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THE

OBJECTS,

ADVANTAGES, AND PLEASURES

OF

SCIENCE.

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DISCOURSE

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SCIENCE.

IN order fully to understand the advantages and the pleasures which are derived from an acquaintance with any Science, it is necessary to become acquainted with that science, and it would therefore be impossible to convey a complete knowledge of the benefits conferred by a study of the various sciences which have hitherto been chiefly cultivated by philosophers, without teaching all the branches of them. But a very distinct idea may be given of those benefits, by explaining the nature and objects of the different sciences; it may be shown by examples how much use and gratification there is in learning a part of any one branch of knowledge; and it may thus be inferred, how great reason there is to learn the whole.

It may easily be demonstrated, that there is an advantage in learning, both for the usefulness and the pleasure of it. There is something positively agreeable to all men, to all at least whose nature is not most grovelling and base, in gaining knowledge for its own sake. When you see any thing for the first time, you at once derive some gratification from the sight being new; your attention is awakened, and you desire to know more about it. If it is a piece of workmanship, as an instrument, a machine of any kind, you wish to know how it is made; how it works; and what use it is of. If it is an animal, you desire to know where it comes from; how it lives; what are its dispositions, and, generally, its nature and habits. This desire is felt, too, without at all considering that the machine or the animal may ever be of the least use to yourself practically; for, in all probability, you may never see them again. But you feel a curiosity to learn all about them, because they are new and unknown to you. You accordingly make inquiries; you feel a gratification in getting answers to your questions, that is, in receiving information, and in knowing more,—in being better informed than you were before. If you ever happen again to see the same instrument or animal, you find it agreeable to recollect having seen it before, and to think that you know something about it. If you see another instrument or animal, in some respects like, but differing in other particulars, you find it pleasing to compare them together, and to note in what they agree, and in what they differ. Now, all this kind of gratification is of a pure and disinterested nature, and has no reference to any of the common purposes of life; yet it is a pleasure—an enjoyment. You are nothing the richer for it; you do not gratify your palate or any other bodily appetite; and yet it is so pleasing that you would give something out of your pocket to obtain it, and would forego some bodily enjoyment for its sake. The pleasure derived from science is exactly of the like nature, or, rather, it is the very same. For what has just been referred to is in fact Science, which in its most comprehensive sense only means *Knowledge*, and in its ordinary sense means *Knowledge reduced to a System*; that is, arranged in a regular order, so as to be conveniently taught, easily remembered, and readily applied.

The practical uses of any science or branch of knowledge are undoubtedly of the highest importance; and there is hardly any man who may not gain some positive advantage in his worldly wealth and comforts, by increasing his stock of information. But there is also a pleasure in seeing the uses to which knowledge may be applied, wholly independent of the share we ourselves may have in those practical benefits. It is pleasing to examine the nature of a new instrument, or the habits of an unknown animal, without considering whether they may be of use to ourselves or to any body. It is another gratification to extend our inquiries, and find that the instrument or animal is useful to man, even although we have no chance ourselves of ever benefiting by the information: as, to find that the natives of some distant country employ the animal in travelling;—nay, though we have no desire of benefiting by the knowledge; as, for example, to find that the instrument is useful in performing some dangerous surgical operation. The mere gratification of curiosity; the knowing more to-day than we knew yesterday; the understanding what before seemed obscure and puzzling; the contemplation of general truths, and the comparing together of different things,—is an agreeable occupation of the mind; and, beside the present enjoyment, elevates the faculties above low pursuits, purifies and refines the passions, and helps our reason to assuage their violence.

It is very true, that the fundamental lessons of philosophy may to many at first sight wear a forbidding aspect, because to comprehend them requires an effort of the mind somewhat, though certainly not much, greater than is wanted for understanding more ordinary matters; and the most important branches of philosophy, those which are of the most general application, are for that very reason the less easily followed, and the less entertaining when apprehended, presenting as they do few particulars and individual objects to the mind. In discoursing of them, moreover, no figures will be at present used to assist the imagination; the appeal is made to reason, without help from the senses.

But be not therefore prejudiced against the doctrine, that the pleasure of learning the truths which philosophy unfolds is truly above all price. Lend but a patient attention to the principles explained, and giving us credit for stating nothing which has not some practical use belonging to it, or some important doctrine connected with it, you will soon perceive the value of the lessons you are learning, and begin to interest yourselves in comprehending and recollecting them; you will find that you have actually learnt something of science, while merely engaged in seeing what its end and purpose is; you will be enabled to calculate for yourselves, how far it is worth the trouble of acquiring, by examining samples of it; you will, as it were, taste a little to try whether or not you relish it, and ought to seek after more; you will enable yourselves to go on, and enlarge your stock of it; and after having first mastered a very little, you will proceed so far as to look back with wonder at the distance you have reached beyond your earliest acquirements.

The Sciences may be divided into three great classes: those which relate to *Number and Quantity*, those which relate to *Matter*, and those which relate to *Mind*. The first are called the *Mathematics*, and teach the properties of numbers and of figures; the second are called *Natural Philosophy*, and teach the properties of the various bodies which we are acquainted with by means of our senses; the third are called *Intellectual* or *Moral Philosophy*, and teach the nature of the mind, of the existence of which we have the most perfect evidence in our own reflections; or, in other words, the moral nature of man, both as an individual and as a member of society. Connected with all the sciences, and subservient to them, though not one of their number, is *History*, or the record of facts relating to all kinds of knowledge.

I. The two great branches of the *Mathematics*, or the two mathematical sciences, are *Arithmetic*, the science of number, from the Greek word signifying *number*, and *Geometry*, the science of figure, from the Greek words signifying *measure of the earth*,—land measuring having first turned men's attention to it.

When I say that 2 and 2 make 4, I state an arithmetical proposition, very simple indeed, but connected with many others of a more difficult and complicated kind. Thus, it is another proposition, somewhat less simple, but still very obvious, that 5 multiplied by 10, and divided by 2 is equal to, or makes the same number with, 100 divided by 4—both results being equal to 25. So, to find how many farthings there are in 1000*l*., and how many minutes in a year, are questions of arithmetic which we learn to work by being taught the principles of the science one after another, or, as they are commonly called, the *rules* of addition, subtraction, multiplication, and division. Arithmetic may be said to be the most simple, though among the most useful of the sciences; but it teaches only the properties of particular and known numbers, and it only enables us to add, subtract, multiply, and divide those numbers. But suppose we wish to add, subtract, multiply, or divide numbers which we have not yet ascertained, and in all respects to deal with them as if they were known, for the purpose of arriving at certain conclusions respecting them, and among other things, of discovering what they are; or, suppose we would examine properties belonging to all numbers; this must be performed by a peculiar kind of arithmetic, called *universal* arithmetic, or *Algebra*.* The common arithmetic, you will presently perceive, carries the seeds of this most important science in its bosom. Thus, suppose we inquire what is the number which multiplied by 5 makes 10? this is found if we divide 10 by 5—it is 2; but suppose that, before finding this number 2, and before knowing what it is, we would add it, whatever it may turn out, to some other number; this can only be done by putting some mark, such as a letter of the alphabet, to stand for the unknown number, and adding that letter as if it were a known number. Thus, suppose we want to find two numbers, which, added together, make 9, and multiplied by one another make 20. There are many, which added together, make 9; as 1 and 8; 2 and 7; 3 and 6; and so on. We have, therefore, occasion to use the second condition, that multiplied by one another they should make 20, and to work upon this condition before we have discovered the particular numbers. We must, therefore, suppose the numbers to be found, and put letters for them, and by reasoning upon those letters, according to both the two conditions of adding and multiplying, we find what they must each of them be in numbers, in order to fulfil or answer the conditions. Algebra teaches the rules for conducting this reasoning, and obtaining this result successfully; and by means of it we are enabled to find out numbers which are unknown, and of which we only know that they stand in certain relations to known numbers, or to one another. The instance now taken is an easy one; and you could, by considering the question a little, answer it readily enough; that is, by trying different numbers, and seeing which suited the conditions; for you plainly see that 5 and 4 are the two numbers sought; but you see this by no certain or general rule applicable to all cases, and therefore you never could work more difficult questions in the same way; and even questions of a moderate degree of difficulty would take an endless number of trials or guesses to answer. Thus, if a ship, say a smuggler, is sailing at the rate of 8 miles an hour, and a revenue cutter, sailing at the rate of 10 miles an hour, descries her 18 miles off, and gives chase, and you want to know in what time the smuggler will be overtaken, and how many miles she will have sailed before being overtaken; this, which is one of the simplest questions in algebra, would take you a long time, almost as long as the chase, to come at by mere trial and guessing (the chase would be 9 hours, and the smuggler would sail 72 miles:) and questions only a little more difficult than this, never could be answered by any number of guesses; yet questions infinitely more difficult can easily be solved by the rules of algebra. In like manner, by arithmetic you can tell the properties of particular numbers; as, for instance, that the number 348 is divided by 3 exactly, so as leave nothing over: but algebra teaches us that it is only one of an infinite variety of numbers, all divisible by 3, and any one of which you can tell the moment you see it; for they all have the remarkable property, that if you add together the figures they consist of, the sum total is divisible by 3. You can easily perceive

* Algebra, from the Arabic words signifying the *reduction of fractions*; the Arabs having brought the knowledge of it into Europe.

this in any one case, as in the number mentioned, for 3 added to 4 and that to 8 make 15, which is plainly divisible by 3; and if you divide 348 by 3, you find the quotient to be 116, and nothing over. But this does not at all prove that any other number, the sum of whose figures is divisible by 3, will itself also be found divisible by 3, as 741; for you must actually perform the division here, and in every other case, before you can know that it leaves nothing over. Algebra, on the contrary, both enables you to discover such general properties, and to prove them in all their generality.*

By means of this science, and its various applications, the most extraordinary calculations may be performed. We shall give, as an example, the method of *Logarithms*, which proceeds upon this principle. Take a set of numbers going on by equal differences; that is to say, the third being as much greater than the second, as the second is greater than the first; thus, 1, 2, 3, 4, 5, 6, and so on, in which the common difference is 1; then take another set of numbers, such that each is equal to twice or three times the one before it, or any number of times the one before it; thus, 2, 4, 8, 16, 32, 64, 128; write this second set of numbers under the first, or side by side, so that the numbers shall stand opposite to one another thus,

1	2	3	4	5	6	7
2	4	8	16	32	64	128

you will find, that if you add together any two of the upper or first set, and go to the number opposite their sum, in the lower or second set, you will have in this last set the number arising from multiplying together the numbers of the lower set corresponding to the numbers added together. Thus, add 2 to 4, you have 6 in the upper set, opposite to which in the lower set is 64, and multiplying the numbers 4 and 16 opposite to 2 and 4, the product is 64. In like manner, if you subtract the upper numbers, and look for the lower numbers opposite to their difference, you obtain the quotient of the lower numbers opposite the number subtracted. Thus, take 4 from 6 and 2 remains, opposite to which you have in the lower line 4; and if you divide 64, the number opposite to 6, by 16, the number opposite to 4, the quotient is 4. The upper set are called the *logarithms* of the lower set, which are called *natural numbers*: and tables may, with a little trouble, be constructed, giving the logarithms of all numbers from 1 to 10,000 and more; so that, instead of multiplying or dividing one number by another, you have only to add or subtract their logarithms, and then you at once find the product or the quotient in the tables. These are made applicable to numbers far higher than any actually in them, by a very simple process; so that you may at once perceive the prodigious saving of time and labour which is thus made. If you had, for instance, to multiply

* Another class of numbers divisible by 3 is discovered in like manner by algebra. Every number of 3 places, the figures (or digits) composing which are in arithmetical progression, (or rise above each other by equal differences,) is divisible by 3: as, 123, 789, 357, 159, and so on. The same is true of numbers of any amount of places, provided they are composed of 3, 6, 9, &c. numbers rising above each other by equal differences, as 289, 299, 309, or 148, 214, 280, 346, or 307142085345648276198756, which number of 24 places is divisible by 3, being composed of 6 numbers in a series whose common difference is 1137.

7,543,283 by itself, and that product again by the original number, you would have to multiply a number of seven places of figures by an equally large number, and then a number of 14 places of figures by one of seven places, till at last you had a product of 21 places of figures—a very tedious operation; but working by logarithms, you would only have to take three times the logarithm of the original number, and that gives the logarithm of the last product of 21 places of figures, without any further multiplication. So much for the time and trouble saved, which is still greater in questions of division; but by means of logarithms many questions can be worked, and of the most important kind, which no time or labour would otherwise enable us to solve.

Geometry teaches the properties of figure, or particular portions of space, and distances of points from each other. Thus, when you see a triangle, or three-sided figure, one of whose sides is perpendicular to another side, you find, by means of geometrical reasoning respecting this kind of triangle, that if squares be drawn on its three sides, the large square upon the slanting side opposite the two perpendiculars, is exactly equal to the two smaller squares upon the perpendiculars, taken together; and this is absolutely true, whatever be the size of the triangle, or the proportions of its sides to each other. Therefore, you can always find the length of any one of the three sides by knowing the lengths of the other two. Suppose one perpendicular side to be 10 feet long, the other 6, and you want to know the length of the third side opposite to the perpendiculars, you have only to find a number such, that if multiplied by itself, it shall be equal to 10 times 10, together with 6 times 6, that is 136. (This number is between $11\frac{4}{7}$ and $11\frac{5}{7}$.) Now only observe the great advantage of knowing this property of the triangle, or of perpendicular lines. If you want to measure a line passing over ground which you cannot reach—to know, for instance, the length of one side covered with water of a field, or the distance of one point on a lake or bay from the opposite side—you can easily find it by measuring two lines perpendicular to one another on the dry land, and running through the two points; for the line wished to be measured, and which runs through the water, is the third side of a perpendicular-sided triangle, the other two sides of which are ascertained. But there are other properties of triangles, which enable us to know the length of two sides of any triangle, whether it has perpendicular sides or not, by measuring one side and also measuring the inclination of the other two sides to this side, or what is called the two angles made by those sides with the measured side. Therefore you can easily find the perpendicular line drawn or supposed to be drawn from the top of a mountain through it to the bottom, that is the height of the mountain; for you can measure a line on level ground, and also the inclination of two lines, supposing them drawn in the air, and reaching from the ends of the measured lines to the mountain's top; and having thus found the length of the one of those lines next the mountain, and its inclination to the ground, you can at once find the perpendicular, though you cannot possibly get near it. In the same way, by measuring lines and angles on the ground, and near, you can find the length of lines at a great distance, and which you cannot get near: for instance, the length and breadth of a field on the opposite side of a lake or sea; the distance of two islands, or the space between the tops of two mountains.

Again, there are curve-lined figures as well as straight, and geometry teaches the properties of these also. The best known of all the curves is the circle, or a figure made by drawing a string round a fixed point, and marking where its other end traces, so that every part of the circle is equally distant from the fixed point or centre. From this fundamental property, an infinite variety of others follow by steps of reasoning more or less numerous, but all necessarily arising one out of another. To give an instance; it is proved by geometrical reasoning, that if from the two ends of any diameter of the circle you draw two lines to meet in any one point of the circle whatever, those lines are perpendicular to each other. Another property, and a most useful one is, that the sizes, or areas, of all circles whatever, from the greatest to the smallest, from the sun to a watch-dial-plate, are in exact proportion to the squares of their distances from the centre; that is, the squares of the strings they are drawn with: so that if you draw a circle with a string 5 feet long, and another with a string 10 feet long, the large circle is four times the size of the small one, as far as the space or area enclosed is concerned; the square of 10 or 100 being four times the squares of 5 or 25. But it is also true, that the lengths of the circumferences themselves, the number of feet over which the ends of the strings move, are in proportion to the lengths of the strings; so that the curve of the larger circle is only twice the length of the curve of the lesser.

But the circle is only one of an infinite variety of curves, all having a regular formation and fixed properties. The *oval* or *ellipse* is, perhaps, next to the circle, the most familiar to us, although we more frequently see another curve line formed by the motions of bodies thrown forward. When you drop a stone, or throw it straight up, it goes in a straight line; when you throw it forward, it goes in a curve line till it reaches the ground; as you may see by the figure in which water runs when forced out of a pump, or from a fire-pipe, or from the spout of a kettle or tea-pot. The line it moves in is called a *parabola;* every point of which bears a certain fixed relation to a certain point within it, as the circle does to its centre. Geometry teaches various properties of this curve; for example, that if the direction in which the stone is thrown, or the bullet fired, or the water spouted, be half the perpendicular to the ground, that is, half way between being level with the ground and being upright, the curve will come to the ground at a greater distance than if any other direction whatever were given, with the same force. So that to make the gun carry furthest, or the fire-pipe play to the greatest distance, they must be pointed, not as you might suppose, level or point blank, but about half way between that direction and the perpendicular. If the air did not resist, and so somewhat disturb the calculation, the direction to give the longest range ought to be exactly half perpendicular.

The *oval*, or *ellipse*, is drawn by taking a string of any certain length, and fixing, not one end as in drawing the circle, but both ends, and then carrying a point, as a pencil or chalk, round inside the string, always keeping it stretched as far as possible. It is plain, that this figure is as regularly drawn as the circle, though it is very different from it; and you perceive that every point of its curve must be so placed, that the straight lines drawn from it to the two points where the string was fixed, are, when added together, always the same; for they make together the length of the string. Among various properties belonging to this curve, in relation to the straight lines drawn within it, is one which gives rise to the construction of the *trammels* or elliptic compasses used for making figures and ornaments of this form; and also to the construction of lathes for turning oval frames, and the like.

If you wish at once to see these three curves, take a sugar-loaf, and cut it any where clean through in a direction parallel to its base or bottom; the outline or edge of the loaf where it is cut will be a *circle*. If the cut is made so as to slant, and not be parallel to the base of the loaf, the outline is an *ellipse*, provided the cut goes quite through the sides of the loaf all round; but if it goes slanting, and parallel to the line of the loaf's side, the outline is a *parabola;* and if you cut in any direction not through the sides all round, but through the sides and base, and not parallel to the line of the side, the outline will be another curve of which we have not yet spoken, but which is called an *hyperbola.* You will see another instance of it, if you take two plates of glass, and lay them on one another; then put their edge in water, holding them upright and pressing them together; the water, which, to make it more plain, you may colour with a few drops of ink or strong tea, rises to a certain height, and its outline is this curve; which, however much it may seem to differ in form from a circle or ellipse, is found by mathematicians to resemble them very closely in many of its most remarkable properties.

These are the curve lines best known and most frequently discussed; but there are an infinite number of others all related to straight lines and other curve lines by certain fixed rules; for example, the course which any part, as the nail in the felly of a wheel rolling along takes through the air, is a curve called the *cycloid*, which has many remarkable properties; and, among others, this, that it is, of all lines possible, the one in which any body not falling perpendicularly, will descend from one point to another the most quickly.

II. You perceive, if you reflect a little, that the science which we have been considering in both its branches, has nothing to do with matter; that is to say, it does not at all depend upon the properties or even upon the existence of any bodies or substances whatever. The distance of one point or place from another is a straight line; and whatever is proved to be true respecting this line, as, for instance, its proportion to other lines of the same kind, and its inclination towards them, what we call the angles it makes with them, would be equally true whether there were any thing in those places, at those two points, or not. So if you find the number of yards in a square field, by measuring one side, 100 yards, and then, multiplying that by itself, which makes the whole area 10,000 square yards, this is equally true whatever the field is, whether corn or grass, or rock or water; it is equally true if the solid part, the earth or water, be removed, for then it would be a field of air bounded by four walls or hedges; but suppose the walls or hedges were removed, and a mark only left at each corner, still it would be true that the space enclosed or bounded by the lines supposed to be drawn between the four marks was 10,000 square yards in size. But the marks need not be there; you only want them while measuring one side; if they were gone, it would be equally true that the lines, supposed to be drawn from the places where the marks had been, enclose 10,000 square yards of air. But if there were no air, and consequently a mere void, or empty space, it would be equally true that this space is of the size you had found it to be by measuring the distance of one point from another, of one of the space's corners or angles from another, and then multiplying that distance by itself. In the same way it would be true, that if the space were circular, its size, compared with another circular space of half its diameter, would be four times larger; of one third its diameter, nine times larger, and of one fourth sixteen times, and so on always in proportion to the squares of the diameters; and that the length of the circumference, the number of feet or yards in the line round the surface, would be twice the length of a circle whose diameter was one half, thrice the circumference of one whose diameter was one third, four times the circumference of one whose diameter was one fourth, and so on, in the simple proportion of the diameters. Therefore every property which is proved to belong to figures belongs to them without the smallest relation to bodies or matter of any kind, although we generally see figures in connection with bodies; but all those properties would be equally true, if no such thing as matter or bodies existed; and the same may be said of the properties of number, the other great branch of the mathematics. When we speak of twice two, and say it makes four, we affirm this without thinking of two horses, or two balls, or two trees; but two of any thing and every thing equally. Nay, this branch of mathematics may be said to apply still more extensively than even the other; for it has no relation to space, which geometry has; and, therefore, it is applicable to cases where figure and size are wholly out of the question. Thus you can speak of two dreams, or two ideas, or two minds, and can calculate respecting them just as you would respecting so many bodies; and the properties you find belonging to numbers, will belong to those numbers when applied to things that have no outward or visible or perceivable existence, and cannot even be said to be in any particular place, just as much as the same numbers applied to actual bodies which may be seen and touched.

It is quite otherwise with the science which we are now going to consider, *Natural Philosophy*. This teaches the nature and properties of actually existing substances, their motions, their connections with each other, and their influence on one another. It is sometimes also called *Physics*, from the Greek word signifying *Nature*, though that Greek word is more frequently, in common speech, confined to one particular branch of the science, concerning the bodily health.

We have mentioned one distinction between Mathematics and Natural Philosophy, that the former does not depend on the nature and existence of bodies, which the latter entirely does. Another distinction, and one closely connected with this, is, that the truths which Mathematics teach us are *necessarily* such,—they are truths of themselves, and wholly independent of facts and experiments,—they depend only upon reasoning; and it is utterly impossible they should be otherwise than true. This is the case with all the properties which we find belong to numbers and to figures—2 and 2 must of *necessity*, and through all time, and in every place, be equal to 4; those numbers must *necessarily* be always divisible by 3 without leaving any remainder over, which have the sums of the figures they consist of divisible by 3; and circles must *necessarily*, and for ever and ever, be to one another in the exact proportion of the squares of their diameters. It cannot be otherwise; we cannot conceive it in our minds to be otherwise. No man can in his own mind suppose to himself that 2 and 2 should ever be more or less than 4; it would be an utter impossibility—a contradiction in the very ideas. The other properties of number, though not so plain at first sight as this, are proved to be true by reasoning, every one step of which follows from the step immediately before, as a matter of course, and so clearly and unavoidably, that it cannot be supposed or even imagined to be otherwise; the mind has no means of fancying how it could be otherwise: the final conclusion from all the steps of the reasoning or demonstration, as it is called, follows in the same way from the last of the steps, and is therefore just as evidently and necessarily true as the first step, which is always something self-evident, as that 2 and 2 make 4, or that the whole is greater than any of its parts, but equal to all its parts put together. It is by this kind of reasoning, step by step, from the most plain and evident things, that we arrive at the knowledge of other things which seem at first not true, or at least not generally true; but when we do arrive at them, we perceive that they are just as true, and for the same reasons, as the first and most obvious matters; that their truth is absolute and necessary, and that it would be as absurd and self-contradictory to suppose they ever could, under any circumstances, be not true, as to suppose that 2 added to 2 could ever make 3, or 5, or 100, or any thing but 4; or, which is the same thing, that 4 should ever be equal to 3, or 5, or 100, or any thing but 4. To find out these reasonings, to pursue them to their consequences, and thereby to discover the truths which are not immediately evident, is what science teaches us; but when the truth is once discovered, it is as certain and plain by the reasoning, as the first truths themselves from which all the reasoning takes its rise, on which it all depends, and which require no proof because they are self-evident at once, the instant they are understood.

But it is quite different with the truths which Natural Philosophy teaches. All these depend upon matter of fact; and that is learnt by observation and experiment, and never could be discovered by reasoning at all. If a man were shut up in a room with pen, ink, and paper, he might by thought discover any of the truths in arithmetic, algebra, or geometry; it is possible, at least; there would be nothing absolutely impossible in his discovering all that is now known of these sciences; and if his memory were as good as we are supposing his judgment and conception to be, he might discover it all without pen, ink, and paper, and in a dark room. But we cannot discover a single one of the fundamental properties of matter without observing what goes on around us, and trying experiments upon the nature and motion of bodies. Thus, the man whom we have supposed shut up could not possibly find out beyond one or two of the very first properties of matter, and those only in a very few cases; so that he could not tell if these were general properties of all matter or not. He could tell that the objects he touched in the dark were hard and resisted his touch; that they were extended and were solid; that is, that they had three dimensions, length, breadth, and thickness. He might guess that other things existed beside those he felt, and that those other things resembled what he felt in these properties, but he could know nothing for certain, and could not even conjecture much beyond this very limited number of qualities. He must remain utterly ignorant of what really exists in nature, and of what properties matter in general has. These properties, therefore, we learn by experience; they are such as we know bodies to have; they happen to have them—they are so formed by Divine Providence as to have them—but they might have been otherwise formed; the great Author of Nature might have thought fit to make all bodies different in every respect. We see that a stone dropped from our hand falls to the ground; this is a fact which we can only know by experience; before observing it, we could not have guessed it, and it is quite *conceivable* that it should be otherwise: for instance, that when we remove our hand from the body it should stand still in the air; or fly upward, or go forward, or backward, or sideways; there is nothing at all absurd, contradictory, or inconceivable in any of these suppositions; there is nothing impossible in any of them, as there would be in supposing the stone equal to half of itself, or double of itself; or both falling down and rising upwards at once; or going to the right and the left at one and the same time. Our only reason for not at once thinking it quite conceivable that the stone should stand in the air, or fly upwards, is, that we have never seen it do so, and have become accustomed to see it do otherwise. But for that, we should at once think it as natural that the stone should fly upwards or stand still, as that it should fall. But no degree of reflection for any length of time could accustom us to think 2 and 2 equal to any thing but 4, or the whole to be equal to a part.

After we have once by observation or experiment ascertained certain things to exist in fact, we may then reason upon them by means of mathematics; that is, we may apply mathematics to our experimental philosophy, and then such reasoning becomes absolutely certain, taking the fundamental facts for granted. Thus, if we find that a stone falls in one direction when dropped, and we further observe the peculiar way in which it falls, that is, quicker and quicker every instant till it reaches the ground, we learn the rule or the proportion by which the quickness goes on increasing; and we further find, that if the same stone is pushed forward on a table, it moves in the direction of the push, till it is either stopped by something, or comes to a pause, by rubbing against the table, and being hindered by the air. These are all facts which we learn by observing and trying, and they might all have been different if matter and motion had been otherwise constituted; but supposing them to be as they are, and as we find them, we can, by reasoning mathematically from them, find out many most curious and important truths depending upon these facts, and depending upon them not accidentally, but of necessity. For example, we can find, in what course the stone will move, if, instead of being dropped to the ground, it is thrown forward: it will go in the curve already mentioned, the parabola, and it will run through that curve in a peculiar way, so that there will always be a certain proportion between the time it takes and the space it moves through, and the time it would have taken, and the space it would have moved through had it fallen from the hand to the ground. So we can prove, in like manner, what we before stated of the relation between the distance at which it will come to the ground, and the direction it is thrown in; the distance being greatest of all when the direction is nearly half way between the level or horizontal and the upright or perpendicular. These are mathematical truths, derived by mathematical reasoning upon physical grounds; that is, upon matter of fact found to exist by actual observation and experiment. The result, therefore, is necessarily true, and proved to be so by reasoning only, provided we have once ascertained the facts; but taken altogether, the result depends partly on the facts learned by experiment or experience, partly on the reasoning from these facts. Thus it is found to be true by reasoning, and necessarily true, that *if* the stone falls in a certain way when unsupported, it must when thrown forward go in the curve called a parabola: this is a necessary or mathematical truth, and it cannot possibly be otherwise. But when we state the matter without any supposition,—without any "*if*,"—and say, a stone thrown forward goes in the curve called a parabola, we state a truth, partly fact, and partly drawn from reasoning on the fact; and it might be otherwise if the nature of things were different. It is called a proposition or truth in Natural Philosophy; and as it is discovered and proved by mathematical reasoning, it is sometimes called a proposition or truth in the *Mixed Mathematics*. The man in the dark room could never discover this truth unless he had been first informed, by those who had observed the fact, in what way the stone falls when unsupported, and moves along the table when pushed. These things he never could have found out by reasoning: they are facts, and he could only reason from them after learning them, by his own experience, or taking them on the credit of other people's experience. But having once so learnt them, he could discover by reasoning merely, and with as much certainty as if he lived in daylight, and saw and felt the moving body, that the motion is in a parabola, and governed by certain rules. As experiment and observation are the great sources of our knowledge of Nature, and as the judicious and careful making of experiments is the only way by which her secrets can be known, Natural and Experimental Philosophy mean one and the same thing; mathematical reasoning being applied to certain branches of it, particularly those which relate to motion and pressure.

III. *Natural Philosophy*, in its most extensive sense, has for its province the investigation of the laws of matter; that is, the properties and the motions of matter; and may be divided into two great branches. The first and most important (which is sometimes on that account called

Natural Philosophy, but more properly *Mechanical Philosophy,)* investigates the sensible motions of all bodies. The second investigates the constitution and qualities of all bodies, and has various names, according to its different objects. It is called *Chemistry*, if it teaches the properties of bodies with respect to heat, mixture together, weight, taste, appearance, and so forth: *Anatomy* and *Animal Physiology*, if it teaches the structure and functions of living bodies, especially the human, for when it shows those of other animals, we term it *Comparative Anatomy: Medicine*, if it teaches the nature of diseases, and the means of preventing them and of restoring health: *Zoology*, (from the Greek words signifying *to speak of animals*,) if it teaches the arrangement or classification and the habits of the different lower animals: *Botany*, if it teaches the arrangement or classification and habits of plants: *Geology*, (from the Greek words meaning *to speak of the earth*,) including *Mineralogy*, if it teaches the arrangement of minerals, the structure of the masses in which they are found, and of the earth composed of those masses. The term *Natural History* is given to the three last branches taken together, but chiefly as far as relates to the classification of different things, or the observation of the resemblances and differences of the various animals, plants, and inanimate and ungrowing substances in nature.

But here we may make two general observations. The *first* is, that every such distribution of the sciences is necessarily imperfect; for one runs unavoidably into another. Thus, Chemistry shows the qualities of plants with relation to other substances, and to each other; and Botany does not overlook those same qualities, though its chief object be arrangement. So Mineralogy, though principally conversant with classifying metals and earths, yet regards also their qualities in respect of heat and mixture. So, too, Zoology, beside arranging animals, describes their structures, like Comparative Anatomy. In truth, all arrangement and classifying depends upon noting the things in which the objects agree and differ; and among those things, in which animals, plants, and minerals agree, must be considered the anatomical qualities of the one and the chemical qualities of the other. From hence, in a great measure, follows the *second* observation, namely, that the sciences mutually assist each other. We have seen how Arithmetic and Algebra aid Geometry, and how both the purely Mathematical Sciences aid Mechanical Philosophy. Mechanical Philosophy, in like manner, assists, though, in the present state of our knowledge, not very considerably, both Chemistry and Anatomy, especially the latter; and Chemistry very greatly assists both Physiology, Medicine, and all the branches of Natural History.

The first great head, then, of Natural Science, is Mechanical Philosophy; and it consists of various subdivisions, each forming a science of great importance. The most essential of these, and which is indeed fundamental, and applicable to all the rest, is called *Dynamics*, from the Greek word signifying *power* or *force*, and it teaches the laws of motion in all its varieties. The case of the stone thrown forward, which we have already mentioned more than once, is an example. Another, of a more general nature, but more difficult to trace, and far more important in its consequences, and of which, indeed, the former is only one particular case, relates to the motions of all bodies, which are attracted (or influenced, or drawn) by any power towards a certain point, while they are, at the same time, driven forward by some push given to them at first, and continuing to act on them while they are drawn towards the point. The line in which a body moves while so drawn and so driven, depends upon the force it is pushed with, the direction it is pushed in, and the kind of power that draws it towards the point; but, at present, we are chiefly to regard the latter circumstance, the attraction towards the point. If this attraction be uniform, that is, the same at all distances from the point, the body will move in a circle, and the point to which it is constantly drawn will be the centre of the circle. Thus, a stone in a sling, when whirled round the hand, moves for this reason in a circle, while it remains in the sling; the force that draws it towards the hand being always the same, and the hand either stopping after setting the stone a-whirling, in which case it is the centre of the circle, or going round in a smaller circle, in which case the point is the centre of the two circles, the one the stone whirls round in, and the one the hand moves round in. (Of course we speak not now of the line the stone moves in after leaving the sling; that is a parabola, as before stated.) If the force that draws the moving body changes at different distances, so as to make the body move quicker, by drawing it more strongly towards the point, the nearer it is to that point, then the body will move, not in a circle, but in other curve lines of various kinds, according as the proportion of the force to the distance varies, and according also to the direction of the forward push, and the force with which it was originally given. If the force drawing towards the point is such, that, at two feet from the point, it is four times less than at one foot; at three feet, nine times less; at four feet, sixteen times less; and so on, always lessening in the same proportion, that is, as the squares of the distances increase; and if the body is pushed forward with a particular degree of force; the line in which it moves will go round the point, but it will not be a circle; it will be an oval or ellipse; the curve described by means of a cord fixed at both ends, in the way we have already explained; the point of attraction will be nearer one end of the ellipse than the other, and the time the body will take to go round, compared with the time any other body would take, moving at a different distance from the same point of attraction, but drawn towards that point with a force which bears the same proportion to the distance, will bear a certain proportion, discovered by mathematicians, to the average distances of the two bodies from the point of common attraction. If you multiply the numbers expressing the times of going round each by itself, the products will be to one another in the proportion of the average distances multiplied each by itself, and that product again by the distance. Thus, if one body take two hours, and is five yards distant, the other, being ten yards off, will take something less than five hours and forty minutes.

Now, this is one of the most important truths in the whole compass of science; for it does so happen, that the force with which bodies fall towards the earth, or what is called their *gravity*, the power that draws or attracts them towards the earth, varies with the distance exactly in the proportion of the squares, lessening as the distance increases: at two miles from the earth, it is four times less than at one mile; at three miles, nine times less; and so forth. It goes on lessening, but never is destroyed, even at the greatest distances to which we can reach, and there can be no doubt of its extending indefinitely beyond. But, by astronomical observations made upon the motion of the heavenly bodies, upon that of the moon for instance, it is proved that her movement is slower and quicker at different parts of her course, in the same manner as a body's motion on the earth would be slower and quicker, according to its distance from the point it was drawn towards, provided it was drawn by a force acting in the proportion to the squares of the distance, which we have frequently mentioned; and the proportion of the time to the distance is also observed to agree with the rule we have referred to. Therefore, she is shown to be attracted towards the earth by a force that varies according to the same proportion in which gravity varies; and she must consequently move in an ellipse round the earth, which is placed in a point nearer the one end than the other of that curve. In like manner, it is shown that the earth moves round the sun in the same curve line, and is drawn towards the sun by the same force; and that all the other planets in their courses, at various distances, follow the same rule, moving in ellipses, and drawn towards the sun by the same kind of power. Three of them have moons like the earth, only more numerous, for Jupiter has four, Saturn seven, and Herschel six, so very distant that we cannot see them without the help of glasses; but all those moons move round their principal planets, as ours does round the earth, in ovals or ellipses; while the planets, with their moons, move in their ovals round the sun, like our own earth with its moon. But this power, which draws them all towards the sun, and regulates their path and their motion round him, and which draws the moons towards the principal planets, and regulates their motion and path round those planets, is the same with the gravity by which bodies fall towards the earth, being attracted by it. Therefore, the whole of the heavenly bodies are kept in their places, and wheel round the sun, by the same influence or power that makes a stone fall to the ground.

It is usual to call the sun, and the planets which with their moons move round him, (twelve in number, including the four lately discovered, and the one discovered by Herschel,) the *Solar System*, because they are a class of the heavenly bodies far apart from the innumerable fixed stars, and so near each other as to exert a perceptible influence on one another, and thus to be connected together. The *Comets* belong to the same system, according to this manner of viewing the subject. They are bodies which move in elliptical paths, but far longer and narrower than the curves in which the earth, and the other planets and their moons roll. Our curves are not much less round than circles; the paths of the comets are long and narrow, so as, in many places, to be more nearly straight lines than circles. They differ from the planets and their moons in another respect; they do not depend on the sun for the light they give, as our moon plainly does, being dark when the earth comes between her and the sun; and as the other planets do, those of them that are nearer the sun than we are, being dark when they come between us and him. But the comets give light always of themselves, being apparently vast bodies heated red-hot by coming in their course far nearer the sun than the nearest of the planets ever do. Their motion is much more rapid than that of the planets: they both approach the sun much nearer, retreat from him to much greater distances, and take much longer time in going round him than any of the planets do. Yet even these comets are subject to the same great law of gravitation, which regulates the motions of the planets. Their year, the time they take to revolve, is in some cases 75, in others 135, in others 300 of our years; their distance is a hundred times our distance when furthest off, and not a hundred and sixtieth of our distance when nearest the sun; their swiftest motion is above twelve times swifter than ours, although ours is a hundred and forty times swifter than a cannon ball's; yet their path is a curve of the same kind with ours, though longer and flatter, differing in its formation only as one oval differs from another by the string you draw it with having the ends fixed at two points more distant from each other; consequently the sun, being in one of those points, is much nearer the end of the path the comet moves in, than he is near the end of our path. The motion, too, follows the same rule, being swifter the nearer the sun; the attraction of the sun varies according to the squares of the distances, being four times less at twice the distance, nine times less at thrice, and so on; and the proportion between the times of revolving and the distances is exactly the same, in the case of those remote bodies, as in that of the moon and the earth. One law prevails over all, and regulates their motions as well as our own: it is the gravity of the comets towards the sun, and they, like our own earth and moon, wheel round him in boundless space, drawn by the same force, acting by the same rule, which makes a stone fall when dropped from the hand.

The more full and accurate our observations are upon these heavenly bodies, the better we find all their motions agreeing with this great doctrine; although, no doubt, many things are to be taken into the account beside the force that draws them to their different centres: thus, while the moon is drawn by the earth, and the earth by the sun, the moon is also drawn directly by the sun; and while Jupiter is drawn by the sun, so are his moons; and both Jupiter and his moons are drawn by Saturn: nay, as this power of gravitation is quite universal, and as no body can attract or draw another without being itself drawn by that other, the earth is drawn by the moon, while the moon is drawn by the earth; and the sun is attracted by the planets which he draws towards himself. These mutual attractions give rise to many deviations from the simple line of the ellipse, and produce many irregularities in the simple calculation of the times and motions of the bodies that compose the system of the universe. But the extraordinary powers of investigation applied to the subject by the modern improvements in Mathematics, have enabled us at length to reduce even the greatest of the irregularities to order and system; and to unfold one of the most wonderful truths in all science, namely, that by certain necessary consequences of the simple fact upon which the whole fabric rests,—the proportion of the attractive force to the distances at which it operates,—all the irregularities which at first seemed to disturb the order of the system, and to make the appearances depart from the doctrine, are themselves subject to a certain fixed rule, and can never go beyond a particular point, but must begin to lessen when they have slowly reached that point, and then lessen until they reach another point, when they begin again to increase; and so on, for ever. Thus, the planets move in ovals, from gravity, the power that attracts them, towards the sun, combined with the original impulse they received forwards; and the disturbing forces are continually varying the course of the curves or ovals, making them bulge out in the middle, as it were, on the sides, though in a very small proportion to the whole length of the ellipse. The oval thus bulging, however, its length never alters, only its breadth, and that breadth increases by a very small quantity yearly and daily; after a certain number of years it becomes as great as it ever can be; then the alteration takes a contrary direction, and the curve gradually flattens as it had bulged; till, in the same number of years which it took to bulge, it becomes as flat as it ever can be, and then it begins to bulge again, and so on for ever; and so of every other disturbance and irregularity in the system. What at first appears to be some departure from the rule, when more fully examined, turns out to be only a consequence of it, or a result of a more general arrangement springing from the principle of gravitation; an arrangement of which the rule itself, and the apparent or supposed exception, form parts.

The power of gravitation, which thus regulates the whole system of the universe, is found to rule each member or branch of it separately. Thus, it is demonstrated, that the tides of the ocean are caused by the gravitation which attracts the water towards the sun and moon; and the figure both of our earth and of such of the other bodies as have a spinning motion round their axis, is determined by gravitation; they are all flattened towards the ends of the axis they spin upon, and bulge out towards the middle.

The great discoverer of the principle on which all these truths rest, Sir Isaac Newton, certainly by far the most extraordinary man that ever lived, concluded by reasoning upon the nature of motion and matter that this flattening must take place in our globe: every one before his time had believed the earth to be a perfect sphere or globe, chiefly from observing the round shadow which it casts on the moon in eclipses; and it was many years after his death that the accuracy of his opinion was proved by measurements on the earth's surface, and by the different weight and attraction of bodies at the equator, where it bulges, and at the poles, where it is flattened. The improved telescopes have enabled us to ascertain the same fact with respect to the planets Jupiter and Saturn.

Beside unfolding the general laws which regulate the motions and figures of the heavenly bodies forming our solar system, Astronomy consists in calculations of the places, times, and eclipses of those bodies, and their moons or *satellites*, (from a Latin word, signifying an *attendant*;) and in observations of the fixed stars, which are innumerable assemblages of bodies, not moving round the sun as our earth and the other planets do, nor receiving the light they shine with from his light; but shining, as the sun and the comets do, with a light of their own; and placed, to all appearance, immovable, at immense distances from our world, that is, from our solar system. Each of them is probably the sun of some other system like our own, composed of planets and their moons, or satellites; but so extremely far off from us, that they all are seen by us like one point of faint light, as you see two lamps, placed a few inches asunder, only like one, when you view them a great way off. The numbers of the fixed stars are prodigious; even to the naked eye they are very numerous, about 3000 being thus visible; but when the heavens are viewed through the telescope, stars become visible in numbers wholly incalculable: 2000 are discovered in one of the small collections of a few visible stars called *Constellations;* nay, what appears to the naked eye only a light cloud, as the *Milky Way*, when viewed through a telescope, proves to be an assemblage of innumerable fixed stars, each of them in all likelihood a sun and a system like the rest, though at an immeasurable distance from ours.

The size, and motions, and distances of the heavenly bodies are such as to exceed the power of ordinary imagination, from any comparison with the smaller things we see around us. The earth's diameter is nearly 8000 miles in length; but the sun's is above 880,000 miles, and the bulk of the sun is above 1,300,000 times greater than that of the earth. The planet Jupiter, which looks like a mere speck, from his vast distance, is nearly 1300 times larger than the earth. Our distance from the sun is above 95 millions of miles; but Jupiter is 490 millions, and Saturn 900 millions of miles distant from the sun. The rate at which the earth moves round the sun is 68,000 miles an hour, or 140 times swifter than the motion of a cannon-ball; and the planet Mercury, the nearest to the sun, moves still quicker, nearly 110,000 miles an hour. We, upon the earth's surface, beside being carried round the sun, move round the earth's axis by the rotatory or spinning motion which it has; so that every 24 hours we move in this manner near 14,000 miles, beside moving round the sun above 1,600,000 miles. These motions and distances, however, prodigious as they are, seem nothing compared to those of the comets, one of which, when furthest from the sun, is 11,200 millions of miles from him; and when nearest the sun, flies at the amazing rate of 880,000 miles an hour. Sir I. Newton calculated its heat at 2000 times that of red-hot iron; and that it would take millions of years to cool. But the distance of the fixed stars is yet more vast: they have been supposed to be 400,000 times further from us than we are from the sun, that is 38 millions of millions of miles: so that a cannon-ball would take between four and five millions of years to reach one of them, supposing there was nothing to hinder it from pursuing its course thither.

Astronomers have, by means of their excellent glasses, aided by Geometry and calculation, been able to observe not only stars, planets, and their satellites, invisible to the naked eye, but to measure the height of mountains in the moon by observations of the shadows which these eminences cast on her surface; and they have discovered volcanoes, or burning mountains, on the same body.

The tables which they have by the same means been enabled to form of the heavenly motions, are of great use in navigation. By means of the eclipses of Jupiter's satellites, and by the tables of the moon's motion, we can ascertain the position of a ship at sea; for the observation of the sun's height at mid-day gives the *latitude* of the place, that is, its distance from the equinoctial or equator, the line passing through the middle of the earth's surface; and these tables, with the observations of the satellites, or moons, give the distance east and west of the observatory for which the tables are calculated; what is called the *longitude* of the place: consequently the mariner can thus tell nearly in what part of the ocean he is, how far he has sailed from his port of departure, and how far he must sail, and in what direction, to gain the port of his destination. The advantage of this knowledge is therefore manifest in the common affairs of life; but it sinks into insignificance compared with the vast extent of those views which the contemplations of the science afford, of numberless worlds filling the immensity of space, and all kept in their places, and adjusted in their prodigious motions by the same simple principle, under the guidance of an all-wise and all-powerful Creator.

We have been considering the application of Dynamics to the motions of the heavenly bodies, which forms the science of *Physical Astronomy*. The application of Dynamics to the calculation, production, and direction of motion, forms the science of *Mechanics*, sometimes called *Practical Mechanics*, to distinguish it from the more general use of the word, which comprehends every thing that relates to motion and force. The fundamental principle of the science upon which it mainly depends, flows immediately from a property of the circle already mentioned, and which, perhaps, appeared at the moment of little value, that the lengths of circles are in proportion to their diameters. Observe how, upon this simple truth, nearly the whole of those contrivances are built by which the power of man is increased, as far as solid matter assists him in extending it; and nearly the whole of those doctrines, too, by which he is enabled to explain the voluntary motions of animals, as far as those depend upon their own bodies. There can be nothing more instructive in showing the importance and fruitfulness of scientific truths, however trivial and forbidding they may at first sight appear. For it is an immediate consequence of this property of the circle, that if a rod of iron, or beam of wood, or any other such solid material, be placed on a point or pivot, so that it may move as the arms of a balance do round its centre, or a see-saw board does round its prop, the two ends will go through parts of circles, each proportioned to that arm of the beam to which it belongs; the two circles will be equal if the pivot is in the centre or middle point of the beam; but if it is nearer one end than the other, say three times, that end will go through a circular space, or arch, three times shorter than the circular space the other end goes through in the same time. If, then, the end of the long beam goes through three times the space, it must move with three times the swiftness of the short beam's end, since both move in the same time; and therefore any force applied to the long end must overcome the resistance of three times that force applied at the opposite end, since the two ends move in contrary directions; hence one pound placed at the long end would balance three placed at the short end. The beam we have been supposing is called a *Lever*, and the same rule must evidently hold for all proportions of the lengths of its beams. If, then, the lever be 17 feet long, and the pivot, or *fulcrum*, (as it is called, from a Latin word signifying *support*,) be a foot from one end, an ounce placed on the other end will balance a pound placed on the near end; and the least additional weight, or the slightest push or pressure on the far end, so loaded, will make the pound weight on the other move upwards. If, instead of an ounce, we place upon the long end the short end of a second beam or lever supported by a fulcrum, one foot from it, and then place the long end of this second lever upon the short end of a third lever, whose fulcrum is one foot from it; and if we put on the end of this third lever's long arm an ounce weight, that ounce will move upwards a pound on the second lever's long arm, and this moving upwards will cause the short arm to force downwards 16 pounds at the long end of the first lever, which will make the short end of the first lever move upwards, though 256 pounds be laid on it; the same thing continuing, a pound on the long end of the third lever will move a ton and three quarters at the short end of the first lever; that is, will balance it so that the slightest touch or pressure with the finger, or a touch from a child's hand will move as much as two horses can draw. The Lever is called on this account a *mechanical power;* and there are five other mechanical powers of which its properties form the foundation; indeed they may be resolved into combinations of levers. Thus the wheel and axle is only a lever moving round an axle, and always retaining the effect gained during every part of the motion, by means of a rope wound round the butt end of the axle; the spoke of the wheel being the long arm of the lever, and the half diameter of the axle its short arm. By a combination of levers, wheels, pullies, so great an increase of force is obtained, that, but for the obstruction from friction, and the resistance of the air, there could be no bounds to the effect of the smallest force thus multiplied; and to this fundamental principle, Archimedes, one of the most illustrious mathematicians of ancient times, referred, when he boasted, that if he only had a pivot or fulcrum whereon he might rest his machinery, he could move the earth. Upon so simple a truth, assisted by the aid derived from other means, rests the whole fabric of mechanical power, whether for raising weights, or cleaving rocks, or pumping up rivers from the bowels of the earth; or, in short, performing any of those works to which human strength, even augmented by the help of the animals whom Providence has subdued to our use, would prove altogether inadequate.

The application of Dynamics to the pressure and motions of fluids, constitutes a science which receives different appellations according as the fluids are heavy and liquid like water, or light and invisible like air. In the former case it is called *Hydrodynamics*, from the Greek words signifying *water* and *power*, or *force;* in the latter *Pneumatics*, from the Greek word signifying *breath* or *air;* and Hydrodynamics is divided into *Hydrostatics*, which treats of the weight and pressure of liquids, from the Greek words for *balancing* of *water*, and *Hydraulics*, which treat of their motion, from the Greek name for certain musical instruments played with *water* in *pipes*.

The discoveries to which experiments, aided by mathematical reasoning, have led, upon the pressure and motion of fluids, are of the greatest importance, whether we regard their application to practical purposes, or to the explanation of the appearances in nature, or their singularity as the subjects of scientific contemplation. When it is found that the pressure of water upon any surface that contains it, is not in the least degree proportioned to its bulk, but only to the height at which it stands, so that a long small pipe-full, containing a pound or two of water, will give the pressure of twenty or thirty ton; nay, of twice or thrice as much, if its length be increased, and its bore lessened, without the least regard to the quantity of the liquid : we are not only astonished with so extraordinary and unexpected a property of matter, but we at once perceive one of the great agents employed in the vast operations of nature, in which the most trifling means are used to work the mightiest effects. We likewise learn to guard against many serious mischiefs in our own works, and to apply safely and usefully a power calculated, according as it is directed, either to produce unbounded devastation, or to render the most beneficial service.

Nor are the discoveries relating to the Air less interesting in themselves, and less applicable to important uses. It is an agent, though invisible, as powerful as water, both in the operations of nature and of art. Experiments of a simple and decisive nature show the amount of its pressure to be between 14 and 15 pounds on every square inch ; but, like all other fluids, it presses equally in every direction; so that, though on our hand there is a pressure downwards of above 250 pounds, yet this is exactly balanced by an equal pressure upwards, from the air pressing round and getting below. If, however, the air be removed below, the whole pressure from above acts unbalanced: hence the ascent of water in pumps, which suck out the air from a barrel, and allow the pressure upon the water to force it up 32 or 33 feet, that body of water being equal to the weight of the atmosphere; hence the ascent of the mercury in the barometer but only 28 or 29 inches, mercury being between 13 and 14 times heavier than water. Hence, too, the motion of the steam-engine; the piston of which is pressed downwards by the weight of the atmosphere from above, all air being removed below it by first filling it with steam, and then suddenly cooling and converting that steam into water. Hence, too, the power which some animals possess of walking along the perpendicular surfaces of walls, and even the ceilings of rooms, by squeezing out the air between the inside of their feet and the surface of the wall, and thus being supported by the pressure of the air against the outside of their feet.

The science of *Optics*, (from the Greek word for *seeing*,) which teaches the nature of light, and of the sensation conveyed by it, presents, of itself, a field of unbounded extent and interest. To it the arts, and the other sciences, owe those most useful instruments which have enabled us at once to examine the minutest parts of the structure of animal and vegetable bodies, and to calculate the size and the motions of the most remote of the heavenly bodies. But as an object of learned curiosity, nothing can be more singular than the fundamental truth discovered by the genius of Newton,—that the light, which we call white, is in fact composed of all the colours, blended in certain proportions; unless, perhaps, it be that astonishing conjecture of his unrivalled sagacity, by which he descried the inflammable nature of the diamond, and its belonging, against all appearance of probability, to the class of oily substances, by observing that it stood among them, and far removed from all crystals, in the degree of its action upon light; a conjecture turned into certainty by discoveries made a century afterwards.

To a man who, for original genius and strong natural sense, is not unworthy of being named after this illustrious sage, we owe the greater part of *Electrical* science. It treats of the peculiar substance, resembling both light and heat, which, by rubbing, is found to be produced in a certain class of bodies, as glass, wax, silk, amber; and to be conveyed easily or *conducted* through others, as wood, metals, water; and it has received the name of *Electricity* from the Greek word for *amber*. Dr. Franklin discovered that this is the same matter which, when collected in the clouds, and conveyed from them to the earth, we call *lightning*, and whose noise, in darting through the air, is *thunder*. The observation of some movements in the limbs of a dead frog gave rise to the discovery of *Animal Electricity or Galvanism*, as it was at first called from the name of the discoverer; and which has of late years given birth to improvements that have changed the face of chemical philosophy; affording a new proof how few there are of the processes of nature, incapable of repaying our labour, bestowed in patiently and diligently examining them. It is to the results of the remark accidentally made upon the twitching in the frog's leg, not, however, hastily dismissed and forgotten, but treasured up and pursued through many an elaborate experiment and calculation, that we owe our acquaintance with the extraordinary metal, liquid like mercury, lighter than water, and more inflammable than phosphorus, which forms when it burns, by mere exposure to the air, one of the salts best known in commerce, and the principal ingredient in saltpetre.

In order to explain the nature and objects of those branches of Natural Science more or less connected with the mathematics, some details were necessary, as without them it was difficult at once to perceive their importance, and, as it were, relish the kind of instruction which they afford. But the same course needs not be pursued with respect to the other branches. The value and the interest of Chemistry is at once perceived, when it is known to teach the nature of all substances, the relations of simple substances to heat and to one another, or their combinations together; the composition of those which nature produces in a compound state, and the application of the whole to the arts and manufactures. Some branches of philosophy, again, are chiefly useful and interesting to particular classes, as surgeons and physicians. Others are easily understood by a knowledge of the principles of Mechanics and Chemistry, of which they are applications and examples; as those which teach the structure of the earth and the changes it has undergone; the motions of the muscles, and the structure of the parts of animals; the qualities of animal and vegetable substances; and that department of Agriculture which treats of soils, manure, and machinery. Other branches are only collections of facts, highly curious and useful indeed, but which any one who reads or listens, perceives as clearly, and comprehends as readily, as the professed student. To this class belongs Natural History, in so far as it describes the habits of animals and plants, and its application to that department of Agriculture which treats of cattle and their management.

IV. But, for the purpose of further illustrating the advantages of Philosophy, its tendency to enlarge the mind, as well as to interest it agreeably, and afford pure and solid gratification, a few instances may be given of the singular truths brought to light by the application of mathematical, mechanical, and chemical knowledge to the habits of animals and plants; and some examples may be added of the more ordinary and easy, but scarcely less interesting observations, made upon those habits, without the aid of the profounder sciences.

We may remember the curve line which mathematicians call a cycloid. It is the path which any point of a circle, moving along a plane, and round its centre, traces in the air; so that the nail on the felly of a cart-wheel moves in a cycloid, as the cart goes along, and as the wheel itself both turns round its axle, and is carried along the ground. Now this curve has certain properties of a peculiar and very singular kind with respect to motion. One is, that if any body whatever moves in a cycloid by its own weight or swing, together with some other force acting upon it, it will go through all distances of the same curve in exactly the same time; and, accordingly, pendulums are contrived to swing in such a manner, that they shall describe cycloids, or curves very near cycloids, and thus move in equal times, whether they go through a long or a short part of the same curve. Again, if a body is to descend from any one point to any other, not in the perpendicular, by means of some force acting on it together with its weight, the line in which it will go the quickest of all will be the cycloid, not the straight line, though that is the shortest of all lines which can be drawn between the two points; nor any other curve whatever, though many are much flatter, and therefore shorter than the cycloid—but the cycloid, which is longer than them, is yet of all curves or straight lines which can be drawn, the one the body will move through in the shortest time. Suppose the body is to move from one point to another, by its weight and some other force acting together, but to go through a certain space, as a hundred yards, the way it must take to do this in the shortest time possible, is by moving in a cycloid; or the length of a hundred yards must be drawn into a cycloid, and then the body will descend through the hundred yards in a shorter time than it could go the same distance in any other path whatever. Now, it is believed that birds which build in the rocks, drop or fly down from height to height in this course. It is impossible to make very accurate observations on their flight and path; but there is a general resemblance certainly between the course they take and the cycloid, which has led ingenious men to adopt this opinion.

If we have a certain quantity of any substance, a pound of wood, for example, and would fashion it in the shape to take the least room, we must make a globe of it; it will in this figure have the smallest surface. But suppose we want to form the pound of wood, so that in moving through the air or water it shall meet with the least possible resistance, then we must lengthen it out for ever, till it becomes not only like a long-pointed pin, but thinner and thinner, longer and longer, till it is quite a straight line, and has no perceptible breadth or thickness at all. If we would dispose of the given quantity of matter so that it shall have a certain length only, say a foot, and a certain breadth at the thickest part, say three inches, and move through the air or water with the smallest possible resistance which a body of those dimensions can meet, then we must form it into a figure of a peculiar kind, called the *Solid of least resistance*, because of all the shapes that can be given to the body, its length and breadth remaining the same, this is the one which will make it move with the least resistance through the air, or water, or other fluid. A very difficult chain of mathematical reasoning, by means of the highest branches of algebra, leads to a knowledge of the curve, which by revolving on its axis makes a solid of this shape, in the same way that a circle by so revolving makes a sphere or globe; and the curve certainly resembles closely the face or head part of a fish. Nature, therefore,(by which we always mean the Divine Author of nature,) has fashioned these fishes so, that, according to mathematical principles, they swim the most easily through the element they live and move in.

Suppose upon the face part of one of these fishes a small insect were bred, endowed with faculties sufficient to reason upon its condition, and upon the motion of the fish it belonged to, but never to have discovered the whole size and shape of the face part, it would certainly complain of the form as clumsy, and fancy that it could have made the fish so as to move with less resistance. Yet if the whole shape were disclosed to it, and it could discover the principle on which that shape was preferred, it would at once perceive, not only that what had seemed clumsy was skilfully contrived, but that if any other shape whatever had been taken, there would have been an error committed; nay, *that there must of necessity* have been an error; and that the very best possible arrangement had been adopted. So it may be with man in the Universe, where, seeing only a part of the great system, he fancies there is evil; and yet, if he were permitted to survey the whole, what had seemed imperfect might appear to be necessary for the general perfection, insomuch that any other arrangement, even of that seemingly imperfect part, must needs have rendered the whole less perfect. The common objection is, that what seems evil might have been avoided; but in the case of the fish's shape it *could not* have been avoided.

It is found by optical inquiries, that the rays or particles of light, in passing through transparent substances of a certain form, are bent to a point where they make an image or picture of the shining bodies they come from, or of the dark bodies they are reflected from. Thus, if a pair of spectacles be held between a candle and the wall, they make two images of the candle upon it; and if they be held between the window and a sheet of paper when the sun is shining, they will make a picture on the paper of the houses, trees, fields, sky, and clouds. The eye is found to be composed of several natural magnifiers which make a picture on a membrane at the back of it, and from this membrane there goes a nerve to the brain, conveying the impression of the picture, by means of which we see it. Now, white light was discovered by Newton to consist of different-coloured parts, which are differently bent in passing through transparent substances, so that the lights of different colours come to a point at different distances, and thus create an indistinct image. This was long found to make our telescopes imperfect, insomuch that it became necessary to make them of reflectors or mirrors, and not of magnifying glasses—the same difference not being observed to affect their reflection. But another discovery was about fifty years afterwards made by Mr. Dollond, that by combining different kinds of glass in a compound magnifier, the difference may be greatly corrected; and on this principle he constructed his telescopes. It is found, too, that the different natural magnifiers of the eye are combined upon a principle of the same kind. Thirty years later, a third discovery was made by Mr. Blair, of the greatly superior effect which combinations of different liquids have in correcting the imperfection; and, most wonderful to think, when the eye is examined, we find it consists of different liquids, acting naturally upon the same principle which was thus recently found out in Optics by many ingenious mechanical and chemical experiments.

Again, the point to which any magnifier collects the light is more or less distant as the magnifier is smaller or rounder, so that a small globe of glass or any transparent substances makes a microscope. And this property of light depends upon the nature of lines, and is purely of a mathematical nature, after we have once ascertained by experiment, that light is bent in a certain way when it passes through transparent bodies. Now birds flying in the air, and meeting with many obstacles, as branches and leaves of trees, require to have their eyes sometimes as flat as possible for protection; but sometimes as round as possible, that they may see the small objects, flies and other insects, which they are chasing through the air, and which they pursue with the most unerring certainty. This could only be accomplished by giving them a power of suddenly changing the form of their eyes. Accordingly, there is a set of hard scales placed on the outer coat of their eye, round the place where the light enters; and over these scales are drawn the muscles or fibres by which motion is communicated; so that, by acting with these muscles, the bird can press the scales, and squeeze the natural magnifier of the eye into a round shape when it wishes to follow an insect through the air, and can relax the scales, in order to flatten the eye again when it would see a distant object, or move safely through leaves and twigs. This power of altering the shape of the eye is possessed by birds of prey in a very remarkable degree. They can see the smallest objects close to them, and can yet discern larger bodies at vast distances, as a carcass stretched upon the plain, or a dying fish afloat on the water.

A singular provision is made for keeping the surface of the bird's eye clean, for wiping the glass of the instrument, as it were, and also for protecting it, while rapidly flying through the air and through thickets, without hindering the sight. Birds are, for these purposes, furnished with a third eyelid, a fine membrane or skin, which is constantly moved very rapidly over the eyeball by two muscles placed in the back of the eye. One of the muscles ends in a loop, the other in a string which goes through the loop, and is fixed in the corner of the membrane, to pull it backward and forward. If you wish to draw a thing towards any place with the least force, you must pull directly in the line between the thing and the place; but if you wish to draw it as quickly as possible, and do not regard the loss of force, you must pull it obliquely, by drawing it in two directions at once. Tie a string to a stone, and draw it straight towards you with one hand; then, make a loop on another string, and running the first through it, draw one string in each hand, not towards you, but side-ways, till both strings are stretched in a straight line: you will see how much swifter the stone moves than it did before when pulled straight forward. Now this is proved, by mathematical reasoning, to be the necessary consequence of forces applied obliquely: there is a loss of power, but a great increase of velocity. The velocity is the thing required to be gained in the third eyelid, and the contrivance is exactly that of a string and a loop, moved each by a muscle, as the two strings are by the hands in the case we have been supposing.

A third eyelid of the same kind is found in the horse, and called the *haw*; it is moistened with a pulpy substance (or mucilage) to take hold of the dust on the eyeball, and wipe it clean off, so that the eye is hardly ever seen with any thing upon it, though greatly exposed from its size and posture. The swift motion of the haw is given to it by a gristly, elastic substance, placed between the eyeball and the socket, and striking obliquely, so as to drive out the haw with great velocity over the eye, and then let it come back as quickly. Ignorant persons when this haw is inflamed from cold and swells so as to appear, which it never does in a healthy state, often mistake it for an imperfection, and cut it off: So nearly does ignorance produce the same mischief as cruelty! They might as well cut off the pupil of the eye, taking it for a black spot.

If any quantity of matter, as a pound of wood or iron, is fashioned into a rod of a certain length, say one foot, the rod will be strong in proportion to its thickness; and, if the figure is the same, that thickness can only be increased by making it hollow. Therefore, hollow rods or tubes, of the same length and quantity of matter, have more strength than solid ones. This is a principle so well understood now, that engineers make their axles and other parts of machinery hollow, and therefore stronger with the same weight, than they would be if thinner and solid. Now the bones of animals are all more or less hollow; and are therefore stronger with the same weight and quantity of matter than they otherwise would be. But birds have the largest bones in proportion to their weight; their bones are more hollow than those of animals which do not fly; and therefore they have strength without having to carry more weight than is absolutely necessary. Their quills derive strength from the same construction. They have another peculiarity to help their flight. No other animals have any communication between the air-vessels of their lungs and the hollow parts of their bodies; but birds have; and by this means they can blow out their bodies as we do a bladder, and thus make themselves lighter when they would either make their flight towards the ground slower, or rise more swiftly, or float more easily in the air. Fishes possess a power of the same kind, though not by the same means. They have air-bladders in their bodies, and can puff them out, or press them closer, at pleasure: when they want to rise in the water, they fill out the bladder, and this lightens them. If the bladder breaks, the fish remains at the bottom, and can only be held up by the most laborious exertions of the fins and tail. Accordingly, flat fish, as skaits and flounders, which have no air-bladders, seldom rise from the bottom, but are found lying on banks in the sea, or at the bottom of sea rivers.

If you have a certain space, as a room, to build up with closets or little cells, all of the same size and shape, there are only three figures which will answer, and enable you to fill the room without losing any space between the cells; they must either be squares, or figures of three equal sides, or figures of six equal sides. With any other figures whatever, space would be lost between the cells. This is evidently true upon considering the matter; and it is proved by mathematical reasoning. The six-sided figure is by far the most convenient of these three shapes, because its corners are flatter, and any round body placed in it has therefore more space, there being less room lost in the corners. Likewise, this figure is the strongest of the three; any pressure either from without or from within will hurt it less, as it has something of the strength of an arch. A round figure would be still stronger, but then room would be lost between the circles, whereas none at all is lost with the six-sided figure. Now, it is a most remarkable fact, that *Bees* build their cells exactly in this shape, and thereby save both room and materials beyond what they could save if they built in any other shape whatever. They build in the very best possible shape for their purpose, which is to save all the room and all the wax they can. So far as to the shape of the walls of each cell; but the roof and floor, or top and bottom, are built on equally true principles. It is proved by mathematicians, that to give the greatest strength and save the most room, the roof and floor must be made of three square planes meeting in a point; and they have further proved by a demonstration belonging to the highest parts of Algebra, that there is one particular angle or inclination of those planes to each other where they meet, which makes a greater saving of materials and of work than any other inclination whatever could possibly do. Now, the bees actually make the tops and bottoms of their cells of three planes meeting in a point, and the inclination or angle at which they meet is precisely the one found out by the mathematicians to be the best possible for saving wax and work. Who would dream for an instant of the bee knowing the highest branches of Mathematics—the fruits of Newton's most wonderful discovery—a result, too, of which he was himself ignorant, one of his most celebrated followers having found it out? This little insect works with a truth and correctness which are quite perfect, and according to the principles at which man has only arrived, after ages of slow improvement in the most difficult branch of the most difficult science. But the mighty and all wise Creator, who made the insect and the philosopher, bestowing reason on the latter, and giving the former to work without it—to Him all truths are known from all eternity, with an intuition that mocks even the conceptions of the sagest of human kind.

It may be recollected, that when the air is exhausted or sucked out of any vessel, there is no longer the force necessary to resist the pressure of the air on the outside; and the sides of the vessel are therefore pressed inwards with violence: a flat glass would thus be broken, unless it were very thick; a round one, having the strength of an arch, would resist better; but any soft substance, as leather or skin, would be crushed or squeezed together at once. If the air was only sucked out slowly, the squeezing would be gradual, or, if it were only half sucked out, the skin would only be partly squeezed together. This is the very process by which *Bees* reach the fine dust and juices of hollow flowers, like the honeysuckle, and some kinds of long fox-glove, which are too narrow for them to enter. They fill up the mouth of the flower with their bodies, and suck out the air, or at least a large part of it; this makes the soft sides of the flower close, and squeezes the dust and juice towards the insect as well as a hand could do, if applied to the outside.

We may remember this pressure or weight of the atmosphere as shown by the barometer, the sucking-pump, and the air-pump. Its weight is near 15 pounds on every square inch, so that if we could entirely squeeze out the air between our two hands, they would cling together with a force equal to the pressure of double this weight, because the air would press upon both hands; and if we could contrive to suck or squeeze out the air between one hand and the wall, the hand would stick fast to the wall, being pressed on it with the weight of above two hundred weight, that is, near 15 pounds on every square inch of the hand. Now, by a late most curious discovery of Sir Everard Home, the distinguished anatomist, it is found that this is the very process by which *Flies* and other insects of a similar description are enabled to walk up perpendicular surfaces, however smooth, as the sides of walls and panes of glass in windows, and to walk as easily along the ceiling of a room with their bodies downwards and their feet over head. Their feet, when examined by a microscope, are found to have flat skins or flaps, like the feet of web-footed animals, as ducks and geese; and they have towards the back part or heel, but inside the skin or flap, two very small toes so connected with the flap as to draw it close down upon the glass or wall the fly walks on, and to squeeze out the air completely, so that there is a vacuum made between the foot and the glass or wall. The consequence of this is, that the air presses the foot on the wall with a very considerable force compared to the weight of the fly; for if its feet are to its body in the same proportion as ours are to our bodies, since we could support by a single hand on the ceiling of the room (provided it made a vacuum) more than our whole weight, namely, a weight of fifteen stone, the fly can easily move on four feet in the same manner by help of the vacuum made under its feet. It has likewise been found that some of the larger sea animals are by the same construction, only upon a greater scale, enabled to climb the perpendicular and smooth surfaces of the ice hills among which they live. Some kinds of lizard have the same power of climbing, and of creeping with their bodies downwards along the ceiling of a room; and the means by which they are enabled to do so are the same. In the large feet of these animals, the contrivance is easily observed, of the two toes or tightners, by which the skin of the foot is pinned down, and the air excluded in the act of walking or climbing; but it is the very same, only upon a larger scale, with the mechanism of a fly's or a butterfly's foot; and both operations, the climbing of the sea-horse on the ice, and the creeping of the fly on the window or the ceiling, are performed exactly by the same power, the weight of the atmosphere, which causes the quicksilver to stand in the weather-glass, the wind to whistle through a key-hole, and the piston to descend in a steam-engine.

Although philosophers are not agreed as to the peculiar action which light exerts upon vegetation, and there is even some doubt respecting the decomposition of air and water during that process, one thing is undeniable, the necessity of light to the growth and health of plants; and accordingly they are for the most part so formed as to receive it at all times when it shines on them. Their cups, and the little assemblages of their leaves before they sprout, are found to be more or less affected by the light, so as to open and receive it. In several kinds of plants this is more evident than in others; their flowers close entirely at night, and open in the day. Some, as the Sunflower, and a tribe of the like description, constantly turn round towards the light, following the sun, as it were, while he makes or seems to make his revolution, so that they receive the greatest quantity possible of his rays. Plants of this kind require more light than others for their growth, and this is the provision made for supplying them.

The lightness of inflammable gas is well known. When bladders, of any size, are filled with it, they rise upwards, and float in the air. Now, it is a most curious fact, that the fine dust, by means of which plants are impregnated one by the other, is composed of very small globules, filled with this gas—in a word, of small air balloons. These globules thus float from the male plant through the air, and striking against the females, are detained by a glue prepared on purpose to stop them, which no sooner moistens the globules than they explode, and their substance remains, the gas flying off which enabled them to float. A provision of a very simple kind is also made to prevent the male and female blossoms of the same plant from breeding together, this being found to hurt the breed of vegetables, just as breeding in and in does the breed of animals. It is contrived that the dust shall be shed by the male blossom before the female is ready to be affected by it, so that the impregnation must be performed by the dust of some other plant, and in this way the breed be crossed. The light gas with which the globules are filled is most essential to this operation, as it conveys them to great distances. A plantation of yew trees has been known, in this way, to impregnate another several hundred yards off.

The contrivance by which some creeper plants are enabled to climb walls, and fix themselves, deserves attention. The *Virginia creeper* has a small tendril, ending in a claw, each toe of which has a knob, thickly set with extremely small bristles; they grow into the invisible pores of the wall, and swelling stick there as long as the plant grows, and prevent the branch from falling; but when the plant dies, they become thin again, and drop out, so that the branch falls down. The *Vanilla* plant of the West Indies climbs round trees likewise by means of tendrils; but when it has fixed itself, the tendrils drop off, and their place is supplied by leaves.

It is found by chemical experiments, that the juice which is in the stomachs of animals, (called the *gastric* juice, from a Greek word signifying *the belly*,) has very peculiar properties. Though it is for the most part a tasteless, clear, and seemingly a very simple liquor, it nevertheless possesses extraordinary powers of dissolving substances which it touches or mixes with; and it varies in different classes of animals. In one particular it is the same in all animals: it will not attack living matter, but only dead; the consequence of which is, that its powers of eating away and dissolving are perfectly safe to the animals themselves, in whose stomachs it remains without ever hurting them. This juice differs in different animals according to the food on which they subsist: thus, in birds of prey, as kites, hawks, owls, it only acts upon animal matter, and does not dissolve vegetables. In other birds, and in all animals feeding on grass, as oxen, sheep, hares, it dissolves vegetable matter, as grass, but will not touch flesh of any kind. This has been ascertained by making them swallow balls with meat in them, and several holes drilled through, to let the gastric juice reach the meat: no effect was produced upon it. We may further observe, that there is a most curious and beautiful correspondence between this juice in the stomach of different animals and the other parts of their bodies, connected with the important operations of eating and digesting their food. The use of the juice is plainly to convert what they eat into a fluid, from which, by various other processes, all their parts, blood, bones, muscles, &c. are afterwards formed. But the food is first of all to be obtained, and then prepared by bruising, for the action of the juice. Now birds of prey have instruments, their claws and beak, for tearing and devouring their food, (that is animals of different kinds,) but those instruments are useless for picking up and crushing seeds: accordingly, they have a gastric juice which dissolves the animals they eat; while birds which have only a beak fit for pecking, drinking, and eating seeds, have a juice that dissolves seeds, and not flesh. Nay more, it is found that the seeds must be bruised before the juice will dissolve them: this you find by trying the experiment in a vessel with the juice; and accordingly the birds have a gizzard, and animals which graze have flat teeth, which grind and bruise their food before the gastric juice is to act upon it.

We have seen how wonderfully the *Bee* works, according to rules discovered by man thousands of years after the insect had followed them with perfect accuracy. The same little animal seems to be acquainted with principles of which we are still ignorant. We can, by crossing, vary the forms of cattle with astonishing nicety; but we have no means of altering the nature of an animal once born, by means of treatment and feeding. This power, however, is undeniably possessed by the bees. When the queen bee is lost, by death or otherwise, they choose a grub from among those which are born for workers; they make three cells into one, and placing the grub there, they build a tube round it; they afterwards build another cell of a pyramidal form, into which the grub grows: they feed it with peculiar food, and tend it with extreme care. It becomes, when transformed from the worm to the fly, not a worker, but a queen bee.

These singular insects resemble our own species, in one of our worst propensities, the disposition to war; but their attention to their sovereign is equally extraordinary, though of a somewhat capricious kind. In a few hours after their queen is lost, the whole hive is in a state of confusion. A singular humming is heard, and the bees are seen moving all over the surface of the combs with great rapidity. The news spread quickly, and when the queen is restored, quiet immediately succeeds. But if another queen is put upon them, they instantly discover the trick, and, surrounding her, they either suffocate or starve her to death. This happens if the false queen is introduced within a few hours after the first is lost or removed; but if twenty-four hours have elapsed, they will receive any queen, and obey her.

The labours and the policy of the *Ants* are, when closely examined, still more wonderful, perhaps, than those of the *Bee*. Their nest is a city consisting of dwelling-places, halls, streets, and squares, into which the streets open. The food they principally like is the honey which comes from another insect found in their neighbourhood, and which they, generally speaking, bring home from day to day as they want it. Later discoveries have shown that they do not eat grain, but live almost entirely on animal food and this honey. Some kinds of ant have the foresight to bring home the insects on whose honey they feed, and keep them in particular cells, where they guard them to prevent their escaping, and feed them with proper vegetable matter which they do not eat themselves. Nay, they obtain the eggs of those insects, and superintend their hatching, and then rear the young insect until he becomes capable of supplying the desired honey. They sometimes remove them to the strongest parts of their nest, where there are cells apparently fortified for protecting them from invasion. In those cells the insects are kept to supply the wants of the whole ants which compose the population of the city. It is a most singular circumstance in the economy of nature, that the degree of cold at which the ant becomes torpid is also that at which this insect falls into the same state. It is considerably below the freezing point; so that they require food the greater part of the winter, and if the insects on which they depend for food were not kept alive during the cold in which the ants can move about, the latter would be without the means of subsistence.

How trifling soever this little animal may appear in our climate, there are few more formidable creatures than the ant of some tropical countries. A traveller who lately filled a high station in the French government, Mr. Malouet, has described one of their cities, and, were not the account confirmed by various testimonies, it might seem exaggerated. He observed at a great distance what seemed a lofty structure, and was informed by his guide that it consisted of an ant hill, which could not be approached without danger of being devoured. Its height was from 15 to 20 feet, and its base 30 or 40 feet square. Its sides inclined like the lower part of a pyramid, the point being cut off. He was informed that it became necessary to destroy these nests, by raising a sufficient force to dig a trench all round, and fill it with fagots, which were afterwards set on fire; and then battering with cannon from a distance, to drive the insects out and make them run into the flames. This was in South America; and African travellers have met with them in the same formidable numbers and strength.

The older writers of books upon the habits of some animals abound with stories which may be of doubtful credit. But the facts now stated respecting the Ant and Bee, may be relied on as authentic. They are the result of very late observations, and experiments made with great accuracy by several most worthy and intelligent men, and the greater part of them have the confirmation arising from more than one observer having assisted in the inquiries. The habits of *Beavers* are equally well authenticated, and, being more easily observed, are vouched by a greater number of witnesses. These animals, as if to enable them to live and move either on land or water, have two web feet like those of ducks or water dogs, and two like those of land animals. When they wish to construct a dwelling-place, or rather city, for it serves the whole body, they choose a level place with a stream running through it; they dam up the stream so as to make a pond, and perform the operation as skilfully as we could ourselves. They drive into the ground stakes of five or six feet long in rows, wattling each row with twigs, and puddling or filling the interstices with clay which they ram close in, so as to make the whole solid and water-tight. This dam is likewise shaped on the truest principles;* for the upper side next the water slopes, and the side below is perpendicular; the base of the dam is 10 or 12 feet thick: the top or narrow part two or three, and it is sometimes as long as 100 feet. The pond being thus formed and secured, they make their houses round the edge of it; they are cells, with vaulted roofs, and upon piles; they are made of stones, earth, and sticks; the walls are two feet thick, and plastered as neatly as if the trowel had been used. Sometimes they have two or three stories for retreating to in case of floods, and they always have two doors, one towards the water, and one towards the land. They keep their winter provisions in stores, and bring them out to use; they make their beds of moss; they live on the bark of trees, gums, and crawfish. Each house holds from twenty to thirty, and there may be from ten to twenty-five houses in all. Some of their communities are therefore larger than others, but there are seldom fewer than two or three hundred inhabitants. In working they all bear their shares: some gnaw the trees and branches with their teeth to form stakes and beams; others roll the pieces to the water; others diving make holes with their teeth to place the piles in; others collect and carry stones and clay; others beat and mix the mortar; and others carry it on their broad tails, and with these beat it and plaster it. Some superintend the rest, and make signals by sharp strokes with the tail, which are carefully attended to; the beavers hastening to the place where

* If the base is 12, and the top 3 feet thick, and the height 6 feet, the face must be the side of a right-angled triangle, whose height is 8 feet. This would be the exact proportion which there ought to be, upon mathematical principles, to give the greatest resistance possible to the water in its tendency to turn the dam round, provided the materials of which it is made were lighter than water in the proportion of 44 to 100. But the materials are probably more than twice as heavy as water, and the form of so flat a dike is taken, in all likelihood, in order to guard against a more imminent danger,—that of the dam being carried away by being shoved forwards. We cannot calculate what the proportions are which give the greatest possible resistance to this tendency, without knowing the tenacity of the materials, as well as their specific gravity. It may very probably be found that the construction is such as to secure the most completely against the two pressures at the same time.

they are wanted to work, or to repair any hole made by the water, or to defend themselves or make their escape, when attacked by an enemy.

The fitness of different animals, by their bodily structure, to the circumstances in which they are found, presents an endless subject of curious inquiry and pleasing contemplation. Thus, the *Camel* which lives in sandy deserts has broad spreading hoofs to support him on the loose soil; and an apparatus in his body by which water is kept for many days, to be used when no moisture can be had. As this would be useless in the neighbourhood of streams or wells, and as it would be equally so in the desert, where no water is to be found, there can be no doubt that it is intended to assist in journeying across the sands from one watered spot to another. There is a singular and beautiful provision made in this animal's foot, for enabling it to sustain the fatigues of journeys under the pressure of its great weight. Beside the yielding of the bones and ligaments, or bindings, which gives elasticity to the foot of the deer and other animals, there is in the camel's foot, between the horny sole and the bones, a cushion, like a ball, of soft matter, almost fluid, but in which there is a mass of threads extremely elastic, interwoven with the pulpy substance. The cushion thus easily changes its shape when pressed, yet it has such an elastic spring, that the bones of the foot press on it uninjured by the heavy body which they support, and this huge animal steps as softly as a cat.

Nor need we flee to the desert in order to witness an example of skilful structure in the foot: the *Horse's* limbs display it strikingly. The bones of the foot are not placed directly under the weight; if they were in an upright position, they would make a firm pillar, and every motion would cause a shock. They are placed slanting or oblique, and tied together by an elastic binding on their lower surfaces, so as to form springs as exact as those which we make of leather or steel for carriages. Then the flatness of the hoof which stretches out on each side, and the frog coming down in the middle between the quarters, adds greatly to the elasticity of the machine. Ignorant of this, ill-informed farriers nail the shoe too far back, fixing the quarters, and causing permanent contraction—so that the contracted hoof loses its elasticity; every step is a shock; inflammation and lameness ensue.

The *Rein-deer* inhabits a country covered with snow the greater part of the year. Observe how admirably its hoof is formed for going over that cold and light substance, without sinking in it, or being frozen. The under side is covered entirely with hair, of a warm and close texture; and the hoof, altogether, is very broad, acting exactly like the snow-shoes which men have constructed for giving them a larger space to stand on than their feet, and thus to avoid sinking. Moreover, the deer spreads the hoof as wide as possible when it touches the ground; but, as this breadth would be inconvenient in the air, by occasioning a greater resistance while he is moving along, no sooner does he lift the hoof than the two parts into which it is cloven fall together, and so lessen the surface exposed to the air, just as we may recollect the birds doing with their bodies and wings. The shape and structure of the hoof is also well adapted to scrape away the snow, and enable the animal to get at the particular kind of moss (or *lichen*) on which he feeds, This plant, unlike others, is in its full growth during the winter season; and the rein-deer, accordingly, thrives from its abundance, notwithstanding the unfavourable effects of extreme cold upon the animal system.

There are some insects, of which the males have wings, and the females are grubs or worms. Of these, the *Glow-worm* is the most remarkable: it is the female, and the male is a fly, which would be unable to find her out, creeping, as she does, in the dark lanes, but for the shining light which she gives, to attract him.

There is a singular fish found in the Mediterranean, called the *Nautilus*, from its skill in navigation. The back of its shell resembles the hulk of a ship; on this it throws itself, with two of its feet raised in the air, and over these two spreads a thin membrane to serve for a sail, paddling itself on with the other two feet as oars.

The *Ostrich* lays and hatches her eggs in the sands; her form being ill adapted to that process, she has a natural oven furnished by the sand, and the strong heat of the sun. The *Cuckoo* is known to build no nest for herself, but to lay in the nests of other birds; but late observations show that she does not lay indiscriminately in the nests of all birds; she only chooses the nests of those which have bills of the same kind with herself, and therefore feed on the same kind of food. The *Duck*, and other birds breeding in muddy places, have a peculiar formation of the bill: it is both made so as to act like a strainer, separating the finer from the grosser parts of the liquid, and it is more furnished with nerves near the point than the bills of birds which feed on substances exposed to the light; so that it serves better to grope in the dark stream for food, being more sensitive. The bill of the *Snipe* is covered with a curious net-work of nerves for the same purpose; but a bird, (the *Toucan* or *Egg-sucker*,) which chiefly feeds on the eggs found in birds' nests, and in countries where these are very deep and dark, has the most singular provision of this kind. Its bill is very broad and long; when examined, it is completely covered with branches of nerves in all directions; so that, by groping in a deep and dark nest, it can feel its way as accurately as the finest and most delicate finger could. Almost all kinds of birds build their nests of materials found where they inhabit, or use the nests of other birds; but the *Swallow of Java* lives in rocky caverns on the sea, where there are no materials at all for the purpose of building. It is therefore so formed as to secrete in its body a kind of slime with which it makes a nest, much prized as a delicate food in eastern countries.

Plants, in many remarkable instances, are provided for by equally wonderful and skilful contrivances. There is one, the *Muscipula*, *Fly-trap*, or *Fly-catcher*, which has small prickles in the inside of two leaves, or half leaves, joined by a hinge; a juice or syrup is provided on their inner surface, and acts as a bait to allure flies. There are three small spines or prickles standing upright in this syrup, and upon the only part of each leaf that is sensitive to the touch. When the fly therefore settles upon this part, its touching as it were the spring of the trap occasions the leaves to shut and kill and squeeze the insect; so that its juices and the air arising from their rotting serve as food to the plant.

In the West Indies, and other hot countries, where rain sometimes does not fall for a great length of time, a kind of plant called the

Wild-pine grows upon the branches of the trees, and also on the bark of the trunk. It has hollow or bag-like leaves so formed as to make little reservoirs of water, the rain falling into them through channels which close at the top when full, to prevent it from evaporating. The seed of this useful plant has long threads, by which, when carried through the air, it catches any tree in the way, and falls on it and grows. Wherever it takes root, though on the under side of a bough, it grows straight upwards, otherwise the leaves would not hold water. It holds in one leaf from a pint to a quart; and although it must be of great use to the trees it grows on, to birds and other animals its use is even greater. Another tree, called the *Water-with*, in Jamaica, has similar uses; it is like a vine in size and shape, but growing in very parched districts, is yet so full of clear sap or water, that on cutting a piece two or three yards long, and merely holding it to the mouth, a plentiful draught is obtained. In the East there is a plant somewhat of the same kind, called the *Bejuco*, which grows near other trees and twines round them, with its end hanging downwards, but so full of juice, that on cutting it, a plentiful stream of water spouts from it; and this, not only by its touching the tree so closely must refresh it, but is a supply to animals, and to the weary herdsman on the mountains.

V. After the many instances or samples which have now been given of the nature and objects of Natural Science, we might proceed to a different field, and describe in the same way the other grand branch of Human Knowledge, that which teaches the properties or habits of *Mind* —the *intellectual faculties* of man; that is to say, the powers of his understanding, by which he perceives, imagines, remembers, and reasons;—his *moral faculties*, that is to say, the feelings and passions which influence him;—and, lastly, as a conclusion or result drawn from the whole, his *duties* both towards himself as an individual, and towards others as a member of society; which last head opens to our view the whole doctrines of *political science*, including the nature of governments, of policy, and generally of laws. But we shall abstain at present from entering at all upon this field, and shall now take up the subject, more particularly pointed at through the course of the preceding observations, and to illustrate which they have been framed, namely,—the use and importance of scientific studies.

Man is composed of two parts, body and mind, connected indeed together, but wholly different from one another. The nature of the union—the part of our outward and visible frame in which it is peculiarly formed—or whether the soul be indeed connected with any particular portion of the body, so as to reside there—are points as yet wholly hid from our knowledge, and which are likely to remain for ever concealed. But this we know, as certainly as we can know any truth, that there is such a thing as the mind; and that we have at the least as good proof of its existence, independent of the body, as we have of the existence of the body itself. Each has its uses, and each has its peculiar gratifications. The bounty of Providence has given us outward senses to be employed, and has furnished the means of gratifying them in various kinds, and in ample measure. As long as we only taste those pleasures according to the rules of prudence and of our duty, that is, in moderation for our own sakes, and in harmlessness towards our neighbours, we fulfil rather than thwart the purposes of our being. But the same bountiful Providence has endowed us with the higher nature also—with understandings as well as with senses—with faculties that are of a more exalted nature, and admit of more refined enjoyments, than any the bodily frame can bestow; and by pursuing such gratifications rather than those of mere sense, we fulfil the highest ends of our creation, and obtain both a present and a future reward. These things are often said, but they are not therefore the less true, or the less worthy of deep attention. Let us mark their practical application to the occupations and enjoyments of all branches of society, beginning with those who form the great bulk of every community, the working classes, by what names soever their vocations may be called—professions, arts, trades, handicrafts, or common labour.

The first object of every man who has to depend upon his own exertions must needs be to provide for his daily wants. This is a high and important office; it deserves his utmost attention; it includes some of his most important duties, both to himself, his kindred, and his country; and although in performing this office he is only influenced by his own interest, or by his necessities, yet it is one which renders him truly the best benefactor of the community to which he belongs. All other pursuits must give way to this; the hours which he gives to learning must be after he has done his work; his independence, without which he is not worthy to be called a man, requires first of all that he should have ensured for himself, and those dependent on him, a comfortable subsistence before he can have a right to taste any indulgence, either of his senses or of his mind; and the more he learns—the greater progress he makes in the sciences—the more will he value that independence, and the more will he prize the industry, the habits of regular labour, whereby he is enabled to secure so prime a blessing.

In one view, it is true, the progress which he makes in science may help his ordinary exertions, the main business of every man's life. There is hardly any trade or occupation in which useful lessons may not be learnt by studying one science or another. The necessity of science to the more liberal professions is self-evident; little less manifest is the use to their members of extending their knowledge beyond the branches of study, with which their several pursuits are more peculiarly conversant. But the other departments of industry derive hardly less benefit from the same source. To how many kinds of workmen must a knowledge of Mechanical Philosophy prove useful! To how many others does Chemistry prove almost necessary! Every one must with a glance perceive that to engineers, watch-makers, instrument-makers, bleachers, and dyers, those sciences are most useful, if not necessary. But carpenters and masons are surely likely to do their work better for knowing how to measure, which Practical Mathematics teaches them, and how to estimate the strength of timber, of walls, and of arches, which they learn from Practical Mechanics; and they who work in various metals are certain to be the more skilful in their trades for knowing the nature of those substances, and their relations to both heat and other metals, and to the airs and liquids they come in contact with. Nay, the farm-servant, or day-labourer, whether in his master's employ, or tending the concerns of his own cottage, must derive great practical benefit,—must be both a better servant, and a more thrifty, and therefore comfortable, cottager, for knowing something of the nature of soils and manures, which Chemistry teaches, and something of the habits of animals, and the qualities and growth of plants, which he learns from Natural History and Chemistry together. In truth, though a man be neither mechanic nor peasant, but only one having a pot to boil, he is sure to learn from science lessons which will enable him to cook his morsel better, save his fuel, and both vary his dish and improve it. The art of good and cheap cookery is intimately connected with the principles of chemical philosophy, and has received much, and will yet receive more, improvement from their application. Nor is it enough to say, that philosophers may discover all that is wanted, and may invent practical methods, which it is sufficient for the working man to learn by rote without knowing the principles. He never will work so well if he is ignorant of the principles; and for a plain reason:—if he only learn his lesson by rote, the least change of circumstances puts him out. Be the method ever so general, cases will always arise in which it must be varied in order to apply; and if the workman only knows the rule without knowing the reason, he must be at fault the moment he is required to make any new application of it. This, then, is the *first* use of learning the principles of science: it makes men more skilful, expert, and useful in the particular kinds of work by which they are to earn their bread, and by which they are to make it go far and taste well when earned.

But another use of such knowledge to handicraftsmen and common labourers is equally obvious: it gives every man a chance, according to his natural talents, of becoming an improver of the art he works at, and even a discoverer in the sciences connected with it. He is daily handling the tools and materials with which new experiments are to be made; and daily witnessing the operations of nature, whether in the motions and pressures of bodies, or in their chemical actions on each other. All opportunities of making experiments must be unimproved, all appearances must pass unobserved, if he has no knowledge of the principles; but with this knowledge he is more likely than another person to strike out something new which may be useful in art, or curious or interesting in science. Very few great discoveries have been made by chance and by ignorant persons—much fewer than is generally supposed. It is commonly told of the steam-engine that an idle boy being employed to stop and open a valve, saw that he could save himself the trouble of attending and watching it, by fixing a plug upon a part of the machine which came to the place at the proper times, in consequence of the general movement. This is possible, no doubt; though nothing very certain is known respecting the origin of the story; but improvements of any value are very seldom indeed so easily found out, and hardly another instance can be named of important discoveries so purely accidental. They are generally made by persons of competent knowledge, and who are in search of them. The improvements of the Steam-engine by Watt resulted from the most learned investigation of mathematical, mechanical, and chemical truths. Arkwright devoted many years, five at the least, to his invention of Spinning jennies, and he was a man perfectly conversant in every thing that relates to the construction of machinery: he had minutely examined it, and knew the effects of each part, though he had not received any thing like a scientific education. If he had, we should in all probability have been indebted to him for scientific discoveries as well as practical improvements. The most beautiful and useful invention of late times, the Safety-lamp, was the reward of a series of philosophical experiments made by one thoroughly skilled in every branch of chemical science. The new process of Refining sugar, by which more money has been made in a shorter time, and with less risk and trouble, than was ever perhaps gained from an invention, was discovered by a most accomplished chemist,* and was the fruit of a long course of experiments, in the progress of which, known philosophical principles were constantly applied, and one or two new principles ascertained. But in so far as chance has any thing to do with discovery, surely it is worth the while of those who are constantly working in particular employments to obtain the knowledge required, because their chances are greater than other people's of so applying that knowledge as to hit upon new and useful ideas: they are always in the way of perceiving what is wanting, or what is amiss in the old methods; and they have a better chance of making the improvements. In a word, to use a common expression, they are in the way of good luck; and if they possess the requisite information, they can take advantage of it when it comes to them. This, then, is the *second* great use of learning the sciences: it enables men to make improvements in the arts, and discoveries in philosophy, which may directly benefit themselves and mankind.

Now, these are the *practical* advantages of learning; but the *third* benefit is, when rightly considered, just as practical as the other two—the pleasure derived from mere knowledge, without any view to our own bodily enjoyments; and this applies to all classes, the idle as well as the industrious, if, indeed, it be not peculiarly applicable to those who have the inestimable blessing of time at their command. Every man is by nature endowed with the power of gaining knowledge, and the taste for it: the capacity to be pleased with it forms equally a part of the natural constitution of his mind. It is his own fault, or the fault of his education, if he derives no gratification from it. There is a satisfaction in knowing what others know—in not being more ignorant than those we live with: there is a satisfaction in knowing what others do not know—in being more informed than they are. But this is quite independent of the pure pleasure of knowledge—of gratifying a curiosity implanted in us by Providence, to lead us towards the better understanding of the universe in which our lot is cast, and the nature wherewithal we are clothed. That every man is capable of being delighted with extending his information upon matters of science will be evident from a few plain considerations.

Reflect how many parts of the reading, even of persons ignorant of all sciences, refer to matters wholly unconnected with any interest or

* Edward Howard, brother of the Duke of Norfolk.

advantage to be derived from the knowledge acquired. Every one is amused with reading a story: a romance may please some, and a fairy tale may entertain others; but no benefit beyond the amusement is derived from this source: the imagination is gratified; and we willingly spend a good deal of time and a little money in this gratification, rather than in rest after fatigue, or in any other bodily indulgence. So we read a newspaper, without any view to the advantage we are to gain from learning the news, but because it interests and amuses us to know what is passing. One object, no doubt, is to become acquainted with matters relating to the welfare of the country; but we read the occurrences which do little or not at all regard the public interests, and we take a pleasure in reading them. Accidents, adventures, anecdotes, crimes, and a variety of other things amuse us, independent of the information respecting public affairs, in which we feel interested as citizens of the state, or as members of a particular body. It is of little importance to inquire how and why these things excite our attention, and wherefore the reading about them is a pleasure: the fact is certain; and it proves clearly that there is a positive enjoyment in knowing what we did not know before; and this pleasure is greatly increased when the information is such as excites our surprise, wonder, or admiration. Most persons who take delight in reading tales of ghosts, which they know to be false, and feel all the while to be silly in the extreme, are merely gratified, or rather occupied, with the strong emotions of horror excited by the momentary belief, for it can only last an instant. Such reading is a degrading waste of precious time, and has even a bad effect upon the feelings and the judgment. But true stories of horrid crimes, as murders, and pitiable misfortunes, as shipwrecks, are not much more instructive. It may be better to read these than to sit yawning and idle—much better than to sit drinking or gaming, which, when carried to the least excess, are crimes in themselves, and the fruitful parents of many more. But this is nearly as much as can be said for such vain and unprofitable reading. If it be a pleasure to gratify curiosity, to know what we were ignorant of, to have our feelings of wonder called forth, how pure a delight of this very kind does Natural Science hold out to its students? Recollect some of the extraordinary discoveries of Mechanical Philosophy. How wonderful are the laws that regulate the motions of fluids! Is there any thing in all the idle books of tales and horrors more truly astonishing than the fact, that a few pounds of water may, by mere pressure, without any machinery, by merely being placed in a particular way, produce an irresistible force? What can be more strange, than that an ounce weight should balance hundreds of pounds, by the intervention of a few bars of thin iron? Observe the extraordinary truths which Optical Science discloses. Can any thing surprise us more, than to find that the colour of white is a mixture of all others—that red, and blue, and green, and all the rest, merely by being blended in certain proportions, form what we had fancied rather to be no colour at all, than all colours together? Chemistry is not behind in its wonders. That the diamond should be made of the same material with coal; that water should be chiefly composed of an inflammable substance; that acids should be almost all formed of different kinds of air, and that one of those acids, whose strength can dissolve almost any of the metals, should be made of the self-same ingredients with the common air we breathe; that salts should be of a metallic nature and composed, in great part, of metals, fluid like quicksilver, but lighter than water, and which, without any heating, take fire upon being exposed to the air, and, by burning, form the substance so abounding in saltpetre and in the ashes of burnt wood: these, surely, are things to excite the wonder of any reflecting mind—nay, of any one but little accustomed to reflect. And yet these are trifling when compared to the prodigies which Astronomy opens to our view: the enormous masses of the heavenly bodies; their immense distances; their countless numbers, and their motions, whose swiftness mocks the uttermost efforts of the imagination.

Akin to this pleasure of contemplating new and extraordinary truths, is the gratification of a more learned curiosity, by tracing resemblances and relations between things, which, to common apprehension, seem widely different. Mathematical science to thinking minds affords this pleasure in a high degree. It is agreeable to know that the three angles of every triangle, whatever be its size, howsoever its sides may be inclined to each other, are always of necessity, when taken together, the same in amount: that any regular kind of figure whatever, upon the one side of a right-angled triangle, is equal to the two figures of the same kind upon the two other sides, whatever be the size of the triangle: that the properties of an oval curve are extremely similar to those of a curve, which appears the least like it of any, consisting of two branches of infinite extent, with their backs turned to each other. To trace such unexpected resemblances is, indeed, the object of all philosophy; and experimental science in particular is occupied with such investigations, giving us general views, and enabling us to explain the appearances of nature, that is, to show how one appearance is connected with another. But we are now only considering the gratification derived from learning these things. It is surely a satisfaction, for instance, to know that the same thing, or motion, or whatever it is, which causes the sensation of heat, causes also fluidity, and expands bodies in all directions; that electricity, the light which is seen on the back of a cat when slightly rubbed on a frosty evening, is the very same matter with the lightning of the clouds;—that plants breathe like ourselves, but differently by day and by night;—that the air which burns in our lamps enables a balloon to mount, and causes the globules of the dust of plants to rise, float through the air, and continue their race;—in a word, is the immediate cause of vegetation. Nothing can at first view appear less like, or less likely to be caused by the same thing, than the processes of burning and of breathing,—the rust of metals and burning,—an acid and rust,—the influence of a plant on the air it grows in by night, and of an animal on the same air at any time, nay, and of a body burning in that air; and yet all these are the same operation. It is an undeniable fact, that the very same thing which makes the fire burn, makes metals rust, forms acids, and causes plants and animals to breathe;

that these operations, so unlike to common eyes, when examined by the light of science, are the same,—the rusting of metals,—the formation of acids,—the burning of inflammable bodies,—the breathing of animals,—and the growth of plants by night. To know this is a positive gratification. Is it not pleasing to find the same substance in various situations extremely unlike each other;—to meet with fixed air as the produce of burning,—of breathing,—and of vegetation;—to find that it is the choak-damp of mines,—the bad air in the grotto at Naples,—the cause of death in neglected brewers' vats,—and of the brisk and acid flavour of Seltzer and other mineral springs? Nothing can be less like than the working of a vast steam-engine, and the crawling of a fly upon the window. We find that these two operations are performed by the same means, the weight of the atmosphere, and that a sea-horse climbs the ice-hills by no other power. Can any thing be more strange to contemplate? Is there in all the fairy tales that ever were fancied any thing more calculated to arrest the attention and to occupy and to gratify the mind, than this most unexpected resemblance between things so unlike to the eyes of ordinary beholders? What more pleasing occupation than to see uncovered and bared before our eyes the very instrument and the process by which nature works? Then we raise our views to the structure of the heavens; and are again gratified with tracing accurate but most unexpected resemblances. Is it not in the highest degree interesting to find, that the power which keeps this earth in its shape, and in its path, wheeling round the sun, extends over all the other worlds that compose the universe, and gives to each its proper place and motion; that this same power keeps the moon in her path round our earth, and our earth in its path round the sun, and each planet in its path; that the same power causes the tides upon our earth, and the peculiar form of the earth itself; and that, after all, it is the same power which makes a stone fall to the ground? To learn these things, and to reflect upon them, fills the mind, and produces certain as well as pure gratification.

But if the knowledge of the doctrines unfolded by science is pleasing, so is the being able to trace the steps by which those doctrines are investigated, and their truth demonstrated: indeed you cannot be said, in any sense of the word, to have learnt them, or to know them, if you have not so studied them as to perceive how they are proved. Without this you never can expect to remember them long, or to understand them accurately; and that would of itself be reason enough for examining closely the grounds they rest on. But there is the highest gratification of all, in being able to see distinctly those grounds, so as to be satisfied that a belief in the doctrines is well founded. Hence to follow a demonstration of a grand mathematical truth—to perceive how clearly and how inevitably one step succeeds another, and how the whole steps lead to the conclusion—to observe how certainly and unerringly the reasoning goes on from things perfectly self-evident, and by the smallest addition at each step, every one being as easily taken after the one before, as the first step of all was, and yet the result being something not only far from self-evident, but so general and strange, that you can hardly believe it to be true, and are only convinced of it by going over the whole reasoning—this operation of the understanding, to those who so exercise themselves, always affords the highest delight. The contemplation of experimental inquiries, and the examination of reasoning founded upon the facts which our experiments and observations disclose, is another fruitful source of enjoyment, and no other means can be devised for either imprinting the results upon our memory, or enabling us really to enjoy the whole pleasures of science. They who found the study of some branches dry and tedious at the first, have generally become more and more interested as they went on; each difficulty overcome gives an additional relish to the pursuit, and makes us feel, as it were, that we have by our work and labour established a right of property in the subject. Let any man pass an evening in listless idleness, or even in reading some silly tale, and compare the state of his mind when he goes to sleep or gets up next morning with its state some other day when he has passed a few hours in going through the proofs, by facts and reasoning, of some of the great doctrines in Natural Science, learning truths wholly new to him, and satisfying himself by careful examination of the grounds on which known truths rest, so as to be not only acquainted with the doctrines themselves, but able to show why he believes them, and to prove before others that they are true—he will find as great a difference as can exist in the same being; the difference between looking back upon time unprofitably wasted, and time spent in self-improvement: he will feel himself in the one case listless and dissatisfied, in the other comfortable and happy; in the one case, if he do not appear to himself humbled, at least he will not have earned any claim to his own respect; in the other case, he will enjoy a proud consciousness of having, by his own exertions, become a wiser and therefore a more exalted creature.

To pass our time in the study of the sciences, in learning what others have discovered, and in extending the bounds of human knowledge, has, in all ages, been reckoned the most dignified and happy of human occupations; and the name of Philosopher, or Lover of Wisdom, is given to those who lead such a life. But it is by no means necessary that a man should do nothing else than study known truths, and explore new, in order to earn this high title. Some of the greatest philosophers, in all ages, have been engaged in the pursuits of active life; and an assiduous devotion of the bulk of our time to the work which our condition requires, is an important duty, and indicates the possession of practical wisdom. This, however, does by no means hinder us from applying the rest of our time, beside what nature requires for meals and rest, to the study of science; and he who, in whatever station his lot may be cast, works his day's work, and improves his mind in the evening, as well as he who, placed above such necessity, prefers the refined and elevating pleasures of knowledge to the low gratification of the senses, richly deserves the name of a True Philosopher.

One of the most gratifying treats which science affords us is the knowledge of the extraordinary powers with which the human mind is endowed. No man, until he has studied philosophy, can have a just idea of the great things for which Providence has fitted his understanding, the extraordinary disproportion which there is between his natural strength and the powers of his mind, and the force which he derives from those powers. When we survey the marvellous truths of Astronomy, we are first of all lost in the feeling of immense space, and of the comparative insignificance of this globe and its inhabitants. But there soon arises a sense of gratification and of new wonder at perceiving how so insignificant a creature has been able to reach such a knowledge of the unbounded system of the universe—to penetrate, as it were, through all space, and become familiar with the laws of nature at distances so enormous as baffle our imagination—to be able to say, not merely that the Sun has 329,630 times the quantity of matter which our globe has, Jupiter $308\frac{9}{10}$, and Saturn $93\frac{1}{2}$ times; but that a pound of lead weighs at the Sun 22 lbs. 15 ozs. 16 dwts. 8 grs. and $\frac{3}{4}$ of a grain; at Jupiter 2 lbs. 1 oz. 19 dwts. 1 gr. $\frac{29}{43}$; and at Saturn 1 lb. 3 ozs. 8 dwts. 20 grs. $\frac{1}{11}$ part of a grain; and what is far more wonderful, to discover the laws by which the whole of this vast system is held together and maintained through countless ages in perfect security and order. It is surely no mean reward of our labour to become acquainted with the prodigious genius of those who have almost exalted the nature of man above its destined sphere; and, admitted to a fellowship with those loftier minds, to know how it comes to pass that by universal consent they hold a station apart, rising over all the Great Teachers of mankind, and spoken of reverently, as if NEWTON and LAPLACE were not the names of mortal men.

The highest of all our gratifications in the contemplations of science remains: we are raised by them to an understanding of the infinite wisdom and goodness which the Creator has displayed in all his works. Not a step can we take in any direction without perceiving the most extraordinary traces of design; and the skill every where conspicuous is calculated in so vast a proportion of instances to promote the happiness of living creatures, and especially of ourselves, that we can feel no hesitation in concluding, that if we knew the whole scheme of Providence, every part would be in harmony with a plan of absolute benevolence. Independently, however, of this most consoling inference, the delight is inexpressible of being able to follow, as it were, with our eyes, the marvellous works of the Great Architect of Nature, to trace the unbounded power and exquisite skill which are exhibited in the most minute, as well as the mightiest parts of his system. The pleasure derived from this study is unceasing, and so various, that it never tires the appetite. But it is unlike the low gratifications of sense in another respect: it elevates and refines our nature, while those hurt the health, debase the understanding, and corrupt the feelings; it teaches us to look upon all earthly objects as insignificant, and below our notice, except the pursuit of knowledge and the cultivation of virtue—that is to say, the strict performance of our duty in every relation of society; and it gives a dignity and importance to the enjoyment of life, which the frivolous and the grovelling cannot even comprehend.

Let us, then, conclude, that the pleasures of Science go hand in hand with the solid benefits derived from it; that they tend, unlike other gratifications, not only to make our lives more agreeable, but better; and that a rational being is bound by every motive of interest and of duty, to direct his mind towards pursuits which are found to be the sure path of virtue as well as of happiness.

SOCIETY

FOR THE

DIFFUSION

OF

USEFUL KNOWLEDGE.

THE OBJECT of the Society is strictly limited to what its title imports, namely, the imparting useful information to all classes of the community, particularly to such as are unable to avail themselves of experienced teachers, or may prefer learning by themselves.

The plan proposed for the attainment of this object, is the periodical publication of Treatises, under the direction and with the sanction of a superintending Committee.

As numerous Societies already exist for the dissemination of Religious Instruction, and as it is the object of this Society to aid the progress of those branches of general knowledge which can be diffused among all classes of the community, no Treatise published with the sanction of the Committee shall contain any matter of Controversial Divinity, or interfere with the principles of revealed Religion.

1. Each Scientific Treatise will contain an Exposition of the Fundamental Principles of some Branch of Science—their proofs and illustrations—their application to practical uses, and to the explanation of facts or appearances.

2. For this purpose, the greater Divisions of Knowledge will be subdivided into Branches; and if one of these Subdivisions or Branches cannot be sufficiently taught in a single Treatise, it will be continued in a second.

3. When any part of a Subdivision is of sufficient practical importance to require being minutely pursued in its details, an extra or separate Treatise upon this part will be given, without interrupting the Series; and care will be taken, as far as possible, to publish those Treatises first that relate to subjects the knowledge of which is necessary for understanding those which follow.

4. Thus the great division of Natural Knowledge, commonly called Natural Philosophy, will be subdivided into different Branches, as, Elementary Astronomy—Mechanical Powers—Application of these to Machinery—Hydrostatics—Hydraulics—Pneumatics—Optics—Electricity—Magnetism. Separate Practical Treatises will be given on Dialling—Millwork—Optical Instruments; and Treatises on Geometry, Algebra, and Trigonometry will be published, before extending Natural Philosophy to its higher branches of Dynamics, Hydrodynamics, and Physical Astronomy,—the object being thus to furnish the means of acquiring, step by step, the whole of any department of Science, to the study of which interest or inclination may lead.

5. To each Treatise will be subjoined a reference to the works or parts of works in which the same subject is discussed more at large, with suggestions for enabling the student, who may feel so disposed, to prosecute his studies further.

6. Each Treatise will consist of about thirty-two pages Octavo, printed so as to contain the quantity of above one hundred ordinary octavo pages, with neat Engravings on Wood, and Tables. It will be sold for Sixpence; and one will appear on the 1st and 15th of each Month. Reading Societies, Mechanics' Institutions, and Education Committees, in the Country, will be furnished with supplies at a liberal abatement in price.

7. The first Treatise, being an INTRODUCTORY DISCOURSE UPON THE OBJECTS, ADVANTAGES, AND PLEASURES OF SCIENTIFIC PURSUITS, will be published on the 1*st of March*, by

MESSRS. BALDWIN, CRADOCK, & JOY, LONDON.

The following are *among* the subjects which the plan of the Work embraces, and will follow each other in regular succession, though not exactly in the order here exhibited. The *extra* Treatises are thus marked *.

NATURAL PHILOSOPHY.

Elementary Astronomy.	Pneumatics.
Mechanical Powers.	Optics.
Practical Mechanics.	Electricity.
Mechanical Anatomy.	Magnetism.
Hydrostatics.	*Dialling.
Hydraulics.	*Millwork.

*Optical Instruments.
*Strength of Materials.
Plane Geometry.
Solid Geometry.
Algebra.
Algebraic Geometry.
Conic Sections.
Dynamics.
Hydrodynamics.
Physical Astronomy.
*Observatories.
*Astronomical Instruments.
*Gunnery and Fortification.
*Land Surveying.
*Navigation.
Heat—(2 *Treatises*).
*Thermometer and Pyrometer.
*Steam Engine.
Affinity.
Chemical Apparatus and Processes.
Definite Proportions.
Electro-Chemistry.
Objects of Chemistry—(4 *Treatises*).
Geology—(2 *Treatises*).
Chemical Functions of Animals.
Chemical Functions of Vegetables.
Meteorology.
*Dyeing
*Bleaching.
*Assaying.
Structure of Plants.
Functions of Plants.
Diseases of Plants.
Geography of Plants.
Arrangement of Plants.
Uses of Plants.
General Principles of Agriculture.
Agricultural Buildings and Machinery.
Management of a Farm.
Breeding of Cattle.
Fattening of Cattle.
Diseases of Cattle.
*Farriery.
*Hop-planting.
*Sheep-farming.
*Dairy-farming.
*Woods and Timber.
*Potatoes, Cottage, and Spade Husbandry.
Account of the PRINCIPIA.
———— OPTICS.
———— MECHANIQUE CELESTE.
———— NOVUM ORGANUM.
———— DE DIGNITATE ET AUGMENTIS.

INTELLECTUAL PHILOSOPHY.

Fundamental Principles of Human Knowledge.
Association of Ideas and Habit.
Signs of Thought (natural and arbitrary).
Grammar and Language.
Judgment and Reasoning.
Evidence and Belief; and the conduct of the Understanding.

ETHICAL PHILOSOPHY.

Pains and Pleasures.
Motives.
Classification of Human Actions.
Human Obligations.

POLITICAL PHILOSOPHY.

Objects of Government, and its means.
Legislative,
Judicial, and
Administrative powers.
Jurisprudence, Civil.
————, Criminal.
————, Preliminary (Police).
Political Economy.

HISTORY OF SCIENCE.

Mathematics.
Natural Philosophy.
Astronomy.
Chemistry.
Anatomy.
Metaphysics.
Ethics.
Religion.
Law.

History of Art.

Useful Arts.	Navigation.	Commerce.
Fine Arts.	War.	Manufactures.

HISTORY OF NATIONS.

Greece.	The Low Countries.	Spanish America.
Rome.	Switzerland.	Portuguese America.
England.	Italy.	British America.
Scotland.	Northern States.	Egypt.
Ireland.	Russia.	Western Asia.
France.	United America.	British India.
Germany.	West Indies.	China.
Spain and Portugal.		

History of Individuals.

Patriots.

Bruce.	Hampden.	Lord Falkland.
De Witt.	Sydney.	Washington.
William Tell.	Russell.	Paoli.

Warriors.

Black Prince.	Wolfe.	Rodney.
Gustavus Adolphus.	Abercrombie.	Nelson.
Marlborough.	Blake.	St. Vincent.
Turenne.	De Ruyter.	Duncan.

Discoverers.

Galileo.	Kepler.	Black.
Copernicus.	Newton.	Cavendish.
Bacon.	Leibnitz.	Priestley.
Tycho Brahe.	Hervey.	Lavoisier.

Self-exalted Men.

Franklin.	Rennie.	Arkwright.
Sir Christopher Wren.	Watt.	Smeaton.

Moral Philosophers.

Locke.	Berkeley.	Turgot.
Malbranche.	Grotius.	Smith.

Navigators.

Columbus.	Vasco di Gama.	Cook.
Drake.	Anson.	La Perouse.

Statesmen.

Wolsey.	Sully.	Somers.
Burleigh.	O. Cromwell.	Chatham.

The foregoing List is not to be considered as comprising every subject belonging to each class, but principally those which it is intended shall be first treated of.

The practical means for ensuring steady adherence to the object of the Society, and for most efficaciously securing a due execution of the plan proposed, with all such improvements of detail as experience may from time to time dictate, will be found in the following Rules for the establishment and continuance of the Society, under the conduct of an efficient Committee.

RULES.

I. The Society to consist of all such individuals as may be induced to contribute the sum of Ten Pounds or upwards, in one payment, or One Pound or upwards, annually.

II. Every Annual Subscription to be considered as made on the preceding 1st of January, and to fall due again on the following 1st of January, in each year.

III. Every Subscriber on having paid his Subscription for the current year, to be entitled to a copy of each Tract as soon as published, and to have the privilege of purchasing twelve, or any greater number, at a considerable reduction from the publication price, for gratuitous distribution.

IV. The business of the Society to be transacted by a Committee, not less than thirty in number, consisting, in the first instance, of the following Subscribers:—

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Secretary—Mr. THOMAS COATES.
Collector—Mr. KENNELL.

V. The Committee to have the entire conduct of the affairs of the Society, and disposal of its Funds towards the attainment of the proposed object.

VI. The Committee to elect from time to time, from their own body, a Chairman, Deputy Chairman, and Treasurer.

VII. The Committee also to engage convenient Apartments, and a Secretary or Clerk, and Collector, taking security from the latter for the faithful discharge of his duty, with power to allow Salaries to them; and to engage, suspend, or discharge such officers as the Committee may think fit.

VIII. The Committee to add to their number and supply vacancies occurring in their own body, by ballot, from among the Subscribers; the person proposed being nominated and seconded at one Meeting in ordinary, and not to be ballotted for until the next following ordinary Meeting of the Committee—notice being given in the summons for such Meeting of the name of the person proposed, and by whom nominated and seconded.

IX. No person deriving any emolument directly or indirectly from the funds of the Society, shall be eligible to be a Member of the Committee.

X. The Committee shall meet the first Monday in every Month, without summons, or oftener, if necessary, upon special summons, under the direction of the Chairman, Deputy Chairman, or Treasurer.

XI. The ordinary business of the Committee to be transacted as soon as five Members shall assemble, and in the absence of the Chairman, Deputy Chairman, or Treasurer, the person who shall have first come, to preside; and such Chairman shall thereupon sign the Minutes of the preceding Meeting.

XII. On any election of Officers, ten Members at the least to be present.

XIII. The Committee to have liberty to appoint Sub-Committees from their own Members, for particular objects, with power for any three to act.

XIV. All questions to be decided by a majority of the Members actually present, the Chairman having only a casting vote in case of equality of numbers.

XV. In the event of any Member of the Committee not having attended one Meeting during the year, he shall be considered as having tendered his resignation.

XVI. For the conduct of their business, the Committee may, from time to time, make such regulations of detail as they shall deem expedient, and may alter or repeal such regulations as often as circumstances shall require, provided they be not inconsistent with these fundamental Rules.

XVII. That the Committee shall promote the establishment of Local and Provincial Committees, throughout the United Kingdom, for extending the object of the Society, and facilitating the attainment of it by every means of co-operation which may be suggested for that purpose; and that Members of such Local Committees shall have the privilege, when in town, of attending, but not voting, at Meetings of the London Committee.

XVIII. That every person who shall have gratuitously contributed a Tract, which shall have been published under the sanction of the Committee, shall immediately be considered an Honorary Member of the Society, and eligible on the Committee.

XIX. The Treasurer to receive all monies on account of the Society; and from time to time to invest the amount in Exchequer

Bills, except a competent sum for current expenses. The Treasurer to pay all demands upon the Society as often as he shall be authorised to do so by a Minute of the Committee: he shall also, make up his Accounts half-yearly, and lay the same before Auditors to be nominated by the Committee; and such Accounts, when passed and verified by the Auditors, shall be signed, and the balance in hand declared by a Minute to be entered on the proceedings of the Committee. The Treasurer, however, to be at liberty to disburse sums for current expenses not exceeding 20*l.* at one time; subject, however, to be checked by the Auditors on passing each half-yearly Account.

XX. The Secretary or Clerk shall keep the Minute-books of the Committee, enter the Reports and Proceedings of all Sub-Committees, send written or printed notices to Members of the Committee to meet at the times and places fixed; and act and correspond as such Committees may direct, in furtherance of the views of the Society; and, in general, perform all the other duties which are understood to belong to the office of Secretary.

XXI. The Collector to act as Messenger, as there may be occasion; and to render such assistance in the office, from time to time, as may be required of him by the Committee, Treasurer, or Secretary; and to be paid such salary or poundage as may be agreed on, he giving security duly to account for all monies which may come to his hands.

XXII. No alteration to be introduced into these Rules, or any new one proposed, unless the same shall have been moved and seconded, in writing, at an ordinary Meeting, and entered on the Minutes for the purpose of being considered at the next Meeting, which shall consist of not less than ten Members; the subject being specially noticed in the summons, and not to be carried into effect until confirmed at a following Meeting.

*** All Communications to the Society; offers of literary assistance, with the Terms, &c., to be addressed to MR. COATES, the Secretary, No. 7, Furnival's Inn, Holborn; and, *if from the Country*, under cover to any of the Committee who may be in Parliament.

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