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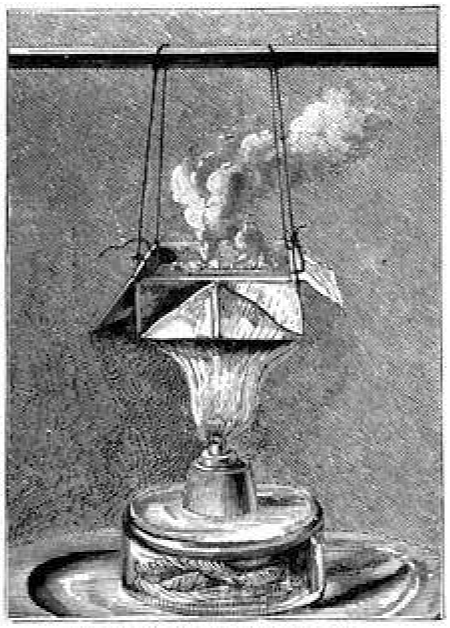
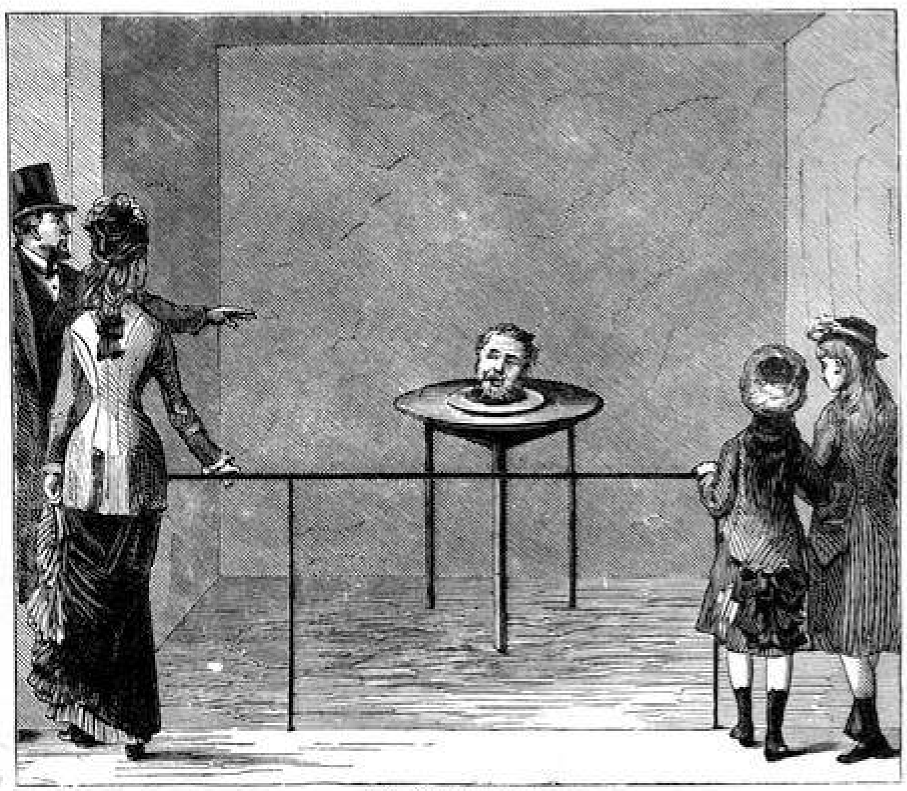


Boiling Water in a Paper Case.

Drawing a Slip of Paper from beneath a Coin.



The Talking Head.

POPULAR
SCIENTIFIC RECREATIONS

IN

NATURAL PHILOSOPHY, ASTRONOMY, GEOLOGY, CHEMISTRY,

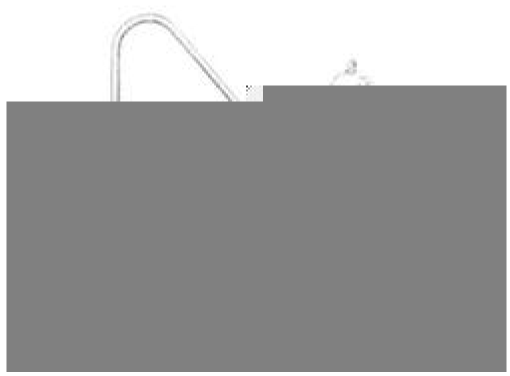
ETC., ETC., ETC.

Translated and Enlarged from "Les Récréations Scientifiques"

OF

GASTON TISSANDIER.

(*Editor of "La Nature."*)



PROFUSELY ILLUSTRATED.

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PREFACE.

A learned mathematician of the seventeenth century, Ozanam by name, a member of the Academy of Sciences and author of several distinguished works, did not think it derogatory to his dignity to write, under the title of "Mathematical and Physical Recreations," a book designed for the amusement of youth, in which science lends itself to every pastime, even jugglery and tricks of legerdemain.

"*Jeux d'esprit*" says Ozanam, "are for all seasons and all ages; they instruct the young, they amuse the old, they are welcomed by the rich, and are not above the reach of the poor."

The object of the book now presented to the reader is also to instruct while it amuses, but we have not thought proper to make use, as Ozanam did, of any physical feats, so called *amusing*. Such do not constitute experiments, and are but ingenious deceptions, intended to disguise the true mode of operation, and we have not desired to make use of or popularise such methods. We wish, on the contrary, that every game we describe, every pastime or amusement of which we give the exposition, should be rigorously based on the scientific method, and looked upon as a genuine exercise in physics, chemistry, mechanics, or natural science. It does not appear to us desirable to teach deception, even in play.

Science in the open air, in the fields, in the sunshine, is our first study; we point out how, in the country, it is possible, pleasantly and unceasingly, to occupy one's leisure in observing nature, in capturing insects or aquatic animals, or in noting atmospheric phenomena.

We next teach a complete course of physics without any apparatus, and point out the methods for studying the different phenomena of heat, light, optics, and electricity, by [Pg v] means of a simple water-bottle, tumbler, stick of sealing-wax, and other ordinary objects, such as everyone has at hand. A series of chemical experiments, performed by means of some phials and inexpensive appliances, completes that part of the book relating to the physical sciences.

Another kind of recreation, both intelligent and useful, consists in collecting the ingenious inventions which are constantly being supplied to our requirements by the applied sciences, and learning how to use them. We have collected a number of mechanical inventions and appliances, with which most ingenious and skilful people will wish to supply themselves, from Edison's electric pen, or the chromograph, which will produce a large number of copies of a letter, drawing, etc., to the more complicated, but not less valuable contrivances, for making science useful in the house.

Having described some scientific toys for the young, we have endeavoured to point out those interesting to persons of riper years, and have grouped together curious systems of locomotion, and ingenious mechanical appliances, such as small steam-boats, ice-boats, swimming apparatus, etc., under proper heads.

In addition to the foregoing subjects, we have included some of the experimental details of Chemical Science, with illustrations. We have added a chapter upon Aërial Navigation and

Ballooning, with anecdotes of some of our celebrated aëronauts. We have also enlarged upon Light, Sound, Heat, Physical Geography, Mineralogy, Geology, Electrical Appliances, the Electric Light, and most of the latest adaptations of electricity.

It will be seen, therefore, that the present work is not only intended for the young; everyone, it is hoped, will find in it something interesting and also profitable, which, if not desired for self-instruction, may at any rate be turned to account as a means of teaching others that science, which is universal, can, when rightly apprehended, preside even over our pleasures and amusements.

The Editor.

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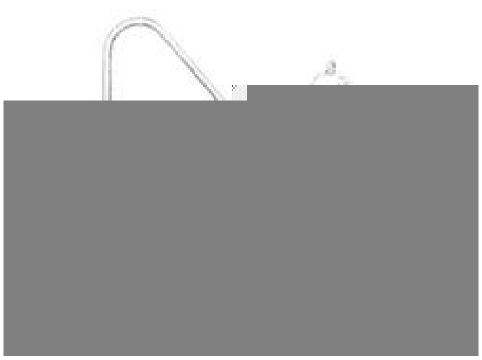
SCIENTIFIC RECREATIONS.

CHAPTER I.—INTRODUCTORY.

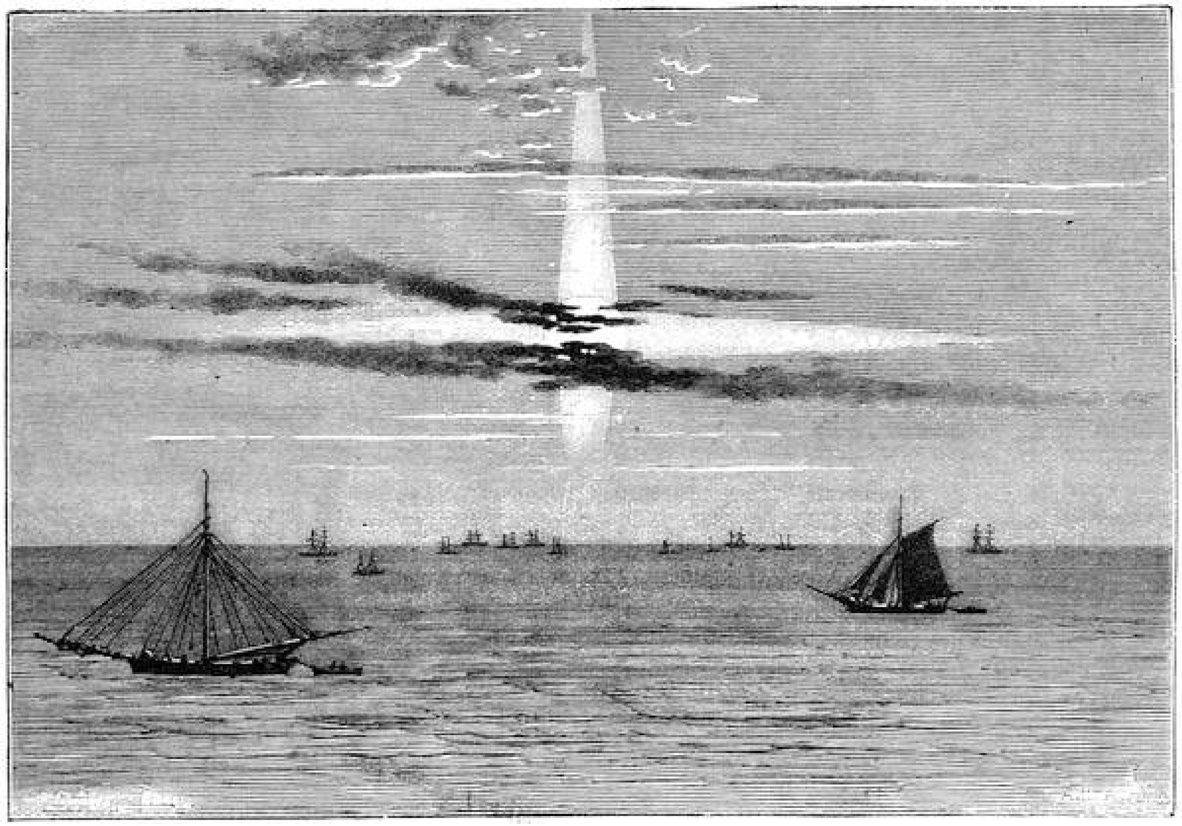
SCIENCE AND RECREATION—THE BOOK OF NATURE—THE SENSES—NATURAL HISTORY—NATURAL PHILOSOPHY—MATTER—OBJECTS—PROPERTIES OF MATTER.



It may at the first glance appear paradoxical to combine Science and Recreation, but we hope to show that true scientific recreation is anything but the dry bones of learning. To those who study science with us, we will point out first how easy and pleasant it is to watch the sky and the plants and Nature generally in the open air. Then we will carry our readers along with us, and by means of illustrations and diagrams instruct them pleasantly in the *reasons for* things. "How?" and "Why?" will be questions fully answered. Not only will the usual scientific courses be touched upon, but we will show how Science is applied to Domestic Economy. We will have Chemistry put before us without needing a laboratory, and we will experiment in Physics without elaborate apparatus. We will have, in short, a complete Encyclopædia of Science free from dryness and technicalities—an amusing volume suited to old and young who wish to find out what is going on around them in their daily life in earth and sea and sky.

Bernard Palissy used to say that he wished "no other book than the earth and the sky," and that "it was given to all to read this wonderful book."

It is indeed by the study of the material world that discoveries are accomplished. Let an attentive observer watch a ray of light passing from the air into water, and he will see it deviate from the straight line by refraction; let him seek the origin of a sound, and he will discover that it results from a shock or a vibration. This is physical science in its infancy. It [Pg 2]
is said that Newton was led to discover the laws of universal gravitation by beholding an apple fall to the ground, and that Montgolfier first dreamt of air-balloons while watching fogs floating in the atmosphere. The idea of the inner chamber of the eye may, in like manner, be developed in the mind of any observer, who, seated beneath the shade of a tree, looks fixedly at the round form of the sun through the openings in the leaves.



Luminous Cross seen at Havre, May 7th, 1877. Sketched from Nature.

Every one, of course, may not possess the ambition to make such discoveries, but there is no one who cannot compel himself to learn to enjoy the pleasure that can be derived from the observation of Nature. [Pg 3]

It must not be imagined that in order to cultivate science it is absolutely necessary to have laboratories and scientific work-rooms. The book of which Palissy spoke is ever present; its pages are always open, wherever we turn our eyes or direct our steps. So we may hope to introduce all our friends to a pleasant and lasting acquaintance with Dame Nature.

"But what *is* Nature?" We are fond of admiring Nature, and the effects of certain causes in the world, and we want to know why things are so. Very well—so you shall; and as to the question "What is Nature?" we will endeavour to answer you at once.

Nature is the united totality of all that the various Senses can perceive. In fact, all that cannot be made by man is termed "Nature"; *i.e.*, God's creation.

From the earliest ages man has sought to read the open leaves of the Book of Nature, and even now, with all our attainments, we cannot grasp all, or nearly all. One discovery only leads up to another. Cause and Effect are followed up step by step till we lose ourselves in the search. Every effect must have a cause. One thing depends upon another in the world, and it does not need Divine revelation to tell us that. Nothing happens by "mere chance." "Chance!" said a Professor to us at the University, "Chance!—Remember, there is no such thing in the world as chance."

Between our minds or consciousness and Nature are our Senses. We feel, we see, we hear, we taste, we smell,—so it is only through the Senses that we can come to any knowledge of the outer world. These attributes, or Senses, act directly upon a certain "primary faculty" called Consciousness, and thus we are enabled to understand what is going on around us. The more this great existing faculty is educated and trained, the more useful it will become. So if we accustom our minds to observation of Nature, we shall find out certain causes and effects, and discover Objects. Now an Object is a thing perceptible both to feeling and sight, and an Object occupies space. Therefore there are objects Artificial as well as Natural. The former are created by man from one or more Natural products. Natural Objects are those such as trees, rocks, plants, and animals. We may also class the heavenly bodies, etc., as Objects, though we cannot touch them, but we can feel their effects, and see them. The Phenomena of Nature include those results which are perceptible by only one sense, as thunder; light and sound may also be classed as Phenomena.

Take a familiar instance. A stone is a Natural Object. We take it up, open our fingers, and it falls. The *motion* of that object is a Phenomenon. We know it falls because we see it fall, and it possesses what we term *weight*; but we cannot tell *why* it possesses weight.

[Professor Huxley says: “Stones do not fall to the ground in consequence of a law of nature,” for a law is not a cause. “A law of nature merely tells us what we may expect [Pg 4] natural objects will do under certain circumstances.”]

A cause of a Phenomenon being independent of human will is called a *Force*, and the stone falls by the force of *Gravitation*, or that natural law which compels every material object to approach every other material object.

A single Force may produce a great number of Phenomena.

Nature being revealed to us by Objects, and by means of Phenomena, we have got already two Branches of Science extending from such Roots; viz., Natural History, the Science of Objects; and Natural Philosophy, the Science of Phenomena.

Both of these Branches have been subdivided thus:

Natural History	Zoology, referring to Animals	Biology.
	Botany, referring to Plants	
	Mineralogy	referring to Minerals, etc.
	Geology	
Natural Philosophy	Physics. Phenomena without essential change of the Objects.	
	Chemistry. Phenomena with change of the Objects.	
	Physiology. Phenomena of animated Objects.	

These two great divisions comprehend, in their extended senses, all that is known respecting the material world.

We have spoken of Objects. Objects occupy *Space*. What is Space? Space is magnitude which can be conceived as extending in three directions—*Length*, *Breadth*, and *Depth*. Matter occupies portions of Space, which is infinite. Matter, when finite, is termed a body or object. The general properties of Matter are *Magnitude*, *Form*, *Impenetrability*, *Inertia*, *Divisibility*, *Porosity*, *Elasticity*, *Compressibility*, *Expansibility*.

Matter is present in Nature in three conditions. We find it as a Solid, a Liquid, and a Gas. We shall explain the various properties of Solids, Liquids, and Gases in their proper places (in Physics). To test the actual existence of Matter in one or other of these forms our Senses help us. We can touch a Solid, or taste it and see it. But touch is the test. We have said that Matter possesses certain properties. We will examine these briefly. The two which belong to all material bodies are Impenetrability and Magnitude. You cannot, *strictly speaking*, penetrate Matter. You can find the form of an object by touch or sight, but you cannot penetrate it. You will think you can drive a nail or a screw into a board, but you cannot; you only *displace* the fibres of the wood by the screw. Take water as a very common instance. Water is Matter, for it occupies a certain space. Water is *impenetrable*, for if you put your hand or foot into a basin full of it, it will overflow, thus proving that you displace, and do not penetrate it. It is almost impossible to compress water.

Divisibility is another quality of Matter; and when we attempt to show how far Matter can be divided, the brain refuses to grasp the infinity. A pin's head is a small object, but it is gigantic compared to some animals, of which millions would occupy a space no larger than [Pg 5] the head of a pin. These tiny animals must contain organs and veins, etc., and those veins are full of blood globules. Professor Tyndall informs us that a drop of blood contains three millions of red globules. So these infinitesimally small animals must have millions of globules in their blood also. Thus we see to what an extent, far beyond our Senses' power to grasp, Matter can be divided.

But there is something even more astonishing than this. It is stated that there are more animals in the milt of a single codfish than there are men in the world; and that *one grain of sand is larger than four millions of these animals*! each of which must be possessed of life germs of an equal amount, which would grow up as it grew to maturity. This carries us back again, and

"Imagination's utmost stretch
In wonder dies away."

Or take other interesting facts. One hundred threads of the silkworm must be placed side by side to make up the thickness of a line (—) about 1/25th of an inch; and metals can be drawn out to such exceeding fineness that twelve hundred of the fine wires will occupy only the space of one hundred silkworms' threads, or one *millimetre*.

Porosity is another attribute of Matter, for in all Matter there are pores, or spaces, between the particles. Sometimes such openings are plainly visible; in very "solid" bodies they are, to a great extent, indistinguishable. But we know that the spaces exist, because we can *compress* the particles together.

Inertia is also a general property of Matter, and the meaning of the term is "inactivity," or passiveness—a want of power in an object to move, or when moving, to stop of itself. It will come to rest apparently by itself, but the resistance of the air and the friction of the ground, or the attraction of the earth, will really occasion the stoppage of the object. We will speak more fully of Inertia presently. Elasticity and Expansibility are evident in fluids and gases.

We have thus introduced our readers to some of the most evident facts connected with Matter. The various Forces and Phenomena of attraction will be fully considered farther on; at present we are about to show our readers how they may first profitably study Science in the open air for themselves, and we will give them our experience of the Book of Nature.

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CHAPTER II.

SCIENCE IN THE OPEN AIR—APHIDES—EVAPORATION BY LEAVES—AN AQUARIUM—THE CATALEPTIC FOWL—NEEDLE POINTS AND THORNS—MICROSCOPIC AQUARIUM—CAPE GRISNEZ—CRYSTALS—ICE ON THE GAS LAMPS.

Fig. 1.—Ants engaged in extracting aphides from a rose-tree (highly magnified)

Some years ago we were staying in Normandy, not far from the town of C——, enjoying, in the midst of most cordial hospitality, the peacefulness of country life; and my kind hosts, with me, took great pleasure in having what we called "a course of science in the open air." The recollections of that time are some of the pleasantest in the whole course of my life, because all our leisure was intelligently occupied. Each of us set himself to provide the subject of some curious observation or instructive experiment; one made a collection of [Pg 7] insects, another studied botany. In the daytime we might have been seen examining, under a magnifying glass, the branch of a rose-tree, from which the ants were endeavouring to extract the aphides[1] (fig. 1). At night we admired through the telescope the stars and planets that were visible; or if the sky was not clear, we examined under a strong magnifier grains of pollen from flowers, or the *infusoria* in a drop of stagnant water. Frequently some very insignificant object became the occasion for some scientific discussion, which terminated with an experimental verification.

I recollect that one day one of us remarked that after a week of dry weather a stream of water had nearly dried up, although sheltered by thick trees, which necessarily impeded the calorific action of the sun; and he expressed surprise at the rapid evaporation. An agriculturist among the company, however, drew his attention to the fact that the roots of the trees were buried in the course of the stream, and that, far from preventing the evaporation of the water, the leaves had contributed to accelerate it. As the first speaker was not convinced, the agriculturist, on our return to the house, prepared an experiment represented in fig. 2. He placed the branch of a tree covered with foliage in a U-shaped tube, the two branches of unequal diameter, and filled with water. He placed the vegetable stem in the water, and secured it to the tube by means of a cork covered with a piece of india-rubber, and tied tightly to make it hermetically closed.

At the commencement of the experiment the water was level with A in the larger branch of the tube, and level with B in the smaller, rising by capillarity to a higher point in the more slender of the two. The evaporation of the water caused by the leaves was so active that in a very short time we beheld the water sink to the points C and C′.

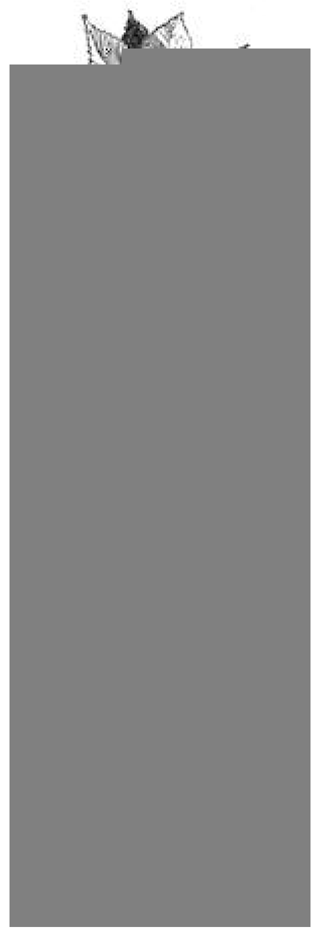

Fig. 2.—Experiment showing evaporation of water by leaves.

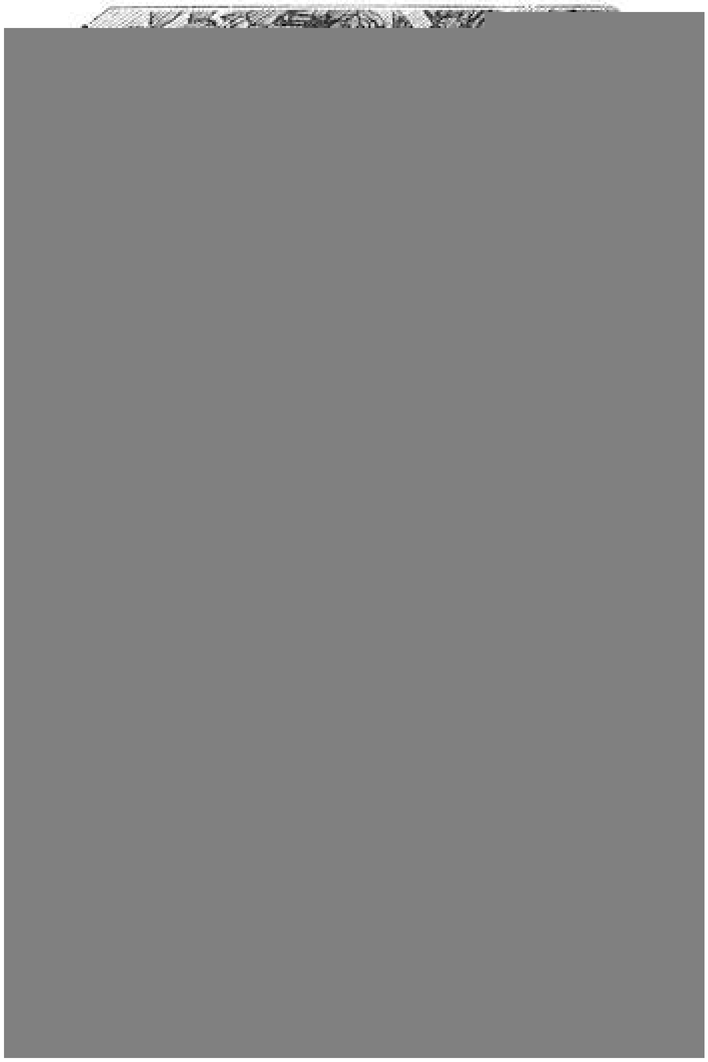

Fig. 3.—Aquarium formed by means of a melon glass.

Thus did the excellent method of seeking the cause of phenomena by experiments often lead us to interesting results. We had among us many children and young people who had reached the age of ardent curiosity. We took pleasure in pointing out to them the means of studying natural science; and we were not long before feeling convinced that our lessons out in the fields had much greater success than those given between the four walls of a class-room. Insects were collected, and preserved by being carefully placed in a small bottle, into which was let fall a drop of sulphuret of carbon;[2] the insect was immediately asphyxiated, and we thus avoided the cruelty of passing a pin through a living body. Having chased [Pg 9] butterflies and insects, we next desired to study the aquatic creatures which swarmed in the pools of the neighbourhood. For this purpose I constructed a fishing-net fitted to an iron ring, and firmly secured to a wooden handle. When this was plunged under the water and drawn quickly out again, it came back full of slime. In the midst of this muddy substance one generally succeeded in finding the hydrophilus, tadpoles, coleoptera, many curious kinds of caddis-worms, tritons, and sometimes frogs, completely astounded by the rapidity of their capture. All these creatures were transported in a bottle to the house, and I then constructed, at small expense, a glass aquarium, by means of the bell of a melon-glass turned upside down, thus forming a transparent receptacle of considerable size. Four wooden stakes were then fixed in the ground, and a plank with a circular hole nailed on the top, in which the glass bell was placed. I next scattered some large pebbles and shells at the bottom of the vase to form a stony bed, poured in some water, placed a few reeds and water plants among the pebbles, and then threw a handful of water lentils on the surface; thus a [Pg 10] comfortable home was contrived for all the captured animals.[3] The aquarium, when placed under the shade of a fine tree in a rustic spot abounding with field flowers, became a favourite rendezvous, and we often took pleasure in watching the antics of the little inmates (fig. 3). Sometimes we beheld very sanguinary scenes; the voracious hydrophilus would seize a poor defenceless tadpole, and rend him in pieces for a meal without any compunction. The more robust tritons defended themselves better, but sometimes they also succumbed in the struggle.

Fig. 4.—Cage for preserving living insects.

Fig. 5.—Small aquarium, with frogs' ladder.

The success of the aquarium was so complete that one of us resolved to continue this museum in miniature, and one day provided himself with an *insects palace*, which nearly made us forget the tadpoles and tritons. It was a charming little cage, having the form of a house, covered with a roof; wires placed at equal distances forming the sides. In it was a [Pg 11] large cricket beside a leaf of lettuce, which served as his food (fig. 4). The little creature moved up and down his prison, which was suspended from the branch of a tree, and when one approached him very closely gave vent to his lively chirps.

Fig. 6.—Frog lying in wait for a fly.

The menagerie was soon further augmented by a hitherto unthought-of object; namely, a frogs' ladder. It was made with much skill. A large bottle served for the base of the structure. The ladder which was fixed in it was composed of the twigs of very small branches, recently cut from a tree, and undivested of their bark, which gave to the little edifice a more picturesque and rustic appearance. The pieces of wood, cleverly fixed into two posts, conducted the green frogs (tree-frogs) on to a platform, whence they ascended the steps of a genuine ladder. There they could disport themselves at pleasure, or climb up further to a branch of birch-tree placed upright in the centre of the bottle (fig. 5). A net with fine meshes prevented the little animals from escaping. We gave the tree-frogs flies for their food, and sometimes they caught them with remarkable dexterity. I have often seen a frog when at liberty watching a fly, on which it pounces as a cat does on a bird (fig. 6). The observations that we made on the animals of our menagerie led us to undertake others of a [Pg 12] very different nature; I recollect particularly a case of catalepsy produced in a cock. I will describe this remarkable experiment, certainly one of the most curious we ever performed.

Fig. 7.—Experiment of the cataleptic cock.

We place a cock on a table of dark colour, rest its beak on the surface, where it is firmly held, and with a piece of chalk slowly draw a white line in continuation from the beak, as shown in our engraving. If the crest is thick, it is necessary to draw it back, so that the animal may follow with his eyes the tracing of the line. When the line has reached a length of about two feet the cock has become cataleptic. He is absolutely motionless, his eyes are [Pg 13] fixed, and he will remain from thirty to sixty seconds in the same posture in which he had at first only been held by force. His head remains resting on the table in the position shown in fig. 7. This experiment, which we have successfully performed on different animals, can also be accomplished by drawing a straight line with a piece of chalk on a slate. M. Azam declares that the same result is also produced by drawing a black line on a table of white wood. According to M. Balbiani, German students had formerly a great predilection for this experiment, which they always performed with marked success. Hens do not, when operated on, fall into a cataleptic condition so easily as cocks; but they may often be rendered motionless by holding their heads fixed in the same position for several minutes. The facts we have just cited come properly under the little studied phenomena, designated by M. Braid in 1843 by the title of *Hypnotism*. MM. Littré and Ch. Robin have given a description of the hypnotic condition in their *Dictionnaire de Médecine*.

Fig. 8.—Ordinary pin and needle, seen through a microscope (magnified 500 diameters).

Fig. 9.—Thorn of a rose, and wasp’s sting through a microscope (magnified 500 diameters).

If any shining object, such as a lancet, or a disc of silver-paper gummed to a plate, is placed at about the distance of a foot from the eyes of a person, slightly above the head, and the patient regards this object fixedly, and without interruption for twenty or thirty minutes, he will become gradually motionless, and in a great number of cases will fall into a condition of torpor and genuine sleep. Dr. Braid affirms that under such circumstances he has been able to perform surgical operations, without the patient having any consciousness of pain. Later also, M. Azam has proved the complete insensibility to pricking on the part of individuals whom he has rendered cataleptic by the fixing of a brilliant object. The [Pg 14] experiment of the cataleptic cock was first described under the name of *Experimentum Mirabile*, by P. Kircher, in his *Ars Magna*, published at Rome in 1646. It evidently belongs to the class of experiments which were performed at the Salpêtrière asylum at Paris, by M. Charcot, on patients suffering from special disorders. It must now be evident to our readers that our scientific occupations were sufficiently varied, and that we easily found around us many objects of study. When the weather was wet and cloudy we remained indoors, and devoted ourselves to microscopical examinations. Everything that came under our hands, insects, vegetables, etc., were worthy of observation. One day, while engaged over a microscopical preparation, I was making use of one of those steel points generally employed in such purposes, when happening to pass it accidentally beneath the microscope, I was astonished to see how rough and uneven it appeared when highly magnified. The idea then occurred to me to have recourse to something still more pointed, and I was thus led to make comparisons between the different objects represented in figs. 8 and 9. It will here be seen how very coarse is the product of our industry when compared with the product of Nature. No. 1 of fig. 8 represents the point of a pin that has already been used, magnified 500 diameters. The point is evidently slightly blunted and flattened. The malleable metal has yielded a little under the pressure necessary to make it pass through a material. No. 2 is a little more pointed; it is a needle. This, too, will be seen to be defective when regarded by the aid of the microscope. On the other hand, what fineness and delicacy do the rose thorn and wasp’s sting present when examined under the same magnifier! (See the two points in [Pg 15] fig. 9.)

An examination of this exact drawing has led me to make a calculation which leads to rather curious results: at a half millimetre from the point, the diameters of the four objects represented are in thousandths of a millimetre respectively, 3·4; 2·2; 1·1; 0·38. The corresponding sections in millionths of a square millimetre are: 907·92; 380·13; 95·03; 11·34; or, in round numbers, 908; 380; 95; 11.

If one bears in mind, which is much below the truth, that the pressure exercised on the point must be proportional to the section, and admitting that a pressure of 11 centigrams suffices to thrust in the sting of a wasp half a millimetre, it will require more than 9 grams of pressure to thrust in a needle to the same extent. In fact, this latter figure is much too small, for we have not taken into account the advantage resulting from the elongated shape of the rose thorn, which renders it more favourable for penetration than a needle through a drop of tallow.

It would be easy to extend observations of this kind to a number of other objects, and the remarks I have just made on natural and artificial points will apply incontestably to textures for example. There is no doubt that the thread of a spider's web would far surpass the thread of the finest lace, and that art will always find itself completely distanced by nature.

We amused ourselves frequently by examining the *infusoria* which are so easily procured by taking from some stagnant water the mucilage adhering to the vegetation on the banks, or attached to the lower part of water lentils. In this way we easily captured *infusoria*, which, when placed under a strong magnifier, presented the most remarkable spectacle that one can imagine. They are animalcules, having the form of transparent tulips attached to a long stem. They form bunches which expand and lengthen; then, suddenly, they are seen to contract with such considerable rapidity that the eye can scarcely follow the movement, and all the stems and flower-bells are folded up into the form of a ball. Then, in another moment, the stems lengthen, and the tulip-bells open once more. One can easily encourage the production of *infusoria* by constructing a small microscopic aquarium, in which one arranges the centre in a manner favourable to the development of the lowest organisms. It suffices to put a few leaves (a piece of parsley answers the purpose perfectly)[4] in a small vase containing water (fig. 10), over which a glass cover is placed, and it is then exposed to the rays of the sun. In two or three days' time, a drop of this water seen under the microscope will exhibit *infusoria*. After a certain time, too, the different species will begin to show themselves. Microscopical observations can be made on a number of different objects. Expose to the air some flour moistened by water, and before long a mouldiness will form on it; it is the *penicillium glaucum*, and when examined under a magnifier of 200 to 300 diameters, cells are distinguishable, branching out from an organism remarkable for its [Pg 16] simplicity. We often amused ourselves by examining, almost at hazard, everything that came within our reach, and sometimes we were led to make very instructive investigations. When the sky was clear, and the weather favourable to walking, we encouraged our young people to run about in the fields and chase butterflies. The capture of butterflies is accomplished, as every one knows, by means of a gauze net, with which we provided the children, and the operation of chasing afforded them some very salutary exercise. It sometimes happens that butterflies abound in such numbers, that it is comparatively easy to capture them. During the month of June 1879, a large part of Western Europe was thronged with swarms of *Vanessa algina* butterflies, in such numbers that their appearance was regarded as an important event, and attracted the lively attention of all entomologists (fig. 11). This passage of butterflies provided the occasion for many interesting studies on the part of naturalists.

Fig. 10.—Arrangement of a microscopic aquarium for examining *infusoria*.

Fig. 11.—Flight of butterflies seen near Berne, June 15th, 1879.

Fig. 12.—Group of rock crystal.

We cannot point out too strongly to our readers that the essential condition for the student of [Pg 17] natural science, is the possession of that sacred fire which imparts the energy and perseverance necessary for acquiring and enlarging collections. It is also necessary that the investigator should furnish himself with certain indispensable tools. For collecting plants, the botanist should be armed with a pickaxe set in a thoroughly strong handle, a trowel, of which there is a variety of shapes, and a knife with a sharp blade. A botanical case must also be included, for carrying the plants. The geologist, or mineralogist, needs no more elaborate instruments; a hammer, a chisel, and a pickaxe with a sharp point for breaking the rocks, and a bag for carrying the specimens, will complete his outfit. We amused ourselves by [Pg 18] having these instruments made by the blacksmith, sometimes even by manufacturing them ourselves; they were simple, but solid, and admirably adapted to the requirements of research. Often we directed our walks to the seashore, where we liked to collect shells on the sandy beach, or fossils among the cliffs and rocks. I recollect, in a walk I had taken some years previously along the foot of the cliffs of Cape Blanc-Nez, near Calais, having found an impression of an ammonite of remarkable size, which has often excited the admiration of amateurs; this ammonite measured no less than twelve inches in diameter. The rocks of Cape Grisnez, not far from Boulogne, also afford the geologian the opportunity of a number of curious investigations. In the Ardennes and the Alps I have frequently procured some fine mineral specimens; in the first locality crystallized pyrites, in the second, fine fragments of rock crystal (fig. 12). I did not fail to recount these successful expeditions to the young people who accompanied me, and their ardour was thereby inflamed by the hope that they also should find something valuable. It often happened when the sun was powerful, and the air extremely calm, that my young companions and I remarked some very beautiful effects of mirage on the beach, due to the heating of the lower *strata* of the atmosphere. The trees and houses appeared to be raised above a sheet of silver, in which their reflections were visible as in a sheet of tranquil water. It can hardly be believed how frequently the atmosphere affords interesting spectacles which pass [Pg 19] unperceived before the eyes of those who know not how to observe. I recollect having once beheld at Jersey a magnificent phenomenon of this nature, on the 24th June, 1877, at eight o'clock in the evening: it was a column of light which rose above the sinking sun like a sheaf of fire. I was walking on the St. Helier pier, where there were also many promenaders, but there were not more than two or three who regarded with me this mighty spectacle. Columns and crosses of light are much more frequent than is commonly supposed, but they often pass unperceived before indifferent spectators. We will describe an example of this phenomenon observed at Havre on the 7th May, 1877. The sun formed the centre of the cross, which was of a yellow, golden colour. This cross had four branches. The upper branch was much more brilliant than the others; its height was about 15°. The lower branch was smaller, as seen in the sketch on page 2, taken from nature by Monsieur Albert Tissandier. The two horizontal branches were at times scarcely visible, and merged in a streak of reddish-yellow colour, which covered a large part of the horizon. A mass of cloud, which the setting sun tinged with a deep violet colour, formed the foreground of the picture. The atmosphere over the sea was very foggy. The phenomenon did not last more than a quarter of an hour, but the conclusion of the spectacle was signalized by an interesting circumstance. The two horizontal branches, and the lower branch of the luminous cross, completely disappeared, whilst the upper branch remained alone for some minutes longer. It had now the appearance of a *vertical column* rising from the sun, like that which Cassini studied on the 21st May, 1672, and that which M. Renon[5] and M. A. Guillemin observed on the 12th July, 1876.[6] Vertical columns, which, it is well known, are extremely rare phenomena, may therefore indicate the existence of a luminous cross, which certain atmospheric conditions have rendered but partially visible.

How often one sees along the roads little whirlwinds of dust raised by the wind accomplishing a rotatory movement, thus producing the imitation of a waterspout! How often halos encompass with a circle of fire the sun or the stars! How often we see the rainbow develop its iridescent beauties in the midst of a body of air traversed by bright raindrops! And there is not one of these great natural manifestations which may not give rise to instructive observations, and become the object of study and research. Thus, in walks and travels alike, the study of Science may always be exercised; and this method of study and instruction in the open air contributes both to health of body and of mind. As we consider the spectacles which Nature spreads before us,—from the insect crawling on the blade of grass, to the celestial bodies moving in the dome of the heavens,—we feel a vivifying and salutary influence awaken in the mind. The habit of observation, too, may be [Pg 20] everywhere exercised—even in towns, where Nature still asserts herself; as, for example, in displays of meteorological phenomena. We will give an example of such.

Fig. 13.—Icicles on gas lamp.

The extraordinary abundance of snow which fell in Paris for more than ten consecutive hours, commencing on the afternoon of Wednesday, January 22nd, 1880, will always be looked upon as memorable among the meteorological events of the city of Paris. It was stated that in the centre of Paris, the thickness of the snow that had fallen at different times exceeded fourteen inches. The snow had been preceded by a fall of small transparent

icicles, of rather more than a millimetre in diameter, some having crystalline facets. They formed on the surface of the ground a very slippery glazed frost. On the evening of the 22nd January, flakes of snow began to hover in the atmosphere like voluminous masses of wool. The greater part of the gas-lamps were ornamented by frozen stalactites, which continually attracted the attention of passers-by. The formation of these stalactites, of which we give a specimen (fig. 13), is easy of explanation. The snow falling on the glass of the lamp became heated by the flame of gas, melted, and trickled down, freezing anew into the shape of a stalactite below the lamp, at a temperature of 0° centigrade. Not only can meteorology be studied in towns, but certain other branches of natural science—entomology, for example. [Pg 21] We will quote what a young student in science, M. A. Dubois, says on this very subject: “Coleoptera,” he declares, “are to be met with everywhere, and I think it may be useful to notice this fact, supporting it by examples. I desire to prove that there are in the midst of our large towns spots that remain unexplored, where some fine captures are to be made. Let us visit, at certain times, the approaches to the quays, even at low tide, and we shall be surprised to find there species which we have searched for far and near.” This opinion is confirmed by the enumeration of several interesting captures.

Was not the great Bacon right when he said, “For the keen observer, nothing in Nature is mute”?

The cliffs of Cape Grisnez.

[Pg 22]

CHAPTER III.

PHYSICS—THE MEANING OF PHYSICS—FORCES OF NATURE—GRAVITY—COHESION—CHEMICAL ATTRACTION—CENTRE OF GRAVITY—EXPERIMENTS—AUTOMATON TUMBLERS.

Having now introduced our readers to Science which they can find for themselves in the open air, and the pursuit of which will both instruct and amuse, we will proceed to investigate the Branch of Science called Physics.

Physics may be briefly described as the Branch of Natural Science which treats of such phenomena as are unaccompanied by any important changes in the objects wherein such phenomena are observed.

For instance, the sounding of a bell or the falling of a stone are physical phenomena, for the objects which cause the sound, or the fall, undergo no change. Heat is set free when coal burns. This disengagement of heat is a physical phenomenon; but the change during combustion which coal undergoes is a *chemical* phenomenon. So the objects may be the same, but the circumstances in which they are placed, and the forces which act upon them, may change their appearance or position.

This brings us at once to the *Forces of Nature*, which are three in number; viz., Gravity, Cohesion, and Affinity, or Chemical Attraction. The phenomena connected with the last-named forms the Science of *Chemistry*. We give these three Forces these names. But first we must see what is Force, for this is very important. Force is a cause—the cause of Motion or of Rest. This may appear paradoxical, but a little reflection will prove it. It requires force to set any object in motion, and this body would never stop unless some other force or forces prevented its movement beyond a certain point. Force is therefore the cause of a change of "state" in matter.

We have said there are three forces in nature. The first is Gravity, or the attraction of particles at a distance from each other. We may say that Gravity, or Gravitation, is the mutual attraction between different portions of matter acting at all distances,—the force of attraction being, of course, in proportion to the mass of the bodies respectively. The greatest body is the Earth, so far as our purposes are concerned. So the attraction of the Earth is *Gravity*, or what we call *Weight*.

We can easily prove this. We know if we jump from a chair we shall come to the floor; and if there were nothing between us and the actual ground sufficient to sustain the force of the attracting power of the earth, we should fall to the earth's surface. [Pg 23] In a teacup the spoon will attract air bubbles, and large air bubbles will attract small ones, till we find a small mass of bubbles formed in the centre of the cup of tea. Divide this bubble, and the component parts will rush to the sides of the cup. This form of attraction is illustrated by the accompanying diagrams.

Fig. 14.

Suppose two balls of equal magnitude, A and B (fig. 14). These being of equal magnitude, attract each other with equal force, and will meet, if not opposed, at a point (M) half-way between the two. But they do not meet, because the attraction of the earth is greater than the attraction they relatively and collectively exercise towards each other. But if the size of the balls be different, the attraction of the greater will be more evident, as shown below, where the points of meeting are indicated respectively (figs. 15 and 16). These experiments will illustrate the phenomena of *falling bodies*. Gravity is the cause of this, because every object on the surface of the earth is very much smaller than the earth itself, and therefore all bodies *fall* towards the centre of the earth. A certain time is thus occupied, and we can find the *velocity* or rapidity of a falling body very easily. On the earth a body, if let fall, will pass through a space sixteen feet in the first second; and as the attraction of the earth still continues and is exercised upon a body already in rapid motion, this rate of progress must be proportionately increased. Just as when steam is kept up in an engine running down hill, the velocity of the train will rapidly increase as it descends the gradient.

Figs. 15 and 16.

A body falling, then, descends sixteen feet in the first second, and for every succeeding second it assumes a greater velocity. The distance the body travels has been calculated, and the space it passes through has been found to *increase in proportion to the square of the time it takes to fall*. For instance, suppose you drop a stone from the top of a cliff to the beach, and it occupies two seconds in falling, if you multiply 2 × 2, and the result by sixteen, you will find how high the cliff is: in this (supposed) case it is (omitting decimals) sixty-four feet high. The depth of a well can also be ascertained in the same way, leaving out the effect of air resistance.

But if we go up into the air, the force of gravity will be diminished. The attraction will be less, because we are more distant from the centre of the earth. This decrease is scarcely, if at all, perceptible, even on very high mountains, because their size is not great in comparison with the mass of the earth's surface. The rule for this is *that gravity decreases in proportion to the square of the distance*. So that if at a certain distance from the earth's surface the force of attraction be 1, if the distance be *doubled* the attraction will be only *one quarter* as much as before—not one-half. [Pg 24]

Gravity has exactly the same influence upon *all* bodies, and the force of the attraction is in proportion to the mass. All bodies of equal mass will fall in the same time in a given distance. Two coins (or a coin and a feather *in vacuo*) will fall together. But in the air the feather will remain far behind the coin, because nearly all the atoms of the former are resisted by the air, while in the coin only some particles are exposed to the resistance, the *density* of the latter preventing the air from reaching more than a few atoms, comparatively speaking. The theory of weight and gravitation, and experiments relating to the falling of bodies, may be easily demonstrated with ordinary objects that we have at hand. I take a halfpenny and a piece of paper, which I cut in the shape of the coin, and holding them side by side, I drop them simultaneously; the halfpenny reaches the ground some time before the paper, a result quite in accordance with the laws of gravitation, as one must bear in mind the presence of air, and the different resistance it offers to two bodies differing in density. I next place the paper disc on the upper surface of the piece of money, and then drop them simultaneously. The two objects now reach the ground at the same time, the paper, in contact with the halfpenny, being preserved from the action of the air. This experiment is so well known that we need not further discuss it; but it must be plainly evident that it is capable of development in experiments on phenomena relating to falling bodies.[7] When a body influenced by the action of a force acts, in its turn, upon another, the latter reacts in an opposite manner upon the first, and with the same intensity.

The Attraction of Cohesion is the attraction of particles of bodies to each other at very small distances apart. Cohesion has received various names in order to express its various degrees. For instance, we say a body is tough or brittle, or soft or hard, according to the degrees of cohesion the particles exercise. We know if we break a glass we destroy the [Pg 25] cohesion; the particles cannot be reunited. Most Liquid particles can be united, but not all. Oil will not mix with water.

The force of cohesion depends upon heat. Heat expands everything, and the cohesion diminishes as temperature increases.

There are some objects or substances upon the earth the particles of which adhere much more closely than others, and can only, with very great difficulty, be separated. These are termed *Solids*. There are other substances whose particles can easily be divided, or their position altered. These are called *Fluids*. A third class seem to have little or no cohesion at all. These are termed *Gases*.

Adhesion is also a form of attraction, and is cohesion existing on the surfaces of two bodies. When a fluid adheres to a solid we say the solid *is wet*. We turn this natural adhesion to our own purposes in many ways,—we whitewash our walls, and paint our houses; we paste our papers together, etc.

On the other hand, many fluids will hot adhere. Oil and water have already been instanced. Mercury will not stick to a glass tube, nor will the oiled glass tube retain any water. We can show the attraction and repulsion in the following manner:—Let one glass tube be dipped into water and another into mercury, you will see that the water will ascend slightly at the side, owing to the attraction of the glass, while the mercury will be higher in the centre, for it possesses no attraction for the glass (fig. 17). If small, or what are termed capillary (or hair) tubes, be used (fig. 18), the water will rise up in the one tube, while in the other the mercury will remain lower than the mercury outside the tube. (See *Capillarity*.)

Figs. 17. and 18.

Chemical Attraction is the force by which two different bodies unite to form a new and different body from either. This force will be fully considered in CHEMISTRY, in a future part.

It is needless for us to dwell upon the uses of these Forces of Nature. Gravity and Cohesion being left out of our world, we can imagine the result. The earth and sun and planets would wander aimlessly about; we should float away into space, and everything would fall to pieces, while our bodies would dissolve into their component parts.

The Balance and Centre of Gravity.—We have spoken at some length about Gravity, and now we must say something respecting that point called the *Centre of Gravity*, and the [Pg 26] *Balance*, and upon the latter we have a few remarks to make first, for a well-adjusted balance is a most useful thing, and we will show you how to make one, and then proceed to our illustrations of the Centre of Gravity, and explain it.

Fig. 19.—Torsion balance, which can easily be constructed, capable of weighing a milligram one-tenth of full size.

All those who cultivate experimental science are aware that it is useful to unite with theoretical ideas that manual dexterity which is acquired by the student accustoming himself to practical operations. One cannot too strongly urge both chemists and physicists to exercise themselves in the construction of the appliances they require, and also to modify those already existing, which may be adapted to their wants. In a large number of cases it is possible to manufacture, at small expense, delicate instruments, capable of rendering the same service as the most elaborate apparatus. Important scientific labours have often been undertaken by men whose laboratories were most simple, who, by means of skill and perseverance, knew how to do great things with small resources. A delicate balance, for instance, indispensable alike to chemist and physicist, can be manufactured at little cost in different ways. A thin platinum wire and a piece of wood is all that is needed to make a balance capable of weighing a milligram; and to make a very sensitive hydrostatic balance, little is required besides a glass balloon. Fig. 19 represents a small torsion balance of extreme simplicity. A thin platinum wire is stretched horizontally through two staples, from the wooden supports, A B, which are fixed in a deal board. A very thin, delicate lever, C D, cut in wood, or made with a wisp of straw, is fixed in the centre of the platinum wire by means of a small clip, which secures it firmly. This lever is placed in such a manner that it is raised perceptibly out of the horizontal line. At D is fixed a paper scale, on which is put the weight of a centigram. The lever is lowered to a certain point, slightly twisting the platinum wire. Near the end of the lever a piece of wood, F, is fixed, on which is marked the extreme point of its movements. Ten equi-distant divisions are marked between these two points, which represent the distance traversed by the lever under the weight of the milligram. If a smaller weight than a centigram is placed on the paper scale the lever falls, and balances itself after a few oscillations. If it falls four divisions, it is evident that the substance weighs [Pg 27] four milligrams. Taking a rather thicker platinum wire, to which a shorter lever must be adapted, one can weigh the decigram, and so on. It would be an easy matter, also, to make, on the same model, balances for weighing considerable weights. The platinum wire should be replaced by iron wires of larger diameter, firmly stretched, and the lever should be made of a piece of very resisting wood. One can also, by adaptation, find the exact value of the most trifling weights. By lengthening a very fine platinum wire several yards, and adapting a long, slender lever, it will not be impossible to ascertain the tenth of a milligram. In this latter case the balance can be set when it is wanted.

Fig. 20.—Nicholson’s Areometer, contrived to serve as a balance.

Fig. 20 represents Nicholson’s Areometer, which any one may construct for himself, and which, as it is here represented, constitutes another kind of balance. A glass balloon, filled with air, is hermetically closed with a cork, through which is passed a cylinder of wood, surmounted by a wooden disc, D. The apparatus is terminated at its lower end by a small tray, C, on which one can put pieces of lead in variable quantities. It is then plunged into a glass filled with water. The pieces of lead on the tray, C, are added by degrees, until the stem of the areometer rises almost entirely above the level of the water; it is next passed through a ring, which keeps it in position, and which is fastened to the upper part of the glass by means of four iron wires in the shape of a cross. The stem is divided in such a way that the space comprised in each division represents the volume of a cubic centimetre. Thus arranged, the apparatus constitutes a balance. The object to be weighed is placed on the disc, D, and the areometer sinks in the water, oscillates, and then remains in equilibrium. If the stem sinks five divisions, it is evident that the weight of the object corresponds to that of five cubic centimetres of displaced water, or five grams.

It is obvious, therefore, from the preceding examples, that it is not impossible to construct a weighing apparatus with ordinary and very inexpensive objects. We can, in the same way, show that it is possible to perform instructive experiments with no appliances at all, or, at any rate, with common things, such as everyone has at hand. The lamented Balard, whose loss science has had recently to deplore, excelled in chemical experiments without a laboratory; fragments of broken glass or earthenware were used by him for improvising [Pg 28] retorts, bottles and vases for forming precipitates, and carrying on many important operations.

Scheele also operated in like manner; he knew how to make great discoveries with the humblest appliances and most slender resources. One cannot too earnestly endeavour to imitate such leaders, both in teaching others and instructing oneself.

The laws relating to the weight of bodies, the centre of gravity, and stable or unstable equilibrium, may be easily taught and demonstrated by means of a number of very familiar objects. By putting into the hands of a child a box of soldiers cut in elder-wood, the end of each fixed into half a bullet, we provide him with the means of making some easy experiments on the centre of gravity. According to some authorities on equilibrium, it is not impossible, with a little patience and delicacy of manipulation, to keep an egg balanced on one of its ends. This experiment should be performed on a perfectly horizontal surface, a marble chimney-piece, for example. If one can succeed in keeping the egg up, it is, according to the most elementary principles of physics, because the vertical line of the centre of gravity passes through the point of contact between the end of the egg and the surface on which it rests.

Fig. 21.—Experiment on “centre of gravity.”

Fig. 21 reproduces a curious experiment in equilibrium, which is performed with great facility. Two forks are stuck into a cork, and the cork is placed on the brim of the neck of a bottle. The forks and the cork form a whole, of which the centre of gravity is fixed over the point of support. We can bend the bottle, empty it even, if it contains fluid, without the little construction over its mouth being in the least disturbed from its balance. The vertical line of [Pg 29] the centre of gravity passes through the point of support, and the forks oscillate with the cork, which serves as their support, thus forming a movable structure, but much more stable than one is inclined to suppose. This curious experiment is often performed by conjurors, who inform their audience, that they will undertake to empty the bottle without disturbing the cork. If a woodcock has been served for dinner, or any other bird with a long beak, take off the head at the extreme end of the neck; then split a cork so that you can insert into it the neck of the bird, which must be tightly clipped to keep it in place; two forks are then fixed into the cork, exactly as in the preceding example, and into the bottom of the cork a pin is inserted. This little contrivance is next placed on a piece of money, which has been put on the opening of the neck of the bottle, and when it is fairly balanced, we give it a rotatory movement, by pushing one of the forks as rapidly as we please, but as much as possible without any jerk (fig. 22). We then see the two forks, and the cork surmounted by the woodcock’s head, turning on the slender pivot of a pin. Nothing can be more comical than to witness the long beak of the bird turning round and round, successively facing all the company assembled round the table, sometimes with a little oscillation, which gives it an almost lifelike appearance. This rotatory movement will last some time, and wagers are often laid as to which of the company the beak will point at when it stops. In laboratories, [Pg 30] wooden cylinders are often to be seen which will ascend an inclined plane without any impulsion. This appears very surprising at first, but astonishment ceases when we perceive that the centre of gravity is close to the end of the cylinder, because of a piece of lead, which has been fixed in it.

Fig. 22.—Another experiment on the same subject.

Fig. 23.—Automatic puppets.

Fig. 23 gives a very exact representation of a plaything which was sold extensively on the Boulevards at Paris at the beginning of the New Year. This little contrivance, which has been known for some time, is one of the most charming applications of the principles relating to the centre of gravity. With a little skill, any one may construct it for himself. It consists of two little puppets, which turn round axles adapted to two parallel tubes containing mercury. When we place the little contrivance in the position of fig. 24, the mercury being at *a*, the two dolls remain motionless, but if we lower the doll S, so that it stands on the second step (No. 2) of the flight, as indicated in fig. 25, the mercury descends to *b* at the other end of the tube; the centre of gravity is suddenly displaced; the doll R then accomplishes a rotatory movement, as shown by the arrow in fig. 25, and finally alights on step No. 3. The same movement is also effected by the doll S, and so on, as many times as there are steps. The dolls may be replaced by a hollow cylinder of cartridge paper closed at both ends, and containing a marble; the cylinder, when placed vertically on an inclined [Pg 31] plane, descends in the same way as the puppets. The laws of equilibrium and displacement of the centre of gravity, are rigorously observed by jugglers, who achieve many wonderful feats, generally facilitated by the rotatory motion given to the bodies on which they operate, which brings into play the centrifugal force. The juggler who balances on his forehead a slender rod, on the end of which a plate turns round, would never succeed in the experiment if the plate did not turn on its axis with great rapidity. But by quick rotation the centre of gravity is kept near the point of support. We need hardly remark, too, that it is the motion of a top that tends to keep it in a vertical position.

Fig. 24.—First position of the puppets.

Fig. 25.—Second position of the puppets.

Many experiments in mechanical physics may occur to one’s mind. To conclude the enumeration of those we have collected on the subject, I will describe the method of lifting a glass bottle full of water by means of a simple wisp of straw. The straw is bent before being passed into the bottle of water, so that, when it is lifted, the centre of gravity is displaced, and brought directly under the point of suspension. Fig. 26 shows the method of [Pg 32] operation very plainly. It is well to have at hand several pieces of straw perfectly intact, and free from cracks, in case the experiment does not succeed with the first attempt.

Having now seen how this point we call the centre of gravity acts, we may briefly explain it.

Fig. 26.—Lifting a bottle with a single straw.

The centre of gravity of a body is that point in which the sum of the forces of gravity, acting upon all the particles, may be said to be united. We know the attraction of the earth causes bodies to have a property we call *Weight*. This property of weight presses upon every particle of the body, and acts upon them as parallel forces. For if a stone be broken all the portions will equal the weight of the stone; and if some of them be suspended, it will be seen that they hang parallel to each other, so we may call these weights parallel forces united in the whole stone, and equal to a single resultant. Now, to find the centre of gravity, we must suspend the body, and it will hang in a certain direction. Draw a line from the point of suspension, and suspend the body again: a line drawn from that point of suspension will pass through the same place as the former line did, and so on. That point is the centre of gravity of that suspended body. If the form of it be regular, like a ball or cylinder, the centre of gravity is the same as the mathematically central point. In such forms as pyramids it will be found near the largest mass; viz., at the bases, about one-fourth of the distance between the apex and the centre of gravity of the base. [Pg 33]

When the centre of gravity of any body is supported, that body cannot fall. So the well-known leaning towers are perfectly safe, because their lines of direction fall within the bases. The centre of gravity is in the centre of the leaning figure. The line of direction drawn vertically from that point falls within the base; but if the tower were built up higher, so that the centre of gravity were higher, then the structure would fall, because the line of direction would fall without the base.

We see that animals (and men) are continually altering the position of the centre of gravity; for if a man bears a load he will lean forward, and if he takes up a can of water in one hand he will extend the other to preserve his balance or equilibrium.

Fig. 27.—Balancing a weight on a nail and key.

The experiment shown in the accompanying illustration is apparently very difficult, but it will be found easy enough in practice if the hand be steady. Take a key, and by means of a crooked nail, or "holdfast," attach it to a bar of wood by a string tied tightly round the bar, as in the picture. To the other extremity of the bar attach a weight, and then drive a large-headed nail into the table. It will be found that the key will balance, and even move upon the head of the nail, without falling. The weight is under the table, and the centre of gravity is exactly beneath the point of suspension.

Another simple experiment may prove amusing. Into a piece of wood insert the points of two knives, and at the centre of the end of the bar insert a needle between the knife handles. The wood and the knives may then be balanced on another needle fixed in a cork at A. [Pg 34]

Fig. 28.—Another experiment.

We may conclude this chapter by summing up in a few words what the Centre of Gravity is. We can define it as "that point in a body upon which the body, acted on solely by the force of gravity, will balance itself in all positions." Such a point exists in every body, and equally in a number of bodies fastened tightly together. The Centre of Gravity has by some writers been denominated the *Centre of Parallel Forces*, or the *Centre of Magnitude*, but the Centre of Gravity is the most usual and best understood term.

[Pg 35]

CHAPTER IV.

SOME PROPERTIES OF SOLID BODIES—INERTIA—MOTION—FRICTION—THE PENDULUM—EQUILIBRIUM.

Those who have followed us through the preceding pages have now, we hope, some ideas upon Gravity and the Forces of Nature. In speaking of Forces we said “Force was a cause of Motion.” Let us now consider Inertia, and Motion with its accompanying opponent, Friction.

Fig. 29.—Shock communicated by elasticity.

Inertia is the passiveness of Matter. This perfect indifference to either rest or motion makes the great distinction between living and lifeless matter. Inertia, or *Vis Inertia*, is this passiveness. Now, to overcome this indifference we must use force, and when we have applied force to matter we set it in motion; that is, we move it. When we move it we find a certain resistance which is always proportionate to the force applied. In mechanics this is termed *Action*, and *Reaction*, which are always equal forces acting in opposite directions. This is Newton’s law, and may be explained by a “weight” on a table, which presses against the table with the same force with which the table presses against the “weight”; or when you [Pg 36] strike a ball, it strikes the hand with the same force.

We can communicate motion by elasticity. For instance, if we place a number of coins upon a table touching each other and in a straight line, and strike the last coin of the line by pushing another sharply against it, the piece at the opposite extremity will slip out of its place from the effect of the shock transmitted by the coin at the other end (fig. 29).

Fig. 30.—Experiment to illustrate inertia.

When two forces act upon a body at the same time, it takes a direction intermediate. This is known as the resultant. The enormous forces exercised by the heavenly bodies will be [Pg 37] treated of later. We will first consider *Inertia*.

There are several experiments relating to the subject of Inertia which may be performed. I once witnessed one quite accidentally when taking a walk.

Fig. 31.—Another experiment on the same subject.

I was one day passing the Observatory at Paris, when I noticed a number of people collected round a professor, who after executing several juggling tricks, proceeded to perform the curious experiment I am about to describe. He took a broomstick and placed it horizontally, passing the ends through two paper rings. He then asked two children to hold the paper rings by means of two razors, so that the rings rested on the blade. This done, the operator took a stout stick, and, with all his strength, struck the broomstick in the centre; it was broken into shivers, but the paper rings were not torn in the least, or even cut by the razors! One of my friends, M. M——, a painter, showed me how to perform this experiment as represented in the illustration (fig. 30). A needle is fixed at each end of the broomstick, and these needles are made to rest on two glasses, placed on chairs; the needles alone must be in contact with the glasses. If the broomstick is then struck violently with another stout stick, the former will be broken, but the glasses will remain intact. The experiment answers all the better the more energetic the action. It is explained by the resistance of inertia in the [Pg 38] broomstick. The shock suddenly given, the impulse has not time to pass on from the particles directly affected to the adjacent particles; the former separate before the movement can be transmitted to the glasses serving as supports.[8]

Fig. 32.—Extracting a "man" from a pile of draughts without overturning the pile.

The experiment represented in fig. 31 is of the same nature. A wooden ball is suspended from the ceiling by a rather slender thread, and a similar thread is attached to the lower end of the ball. If the lower thread is pulled forcibly it will break, as shown in the illustration; the movement communicated to it has not time to pass into the ball; if, on the contrary, it is pulled very gradually and without any shock, the upper thread instead will break, because in this case it supports the weight of the ball. Motion is not imparted simultaneously to all parts of a body, but only to the particles first exposed to a blow, for instance. One might multiply examples of this. If a bullet be shot from a gun, it will make a round hole in a piece of wood or glass, whilst if thrown by the hand,—that is to say, with much less force,— it [Pg 39] will shiver the wood or the pane of glass to pieces. When the celerity of the motive force is very great, the particles directly affected are disturbed so quickly that they separate from the adjacent particles before there is time for the movement to be communicated to the latter.

It is possible, for the same reason, to extract from a pile of money a piece placed in the middle of the pile without overturning the others. It suffices to move them forcibly and quickly with a flat wooden ruler. The experiment succeeds very well also if performed with draughtsmen piled up on the draught-board (fig. 32).

Fig. 33.—Calling out a sixpence from the glass.

Fig. 33 represents another experiment which belongs to the laws of resisting force. A sixpence is placed on a table covered with a cloth or napkin. It is covered with a glass, turned over so that its brim rests on two penny pieces. The problem to be solved is how to extract the sixpence from underneath the glass without touching it, or slipping anything beneath it. To do this it is necessary to scratch the cloth with the nail of the forefinger; the elasticity of the material communicates the movement to the sixpence, which slowly moves in the direction of the finger, until it finally comes out completely from beneath the glass.

We may give another experiment concerning Inertia. Take a strip of paper, and upon it place a coin, on a marble chimney-piece, as in the illustration. If, holding the paper in the left hand, you strike it rapidly and forcibly, you will be enabled to draw away the paper without [Pg 40] causing the coin (say a five-shilling-piece) to fall down (fig. 34).

It is not impossible to draw away a napkin laid as a tablecloth for one person's dinner, without disturbing the various articles laid upon it. A quick motion is all that is necessary, keeping the napkin tightly extended by the hands at the same time. This latter experiment, however, is not recommended to boys home for the holidays, as they may unwillingly practise a feat analogous to that executed by Humpty-Dumpty, and find equal difficulty to match the pieces.

Fig. 34.—Drawing a slip of paper from beneath a coin.

We will now examine the term *Motion*. A body is said to be in motion when it changes its position in relation to surrounding objects. To perceive motion the surrounding objects must be relatively at rest, for if they all hurried along at the same rate no motion would be perceptible. This is evident, for when we stand still trees and houses appear stationary, as do we ourselves, but we know we all are rushing round with the earth, though our *relative* positions are unchanged. Hence there is no *absolute* rest.

What are the causes of motion?—Gravity is one. The influence of heat, which is itself caused by the motion of atoms, the effects of electricity, etc., and finally, the power of force in men or animals—any of these causes will produce motion. But a body at rest cannot put itself in motion, nor can a body in motion stop itself, or change its condition of motion.

But you may say a body will stop itself. Your ball on the ground, or even upon ice, will eventually come to a stop. We fire a bullet, and it will stop in time. We reply it does not stop of itself, The resistance of the Air and Friction tend to bring the body in motion to a state of rest. In the case of a bullet gravity brings it down. [Pg 41]

There is no need to insist upon the resistance offered by the air even when it is not rushing violently past to fill up a vacuum beyond us, and called a breeze, or high wind. But we may say something of *Friction*.

Friction is derived from the Latin *frico*, to rub, and expresses the resistance to motion which arises from uneven surfaces. It is a passive resistance, and depends upon the force which keeps the bodies together. Thus a train running upon a smooth iron rail would never be able to proceed but for friction, which gives the necessary purchase or grip to the wheel and rail in contact.

No surface is perfectly smooth, for we must push a body upon the smoothest surface we possess. Friction tends to resist motion always, and is the cause of a great loss of power in mechanics, though it is employed to stop motion by certain appliances, such as “brakes” and “drags,” for sliding friction is greater than rolling friction. But without friction most structures would fall to pieces, and all forward motion would cease. So though it is an inconvenient force to overcome, we could not do without it.

If a body is set in motion, we see that the tendency of it is to go on for ever. Such, indeed, is the case with the stars; but so long as we are within the influence of the earth’s attraction, we cannot expect such a result. We know now what motion is; we must also, to understand it perfectly, consider its direction and its velocity.

The line which indicates the way from the starting point to the end is the *direction* of the object in motion, and the rate it moves at its *velocity*. The latter is calculated at so many miles an hour, as a train; or so many feet in a second if the object be a shot, or other very rapidly-moving body. In equal velocity the same distance is traversed in the same time; and so if a train run a mile in a minute, we know it will travel sixty miles in an hour, and is therefore during that minute going at *the rate* of sixty miles an hour. We have already spoken of the velocity of a stone falling from a cliff as sixteen feet in a second, and a stone thrown into the air to rise sixteen feet will be a second in going up, and a second in descending. But the velocity will be accelerated in the descent after the first second of time, and retarded in the upward cast by gravity. So we have two terms—*accelerated* and *retarded* velocity—used to express an increased or decreased force of attraction.

Perpetual motion has often been sought, but never discovered, nor will it ever be till the elixir of life has been found. It is quite impossible to construct any machine that will work without friction; if any work be done energy will be expended and transformed into other energy, so the total must be diminished by so much as was employed to transform the remainder. No body can give unlimited work, therefore the perpetual motion theory is untenable and impossible. [Pg 42]

Fig. 35.—The pendulum.

The *pendulum* is considered the nearest approach to perpetual motion. This is so well known that no description is needed, but we may say a few words concerning it. By the diagram, we see that if we lift the ball to *b*, and let it fall, it will descend to *l*, and pass it to *a* opposite, nearly as far from *l* as *b* is from it. So the oscillations will continue, each beat being less and less, till rest is reached by the action of gravity (page 23). Were it not for friction and the pressure of the air, the oscillations would continue for ever; as it is, it declines by shorter swings till it remains in equilibrium.

The seconds' pendulum oscillates sixty times an hour, and must be of a certain length in certain places. In London it is 39·1393 inches, and furnishes a certain standard of length, and by an Act of Parliament the yard is divided into 36 parts, and 39·1393 such parts make the seconds' pendulum in the latitude of London (*in vacuo*) in a temperature of 62°.

Fig. 36.—Centrifugal Force.

But the same pendulum will not perform the same number of oscillations in one minute in all parts of the globe. At the equator they will be less, and at the pole more. Thus it was discovered that, as the movements of the pendulum are dependent upon the force of gravity, and as this force decreases the farther we get from the centre of the earth, the equator must be farther from the earth's centre than the poles, and therefore the poles must be depressed. The decline of the pendulum at the equator is also, in a measure, due to Centrifugal Force. [Pg 43]

Centrifugal Force, which means "flying from the centre," is the force which causes an object to describe a circle with uniform velocity, and fly away from the centre; the force that counteracts it is called the *centripetal* force. A very simple experiment will illustrate it.

Fig. 37.—Another illustration of centrifugal force.

To represent its action, we shall have recourse to an ordinary glass tumbler placed on a round piece of cardboard, held firmly in place by cords. Some water is poured in the glass, and we then show that it can be swung to and fro and round without the water being spilt, even when the glass is upside down (fig. 36).

Another experiment on the same subject is as shown in the above illustration, by which a napkin ring can be kept in revolution around the forefinger, and by a continued force the ring may be even held suspended at the tip of the finger, apparently in the air, without support (fig. 37).

[Pg 44]

CHAPTER V.

GASES AND LIQUIDS—PRESSURE OF THE AIR—EXPERIMENTS.

We have more than once referred to the pressure of the air which exerts a great influence upon bodies in motion, but a few experiments will make this more obvious, and clearly demonstrate the fact. We have also told you some of the properties of Solids, such as Weight, Inertia, Friction, and Resistance, or Strength. Solids also, as we have seen, occupy space, and cannot be readily compressed, nor bent to other shapes. Now the subject of the Pressure of the Air leads us to the other forms of Matter; namely, Gases and Liquids, which will be found very interesting to study.

Fig. 38.—Blowing an egg from one glass to another.

[Pg 45] The force of air can very soon be shown as acting with considerable pressure upon an egg in a glass. By blowing in a claret glass containing a hard-boiled egg, it is possible to cause the egg to jump out of the glass; and with practice and strength of lungs it is not impossible to make it pass from one glass to another, as per illustration (fig. 38).

The force of heated air ascending can also be ascertained by cutting up a card into a spiral, and holding it above the flame of a lamp (fig. 39). The spiral, if lightly poised, will turn round rapidly.

Now let us turn to a few experiments with the air, which is composed in two gases, Oxygen and Nitrogen, of which we shall hear more when we come to CHEMISTRY.

Fig. 39.—Movement of heated air.

Fig. 40.—Pressure of the air.

It is not intended here to prosecute researches, but rather to sketch a programme for instruction, based on amusing experiments in Physics, performed without apparatus. The greater part of these experiments are probably well known, and we desire to say that we merely claim to have collected and arranged them for our descriptions. We must also add that we have performed and verified these experiments; the reader, therefore, can attempt them with every certainty of success. We will suppose that we are addressing a young auditory, and commence our course of Physics with some facts relating to the pressure of air. A wine glass, a plate, and water, will serve for our first experiments. Pour some water on the plate, light a piece of paper resting on a cork, and cover the flame with the glass [Pg 46] which I turn upside down (fig. 40). What follows?—The water rises in the glass. Why?—Because the burning of the paper having absorbed a part of the oxygen, and the volume of confined gas being diminished, the pressure of the outer air has driven back the fluid. I next fill a goblet with water up to the brim, and cover it with a sheet of paper which touches both the edge of the glass and the surface of the water. I turn the glass upside down, and the sheet of paper prevents the water running out, because it is held in place by atmospheric pressure (fig. 41). It sometimes happens that this experiment does not succeed till after a few attempts on the part of the operator; thus it is prudent to turn the glass over a basin, so that, in case of failure, the water is not spilt. Having obtained a vase and a bottle, both quite full of water, take the bottle, holding it round the neck so that the thumb can be used as a stopper, then turn it upside down, and pass the neck into the water in the vase. Remove your thumb, or stopper, keeping the bottle in a vertical position, and you will see that the water it contains does not escape, but remains in suspension. It is atmospheric pressure which produces this phenomenon. If, instead of water, we put milk in the bottle, or some other fluid denser than water, we shall see that the milk also remains suspended in the bottle, only there is a movement of the fluid in the neck of the bottle, and on careful examination we perceive very plainly that the milk descends to the bottom of the vase, and the water rises into the bottle. Here, again, it is atmospheric pressure which maintains the fluid in the [Pg 47] bottle, but the milk descends, because fluids are superposed according to their order of density, and the densest liquid falls to the bottom.

This can be verified by means of the *phial of the four elements*, which is a plain, long, and narrow bottle, containing equal volumes of metallic mercury, salt water, alcohol, and oil. These four liquids will lie one on the top of the other without ever mixing, even if shaken.

Another experiment as to the pressure of the air may be made (fig. 42). Take a penny and press it against some oaken bookcase or press, rub the coin against the wood for a few seconds, then press it, and withdraw the fingers. The coin will continue to adhere to the wood. The reason of this is, because by the rubbing and the pressure you have dispersed the film of air which was between the penny and the wood, and under those conditions the pressure of the atmospheric air was sufficient to keep the penny in its place.

Fig. 41.—Pressure of the air.

Or, again, let us now add a water-bottle and a hard-boiled egg to our appliances; we will make use of the air-pump, and easily perform another experiment. I light a piece of paper, and let it burn, plunging it into a water-bottle full of air. When the paper has been burning a few seconds I close the opening of the water-bottle by means of a hard-boiled egg, which I have previously divested of its shell, so that it forms a hermetic stopper. The burning of the paper has now caused a vacuum of air in the bottle, and the egg is gradually thrust in by the [Pg 48] atmospheric pressure outside. Fig. 43 exhibits it slowly lengthening and stretching out as it passes through the aperture; then it is suddenly thrust completely into the bottle with a little explosive sound, like that produced by striking a paper bag expanded with air. This is atmospheric pressure demonstrated in the clearest manner, and at little cost.

Fig. 42.—Coin adhering by pressure of air.

If it is desired to pursue a little further the experiments relating to atmospheric pressure, it will be easy enough to add to the before-mentioned appliances a closed glass-tube and some mercury, and one will then have the necessary elements for performing Torricelli’s and Pascal’s experiments, and explaining the theory of the barometer (page 52).

An amusing toy, well-known to schoolboys, called the “sucker,” may also be made the object of many dissertations on the vacuum and the pressure of air. It is composed of a round piece of soft leather, to the centre of which is attached a small cord. This leather is placed on the ground and pressed under foot, and when the cord is pulled it forms a cupping-glass, and is only separated with difficulty from the pavement.

Atmospheric air, in common with other gases, has a tendency to fill any space into which it may enter. The mutual attraction of particles of air is *nil*; on the contrary, they appear to have a tendency to fly away from each other; this property is called "repulsion." Air also possesses an expansive property—a tendency to press against all the sides of any vessel in [Pg 49] which it may be enclosed. Of course the larger the vessel containing a given quantity of air, the less actual pressure it will exert on the sides of the vessel. The elasticity of air therefore decreases with increasing expansion, but it gains in elasticity or force when compressed.

There is a law in Physics which expresses the relation between expansion and elasticity of gases, which may be said to be as follows:—

The elasticity (of a gas) is in inverse ratio to the space it occupies, and therefore by compressing air into a small space we can obtain a great force, as in the air-gun and the pop-gun of our youthful days.

Fig. 43.—Hard boiled egg, divested of its shell, passing through the neck of a glass bottle, under the influence of atmospheric pressure.

In the cut below we can illustrate the principle of the pop-gun. The chamber full of air is closed by a cork and by an air-tight piston (s) at *p* and *p*. When the piston is pushed into the chamber the air is compressed between it and the stopper, which at length flies out forcibly with a loud report

Fig. 44.—The principle of the pop-gun.

We have said that the tendency of air particles is to fly away from each other, and were it not for the earth's attraction the air might be dispersed. The height of the atmosphere has been variously estimated from a height of 45 miles to 212 miles in an attenuated form; but [Pg 50] perhaps 100 miles high would be a fair estimate of the height to which our atmosphere extends.

Fig. 45.—Weighing the air.

The pressure of such an enormous body of gas is very great. It has been estimated that this pressure on the average human body amounts to fourteen tons, but being balanced by elastic fluids in the body, the inconvenience is not felt. The *Weight* of Air can easily be ascertained, though till the middle of the seventeenth century the air was believed to be without weight. The accompanying illustration will prove the weight of air. Take an ordinary balance; and suspend to one side a glass globe fitted with a stop-cock. From this globe extract the air by means of the air-pump, and weigh it. When the exact weight is ascertained turn the stop-cock, the air will rush in, and the globe will then pull down the balance, thus proving that air possesses weight. The experiments of Torricelli and Otto von Guerike, however, demonstrated that the air has weight and great pressure. Torricelli practically invented the barometer, but Otto von Guerike, by the cups known as *Magdeburg Hemispheres*, proved the pressure of the outward air. This apparatus is well known, and consists of two hollow [Pg 51] copper hemispheres which fit very closely. By means of the air-pump which he invented in 1650, Otto von Guerike exhausted the air from the closed hemispheres. So long as air remained in them, there was no great difficulty in separating them; but when it had been finally exhausted, the pressure of the surrounding atmosphere was so great that the hollow spheres could not be dragged asunder even by horses harnessed to rings which had been inserted in the globes.

Fig. 46.—Magdeburg Hemispheres.

The *Air-Pump* is a very useful machine, and we will now briefly explain its action. The inventor was, as remarked above, Otto von Guerike, of Magdeburg. The pump consists of a cylinder and piston and rod, with two valves opening upwards—one valve being in the bottom of the cylinder, the other in the piston. This pump is attached by a tube to a plate with a hole in it, one extremity of the tube being fixed in the centre of the plate, and the other at the valve at the bottom of the cylinder. A glass shade, called the *receiver*, is placed on the top of the plate, and of course this shade will be full of air (fig. 47).

Fig. 47.—The air-pump.

When the receiver is in position, we begin to work the pump. We have said there are two valves. So when the piston is drawn up, the cylinder would be quite empty did not the valve at the bottom, opening upwards, admit some air from the glass shade through the tube to enter the cylinder. Now the lower part of the cylinder is full of air drawn from the glass shade. When we press the piston down again, we press against the air in it, which, being compressed, tries to escape. It cannot go back, because the valve at the bottom of the cylinder won't open, so it escapes by the valve in the piston, and goes away. Thus a certain amount of air is got rid of at each stroke of the piston. Two cylinders and pistons can be used, and so by means of cog-wheels, etc., the air may be rapidly exhausted from the receiver. Many experiments are made with the assistance of the air-pump and receiver, though the air is never *entirely* exhausted from the glass.

The "Sprengel" air-pump is used to create an almost perfect vacuum, by putting a vessel to be exhausted in connection with the vacuum at the top of a tube of mercury thirty inches high. Some air will bubble out, and the mercury will fall. By filling up again and repeating the process, the air vessel will in time be completely exhausted. This is done by Mr. Sprengel's pump, and a practically perfect vacuum is obtained, like the *Torricellian* vacuum.

The "Torricellian vacuum" is the empty space above the column of mercury in the barometer which we will proceed to describe. Air has a certain weight or pressure which is sufficient to raise a column of mercury thirty inches. We will prove this by illustration. Take [Pg 52]
a bent tube and fill it with mercury; the liquid will stand equally high in both arms, in consequence of the ratio of equilibrium in fluids, of which we shall read more when we come to consider Water. So the two columns of mercury are in equilibrium. (See A.) Now stop the arm a with a cork, and take out half the mercury. It will remain in one arm only. Remove the cork, and the fluid will fall in both arms, and remain in equilibrio. If a long bent glass tube be used, the arms being thirty-six inches high, the mercury will fall to a point *c*, which measures 29·9 inches from the bottom. If the tube be a square inch in bore, we have 29·9 cubic inches of mercury, weighing 14⅘ lbs., balancing a column of air one square inch thick and as high as the atmosphere. So the mercury and the column of air must weigh the same. Thus every square inch on the earth supports a weight of (nearly) 15 lbs (figs. 48 and 50).

Fig. 48.—Air Pressure.

The barometer invented by Pascal, working on the investigations of Torricelli, is a very simple and useful instrument. Fill a tube with mercury from which all moisture has been expelled, and turn it over in a dish of mercury; the mercury will rise to a certain height (30 inches), and no higher in vacuo. When the pressure of the air increases the mercury rises a little, and falls when the pressure is removed. Air charged with aqueous vapour is lighter than dry air, so a fall in the mercury indicates a certain amount of water-vapour in the air, which may condense and become rain. The action of mercury is therefore used as a weather-glass, by which an index-point shows the movements of the fluid, by means of a wheel over which a thread passes, sustaining a float and a counterpoise. When the mercury rises the float goes up, and the weight falls, and turns the wheel by means of the thread. The wheel having a pointer on the dial tells us how the mercury moves. This *weather-glass* is the usual *syphon barometer* with the float on the surface and a weight (fig. 50). [Pg 53]

Fig. 49.—The Barometer.

The Syphon Barometer is a bent tube like the one already shown, with one limb much shorter than the other.

Fig. 50.—Syphon barometer.

The Aneroid Barometer, so called because it is "without moisture," is now in common use. In these instruments the atmospheric pressure is held in equilibrium by an elastic metal spring or tube. A metal box, or tube, is freed from air, and then hermetically sealed. This box has a flexible side, the elasticity of which, and the pressure of the air on it, keep each other in equilibrium. Upon this elastic side the short arm of a lever is pressed, while the longer arm works an index-point, as in the circular barometer. When pressure increases the elastic box "gives"; when pressure diminishes it returns to its former place, and the index moves in the opposite direction. It is necessary to compare and "set" the aneroid with the mercurial barometer to ensure correctness. A curved tube is sometimes used, which coils and uncoils like a spring, according to the pressure on it.

Fig. 51.—The Water Barometer.

There are other barometers, such as the Water Barometer, which can be fixed against the side of a house, and if the water be coloured, it will prove a useful indicator. As the name indicates, water is used instead of mercury, but as the [Pg 54] latter is thirteen-and-half times heavier than water, a much longer tube is necessary; viz., one about thirty-five feet in length. The construction is easy enough. A leaden pipe can be fixed against the house; on the top is a funnel furnished with a stop-cock, and placed in a vase of water. The lower part of the tube is bent, and a glass cylinder attached, with another stop-cock—the glass being about three feet long, and graduated. Fill the tube with water, shut the upper stop-cock, and open the lower one. The vacuum will be formed in the top of the tube, and the barometer will act on a larger scale than the mercury.

The Glycerine Barometer, invented by Mr. Jordan, and in use at the *Times* office, registers as more than one inch movements which on the mercurial thermometer are only one-tenth of an inch, and so are very distinctly visible. The specific gravity of pure glycerine is less than one-tenth that of mercury, so the mean height of the glycerine column is twenty-seven feet at sea level. The glycerine has, however, a tendency to absorb moisture from the air, but Mr. Jordan, by putting some petroleum oil upon the glycerine, neutralized that tendency, and the atmospheric pressure remains the same. A full description of this instrument was given in the *Times* of 25th October, 1880.

Fig. 52.—The principle of the diving-bell.

The uses of the barometer are various. It is employed to calculate the heights of mountains; for if a barometer at sea level stand at 30", it will be lower on a mountain top, because the amount of air at an elevation of ten thousand feet is less than at the level of the sea, and consequently exercises less pressure, and the mercury descends. [The pressure is on the bulb of mercury at the bottom, not on the *top*, remember.] [Pg 55]

The pressure of the air at the tops of mountains sometimes decreases very much, and it is not sufficiently dense for perfect respiration, as many people find. Some climbers suffer from bleeding at the nose, etc., at great altitudes. This is occasioned by the action of the heart, which pumps with great force, and the outward pressure upon the little veins being so much less than usual, they give way.

Fig. 53.—Diver under water.

Many important instruments depend upon atmospheric pressure. The most important of these is the pump, which will carry us to the consideration of water and Fluids generally. The fire-engine is another example, but we will now proceed to explain the diving-bell already referred to.

Fig. 52 represents the experiment of the diving-bell, which is so simple, and is explained below. It belongs to the same category of experiments as those relating to the pressure of air and compression of gas. Two or three flies have been introduced into the glass, and they prove by their buzzing about that they are quite at their ease in the rather confined space. [Pg 56]

The Diving-Bell in a crude form appears to have been used as early as 1538. It was used by two Greeks in the presence of the Emperor Charles V., and numerous spectators. In the year 1720 Doctor Halley improved the diving-bell, which was a wooden box or chamber open at the bottom. Air casks were used to keep the inmate supplied with air. The modern diving-bell was used by Smeaton in 1788, and was made of cast iron. It sinks by its own weight. The pressure of the air inside is sufficient to keep the water out. Air being easily compressed, it is always pumped in to keep the hollow iron "bell" full, and to supply the workmen. There are inventions now in use by which the diver carries a supply of air with him on his back, and by turning a tap can supply himself for a long time at a distance from the place of descent, and thus is able to dispense with the air-tube from the boat at the surface. This apparatus was exhibited at the Crystal Palace some years ago.

Fig. 54.—The Hand Fire-Engine

The Pump.

We have seen in the case of the Water Barometer that the pressure of the air will sustain a column of water about thirty feet high. So the distance between the lower valve and the reservoir or cistern must not be more than thirty-two feet, practically the distance is about twenty-five feet in pumps.

We can see by the illustration that the working is much the same as in the air-pump. The suction pipe B is closed by the valve C, the cylinder D and spout E are above, the piston rod F lifts the air-tight piston in which is a valve H. When the piston is raised the valve C opens and admits the water into the cylinder. When the piston is depressed the valve C is closed, the water already in forces H open, and passing through the piston, reaches the cylinder and the spout (fig. 55). [Pg 57]

The hand fire-engine depends upon the action of compressed air, which is so compressed by pumping water into the air chamber *a*. The tube is closed at *g*, and the pumps *e e* drive water into the air chamber. At length the tap is opened, and the air drives the water out as it is continually supplied (fig. 54).

Compressed air was also used for driving the boring machines in the Mount Cenis tunnel. In this case also the air was compressed by water, and then let loose, like steam, to drive a machine furnished with boring instruments.

Fig. 55..—The Pump.

A pretty little toy may be made, and at the same time exemplify an interesting fact in Physics. It is called the *ludion*, and it "lies in a nut shell" in every sense. When the kernel has been extracted from the shell, fasten the portions together with sealing wax, so that no water can enter. At one end O, as in the illustration, leave a small hole about as large as a pin's head; fasten two threads to the sealing wax, and to the threads a wooden doll. Let a weight be attached to his waist. When the figure is in equilibrium, and will float, put it into a jar of water, and tie a piece of bladder over the top. If this covering be pressed with the finger, the doll will descend and remount when the finger is removed. By quick successive pressure the figure may be made to execute a *pas seul*. The reason of the movement is because the slight cushion of air in the upper part of the vase is compressed, and the little water thus caused to enter the nut shell makes it heavier, and it descends with the figure (fig. 56).

We have now seen that air is a gas, that it exercises pressure, that it possesses weight. We know it can be applied to many useful purposes, and that the air machines and inventions—such as the air-pump and the "Pneumatic Despatch"—are in daily use in our laboratories, our steam engines, our condensed milk manufactories, and in many other industries, and for our social benefit. Compressed air is a powerful motor for boring machinery in tunnels where steam cannot be used, even if water could be supplied, for smoke or fire would suffocate the workers. To air we owe our life and our happiness on earth.

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Pneumatics, then, deals with the mechanical properties of elastic fluids represented by air. A gas is an elastic fluid, and differs very considerably, from water; for a gas will fill a large or small space with equal convenience, like the genii which came out of the bottle and obligingly retired into it again to please the fisherman. We have seen that the pressure of the air is 14⅘ per square inch at a temperature of 32°. It is not so easy to determine the pressure of air at various times as that of water. We can always tell the pressure of a column of water when we find the height of the column, as it is the weight of so many cubic inches of the liquid. But the pressure of the atmosphere per square inch at any point is equal to the weight of a vertical column of air one inch square, reaching from that point to the limit of the atmosphere above it. Still the density is not the same at all points, so we have to calculate. The average pressure at sea level is 14·7 per square inch, and sustains a column of mercury 1 square inch in thickness, 29·92, or say 30 inches high. These are the data upon which the barometer is based, as we have seen.

Fig: 56.—The "Ludion."

In our article upon "Chemistry" we will speak more fully of the atmosphere and of its constituents, etc.

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CHAPTER VI.

ABOUT WATER—HYDROSTATICS AND HYDRAULICS—LAW OF ARCHIMEDES —THE BRAMAH PRESS—THE SYPHON.

At present we will pass from Air to Water, from Pneumatics to Hydrostatics and Hydraulics. We must remember that Hydrostatics and Hydraulics are very different. The former treats of the weight and pressure of liquids when they are at rest, the latter treats of them in motion. We will now speak of the properties of Liquids, of which Water may be taken as the most familiar example.

We have already seen that Matter exists in the form of Solids, Liquids, and Gases, and of course Water is one form of Matter. It occupies a certain space, is slightly compressible; it possesses weight, and exercises force when in motion. It is a fluid, but also a liquid. There are fluids not liquid, such as air or steam, to take equally familiar examples. These are elastic fluids and compressible, while water is inelastic, and termed incompressible.

The chemical composition of water will be considered hereafter, but at present we may state that water is composed of oxygen and hydrogen, and proportions of eight of the former to one of the latter by weight; in volume the hydrogen is as two to one.

From these facts, as regards water, we learn that volume and weight are very different things,—that equal volumes of various things may have different weights, and that volume (or bulk) by no means indicates weight Equal volumes of feathers and sand will weigh very differently.

> [The old "catch" question of the "difference in weight between a pound of lead and a pound of feathers" here comes to the mind. The answer generally given is that "feathers make the heavier 'pound' because they are weighed by avoirdupois, and lead by troy weight." This is an error. They are both weighed in the same way, and pound for pound are the same *weight*, though different in *volume*.]

Fluids in equilibrium have all their particles at the same distance from the centre of the earth, and although within small distances liquids appear perfectly level (in a direct line), they must, as the sea does, conform to the shape of the earth, though in small levels the space is too limited to admit of any deviation from the plane at right angle to the direction of gravity.

Liquids always fall to a perfectly level surface, and water will seek to find its original level, whether it be in one side of a bent tube, in a watering pot and its spout, or as a fountain. The surface of the water will be on the same level in the arms of a bent tube, and the fountain will rise to a height corresponding with the elevation of the parent spring whence it issues. [Pg 60] The waterworks companies first pump the water to a high reservoir, and then it rises equally high in our high-level cisterns.

As an example of the force of water, a pretty little experiment may be easily tried, and, as many of our readers have seen in a shop in the Strand in London, it always is attractive. A good-sized glass shade should be procured and placed over a water tap and basin, as per the illustration herewith. Within the glass put a number of balls of cork or other light material. Let a stop-cock, with a small aperture, be fixed upon the tube leading into the glass. Another tube to carry away the water should, of course, be provided, but it may be used over again. When the tap is properly fixed, if the pressure of the water be sufficient, it will rush out with some force, and catching the balls as they fall to the bottom of the glass shade bear them up as a juggler would throw oranges from hand to hand. If coloured balls be used the effect may be enhanced, and much variety imparted to the experiment, which is very easy to make.

Fig. 57.—Water jet and balls.

Water exercises an enormous pressure, but the pressure does not depend upon the amount of water in the vessel. It depends upon the vessel's height, and the dimensions of the base. This has been proved by filling vessels whose bases and heights are equal, but whose shapes are different, each holding a different quantity of water. The pressure at the bottom of each [Pg 61] vessel is the same, and depends upon the depth of the water. If we subject a portion of the liquid surface to certain force, this pressure will be dispersed equally in all directions, and from an acquaintance with this fact the Hydraulic Press was brought into notice. If a vessel with a horizontal bottom be filled with water to a depth of one foot, every square foot will sustain a pressure of 62·37 lbs., and each square inch of 0·433 lbs.

Figs. 58, 59, 60, 61.—Pressure of Water.

We will now explain the principle of this WATER PRESS. In the small diagram, the letters A B represent the bottom of a cylinder which has a piston fitted in it (P). Into the opposite side a pipe is let in, which leads from a force-pump D, which is fitted with a valve E, opening upwards. When the piston in D is pulled up water enters through the valve; when the piston is forced down the valve shuts, and the water rushes into the chamber A B. The pressure pushes up the large piston with a force multiplied as many times as the area of the small piston is contained in the large one. So if the large one be ten times as great as the small one, and the latter be forced down with a 10 lb. pressure, the pressure on the large one will be 100 lbs., and so on.

The accompanying illustration shows the form of the Hydraulic or Bramah Press. A B C D is a strong frame, F the force-pump worked by means of a lever fixed at G, and H is the counterprise. E is the stop-cock to admit the water (fig. 63).

Fig. 62.—Water Press.

The principles of hydrostatics will be easily explained. The Lectures of M. Aimé Schuster, Professor and Librarian at Metz, have taught us in a very simple manner the principle of Archimedes, in which it is laid down that "a body immersed in a liquid loses a portion of its weight equal to the weight of the liquid displaced by it." We take [Pg 62] a body of as irregular form as we please; a stone, for example. A thread is attached to the stone, and it is then placed in a glass of water full up to the brim. The water overflows; a volume of the liquid equal to that of the stone runs over. The glass thus partially emptied is then dried, and placed on the scale of a balance, beneath which we suspend the stone; equilibrium is established by placing some pieces of lead in the other scale. We then take a vase full of water, into which we plunge the stone suspended from the scale, supporting the vase by means of bricks. The equilibrium is now broken; to re-establish it, it is necessary to fill up with water the glass placed on the scale; that is to say, we put back in the glass the weight of a volume of water precisely equal to that of the stone.

Fig. 63.—Bramah Press.

Fig. 64.—Demonstration of the upward pressure of liquids.

If it is desired to investigate the principles relating to connected vessels, springs of water, artesian wells, etc., two funnels, connected by means of an india-rubber tube of certain length, will serve for the demonstration; and by placing the first funnel at a higher level, and pouring in water abundantly, we shall see that it overflows from the second.

A disc of cardboard and a lamp-glass will be all that is required to show the upward pressure of liquids. I apply to the opening of the lamp-glass a round piece of cardboard, which I hold in place by means of a string; the tube thus closed I plunge into a vessel filled with water. The piece of cardboard is held by the pressure of the water upwards. To separate it from the opening it suffices to pour some water into the tube up to the level of the water [Pg 63] outside (fig. 64). The outer pressure exercised on the disc, as well as the pressure beneath, is now equal to the weight of a body of water having for its base the surface of the opening of the tube, its depth being the distance from the cardboard to the level of the water.

Syringes, pumps, etc., are the effects of atmospheric pressure. Balloons rise in the air by means of the pressure of gas; a balloon being a body plunged in gas, is consequently submitted to the same laws as a body plunged in water.

Boats float because of the pressure of liquid, and water spurts from a fountain for the same reason. I recollect having read a very useful application of the principles of fluid pressure.

Fig 65.—Experiment on the convexity of a meniscus.

A horse was laden with two tubs for carrying a supply of water, and in the bottom of the tubs a valve was fixed. When the horse entered the stream the tubs were partly immersed; the water then exercised its upward pressure, the valve opened, and the tubs slowly filled. When they were nearly full the horse turned round and came out of the water; the pressure had ceased.

Thus the action of the water first opened the valve, and then closed it.

The particular phenomena observable in the water level in narrow spaces, as of a fine glass tube, or the level of two adjoining waves, capillary phenomena, etc., do not need any special [Pg 64] appliance for demonstration, and it is the same with the convexity or concavity of meniscuses.

Fig. 65 represents a pretty experiment in connection with these phenomena. I take a glass, which I fill up to the brim, taking care that the meniscus be concave, and near it I place a pile of pennies. I then ask my young friends how many pennies can be thrown into the glass without the water overflowing. Everyone who is not familiar with the experiment will answer that it will only be possible to put in one or two, whereas it is possible to put in a considerable number, even ten or twelve. As the pennies are carefully and slowly dropped in, the surface of the liquid will be seen to become more and more convex, and one is surprised to what an extent this convexity increases before the water overflows.

Fig. 66.—The Syphon.

The common *syphon* may be mentioned here. It consists of a bent tube with limbs of unequal length. We give an illustration of the syphon (fig. 66). The shorter leg being put into the mixture, the air is exhausted from the tube at *o*, the aperture at *g* being closed with the finger. When the finger is removed the liquid will run out. If the water were equally high in both legs the pressure of the atmosphere would hold the fluid in equilibrium, but one leg being longer, the column of water in it preponderates, and as it falls, the pressure on the water in the vessel keeps up the supply.

Apropos of the syphon, we may mention a very simple application of the principle. Cut off a strip of cloth, and arrange it so that one end shall remain in a glass of water while the other hangs down, as in the illustration. In a short time the water from the upper glass will have passed through the cloth-fibres to the lower one (fig. 67).

This attribute of porous substances is called *capillarity*, and shows itself by *capillary attraction* in very fine pores or tubes. The same phenomenon is exhibited in blotting paper, sugar, wood, sand, and lamp-wicks, all of which give familiar instances of capillarity. The cook makes use of this property by using thin paper to absorb grease from the surface of soups.

Capillarity (referred to on page 25) is the term used to define capillary force, and is derived from the word *capillus*, a hair; and so very small bore tubes are called capillary tubes. We know that when we plunge a glass tube into water the liquid will rise up in it, and the narrower the tube the higher the water will go; moreover, the water inside will be higher than at the outside. This is in accordance with a well-known law of adhesion, which induces concave or convex surfaces[9] in the liquids in the tubes, according as the tube is wetted with the liquid or not. For instance, water, as we have said, will be higher in the tube, and [Pg 65] concave in form; but mercury will be depressed below the outside level, and convex, because mercury will not adhere to glass. When the force of cohesion to the sides of the tube is more than twice as great as the adhesion of the particles of the liquid, it will rise up the sides, and if the forces be reversed, the rounded appearance will follow. This accounts for the convex appearance, or "meniscus," in the column of mercury in a barometer.

Amongst the complicated experiments to demonstrate molecular attraction, the following is very simple and very pretty:—Take two small balls of cork, and having placed them in a basin half-filled with water, let them come close to each other. When they have approached within a certain distance they will rush together. If you fix one of them on the blade of your penknife, it will attract the other as a magnet, so that you can lead it round the basin (fig. 68). But if the balls of cork are covered with grease they will *repel* each other, which fact is accounted for by the form of the *menisques*, which are convex or concave, according as they are moistened, or preserved from action of the water by the grease.

Fig. 67.—An improvised syphon.

This attribute is of great use in the animal and vegetable kingdoms. The rising of the sap is one instance of the latter.

Experience in hydrostatics can be easily applied to amusing little experiments. For instance, as regards the syphon, we may make an image of *Tantalus* as per illustration (fig. 69). A [Pg 66] wooden figure may be cut in a stooping posture, and placed in the centre of a wide vase, as if about to drink. If water be poured slowly into the vase it will never rise to the mouth of the figure, and the unhappy *Tantalus* will remain in expectancy. This result is obtained by the aid of a syphon hidden in the figure, the shorter limb of which is in the chest. The longer limb descends through a hole in the table, and carries off the water. These vases are called *vases of Tantalus*.

The principle of the syphon may also be adapted to our domestic filters. Charcoal, as we know, makes an excellent filter, and if we have a block of charcoal in one of those filters,—now so common,—we can fix a tube into it, and clear any water we may require. It sometimes (in the country) happens that drinking-water may become turgid, and in such a case the syphon filter will be found useful.

Fig. 68.—Molecular attraction.

The old "deception" jugs have often puzzled people. We give an illustration of one, and also a sketch of the "deceptive" portion (figs. 70 and 71). This deception is very well managed, and will create much amusement if a jug can be procured; they were fashionable in the eighteenth century, and previously. A cursory inspection of these curious utensils will lead one to vote them utterly useless. They are, however, very quaint, and if not exactly useful are ornamental. They are so constructed, that if an inexperienced person wish to pour out the wine or water contained in them, the liquid will run out through the holes cut in the jug. [Pg 67]

To use them with safety it is necessary to put the spout A in one's mouth, and close the opening B with the finger, and then by drawing in the breath, cause the water to mount to the lips by the tube which runs around the jug. The specimens herein delineated have been copied from some now existent in the museum of the Sèvres china manufactory.

The *Buoyancy of Water* is a very interesting subject, and a great deal may be written respecting it. The swimmer will tell us that it is easier to float in salt water than in fresh. He knows by experience *how difficult it is to sink* in the sea; and yet hundreds of people are drowned in the water, which, if they permitted it to exercise its power of buoyancy, would help to save life.

Fig. 69.—Vase of Tantalus.

The sea-water holds a considerable quantity of salt in solution, and this adds to its resistance, or floating power. It is heavier than fresh water, and the Dead Sea is so salt that a man cannot possibly sink in it. This means that the man's body, bulk for bulk, is much lighter than the water of the Dead Sea. A man will sink in fresh, or ordinary salt water if the air in his lungs be exhausted, because without the air he is much heavier than water, bulk for bulk. So if anything is weighed in water, it apparently loses in weight exactly equal to its own bulk of water.

Water is the means by which the *Specific Gravity* of liquids or solids is found, and by it we can determine the relative densities of matter in proportion. Air is the standard for gases and vapours. Let us examine this, and see what is meant by SPECIFIC GRAVITY. [Pg 68]

We have already mentioned the difference existing between two equal volumes of different substances, and their weight, which proves that they may contain a different number of atoms in the same space. We also know, from the principle of Archimedes, that *if a body be immersed in a fluid, a portion of its weight will be sustained by the fluid equal to the weight of the fluid displaced*.

Fig. 70.—Deception jugs of old pattern.

[This theorem is easily proved by filling a bucket with water, and moving it about in water, when it will be easy to lift; and likewise the human body may be easily sustained in water by a finger under the chin.]

The manner in which Archimedes discovered the displacement of liquids is well known, but is always interesting. King Hiero, of

Syracuse, ordered a crown of gold to be made, and when it had been completed and delivered to His Majesty, he had his doubts about the [Pg 69] honesty of the goldsmith, and called to Archimedes to tell him whether or not the crown was of gold, pure and simple. Archimedes was puzzled, and went home deep in thought. Still considering the problem he went to the bath, and in his abstraction filled it to the brim. Stepping in he spilt a considerable quantity of water, and at once the idea struck him that any body put into water would displace its own weight of the liquid. He did not wait to dress, but ran half-naked to the palace, crying out, "Eureka, Eureka! I have found it, I have found it! "What had he found?—He had solved the problem.

Fig. 71.—Section of jug.

He got a lump of gold the same weight as the crown, and immersed it in water. He found it weighed nineteen times as much as its own bulk of water. But when he weighed the kings crown he found it displaced more water than the pure gold had done, and consequently it had been adulterated by a lighter metal. He assumed that the alloy was silver, and by immersing lumps of silver and gold of equal weight with the crown, and weighing the water that overflowed from each dip, he was able to tell the king how far he had been cheated by the goldsmith.

Fig. 72.—Weighing metal in water.

It is by this method now that we can ascertain the specific gravity of bodies. One cubic inch of water weighs about half an ounce (or to be exact, 252½ grains). Take a piece of lead and weigh it in air; it weighs, say, eleven ounces. Then weigh it in a vase of water, and it will be only ten ounces in weight. So lead is eleven times heavier than water, or eleven ounces of lead occupy the same space as one ounce of water.

[The heavier a fluid is, or the greater its density, the greater will be the weight it will support. Therefore we can ascertain the purity or otherwise of certain liquids by using hydrometers, etc., which will float higher or lower in different liquids, and being gauged at the standard of purity, we can ascertain (for instance) how much water is in the milk when supplied from the dairy.]

Fig. 73.—Hydrometer.

But to return to Specific Gravity, which means the "Comparative density of any substance relatively to water," or as Professor Huxley says, "The weight of a volume of any liquid or solid in proportion to the weight of the same volume of water, at a known temperature and pressure." [Pg 70]

Water, therefore, is taken as the unit; so anything whose equal volume under the same circumstances is twice as heavy as the water, is declared to have its specific gravity 2; if three-and-a-half times it is 3·5, and so on. We append a few examples; so we see that things which possess a higher specific gravity than water sink, which comes to the same thing as saying they are heavier than water, and *vice versâ*.

To find the specific gravity of any solid body proceed as above, in the experiment of the lead. By weighing the substance in and out of water we find the weight of the water displaced; that is, the first weight less the second. Divide the weight in air by the remainder, and we shall find the specific gravity of the substance.

Fig. 74.—Over-shot wheel of mill.

The following is a table of specific gravities of some very different substances, taking water as the unit.

Substance.	Specific Gravity.	Substance.	Specific Gravity.	Substance.	Specific Gravity.
Platinum	21·5	Iron	7·79	Water	1·000
Gold	19·5	Tin	7·29	Sea Water	1·026
Mercury	13·59	Granite	2·62	Rain Water	1·001
Lead	11·45	Oak Wood	0·77	Ice	·916
Silver	10·50	Cork	0·24	Ether	0