases his hierarchy of the sciences.

In the condensed translation of the *Positive Philosophy* , by Miss Martineau, M. Comte says: – "Our problem is, then, to find the one *rational* order, amongst a host of possible systems.". "This order is determined by the degree of simplicity, or, what comes to the same thing, of generality of their phenomena." And the arrangement he deduces runs thus: – *Mathematics* , *Astronomy* , *Physics* , *Chemistry* , *Physiology* , *Social Physics*. This he asserts to be "the true *filiation* of the sciences." He asserts further, that the principle of progression from a greater to a less degree of generality, "which gives this order to the whole body of science, arranges the parts of each science." And, finally, he asserts that the gradations thus established *à priori* among the sciences and the parts of each science, "is in essential conformity with the order which has spontaneously taken place among the branches of natural philosophy;" or, in other words – corresponds with the order of historic development.

Let us compare these assertions with the facts. That there may be perfect fairness, let us make no choice, but take as the field for our comparison, the succeeding section treating of the first science – Mathematics; and let us use none but M. Comte's own facts, and his own admissions. Confining ourselves to this one science, we are limited to comparisons between its several parts. M. Comte says, that the parts of each science must be arranged in the order of their decreasing generality; and that this order of decreasing generality agrees with the order of historic development. Our inquiry will be, then, whether the history of mathematics confirms this statement.

Carrying out his principle, M. Comte divides Mathematics into "Abstract Mathematics, or the Calculus (taking the word in its most extended sense) and Concrete Mathematics, which is composed of General Geometry and of Rational Mechanics." The subject-matter of the first of these is *number*; the subject-matter of the second includes *space* , *time* , *motion* , *force*. The one possesses the highest possible degree of generality; for all things whatever admit of enumeration. The others are less general; seeing that there are endless phenomena that are not cognizable either by general geometry or rational mechanics. In conformity with the alleged law, therefore, the evolution of the calculus must throughout have preceded the evolution of the concrete sub-sciences. Now somewhat awkwardly for him, the first remark M. Comte makes bearing on this point is, that "from an historical point of view, mathematical analysis *appears to have arisen out of* the contemplation of geometrical and mechanical facts." True, he goes on to say that, "it is not the less independent of these sciences logically speaking;" for that "analytical ideas are, above all others, universal, abstract, and simple; and geometrical conceptions are necessarily founded on them." We will not take advantage of this last passage to charge M. Comte with teaching, after the fashion of Hegel, that there can be thought without things thought of. We are content simply to compare the assertion, that analysis arose out of the contemplation of geometrical and mechanical facts, with the assertion that geometrical conceptions are founded upon analytical ones. Literally interpreted they exactly cancel each other. Interpreted, however, in a liberal sense, they imply, what we believe to be demonstrable, that the two had *a simultaneous origin*. The passage is either nonsense, or it is an admission that abstract and concrete mathematics are coeval. Thus, at the very first step, the alleged congruity between the order of generality and the order of evolution, does not hold good.

But may it not be that though abstract and concrete mathematics took their rise at the same time, the one afterwards developed more rapidly than the other; and has ever since remained in advance of it? No: and again we call M. Comte himself as witness. Fortunately for his argument he has said nothing respecting the early stages of the concrete and abstract divisions after their divergence from a common root; otherwise the advent of Algebra long after the Greek geometry had reached a high development, would have been an inconvenient fact for him to deal with. But passing over this, and limiting ourselves to his own statements, we find, at the opening of the next chapter, the admission, that "the historical development of the abstract portion of mathematical science has, since the time of Descartes, been for the most part *determined* by that of the concrete." Further on we read respecting algebraic functions that "most functions were concrete in their origin – even those which are at present the most purely abstract; and the ancients discovered only through geometrical definitions elementary algebraic properties of functions to which a numerical value was not attached till long afterwards, rendering abstract to us what was concrete to the old geometers." How do these statements tally with his doctrine? Again, having divided the calculus into algebraic and arithmetical, M. Comte admits, as perforce he must, that the algebraic is more general than the arithmetical; yet he will not say that algebra preceded arithmetic in point of time. And again, having divided the calculus of functions into the calculus of direct functions (common algebra) and the calculus of indirect functions (transcendental analysis), he is obliged to speak of this last as possessing a higher generality than the first; yet it is far more modern. Indeed, by implication, M. Comte himself confesses this incongruity; for he says: – "It might seem that the transcendental analysis ought to be studied before the ordinary, as it provides the equations which the other has to resolve. But though the transcendental *is logically independent of the ordinary* , it is best to follow the usual method of study, taking the ordinary first." In all these cases, then, as well as at the close of the section where he predicts that mathematicians will in time "create procedures of a *wider generality* ," M. Comte makes admissions that are diametrically opposed to the alleged law.

In the succeeding chapters treating of the concrete department of mathematics, we find similar contradictions. M. Comte himself names the geometry of the ancients *special* geometry and that of the moderns *general* geometry. He admits that while "the ancients studied geometry with reference to the *bodies* under notice, or specially; the moderns study it with reference to the *phenomena* to be considered, or generally." He admits that while "the ancients extracted all they could out of one line or surface before passing to another," "the moderns, since Descartes, employ themselves on questions which relate to any figure whatever." These facts are the reverse of what, according to his theory, they should be. So, too, in mechanics. Before dividing it into statics and dynamics, M. Comte treats of the three laws of *motion* , and is obliged to do so; for statics, the more *general* of the two divisions, though it does not involve motion, is impossible as a science until the laws of motion are ascertained. Yet the laws of motion pertain to dynamics, the more *special* of the divisions. Further on he points out that after Archimedes, who discovered the law of equilibrium of the lever, statics made no progress until the establishment of dynamics enabled us to seek "the conditions of equilibrium through the laws of the composition of forces." And he adds – "At this day *this is the method universally employed*. At the first glance it does not appear the most rational – dynamics being more complicated than statics, and precedence being natural to the simpler. It would, in fact, be more philosophical to refer dynamics to statics, as has since been done." Sundry discoveries are afterwards detailed, showing how completely the development of statics has been achieved by considering its problems dynamically; and before the close of the section M. Comte remarks that "before hydrostatics could be comprehended under statics, it was necessary that the abstract theory of equilibrium should be made so general as to apply directly to fluids as well as solids. This was accomplished when Lagrange supplied, as the basis of the whole of rational mechanics, the single principle of virtual velocities." In which statement we have two facts directly at variance with M. Comte's doctrine; – first, that the simpler science, statics, reached its present development only by the aid of the principle of virtual velocities, which belongs to the more complex science, dynamics; and that this "single principle" underlying all rational mechanics – this *most general form* which includes alike the relations of statical, hydrostatical, and dynamical forces – was reached so late as the time of Lagrange.

Thus it is *not* true that the historical succession of the divisions of mathematics has corresponded with the order of decreasing generality. It is *not* true that abstract mathematics was evolved antecedently to, and independently of, concrete mathematics. It is *not* true that of the subdivisions of abstract mathematics, the more general came before the more special. And it is *not* true that concrete mathematics, in either of its two sections, began with the most abstract and advanced to the less abstract truths.

It may be well to mention, parenthetically, that, in defending his alleged law of progression from the general to the special, M. Comte somewhere comments upon the two meanings of the word *general* , and the resulting liability to confusion. Without now discussing whether the asserted distinction exists in other cases, it is manifest that it does not exist here. In sundry of the instances above quoted, the endeavours made by M. Comte himself to disguise, or to explain away, the precedence of the special over the general, clearly indicate that the generality spoken of is of the kind meant by his formula. And it needs but a brief consideration of the matter to show that, even did he attempt it, he could not distinguish this generality which, as above proved, frequently comes last, from the generality which he says always comes first. For what is the nature of that mental process by which objects, dimensions, weights, times, and the rest, are found capable of having their relations expressed numerically? It is the formation of certain abstract conceptions of unity, duality, and multiplicity, which are applicable to all things alike. It is the invention of general symbols serving to express the numerical relations of entities, whatever be their special characters. And what is the nature of the mental process by which numbers are found capable of having their relations expressed algebraically? It is the same. It is the formation of certain abstract conceptions of numerical functions which are constant whatever be the magnitudes of the numbers. It is the invention of general symbols serving to express the relations between numbers, as numbers express the relations between things. Just as arithmetic deals with the common properties of lines, areas, bulks, forces, periods; so does algebra deal with the common properties of the numbers which arithmetic presents.

Having shown that M. Comte's alleged law of progression does not hold among the several parts of the same science, let us see how it agrees with the facts when applied to the separate sciences. "Astronomy," says M. Comte (*Positive Philosophy* , Book III.), "was a positive science, in its geometrical aspect, from the earliest days of the school of Alexandria; but Physics, which we are now to consider, had no positive character at all till Galileo made his great discoveries on the fall of heavy bodies." On this, our comment is simply that it is a misrepresentation based upon an arbitrary misuse of words – a mere verbal artifice. By choosing to exclude from terrestrial physics those laws of magnitude, motion, and position, which he includes in celestial physics, M. Comte makes it appear that the last owes nothing to the first. Not only is this unwarrantable, but it is radically inconsistent with his own scheme of divisions. At the outset he says – and as the point is important we quote from the original – "Pour la *physique inorganique* nous voyons d'abord, en nous conformant toujours à l'ordre de généralité et de dépendance des phénomènes, qu'elle doit être partagée en deux sections distinctes, suivant qu'elle considère les phénomènes généraux de l'univers, ou, en particulier, ceux que présentent les corps terrestres. D'où la physique céleste, ou l'astronomie, soit géométrique, soit mechanique; et la physique terrestre." Here then we have *inorganic physics* clearly divided into *celestial physics* and *terrestrial physics* – the phenomena presented by the universe, and the phenomena presented by earthly bodies. If now celestial bodies and terrestrial bodies exhibit sundry leading phenomena in common, as they do, how can the generalization of these common phenomena be considered as pertaining to the one class rather than to the other? If inorganic physics includes geometry (which M. Comte has made it do by comprehending *geometrical* astronomy in its sub-section, celestial physics); and if its other sub-section, terrestrial physics, treats of things having geometrical properties; how can the laws of geometrical relations be excluded from terrestrial physics? Clearly if celestial physics includes the geometry of objects in the heavens, terrestrial physics includes the geometry of objects on the earth. And if terrestrial physics includes terrestrial geometry, while celestial physics includes celestial geometry, then the geometrical part of terrestrial physics precedes the geometrical part of celestial physics; seeing that geometry gained its first ideas from surrounding objects. Until men had learnt geometrical relations from bodies on the earth, it was impossible for them to understand the geometrical relations of bodies in the heavens. So, too, with celestial mechanics, which had terrestrial mechanics for its parent. The very conception of *force* , which underlies the whole of mechanical astronomy, is borrowed from our earthly experiences; and the leading laws of mechanical action as exhibited in scales, levers, projectiles, &c., had to be ascertained before the dynamics of the Solar System could be entered upon. What were the laws made use of by Newton in working out his grand discovery? The law of falling bodies disclosed by Galileo; that of the composition of forces also disclosed by Galileo; and that of centrifugal force found out by Huyghens – all of them generalizations of terrestrial physics. Yet, with facts like these before him, M. Comte places astronomy before physics in order of evolution! He does not compare the geometrical parts of the two together, and the mechanical parts of the two together; for this would by no means suit his hypothesis. But he compares the geometrical part of the one with the mechanical part of the other, and so gives a semblance of truth to his position. He is led away by a verbal illusion. Had he confined his attention to the things and disregarded the words, he would have seen that before mankind scientifically co-ordinated *any one class of phenomena* displayed in the heavens, they had previously co-ordinated *a parallel class of phenomena* displayed on the surface of the earth.

Were it needful we could fill a score pages with the incongruities of M. Comte's scheme. But the foregoing samples will suffice. So far is his law of evolution of the sciences from being tenable, that, by following his example, and arbitrarily ignoring one class of facts, it would be possible to present, with great plausibility, just the opposite generalization to that which he enunciates. While he asserts that the rational order of the sciences, like the order of their historic development, "is determined by the degree of simplicity, or, what comes to the same thing, of generality of their phenomena;" it might contrariwise be asserted that, commencing with the complex and the special, mankind have progressed step by step to a knowledge of greater simplicity and wider generality. So much evidence is there of this as to have drawn from Whewell, in his *History of the Inductive Sciences* , the remark that "the reader has already seen repeatedly in the course of this history, complex and derivative principles presenting themselves to men's minds before simple and elementary ones." Even from M. Comte's own work, numerous facts, admissions, and arguments, might be picked out, tending to show this. We have already quoted his words in proof that both abstract and concrete mathematics have progressed towards a higher degree of generality, and that he looks forward to a higher generality still. Just to strengthen this adverse hypothesis, let us take a further instance. From the *particular* case of the scales, the law of equilibrium of which was familiar to the earliest nations known, Archimedes advanced to the more *general* case of the lever of which the arms may or may not be equal; the law of equilibrium of which *includes* that of the scales. By the help of Galileo's discovery concerning the composition of forces, D'Alembert "established, for the first time, the equations of equilibrium of *any* system of forces applied to the different points of a solid body" – equations which include all cases of levers and an infinity of cases besides. Clearly this is progress towards a higher generality – towards a knowledge more independent of special circumstances – towards a study of phenomena "the most disengaged from the incidents of particular cases;" which is M. Comte's definition of "the most simple phenomena." Does it not indeed follow from the admitted fact, that mental advance is from the concrete to the abstract, from the particular to the general, that the universal and therefore most simple truths are the last to be discovered? Should we ever succeed in reducing all orders of phenomena to some single law – say of atomic action, as M. Comte suggests – must not that law answer to his test of being *independent* of all others, and therefore most simple? And would not such a law generalize the phenomena of gravity, cohesion, atomic affinity, and electric repulsion, just as the laws of number generalize the quantitative phenomena of space, time and force?

The possibility of saying so much in support of an hypothesis the very reverse of M. Comte's, at once proves that his generalization is only a half-truth. The fact is that neither proposition is correct by itself; and the actuality is expressed only by putting the two together. The progress of science is duplex. It is at once from the special to the general, and from the general to the special. It is analytical and synthetical at the same time.

M. Comte himself observes that the evolution of science has been accomplished by the division of labour; but he quite misstates the mode in which this division of labour has operated. As he describes it, it has been simply an arrangement of phenomena into classes, and the study of each class by itself. He does not recognize the effect of progress in each class upon *all* other classes: he recognizes only the effect on the class succeeding it in his hierarchical scale. Or if he occasionally admits collateral influences and intercommunications, he does it so grudgingly, and so quickly puts the admissions out of sight and forgets them, as to leave the impression that, with but trifling exceptions, the sciences aid one another only in the order of their alleged succession. The fact is, however, that the division of labour in science, like the division of labour in society, and like the "physiological division of labour" in individual organisms, has been not only a specialization of functions, but a continuous helping of each division by all the others, and of all by each. Every particular class of inquirers has, as it were, secreted its own particular order of truths from the general mass of material which observation accumulates; and all other classes of inquirers have made use of these truths as fast as they were elaborated, with the effect of enabling them the better to elaborate each its own order of truths. It was thus in sundry of the cases we have quoted as at variance with M. Comte's doctrine. It was thus with the application of Huyghens's optical discovery to astronomical observation by Galileo. It was thus with the application of the isochronism of the pendulum to the making of instruments for measuring intervals, astronomical and other. It was thus when the discovery that the refraction and dispersion of light did not follow the same law of variation, affected both astronomy and physiology by giving us achromatic telescopes and microscopes. It was thus when Bradley's discovery of the aberration of light enabled him to make the first step towards ascertaining the motions of the stars. It was thus when Cavendish's torsion-balance experiment determined the specific gravity of the Earth, and so gave a datum for calculating the specific gravities of the Sun and Planets. It was thus when tables of atmospheric refraction enabled observers to write down the real places of the heavenly bodies instead of their apparent places. It was thus when the discovery of the different expansibilities of metals by heat, gave us the means of correcting our chronometrical measurements of astronomical periods. It was thus when the lines of the prismatic spectrum were used to distinguish the heavenly bodies that are of like nature with the sun from those which are not. It was thus when, as recently, an electro-telegraphic instrument was invented for the more accurate registration of meridional transits. It was thus when the difference in the rates of a clock at the equator, and nearer the poles, gave data for calculating the oblateness of the earth, and accounting for the precession of the equinoxes. It was thus – but it is needless to continue. Here, within our own limited knowledge of its history, we have named ten additional cases in which the single science of astronomy has owed its advance to sciences coming *after* it in M. Comte's series. Not only its minor changes, but its greatest revolutions have been thus determined. Kepler could not have discovered his celebrated laws had it not been for Tycho Brahe's accurate observations; and it was only after some progress in physical and chemical science that the improved instruments with which those observations were made, became possible. The heliocentric theory of the Solar System had to wait until the invention of the telescope before it could be finally established. Nay, even the grand discovery of all – the law of gravitation – depended for its proof upon an operation of physical science, the measurement of a degree on the Earth's surface. So completely, indeed, did it thus depend, that Newton *had actually abandoned his hypothesis* because the length of a degree, as then stated, brought out wrong results; and it was only after Picart's more exact measurement was published, that he returned to his calculations and proved his great generalization. Now this constant intercommunion which, for brevity's sake, we have illustrated in the case of one science only, has been taking place with all the sciences. Throughout the whole course of their evolution there has been a continuous *consensus* of the sciences – a *consensus* exhibiting a general correspondence with the *consensus* of the faculties in each phase of mental development; the one being an objective registry of the subjective state of the other.

From our present point of view, then, it becomes obvious that the conception of a *serial* arrangement of the sciences is a vicious one. It is not simply that, as M. Comte admits, such a classification "will always involve something, if not arbitrary, at least artificial;" it is not, as he would have us believe, that, neglecting minor imperfections such a classification may be substantially true; but it is that any grouping of the sciences in a succession gives a radically erroneous idea of their genesis and their dependencies. There is no "one *rational* order among a host of possible systems." There is no "true *filiation* of the sciences." The whole hypothesis is fundamentally false. Indeed, it needs but a glance at its origin to see at once how baseless it is. Why a *series*? What reason have we to suppose that the sciences admit of a *linear* arrangement? Where is our warrant for assuming that there is some *succession* in which they can be placed? There is no reason; no warrant. Whence then has arisen the supposition? To use M. Comte's own phraseology, we should say, it is a metaphysical conception. It adds another to the cases constantly occurring, of the human mind being made the measure of Nature. We are obliged to think in sequence; it is a law of our minds that we must consider subjects separately, one after another: *therefore* Nature must be serial – *therefore* the sciences must be classifiable in a succession. See here the birth of the notion, and the sole evidence of its truth. Men have been obliged when arranging in books their schemes of education and systems of knowledge, to choose *some* order or other. And from inquiring what is the best order, have fallen into the belief that there is an order which truly represents the facts – have persevered in seeking such an order; quite overlooking the previous question whether it is likely that Nature has consulted the convenience of book-making. For German philosophers, who hold that Nature is "petrified intelligence," and that logical forms are the foundations of all things, it is a consistent hypothesis that as thought is serial, Nature is serial; but that M. Comte, who is so bitter an opponent of all anthropomorphism, even in its most evanescent shapes, should have committed the mistake of imposing upon the external world an arrangement which so obviously springs from a limitation of the human consciousness, is somewhat strange. And it is the more strange when we call to mind how, at the outset, M. Comte remarks that in the beginning " *toutes les sciences sont cultivées simultanément par les mêmes esprits* ;" that this is " *inevitable et même indispensable* ;" and how he further remarks that the different sciences are " *comme les diverses branches d'un tronc unique* ." Were it not accounted for by the distorting influence of a cherished hypothesis, it would be scarcely possible to understand how, after recognizing truths like these, M. Comte should have persisted in attempting to construct " *une échelle encyclopédique* ."

The metaphor which M. Comte has here so inconsistently used to express the relations of the sciences – branches of one trunk – is an approximation to the truth, though not the truth itself. It suggests the facts that the sciences had a common origin; that they have been developing simultaneously; and that they have been from time to time dividing and sub-dividing. But it fails to suggest the fact, that the divisions and sub-divisions thus arising do not remain separate, but now and again re-unite in direct and indirect ways. They inosculate; they severally send off and receive connecting growths; and the intercommunion has been ever becoming more frequent, more intricate, more widely ramified. There has all along been higher specialization, that there might be a larger generalization; and a deeper analysis, that there might be a better synthesis. Each larger generalization has lifted sundry specializations still higher; and each better synthesis has prepared the way for still deeper analysis.

And here we may fitly enter upon the task awhile since indicated – a sketch of the Genesis of Science, regarded as a gradual outgrowth from common knowledge – an extension of the perceptions by the aid of the reason. We propose to treat it as a psychological process historically displayed; tracing at the same time the advance from qualitative to quantitative prevision; the progress from concrete facts to abstract facts, and the application of such abstract facts to the analysis of new orders of concrete facts; the simultaneous advance in generalization and specialization; the continually increasing subdivision and reunion of the sciences; and their constantly improving *consensus*.

To trace out scientific evolution from its deepest roots would, of course, involve a complete analysis of the mind. For as science is a development of that common knowledge acquired by the unaided senses and uncultured reason, so is that common knowledge itself gradually built up out of the simplest perceptions. We must, therefore, begin somewhere abruptly; and the most appropriate stage to take for our point of departure will be the adult mind of the savage.

Commencing thus, without a proper preliminary analysis, we are naturally somewhat at a loss how to present, in a satisfactory manner, those fundamental processes of thought out of which science originates. Perhaps our argument may be best initiated by the proposition, that all intelligent action whatever depends upon the discerning of distinctions among surrounding things. The condition under which only it is possible for any creature to obtain food and avoid danger, is, that it shall be differently affected by different objects – that it shall be led to act in one way by one object, and in another way by another. In the lower orders of creatures this condition is fulfilled by means of an apparatus which acts automatically. In the higher orders the actions are partly automatic, partly conscious. And in man they are almost wholly conscious. Throughout, however, there must necessarily exist a certain classification of things according to their properties – a classification which is either organically registered in the system, as in the inferior creation, or is formed by conscious experience, as in ourselves. And it may be further remarked, that the extent to which this classification is carried, roughly indicates the height of intelligence – that, while the lowest organisms are able to do little more than discriminate organic from inorganic matter; while the generality of animals carry their classifications no further than to a limited number of plants or creatures serving for food, a limited number of beasts of prey, and a limited number of places and materials; the most degraded of the human race possess a knowledge of the distinctive natures of a great variety of substances, plants, animals, tools, persons, &c.; not only as classes but as individuals.

What now is the mental process by which classification is effected? Manifestly it is a recognition of the *likeness* or *unlikeness* of things, either in respect of their sizes, colours, forms, weights, textures, tastes, &c., or in respect of their modes of action. By some special mark, sound, or motion, the savage identifies a certain four-legged creature he sees, as one that is good for food, and to be caught in a particular way; or as one that is dangerous; and acts accordingly. He has classed together all the creatures that are *alike* in this particular. And manifestly in choosing the wood out of which to form his bow, the plant with which to poison his arrows, the bone from which to make his fish-hooks, he identifies them through their chief sensible properties as belonging to the general classes, wood, plant, and bone, but distinguishes them as belonging to sub-classes by virtue of certain properties in which they are *unlike* the rest of the general classes they belong to; and so forms genera and species.

And here it becomes manifest that not only is classification carried on by grouping together in the mind things that are *like*; but that classes and sub-classes are formed and arranged according to the *degrees of unlikeness*. Things strongly contrasted are alone distinguished in the lower stages of mental evolution; as may be any day observed in an infant. And gradually as the powers of discrimination increase, the strongly-contrasted classes at first distinguished, come to be each divided into sub-classes, differing from each other less than the classes differ; and these sub-classes are again divided after the same manner. By the continuance of which process, things are gradually arranged into groups, the members of which are less and less *unlike*; ending, finally, in groups whose members differ only as individuals, and not specifically. And thus there tends ultimately to arise the notion of *complete likeness*. For manifestly, it is impossible that groups should continue to be subdivided in virtue of smaller and smaller differences, without there being a simultaneous approximation to the notion of *no difference*.

Let us next notice that the recognition of likeness and unlikeness, which underlies classification, and out of which continued classification evolves the idea of complete likeness – let us next notice that it also underlies the process of *naming* , and by consequence *language*. For all language consists, at the outset, of symbols which are as *like* to the things symbolized as it is practicable to make them. The language of signs is a means of conveying ideas by mimicking the actions or peculiarities of the things referred to. Verbal language also, in its first stage, is a mode of suggesting objects or acts by imitating the sounds which the objects make, or with which the acts are accompanied. Originally these two languages were used simultaneously. It needs but to watch the gesticulations with which the savage accompanies his speech – to see a Bushman dramatizing before an audience his mode of catching game – or to note the extreme paucity of words in primitive vocabularies; to infer that in the beginning, attitudes, gestures, and sounds, were all combined to produce as good a *likeness* as possible of the things, animals, persons, or events described; and that as the sounds came to be understood by themselves the gestures fell into disuse: leaving traces, however, in the manners of the more excitable civilized races. But be this as it may, it suffices simply to observe, how many of the words current among barbarous peoples are like the sounds appertaining to the things signified; how many of our own oldest and simplest words have the same peculiarity; how children habitually invent imitative words; and how the sign-language spontaneously formed by deaf mutes is based on imitative actions – to be convinced that the notion of *likeness* is that from which the nomenclature of objects takes its rise. Were there space we might go on to point out how this law of likeness is traceable, not only in the origin but in the development of language; how in primitive tongues the plural is made by a duplication of the singular, which is a multiplication of the word to make it *like* the multiplicity of the things; how the use of metaphor – that prolific source of new words – is a suggesting of ideas which are *like* the ideas to be conveyed in some respect or other; and how, in the copious use of simile, fable, and allegory among uncivilized races, we see that complex conceptions which there is no direct language for, are rendered, by presenting known conceptions more or less *like* them.

This view is confirmed, and the predominance of this notion of likeness in primitive thought further illustrated, by the fact that our system of presenting ideas to the eye originated after the same fashion. Writing and printing have descended from picture-language. The earliest mode of permanently registering a fact was by depicting it on a skin and afterwards on a wall; that is – by exhibiting something as *like* to the thing to be remembered as it could be made. Gradually as the practice grew habitual and extensive, the most frequently repeated forms became fixed, and presently abbreviated; and, passing through the hieroglyphic and ideographic phases, the symbols lost all apparent relation to the things signified: just as the majority of our spoken words have done.

Observe, again, that the same thing is true respecting the genesis of reasoning. The *likeness* which is perceived to exist between cases, is the essence of all early reasoning and of much of our present reasoning. The savage, having by experience discovered a relation between a certain object and a certain act, infers that the *like* relation will be found in future. And the expressions we use in our arguments – " *analogy* implies," "the cases are not *parallel* ," "by *parity* of reasoning," "there is no *similarity* ," – show how constantly the idea of likeness underlies our ratiocinative processes. Still more clearly will this be seen on recognizing the fact that there is a close connexion between reasoning and classification; that the two have a common root; and that neither can go on without the other. For on the one hand, it is a familiar truth that the attributing to a body in consequence of some of its properties, all those other properties in virtue of which it is referred to a particular class, is an act of inference. And, on the other hand, the forming of a generalization is the putting together in one class, all those cases which present like relations; while the drawing a deduction is essentially the perception that a particular case belongs to a certain class of cases previously generalized. So that as classification is a grouping together of *like things*; reasoning is a grouping together of *like relations* among things. Add to which, that while the perfection gradually achieved in classification consists in the formation of groups of *objects* which are *completely alike*; the perfection gradually achieved in reasoning consists in the formation of groups of *cases* which are *completely alike*.

Once more we may contemplate this dominant idea of likeness as exhibited in art. All art, civilized as well as savage, consists almost wholly in the making of objects *like* other objects; either as found in Nature, or as produced by previous art. If we trace back the varied art-products now existing, we find that at each stage the divergence from previous patterns is but small when compared with the agreement; and in the earliest art the persistency of imitation is yet more conspicuous. The old forms and ornaments and symbols were held sacred, and perpetually copied. Indeed, the strong imitative tendency notoriously displayed by the lowest human races – often seeming to be half automatic, ensures among them a constant reproducing of likenesses of things, forms, signs, sounds, actions and whatever else is imitable; and we may even suspect that this aboriginal peculiarity is in some way connected with the culture and development of this general conception, which we have found so deep and wide-spread in its applications.

And now let us go on to consider how, by a further unfolding of this same fundamental notion, there is a gradual formation of the first germs of science. This idea of likeness which underlies classification, nomenclature, language spoken and written, reasoning, and art; and which plays so important a part because all acts of intelligence are made possible only by distinguishing among surrounding things, or grouping them into like and unlike; – this idea we shall find to be the one of which science is the especial product. Already during the stage we have been describing, there has existed *qualitative* prevision in respect to the commoner phenomena with which savage life is familiar; and we have now to inquire how the elements of *quantitative* prevision are evolved. We shall find that they originate by the perfecting of this same idea of likeness – that they have their rise in that conception of *complete likeness* which, as we have seen, necessarily results from the continued process of classification.

For when the process of classification has been carried as far as it is possible for the uncivilized to carry it – when the animal kingdom has been grouped not merely into quadrupeds, birds, fishes, and insects, but each of these divided into kinds – when there come to be classes, in each of which the members differ only as individuals, and not specifically; it is clear that there must frequently occur an observation of objects which differ so little as to be indistinguishable. Among several creatures which the savage has killed and carried home, it must often happen that some one, which he wished to identify, is so exactly like another that he cannot tell which is which. Thus, then, there originates the notion of *equality*. The things which among ourselves are called *equal* – whether lines, angles, weights, temperatures, sounds or colours – are things which produce in us sensations which cannot be distinguished from each other. It is true that we now apply the word *equal* chiefly to the separate traits or relations which objects exhibit, and not to those combinations of them constituting our conceptions of the objects; but this limitation of the idea has evidently arisen by analysis. That the notion of equality originated as alleged, will, we think, become obvious on remembering that as there were no artificial objects from which it could have been abstracted, it must have been abstracted from natural objects; and that the various families of the animal kingdom chiefly furnish those natural objects which display the requisite exactitude of likeness.

The experiences out of which this general idea of equality is evolved, give birth at the same time to a more complex idea of equality; or, rather, the process just described generates an idea of equality which further experience separates into two ideas – *equality of things* and *equality of relations*. While organic forms occasionally exhibit this perfection of likeness out of which the notion of simple equality arises, they more frequently exhibit only that kind of likeness which we call *similarity*; and which is really compound equality. For the similarity of two creatures of the same species but of different sizes, is of the same nature as the similarity of two geometrical figures. In either case, any two parts of the one bear the same ratio to one another, as the homologous parts of the other. Given in a species, the proportions found to exist among the bones, and we may, and zoologists do, predict from any one, the dimensions of the rest; just as, when knowing the proportions subsisting among the parts of a geometrical figure, we may, from the length of one, calculate the others. And if, in the case of similar geometrical figures, the similarity can be established only by proving exactness of proportion among the homologous parts – if we express this relation between two parts in the one, and the corresponding parts in the other, by the formula A is to B as *a* is to *b*; if we otherwise write this, A to B = *a* to *b*; if, consequently, the fact we prove is that the relation of A to B *equals* the relation of *a* to *b*; then it is manifest that the fundamental conception of similarity is *equality of relations*. With this explanation we shall be understood when we say that the notion of equality of relations is the basis of all exact reasoning. Already it has been shown that reasoning in general is a recognition of *likeness* of relations; and here we further find that while the notion of likeness of things ultimately evolves the idea of simple equality, the notion of likeness of relations evolves the idea of equality of relations: of which the one is the concrete germ of exact science, while the other is its abstract germ. Those who cannot understand how the recognition of similarity in creatures of the same kind, can have any alliance with reasoning, will get over the difficulty on remembering that the phenomena among which equality of relations is thus perceived, are phenomena of the same order and are present to the senses at the same time; while those among which developed reason perceives relations, are generally neither of the same order, nor simultaneously present. And if, further, they will call to mind how Cuvier and Owen, from a single part of a creature, as a tooth, construct the rest by a process of reasoning based on this equality of relations, they will see that the two things are intimately connected, remote as they at first seem. But we anticipate. What it concerns us here to observe is, that from familiarity with organic forms there simultaneously arose the ideas of *simple equality* , and *equality of relations*.

At the same time, too, and out of the same mental processes, came the first distinct ideas of *number*. In the earliest stages, the presentation of several like objects produced merely an indefinite conception of multiplicity; as it still does among Australians, and Bushmen, and Damaras, when the number presented exceeds three or four. With such a fact before us we may safely infer that the first clear numerical conception was that of duality as contrasted with unity. And this notion of duality must necessarily have grown up side by side with those of likeness and equality; seeing that it is impossible to recognize the likeness of two things without also perceiving that there are two. From the very beginning the conception of number must have been, as it is still, associated with likeness or equality of the things numbered; and for the purposes of calculation, an ideal equality of the things is assumed. Before any *absolutely true* numerical results can be reached, it is requisite that the units be *absolutely equal*. The only way in which we can establish a numerical relationship between things that do not yield us like impressions, is to divide them into parts that *do* yield us like impressions. Two unlike magnitudes of extension, force, time, weight, or what not, can have their relative amounts estimated, only by means of some small unit that is contained many times in both; and even if we finally write down the greater one as a unit and the other as a fraction of it, we state, in the denominator of the fraction, the number of parts into which the unit must be divided to be comparable with the fraction. It is, indeed, true, that by a modern process of abstraction, we occasionally apply numbers to unequal units, as the furniture at a sale or the various animals on a farm, simply as so many separate entities; but no exact quantitative result can be brought out by calculation with units of this order. And, indeed, it is the distinctive peculiarity of the calculus in general, that it proceeds on the hypothesis of that absolute equality of its abstract units, which no real units possess; and that the exactness of its results holds only in virtue of this hypothesis. The first ideas of number must necessarily then have been derived from like or equal magnitudes as seen chiefly in organic objects; and as the like magnitudes most frequently observed were magnitudes of extension, it follows that geometry and arithmetic had a simultaneous origin.

Not only are the first distinct ideas of number co-ordinate with ideas of likeness and equality, but the first efforts at numeration display the same relationship. On reading accounts of savage tribes, we find that the method of counting by the fingers, still followed by many children, is the aboriginal method. Neglecting the several cases in which the ability to enumerate does not reach even to the number of fingers on one hand, there are many cases in which it does not extend beyond ten – the limit of the simple finger notation. The fact that in so many instances, remote, and seemingly unrelated nations, have adopted *ten* as their basic number; together with the fact that in the remaining instances the basic number is either *five* (the fingers of one hand) or *twenty* (the fingers and toes); of themselves show that the fingers were the original units of numeration. The still surviving use of the word *digit* , as the general name for a figure in arithmetic, is significant; and it is even said that our word *ten* (Sax. tyn; Dutch, tien; German, zehn) means in its primitive expanded form *two hands*. So that, originally, to say there were ten things, was to say there were two hands of them. From all which evidence it is tolerably clear that the earliest mode of conveying the idea of a number of things, was by holding up as many fingers as there were things; that is, by using a symbol which was *equal* , in respect of multiplicity, to the group symbolized. For which inference there is, indeed, strong confirmation in the statement that our own soldiers spontaneously adopted this device in their dealings with the Turks during the Crimean war. And here it should be remarked that in this re-combination of the notion of equality with that of multiplicity, by which the first steps in numeration are effected, we may see one of the earliest of those inosculations between the diverging branches of science, which are afterwards of perpetual occurrence.

As this observation suggests, it will be well, before tracing the mode in which exact science emerges from the inexact judgments of the senses, and showing the non-serial evolution of its divisions, to note the non-serial character of those preliminary processes of which all after development is a continuation. On re-considering them it will be seen that not only are they divergent branches from a common root, – not only are they simultaneous in their growth; but that they are mutual aids; and that none can advance without the rest. That progress of classification for which the unfolding of the perceptions paves the way, is impossible without a corresponding progress in language, by which greater varieties of objects are thinkable and expressible. On the one hand classification cannot be carried far without names by which to designate the classes; and on the other hand language cannot be made faster than things are classified. Again, the multiplication of classes and the consequent narrowing of each class, itself involves a greater likeness among the things classed together; and the consequent approach towards the notion of complete likeness itself allows classification to be carried higher. Moreover, classification necessarily advances *pari passu* with rationality – the classification of *things* with the classification of *relations*. For things that belong to the same class are, by implication, things of which the properties and modes of behaviour – the co-existences and sequences – are more or less the same; and the recognition of this sameness of co-existences and sequences is reasoning. Whence it follows that the advance of classification is necessarily proportionate to the advance of generalizations. Yet further, the notion of *likeness* , both in things and relations, simultaneously evolves by one process of culture the ideas of *equality* of things and *equality* of relations; which are the respective bases of exact concrete reasoning and exact abstract reasoning – Mathematics and Logic. And once more, this idea of equality, in the very process of being formed, necessarily gives origin to two series of relations – those of magnitude and those of number; from which arise geometry and the calculus. Thus the process throughout is one of perpetual subdivision and perpetual intercommunication of the divisions. From the very first there has been that *consensus* of different kinds of knowledge, answering to the *consensus* of the intellectual faculties, which, as already said, must exist among the sciences.

Let us now go on to observe how, out of the notions of *equality* and *number* , as arrived at in the manner described, there gradually arose the elements of quantitative prevision.

Equality, once having come to be definitely conceived, was recognizable among other phenomena than those of magnitude. Being predicable of all things producing indistinguishable impressions, there naturally grew up ideas of equality in weights, sounds, colours, &c.; and, indeed, it can scarcely be doubted that the occasional experience of equal weights, sounds, and colours, had a share in developing the abstract conception of equality – that the ideas of equality in sizes, relations, forces, resistances, and sensible properties in general, were evolved during the same stage of mental development. But however this may be, it is clear that as fast as the notion of equality gained definiteness, so fast did that lowest kind of quantitative prevision which is achieved without any instrumental aid, become possible. The ability to estimate, however roughly, the amount of a foreseen result, implies the conception that it will be *equal* to a certain imagined quantity; and the correctness of the estimate will manifestly depend on the precision which the perceptions of sensible equality have reached. A savage with a piece of stone in his hand, and another piece lying before him of greater bulk but of the same kind (sameness of kind being inferred from the *equality* of the two in colour and texture) knows about what effort he must put forth to raise this other piece; and he judges accurately in proportion to the accuracy with which he perceives that the one is twice, three times, four times, &c. as large as the other; that is – in proportion to the precision of his ideas of equality and number. And here let us not omit to notice that even in these vaguest of quantitative previsions, the conception of *equality of relations* is also involved. For it is only in virtue of an undefined consciousness that the relation between bulk and weight in the one stone is *equal* to the relation between bulk and weight in the other, that even the roughest approximation can be made.

But how came the transition from those uncertain perceptions of equality which the unaided senses give, to the certain ones with which science deals? It came by placing the things compared in juxtaposition. Equality being asserted of things which give us indistinguishable impressions, and no distinct comparison of impressions being possible unless they occur in immediate succession, it results that exactness of equality is ascertainable in proportion to the closeness of the compared things. Hence the fact that when we wish to judge of two shades of colour whether they are alike or not, we place them side by side; hence the fact that we cannot, with any precision, say which of two allied sounds is the louder, or the higher in pitch, unless we hear the one immediately after the other; hence the fact that to estimate the ratio of weights, we take one in each hand, that we may compare their pressures by rapidly alternating in thought from the one to the other; hence the fact, that in a piece of music, we can continue to make equal beats when the first beat has been given, but cannot ensure commencing with the same length of beat on a future occasion; and hence, lastly, the fact, that of all magnitudes, those of *linear extension* are those of which the equality is most precisely ascertainable, and those to which, by consequence, all others have to be reduced. For it is the peculiarity of linear extension that it alone allows its magnitudes to be placed in *absolute* juxtaposition, or, rather, in coincident position; it alone can test the equality of two magnitudes by observing whether they will coalesce, as two equal mathematical lines do, when placed between the same points; it alone can test *equality* by trying whether it will become *identity*. Hence, then, the fact, that all exact science is reducible, by an ultimate analysis, to results measured in equal units of linear extension.

Still it remains to be noticed in what manner this determination of equality by comparison of linear magnitudes originated. Once more may we perceive that surrounding natural objects supplied the needful lessons. From the beginning there must have been a constant experience of like things placed side by side – men standing and walking together; animals from the same herd; fish from the same shoal. And the ceaseless repetition of these experiences could not fail to suggest the observation, that the nearer together any objects were, the more visible became any inequality between them. Hence the obvious device of putting in apposition, things of which it was desired to ascertain the relative magnitudes. Hence the idea of *measure*. And here we suddenly come upon a group of facts which afford a solid basis to the remainder of our argument; while they also furnish strong evidence in support of the foregoing speculations. Those who look sceptically on this attempted rehabilitation of early mental development, and who think that the derivation of so many primary notions from organic forms is somewhat strained, will perhaps see more probability in the hypotheses which have been ventured, on discovering that all measures of *extension* and *force* originated from the lengths and weights of organic bodies, and all measures of *time* from the periodic phenomena of either organic or inorganic bodies.

Thus, among linear measures, the cubit of the Hebrews was the *length of the forearm* from the elbow to the end of the middle finger; and the smaller scriptural dimensions are expressed in *hand-breadths* and *spans*. The Egyptian cubit, which was similarly derived, was divided into digits, which were *finger-breadths*; and each finger-breadth was more definitely expressed as being equal to four *grains of barley* placed breadthwise. Other ancient measures were the orgyia or *stretch of the arms* , the *pace* , and the *palm*. So persistent has been the use of these natural units of length in the East, that even now some Arabs mete out cloth by the forearm. So, too, is it with European measures. The *foot* prevails as a dimension throughout Europe, and has done so since the time of the Romans, by whom, also, it was used: its lengths in different places varying not much more than men's feet vary. The heights of horses are still expressed in *hands*. The inch is the length of the terminal joint of *the thumb*; as is clearly shown in France, where *pouce* means both thumb and inch. Then we have the inch divided into three *barley-corns*. So completely, indeed, have these organic dimensions served as the substrata of mensuration, that it is only by means of them that we can form any estimate of some of the ancient distances. For example, the length of a degree on the Earth's surface, as determined by the Arabian astronomers shortly after the death of Haroun-al-Raschid, was fifty-six of their miles. We know nothing of their mile further than that it was 4000 cubits; and whether these were sacred cubits or common cubits, would remain doubtful, but that the length of the cubit is given as twenty-seven inches, and each inch defined as the thickness of six barley-grains. Thus one of the earliest measurements of a degree comes down to us in barley-grains. Not only did organic lengths furnish those approximate measures which satisfied men's needs in ruder ages, but they furnished also the standard measures required in later times. One instance occurs in our own history. To remedy the irregularities then prevailing, Henry I. commanded that the ulna, or ancient ell, which answers to the modern yard, should be made of the exact length of *his own arm*.

Measures of weight had a kindred derivation. Seeds seem commonly to have supplied the units. The original of the carat used for weighing in India is *a small bean*. Our own systems, both troy and avoirdupois, are derived primarily from wheat-corns. Our smallest weight, the grain is *a grain of* *wheat*. This is not a speculation; it is an historically-registered fact. Henry III. enacted that an ounce should be the weight of 640 dry grains of wheat from the middle of the ear. And as all the other weights are multiples or sub-multiples of this, it follows that the grain of wheat is the basis of our scale. So natural is it to use organic bodies as weights, before artificial weights have been established, or where they are not to be had, that in some of the remoter parts of Ireland the people are said to be in the habit, even now, of putting a man into the scales to serve as a measure for heavy commodities.

Similarly with time. Astronomical periodicity, and the periodicity of animal and vegetable life, are simultaneously used in the first stages of progress for estimating epochs. The simplest unit of time, the day, nature supplies ready made. The next simplest period, the moneth or month, is also thrust upon men's notice by the conspicuous changes constituting a lunation. For larger divisions than these, the phenomena of the seasons, and the chief events from time to time occurring, have been used by early and uncivilized races. Among the Egyptians the rising of the Nile served as a mark. The New Zealanders were found to begin their year from the reappearance of the Pleiades above the sea. One of the uses ascribed to birds, by the Greeks, was to indicate the seasons by their migrations. Barrow describes the aboriginal Hottentot as expressing dates by the number of moons before or after the ripening of one of his chief articles of food. He further states that the Kaffir chronology is kept by the moon, and is registered by notches on sticks – the death of a favourite chief, or the gaining of a victory, serving for a new era. By which last fact, we are at once reminded that in early history, events are commonly recorded as occurring in certain reigns, and in certain years of certain reigns: a proceeding which made a king's reign a rude measure of duration. And, as further illustrating the tendency to divide time by natural phenomena and natural events, it may be noticed that even by our own peasantry the definite divisions of months and years are but little used; and that they habitually refer to occurrences as "before sheep-shearing," or "after harvest," or "about the time when the squire died." It is manifest, therefore, that the approximately equal periods perceived in Nature gave the first units of measure for time; as did Nature's approximately equal lengths and weights give the first units of measure for space and force.

It remains only to observe, that measures of value were similarly derived. Barter, in one form or other, is found among all but the very lowest human races. It is obviously based upon the notion of *equality of worth*. And as it gradually merges into trade by the introduction of some kind of currency, we find that the *measures of worth* , constituting this currency, are organic bodies; in some cases *cowries* , in others *cocoa-nuts* , in others *cattle* , in others *pigs*; among the American Indians peltry or *skins* , and in Iceland *dried fish*.

Notions of exact equality and of measure having been reached, there arose definite ideas of magnitudes as being multiples one of another; whence the practice of measurement by direct apposition of a measure. The determination of linear extensions by this process can scarcely be called science, though it is a step towards it; but the determination of lengths of time by an analogous process may be considered as one of the earliest samples of quantitative prevision. For when it is first ascertained that the moon completes the cycle of her changes in about thirty days – a fact known to most uncivilized tribes that can count beyond the number of their fingers – it is manifest that it becomes possible to say in what number of days any specified phase of the moon will recur; and it is also manifest that this prevision is effected by an apposition of two times, after the same manner that linear space is measured by the apposition of two lines. For to express the moon's period in days, is to say how many of these units of measure are contained in the period to be measured – is to ascertain the distance between two points in time by means of a *scale of days* , just as we ascertain the distance between two points in space by a scale of feet or inches; and in each case the scale coincides with the thing measured – mentally in the one, visibly in the other. So that in this simplest, and perhaps earliest case of quantitative prevision, the phenomena are not only thrust daily upon men's notice, but Nature is, as it were, perpetually repeating that process of measurement by observing which the prevision is effected.

This fact, that in very early stages of social progress it is known that the moon goes through her changes in nearly thirty days, and that in rather more than twelve moons the seasons return – this fact that chronological astronomy assumes a certain scientific character even before geometry does; while it is partly due to the circumstance that the astronomical divisions, day, month, and year, are ready made for us, is partly due to the further circumstances that agricultural and other operations were at first regulated astronomically, and that from the supposed divine nature of the heavenly bodies their motions determined the periodical religious festivals. As instances of the one we have the observation of the Egyptians, that the rising of the Nile corresponded with the heliacal rising of Sirius; the directions given by Hesiod for reaping and ploughing, according to the positions of the Pleiades; and his maxim that "fifty days after the turning of the sun is a seasonable time for beginning a voyage." As instances of the other, we have the naming of the days after the sun, moon, and planets; the early attempts among Eastern nations to regulate the calendar so that the gods might not be offended by the displacement of their sacrifices; and the fixing of the great annual festival of the Peruvians by the position of the sun. In all which facts we see that, at first, science was simply an appliance of religion and industry.

After the discoveries that a lunation occupies nearly thirty days, and that some twelve lunations occupy a year – discoveries which we may infer were the earliest, from the fact that existing uncivilized races have made them – we come to the first known astronomical records, which are those of eclipses. The Chaldeans were able to predict these. "This they did, probably," says Dr. Whewell in his useful history, from which most of the materials we are about to use will be drawn, "by means of their cycle of 223 months, or about eighteen years; for, at the end of this time, the eclipses of the moon begin to return, at the same intervals and in the same order as at the beginning." Now this method of calculating eclipses by means of a recurring cycle, – the *Saros* as they called it – is a more complex case of prevision by means of coincidence of measures. For by what observations must the Chaldeans have discovered this cycle? Obviously, as Delambre infers, by inspecting their registers; by comparing the successive intervals; by finding that some of the intervals were alike; by seeing that these equal intervals were eighteen years apart; by discovering that *all* the intervals that were eighteen years apart were equal; by ascertaining that the intervals formed a series which repeated itself, so that if one of the cycles of intervals were superposed on another the divisions would fit. And this being once perceived, it became possible to use the cycle as a scale of time by which to measure out future periods of recurrence. Seeing thus that the process of so predicting eclipses, is in essence the same as that of predicting the moon's monthly changes by observing the number of days after which they repeat – seeing that the two differ only in the extent and irregularity of the intervals; it is not difficult to understand how such an amount of knowledge should so early have been reached. And we shall be the less surprised on remembering that the only things involved in these previsions were *time* and *number*; and that the time was in a manner self-numbered.

Still, the ability to predict events recurring only after so long a period as eighteen years, implies a considerable advance in civilization – a considerable development of general knowledge; and we have now to inquire what progress in other sciences accompanied, and was necessary to, these astronomical previsions. In the first place, there must have been a tolerably efficient system of calculation. Mere finger-counting, mere head-reckoning, even with the aid of a decimal notation, could not have sufficed for numbering the days in a year; much less the years, months, and days between eclipses. Consequently there must have been a mode of registering numbers; probably even a system of numerals. The earliest numerical records, if we may judge by the practices of the less civilized races now existing, were probably kept by notches cut on sticks, or strokes marked on walls; much as public-house scores are kept now. And there is reason to think that the first numerals used were simply groups of straight strokes, as some of the still-extant Roman ones are; leading us to suspect that these groups of strokes were used to represent groups of fingers, as the groups of fingers had been used to represent groups of objects – a supposition harmonizing with the aboriginal practice of picture writing. Be this so or not, however, it is manifest that before the Chaldeans discovered their *Saros* , they must have had both a set of written symbols serving for an extensive numeration, and a familiarity with the simpler rules of arithmetic.

Not only must abstract mathematics have made some progress, but concrete mathematics also. It is scarcely possible that the buildings belonging to this era should have been laid out and erected without any knowledge of geometry. At any rate, there must have existed that elementary geometry which deals with direct measurement – with the apposition of lines; and it seems that only after the discovery of those simple proceedings, by which right angles are drawn, and relative positions fixed, could so regular an architecture be executed. In the case of the other division of concrete mathematics – mechanics, we have definite evidence of progress. We know that the lever and the inclined plane were employed during this period: implying that there was a qualitative prevision of their effects, if not a quantitative one. But we know more. We read of weights in the earliest records; and we find weights in ruins of the highest antiquity. Weights imply scales, of which we have also mention; and scales involve the primary theorem of mechanics in its least complicated form – involve not a qualitative but a quantitative prevision of mechanical effects. And here we may notice how mechanics, in common with the other exact sciences, took its rise from the simplest application of the idea of *equality*. For the mechanical proposition which the scales involve, is, that if a lever with *equal* arms, have *equal* weights suspended from them, the weights will remain at *equal* altitudes. And we may further notice how, in this first step of rational mechanics, we see illustrated the truth awhile since named, that as magnitudes of linear extension are the only ones of which the equality is exactly ascertainable, the equalities of other magnitudes have at the outset to be determined by means of them. For the equality of the weights which balance each other in scales, depends on the equality of the arms: we can know that the weights are equal only by proving that the arms are equal. And when by this means we have obtained a system of weights, – a set of equal units of force and definite multiples of them, then does a science of mechanics become possible. Whence, indeed, it follows, that rational mechanics could not possibly have any other starting-point than the scales.

Let us further remember that during this same period there was some knowledge of chemistry. Sundry of the arts which we know to have been carried on, were made possible only by a generalized experience of the modes in which certain bodies affect each other under special conditions. In metallurgy, which was extensively practised, this is abundantly illustrated. And we even have evidence that in some cases the knowledge possessed was, in a sense, quantitative. For, as we find by analysis that the hard alloy of which the Egyptians made their cutting tools, was composed of copper and tin in fixed proportions, there must have been an established prevision that such an alloy was to be obtained only by mixing them in these proportions. It is true, this was but a simple empirical generalization; but so was the generalization respecting the recurrence of eclipses; so are the first generalizations of every science.

Respecting the simultaneous advance of the sciences during this early epoch, it remains to point out that even the most complex of them must have made some progress. For under what conditions only were the foregoing developments possible? The conditions furnished by an established and organized social system. A long continued registry of eclipses; the building of palaces; the use of scales; the practice of metallurgy – alike imply a settled and populous nation. The existence of such a nation not only presupposes laws and some administration of justice, which we know existed, but it presupposes successful laws – laws conforming in some degree to the conditions of social stability – laws enacted because it was found that the actions forbidden by them were dangerous to the State. We do not by any means say that all, or even the greater part, of the laws were of this nature; but we do say, that the fundamental ones were. It cannot be denied that the laws affecting life and property were such. It cannot be denied that, however little these were enforced between class and class, they were to a considerable extent enforced between members of the same class. It can scarcely be questioned, that the administration of them between members of the same class was seen by rulers to be necessary for keeping society together. But supposition aside, it is clear that the habitual recognition of these claims in their laws, implied some prevision of social phenomena. That same idea of *equality* , which, as we have seen, underlies other science, underlies also morals and sociology. The conception of justice, which is the primary one in morals; and the administration of justice, which is the vital condition to social existence; are impossible without the recognition of a certain likeness in men's claims, in virtue of their common humanity. *Equity* literally means *equalness*; and if it be admitted that there were even the vaguest ideas of equity in these primitive eras, it must be admitted that there was some appreciation of the equalness of men's liberties to pursue the objects of life – some appreciation, therefore, of the essential principle of national equilibrium.

Thus in this initial stage of the positive sciences, before geometry had yet done more than evolve a few empirical rules – before mechanics had passed beyond its first theorem – before astronomy had advanced from its merely chronological phase into the geometrical; the most involved of the sciences had reached a certain degree of development – a development without which no progress in other sciences was possible.

Only noting as we pass, how, thus early, we may see that the progress of exact science was not only towards an increasing number of previsions, but towards previsions more accurately quantitative – how, in astronomy, the recurring period of the moon's motions was by and by more correctly ascertained to be two hundred and thirty-five lunations; how Callipus further corrected this Metonic cycle, by leaving out a day at the end of every seventy-six years; and how these successive advances implied a longer continued registry of observations, and the co-ordination of a greater number of facts; let us go on to inquire how geometrical astronomy took its rise. The first astronomical instrument was the gnomon. This was not only early in use in the East, but it was found among the Mexicans; the sole astronomical observations of the Peruvians were made by it; and we read that 1100 B.C., the Chinese observed that, at a certain place, the length of the sun's shadow, at the summer solstice, was to the height of the gnomon, as one and a half to eight. Here again it is observable, both that the instrument is found ready made, and that Nature is perpetually performing the process of measurement. Any fixed, erect object – a column, a pole, the angle of a building – serves for a gnomon; and it needs but to notice the changing position of the shadow it daily throws, to make the first step in geometrical astronomy. How small this first step was, may be seen in the fact that the only things ascertained at the outset were the periods of the summer and winter solstices, which corresponded with the least and greatest lengths of the mid-day shadow; and to fix which, it was needful merely to mark the point to which each day's shadow reached. And now let it not be overlooked that in the observing at what time during the next year this extreme limit of the shadow was again reached, and in the inference that the sun had then arrived at the same turning point in his annual course, we have one of the simplest instances of that combined use of *equal magnitudes* and *equal relations*, by which all exact science, all quantitative prevision, is reached. For the relation observed was between the length of the gnomon's shadow and the sun's position in the heavens; and the inference drawn was that when, next year, the extremity of the shadow came to the same point, he occupied the same place. That is, the ideas involved were, the equality of the shadows, and the equality of the relations between shadow and sun in successive years. As in the case of the scales, the equality of relations here recognized is of the simplest order. It is not as those habitually dealt with in the higher kinds of scientific reasoning, which answer to the general type – the relation between two and three equals the relation between six and nine; but it follows the type – the relation between two and three equals the relation between two and three: it is a case of not simply *equal* relations, but *coinciding* relations. And here, indeed, we may see beautifully illustrated how the idea of equal relations takes its rise after the same manner that that of equal magnitudes does. As already shown, the idea of equal magnitudes arose from the observed coincidence of two lengths placed together; and in this case we have not only two coincident lengths of shadows, but two coincident relations between sun and shadows.

From the use of the gnomon there naturally grew up the conception of angular measurements; and with the advance of geometrical conceptions came the hemisphere of Berosus, the equinoctial armil, the solstitial armil, and the quadrant of Ptolemy – all of them employing shadows as indices of the sun's position, but in combination with angular divisions. It is out of the question for us here to trace these details of progress. It must suffice to remark that in all of them we may see that notion of equality of relations of a more complex kind, which is best illustrated in the astrolabe, an instrument which consisted "of circular rims, moveable one within the other, or about poles, and contained circles which were to be brought into the position of the ecliptic, and of a plane passing through the sun and the poles of the ecliptic" – an instrument, therefore, which represented, as by a model, the relative positions of certain imaginary lines and planes in the heavens; which was adjusted by putting these representative lines and planes into parallelism with the celestial ones; and which depended for its use on the perception that the relations among these representative lines and planes were *equal* to the relations among those represented. We might go on to point out how the conception of the heavens as a revolving hollow sphere, the explanation of the moon's phases, and indeed all the successive steps taken, involved this same mental process. But we must content ourselves with referring to the theory of eccentrics and epicycles, as a further marked illustration of it. As first suggested, and as proved by Hipparchus to afford an explanation of the leading irregularities in the celestial motions, this theory involved the perception that the progressions, retrogressions, and variations of velocity seen in the heavenly bodies, might be reconciled with their assumed uniform movements in circles, by supposing that the earth was not in the centre of their orbits; or by supposing that they revolved in circles whose centres revolved round the earth; or by both. The discovery that this would account for the appearances, was the discovery that in certain geometrical diagrams the relations were such, that the uniform motion of points along curves conditioned in specified ways, would, when looked at from a particular position, present analogous irregularities; and the calculations of Hipparchus involved the belief that the relations subsisting among these geometrical curves were *equal* to the relations subsisting among the celestial orbits.

Leaving here these details of astronomical progress, and the philosophy of it, let us observe how the relatively concrete science of geometrical astronomy, having been thus far helped forward by the development of geometry in general, reacted upon geometry, caused it also to advance, and was again assisted by it. Hipparchus, before making his solar and lunar tables, had to discover rules for calculating the relations between the sides and angles of triangles – *trigonometry* , a subdivision of pure mathematics. Further, the reduction of the doctrine of the sphere to a quantitative form needed for astronomical purposes, required the formation of a *spherical trigonometry* , which was also achieved by Hipparchus. Thus both plane and spherical trigonometry, which are parts of the highly abstract and simple science of extension, remained undeveloped until the less abstract and more complex science of the celestial motions had need of them. The fact admitted by M. Comte, that since Descartes the progress of the abstract division of mathematics has been determined by that of the concrete division, is paralleled by the still more significant fact that even thus early the progress of mathematics was determined by that of astronomy. And here, indeed, we see exemplified the truth, which the subsequent history of science frequently illustrates, that before any more abstract division makes a further advance, some more concrete division suggests the necessity for that advance – presents the new order of questions to be solved. Before astronomy put before Hipparchus the problem of solar tables, there was nothing to raise the question of the relations between lines and angles: the subject-matter of trigonometry had not been conceived.

Just incidentally noticing the circumstance that the epoch we are describing witnessed the evolution of algebra, a comparatively abstract division of mathematics, by the union of its less abstract divisions, geometry and arithmetic (a fact proved by the earliest extant samples of algebra, which are half algebraic, half geometric) we go on to observe that during the era in which mathematics and astronomy were thus advancing, rational mechanics made its second step; and something was done towards giving a quantitative form to hydrostatics, optics, and acoustics. In each case we shall see how the idea of equality underlies all quantitative prevision; and in what simple forms this idea is first applied.

As already shown, the first theorem established in mechanics was, that equal weights suspended from a lever with equal arms would remain in equilibrium. Archimedes discovered that a lever with unequal arms was in equilibrium when one weight was to its arm as the other arm to its weight; that is – when the numerical relation between one weight and its arm was *equal* to the numerical relation between the other arm and its weight.

The first advance made in hydrostatics, which we also owe to Archimedes, was the discovery that fluids press *equally* in all directions; and from this followed the solution of the problem of floating bodies; namely, that they are in equilibrium when the upward and downward pressures are *equal*.

In optics, again, the Greeks found that the angle of incidence is *equal* to the angle of reflection; and their knowledge reached no further than to such simple deductions from this as their geometry sufficed for. In acoustics they ascertained the fact that three strings of *equal* lengths would yield the octave, fifth and fourth, when strained by weights having certain definite ratios; and they did not progress much beyond this. In the one of which cases we see geometry used in elucidation of the laws of light; and in the other, geometry and arithmetic made to measure certain phenomena of sound.

While sundry sciences had thus reached the first stages of quantitative prevision, others were progressing in qualitative prevision. It must suffice just to note that some small generalizations were made respecting evaporation, and heat, and electricity, and magnetism, which, empirical as they were, did not in that respect differ from the first generalizations of every science; that the Greek physicians had made advances in physiology and pathology, which, considering the great imperfection of our present knowledge, are by no means to be despised; that zoology had been so far systematized by Aristotle, as, to some extent, enabled him from the presence of certain organs to predict the presence of others; that in Aristotle's *Politics* , is shown progress towards a scientific conception of social phenomena, and sundry previsions respecting them; and that in the state of the Greek societies, as well as in the writings of Greek philosophers, we may recognize both an increasing clearness in the conception of equity and some appreciation of the fact that social stability depends on the maintenance of equitable relations. Space permitting, we might dwell on the causes which retarded the development of some of the sciences, as for example, chemistry; showing that relative complexity had nothing to do with it – that the oxidation of a piece of iron is a simpler phenomenon than the recurrence of eclipses, and the discovery of carbonic acid less difficult than that of the precession of the equinoxes. The relatively slow advance of chemical knowledge might be shown to be due, partly to the fact that its phenomena were not daily thrust on men's notice as those of astronomy were; partly to the fact that Nature does not habitually supply the means, and suggest the modes of investigation, as in the sciences dealing with time, extension, and force; partly to the fact that the great majority of the materials with which chemistry deals, instead of being ready to hand, are made known only by the arts in their slow growth; and partly to the fact that even when known, their chemical properties are not self-exhibited, but have to be sought out by experiment.

Merely indicating these considerations, however, let us go on to contemplate the progress and mutual influence of the sciences in modern days; only parenthetically noticing how, on the revival of the scientific spirit, the successive stages achieved exhibit the dominance of the law hitherto traced – how the primary idea in dynamics, a uniform force, was defined by Galileo to be a force which generates *equal* velocities in *equal* successive times – how the uniform action of gravity was first experimentally determined by showing that the time elapsing before a body thrown up, stopped, was *equal* to the time it took to fall – how the first fact in compound motion which Galileo ascertained was, that a body projected horizontally, will describe *equal* horizontal spaces in *equal* times, compounded vertical spaces described which increase by equal increments in *equal* times – how his discovery respecting the pendulum was, that its oscillations occupy *equal* intervals of time whatever their lengths

– how the law which he established that in any machine the weights that balance each other, are reciprocally as their virtual velocities implies that the relation of one set of weights to their velocities *equals* the relation of the other set of velocities to their weights; – and how thus his achievements consisted in showing the equalities of certain magnitudes and relations, whose equalities had not been previously recognized.

And now, but only now, physical astronomy became possible. The simple laws of force had been disentangled from those of friction and atmospheric resistance by which all their earthly manifestations are disguised. Progressing knowledge of *terrestrial physics* had given a due insight into these disturbing causes; and, by an effort of abstraction, it was perceived that all motion would be uniform and rectilinear unless interfered with by external forces. Geometry and mechanics having diverged from a common root in men's sensible experiences, and having, with occasional inosculations, been separately developed, the one partly in connexion with astronomy, the other solely by analyzing terrestrial movements, now join in the investigations of Newton to create a true theory of the celestial motions. And here, also, we have to notice the important fact that, in the very process of being brought jointly to bear upon astronomical problems, they are themselves raised to a higher phase of development. For it was in dealing with the questions raised by celestial dynamics that the then incipient infinitesimal calculus was unfolded by Newton and his continental successors; and it was from inquiries into the mechanics of the solar system that the general theorems of mechanics contained in the *Principia* – many of them of purely terrestrial application – took their rise. Thus, as in the case of Hipparchus, the presentation of a new order of concrete facts to be analyzed, led to the discovery of new abstract facts; and these abstract facts then became instruments of access to endless groups of concrete facts previously beyond quantitative treatment.

Meanwhile, physics had been carrying further that progress without which, as just shown, rational mechanics could not be disentangled. In hydrostatics, Stevinus had extended and applied the discovery of Archimedes. Torricelli had proved atmospheric pressure, "by showing that this pressure sustained different liquids at heights inversely proportional to their densities;" and Pascal "established the necessary diminution of this pressure at increasing heights in the atmosphere": discoveries which in part reduced this branch of science to a quantitative form. Something had been done by Daniel Bernouilli towards the dynamics of fluids. The thermometer had been invented; and sundry small generalizations reached by it. Huyghens and Newton had made considerable progress in optics; Newton had approximately calculated the rate of transmission of sound; and the continental mathematicians had ascertained some of the laws of sonorous vibrations. Magnetism and electricity had been considerably advanced by Gilbert. Chemistry had got as far as the mutual neutralization of acids and alkalies. And Leonardo da Vinci had advanced in geology to the conclusion that the deposition of animal remains in marine strata is the origin of fossils. Our present purpose does not require that we should give particulars. Here it only concerns us to illustrate the *consensus* subsisting in this stage of growth, and afterwards. Let us look at a few cases.

The theoretic law of the velocity of sound deduced by Newton from purely mechanical data, was found wrong by one-sixth. The error remained unaccounted for until the time of Laplace, who, suspecting that the heat disengaged by the compression of the undulating strata of the air, gave additional elasticity, and so produced the difference, made the needful calculations and found he was right. Thus acoustics was arrested until thermology overtook and aided it. When Boyle and Marriot had discovered the relation between the densities of gases and the pressures they are subject to; and when it thus became possible to calculate the rate of decreasing density in the upper parts of the atmosphere; it also became possible to make approximate tables of the atmospheric refraction of light. Thus optics, and with it astronomy, advanced with barology. After the discovery of atmospheric pressure had led to the invention of the air-pump by Otto Guericke; and after it had become known that evaporation increases in rapidity as atmospheric pressure decreases; it became possible for Leslie, by evaporation in a vacuum, to produce the greatest cold known; and so to extend our knowledge of thermology by showing that there is no zero within reach of our researches. When Fourier had determined the laws of conduction of heat, and when the Earth's temperature had been found to increase below the surface one degree in every forty yards, there were data for inferring the past condition of our globe; the vast period it has taken to cool down to its present state; and the immense age of the solar system – a purely astronomical consideration. Chemistry having advanced sufficiently to supply the needful materials, and a physiological experiment having furnished the requisite hint, there came the discovery of galvanic electricity. Galvanism reacting on chemistry disclosed the metallic bases of the alkalies and earths, and inaugurated the electro-chemical theory; in the hands of Oersted and Ampère it led to the laws of magnetic action; and by its aid Faraday has detected significant facts relative to the constitution of light. Brewster's discoveries respecting double refraction and dipolarization proved the essential truth of the classification of crystalline forms according to the number of axes, by showing that the molecular constitution depends on the axes. Now in these and in numerous other cases, the mutual influence of the sciences has been quite independent of any supposed hierarchical order. Often, too, their inter-actions are more complex than as thus instanced – involve more sciences than two. One illustration of this must suffice. We quote it in full from the *History of the Inductive Sciences*. In Book XI., chap. II., on "The Progress of the Electrical Theory," Dr. Whewell writes: —

"Thus at that period, mathematics was behind experiment, and a problem was proposed, in which theoretical numerical results were wanted for comparison with observation, but could not be accurately obtained; as was the case in astronomy also, till the time of the approximate solution of the problem of three bodies, and the consequent formation of the tables of the moon and planets, on the theory of universal gravitation. After some time, electrical theory was relieved from this reproach, mainly in consequence of the progress which astronomy had occasioned in pure mathematics. About 1801 there appeared in the *Bulletin des Sciences* , an exact solution of the problem of the distribution of electric fluid on a spheroid, obtained by Biot, by the application of the peculiar methods which Laplace had invented for the problem of the figure of the planets. And, in 1811, M. Poisson applied Laplace's artifices to the case of two spheres acting upon one another in contact, a case to which many of Coulomb's experiments were referrible; and the agreement of the results of theory and observation, thus extricated from Coulomb's numbers obtained above forty years previously, was very striking and convincing."

Not only do the sciences affect each other after this direct manner, but they affect each other indirectly. Where there is no dependence, there is yet analogy – *likeness of relations*; and the discovery of the relations subsisting among one set of phenomena, constantly suggests a search for similar relations among another set. Thus the established fact that the force of gravitation varies inversely as the square of the distance, being recognized as a necessary characteristic of all influences proceeding from a centre, raised the suspicion that heat and light follow the same law; which proved to be the case – a suspicion and a confirmation which were repeated in respect to the electric and magnetic forces. Thus, again, the discovery of the polarization of light led to experiments which ended in the discovery of the polarization of heat – a discovery that could never have been made without the antecedent one. Thus, too, the known refrangibility of light and heat lately produced the inquiry whether sound also is not refrangible; which on trial it turns out to be. In some cases, indeed, it is only by the aid of conceptions derived from one class of phenomena that hypotheses respecting other classes can be formed. The theory, at one time favoured, that evaporation is a solution of water in air, assumed that the relation between water and air is *like* the relation between water and a dissolved solid; and could never have been conceived if relations like that between salt and water had not been previously known. Similarly the received theory of evaporation – that it is a diffusion of the particles of the evaporating fluid in virtue of their atomic repulsion – could not have been entertained without a foregoing experience of magnetic and electric repulsions. So complete in recent days has become this *consensus* among the sciences, caused either by the natural entanglement of their phenomena, or by analogies between the relations of their phenomena, that scarcely any considerable discovery concerning one order of facts now takes place, without shortly leading to discoveries concerning other orders.

To produce a complete conception of this process of scientific evolution it would be needful to go back to the beginning, and trace in detail the growth of classifications and nomenclatures; and to show how, as subsidiary to science, they have acted upon it while it has reacted upon them. We can only now remark that, on the one hand, classifications and nomenclatures have aided science by subdividing the subject-matter of research, and giving fixity and diffusion to the truths disclosed; and that on the other hand, they have caught from it that increasing quantitativeness, and that progress from considerations touching single phenomena to considerations touching the relations among many phenomena, which we have been describing. Of this last influence a few illustrations must be given. In chemistry it is seen in the facts that the dividing of matter into the four elements was ostensibly based on the single property of weight, that the first truly chemical division into acid and alkaline bodies, grouped together bodies which had not simply one property in common but in which one property was constantly related to many others, and that the classification now current, places together in the groups *supporters of combustion* , *metallic and non-metallic bases* , *acids* , *salts* , &c., bodies which are often quite unlike in sensible qualities, but which are like in the majority of their *relations* to other bodies. In mineralogy again, the first classifications were based on differences in aspect, texture, and other physical attributes. Berzelius made two attempts at a classification based solely on chemical constitution. That now current recognizes, as far as possible, the *relations* between physical and chemical characters. In botany the earliest classes formed were *trees* , *shrubs* , and *herbs*: magnitude being the basis of distinction. Dioscorides divided vegetables into *aromatic* , *alimentary* , *medicinal* , and *vinous*: a division of chemical character. Cæsalpinus classified them by the seeds and seed-vessels, which he preferred because of the *relations* found to subsist between the character of the fructification and the general character of the other parts. While the "natural system" since developed, carrying out the doctrine of Linnæus, that "the natural orders must be formed by attention not to one or two, but to *all* the parts of plants," bases its divisions on like peculiarities which are found to be *constantly related* to the greatest number of other like peculiarities. And similarly in zoology, the successive classifications, from having been originally determined by external and often subordinate characters not indicative of the essential nature, have been more and more determined by those internal and fundamental differences, which have uniform *relations* to the greatest number of other differences. Nor shall we be surprised at this analogy between the modes of progress of positive science and classification, when we bear in mind that both proceed by making generalizations; that both enable us to make previsions, differing only in their precision; and that while the one deals with equal properties, magnitudes, and relations, the other deals with properties and relations which approximate towards equality in various degrees.

Without further argument it will, we think, be admitted that the sciences are none of them separately evolved – are none of them independent either logically or historically; but that all of them have, in a greater or less degree, required aid and reciprocated it. Indeed, it needs but to throw aside hypotheses, and contemplate the mixed character of surrounding phenomena, to see at once that these notions of division and succession in the kinds of knowledge are simply scientific fictions: good, if regarded merely as aids to study; bad, if regarded as representing realities in Nature. No facts whatever are presented to our senses uncombined with other facts – no facts whatever but are in some degree disguised by accompanying facts: disguised in such a manner that all must be partially understood before any one can be understood. If it be said, as by M. Comte, that gravitating force should be treated of before other forces, seeing that all things are subject to it, it may on like grounds be said that heat should be first dealt with; seeing that thermal forces are everywhere in action. Nay more, it may be urged that the ability of any portion of matter to manifest visible gravitative phenomena depends on its state of aggregation, which is determined by heat; that only by the aid of thermology can we explain those apparent exceptions to the gravitating tendency which are presented by steam and smoke, and so establish its universality; and that, indeed, the very existence of the Solar System in a solid form is just as much a question of heat as it is one of gravitation. Take other cases: – All phenomena recognized by the eyes, through which only are the data of exact science ascertainable, are complicated with optical phenomena, and cannot be exhaustively known until optical principles are known. The burning of a candle cannot be explained without involving chemistry, mechanics, thermology. Every wind that blows is determined by influences partly solar, partly lunar, partly hygrometric; and implies considerations of fluid equilibrium and physical geography. The direction, dip, and variations of the magnetic needle, are facts half terrestrial, half celestial – are caused by earthly forces which have cycles of change corresponding with astronomical periods. The flowing of the gulf-stream and the annual migration of icebergs towards the equator, involve in their explanation the Earth's rotation and spheroidal form, the laws of hydrostatics, the relative densities of cold and warm water, and the doctrines of evaporation. It is no doubt true, as M. Comte says, that "our position in the Solar System, and the motions, form, size, and equilibrium of the mass of our world among the planets, must be known before we can understand the phenomena going on at its surface." But, fatally for his hypothesis, it is also true that we must understand a great part of the phenomena going on at its surface before we can know its position, &c., in the Solar System. It is not simply that, as already shown, those geometrical and mechanical principles by which celestial appearances are explained, were first generalized from terrestrial experiences; but it is that even the obtainment of correct data on which to base astronomical generalizations, implies advanced terrestrial physics. Until after optics had made considerable advance, the Copernican system remained but a speculation. A single modern observation on a star has to undergo a careful analysis by the combined aid of various sciences – has to *be digested by the organism of the sciences*; which have severally to assimilate their respective parts of the observation, before the essential fact it contains is available for the further development of astronomy. It has to be corrected not only for nutation of the Earth's axis and for precession of the equinoxes, but for aberration and for refraction; and the formation of the tables by which refraction is calculated, presupposes knowledge of the law of decreasing density in the upper atmospheric strata, of the law of decreasing temperature and the influence of this on the density, and of hygrometric laws as also affecting density. So that, to get materials for further advance, astronomy requires not only the indirect aid of the sciences which have presided over the making of its improved instruments, but the direct aid of an advanced optics, of barology, of thermology, of hygrometry; and if we remember that these delicate observations are in some cases registered electrically, and that they are further corrected for the "personal equation" – the time elapsing between seeing and registering, which differs with different observers – we may even add electricity and psychology. And here, before leaving these illustrations, and especially this last one, let us not omit to notice how well they exhibit that increasingly active *consensus* of the sciences which characterizes their advancing development. Besides finding that in these later times a discovery in one science commonly causes progress in others; besides finding that a great part of the questions with which modern science deals are so mixed as to require the co-operation of many sciences for their solution; we find that, to make a single good observation in the purest of the natural sciences, requires the combined aid of half a dozen other sciences.

Perhaps the clearest comprehension of the interconnected growth of the sciences may be obtained by contemplating that of the arts, to which it is strictly analogous, and with which it is bound up. Most intelligent persons must have been occasionally struck with the numerous antecedents presupposed by one of our processes of manufacture. Let him trace the production of a printed cotton, and consider all that is implied by it. There are the many successive improvements through which the power-looms reached their present perfection; there is the steam-engine that drives them, having its long history from Papin downwards; there are the lathes in which its cylinder was bored, and the string of ancestral lathes from which those lathes proceeded; there is the steam-hammer under which its crank shaft was welded; there are the puddling furnaces, the blast-furnaces, the coal-mines and the iron-mines needful for producing the raw material; there are the slowly improved appliances by which the factory was built, and lighted, and ventilated; there are the printing engine, and the dye-house, and the colour-laboratory with its stock of materials from all parts of the world, implying cochineal-culture, logwood-cutting, indigo-growing; there are the implements used by the producers of cotton, the gins by which it is cleaned, the elaborate machines by which it is spun; there are the vessels in which cotton is imported, with the building-slips, the rope-yards, the sail-cloth factories, the anchor-forges, needful for making them; and besides all these directly necessary antecedents, each of them involving many others, there are the institutions which have developed the requisite intelligence, the printing and publishing arrangements which have spread the necessary information, the social organization which has rendered possible such a complex co-operation of agencies. Further analysis would show that the many arts thus concerned in the economical production of a child's frock, have each been brought to its present efficiency by slow steps which the other arts have aided; and that from the beginning this reciprocity has been on the increase. It needs but on the one hand to consider how impossible it is for the savage, even with ore and coal ready, to produce so simple a thing as an iron hatchet; and then to consider, on the other hand, that it would have been impracticable among ourselves, even a century ago, to raise the tubes of the Britannia bridge from lack of the hydraulic press; to see how mutually dependent are the arts, and how all must advance that each may advance. Well, the sciences are involved with each other in just the same manner. They are, in fact, inextricably woven into this same complex web of the arts; and are only conventionally independent of it. Originally the two were one. How to fix the religious festivals; when to sow; how to weigh commodities; and in what manner to measure ground; were the purely practical questions out of which arose astronomy, mechanics, geometry. Since then there has been a perpetual inosculation of the sciences and the arts. Science has been supplying art with truer generalizations and more completely quantitative previsions. Art has been supplying science with better materials, and more perfect instruments. And all along the interdependence has been growing closer, not only between art and science, but among the arts themselves, and among the sciences themselves. How completely the analogy holds throughout, becomes yet clearer when we recognize the fact that *the sciences are arts to one another*. If, as occurs in almost every case, the fact to be analyzed by any science, has first to be prepared – to be disentangled from disturbing facts by the afore discovered methods of other sciences; the other sciences so used, stand in the position of arts. If, in solving a dynamical problem, a parallelogram is drawn, of which the sides and diagonal represent forces, and by putting magnitudes of extension for magnitudes of force a measurable relation is established between quantities not else to be dealt with; it may be fairly said that geometry plays towards mechanics much the same part that the fire of the founder plays towards the metal he is going to cast. If, in analyzing the phenomena of the coloured rings surrounding the point of contact between two lenses, a Newton ascertains by calculation the amount of certain interposed spaces, far too minute for actual measurement; he employs the science of number for essentially the same purpose as that for which the watchmaker employs tools. If, before calculating the orbit of a comet from its observed position, the astronomer has to separate all the errors of observation, it is manifest that the refraction-tables, and logarithm-books, and formulæ, which he successively uses, serve him much as retorts, and filters, and cupels serve the assayer who wishes to separate the pure gold from all accompanying ingredients. So close, indeed, is the relationship, that it is impossible to say where science begins and art ends. All the instruments of the natural philosopher are the products of art; the adjusting one of them for use is an art; there is art in making an observation with one of them; it requires art properly to treat the facts ascertained; nay, even the employing established generalizations to open the way to new generalizations, may be considered as art. In each of these cases previously organized knowledge becomes the implement by which new knowledge is got at: and whether that previously organized knowledge is embodied in a tangible apparatus or in a formula, matters not in so far as its essential relation to the new knowledge is concerned. If art is applied knowledge, then such portion of a scientific investigation as consists of applied knowledge is art. Hence we may even say that as soon as any prevision in science passes out of its originally passive state, and is employed for reaching other previsions, it passes from theory into practice – becomes science in action – becomes art. And after contemplating these facts, we shall the more clearly perceive that as the connexion of the arts with each other has been becoming more intimate; as the help given by sciences to arts and by arts to sciences, has been age by age increasing; so the interdependence of the sciences themselves has been ever growing greater, their relations more involved, their *consensus* more active.

In here ending our sketch of the Genesis of Science, we are conscious of having done the subject but scant justice. Two difficulties have stood in our way: one, the having to touch on so many points in such small space; the other, the necessity of treating in serial arrangement a process which is not serial. Nevertheless, we believe the evidence assigned suffices to substantiate the leading propositions with which we set out. Inquiry into the first stages of science confirms the conclusion drawn from analysis of science as now existing, that it is not distinct from common knowledge, but an outgrowth from it – an extension of perception by means of reason. That more specific characteristic of scientific previsions, which was analytically shown to distinguish them from the previsions of uncultured intelligence – their quantitativeness – we also see to have been the characteristic alike of the initial steps in science, and of all the steps succeeding them. The facts and admissions cited in disproof of the assertion that the sciences follow one another, both logically and historically, in the order of their decreasing generality, have been enforced by the instances we have met with, showing that a more general science as much owes its progress to the presentation of new problems by a more special science, as the more special science owes its progress to the solutions which the more general science is thus led to attempt – instances, therefore, illustrating the position that scientific advance is as much from the special to the general as from the general to the special. Quite in harmony with this position we find to be the admissions that the sciences are as branches of one trunk, and that they were at first cultivated simultaneously. This harmony becomes the more marked on finding, as we have done, not only that the sciences have a common root, but that science in general has a common root with language, classification, reasoning, art; that throughout civilization these have advanced together, acting and reacting upon each other just as the separate sciences have done; and that thus the development of intelligence in all its divisions and sub-divisions has conformed to this same law which we have shown that the sciences conform to. From all which we may perceive that the sciences can with no greater propriety be arranged in a succession, than language, classification, reasoning, art, and science, can be arranged in a succession; that, however needful a succession may be for the convenience of books and catalogues, it must be recognized as merely a convention; and that so far from its being the function of a philosophy of the sciences to establish a hierarchy, it is its function to show that the linear arrangements required for literary purposes, have none of them any basis either in Nature or History.

There is one further remark we must not omit – a remark touching the importance of the question that has been discussed. Topics of this abstract nature are commonly slighted as of no practical moment; and, doubtless, many will think it of little consequence what theory respecting the genesis of science may be entertained. But the value of truths is often great, in proportion as their generality is wide. And it must be so here. A correct theory of the development of the sciences must have an important effect on education; and, through education, on civilization. Much as we differ from him in other respects, we agree with M. Comte in the belief that, rightly conducted, the education of the individual must have a certain correspondence with the evolution of the race. No one can contemplate the facts we have cited in illustration of the early stages of science, without recognizing the *necessity* of the processes through which those stages were reached – a necessity which, in respect to the leading truths, may likewise be traced in all after stages. This necessity, originating in the very nature of the phenomena to be analyzed and the faculties to be employed, partially applies to the mind of the child as to that of the savage. We say partially, because the correspondence is not special but general only. Were the *environment* the same in both cases, the correspondence would be complete. But though the surrounding material out of which science is to be organized, is, in many cases, the same to the juvenile mind and the aboriginal mind, it is not so throughout; as, for instance, in the case of chemistry, the phenomena of which are accessible to the one but were inaccessible to the other. Hence, in proportion as the environment differs, the course of evolution must differ. After admitting exceptions, however, there remains a substantial parallelism; and, if so, it is of moment to ascertain what really has been the process of scientific evolution. The establishment of an erroneous theory must be disastrous in its educational results; while the establishment of a true one must be fertile in school-reforms and consequent social benefits.

THE CLASSIFICATION OF THE SCIENCES

[First published as a brochure in April 1864. The preface to the second edition, published in April 1869, I reproduce because of certain facts contained in it which are not without interest.]

The first edition of this Essay is not yet out of print. But a proposal to translate it into French having been made by Professor Réthoré, I have decided to prepare a new edition free from the imperfections which criticism and further thought have disclosed, rather than allow these imperfections to be reproduced.

The occasion has almost tempted me into some amplification. Further arguments against the classification of M. Comte, and further arguments in support of the classification here set forth, have pleaded for utterance. But reconsideration has convinced me that it is both needless and useless to say more – needless because those who are not committed will think the case sufficiently strong as it stands; and useless because to those who are committed, additional reasons will seem as inadequate as the original ones. [In the preface to the third edition, however, a reason is given for a change of decision on this point at that time made (February 1871): the reason being "the publication of several objections by Prof. Bain in his Logic."]

This last conclusion is thrust on me by seeing how little M. Littré, the leading expositor of M. Comte, is influenced by fundamental objections the force of which he admits. After quoting one of these, he says, with a candour equally rare and admirable, that he has vainly searched M. Comte's works and his own mind for an answer. Nevertheless, he adds – "j'ai réussi, je crois, à écarter l'attaque de M. Herbert Spencer, et à sauver le fond par des sacrifices indispensables mais accessoires." The sacrifices are these. He abandons M. Comte's division of Inorganic Science into Celestial Physics and Terrestrial Physics – a division which, in M. Comte's scheme, takes precedence of all the rest; and he admits that neither logically nor historically does Astronomy come before Physics, as M. Comte alleges. After making these sacrifices, which most will think too lightly described as "sacrifices indispensables mais accessoires," M. Littré proceeds to rehabilitate the Comtean classification in a way which he considers satisfactory, but which I do not understand. In short, the proof of these incongruities affects his faith in the Positivist theory of the sciences, no more than the faith of a Christian is affected by proof that the Gospels contradict one another.

Here in England I have seen no attempt to meet the criticisms with which M. Littré thus deals. There has been no reply to the allegation, based on examples, that the several sciences do not develop in the order of their decreasing generality; nor to the allegation, based on M. Comte's own admissions, that within each science the progress is not, as he says it is, from the general to the special; nor to the allegation that the seeming historical precedence of Astronomy over Physics in M. Comte's pages, is based on a verbal ambiguity – a mere sleight of words; nor to the allegation, abundantly illustrated, that a progression in an order the reverse of that asserted by M. Comte may be as well substantiated; nor to various minor allegations equally irreconcileable with his scheme. I have met with nothing more than iteration of the statement that the sciences *do* conform, logically and historically, to the order in which M. Comte places them; regardless of the assigned evidence that they *do not*.

Under these circumstances it is unnecessary for me to say more; and I think I am warranted in continuing to hold that the Comtean classification of the sciences is demonstrably untenable.

In an essay on "The Genesis of Science," originally published in 1854, I endeavoured to show that the Sciences cannot be rationally arranged in serial order. Proof was given that neither the succession in which the Sciences are placed by M. Comte (to a criticism of whose scheme the essay was in part devoted), nor any other succession in which the Sciences can be placed, represents either their logical dependence or their historical dependence. To the question – How may their relations be rightly expressed? I did not then attempt any answer. This question I propose now to consider.

A true classification includes in each class, those objects which have more characteristics in common with one another, than any of them have in common with any objects excluded from the class. Further, the characteristics possessed in common by the colligated objects, and not possessed by other objects, involve more numerous dependent characteristics. These are two sides of the same definition. For things possessing the greatest number of attributes in common, are things that possess in common those essential attributes on which the rest depend; and, conversely, the possession in common of the essential attributes, implies the possession in common of the greatest number of attributes. Hence, either test may be used as convenience dictates.

If, then, the Sciences admit of classification at all, it must be by grouping together the like and separating the unlike, as thus defined. Let us proceed to do this.

The broadest natural division among the Sciences, is the division between those which deal with the abstract relations under which phenomena are presented to us, and those which deal with the phenomena themselves. Relations of whatever orders, are nearer akin to one another than they are to any objects. Objects of whatever orders, are nearer akin to one another than they are to any relations. Whether, as some hold, Space and Time are nothing but forms of Thought [2]; or whether, as I hold myself, they are forms of Things, that have generated forms of Thought through organized and inherited experience of Things; it is equally true that Space and Time are contrasted absolutely with the existences disclosed to us in Space and Time; and hence the Sciences which deal exclusively with Space and Time, are separated by the profoundest of all distinctions from the Sciences which deal with the existences contained in Space and Time. Space is the abstract of all relations of co-existence. Time is the abstract of all relations of sequence. And dealing as they do entirely with relations of co-existence and sequence, in their general or special forms, Logic and Mathematics form a class of the Sciences more widely unlike the rest, than any of the rest are from one another.

The Sciences which deal with existences themselves, instead of the blank forms in which existences are presented to us, admit of a sub-division less profound than the division above made, but more profound than any of the divisions among the Sciences individually considered. They fall into two classes, having quite different aspects, aims, and methods. Every phenomenon is more or less composite – is a manifestation of force under several distinct modes. Hence result two objects of inquiry. We may study the component modes of force separately; or we may study them as co-operating to generate in this composite phenomenon. On the one hand, neglecting all the incidents of particular cases, we may aim to educe the laws of each mode of force, when it is uninterfered with. On the other hand, the incidents of the particular case being given, we may seek to interpret the entire phenomenon, as a product of the several forces simultaneously in action. The truths reached through the first kind of inquiry, though concrete inasmuch as they have actual existences for their subject-matters, are abstract inasmuch as they refer to the modes of existence apart from one another; while the truths reached by the second kind of inquiry are properly concrete, inasmuch as they formulate the facts in their combined order, as they occur in Nature.

The Sciences, then, in their main divisions, stand thus: —

- SCIENCE is

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[2] I have been charged with misrepresenting Kant and misunderstanding him, because I have used the expression “forms of Thought” instead of “forms of Intuition.” Elsewhere I have shown that my argument against him remains equally valid when the phrase “forms of Intuition” is used. Here I may in the first place add that I did but follow some Kantists in saying “forms of Thought,” and I may add in the second place that the objection is superficial and quite irrelevant to the issue. Thought when broadly used as antithetical to Things includes Intuition: it comprehends in this sense all that is subjective as distinguished from all that is objective, and in so doing comprehends Intuition. Nor is this all. There cannot be Intuition without Thought: every act of intuition implies an act of classing without which the thing intuited is not known as such or such; and every act of classing is an act of thought.

• that which treats of the forms in which phenomona are known to us: ABSTRACT SCIENCE (Logic and Mathematics)

• that which treats of the phenomena themselves:

• in their elements: ABSTRACT-CONCRETE SCIENCE (Mechanics, Physics, Chemistry, etc.)

• in their totalities: CONCRETE SCIENCE (Astronomy, Geology, Biology, Psychology, Sociology, etc.)

It is needful to define the words *abstract* and *concrete* as thus used; since they are sometimes used with other meanings. M. Comte divides Science into abstract and concrete; but the divisions which he distinguishes by these names are quite unlike those above made. Instead of regarding some Sciences as wholly abstract, and others as wholly concrete, he regards each Science as having an abstract part, and a concrete part. There is, according to him, an abstract mathematics and a concrete mathematics – an abstract biology and concrete biology. He says: – "Il faut distinguer, par rapport à tous les ordres de phénomènes, deux genres de sciences naturelles: les unes abstraites, générales, ont pour objet la découverte des lois qui régissent les diverses classes de phénomènes, en considérant tous les cas qu'on peut concevoir; les autres concrètes, particulières, descriptives, et qu'on désigne quelquefois sous le nom de sciences naturelles proprement dites, consistent dans l'application de ces lois a l'histoire effective des différens êtres existans." And to illustrate the distinction, he names general physiology as abstract, and zoology and botany as concrete. Here it is manifest that the words *abstract* and *general* are used as synonymous. They have, however, different meanings; and confusion results from not distinguishing their meanings. Abstractness means *detachment from* the incidents of particular cases. Generality means *manifestation in* numerous cases. On the one hand, the essential nature of some phenomenon is considered, apart from disguising phenomena. On the other hand, the frequency of the phenomenon, with or without disguising phenomena, is the thing considered. Among the phenomena presented by numbers, which are purely ideal, the two coincide; but excluding these, an abstract truth is not realizable to perception in any case of which it is asserted, whereas a general truth is realizable to perception in every case of which it is asserted. Some illustrations will make the distinction clear. Thus it is an abstract truth that the angle contained in a semi-circle is a right angle – abstract in the sense that though it does not hold of actually-constructed semi-circles and angles, which are always inexact, it holds of the ideal semi-circles and angles abstracted from real ones; but this is not a general truth, either in the sense that it is commonly manifested in Nature, or in the sense that it is a space-relation that comprehends many minor space-relations: it is a quite special space-relation. Again, that the momentum of a body causes it to move in a straight line at a uniform velocity, is an abstract-concrete truth – a truth abstracted from certain experiences of concrete phenomena; but it is by no means a general truth: so little generality has it, that no one fact in Nature displays it. Conversely, surrounding things supply us with hosts of general truths that are not in the least abstract. It is a general truth that the planets go round the Sun from West to East – a truth which holds good in several hundred cases (including the cases of the planetoids); but this truth is not at all abstract, since it is perfectly realized as a concrete fact in every one of these cases. Every vertebrate animal whatever, has a double nervous system; all birds and all mammals are warm-blooded – these are general truths, but they are concrete truths: that is to say, every vertebrate animal individually presents an entire and unqualified manifestation of this duality of the nervous system; every living bird exemplifies absolutely or completely the warm-bloodedness of birds. What we here call, and rightly call, a general truth, is simply a proposition which *sums up* a number of our actual experiences; and not the expression of a truth *drawn from* our actual experiences, but never presented to us in any of them. In other words, a general truth colligates a number of particular truths; while an abstract truth colligates no particular truths, but formulates a truth which certain phenomena all involve, though it is actually seen in none of them.

Limiting the words to their proper meanings as thus defined, it becomes manifest that the three classes of Sciences above separated, are not distinguishable at all by differences in their degrees of generality. They are all equally general; or rather they are all, considered as groups, universal. Every object whatever presents at once the subject-matter for each of them. In every fragment of substance we have simultaneously illustrated the abstract truths of relation in Time and Space; the abstract-concrete truths in conformity with which the fragment manifests its several modes of force; and the concrete truths resulting from the joint manifestation of these modes of force, and which give to the fragment the characters by which it is known as such or such. Thus these three classes of Sciences severally formulate different, but co-extensive, classes of facts. Within each group there are truths of greater and less generality: there are general abstract truths, and special abstract truths; general abstract-concrete truths, and special abstract-concrete truths; general concrete truths, and special concrete truths. But while within each class there are groups and sub-groups and sub-sub-groups which differ in their degrees of generality, the classes themselves differ only in their degrees of abstractness. [3]

Let us pass to the sub-divisions of these classes. The first class is separable into two parts – the one containing universal truths, the other non-universal truths. Dealing wholly with relations apart from related things, Abstract Science considers first, that which is common to all relations

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[3] Some propositions laid down by M. Littré, in his book – *Auguste Comte et la Philosophie Positive* (published in 1863), may fitly be dealt with here. In the candid and courteous reply he makes to my strictures on the Comtean classification in "The Genesis of Science," he endeavours to clear up some of the inconsistencies I pointed out; and he does this by drawing a distinction between objective generality and subjective generality. He says – "qu'il existe deux ordres de généralité, l'une objective et dans les choses, l'autre subjective, abstraite et dans l'esprit." This sentence, in which M. Littré makes subjective generality synonymous with abstractness, led me at first to conclude that he had in view the same distinction as that which I have above explained between generality and abstractness. On re-reading the paragraph, however, I found this was not the case. In a previous sentence he says – "La biologie a passé de la considération des organes à celles des tissus, plus généraux que les organes, et de la considération des tissus à celle des éléments anatomiques, plus généraux que les tissus. Mais cette généralité croissante est subjective non objective, abstraite non concrète." Here it is manifest that abstract and concrete, are used in senses analogous to those in which they are used by M. Comte; who, as we have seen, regards general physiology as abstract and zoology and botany as concrete. And it is further manifest that the word abstract, as thus used, is not used in its proper sense. For, as above shown, no such facts as those of anatomical structure can be abstract facts; but can only be more or less general facts. Nor do I understand M. Littré's point of view when he regards these more general facts of anatomical structure, as *subjectively* general and not *objectively* general. The structural phenomena presented by any tissue, such as mucous membrane, are more general than the phenomena presented by any of the organs which mucous membrane goes to form, simply in the sense that the phenomena peculiar to the membrane are repeated in a greater number of instances than the phenomena peculiar to any organ into the composition of which the membrane enters. And, similarly, such facts as have been established respecting the anatomical elements of tissues, are more general than the facts established respecting any particular tissue, in the sense that they are facts which the various parts of organized bodies exhibit in a greater number of cases – they are *objectively* more general; and they can be called *subjectively* more general only in the sense that the conception corresponds with the phenomena.Let me endeavour to clear up this point: – There is, as M. Littré truly says, a decreasing generality that is objective. If we omit the phenomena of Dissolution, which are changes from the special to the general, all changes which matter undergoes are from the general to the special – are changes involving a decreasing generality in the united groups of attributes. This is the progress of *things*. The progress of *thought* , is not only in the same direction, but also in the opposite direction. The investigation of Nature discloses an increasing number of specialities; but it simultaneously discloses more and more the generalities within which these specialities fall. Take a case. Zoology, while it goes on multiplying the number of its species, and getting a more complete knowledge of each species (decreasing generality); also goes on discovering the common characters by which species are united into larger groups (increasing generality). Both these are subjective processes; and in this case, both orders of truth reached are concrete – formulate the phenomena as actually manifested. The truth that mammals of all kinds have seven cervical vertebræ (I believe there is one exception) is a generalization – a general relation in thought answering to a general relation in things. As the existence of seven cervical vertebræ in each mammal is a concrete fact, the statement of it is a concrete truth, and the statement colligating such truths is not made other than concrete by holding of case after case.M. Littré, recognizing the necessity for some modification of the hierarchy of the Sciences, as enunciated by M. Comte, still regards it as substantially true; and for proof of its validity, he appeals mainly to the essential *constitutions* of the Sciences. It is unnecessary for me here to meet, in detail, the arguments by which he supports the proposition, that the essential constitutions of the Sciences, justify the order in which M. Comte places them. It will suffice to refer to the foregoing pages, and to the pages which are to follow, as containing the definitions of those fundamental characteristics which demand the grouping of the Sciences in the way I have pointed out. As already shown, and as will be shown still more clearly by and bye, the radical differences of constitution among the Sciences, necessitate the colligation of them into the three classes – Abstract, Abstract-Concrete, and Concrete. How irreconcilable is M. Comte's classification with these groups, will be at once apparent on inspection. It stands thus: —• Mathematics (including rational Mechanics)… partly Abstract, partly Abstract-Concrete.• Astronomy.. Concrete.• Physics.. Abstract-Concrete.• Chemistry.. Abstract-Concrete.• Biology.. Concrete.• Sociology.. Concrete.

whatever; and, second, that which is common to each order of relations. Besides the indefinite and variable connexions which exist among phenomena, as occurring together in Space and Time, we find that there are also definite and invariable connexions – that between each kind of phenomenon and certain other kinds of phenomena, there exist uniform relations. This is a universal abstract truth – that there is an unchanging order, or fixity of law, in Space and Time. We come next to the several kinds of unchanging order, which, taken together, form the subjects of the second division of Abstract Science. Of this second division, the most general sub-division is that which deals with the natures of the connexions in Space and Time, irrespective of the terms connected. The conditions under which we may predicate a relation of coincidence or proximity in Space and Time (or of non-coincidence or non-proximity) from the subject-matter of Logic. Here the natures and amounts of the terms between which the relations are asserted (or denied) are of no moment: the propositions of Logic are independent of any qualitative or quantitative specification of the related things. The other sub-division has for its subject-matter, the relations between terms which are specified quantitatively but not qualitatively. The amounts of the related terms, irrespective of their natures, are here dealt with; and Mathematics is a statement of the laws of quantity considered apart from reality. Quantity considered apart from reality, is occupancy of Space or Time; and occupancy of Space or Time is measured by units of one or other order, but of which the ultimate ones are simply separate places in consciousness, either coexistent or sequent. Among units that are unspecified in their natures (extensive, protensive, or intensive), but are ideally endowed with existence considered apart from attributes, the quantitative relations that arise, are those most general relations expressed by numbers. Such relations fall into either of two orders, according as the units are considered simply as capable of filling separate places in consciousness, or according as they are considered as filling places that are not only separate, but equal. In the one case, we have that indefinite calculus by which numbers of abstract existences, but not sums of abstract existence, are predicable. In the other case, we have that definite calculus by which both numbers of abstract existences and sums of abstract existence are predicable. Next comes that division of Mathematics which deals with the quantitative relations of magnitudes (or aggregates of units) considered as coexistent, or as occupying Space – the division called Geometry. And then we arrive at relations, the terms of which include both quantities of Time and quantities of Space – those in which times are estimated by the units of space traversed at a uniform velocity, and those in which equal units of time being given, the spaces traversed with uniform or variable velocities are estimated. These Abstract Sciences, which are concerned exclusively with relations and with the relations of relations, may be grouped as shown in Table I.

• TABLE I.

• ABSTRACT SCIENCE.

• Universal law of relation – an expression of the truth that uniformities of connexion obtain among modes of Being, irrespective of any specification of the natures of the uniformities of connexion.

• Laws of relations

• that are qualitative; or that are specified in their natures as relations of coincidence or proximity in Time and Space, but not necessarily in their terms the natures and amount of which are indifferent. (LOGIC.)[4]

• that are quantitative (MATHEMATICS)

• negatively: the terms of the relations being definitely-related sets of positions in space; and the facts predicated being the absences of certain quantities. (*Geometry of Position.*[5])

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[4] This definition includes the laws of relations called necessary, but not those of relations called contingent. These last, in which the probability of an inferred connexion varies with the number of times such connexion has occurred in experience, are rightly dealt with mathematically.

[5] Here, by way of explanation of the term negatively-quantitative, it will suffice to instance the proposition that certain three lines will meet in a point, as a negatively-quantitative proposition; since it asserts the absence of any quantity of space between their

- positively: the terms being magnitudes composed of
- units that are equal only as having independent existences. (*Indefinite Calculus.*[6])
- equal units
- the equality of which is not defined as extensive, protensive, or intensive (*Definite Calculus*)
- when their numbers are completely specified (*Arithmetic.*)
- when their numbers are specified only
- in their relations (*Algebra.*)
- in the relations of their relations. (*Calculus of Operations.*)
- the equality of which is that of extension
- considered in their relations of coexistence. (*Geometry.*)
- considered as traversed in Time
- that is wholly indefinite. (*Kinematics.*)
- that is divided into equal units (*Geometry of Motion.*[7])

Passing from the Sciences concerned with the ideal or unoccupied forms of relations, and turning to the Sciences concerned with real relations, or the relations among realities, we come first to those Sciences which treat of realities, not as they are habitually manifested, but with realities as manifested in their different modes, when these are artificially separated from one another. While the Abstract Sciences are wholly ideal, relatively to the Abstract-Concrete and Concrete Sciences; the Abstract-Concrete Sciences are partially ideal, relatively to the Concrete Sciences. Just as Logic and Mathematics generalize the laws of relation, qualitative and quantitative, apart from related things; so, Mechanics, Physics, Chemistry generalize the laws of relation which different modes of Matter and Motion conform to, when severally disentangled from those actual phenomena in which they are mutually modified. Just as the geometrician formulates the properties of lines and surfaces, independently of the irregularities and thicknesses of lines and surfaces as they really exist; so the physicist and the chemist formulate the manifestations of each mode of force, independently of the disturbances in its manifestations which other modes of force cause in every actual case. In works on Mechanics, the laws of motion are expressed without reference to friction and resistance of the medium. Not what motion ever really is, but what it would be if retarding forces were absent, is asserted. If afterwards any retarding force is taken into account, then the effect of this retarding force is dealt with by itself: neglecting the other retarding forces. Consider, again, the generalizations of the physicist respecting molecular motion. The law that light varies inversely as the square of the distance, is absolutely true only when the radiation goes on from a point without dimensions, which it never does; and it also assumes that the rays are perfectly straight, which they cannot be unless the medium differs from all actual media in being perfectly homogeneous. If the disturbing effects of changes of media are investigated, the formulæ expressing the refractions take for granted that the new media entered are homogeneous; which they never really are. Even when a compound disturbance is allowed for, as when the refraction undergone by light in traversing a medium of increasing density, like the atmosphere, is calculated, the calculation still supposes conditions that are unnaturally simple – it supposes that the atmosphere is not pervaded by heterogeneous currents, which it always is. Similarly with the inquiries of the chemist. He does not take his substances as Nature supplies them. Before he proceeds to specify their respective properties, he purifies them – separates from each all trace of every other. Before ascertaining the specific gravity of a gas, he has to free this gas from the

intersections. Similarly, the assertion that certain three points will always fall in a straight line, is negatively-quantitative; since the conception of a straight line implies the negation of any lateral quantity, or deviation.

[6] Lest the meaning of this division should not be understood, it may be well to name, in illustration, the estimates of the statistician. Calculations respecting population, crime, disease, etc., have results which are correct only numerically, and not in respect of the totalities of being or action represented by the numbers.

[7] Perhaps it will be asked – how can there be a Geometry of Motion into which the conception of Force does not enter? The reply is, that the time-relations and space-relations of Motion may be considered apart from those of Force, in the same way that the space-relations of Matter may be considered apart from Matter.

vapour of water, usually mixed with it. Before describing the properties of a salt, he guards against any error that may arise from the presence of an uncombined portion of the acid or base. And when he alleges of any element that it has a certain atomic weight, and unites with such and such equivalents of other elements, he does not mean that the results thus expressed are exactly the results of any one experiment; but that they are the results which, after averaging many trials, he concludes would be realized if absolute purity could be obtained, and if the experiments could be conducted without loss. His problem is to ascertain the laws of combination of molecules, not as they are actually displayed, but as they would be displayed in the absence of those minute interferences which cannot be altogether avoided. Thus all Abstract-Concrete Sciences have for their object, *analytical interpretation*. In every case it is the aim to decompose the phenomenon, and formulate its components apart from one another; or some two or three apart from the rest. Wherever, throughout these Sciences, synthesis is employed, it is for the verification of analysis. [8] The truths elaborated are severally asserted, not as truths exhibited by this or that particular object; but as truths universally holding of Matter and Motion in their more general or more special forms, considered apart from particular objects, and particular places in space.

The sub-divisions of this group of Sciences, may be drawn on the same principle as that on which the sub-divisions of the preceding group were drawn. Phenomena, considered as more or less involved manifestations of force, yield on analysis, certain laws of manifestation which are universal, and other laws of manifestation, which, being dependent on conditions, are not universal. Hence the Abstract-Concrete Sciences are primarily divisible into – the laws of force considered apart from its separate modes, and laws of force considered under each of its separate modes. And this second division of the Abstract-Concrete group, is sub-divisible after a manner essentially analogous. It is needless to occupy space by defining these several orders and genera of Sciences. Table II. will sufficiently explain their relations.

- TABLE II.
- ABSTRACT-CONCRETE SCIENCE.
- Universal laws of forces (tensions and pressures), as deducible from the persistence of force: the theorems of resolution and composition of forces.
- Laws of forces as manifested by matter
- in masses (MECHANICS)
- that are in equilibrium relatively to other masses
- and are solid. (*Statics.*)
- and are fluid. (*Hydrostatics.*)
- that are not in equilibrium relatively to other masses
- and are solid. (*Dynamics.*)
- and are fluid. (*Hydrodynamics.*)
- in molecules (MOLECULAR MECHANICS)
- when in equilibrium: (*Molecular Statics*)
- giving statical properties of matter
- general, as impenetrability or space-occupancy.

[8] I am indebted to Prof. Frankland for reminding me of an objection that may be made to this statement. The production of new compounds by synthesis, has of late become an important branch of chemistry. According to certain known laws of composition, complex substances, which never before existed, are formed, and fulfil anticipations both as to their general properties and as to the proportions of their constituents – as proved by analysis. Here it may be said with truth, that analysis is used to verify synthesis. Nevertheless, the exception to the above statement is apparent only, – not real. In so far as the production of new compounds is carried on merely for the obtainment of such new compounds, it is not Science but Art – the application of pre-established knowledge to the achievement of ends. The proceeding is a part of Science, only in so far as it is a means to the better interpretation of the order of Nature. And how does it aid the interpretation? It does it only by verifying the pre-established conclusions respecting the laws of molecular combination; or by serving further to explain them. That is to say, these syntheses, considered on their scientific side, have simply the purpose of *forwarding the analysis of the laws of chemical combination*.

• special, as the forms resulting from molecular equilibrium.
• giving statico-dynamical properties of matter (cohesion, elasticity, etc.)
• when solid.
• when liquid.
• when gaseous.
• when not in equilibrium: (*Molecular Dynamics*)
• as resulting in a changed distribution of molecules
• which alters their relative positions homogeneously
• causing increase of volume (expansion, liquefaction, evaporation).
• causing decrease of volume (condensation, solidification, contraction).
• which alters their relative positions heterogeneously (*Chemistry*)
• producing new relations of molecules (new compounds).
• producing new relations of forces (new affinities).
• as resulting in a changed distribution of molecular motion,
• which, by integration, generates sensible motion.
• which, by disintegration, generates insensible motion, under the forms of {*Heat. Light. Electricity. Magnetism.*}

We come now to the third great group. We have done with the Sciences which are concerned only with the blank forms of relations under which Being is manifested to us. We have left behind the Sciences which, dealing with Being under its universal mode, and its several non-universal modes regarded as independent, treat the terms of its relations as simple and homogeneous; which they never are in Nature. There remain the Sciences which, taking these modes of Being as they are habitually connected with one another, have for the terms of their relations, those heterogeneous combinations of forces that constitute actual phenomena. The subject-matter of these Concrete-Sciences is the real, as contrasted with the wholly or partially ideal. It is their aim, not to separate and generalize apart the components of all phenomena, but to explain each phenomenon as a product of these components. Their relations are not, like those of the simplest Abstract-Concrete Sciences, relations between one antecedent and one consequent; nor are they, like those of the more involved Abstract-Concrete Sciences, relations between some few antecedents cut off in imagination from all others, and some few consequents similarly cut off; but they are relations each of which has for its terms a complete plexus of antecedents and a complete plexus of consequents. This is manifest in the least involved Concrete Sciences. The astronomer seeks to explain the Solar System. He does not stop short after generalizing the laws of planetary movement, such as planetary movement would be did only a single planet exist; but he solves this abstract-concrete problem, as a step towards solving the concrete problem of the planetary movements as affecting one another. In astronomical language, "the theory of the Moon" means an interpretation of the Moon's motions, not as determined simply by centripetal and centrifugal forces, but as perpetually modified by gravitation towards the Earth's equatorial protuberance, towards the Sun, and even towards Venus: forces daily varying in their amounts and combinations. Nor does the astronomer leave off when he has calculated what will be the position of a given body at a given time, allowing for all perturbations; but he goes on to consider the effects produced by reactions on the perturbing masses. And he further goes on to consider how the mutual perturbations of the planets cause, during a long period, increasing deviations from a mean state; and then how compensating perturbations cause continuous decrease of the deviations. That is, the goal towards which he ever strives, is a complete explanation of these complex planetary motions in their totality. Similarly with the geologist. He does not take for his problem only those irregularities of the Earth's crust that are worked by denudation; or only those which igneous action causes. He does not seek simply to understand how sedimentary strata were formed; or how faults were produced; or how moraines originated; or how the beds of Alpine lakes were scooped out. But taking into account all agencies co-operating in endless and ever-varying combinations, he aims to interpret the entire structure of the Earth's crust. If he studies separately the actions of rain, rivers, glaciers, icebergs, tides, waves, volcanoes, earthquakes, etc.; he does so that he may be better able to comprehend their joint actions as factors in geological phenomena: the object of his science being to generalize these phenomena in all their intricate connexions, as parts of one whole. In like manner Biology is the elaboration of a complete theory of Life, in each and all of its involved manifestations. If different aspects of its phenomena are investigated apart – if one observer busies himself in classing organisms, another in dissecting them, another in ascertaining their chemical compositions, another in studying functions, another in tracing laws of modification; they are all, consciously or unconsciously, helping to work out a solution of vital phenomena in their entirety, both as displayed by individual organisms and by organisms at large. Thus, in these Concrete Sciences, the object is the converse of that which the Abstract-Concrete Sciences propose to themselves. In the one case we have *analytical interpretation*; while in the other case we have *synthetical interpretation*. Instead of synthesis being used merely to verify analysis; analysis is here used only to aid synthesis. Not to formulate the factors of phenomena is now the object; but to formulate the phenomena resulting from these factors, under the various conditions which the Universe presents.

This third class of Sciences, like the other classes, is divisible into the universal and the non-universal. As there are truths which hold of all phenomena in their elements; so there are truths which hold of all phenomena in their totalities. As force has certain ultimate laws common to its separate modes of manifestation, so in those combinations of its modes which constitute actual phenomena, we find certain ultimate laws that are conformed to in every case. These are the laws of the re-distribution of force. Since we can become conscious of a phenomenon only by some change wrought in us, every phenomenon necessarily implies re-distribution of force – change in the arrangements of matter and motion. Alike in molecular movements and the movements of masses, one great uniformity may be traced. A decreasing quantity of motion, sensible or insensible, always has for its concomitant an increasing aggregation of matter; and, conversely, an increasing quantity of motion, sensible or insensible, has for its concomitant a decreasing aggregation of matter. Give to the molecules of any mass, more of that insensible motion which we call heat, and the parts of the mass become somewhat less closely aggregated. Add a further quantity of insensible motion, and the mass so far disintegrates as to become liquid. Add still more insensible motion, and the mass disintegrates so completely as to become gas; which occupies a greater space with every extra quantity of insensible motion given to it. On the other hand, every loss of insensible motion by a mass, gaseous, liquid, or solid, is accompanied by a progressing integration of the mass. Similarly with sensible motions, be the bodies moved large or small. Augment the velocities of the planets, and their orbits will enlarge – the Solar System will occupy a wider space. Diminish their velocities, and their orbits will lessen – the Solar System will contract, or become more integrated. And in like manner we see that sensible motions given to bodies on the Earth's surface involve partial disintegrations of the bodies from the Earth; while the loss of their motions are accompanied by their re-integration with the Earth. In all changes we have either an integration of matter and concomitant dissipation of motion; or an absorption of motion and concomitant disintegration of matter. And where, as in living bodies, these processes go on simultaneously, there is an integration of matter proportioned to the dissipation of motion, and an absorption of motion proportioned to the disintegration of matter. Such, then, are the universal laws of that re-distribution of matter and motion everywhere going on – a re-distribution which results in Evolution so long as the aggregation of matter and dispersion of motion predominate; but which results in Dissolution where there is a predominant aggregation of motion and dispersion of matter. Hence we have a division of Concrete Science which bears towards the other Concrete Sciences, a relation like that which the Universal Law of Relation bears to Mathematics, and like that which Universal Mechanics (composition and resolution of forces) bears to Physics. We have a division of Concrete Science which generalizes those concomitants of this re-distribution that hold good among all orders of concrete objects – a division which explains why, along with a predominating integration of matter and dissipation of motion, there goes a change from an indefinite, incoherent homogeneity, to a definite, coherent heterogeneity; and why a reverse re-distribution of matter and motion, is accompanied by a reverse structural change. Passing from this universal Concrete Science, to the non-universal Concrete Sciences; we find that these are primarily divisible into the science which deals with the re-distributions of matter and motion among masses in space, consequent on their mutual actions as wholes; and the science which deals with the re-distributions of matter and motion consequent on the mutual actions of the parts of each mass. And of these equally general Sciences, this last is re-divisible into the Science which is limited to the concomitants of re-distribution among the parts of each mass when regarded as independent, and the Science which takes into account the molecular motion received by radiation from other masses. But these sub-divisions, and their sub-sub-divisions, will be best seen in the annexed Table III.

- TABLE III.
- CONCRETE SCIENCE.
- Universal laws of the continuous re-distribution of Matter and Motion; which results in Evolution where there is a predominant integration of Matter and dissipation of Motion, and which results in Dissolution where there is a predominant absorption of Motion and disintegration of Matter.
- Laws of the redistributions of Matter and Motion actually going on
- among the celestial bodies in their relations to one another as masses: comprehending (ASTRONOMY)
- the dynamics of our solar system. (*Planetary Astronomy.*)
- the dynamics of our stellar universe. (*Sidereal Astronomy.*)
- among the molecules of any celestial mass; as caused by
- the actions of these molecules on one another (ASTROGENY)
- resulting in the formation of compound molecules. (*Solar Mineralogy.*)
- resulting in molecular motions and genesis of radiant forces.[9]
- resulting in movements of gases and liquids. (*Solar Meteorology.*[10])
- the actions of these molecules on one another, joined with the actions on them of forces radiated by the molecules of other masses: (GEOGENY)
- as exhibited in the planets generally.
- as exhibited in the Earth
- causing composition and of decomposition of inorganic matters. (*Mineralogy.*)
- causing re-distributions of gases and liquids. (*Meteorology.*)
- causing re-distributions of solids. (*Geology.*)
- causing organic phenomena; which are (*Biology*)
- those of structure (*Morphology*)
- general.
- special.
- those of function
- in their internal relations (*Physiology*)
- general.
- special.
- in their external relations (*Psychology*)
- general
- special
- separate.

[9] This must not be supposed to mean chemically-produced forces. The molecular motion here referred to as dissipated in radiations, is the equivalent of that sensible motion lost during the integration of the mass of molecules, consequent on their mutual gravitation.

[10] Embracing the interpretation of such phenomena as the solar spots, the faculæ and the coronal flames.

• combined. (*Sociology.*[11])

That these great groups of Sciences and their respective sub-groups, fulfil the definition of a true classification given at the outset, is, I think, tolerably manifest. The subjects of inquiry included in each primary division, have essential attributes in common with one another, which they have not in common with any of the subjects contained in the other primary divisions; and they have, by consequence, a greater number of attributes in which they are severally like the subjects they are grouped with, and unlike the subjects otherwise grouped. Between Sciences which deal with relations apart from realities, and Sciences which deal with realities, the distinction is the widest possible; since Being, in some or all of its attributes, is common to all Sciences of the second class, and excluded from all Sciences of the first class. And when we divide the Sciences which treat of realities, into those which deal with their component phenomena considered in ideal separation and those which deal with their component phenomena as actually united, we make a profounder distinction than can exist between the Sciences which deal with one or other order of the components, or than can exist between the Sciences which deal with one or other order of the things composed. The three groups of Sciences may be briefly defined as – laws of the *forms*; laws of the *factors*; laws of the *products*. When thus defined, it becomes manifest that the groups are so radically unlike in their natures, that there can be no transitions between them; and that any Science belonging to one of the groups must be quite incongruous with the Sciences belonging to either of the other groups, if transferred. How fundamental are the differences between them, will be further seen on considering their functions. The first, or abstract group, is *instrumental* with respect to both the others; and the second, or abstract-concrete group is *instrumental* with respect to the third or concrete group. An endeavour to invert these functions will at once show how essential is the difference of character. The second and third groups supply subject-matter to the first, and the third supplies subject-matter to the second; but none of the truths which constitute the third group are of any use as solvents of the problems presented by the second group; and none of the truths which the second group formulates can act as solvents of problems contained in the first group.

Concerning the sub-divisions of these great groups, little remains to be added. That each of the groups, being co-extensive with all phenomena, contains truths that are universal and others that are not universal, and that these must be classed apart, is obvious. And that the sub-divisions of the non-universal truths, are to be made according to their decreasing generality in something like the manner shown in the Tables, is proved by the fact that when the descriptive words are read from the root to the extremity of any branch, they form a definition of the Science constituting that branch. That the minor divisions might be otherwise arranged, and that better definitions of them might be given, is highly probable. They are here set down merely for the purpose of showing how this method of classification works out.

I will only further remark that the relations of the Sciences as thus represented, are still but imperfectly represented: their relations cannot be truly shown on a plane, but only in space of three dimensions. The three groups cannot rightly be put in linear order as they have here been. Since the first stands related to the third, not only indirectly through the second, but also directly – it is directly instrumental with respect to the third, and the third supplies it directly with subject-matter. Their relations can thus only be truly shown by branches diverging from a common root on different sides, in such a way that each stands in juxta-position to the other two. And only by a like mode of arrangement, can the relations among the sub-divisions of each group be correctly represented.

The foregoing exposition, highly abstract as it is, will by some readers be less readily followed than a more concrete one. With the view of carrying conviction to such I will re-state the case in two ways: the first of them adapted only to those who accept the doctrine of Evolution in its most general form.

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[11] Want of space prevents anything beyond the briefest indication of these subdivisions.

We set out with concentrating nebulous matter. Tracing the re-distributions of this, as the rotating contracting spheroid leaves behind successive annuli and as these severally form secondary rotating spheroids, we come at length to planets in their early stages. Thus far we consider the phenomena dealt with purely astronomical; and so long as our Earth, regarded as one of these spheroids, was made up of gaseous and molten matters only, it presented no data for any more complex Concrete Science. In the lapse of cosmical time a solid film forms, which, in the course of millions of years, thickens, and, in the course of further millions of years, becomes cool enough to permit the precipitation, first of various other gaseous compounds, and finally of water. Presently, the varying exposure of different parts of the spheroid to the Sun's rays, begins to produce appreciable effects; until at length there have arisen meteorological actions, and consequent geological actions, such as those we now know: determined partly by the Sun's heat, partly by the still-retained internal heat of the Earth, and partly by the action of the Moon on the ocean? How have we reached these geological phenomena? When did the astronomical changes end and the geological changes begin? It needs but to ask this question to see that there is no real division between the two. Putting pre-conceptions aside, we find nothing more than a group of phenomena continually complicating under the influence of the same original factors; and we see that our conventional division is defensible only on grounds of convenience. Let us advance a stage. As the Earth's surface continues to cool, passing through all degrees of temperature by infinitesimal gradations, the formation of more and more complex inorganic compounds becomes possible. Later, its surface sinks to that heat at which the less complex compounds of the kinds called organic can exist; and, finally, the formation of the more complex organic compounds takes place. Chemists now show us that these compounds may be built up synthetically in the laboratory – each stage in ascending complexity making possible the next higher stage. Hence it is inferable that, in the myriads of laboratories, endlessly diversified in their materials and conditions, which the Earth's surface furnished during the myriads of years occupied in passing through these stages of temperature, such successive syntheses were effected; and that the highly complex unstable substance out of which all organisms are composed, was eventually formed in microscopic portions: from which, by continuous integrations and differentiations, the evolution of all organisms has proceeded. Where then shall we draw the line between Geology and Biology? The synthesis of this most complex compound, is but a continuation of the syntheses by which all simpler compounds were formed. The same primary factors have been co-operating with those secondary factors, meteorologic and geologic, previously derived from them. Nowhere do we find a break in the ever-complicating series; for there is a manifest connexion between those movements which various complex compounds undergo during their isomeric transformations, and those changes of form undergone by the protoplasm which we distinguish as living. Strongly contrasted as they eventually become, biological phenomena are at their root inseparable from geological phenomena – inseparable from the aggregate of transformations continually wrought in the matters forming the Earth's surface by the physical forces to which they are exposed. Further stages I need not particularize. The gradual development out of the biological group of phenomena, of the more specialized group we class as psychological, needs no illustration. And when we come to the highest psychological phenomena, it is clear that since aggregations of human beings may be traced upwards from single wandering families to tribes and nations of all sizes and complexities, we pass insensibly from the phenomena of individual human action to those of corporate human action. To resume, then, is it not manifest that in the group of sciences – Astronomy, Geology, Biology, Psychology, Sociology, we have a natural group that admits neither of disruption nor change of order? Here there is both a genetic dependence, and a dependence of interpretations. The phenomena have arisen in this succession in cosmical time; and complete scientific interpretation of each group depends on scientific interpretation of the preceding groups. No other science can be thrust in anywhere without destroying the continuity. To insert Physics between Astronomy and Geology, would be to make a break in the history of a continuous series of changes; and a like break would be produced by inserting Chemistry between Geology and Biology. It is true that Physics and Chemistry are needful as interpreters of these successive assemblages of facts; but it does not therefore follow that they are themselves to be placed among these assemblages.

Concrete Science, made up of these five concrete sub-sciences, being thus coherent within itself, and separated from all other science, there comes the question – Is all other science similarly coherent within itself? or is it traversed by some second division that is equally decided? It is thus traversed. A statical or dynamical theorem, however simple, has always for its subject-matter something that is conceived as extended, and as displaying force or forces – as being a seat of resistance, or of tension, or of both, and as capable of possessing more or less of *vis viva*. If we examine the simplest proposition of Statics, we see that the conception of Force must be joined with the conception of Space, before the proposition can be framed in thought; and if we similarly examine the simplest proposition in Dynamics, we see that Force, Space, and Time, are its essential elements. The amounts of the terms are indifferent; and, by reduction of its terms beyond the limits of perception, they are applied to molecules: Molar Mechanics and Molecular Mechanics are continuous. From questions concerning the relative motions of two or more molecules, Molecular Mechanics passes to changes of aggregation among many molecules, to changes in the amounts and kinds of the motions possessed by them as members of an aggregate, and to changes of the motions transferred through aggregates of them, as those constituting light. Daily extending its range of interpretations, it is coming to deal even with the components of each compound molecule on the same principles. And the unions and disunions of such more or less compound molecules, which constitute the phenomena of Chemistry, are also being conceived as resultant phenomena of essentially kindred natures – the affinities of molecules for one another, and their reactions in relation to light, heat, and other modes of force, being regarded as consequent on the combinations of the various mechanically-determined motions of their various components. Without at all out-running, however, this progress in the mechanical interpretation of molecular phenomena, it suffices to point out that the indispensable elements in any chemical conception are units occupying places in space, and exerting forces on one another. This, then, is the common character of all these sciences which we at present group under the names of Mechanics, Physics, Chemistry. Leaving undiscussed the question whether it is possible to conceive of force apart from extended somethings exerting it, we may assert, as beyond dispute, that if the conception of force be expelled, no science of Mechanics, Physics, or Chemistry remains. Made coherent, as these sciences are, by this bond of union, it is impossible to thrust among them any other science without breaking their continuity. We cannot place Logic between Molar Mechanics and Molecular Mechanics. We cannot place Mathematics between the group of propositions concerning the behaviour of homogeneous molecules to one another, and the group of propositions concerning the behaviour of heterogeneous molecules to one another (which we call Chemistry). Clearly these two sciences lie outside the coherent whole we have contemplated; separated from it in some radical way.

By what are they radically separated? By the absence of the conception of force through which alone we know objects as existing or acting. However true it may be that so long as Logic and Mathematics have any terms at all, these must be capable of affecting consciousness, and, by implication, of exerting force; yet it is the distinctive trait of these sciences that not only do their propositions make no reference to such force, but, as far as possible, they deliberately ignore it. Instead of being, as in all the other sciences, an element that is not only recognized but vital; in Mathematics and Logic, force is an element that is not only not vital, but is studiously not recognized. The terms in which Logic expresses its propositions, are symbols that do not profess to represent things, properties, or powers, of one kind more than another; and may equally well stand for the attributes belonging to members of some connected series of ideal curves which have never been drawn, as for so many real objects. And the theorems of Geometry, so far from contemplating perceptible lines and surfaces as elements in the truths enunciated, consider these truths as becoming absolute only when such lines and surfaces become ideal – only when the conception of something exercising force is extruded.

Let me now make a second re-statement, not implying acceptance of the doctrine of Evolution, but exhibiting with a clearness almost if not quite as great, these fundamental distinctions.

The concrete sciences, taken together or separately, contemplate as their subject-matters, *aggregates* – either the entire aggregate of sensible existences, or some secondary aggregate separable from this entire aggregate, or some tertiary aggregate separable from this, and so on. Sidereal Astronomy occupies itself with the totality of visible masses distributed through space; which it deals with as made up of identifiable individuals occupying specified places, and severally standing towards one another, towards sub-groups, and towards the entire group, in defined ways. Planetary Astronomy, cutting out of this all-including aggregate that relatively minute part constituting the Solar System, deals with this as a whole – observes, measures, and calculates the sizes, shapes, distances, motions, of its primary, secondary, and tertiary members; and, taking for its larger inquiries the mutual actions of all these members as parts of a coordinated assemblage, takes for its smaller inquiries the actions of each member considered as an individual, having a set of intrinsic activities that are modified by a set of extrinsic activities. Restricting itself to one of these aggregates, which admits of close examination, Geology (using this word in its comprehensive meaning) gives an account of terrestrial actions and terrestrial structures, past and present; and, taking for its narrower problems local formations and the agencies to which they are due, takes for its larger problems the serial transformations undergone by the entire Earth. The geologist being occupied with this cosmically small, but otherwise vast, aggregate, the biologist occupies himself with small aggregates formed out of parts of the Earth's superficial substance, and treats each of these as a coordinated whole in its structures and functions; or, when he treats of any particular organ, considers this as a whole made up of parts held in a sub-coordination that refers to the coordination of the entire organism. To the psychologist he leaves those specialized aggregates of functions which adjust the actions of organisms to the complex activities surrounding them: doing this, not simply because they are a stage higher in speciality, but because they are the counterparts of those aggregated states of consciousness dealt with by the science of Subjective Psychology, which stands entirely apart from all other sciences. Finally, the sociologist considers each tribe and nation as an aggregate presenting multitudinous phenomena, simultaneous and successive, that are held together as parts of one combination. Thus, in every case, a concrete science deals with a real aggregate (or a plurality of real aggregates); and it includes as its subject-matter whatever is to be known of this aggregate in respect of its size, shape, motions, density, texture, general arrangement of parts, minute structure, chemical composition, temperature, etc., together with all the multitudinous changes, material and dynamical, gone through by it from the time it begins to exist as an aggregate to the time it ceases to exist as an aggregate.

No abstract-concrete science makes the remotest attempt to do anything of this sort. Taken together, the abstract-concrete sciences give an account of the various kinds of *properties* which aggregates display; and each abstract-concrete science concerns itself with a certain order of these properties. By this, the properties common to all aggregates are studied and formulated; by that, the properties of aggregates having special forms, special states of aggregation, etc.; and by others, the properties of particular components of aggregates when dissociated from other components. But by all these sciences the aggregate, considered as an individual object, is tacitly ignored; and a property, or a connected set of properties, exclusively occupies attention. It matters not to Mechanics whether the moving mass it considers is a planet or a molecule, a dead stick thrown into the river or the living dog that leaps after it: in any case the curve described by the moving mass conforms to the same laws. Similarly when the physicist takes for his subject the relation between the changing bulk of matter and the changing quantity of molecular motion it contains. Dealing with the subject generally, he leaves out of consideration the kind of matter; and dealing with the subject specially in relation to this or that kind of matter, he ignores the attributes of size and form: save in the still more special cases where the effect on form is considered, and even then size is ignored. So, too, is it with the chemist. A substance he is investigating, never thought of by him as distinguished in extension or amount, is not even required to be perceptible. A portion of carbon on which he is experimenting, may or may not have been visible under its forms of diamond or graphite or charcoal – this is indifferent. He traces it through various disguises and various combinations – now as united with oxygen to form an invisible gas; now as hidden with other elements in such more complex compounds as ether, and sugar, and oil. By sulphuric acid or other agent he precipitates it from these as a coherent cinder, or as a diffused impalpable powder; and again, by applying heat, forces it to disclose itself as an element of animal tissue. Evidently, while thus ascertaining the affinities and atomic equivalence of carbon, the chemist has nothing to do with any aggregate. He deals with carbon in the abstract, as something considered apart from quantity, form, appearance, or temporary state of combination; and conceives it as the possessor of powers or properties, whence the special phenomena he describes result: the ascertaining of all these powers or properties being his sole aim.

Finally, the Abstract Sciences ignore alike aggregates and the powers which aggregates or their components possess; and occupy themselves with *relations* – either with the relations among aggregates, or among their parts, or the relations among aggregates and properties, or the relations among properties, or the relations among relations. The same logical formula applies equally well, whether its terms are men and their deaths, crystals and their planes of cleavage, or plants and their seeds. And how entirely Mathematics concerns itself with relations, we see on remembering that it has just the same expression for the characters of an infinitesimal triangle, as for those of the triangle which has Sirius for its apex and the diameter of the Earth's orbit for its base.

I cannot see how these definitions of these groups of sciences can be questioned. It is undeniable that every Concrete Science gives an account of an aggregate or of aggregates, inorganic, organic, or super-organic (a society); and that, not concerning itself with properties of this or that order, it concerns itself with the co-ordination of the assembled properties of all orders. It seems to me no less certain that an Abstract-Concrete Science gives an account of some order of properties, general or special; not caring about the other traits of an aggregate displaying them, and not recognizing aggregates at all further than is implied by discussion of the particular order of properties. And I think it is equally clear that an Abstract Science, freeing its propositions, so far as the nature of thought permits, from aggregates and properties, occupies itself with relations of co-existence and sequence, as disentangled from all particular forms of being and action. If then these three groups of sciences are, respectively, accounts of *aggregates* , accounts of *properties* , accounts of *relations* , it is manifest that the divisions between them are not simply perfectly clear, but that the chasms between them are absolute.

Here, perhaps more clearly than before, will be seen the untenability of the classification made by M. Comte. Already, after setting forth in a general way these fundamental distinctions, I have pointed out the incongruities that arise when the sciences, conceived as Abstract, Abstract-Concrete, and Concrete, are arranged in the order proposed by him. Such incongruities become still more conspicuous if for these general names of the groups we substitute the definitions given above. The series will then stand thus: —

- MATHEMATICS.. An account of *relations* (including, under Mechanics, an account of *properties*).
- ASTRONOMY.. An account of *aggregates.*
- PHYSICS.. An account of *properties.*
- CHEMISTRY.. An account of *properties.*
- BIOLOGY.. An account of *aggregates.*
- SOCIOLOGY.. An account of *aggregates.*

That those who espouse opposite views see clearly the defects in the propositions of their opponents and not those in their own, is a trite remark that holds in philosophical discussions as in all others: the parable of the mote and the beam applies as well to men's appreciations of one another's opinions as to their appreciations of one another's natures. Possibly to my positivist friends I exemplify this truth, – just as they exemplify it to me. Those uncommitted to either view must decide where the mote exists and where the beam. Meanwhile it is clear that one or other of the two views is essentially erroneous; and that no qualifications can bring them into harmony. Either the sciences admit of no such grouping as that which I have described, or they admit of no such serial order as that given by M. Comte.

POSTSCRIPT REPLYING TO CRITICISMS

Among objections made to any doctrine, those which come from avowed supporters of an adverse doctrine must be considered, other things equal, as of less weight than those which come from men uncommitted to an adverse doctrine, or but partially committed to it. The element of prepossession, distinctly present in the one case and in the other case mainly or quite absent, is a well-recognized cause of difference in the values of the judgments: supposing the judgments to be otherwise fairly comparable. Hence, when it is needful to bring the replies within a restricted space, a fit course is that of dealing rather with independent criticisms than with criticisms which are really indirect arguments for an opposite view, previously espoused.

For this reason I propose here to confine myself substantially, though not absolutely, to the demurrers entered against the foregoing classification by Prof. Bain, in his recent work on Logic. Before dealing with the more important of these, let me clear the ground by disposing of the less important.

Incidentally, while commenting on the view I take respecting the position of Logic, Prof. Bain points out that this, which is the most abstract of the sciences, owes much to Psychology, which I place among the Concrete Sciences; and he alleges an incongruity between this fact and my statement that the Concrete Sciences are not instrumental in disclosing the truths of the Abstract Sciences. Subsequently he re-raises this apparent anomaly when saying —

"Nor is it possible to justify the placing of Psychology wholly among Concrete Sciences. It is a highly analytic science, as Mr. Spencer thoroughly knows."

For a full reply, given by implication, I must refer Prof. Bain to § 56 of *The Principles of Psychology* , where I have contended that "while, under its objective aspect, Psychology is to be classed as one of the Concrete Sciences which successively decrease in scope as they increase in speciality; under its subjective aspect, Psychology is a totally unique science, independent of, and antithetically opposed to, all other sciences whatever." A pure idealist will not, I suppose, recognize this distinction; but to every one else it must, I should think, be obvious that the science of subjective existences is the correlative of all the sciences of objective existences; and is as absolutely marked off from them as subject is from object. Objective Psychology, which I class among the Concrete Sciences, is purely synthetic, so long as it is limited, like the other sciences, to objective data; though great aid in the interpretation of these data is derived from the observed correspondence between the phenomena of Objective Psychology as presented in other beings and the phenomena of Subjective Psychology as presented in one's own consciousness. Now it is Subjective Psychology only which is analytic, and which affords aid in the development of Logic. This being explained, the apparent incongruity disappears.

A difficulty raised respecting the manner in which I have expressed the nature of Mathematics, may next be dealt with. Prof. Bain writes: —

"In the first place, objection may be taken to his language, in discussing the extreme Abstract Sciences, when he speaks of the *empty forms* therein considered. To call Space and Time empty forms, must mean that they can be thought of without any concrete embodiment whatsoever; that one can think of Time, as a pure abstraction, without having in one's mind any concrete succession. Now, this doctrine is in the last degree questionable."

I quite agree with Prof. Bain that "this doctrine is in the last degree questionable;" but I do not admit that this doctrine is implied by the definition of Abstract Science which I have given. I speak of Space and Time as they are dealt with by mathematicians, and as it is alone possible for pure Mathematics to deal with them. While Mathematics habitually uses in its points, lines, and surfaces, certain existences, it habitually deals with these as representing points, lines, and surfaces that are ideal; and *its conclusions are true only on condition that it does this*. Points having dimensions, lines having breadths, planes having thicknesses, are negatived by its definitions. Using, though it does, material representatives of extension, linear, superficial, or solid, Geometry deliberately ignores their materiality; and attends only to the truths of relation they present. Holding with Prof. Bain, as I do, that our consciousness of Space is disclosed by our experiences of Matter – arguing, as I have done in *The Principles of Psychology* , that it is a consolidated aggregate of all relations of co-existence that have been severally presented by Matter; I nevertheless contend that it is possible to dissociate these relations from Matter to the extent required for formulating them as abstract truths. I contend, too, that this separation is of the kind habitually made in other cases; as, for instance, when the general laws of motion are formulated (as M. Comte's system, among others, formulates them) in such way as to ignore all properties of the bodies dealt with save their powers of taking up, and retaining, and giving out, quantities of motion; though these powers are inconceivable apart from the attribute of extension, which is intentionally disregarded.

Taking other of Prof. Bain's objections, not in the order in which they stand but in the order in which they may be most conveniently dealt with, I quote as follows: —

"The law of the radiation of light (the inverse square of the distance) is said by Mr. Spencer to be Abstract-Concrete, while the disturbing changes in the medium are not to be mentioned except in a Concrete Science of Optics. We need not remark that such a separate handling is unknown to science."

It is perfectly true that "such a separate handling is unknown to science." But, unfortunately for the objection, it is also perfectly true that no such separate handling is proposed by me, or is implied by my classification. How Prof. Bain can have so missed the meaning of the word "concrete," as I have used it, I do not understand. After pointing out that "no one ever drew the line," between the Abstract-Concrete and the Concrete Sciences, "as I have done it," he alleges an anomaly which exists only supposing that I have drawn it where it is ordinarily drawn. He appears inadvertently to have carried with him M. Comte's conception of Optics as a Concrete Science, and, importing it into my classification, debits me with the incongruity. If he will re-read the definition of the Abstract-Concrete Sciences, or study their sub-divisions as shown in Table II., he will, I think, see that the most special laws of the redistribution of light, equally with its most general laws, are included. And if he will pass to the definition and the tabulation of the Concrete Sciences, he will, I think, see no less clearly that Optics cannot be included among them.

Prof. Bain considers that I am not justified in classing Chemistry as an Abstract-Concrete Science, and excluding from it all consideration of the crude forms of the various substances dealt with; and he enforces his dissent by saying that chemists habitually describe the ores and impure mixtures in which the elements, etc., are naturally found. Undoubtedly chemists do this. But do they therefore intend to include an account of the ores of a substance, *as a part of the science* which formulates its molecular constitution and the constitutions of all the definite compounds it enters into? I shall be very much surprised if I find that they do. Chemists habitually prefix to their works a division treating of Molecular Physics; but they do not therefore claim Molecular Physics as a part of Chemistry. If they similarly prefix to the chemistry of each substance an outline of its mineralogy, I do not think they therefore mean to assert that the last belongs to the first. Chemistry proper, embraces nothing beyond an account of the constitutions and modes of action and combining proportions of substances that are taken as absolutely pure; and its truths no more recognize impure substances than the truths of Geometry recognize crooked lines.

Immediately after, in criticizing the fundamental distinction I have made between Chemistry and Biology, as Abstract-Concrete and Concrete respectively, Prof. Bain says: —

"But the objects of Chemistry and the objects of Biology are equally concrete, so far as they go; the simple bodies of chemistry, and their several compounds, are viewed by the Chemist as concrete wholes, and are described by him, not with reference to one factor, but to all their factors."

Issue is here raised in a form convenient for elucidation of the general question. It is true that, *for purposes of identification* , a chemist gives an account of all the sensible characters of a substance. He sets down its crystalline form, its specific gravity, its power of refracting light, its behaviour as magnetic or diamagnetic. But does he thereby include these phenomena as part of the Science of Chemistry? It seems to me that the relation between the weight of any portion of matter and its bulk, which is ascertained on measuring its specific gravity, is a physical and not a chemical fact. I think, too, that the physicist will claim, as part of his science, all investigations touching the refraction of light: be the substance producing this refraction what it may. And the circumstance that the chemist may test the magnetic or diamagnetic property of a body, as a means of ascertaining what it is, or as a means of helping other chemists to determine whether they have got before them the same body, will neither be held by the chemist, nor allowed by the physicist, to imply a transfer of magnetic phenomena from the domain of the one to that of the other. In brief, though the chemist, in his account of an element or a compound, may refer to certain physical traits associated with its molecular constitution and affinities, he does not by so doing change these into chemical traits. Whatever chemists may put into their books, Chemistry, considered as a science, includes only the phenomena of molecular structures and changes – of compositions and decompositions. [12] I contend, then, that Chemistry does *not* give an account of anything as a concrete whole, in the same way that Biology gives an account of an organism as a concrete whole. This will become even more manifest on observing the character of the biological account. All the attributes of an organism are comprehended, from the most general to the most special – from its conspicuous structural traits to its hidden and faint ones; from its outer actions that thrust themselves on the attention, to the minutest sub-divisions of its multitudinous internal functions; from its character as a germ, through the many changes of size, form, organization, and habit, it goes through until death; from the physical characters of it as a whole, to the physical characters of its microscopic cells, and vessels, and fibres; from the chemical characters of its substance in general to the chemical characters of each tissue and each secretion – all these, with many others. And not only so, but there is comprehended as the ideal goal of the science, the *consensus* of all these phenomena in their co-existences and successions, as constituting a coherent individualized group definitely combined in space and in time. It is this recognition of *individuality* in its subject-matter, that gives its concreteness to Biology, as to every other Concrete Science. As Astronomy deals with bodies that have their several proper names, or (as with the smaller stars) are registered by their positions, and considers each of them as a distinct individual – as Geology, while dimly perceiving in the Moon and nearest planets other groups of geological phenomena (which it would deal with as independent wholes, did not distance forbid), occupies itself with that individualized group presented by the Earth; so Biology treats either of an individual distinguished from all others, or of parts or products belonging to such an individual, or of structural or functional traits common

[12] Perhaps some will say that such incidental phenomena as those of the heat and light evolved during chemical changes, are to be included among chemical phenomena. I think, however, the physicist will hold that all phenomena of re-distributed molecular motion, no matter how arising, come within the range of Physics. But whatever difficulty there may be in drawing the line between Physics and Chemistry (and, as I have incidentally pointed out in *The Principles of Psychology* , § 55, the two are closely linked by the phenomena of allotropy and isomerism), applies equally to the Comtean classification, or to any other. And I may further point out that no obstacle hence arises to the classification I am defending. Physics and Chemistry being both grouped by me as Abstract-Concrete Sciences, no difficulty in satisfactorily dividing them in the least affects the satisfactoriness of the division of the great group to which they both belong, from the other two great groups.

to many such individuals that have been observed, and supposed to be common to others that are like them in most or all of their attributes. Every biological truth connotes a specifically individualized object, or a number of specifically individualized objects of the same kind, or numbers of different kinds that are severally specific. See, then, the contrast. The truths of the Abstract-Concrete Sciences do not imply specific individuality. Neither Molar Physics, nor Molecular Physics, nor Chemistry, concerns itself with this. The laws of motion are expressed without any reference whatever to the sizes or shapes of the moving masses; which may be taken indifferently to be suns or atoms. The relations between contraction and the escape of molecular motion, and between expansion and the absorption of molecular motion, are expressed in their general forms without reference to the kind of matter; and, if the degree of either that occurs in a particular kind of matter is formulated, no note is taken of the quantity of that matter, much less of its individuality. Similarly with Chemistry. When it inquires into the atomic weight, the molecular structure, the atomicity, the combining proportions, etc., of a substance, it is indifferent whether a grain or a ton be thought of – the conception of amount is absolutely irrelevant. And so with more special attributes. Sulphur, considered chemically, is not sulphur under its crystalline form, or under its allotropic viscid form, or as a liquid, or as a gas; but it is sulphur considered apart from those attributes of quantity, and shape, and state, that give individuality.

Prof. Bain objects to the division I have drawn between the Concrete Science of Astronomy and that Abstract-Concrete Science which deals with the mutually-modified motions of hypothetical masses in space, as "not a little arbitrary." He says: —

"We can suppose a science to confine itself *solely* to the 'factors,' or the separated elements, and never, on any occasion, to combine two into a composite third. This position is intelligible, and possibly defensible. For example, in Astronomy, the Law of Persistence of Motion in a straight line might be discussed in pure ideal separation; and so, the Law of Gravity might be discussed in equally pure separation – both under the Abstract-Concrete department of Mechanics. It might then be reserved to a *concrete* department to unite these in the explanation of a projectile or of a planet. Such, however, is not Mr. Spencer's boundary line. He allows Theoretical Mechanics to make this particular combination, and to arrive at the laws of planetary movement, *in the case of a single planet*. What he does not allow is, to proceed to the case of two planets, mutually disturbing one another, or a planet and a satellite, commonly called the 'problem of the Three Bodies.'"

If I held what Prof. Bain supposes me to hold, my position would be an absurd one; but he misapprehends me. The misapprehension results in part from his having here, as before, used the word "concrete" with the Comtean meaning, as though it were my meaning; and in part from the inadequacy of my explanation. I did not in the least mean to imply that the Abstract-Concrete Science of Mechanics, when dealing with the motions of bodies in space, is limited to the interpretation of planetary movement such as it would be did only a single planet exist. It never occurred to me that my words might be so construed. Abstract-Concrete problems admit, in fact, of being complicated indefinitely, without going in the least beyond the definition. I do not draw the line, as Prof. Bain alleges, between the combination of two factors and the combination of three, or between the combination of any number and any greater number. I draw the line between the science which deals with the theory of the factors, taken singly and in combinations of two, three, four, or more, and the science which, *giving to these factors the values derived from observations of actual objects, uses the theory to explain actual phenomena*

Конец ознакомительного фрагмента.