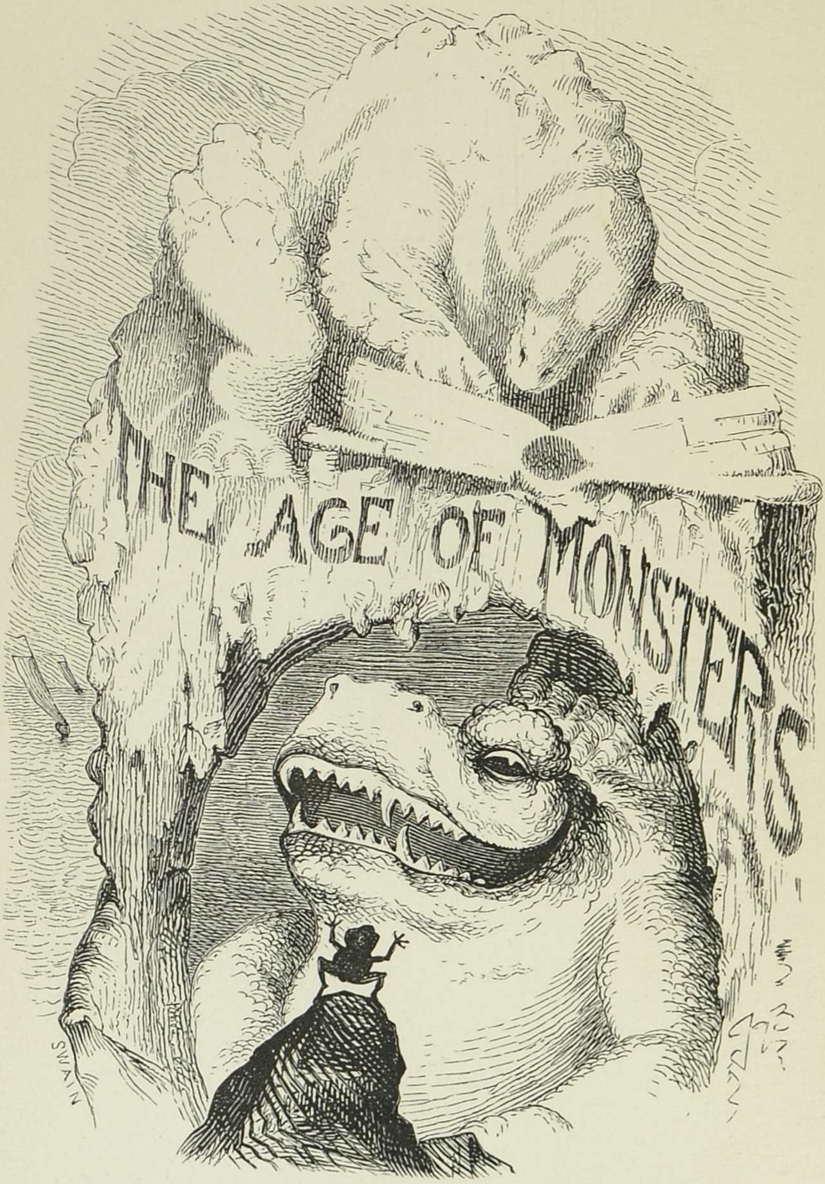
FAIRY TALES OF SCIENCE


THE AGE OF MONSTERS
SWAIN

THE FAIRY TALES OF SCIENCE.

A BOOK FOR YOUTH.

BY

JOHN CARGILL BROUGH.

WITH SIXTEEN ILLUSTRATIONS
BY CHARLES H. BENNETT.

SECOND EDITION REVISED BY THE AUTHOR.

'Here about the beach I wander'd, nourishing a youth sublime,
With the fairy tales of science, and the long result of time.'
TENNYSON.

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PREFACE.

TO place before the youthful student a compact and concise compendium of the leading and most universally important branches of Science, has been my principal object in the preparation of this little volume.

To adapt the work to the capacity of all, I have endeavoured to divest the different subjects treated in it of hard and dry technicalities, and to clothe them in the more attractive garb of fairy tales—a task by no means easy.

That I have been obliged, in the composition of the work, to consult a crowd of authorities, need hardly be stated, nor will any more formal enumeration or systematic acknowledgment be expected.

In the fanciful sketches which illustrate these pages, my friend Mr C. H. Bennett has most fully entered into the spirit in which I conceived the work.

I have to tender my sincere thanks to my esteemed friend, Dr G. L. Strauss, who came to my aid at a time when severe indisposition seemed to threaten that many of these Fairy Tales of Science should remain untold.

J. C. B.

STOCKWELL, 1858.

ADVERTISEMENT TO THE SECOND EDITION.

IN revising this little work, the Author has been compelled to make many alterations, in consequence of the great progress of science during the last seven years. Three chapters have been entirely re-written, and all have been carefully revised. The few atomic weights and names of compounds that are given in the chapters on chemical subjects are those adopted by the modern school of chemists. Though the work embraces a great many subjects, the Author believes that the information afforded by each chapter is sound and accurate.

STOCKWELL, *October* 1865.

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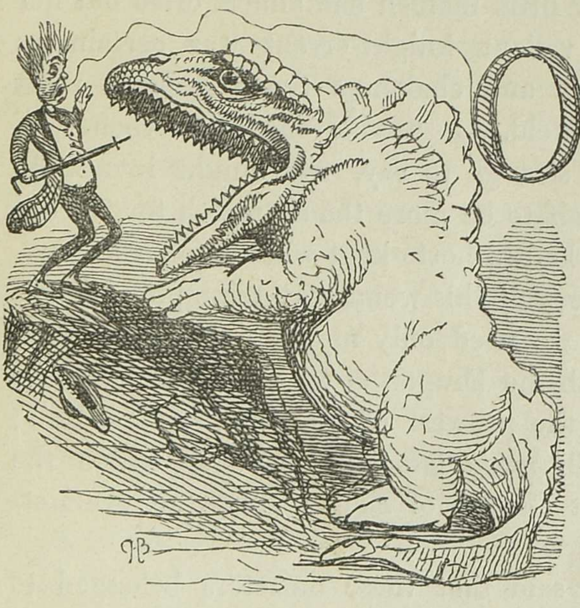
The Age of Monsters.

'Mighty pre-Adamites that walked the earth
Of which ours is the wreck.'—BYRON.



ONCE upon a time—if we are to believe our Fairy books—a terrible race of monsters devastated this fair earth. Dragons and Griffins roamed at large, and a passing visit from one of these rapacious creatures was held to be the greatest calamity that could befall a nation. All the King's horses and all the King's men were powerless in the presence of such a foe, and the bravest monarch stooped to purchase his own safety with the most humiliating concessions. The dragon was allowed to run riot over the face of the country; to devour the flocks and herds at his pleasure ; and when sheep and oxen ceased to gratify him, scores of beautiful damsels were sacrificed to allay the cravings of his ravenous appetite.

Sometimes the fastidious monster would go so far as to order a princess for dinner, but he generally had to pay dearly for his audacity. When the monarch had exhausted his stock of prayers, and the poor little maiden had almost cried out her eyes, some valiant knight-errant was certain to come forward and challenge the dragon to meet him in the field. A terrific encounter then took place; and, strange to say, the knight invariably proved himself to be more than a match for the destroyer who had hitherto kept whole armies at bay.

As instances of this wonderful triumph of Right over Might, we need only mention that celebrated duel in which the Dragon of Wantley was forced to succumb to the prowess of Moore of Moore Hall; and that still more famous combat in which the invincible St George of England won an everlasting renown.

We have said that these monsters belonged to that mythical age known as 'once upon a time;' unfortunately we can find no trace of them in authentic history, and are compelled to admit that they had their origin in the fanciful brains of those old story-tellers whose wondrous legends we delight to linger over.

In more credulous times, however, these monsters of enchantment were religiously believed in, and no one doubted that they had their lairs in the dark and impenetrable forests, in the desolate mountain passes, and in those vast and gloomy caverns which are even now regarded with superstitious dread by the ignorant.

At length the lamp of science was kindled, and its beneficent rays penetrated the darkest recesses of the earth; roads were cut through the tangled woods, busy factories sprang up in the lonely glens, and curious man even ventured to pry into the secrets of those terrible caves. The monsters of romance were nowhere to be found. Triumphant science had banished them from the realms of fact, with the same pitiless severity that the uncompromising St Patrick had previously displayed towards the poisonous reptiles of Ireland.

The poor ill-used Dragon has now no place to lay his scaly head, the Griffin has become a denless wanderer, and the Fiery Serpent has been forced to emigrate to a more genial clime!

Fortunately truth is stranger than fiction; the revelations of modern science transcend the wildest dreams of the old poets; and in exchange for a few shadowy griffins and dragons, we are presented with a whole host of monsters, real and tangible monsters too, who in the early days of the world's history were the monarchs of all they surveyed, and had no troublesome Seven Champions to dispute their sway.

. . . . .

We are on the shores of the Ancient Ocean. We search in vain for any sign of man's handiwork; no iron steam-ship, no vessel of war, no rude canoe even, has yet been launched upon its bosom, though the tides ebb and flow, and the waves chant their eternal hymn, according to those immutable laws which the Creator ordained at the beginning.

The ocean teems with life, but it contains no single creature which has its exact likeness in modern seas. Its fishes belong for the most part to the great Shark family, but their forms are much more uncouth than those of their savage descendants. Whales, dolphins, and porpoises are not to be found in these waters; but their places are filled up by strange marine reptiles, which equal them in bulk, and greatly surpass them in voraciousness.

Yonder is one of these old monsters of the deep:[1] as it rests there with its broad back glistening in the sun, it might easily be mistaken for some rocky islet; but see, it moves! Now it lashes the water with its enormous tail, creating quite a whirlpool in its neighbourhood; now it raises its huge head, and displays a row of teeth at which the bravest might shudder; and now it darts away from the

[1] The Cetiosaurus, or *Whale-like Lizard.*

shore, leaving a wide track of foam on the dark blue waters.

Another member of the Saurian or Lizard race is disporting himself in a little bay close by. The imagination of man never called up a shape so weird and fantastic as this, in which we see combined a fish-like body, a long serpentine neck, and the tapering tail of a lizard.[1] As he paddles through the water with his neck arched over his back in a graceful curve, he looks a very handsome fellow, in spite of the somewhat evil expression of his countenance; but he is anything but handsome, if we judge him by the adage which restricts the use of that epithet to handsome doers. Look at him now: how eagerly he pounces upon every living thing that comes within the range of his pliant neck, how cruelly he crushes the bones of his victims, and how greedily he devours them! We never witnessed such unhandsome conduct in a monster before. Leaving him at his disgusting banquet, let us penetrate into the interior of the old continent, where we shall encounter some terrestrial reptiles of a very formidable character.[2]

We are in the heart of a strange, wild country. At our feet runs a mighty river, whose tortuous course we can trace far away on the distant landscape. The scenery around us is grandly picturesque, being diversified by high mountains with

[1] The Plesiosaurus.
[2] The Dinosaurians, or *Fearfully-great Lizards*.

harsh and rugged outlines, yawning chasms, swampy plains, and thick forests. Here a broad stream dashes impetuously through a narrow glen, and there a placid lake glistens like polished silver. Huge masses of rock arise in a thousand fantastic forms on one side, while on the other vast desert tracts, monotonously level, spread out as far as the eye can reach.

The general aspect of the country is utterly unlike that of any modern land, and we gaze on the savage panorama before us with mingled feelings of admiration and awe. We are surrounded by wonders. The vegetation which fringes the banks of the river is strangely unfamiliar. Some of the trees remind us of the palms and arborescent ferns of the tropics, and others seem to be allied to the cypress and juniper; but they all belong to unknown species.

The air, which is hot and oppressive, swarms with insects; curious flies and beetles hum around us, and every now and then a huge dragon-fly darts past like a meteor.

Looking towards the river, other more striking forms of animal life meet our gaze. Hundreds of gigantic crocodiles are swimming in the stream and lying on the muddy shore; horrible creatures are they, with their thick coats of mail and sharp elongated muzzles, and we cannot watch their ungainly movements without experiencing an involuntary sensation of disgust.

On the oozy banks of the river another type of reptilian life is represented by a shoal of fresh-water turtles, which we see crawling along at a slow and steady pace. Now one of these sluggish fellows stops to pick up some dainty morsel (a mussel perhaps, a snail, or a crocodile's egg); but the exertion appears to cost him no small annoyance, and now he draws in his head and prepares for a nap. As he has in all probability a hundred years yet to live, he can afford to devote an hour or two to digestion.

But hark! What noise was that? Surely that harsh discordant roar must have proceeded from the deep throat of some monster concealed in yonder forest. The crocodiles seem to understand it perfectly; for see, they are making for the opposite bank with most undignified speed. There it is again, still louder than before! Now a crashing among the trees, followed by a wild unearthly shriek.

Look at that terrible form which has just emerged from the thicket. It rushes towards us, trampling down the tall shrubs that impede its progress as though they were but so many blades of grass. Now it stops as if exhausted, and turns its huge head in the direction of the forest.

How shall we describe this monster of the Old World, which is so unlike any modern inhabitant of the woods? Its body, which is at least twenty feet long, is upheld by legs of proportional size, and a massive tail, which drags upon the ground and forms a fifth pillar of support. Its head is hideously ugly, its immense jaws and flat forehead recalling the features of those grim monsters which figure in our story-books. Its dragon-like appearance is still further increased by a ridge of large triangular bones or spines which extends along its back.[1] We should not be at all surprised were we to see streams of fire issuing from the mouth of this creature, and we look towards the palm-forest half expecting a St George to ride forth on his milk-white charger.

See!—some magic power causes the trees to bend and fall—the dragon-slayer is approaching! Gracious powers! It is not St George, but another Dragon nearly double the size of the first. He proclaims his arrival by a loud roar of defiance, which is unanswered save by the echoes of the surrounding hills. The first monster tries to conceal himself behind a clump of trees, and preserves a discreet silence, being evidently no match for his formidable challenger.

The new-comer is certainly a very sinister-looking beast. His magnitude is perfectly astounding. From the muzzle to the tip of his tail he seems to measure about forty feet, and his legs are at least two yards long. His feet are furnished with sharp claws for tearing the flesh from the bones of his victims, and his teeth are fearful instruments of

[1] The Hylæosaurus, or *Wealden Lizard.*

destruction, each tooth being curved, and pointed like a sabre, with jagged saw-like edges.[1] His disposition is decidedly unamiable. Look at him now: how furiously he tears up the earth, and how savagely he looks about him for some trace of his lost prey! Now he catches a glimpse of the crested monster among the trees, and dashes towards him with a terrific yell of delight.

Alas! there is no escape for you, unfortunate Dragon! The great monster can outstrip you in the chase, and you may as well show a bold front.

Now they meet in the hollow with a fearful crash. The lesser monster is determined to sell his life dearly, and with the aid of the spines along his back he contrives to inflict some severe wounds upon the huge body of his opponent.

What a fearful conflict! How they snort and roar! Now they roll over among the ferns, linked together in a terrible embrace. The hero of the crest is the first to rise; he makes off towards the forest, and may yet escape. Alas! he falls exhausted, and the great monster is on his track. His temper does not seem to be improved by his wounds; —how angrily he tosses his head, and how fiercely he gnashes his sabre-like teeth! He approaches his fallen enemy. Now he jumps upon him with a crushing force, and now his enormous jaws close upon the neck of his victim, who expires with a shriek of pain.

[1] The Megalosaurus, or *Great Lizard.*

We can gaze no longer at this awful scene. The battle was sufficiently exciting to absorb our attention, but we have no desire to see how the great monster disposes of the body of his valiant foe. Let us therefore leave the river bank, and visit another portion of the old continent.

We stand in a lovely valley surrounded on all sides by high mountains, whose slopes are covered with luxuriant vegetation. A crystal stream meanders through the fertile plains, and runs into a fairy-like lake, upon whose margin there are little groups of arborescent ferns and palms. The whole valley has the appearance of a rich garden, and we regard its varied beauties with rapturous admiration.

As we look around we fail to discover any trace of man: no temple, palace, nor hut bears witness to the existence of a being capable of appreciating the charms of which nature has been so prodigal. We are profound egotists, and think that everything beautiful must have been created for our especial advantage. Here, however, trees spring up though there be no woodman to hew them down, fruits ripen though there be none to gather them, and the stream flows though there be no mill to set in motion; in fact, the age of Man has not yet dawned upon the earth.

We have already seen some of the weird inhabitants of the Old World: this valley is the favourite haunt of another and a still more remarkable creature, who loves the shelter which these trees afford.

Yonder is one of these extraordinary monsters. He has just emerged from the forest, and is marching towards the lake slowly and majestically, a regular moving mountain! His legs are like trunks of trees, and his body, which rivals that of the elephant in bulk, is covered with scales. In length and height he equals the great lizard we have already described, but his whole appearance is far less awe-inspiring. There is a good-humoured expression in his face, and his teeth are not nearly so formidable as those of his predacious neighbour, being blunt and short, and evidently fitted for the mastication of vegetable food.[1]

Look! he is quietly grazing on those luxuriant ferns which lie in his path. Now the foliage of a tall palm-like tree seems to offer a tempting mouthful, but it is beyond his reach. There are more ways than one of procuring a meal: see, the great vegetarian places his fore-paws against the stem of the tree, and coolly pushes it down. Having stript the fallen stem of its sword-like leaves, he plunges into the lake, and flounders about in the water as though the bath were his greatest source of enjoyment. This huge herbivorous monster would probably be no match for the cruel creature whom we left devouring his enemy by the river, as all its actions prove it to be a harmless and peaceably disposed animal.

[1] The Iguanodon, so named from its teeth, which resemble those of a recent lizard called the *Iguana*.

Look at that strange bird overhead. Its body does not appear to be larger than that of a pigeon; but what enormous wings it is provided with! Now it descends. Is it a bird or a large bat? Its wings seem to be formed of leather, and its body has anything but a bird-like form. See! it alights, and runs upon the ground with considerable speed; now it jumps into the lake, and swims about the surface, as if water were its natural element. Again it rises in the air, directing its course towards the spot where we are standing; and now it perches upon a fragment of rock close to us.

What an extraordinary creature! it is neither bird nor bat, but a winged reptile. Its head, which is small and bird-like, and supported on a long slender neck, is provided with elongated jaws, in which are set some fifty or sixty sharp little teeth. Its wing consists of folds of skin, sustained by the outer finger enormously lengthened; the other fingers being short, and armed with powerful claws. Its body is covered with scales instead of feathers; and in addition to this strange mixture of bird-like and reptilian features, the creature is provided with the long stiff tail of a mammal.[1]

Of all the inhabitants of this country of marvels, the Flying Reptile is by far the strangest; and as we gaze upon its weird form, we cannot help comparing it with one of those horrible and grotesque imps which are described so minutely in monkish legends.

[1] The Pterodactyle, or *Wing-fingered Lizard.*

Again the scene changes: the country of the monsters fades away, and we are once more in our cosy study, surrounded by our favourite volumes.

Perhaps the curious reader would like to know where the marvellous country is situated; but as we do not intend to tack a long scientific essay upon our fairy-tale, he must be content with a very few words of explanation.

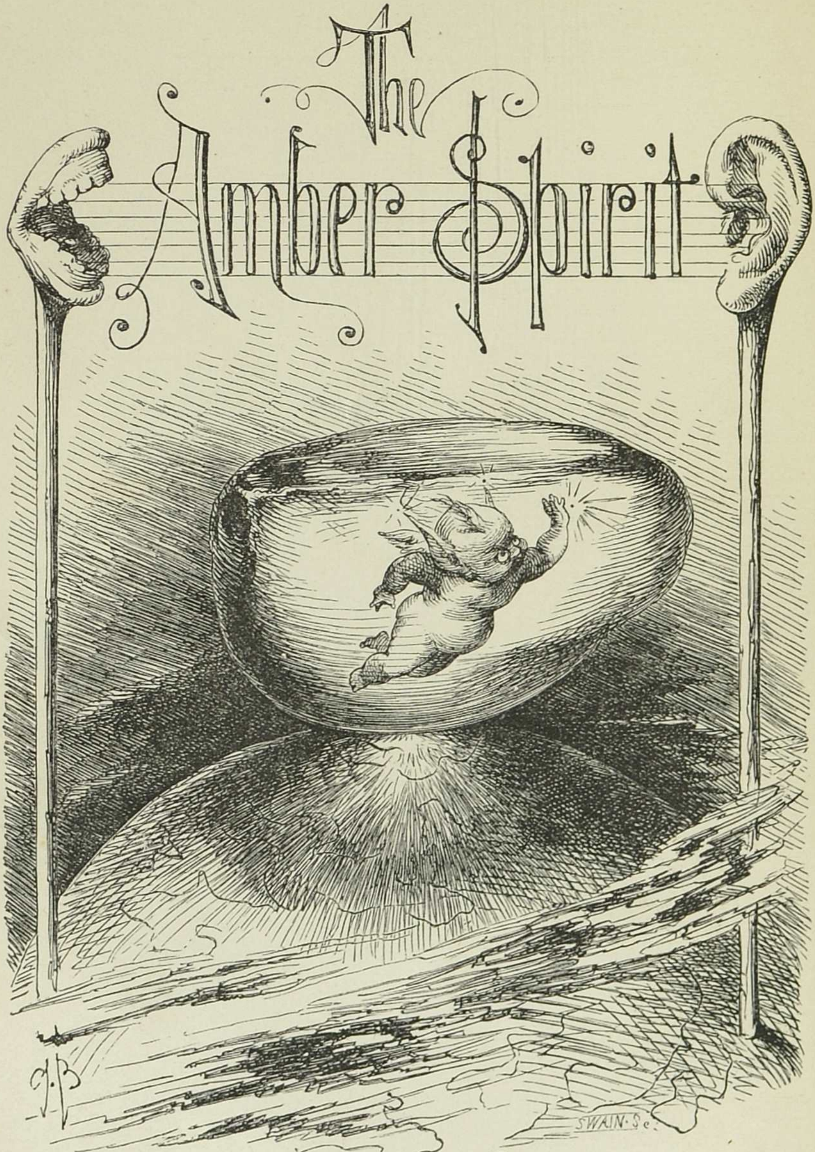
All that remains of the monsters' country is a large tract of land or *delta*, which was formed ages and ages ago at the mouth of a mighty river.[1] The continent through which this river flowed now forms a large portion of the bed of the Atlantic.

How can we know anything about this submerged country?—how can we come to any conclusion respecting the kind of creatures which lived and died there? These questions will probably occur to the reader, and give rise to certain doubts as to the credibility of our narrative.

The monsters have been their own historians. They have described themselves in the gorgeously illuminated volume called the Stone Book, every page of which is formed of the solid rock. The truth of the matter is simply this: when the geologist came to examine the structure of the old river delta, he found embedded in the rocks, broken

[1] The Wealden Beds, so called from their forming a district known as the Weald of Kent and Sussex. These strata, which were deposited at the mouth of a river rivalling the Mississippi in magnitude, occupy the whole area between the North and South Downs.

and water-worn bones, detached teeth, fresh-water shells, fragments of trees, and even the bodies of insects. With untiring industry and perseverance he classified these organic remains; he placed together the gigantic bones, and reproduced the forms of those enormous creatures which are now represented by our tiny frogs and lizards; he examined every leaf and fir-cone, and found out the order of plants to which they belonged; every relic he submitted to a close scrutiny, and at length he was rewarded by a vision of the ancient continent and its inhabitants as they existed at that remote period which we can only vaguely describe as 'once upon a time.'


The Amber Spirit
SWAIN Sc

The Amber Spirit.

Puck. 'I go, I go; look how I go,
Swifter than arrow from the Tartar's bow.'
A Midsummer Night's Dream.

THAT merry wanderer of the night, Puck, who boasted that he could 'put a girdle round about the earth in forty minutes,' was a sluggard compared with the fairy messenger who now flies hither and thither at our bidding, with a velocity which might carry him round the globe several times in a single second. Four and twenty centuries have elapsed since Thales of Miletus evoked this nimble Spirit by rubbing a piece of yellow amber; just as the heroes of Romance summoned genii, fairies, and hobgoblins, by the friction of rings and amulets. The Greek name for amber was *electron*, and thus our Spirit came to be called *Electricity*.

The ancients were ignorant of the potency of this ethereal being; indeed, their knowledge was confined to the isolated fact that amber, when rubbed, acquired the property of attracting light bodies.

The grander manifestations of the Amber Spirit's power received a religious interpretation: thus, the forked flashes which sometimes darted through the sky were supposed to come from the hand of the mighty Thunderer; and those fiery meteors which now and then rested on the javelins of the Roman legionaries, were looked upon as omens of victory sent by the War-god.

It was left for modern philosophers to trace these great phenomena to the Amber Spirit, and to show that his presence may be detected, not only in the fossil gum which Thales imagined to be his favourite haunt, but in every particle of dust and every drop of water.

Let us now describe the cunning means which man employed to enslave this wild Spirit. Two hundred years ago the fragments of amber were laid aside, and a large globe of sulphur was set whirling on a vertical axis, whilst it was rubbed by the hand. By this machine the Spirit was dragged from his hiding-place, and made to reveal some important secrets. Flashes of light issued from this revolving globe, and balls of pith, feathers, and straw danced towards it as though endowed with life.

Sixty years later the discovery was made that all solid bodies may be divided into two great classes, namely, those which, when held in the hand and rubbed, set free the Amber Spirit; and those which, under similar circumstances, fail to exhibit any attractive force. Amber, sulphur, and glass belong to the first class; all the metals to the second. It was also found that certain bodies allowed the Spirit to pass along them with great celerity, while others completely obstructed his passage.

Towards the middle of the last century, cylinders, spheres, and plates of glass, were substituted for the cumbrous globe of sulphur, and with these new implements man began to forge the chains which were to bind the subtle Spirit.

In the year 1746, an ingenious Dutchman actually managed to coax him into a glass bottle, coated within and without with metal;[1] but the Spirit soon escaped from his narrow prison by passing through the limbs and body of the experimentalist, who received such a violent shock that he was compelled to take to his bed. This incident, however, did not deter the philosopher from prosecuting his inquiries, and his endeavours to construct a secure prison were eventually crowned with success.

Six years after this, an American sage summoned the now docile Spirit from the clouds during a thunderstorm, by means of a boy's kite, and thus proved the identity of lightning and that force which for two thousand years was regarded as an emanation peculiar to rubbed amber.

The nineteenth century was heralded in by the announcement of a still greater fact. A learned Italian now found that he could dispense with all the old machinery of incantation, and evoke the

[1] The Leyden Jar.

Amber Spirit by the action of acids upon metals. He piled up alternate disks of zinc and copper, kept separate by the interposition of moistened paste-board, and with this simple apparatus[1] he obtained absolute control over the movements of the Spirit. He compelled him to travel along metal wires of any length; to force asunder the elementary atoms of water; to bring to light substances hitherto unknown; and to perform a hundred other feats equally wonderful. The Spirit was vanquished—the lightning was chained—and man reigned supreme.

It had long been suspected that the magnet owed its peculiar properties to the Amber Spirit, but the occult relation that subsisted between them had never been detected. This mystery was now cleared up by a Danish philosopher. He caused the Spirit to travel along a wire from south to north, and beneath this wire he placed a compass-needle. The Spirit passed, and lo! the magic needle moved, and assumed a position at right angles with the wire. It no longer pointed to the north, but obeyed the peremptory mandates of the potent Spirit. New facts were soon brought to light; thus it was shown that the Spirit could render iron magnetic. A copper wire was coiled round a bar of soft iron, and our Spirit was made to run along the wire: the iron at once became a powerful magnet, and exhibited all the properties of the loadstone.

[1] The Voltaic Pile.

These discoveries enabled man to employ the Amber Spirit as a courier, a vocation for which he is eminently suited, as the speed at which he travels has been estimated at 288,000 miles in a second.[1]

Let us see how our messages may be conveyed.

In London we have a pile of zinc and copper disks, or, what amounts to the same thing, an arrangement of metal plates and acids which we call a *battery*. We have only to connect the extremities of this machine by means of a wire to set the Amber Spirit in motion, and he will continue to move as long as the connection remains complete, but will stop the instant it is broken. His route is from the zinc to the copper through the acid solution, and along the wire back again to the zinc. He will never leave the battery at one end unless he is quite satisfied that he can re-enter it at the other, but while there is nothing to obstruct his course he will continue to circulate through the arrangement without exhibiting the least sign of fatigue.

Let the wire which connects the opposite ends of the battery be long enough to reach to Edinburgh and back; and at the northern capital let there be a mariner's compass placed so that the needle shall be directly below, and parallel to the wire. It is evident that with this simple apparatus we can compel our courier to travel to Scotland and back. Every time we connect the homeward wire with the zinc end of the battery, the Spirit will rush to Edin-

[1] Wheatstone.

burgh, and cause the magic needle stationed there to move.

The deflections of this needle may be converted into intelligible signs. They can be made to spell words: thus, one movement may stand for *a*; two for *b*; three for *c*, and so on to the end of the alphabet.

We have said that our courier will refuse to leave the battery unless he be provided with a return ticket, or in other words, unless he can secure a safe passage home: it does not follow, however, that his homeward path must be a wire, as by a peculiar arrangement we can force him to find his way from Edinburgh to London *through the earth*.

We have supposed that only one kind of motion can be given to the magnetic needle, and that the Amber Spirit can only be made to travel in one direction, that is to say, from the copper end of the battery through the wire, and back again through the earth. If we connect the wire with the zinc end, this direction is reversed, and, as a matter of course, the Spirit passes over the needle from north to south, instead of from south to north as before.

This new direction is at once detected by the needle, and its north pole moves to the right, whereas it had previously moved to the left. We may take advantage of this double movement in simplifying our alphabet: thus, one movement to the right may stand for *a*; one to the left for *b*; one right and one left for *c*, and so forth.

We will not trouble our readers with any more explanations, but will confine ourselves to a consideration of some of the ingenious methods which have been devised to render the Amber Spirit a useful messenger.

Some twenty-eight years ago, a famous man of science in this country[1] proposed a system of five wires, in connection with as many needles, which indicated the letters of the alphabet at the rate of twenty a minute. Attention was to be drawn to the signals by the stroke of a bell, the hammer of which was moved by the magnetic force which the Spirit communicated to a piece of iron; thus the ear as well as the eye was to be addressed. He afterwards simplified this instrument by employing only two wires, and so increased its power that thirty letters could be indicated in a minute.

In America, another philosopher[2] was simultaneously engaged in perfecting a still more extraordinary contrivance, by means of which the Spirit was made to jot down an alphabet of dots and strokes which represented definite characters. One wire only was employed, and the marks were impressed on a moving ribbon of paper by a fine steel point worked by the Spirit's magnetic power. A momentary touch of the point produced a dot or puncture ; a lengthened pressure, a stroke or scratch.[3]

[1] Professor Wheatstone. [2] Professor Morse.

[3] As some of our readers may wonder how a complete system of telegraphic signs can be formed out of two simple marks—

The Spirit had no sooner been taught to write, than man set about teaching him the art of printing. Behold him now a master of the craft, printing messages letter by letter in the ordinary Roman characters, under the direction of an operator stationed at a distant city![1]

The Spirit's education was not yet finished; he had to acquire another accomplishment. He could communicate intelligence by means of moving needles and revolving dials, by written dots and printed characters, but he could not yet imitate the handwriting of the individual who forwarded the message. An ingenious gentleman now took him in hand, and soon made him an expert copyist. A message was written with a non-conducting varnish on a piece of tin-foil in London, and almost as soon as the varnish was dry an exact copy was seen upon paper in Brighton!

The philosopher Thales wondered to see certain minute bodies fly towards a piece of amber; but how great would have been his astonishment had some superior intelligence informed him, that the invisible agent which moved the particles would one day be taught to trace figures upon paper exactly like those just written on a metallic surface by some one far away! We will not attempt to explain the

a stroke and a dot—we give, by way of illustration, the first six letters of Professor Morse's Alphabet: A . — B — . . . C . . . D — . . E . F . — .

[1] Bain's Printing Telegraph.

action of the Spirit's magic copying-press, as it would lead us too far into the dark domain of chemistry.[1]

A hundred systems of communication might be enumerated in addition to those we have noticed, so great has been the intellectual activity of the last twenty years.

In England, America, and many continental countries, iron wires, plated with zinc to prevent rusting, form the principal roads along which our ethereal courier travels. These wires are supported by wooden posts, erected some sixty yards apart on every railway; they are not permitted to touch the wood, but are passed through short tubes of porcelain attached to the posts. Were we to omit these little tubes, the Spirit would shirk his duty, and would travel no farther than the first post, down which he would pass to the earth.

These aërial roads are sometimes rendered impassable by fogs, snow-storms, and heavy rains; they are, moreover, seriously affected by Amber Spirit himself when he takes the form of Lightning. During a thunderstorm everything goes wrong, and the Spirit having escaped from his thraldom, sets man at defiance. He takes possession of the wires and plays a hundred antics. The signal bells ring

[1] The Copying Telegraph invented by Mr F. C. Bakewell, has not displaced the needle and printing instruments. It does not seem to be adapted for ordinary telegraphic work, and is now regarded merely as a beautiful scientific curiosity.

without ceasing; the needles vibrate to and fro, or remain for hours deflected to one side; while the printing machines strike off unmeaning rows of dots and lines, or long sentences of an unknown tongue.

In Prussia, Saxony, and Austria, copper wires, covered with gutta percha, and buried at some little depth in the ground, are commonly employed as a means of communication. These subterranean wires are not subject to the influence of thunderstorms, but in other respects they are more troublesome than those suspended in mid air. The buried wires are greatly affected by the earth's magnetism, and other disturbing influences; moreover, trenches have to be dug for their reception, and they are with difficulty reached when deranged. Thus we see that each kind of road has its peculiar advantages and defects.

As gutta percha effectually cuts off all communication between a wire and surrounding conductors, we make use of this marvellous substance to enclose the wires which convey our Spirit through the sea.

The practicability of these submarine roads was demonstrated in 1849, when a trial was made with two miles of covered wire laid in water. Soon after this a cable was constructed, which enclosed four copper wires covered with gutta percha; and by means of this cable, France and England were brought within a speaking distance of each other.

The Amber Spirit soon gave proofs of his aptitude as a continental messenger, and on the 14th of

November 1851, our great morning journal published a despatch from Paris, dated seven o'clock the preceding evening!

Another cable was now stretched across the Irish Sea, by means of which England was able to exchange civilities with her sister isle. Others followed, and man, emboldened by their success, now began to think of despatching his obedient courier across the Ocean. Europe was covered with a network of wires, and so was America: to unite these two great systems of communication would be a feat unparalleled in the annals of Science.

This wondrous feat was first attempted in 1857. A conducting cable long enough to span the broad Atlantic was constructed, and successfully laid between Valentia, in Ireland, and Newfoundland. On the 10th of August the Amber Spirit commenced his transatlantic journeys, and proved that the idea of connecting the Old and New Worlds was no idle dream. Again and again at man's bidding he sped along the sunken cable, and having registered a single letter at its farther end, found his way back to the battery through the pathless deep. Many long messages were conveyed by him from continent to continent, yet in spelling out a single word of one syllable he had to perform a series of journeys which together far exceeded the length of Puck's famous girdle.[1] But the guardians of the Spirit knew from

[1] On the 31st of August the British Government made use of the Atlantic Telegraph to countermand an order for the return

the first that there were many pitfalls in his submarine road, and that the communication between Europe and America could not last long. Day by day his manifestations became weaker, and at length they ceased to be intelligible. The cable, which had been made in a hurry, was very faulty; and the strong measures that were taken to compel the Spirit to travel along it, destroyed its conducting power altogether. Early in September the cable, representing three quarters of a million sterling, was lying useless at the bottom of the ocean. The nerve that for a brief period had connected the two Anglo-Saxon systems of communication was dead!

Undaunted by the failure of his first great oceanic line, man resolved to lay down another. In the summer of 1865, two thousand five hundred miles of cable were completed and stowed away in the largest vessel ever built.[1] The magic line had been thoroughly tested, and when the *Great Eastern* left the coast of Ireland on the 23d of July, those who remained in charge of the shore end had no fears for the success of the undertaking. For eight days the great ship pursued her course towards Heart's Content, in Newfoundland, and on the 1st of August, at noon, she was 948 miles from Valentia, and had

of the 62d and 39th Regiments from Canada. It is said that this message prevented the useless expenditure of £50,000.

[1] The cable of 1857 was divided between two vessels, the *Niagara* and the *Agamemnon*. They met in the middle of the Atlantic, joined their respective ends, and steamed away in opposite directions.

payed out 1081 miles of cable. Two serious 'faults' had been detected and repaired, but the cable was now running out with delightful monotony, while the Amber Spirit darted backwards and forwards between the ship and the shore. Next morning, soon after daybreak, the Spirit gave warning that another 'fault' had gone overboard, and preparations were at once made to haul up the cable. When more than two miles had been recovered, a portion of the cable which had been chafed and strained in passing over the side of the vessel, received a sudden shock through slipping off the guiding wheel, and immediately after those on board saw a loose end leaping into the sea. Down went the end in two thousand five hundred fathoms of water, and the second attempt to make an oceanic pathway for the Amber Spirit was frustrated. The great ship did not leave the scene of the disaster until the energetic men on board had fished for the sunken treasure. The water was deep enough to drown Mont Blanc, yet the cable lying in the ooze at the bottom was twice caught by the grapnels, and once raised to the height of a mile; but the fishing-tackle used was too weak, and the greater part of it is now lying with the cable on the ocean bed.

These attempts to unite Europe and America have been costly experiments, but they have established the important fact that the Atlantic is neither too broad nor too deep to be traversed by the Amber Spirit. The first cable was successfully laid; but its numerous flaws impeded the Spirit in his passage from shore to shore, and eventually forced him to take a short cut home through the open sea. The second cable was free from the defects of the first, and the Spirit passed through the thousand miles that were payed out without exhibiting any signs of fatigue. The only 'faults' detected in it were produced by minute pieces of iron wire, which had accidentally fallen between the coils and pierced the insulating coating of the copper core. The third attempt to connect the Old and New Worlds will probably be thoroughly successful; but even if this should fail, the day cannot be far distant when the Amber Spirit will travel by several submarine roads between the widely separated shores. Europe, Asia, and Africa have been united; America will soon be joined to the Old World, and then we shall probably attempt to carry our Spirit lines to Australia.[1]

The Amber Spirit has had other duties imposed upon him besides those of a courier.

He has been taught to measure *time* with great accuracy, an accomplishment which scarcely seems to harmonize with his astonishing fleetness. Measuring time must be a tedious occupation to one accustomed to annihilate it; nevertheless, clocks are moved by our versatile Spirit, which have neither weights nor springs, and which will go for ever without winding.

[1] This passage was written soon after the return of the *Great Eastern* in August 1865.

We have seen how needles may be moved and bells rung; let us now consider how a pendulum may be set in motion. A battery is connected with a pendulum of peculiar construction, its bob being formed of a hollow brass reel, on which a long copper wire covered with silk is coiled. In the clock-case, on either side, are magnets, fixed so that their opposite poles enter the reel.

Our readers have already been informed that a magnet freely supported, as in the mariner's compass, will move when the Amber Spirit passes over it. We will now confide to them another secret, namely, that a fixed magnet will give motion to a moveable wire along which the Spirit is passing. We shall now be able to explain the motion of our magic pendulum.

As soon as the Spirit is sent along the coil of wire, the pendulum moves towards one side, being attracted by the one magnet and repelled by the other; but by an ingenious contrivance the connection between the coil and the battery is now broken, and the pendulum falls back by its own weight, again to be pulled aside by the magnets. The pendulum is thus made to oscillate; and so long as there is power enough in the battery to force the Spirit through the coil, it will keep swinging, and give motion to a series of wheels acting upon each other which carry round the hands of the clock.[1]

Other methods have been devised to render the

[1] Bain's Electric Clock.

Spirit an effective time-keeper, but the simple arrangement we have described may be taken as the type of them all.

The great peculiarity of these wonderful clocks is, that they may be connected by wires, and made to keep exactly equal time, though separated from each other by hundreds of miles. With a single battery of sufficient power all the clocks in London might be kept going; and what is still more extraordinary, the London clocks might be made to regulate those of Edinburgh and Dublin, or even those of Paris and New York!

The Spirit has been employed to move more ponderous things than pendulums. He has been taught to turn a lathe, work a pump, and propel a boat through the water; but as it is much more expensive to evoke the Spirit by means of metals and acids, than to raise Steam from water, he is not likely to supersede Steam as a mover of machinery.

In the useful Arts the Amber Spirit has long been employed as a worker of metals, and with his assistance we now cast copper medallions, vases, and statues, without making use of a furnace; we gild or silver all kinds of utensils, and cover the most delicate productions of nature with thin films of metal. We will proceed to consider these mysterious operations. When the Spirit is made to travel through a solution of copper, silver, or gold, he decomposes it, and deposits the metal, particle by particle, on the wire which conducts him back to the battery. Now by attaching a suitable model or mould to this wire, we can procure this metallic deposit in any shape; and by substituting any utensil for this mould, we may cover it with a film of gold or silver.[1]

We have not done full justice to our Spirit's abilities, as we have omitted to mention the many services he has rendered to the astronomer, the geographer, the chemist, and the physician; we have said enough, however, to give the reader an idea of his versatile powers.

We have shown that he can travel with the rapidity of thought across a continent or an ocean; that he can write and print our messages in the most distant places; that he can measure time as it flies, move all kinds of machinery, and melt copper in cold water. We may search through our old fairy tales and romances in vain to find a spirit capable of performing such miracles as these.

[1] The Electrotype.


FOUR ELEMENTS

The Four Elements.

'Does not our life consist of the four elements?'—
Twelfth Night.

WHAT is the world made of? According to the ancient doctrine of the Four Elements, all things are formed of Fire, Air, Earth, and Water; and the varieties and differences in the properties of bodies depend entirely on the proportion in which these great principles are mingled.

While we confine our observations to the external properties of matter, this beautiful doctrine seems incontestable. If we kindle a few dry sticks on a cool hearth, we may remark that while the wood burns there rises smoke or *air;* the smoke is followed by flame or *fire;* moisture or *water* is deposited on the hearth; and ash or *earth* remains.

Everywhere can we detect the presence of the mighty elements. Fire can be set free from innumerable substances; air penetrates the pores of all bodies, and covers the world like a mantle; water forms the all-embracing sea, and nourishes every plant and animal; while earth enters into the composition of all solids, and gives form and stability to the universe.

Man himself seems to be built up of the four elements; and according to the first theoretical system of medicine, *health* indicates their perfect balance, and *disease* the preponderance of one of them.

Such is the old doctrine of the Four Elements, simple and concise enough, but unfortunately false.

Modern science has satisfactorily demonstrated the compound nature of fire, air, earth, and water, and they can no longer be regarded as elements. By the term element, we understand any kind of matter which, up to the present time, has never been decomposed into constituents, and which consequently appears to have a simple nature. The true elementary bodies may be compared to the letters of the alphabet, and the diversified compounds which compose the material world to the words which form a language.

Let us examine the imaginary elements of the ancients, and see whether they will help us to arrive at the true solution of the problem—What is the world made of?

A candle in burning seems to disappear completely, and when the combustion is over, an insignificant trace of ash from the wick is all that remains to the eye. According to the ancient doctrine, tallow contains an ethereal substance called

Fire, which being set free, takes the form of flame: the gradual decrease of the candle is therefore accounted for by the dissipation of its chief constituent.

Before we can accept this explanation we must be quite satisfied that Fire is a substance.

Wherever we perceive light and heat emanating simultaneously from a combustible body, we say, there is fire; but we can bring forward no proof of the material existence of this so-called element. We cannot weigh it, measure it, or put it in a bottle; nor can we imagine it existing apart from a burning substance. Fire, after all, may be nothing but a name for certain phenomena of heat and light. These two great forces are intimately connected: thus, whenever we raise a solid object to a high temperature, it becomes luminous; first it emits a dull red light, which changes as the temperature increases to orange, then to yellow, and finally to full white.

The flame of a candle is a white hot cone of volatile matter, which we vaguely term Fire. If we can discover the real nature of this cone, we shall be able to define Fire with some degree of accuracy.

The chemist tells us that nothing can be absolutely destroyed, and that what we call destruction is merely the conversion of a visible body into an invisible one. To reconcile this statement with the gradual disappearance of the burning candle, we are forced to conclude that the tallow is changed into an invisible gas or vapour, and escapes into the air. Now, as no solid can become aëriform without the agency of heat, the question naturally arises—Whence comes the heat that vaporizes the tallow?

Everybody is familiar with the fact that a considerable amount of heat is evolved when water is poured upon quicklime; a fact which illustrates the great chemical law, that no union of two bodies can take place without a change in their temperature.

The intense heat emitted by the flame of a candle may likewise be traced to chemical action. If we cover a lighted candle with a glass shade, the flame will soon begin to languish, and in a few minutes it will expire. The flame seems to rob the confined air of a certain virtue which is essential to its continued existence. This is the true interpretation of the phenomenon. The air contains a wonderful gas called *oxygen*, which combines with the vaporized tallow, just as water combines with quicklime, and their union is attended by a development of heat.

The phenomena presented by a burning candle may now be easily understood. The tallow is melted and sucked up to the top of the wick, where it is boiled and converted into vapour. This vapour combines rapidly with the oxygen of the surrounding atmosphere, and the heat evolved is such as to render the vapour luminous. To bring about the combustion of the candle, it is necessary to apply heat to the wick, but afterwards the heat which is liberated is more than sufficient to sustain the action.

We have now arrived at a tolerably clear conception of Flame; it is merely volatile combustible matter heated to whiteness. Fire is simply a convenient word which we make use of to denote the extrication of light and heat during combustion; and the ancient notion, that it is one of the primordial constituents of the material world, is no longer tenable.

Fire is often spoken of as the destroying element, but we must bear in mind that combustion only alters the state of bodies; there is no actual destruction or loss of weight when a body is burned, though the products of combustion may be invisible.

If we set fire to a small fragment of phosphorus and cover it with a dry tumbler, dense white fumes will arise, which will condense on the sides of the glass in snow-like flakes. If we collect this white substance and weigh it, we shall find that it is more than twice as heavy as the phosphorus. How is this? The explanation of this apparent anomaly is simple enough. The phosphorus, in burning, combines with the oxygen of the atmosphere to form this white compound, which is known to modern chemists by the name of *phosphoric anhydride;* the weight of the oxygen is therefore added to that of the phosphorus.

Some of our readers will doubtless receive this information with astonishment. It seems scarcely credible that a substance having the appearance of snow should be produced by the union of an invisible gas and a yellow wax-like solid. Chemistry is a science of marvels, and this wonderful dissimilitude between a compound body and its constituents is anything but an exceptional case; in fact it is this change of properties that distinguishes chemical union from mere mechanical mixture.

Our tallow candle is composed of two invisible gases and a black solid, and is therefore a much more extraordinary compound than the white phosphoric anhydride. When a candle is burned, the products of the combustion are invisible gases: these gases can nevertheless be collected by the chemist, and are found to weigh more than the original candle. Coal, coke, wood, and other combustibles which are employed as fuel, likewise form gaseous compounds with the oxygen of the atmosphere. This is a very significant fact; for were the products of combustion invariably solid, like phosphoric anhydride, the world would long since have been buried in ashes.

We have examined the first of the so-called elements of the ancients, and have proved it to be a manifestation of intense chemical action between two or more bodies. Let us now proceed to consider the nature of Air.

'There exists a certain thing,' says a philosopher of the sixteenth century, 'which we do not perceive, and in the midst of which is plunged the whole universe of living beings. This thing comes from the stars, and we call it air. Fire, in order that it may burn, requires wood, but it also requires air. The air, then, is the life; for if air be wanting, all living beings would be suffocated and die.' In all ages the atmosphere has been regarded as the great source of life; and long before the famous dogma of the Four Elements was propounded, a Grecian sage declared that air was the one universal principle from which everything proceeded.

We have already alluded to the fact that combustible bodies combine with a certain gas called oxygen, which is contained in the atmosphere: our readers will not therefore be surprised when we tell them that air is a mixture of dissimilar gases, but they will marvel greatly when we describe the properties of its constituents.

If we boil some mercury or quicksilver in a closed glass vessel for many successive days, the metal will undergo a very extraordinary change. It will lose its metallic character entirely, and in place of the glistening fluid we shall find a heap of bright red scales. As these scales weigh more than the original mercury, we may safely conclude that something has been abstracted from the air contained in the vessel.

If we now take a lighted match and plunge it into the air that remains, it will be instantly extinguished; it is therefore evident that the abstracted something is oxygen.

Let us close the vessel once more and apply to it a strong heat: the red scales are now converted into metallic mercury, and the air regains its property of supporting combustion.

This beautiful experiment proves air to be a mixture of oxygen and a certain gas in which no ordinary combustible will burn. This gas has been named *nitrogen.*

Oxygen forms about one-fifth, by bulk, of the atmosphere, and nitrogen nearly the remaining four-fifths; to these components must be added a minute proportion of a gas called *carbonic anhydride*, or more commonly *carbonic acid*, and traces of another body called *ammonia.* Though these two last-named constituents bear such a small proportion to the others, we shall presently see that they have important duties to perform in the economy of nature.[1]

We may regard the atmosphere as a gaseous mass of uniform composition, though recent researches lead us to the conclusion that the proportions of its constituents vary within extremely small limits. We may bring down air from the summit of the highest mountain, and collect it in the deepest valley, but we shall probably fail to detect the slightest variation in its composition, even though we employ the

[1] The average amount of carbonic anhydride in the air is four volumes in 10,000. In the air of crowded rooms it is much greater. A very large proportion is also found in the air contained in deep wells, mines, quarries and caverns, especially in limestone districts, where the gas is continually escaping from fissures.

most precise methods of analysis devised by modern chemists.

The same uniformity is apparent whether we examine the air of the polar regions or that of the tropics; whether we collect it in the densely populated city or in the untrodden forest. This fact seems all the more wonderful when we consider the contaminating influence of the countless exhalations that are continually rising into the atmosphere. The clouds of smoke poured forth by our chimneys, the expired breath of animals, and the gases that proceed from decaying matters, do not perceptibly disturb the equilibrium of the constituents of the atmospheric ocean.

We must remember that this aërial ocean is some forty-five miles in depth, and that the vapours which arise from the earth are rapidly diffused throughout its entire extent.

The atmosphere exerts a pressure upon the earth's surface equal to about fourteen and a half pounds upon each square inch; and it has been calculated that its entire weight amounts to more than five thousand one hundred and fourteen billions of tons—a sum which words may express, but which the human mind cannot appreciate. Our readers will gain a clearer conception of this enormous sum, when we tell them that it is equivalent to the weight of a solid globe of lead some sixty miles in diameter!

We have said that the atmosphere contains an aëriform body called carbonic anhydride. Let us now see how this fact may be proved. When slaked lime is exposed to the air, it gradually loses its caustic properties, and increases in weight; this increase of weight depends on the absorption of carbonic anhydride from the surrounding atmosphere.

We may expel this gas from the altered lime by heat, and collect it in suitable vessels for examination. We find it to be much heavier than ordinary air,—so heavy, indeed, that we may pour it from one vessel to another, like water. If we plunge a lighted taper in it, the flame will be instantly extinguished; and if we substitute a mouse or any other small animal for the taper, the poor creature will be suffocated.

This gas is the chief product of combustion; our candles and fires are continually pouring it forth into the atmosphere, animals expire it from their lungs, and it is produced in every case of putrefaction and fermentation.

Carbonic anhydride, so fatal to animal life, is essential to the life of plants; indeed the existence of the whole vegetable kingdom depends on the presence of this gas in the atmosphere. Carbonic anhydride is a compound of oxygen and *carbon* or charcoal, which substance is the principal constituent of all plants. Every green leaf may be compared to a little chemical laboratory, in which the carbonic anhydride of the air is decomposed, the carbon being retained by the plant, while the pure oxygen is cast forth into the atmosphere.

Vegetables absorb the carbon which is exhaled in combination with oxygen by animals, and the two great divisions of organized beings are thus indissolubly connected by the interchange of substances necessary to their existence.

The old fable of the Hamadryads who presided over the trees of the forest, and who died when the trees were cut down, shadowed forth a deep truth. In the fairy tales of science we read that the lives not merely of wood-nymphs, but of all living creatures, are dependent on trees and herbs!

The atmosphere invariably contains a minute portion of ammonia, another compound body, its constituents being nitrogen and a gas called *hydrogen*. Ammonia is absorbed by water, and it is therefore brought down to the earth by rain, where it forms a valuable manure for plants. Its importance may be conceived when we state that the most nutritive principles in grain and other vegetable substances contain large proportions of nitrogen, derived from this aërial manure.

Watery vapour is constantly present in the atmosphere, though we can scarcely call it a constituent of air. Its presence can be easily demonstrated by putting some ice in a tumbler; for when the glass is sufficiently cool, the vapour will be condensed upon its outer surface in the form of dew.

We have resolved air into its component gases, and have thus exploded the old notion of air being an element.

Our investigations have brought to light certain bodies which may be justly considered elements,—namely, oxygen, hydrogen, nitrogen, and carbon. These substances have never yet been resolved into constituents, but we do not dogmatically assert that they are absolutely simple in their nature. We call them elements because we cannot prove them to be compounds, though it is not impossible that they may turn out to be such at some future time.

That a mixture of four dissimilar elements should produce the life-supporting atmosphere, is a fact that may well excite our wonder. Who would suspect that the mild and genial air which envelopes our planet could be formed of ingredients which separately exhibit such striking peculiarities, and which combine in other proportions to form compounds all more or less fatal to life?

An atmosphere of pure oxygen would be too exciting to be compatible with long life in animals, even if we could imagine the existence of life in a blazing world; for not only those substances which are generally spoken of as combustibles, but even the metals, burn with great violence in oxygen.

In an atmosphere of nitrogen, animals could not exist at all; indeed this gas formerly went by the name of *azote*, the literal significance of which is 'fatal to life.'

Two volumes of oxygen mixed with eight of nitrogen form 'the breath of life;' but when these gases are combined in other proportions, they form compounds which have very different properties.

One of these compounds is the protoxide of nitrogen, a gas which may be inhaled for a few minutes without danger, but which is incapable of supporting life for any length of time. When breathed it produces great mental excitement, and occasions a total loss of volition. The person who inhales it performs a hundred strange antics: he talks incoherently, laughs wildly, sings, dances, and sometimes fights; he feels that he is lighter than the atmosphere, and sees all things under a new aspect.

In old times these extraordinary effects would probably have been ascribed to some mischievous demon contained in the *laughing gas*, and the 'bell, book, and candle' would have been deemed indispensable for its exorcism.

Another compound is a colourless and invisible gas, so poisonous that animals plunged into it instantly expire; a third and a fourth are corrosive red vapours, equally noxious; while a fifth is a crystalline body that reacts with water to form the well-known liquid called *aqua fortis*, a powerful acid which dissolves copper and other metals, and which destroys all organic substances.

Such are the compounds of nitrogen and oxygen, the very elements which we draw into our lungs at every inspiration, and without which we could not exist.

Carbonic anhydride, though incapable of supporting life, is not poisonous, and its presence in the atmosphere does not disturb our vital functions. Animals may be drowned in pure carbonic acid, but they cannot be poisoned by it. If the atmosphere contained another compound of carbon and oxygen, namely, carbonic oxide, in place of this innocuous gas, the world would be a lifeless desert, as carbonic oxide is an active poison, and a very small quantity of it would suffice to infect the air.

The philosopher who declared that air came from the stars, figuratively expressed a great truth. We have only to examine the wondrous constitution of the gaseous mixture to be convinced that it must have had a celestial origin, and that the potent elements of which it is composed must have been mingled by an all-wise and beneficent Power.

We have resolved fire into the phenomena of light and heat, and have separated the constituents of air; let us now summon Water into our presence, and compel that supposed element to reveal its true nature.

Water, like air, was once regarded as the origin of all things; indeed this belief in the universality of moisture may be said to have laid the foundation of speculative philosophy among the Greeks.

Water exists in the three physical states—the solid, liquid, aëriform. By adding heat to liquid water we convert it into aëriform water, or *steam;* by abstracting heat from it, we change it into solid water, or *ice:* in either case the chemical composition of water remains unaltered.

We can demonstrate the compound nature of water by analysis or by synthesis; in plainer language, by resolving it into its elements, or by forming it from its elements. Let us first see how its analysis may be effected.

Some chemical compounds—the red mercurial scales, for example—are decomposable by heat, but water is merely vaporized by this potent agent. To overcome the attractive force or *affinity* which binds the elements of water together, we must call in the aid of some substance which has a superlative affinity for one of these elements.

Such a substance is potassium, one of the lightest of our metals. When heated in dry air, potassium undergoes combustion, and rapidly loses its metallic character. The resulting white substance contains oxygen, and its production proves that potassium has a strong affinity for this element.

If we throw a small fragment of this metal into water, it takes fire and burns, while swimming about on the surface of the liquid, with a brilliant light of a violet-red colour. When the combustion is over, no vestige of the potassium remains, but we find that the water has acquired the acrid taste of *potash.* The chemist thus interprets the phenomenon: water is a compound of oxygen and a highly inflammable gas called *hydrogen;* when potassium is thrown into water, it combines with a portion of its oxygen to form potash, and the heat which attends their union sets fire to the liberated hydrogen. It is not the metal that burns so furiously, but one of the constituents of water.[1]

Here is a revelation far more wonderful than anything we find in our old story books!

Oxygen gas is the great supporter of combustion; even the metals will burn away in it like tinder. Hydrogen is the lightest gas known; it is very inflammable, and gives out an intense heat while burning. Water, the great antagonist of fire, is built up of these two fiery elements!

Wherever we find water we may be sure that these two elements are present. We may detect them in the water of the boundless ocean, the placid lake, and the murmuring rivulet; in the floating cloud and the jagged iceberg; in the rain-drop, the hailstone, and the snow-flake; in the jewel that glitters upon the bosom of the rose, and in the tear that falls from the mourner's eye!

Potassium is not the only substance that decomposes water. Everybody is familiar with the fact that iron *rusts* when placed in water. Now the rusting of iron is a similar phenomenon to the conversion of potassium into potash; they both depend upon the absorption of oxygen. At a red heat, iron decomposes water very rapidly. When steam is made to pass through a long red-hot iron tube, it is

[1] Potash or *hydrate of potassium* may be regarded as water, in which half of the hydrogen is replaced by potassium.

resolved into its elements. The oxygen unites with the iron to form a species of *rust*, and the hydrogen is set free. By weighing the tube before and after the operation, the chemist is able to determine the proportion in which the two elements are combined.

In a hundred parts by weight of water he invariably finds eighty-nine of oxygen and eleven of hydrogen.

We may employ our old friend the Amber Spirit to separate the elements of water, as this versatile being is a most skilful analytical chemist. The Spirit can set free the oxygen and hydrogen in two distinct streams of bubbles; whereas the human operator can only liberate one of these gases by forcing the other to combine with some new body.

We have spoken of the inflammable nature of hydrogen, but we have not yet explained the phenomena which attend its combustion. This gas, when pure, burns with a very pale flame, the product of its combustion being *water*, which escapes into the atmosphere in the form of an invisible vapour. If a cool tumbler be inverted over the flame, this vapour will be condensed into minute drops, which will trickle down the inner surface of the glass. The combustion of hydrogen is therefore a manifestation of the intense affinity of this gas for the oxygen of the air.

If we mix the two gases in the proportion in which they combine to form water, and apply a lighted match to the mixture, the gases will instantly unite with a deafening explosion. All the water produced will merely suffice to damp the surface of the vessel in which the explosion takes place, as no less than 2550 measures of the gaseous mixture are required to form one measure of water.

Here is another marvellous revelation! The two gases have separately resisted every attempt made by the joint efforts of cold and pressure to liquefy them, yet they combine and form water, the type of liquidity!

According to the dogma of the Four Elements, everything that is neither fire, air, nor water, is necessarily earth. Now a moment's consideration will convince us that innumerable bodies, having the most diverse properties, are comprised in this definition of the so-called element.

We cannot therefore deal with Earth as we have dealt with its mighty brethren; we cannot deduce any general conclusions as to its nature from the analysis of a single sample. We may resolve a particular handful of soil into its elements, but we dare not assert that these elements are common to the multitudinous handfuls which constitute the solid portions of our planet.

How, then, are we to proceed with our investigations? Were we to examine in regular order the various compounds included in the ancient conception of earth, our fairy tale would assume the character and proportions of an encyclopædia. To preclude such a result, we must abandon the analytical method of inquiry, and be content to accept certain comprehensive truths that chemistry has revealed regarding the constitution of different kinds of earth.

The diversified compounds which form the material world have been resolved by the chemist into sixty-two elementary bodies, forty-nine of which are metallic. These elements are rarely found in a state of purity, owing to their strong tendency to combine with each other.[1]

The principal ingredients of Earth are compounds of oxygen with certain elementary bodies that are never found pure in nature.

Silica, the most widely diffused compound, contains oxygen, and another of the metalloïds or non-metallic elements, called *silicon*, which can be isolated as a dark-brown powder. Sand, flint, and quartz consist almost entirely of silica; so do the granitic and siliceous rocks which form so large a portion of the earth's crust.

The highest and most extensive mountain ranges are huge masses of silica, and the deserts of Africa and Asia are vast plains of the same abundant substance. Silica forms the sand and shingle of the sea-shore, and enters into the composition of every soil; it is the chief ingredient of some of our most precious jewels, of the invaluable material glass, and of the stones with which we pave our streets and build our temples.

[1] Future researches will doubtless bring to light many elementary bodies that have hitherto escaped detection.

Alumina is a compound of oxygen with a very extraordinary metal called *aluminium*, of which we shall have to speak in another of our fairy tales. Alumina is the basis of every kind of clay, and is only second in importance to silica. It is also a constituent of our rocks and soils, of our gems, and our building materials; and we make use of it to form earthenware, a substance which rivals glass in usefulness.

Lime is another abundant metallic oxide or rust, its base being *calcium*, a beautiful silver-white metal, which burns brilliantly when heated in the air. In nature, lime is generally found combined with the elements of carbonic anhydride, one of the constituents of the atmosphere. The well-known substance chalk, which forms our far-famed white cliffs, the compact limestones used in architecture, and all the elegant varieties of marble, are examples of this union.

The solid portions of our globe are almost as rich in oxygen as the atmosphere and ocean. Every rock is a compound of oxygen with certain metallic and non-metallic bodies. Silica contains a little more than half its weight of this abundant element; alumina nearly one-half; and lime two-sevenths.

In some compounds oxygen is replaced by another metalloïd. Common salt, the chief saline matter of sea-water, is a compound of *sodium*, a metal closely allied to potassium, with *chlorine*, a remarkable gaseous body, which in some respects resembles oxygen. The glistening yellow mineral called iron pyrites, contains *iron*, and the metalloïd *sulphur*. The variegated crystalline substance known as fluorspar, is a compound of *calcium*, the metallic base of lime, with *fluorine*, a mysterious body which the chemist has never yet been able to procure in a separate state.

A few of the so-called noble metals—namely, gold, platinum, palladium, iridium, and rhodium, and a few others—are usually found in a state of purity; silver, copper, mercury, bismuth, and arsenic often occur in the metallic state; oxygen and nitrogen have a free existence in the atmosphere; sulphur is frequently met with uncombined; and carbon is found pure in the diamond. With these exceptions, the material world may be said to be an assemblage of compounds formed by the union of thirteen metalloïds with forty-nine metals.

Plants and animals are almost wholly composed of oxygen, hydrogen, nitrogen, and carbon; hence these metalloïds have been styled the *organogens*, or organ-forming elements. The chemist tells us that wood, sap, starch, muscle, blood, nerve, and all other organized substances, result from the combination of these four principles in varying proportions.

Vegetables feed upon inorganic matter; they derive their carbon from *carbonic anhydride*, their nitrogen from *ammonia*, and their oxygen and hydrogen from *water*.

Animals are chiefly dependent upon the vegetable kingdom for their sustenance. A large number of races feed directly upon herbs and fruits; others prey upon the bodies of these vegetable-feeders. When animals die, their bodies suffer decomposition, and their original constituents—water, ammonia, and carbonic anhydride—return to the atmosphere, to nourish another generation of plants, for another generation of animals to feed upon.

The elements are indestructible, and death merely alters the arrangement of their atoms.

The ancient philosopher contended that all things were formed out of four elements: the modern philosopher declares that the two great organic kingdoms spring from a few invisible gases. The theory seems almost as credible as the fact! The following words from the pen of a celebrated chemist,[1] read like a page of some wild romance, and yet they deal with facts that are incontrovertible: 'Man is formed of condensed air (or solidified and liquefied gases). He lives on condensed as well as uncondensed air, and clothes himself in condensed air. He prepares his food by means of condensed air, and by means of the same agent moves the heaviest weights with the velocity of the wind. But the strangest part of the matter is, that thousands of these tabernacles formed of condensed air, and going upon two legs, occasionally, and on account of the production and supply of those forms

[1] Liebig.

of condensed air which they require for food and clothing, or on account of their honour and power, destroy each other in pitched battles by means of condensed air.'

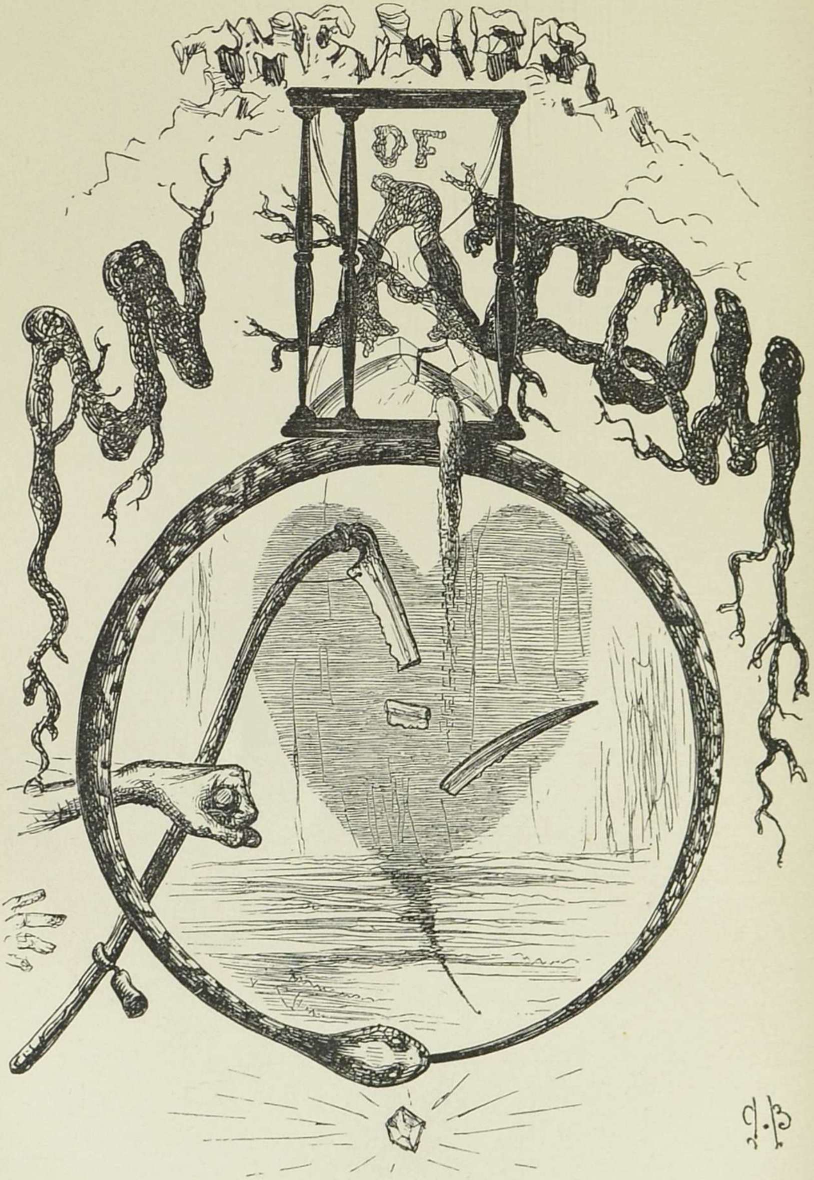
We have now arrived at a true solution of the great problem—What is the world made of?

The three kingdoms of nature are built up of some sixty-two elementary bodies, endowed with the most diverse properties and affinities, each being destined to perform some important part in the great system of creation. Truly has it been said, that the powers of not one element could be modified without destroying at once the balance of harmonies, and involving in one ruin the economy of the world!

Although the ancient doctrine of the Four Elements has been exploded by chemistry, we must still honour the mighty sages by whom it was propounded. The doctrine is not wholly false; and were we to confine our observations, as they did, to the external properties of matter, we should be forced to acknowledge the justice of their conclusions.

In one sense the world is really made up of the four elements. Fire may be said to represent the imponderable agents—heat, light, and electricity; the remaining elements, the three physical states of ponderable matter, namely, the gaseous, liquid, and solid. The difference between our present views and those of the ancients consists in this: we regard these states as mere modes of existence, while they believed them to be distinct principles.

We must now take leave of the Four Elements, as we fear our readers are growing impatient for another story from the plenteous budget of Science.


OF

The Life of an Atom.

'Why may not imagination trace the noble dust of Alexander, till he find it stopping a bung-hole!'—*Hamlet.*

THE particles of matter are subject to strange vicissitudes. Every atom has its peculiar history. In all probability the countless atoms of carbon, oxygen, and hydrogen which are aggregated into this lump of white sugar, met together for the first time in the juice of the cane. Where were they before the sugar-cane was planted? Who can tell? One of these atoms of carbon may have coursed through the veins of a Hottentot, another may have existed in the brain of a Laplander!

The old story-tellers never scrupled to endow inanimate objects with the faculty of speech. Let us follow in their footsteps, and create a talking atom. Such a gifted entity might thus recount his adventures in the three kingdoms of nature:—

'I am an atom of carbon. The members of my family are innumerable, and are disseminated throughout the universe. Some of my brethren are grouped together in those diamonds which are so much prized by the strange atomic fabrics called human beings. These jewel-forming atoms are much to be pitied, though they give themselves great airs, and sneer at their poor relations. I would a hundred times rather be the roving atom that I am, than one of the particles of the Koh-i-noor itself.

'When the world was young, I led a very steady life. I remember forming part of a huge mass of rock which was built up of atoms of carbon, oxygen, and calcium.[1] For ages I never saw the light, and remained in ignorance as to the existence of anything besides the atoms which surrounded me. Fortunately I was situated very near the surface of the rock, and in course of time the atoms above me were removed, probably by the drops of water which fell from the heavens.

'Never shall I forget the delight I experienced on first beholding the outer world! I thought I should never be able to bear the brilliant sunlight, which dazzled me so that it was some time before I could make out the separate features of the scene. How beautiful, how grand everything seemed! and yet the landscape that was then unfolded before me was unenlivened by organic forms; there was not a tree to be seen—not so much as a blade of grass—life had but just dawned upon the globe. The rock of which I was a constituent, was part of

[1] Limestone.

an island, and from my station I could see the ever restless ocean, whose atoms danced about so joyously that I longed to be among them. At the foot of the rock ran a little stream, which probably conveyed some atoms like myself into new scenes of existence.

'Night came on, and new wonders were revealed. Those marvellous celestial atoms, the stars, looked down upon me with their sparkling eyes; and the silvery light of the moon gave fresh grandeur to the ocean and my rocky island. As I gazed upon the glittering waters I thought of my poor brethren who were deep down in the rock, and sighed!

'Next day the sun was obscured by clouds, and large drops of water fell from the sky. The stream became a river, and dashed through the valley at a headlong pace. The atoms constituting the rain-drops buffeted me very severely, and at length their blows detached me, with a few old friends, from the mass of my brother atoms. The friends who clung to me in the hour of adversity were three atoms of oxygen and two of calcium. For countless ages we had been united, and now the rain-drops, with all their bluster, could not sever us.

'No sooner were we detached, than a stream of moving atoms impelled us down the sloping sides of the rock, and hurled us into the river. There could be no rest for us there. The rapid current carried us through numerous valleys and gorges, and finally launched us into the ocean.

'We now began to lead a new kind of life. The molecules of the ocean were not fixed, like those of the rock. They glided over each other with perfect ease, and were continually in motion. As a matter of course, these molecules communicated their motion to us. It would be impossible for six little atoms to stand still while myriads were pushing them. We performed some wonderful voyages during the ages that we spent among the oceanic atoms. Sometimes we passed from the Equator to the Poles; but our usual course was from west to east, in which direction a mighty stream of atoms constantly flowed round the globe.

'A strange mishap forced us to relinquish our roving habits. In traversing a chain of rocks we were sucked into the stomach of a tiny plant-like animal,[1] whose frame was built up of numberless atoms, most of them members of the carbon family. A place was found for us in this living organism beside certain atomic groups, each composed of six individuals exactly like ourselves.

'In course of time the vital force which had aggregated the various molecules into such a wondrous system ceased to act; in other words, the animal died. The atoms which formed the soft portions of the body now began to change their position, and in a very short time they were all carried away by the wandering molecules of the ocean. As for me, I was still surrounded by my five friends, and still associated with numerous hexatomic groups. The

[1] The Coral Polype.

creature who had robbed us of our liberty was now no more, but for all that we were unable to move. We were fixed to the rock upon which the organism had flourished; indeed, incredible as the statement may appear, the entire reef, which extended for some hundreds of miles, was composed of atoms that had been snatched from the ocean by innumerable generations of those gelatinous little animals.[1]

'I cannot say how long I existed as a constituent of this marine rock. An atom takes no heed of time, and a few millions of years pass by very quickly. Time affects only those compound entities called plants and animals.

'The surface of the earth underwent some strange mutations while I was a rock atom. The relative position of land and water changed. Mountains were upheaved by the internal fires of the globe, and deep valleys were eroded by rivers. The waters of the ocean receded from the reef to which I belonged, and left it high and dry, as a chain of hills in the interior of a vast continent. None of these changes, however, disturbed my repose. The ties which bound me to my fellow-atoms seemed indissoluble.

'At length the rock of which I was a constituent was subjected to a new mutation by volcanic agency. The pent-up fires of the earth burst through the

[1] The barrier reef along the north coast of Australia is composed of a chain of coral rocks, and is more than 1000 miles long, and from 10 to 90 miles in breadth, while it rises from depths which in some places certainly exceed 1800 feet. What a mausoleum for creatures so low in the scale of being!

ancient reef, and liberated myriads of its component atoms. For some time I remained unaffected by the commotion, but eventually I felt the disturbing effects of the intense heat, and found that my bonds were loosened. I was no longer a rock atom, and the ascending stream of fiery particles bore me into the atmosphere.

'As for my old companions who had hitherto shared my reverses, only two of them attended me now, for the atoms of calcium had persuaded one of the atoms of oxygen to remain with them in the rock. The metallic atoms were not fitted for an aërial life, and did not care to be separated from all their friends. What a marvellous difference the absence of those three atoms made in the group to which I belonged! When there were six of us, we constituted a solid molecule; now as a triad, we formed a restless gaseous molecule.[1]

'Who can describe the joys of an aërial atom? I have never yet been a part of a poet's brain, and it is therefore quite out of my power to set forth in appropriate language the varied pleasures of an atmospheric existence. My roving life as an atom of the ocean had its charms, but it was not to be compared with the life I now led among the sportive atoms of the air. My two friends remained true to me; indeed, had it not been for their constant watchfulness, I should have fallen to the earth, for I was not buoyant enough to float unsupported.

[1] Carbonic Anhydride.

'Sometimes we soared to a great height, where the aërial atoms were very far apart; but we usually kept near the surface of the earth. How changed was the aspect of nature! When I first beheld the outer world, all was barren and lifeless; now every scrap of dry land was covered with a luxuriant vegetation. The plants were mostly of great magnitude, though, strange to say, some of them were closely allied to the humble ferns and tiny mosses of the age of man. I have seen many wondrous things in my time, but nothing to surpass those ancient forests, composed of ferns as large as oaks, and mosses seventy feet high![1]

'I was destined to become a part of one of these gigantic mosses. As I was passing through a forest with myriads of aërial atoms, I happened to strike against a leaf, which instantly absorbed me, but allowed my two companions, who had never been separated from me before, to pass on with the rest. For some time I circulated through the vessels of the living plant as a constituent of the sap, but at length I settled down among the atoms of carbon, oxygen, and hydrogen, which were aggregated into particles of wood. Such are the vicissitudes of an atom, now literally as free as the air, now a captive in the tissues of a living organism! A second time the hidden processes of life had compelled me to part with my liberty.

'I have already alluded to the mutability of the

[1] The Carboniferous Period.

earth's surface. The disturbances that took place during the time that I was a vegetable atom were of a very extraordinary character. The group of islands upon which the monster ferns and mosses flourished sank beneath the waves, and in course of time they became overlaid with beds of rock, formed by the deposition of sand, clay, and other materials at the bottom of the ocean, the sedimentary matter being hardened by heat and pressure. Human beings talk of the stability of the earth, but we atoms know very well that its great characteristic is instability. Why! the crust of this so-called immovable earth is continually bulging out in some places and falling in others!

'I did not lead a very merry life in the depths of the earth, but still I did not repine. Experience had taught me that I was a creature of circumstances, and must submit to my destiny. How long I remained underground I cannot say. Millions of years may have flown by, but they brought me no change. Numberless atoms of oxygen and hydrogen that were associated with me in the living plant, forced their way between the molecules of the overlying rocks, and thus escaped from their subterranean prison. I was too firmly attached to my solid brethren to accompany these adventurous atoms, so I waited patiently for succour, assured that it would come sooner or later.

'My deliverance was effected by the agency of Man, that wondrous being, partly composed of atoms like myself, and partly of an immaterial spirit, who now reigned supreme over the other organisms of the world. Having found that the compressed remains of the ancient forests[1] could be made to yield light and heat, agents which greatly contributed to his happiness, he sank deep pits through the rocks, and transferred me, with myriads of my brethren, from the earth's gloomy depths to its sun-gilt surface.

'Now commenced the eventful period of my life. Hitherto my transitions had been few. Twice had I been a constituent of stone; twice a part of a living organism. I had tasted the pleasures of a marine existence; I had floated joyously in the air; I had lain for ages in the bosom of the earth. But in the few short years that have elapsed since my release from bondage, I have passed through a far more wonderful series of changes.

'Let me now recount the chief incidents of my modern career. I will make use of as few words as possible, lest my narrative should be cut short by a new alteration in my condition.

'Soon after my arrival at the surface of the earth, I was separated from my brother atoms by the process of combustion, and carried aloft by two members of the great oxygen family. My freedom was of short duration. Nature had set innumerable traps for me, in the shape of living organisms, and by one of them I was soon made captive.

[1] Coal.

'I now became a part of a grain of wheat, and in course of time I found myself in the stomach of a man. In the human frame I passed through a definite course of vicissitude, and was then breathed forth to make room for a new-comer. Once more I enjoyed the pleasures of an aërial life, which, I need scarcely say, were again shared by two atoms of oxygen.

'From the atmosphere I passed into the substance of a tree, which was destined to fall by the hand of man soon after my absorption. By a cunning process the wood was decomposed; its volatile atoms of oxygen and hydrogen were set free, and an aggregate of carbon atoms[1] remained.

'Man had not yet done with me and my dusky brethren; he had separated us from our companions, in order that we might be at liberty to unite with certain atoms of iron, and thus produce a substance which he greatly prized.[2] This strange union was effected, and in course of time I became a part of one of those weapons with which man destroys his fellow-man.

'I now witnessed some fearful scenes of bloodshed; and being an atom of a philosophical turn of mind, I often speculated upon the motives that induced those short-lived atomic structures called men to hasten each other's dissolution. When I speak of these scenes as fearful, I make use of a human expression, for I need scarcely say that death can have no terrors for an undying atom.

[1] Charcoal. [2] Steel.

'I was detached from the metallic mass by the agency of heat, and two friendly atoms again conveyed me into the atmosphere. My next move was into the juice of a grape, where I remained in peaceful retirement, until man induced me to become a constituent of a bright and sparkling liquid, which he confined in strong glass bottles.[1] How long I remained a prisoner I cannot say, but as soon as my bottle was opened, I made my escape in a bubble of gas. After a short flight through the air, I passed into a blade of grass, and thence into the huge frame of an ox.

'The next change in my condition was brought about by human agency, and I became a constituent of a volatile and colourless liquid, which was such a terrible poison that a few drops of it would suffice to kill the largest animal.[2] Now, it so happened that a foolish man swallowed a small quantity of this liquid. He grasped the little phial which contained the poison with a trembling hand, he raised it to his lips, and in another moment I found myself in his lifeless body. A simple atom can form no idea of the motives which induce composite beings to perform certain actions; but as far as I can judge, this self-destruction seems to be unworthy of a being like man.

'When I escaped from the dead body, I passed into the vegetable kingdom, where I became a part of a beautiful flower. Soon after, I found myself

[1] Champagne. [2] Prussic Acid.

in the body of a bee, and in course of time I became a constituent of one of the waxen cells which the little artisan had so cleverly constructed. From the honeycomb I passed into a wax taper, from which I was released by the process of combustion.

'It was now my lot to spend some time among the aërial atoms; but at length I came in contact with the sugar-cane, and became a constituent of the sweet juice from which the lump of sugar was extracted.

'Such is the story of my life, or rather of a fragment of my life. I enjoy perpetual youth. To-day I may be buried in a mass of corruption, but to-morrow I may form a part of a newly opened rose. Time cannot reach me; his hour-glass may be broken and his scythe may be shattered, but still I shall exist. At the present moment I am joined to countless atoms, indestructible and eternal like myself, in a fragment of sugar; but who can tell where I shall be in a year's time!'

This peroration has been cut short by our first-born, who has run away with the lump of sugar, and we have every reason to believe that the atom is now undergoing new transitions.

A Little Bit.

'Many a little, makes a mickle.'—OLD PROVERB.

IN the foregoing pages we have assumed that all things are made up of very little bits called *atoms*. This view of the nature of matter is purely conjectural, but it agrees so well with the truths revealed by Science, that we must admit it to be highly probable. Let us descend for a while from the realms of imagination, and lay before our reader the facts upon which the beautiful theory of atoms is based.

The word 'atom' is derived from the Greek language, and signifies 'that which cannot be cut,'—a very appropriate term, for an atom being the smallest possible particle of a substance, must necessarily be indivisible. The existence of half an atom is inadmissible, because the mind cannot form an idea of a particle smaller than the smallest.

Philosophers are divided in their opinions respecting the nature of the ultimate particles of matter: some maintain that they are hard and solid, and therefore of a definite size and weight, though so minute as to defy all our optical instruments to enable us to perceive them; others hold them to be mere points or centres of force. What is an atom? This is a problem which the human mind can never solve, it can only throw out shrewd guesses at the truth. We will, however, take it for granted that the ultimate particles of matter are indivisible and indestructible, without wasting our time on metaphysical subtleties.

Though we can form no conception of the absolute size of atoms, the wonderful divisibility of matter furnishes many proofs of their extreme minuteness. The gold-beater hammers out a single grain of the precious metal until it covers forty-nine square inches. Now, each square inch of this gold leaf may readily be cut into a hundred strips, and each strip into a hundred pieces, each of which is distinctly visible to the unaided eye. A single grain of gold may thus be subdivided into 490,000 visible parts. But this is not all: if attached to a slip of glass, the leaf may be subdivided still further, as ten thousand lines may then be ruled in the space of a square inch, and in this manner the entire leaf, weighing but a grain, may be cut into 4,900,000,000 fragments, each visible by means of the microscope. As we require no less than ten figures to express the number of parts into which a grain of matter may be subdivided by mechanical means, and as each of these parts must contain a vast number of particles, we see that an atom must be a very little bit indeed ! But gold furnishes a still more remarkable instance of the extension of matter. The gilt wire used in embroidery is formed by extending gold over the surface of silver. A very little gold is here made to go a very long way, for each grain is spread over a surface of nearly ten thousand square inches.

In the animal and vegetable kingdoms we meet with some surprising instances of the divisibility of matter. The microscope reveals the existence of animals so wonderfully minute that it takes a hundred millions of them to weigh a grain, yet each creature is possessed of distinct organs, and must be composed of innumerable atoms.

The spores of the lycoperdon, or puff-ball, are found to be little orange-coloured globes; and although each spore is capable of becoming a living plant, no less than 125,000 of them would be requisite to form a single globe of the diameter of a human hair.

The sense of smell enables us to perceive particles of whose magnitude we can form no adequate conception. Odour is simply the disengagement of the volatile particles of a substance, yet a single grain of musk has been known to perfume a large room for the space of twenty years.

We may rest assured, then, that the atoms of matter are exceedingly minute, though their actual size can never be determined by our powers of perception. Let us now consider the aggregation of these little bits into masses.

The force which holds the atoms together is called *cohesion*; it is greater in solids than in liquids, while in aëriform bodies it seems to be altogether absent.

We have every reason to believe that the ultimate particles of a body are never in actual contact, but are placed at a certain distance from each other, so that there exists around every individual particle a space void of matter. All bodies are more or less compressible, and unless we acknowledge the existence of these empty spaces, we must suppose that two or more particles are capable of occupying the same place at the same time; a supposition which is opposed to the notion of an atom having a definite size.

A volume of air can be compressed into a space a thousand times smaller than that which it originally occupied, and we must therefore conclude that the atoms of air are separated by wide intervals. Solids and liquids must also have interstices or pores between their particles, as they invariably expand when heated and contract when exposed to a low temperature.

The porosity of gold was demonstrated some two hundred years ago by the famous Florentine experiment. A hollow ball of the precious metal, filled with water, was submitted to a great pressure, by which the fluid was made to ooze through its pores and bedew its outer surface.

The distance between the particles of matter is greater in liquids than in solids, and greatest in gases and vapours. It is highly probable that all bodies, even the densest metals, contain more space than matter; in other words, that the atoms are much smaller than the spaces which separate them. Some of our greatest philosophers have held the atoms of matter to be immeasurably small, compared with their surrounding spaces.

Newton thought that the whole material world might be compressed into the space of a single cubic inch, provided that its particles could be brought into actual contact.

Sir John Herschel compares a ray of light penetrating glass, to a bird threading the mazes of a forest; and says that there is no absurdity in imagining the atoms of a solid to be as thinly distributed through the space it occupies as the stars that compose a nebula.

We need scarcely say that these hidden truths do not fall within the sphere of scientific inquiry, but can only be subjects for the exercise of speculation. All our instruments are far too clumsy to help us to a knowledge of atomic magnitudes; the compasses that can measure the interval that separates particle from particle, and the scale that will turn with the weight of an atom, do not belong to man, though the imagination may picture such delicate contrivances in the laboratory of a scientific fairy.

These considerations lead us to a subject about which we do know something, namely, the *relative weights* of the ultimate particles or atoms of bodies.

Chemistry has revealed the existence of some sixty-two elementary bodies, or, according to the atomic theory, sixty-two different kinds of atoms. Now, although we cannot ascertain the actual weight of a single atom, we have good grounds for believing that an atom of oxygen is heavier than an atom of carbon and lighter than one of sulphur. Before we enter into this subject, we have a few words about the great man who revived the ancient theory of atoms, and made use of it to explain the mysterious laws of chemical combination.

John Dalton was born in Westmoreland, in the latter portion of the last century, and belonged to the Society of Friends. When very young he resided with Mr Gough of Kendal, a blind philosopher, to whom he read, and whom he assisted in his scientific investigations. It was here that he acquired a considerable part of his education, particularly his taste for mathematics. From Kendal, Dalton went to Manchester, and commenced teaching elementary mathematics to young men. In this way, together with a few courses of chemical lectures which he occasionally delivered, he contrived to support himself during a long and useful life. His slender income was always equal to his wants, and in his contempt for riches he resembled the sages of antiquity.

His kind heart and powerful mind gained him many friends and admirers, and in course of time he came to be regarded as a great philosopher, though he still continued to earn his bread as a tutor. Such was the founder of the beautiful atomic theory of Chemistry, which is so well adapted to render certain natural laws intelligible to our understanding.

In examining the so-called Four Elements, we alluded to the fact that bodies united to form compounds in definite proportions. Let us explain this matter more fully. Water invariably contains oxygen and hydrogen, in the proportion of sixteen parts by weight of the former element to two of the latter, whether these parts represent tons, pounds, grains, or any other quantities.[1] The whole of the oxygen contained in the ocean is exactly eight times heavier than the hydrogen with which it is combined, and the weights of the two gases bear the same relation to each other in the dew-drop. If we take any other chemical compound, we shall find that the proportions by weight of its constituents are invariable; thus there is a broad distinction between such a compound and a mere mixture in which the ingredients are present in indefinite proportions.

Water is not the only compound that can be formed of oxygen and hydrogen. We can compel two parts of hydrogen to combine with thirty-two parts of oxygen; and the result of their union is a colourless liquid, less volatile than water, and having

[1] The proportion is given as 16 to 2, instead of as 8 to 1, to simplify the explanations that follow.

a metallic taste. It is a very unstable compound, and spontaneously undergoes decomposition into water and oxygen. This liquid, called peroxide of hydrogen, and water, are the only compounds that can be formed of the two gases. This fact is well worthy of consideration. Two parts of hydrogen will combine with sixteen or with thirty-two parts of oxygen, but in no other proportions. Let us now glance at some other compounds. When potassium acts upon water, it displaces half of its hydrogen to form hydrate of potassium, which consists of one part of hydrogen, sixteen parts of oxygen, and thirty-nine of the metal. Again, by acting upon this compound with more potassium, we may displace the remaining hydrogen, and form oxide of potassium, which has sixteen parts of oxygen to twice thirty-nine or seventy-eight parts of the metal. The poisonous gas known as carbonic oxide, contains twelve parts of carbon and sixteen of oxygen; but twelve parts of carbon also combine with thirty-two of oxygen to form carbonic anhydride. The deadly liquid commonly known as prussic acid contains twelve parts of carbon and one part of hydrogen, with fourteen parts of a third element, nitrogen. In nitric acid we again find fourteen parts of nitrogen, and one part of hydrogen, with three times sixteen or forty-eight parts of oxygen.

How can we account for these recurrent numbers? What relation subsists between the number 16 or its multiples, and oxygen; between 1 and hydrogen;

39 and potassium; 12 and carbon; or 14 and nitrogen? Why should these bodies combine in fixed numerical proportions?

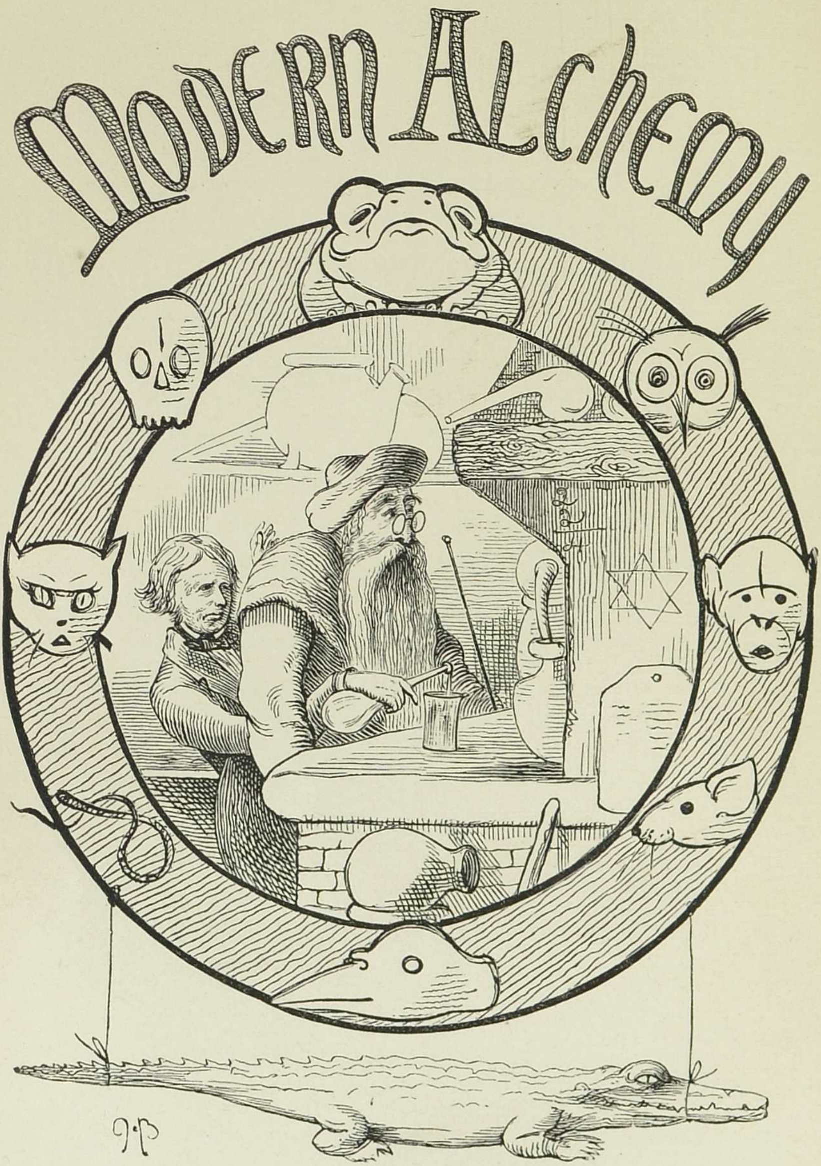
According to the beautiful atomic theory of Dalton, these numbers express the relative weights of the ultimate particles of matter. Let us consider the composition of some of the bodies we have noticed in this light. Each molecule of water is composed of two atoms of hydrogen gas and one atom of oxygen, the latter being sixteen times heavier than each atom of hydrogen. Now, it is evident that whatever may be the number of molecules in a given volume of water, the relative weights of the two gases will remain constant. The molecule of carbonic oxide is composed of one atom of carbon, and one atom of oxygen, their relative weights being 12 and 16. But the molecule of carbonic anhydride contains one carbon atom, and *two* atoms of oxygen. There can be no compound of carbon and oxygen between carbonic oxide and carbonic anhydride, according to the atomic theory, as we cannot admit the existence of half atoms. We have only spoken of a few of the elementary bodies, as we wished our remarks to be as simple as possible; each of the sixty-two elements has, however, a definite combining proportion or atomic weight.

How admirably this atomic theory explains the laws of chemical combination! how intelligible it renders those fixed, invariable weights in which the elements unite to form compounds! All is shown to depend on the properties with which those inconceivably small particles of matter are invested.

We have told the reader all we know about atoms —at least all we think we know, for we can never be certain that atoms exist. They are immeasurably minute, they are separated from each other by wide intervals, and they have a definite weight.

A German chemist has endeavoured to render the atomic theory intelligible by a very ingenious illustration. He compares atoms to the heavenly bodies, which, in comparison with the extent of the space in which they are suspended, are infinitely small; that is, are *atoms*. Innumerable suns, with their planets and attendant satellites, move in infinite space, at definite and measured distances from each other. They are individually indivisible, inasmuch as there exists no force capable of separating them into parts, tearing off from them anything material, or altering their size or form in such a degree as to be perceptible, or to impair or disturb their relations to the other heavenly bodies. In this sense the whole universe coalesces into one immense body, the atoms of which—that is, suns, planets, and satellites—are indivisible and unchangeable!

There are many things in nature which the human mind will never be able to comprehend; and foremost among them we must place our Little Bit.


MODERN ALCHEMY

Modern Alchemy.

'But when you see th' effects of the Great Medicine,
Of which one part projected on a hundred
Of Mercury, or Venus, or the Moon,
Shall turn it to as many of the Sun,
Nay, to a thousand, so *ad infinitum*,
You will believe me.'—BEN JONSON.

WHO has not heard of the Philosopher's Stone, that much-coveted but unattainable red powder of the alchemists, which was supposed to possess the powers of transmuting baser metals into gold, of healing disease, and of restoring youth? Who has not read of those misguided men of former ages, whose lives were passed in attempting to discover this precious substance, which was to confer upon them inexhaustible wealth, health, and longevity, but whose labours too often resulted in poverty, sickness, and death?

In the present day we are too apt to regard the doctrine of transmutation, which formed the basis of alchemy, as a mere hallucination of the human mind; and to look upon the men who entertained it with mixed feelings of pity and contempt. Now if we only take the trouble to dip into the subject of Alchemy, we shall find that the idea of the transmutation of baser metals into gold stood in the most perfect harmony with all the observations and all the knowledge of the age in which it was conceived, and that the alchemists, instead of being crack-brained enthusiasts, were the most learned and acute men of their time.

In the sixteenth and seventeenth centuries there were many impostors who pretended to a knowledge of gold-making; but it is unjust to confound them with the true alchemists, who were equivalent to the chemists of the present day. We cannot really draw a line of demarcation between alchemy and chemistry, as the one science passed by an imperceptible transition into the other. Alchemy is ancient chemistry, and chemistry modern alchemy. Many of the opinions entertained by the chemists of to-day are quite as extravagant as those held by the alchemists. Indeed, as our knowledge increases, the transmutation of metals seems to grow more and more probable.

Before we consider the magical transformations that are effected by the modern alchemist, let us examine some of the doctrines propounded by his ancient representative.

The alchemist maintained that all the metals are compounds; that the baser metals contain the same constituents as gold, contaminated with various impurities. To transmute any metals into gold, these impurities must be removed or remedied, a result only to be attained through the agency of the great medicine, or philosopher's stone.

This view of the nature of metallic bodies was perfectly consistent with known facts. It was known that the colour or hardness of a metal could be modified by the addition of a foreign substance, and it was only natural to suppose that the different qualities of the metals depended on certain impurities.

Gold was the only pure or healthy metal. Brass was diseased gold; mercury was diseased silver; but these metals, and all the others, might be healed, or transmuted into gold, by the wonderful red powder. In the mystical language of the alchemists, gold was called Sol, or the sun; silver, being the next metal in purity, was Luna, or the moon; and the other five metals then known received the names of the planets.

The idea that the philosopher's stone possessed the powers of curing diseases, and of prolonging life, was evidently suggested by its supposed effect on ignoble metals. Since it could heal the metallic lepers, and convert them into gold, why should it not ennoble the human body?

The existence of the philosopher's stone was never questioned, though few of the alchemists who have left writings behind them boast of having had it in their possession. In all the wonderful stories that are told of the conversion of the baser metals into gold, some *mysterious unknown* is made the fortunate possessor of the magical substance. The narrative of Helvetius, the distinguished physician to the Prince of Orange, is a good example of these stories:—

At the close of the year 1666, a stranger called upon Helvetius, and showed him five large plates of gold, which he said he had made by means of the philosopher's stone. The physician, who had hitherto been a bitter opponent of alchemy, was not prepared to receive this extraordinary statement without some convincing proof of its truth; he therefore besought the stranger to give him a small portion of the stone, or at least to make a trial of its powers in his presence. The stranger refused to accede to either of these requests, and took his leave, promising, however, to return in six weeks. He kept his promise, and presented Helvetius with a piece of the stone about the size of a mustard-seed. Next day the physician, in the presence of his wife and son, put six drachms of lead into a crucible, and as soon as it was melted, threw into it the fragment which he had obtained from the adept. The crucible was now covered with its lid, and left in the fire for a quarter of an hour, at the end of which time the whole of the lead was converted into gold. The melted metal was at first of a deep green colour, then it became blood-red, but when cold it assumed the true tint of gold. This ingot stood all the tests that were applied to it by

Porelius, the Warden of the Dutch Mint, and was found to be pure gold! We need scarcely add that the sceptical Helvetius became a firm believer in the transmutation of metals.

We dare not accept this strange story as a true one, though we cannot comprehend the motives that could have induced Helvetius to promulgate that which he knew to be false. In the present state of our knowledge, we regard lead and gold as distinct bodies, and not modifications of the same substance.

If the alchemists failed to discover the philosopher's stone, we must not conclude that their labours were fruitless. In seeking that which had no real existence, they found some inestimable treasures; for most of those acids, alkalies, and salts that are indispensable to the modern experimentalists were discovered hundreds of years ago by the alchemists.

'The philosopher's stone,' says Baron Liebig, 'for which the ancients sought with a dim and ill-defined impulse, was in its perfection nothing else than the science of chemistry. Is that not the philosopher's stone which promises to increase the fertility of our fields, and to ensure the prosperity of additional millions of mankind? Does not chemistry promise that instead of seven grains we shall be enabled to raise eight, or more, on the same soil? Is that science not the philosopher's stone which changes the ingredients of the crust of the earth into useful products, to be further transformed by commerce into gold? Is that knowledge not the philosopher's stone which promises to disclose the laws of life, and which must finally yield to us the means of curing diseases and of prolonging life?' With these remarks we will take our leave of the ancient alchemists, and proceed to consider the labours of the alchemists of the present day.

Let us step into a laboratory, and surprise one of these men of science at his work. What a different place from the smoky workshop of the alchemist of former days! The massive furnaces have given way to cunning contrivances for gas, and all the clumsy alembics, aludels, and earthen vessels which were once in vogue, have been displaced to make room for tiny bottles, retorts, glass tubes, and balances.

The alchemist himself has shaved off his long beard, and has discarded his ample gown; he now wears a most unpicturesque black coat, and looks for all the world like an ordinary person.

What is he doing? Is he trying to transmute lead into gold? No; he is not satisfied that the metals are transmutable, and he cannot afford to waste his life in researches which may never lead to satisfactory results. He is doing something which seems quite as extraordinary as gold-making—he is extracting a beautiful metal from clay!

This metal, which is called *aluminium*, was first procured in a separate state thirty-six years ago, but in so small a quantity that its peculiar qualities could not be defined. We are indebted to a celebrated French adept[1] for the process by which the metal can be obtained in considerable masses.

Here is a bar of aluminium. It resembles silver in its beautiful lustre, but can be easily distinguished from that metal by its faint tinge of blue. If we handle the bar we shall marvel greatly at its lightness, as aluminium is only about two and a half times as heavy as water, or one-fourth the weight of silver. The alchemist will tell us that it is endowed with many striking properties. It can be fused almost as easily as zinc, and cast into any form. It is malleable and ductile to a great extent, and can be beaten into the thinnest plates, or drawn out into the finest wires. It equals silver as a conductor of electricity. It does not tarnish on exposure to the air, and is not affected by the sulphurous vapours that prove so destructive to the lustre of silver. It is admirably adapted for the manufacture of bells, as it has all the sonorous qualities of the most expensive bronzes. Its marvellous lightness and strength render it an invaluable material for defensive armour. It is free from deleterious qualities, and therefore suited for domestic utensils. It may be fashioned into ornaments that will never lose their splendour, and into delicate scale-beams and watch-wheels that will never be affected by rust. With copper it forms a beautiful alloy called *aluminium-bronze*, which has the colour of gold, and a tenacity equal to that of the best steel. In fine,

[1] H. St Claire Deville.

aluminium seems to possess properties which render it useful in a thousand ways; and if the process by which it is obtained can be further simplified, it will prove an inestimable boon to mankind. The source of aluminium is inexhaustible, since it is the base of every kind of clay. About one-sixth of the weight of every brick, every stone-jar, and every tea-cup consists of this curious metal.

Who will say that alchemy is extinct? What science but alchemy would enable us to extract a metal having an intrinsic value equal to that of gold, from a lump of worthless clay?[1]

The artificial formation of *lapis lazuli* is another brilliant achievement of modern alchemy. This mineral has always been esteemed for its beautiful azure-blue colour, and for furnishing us with the valuable pigment ultramarine.

Before the chemist could produce ultramarine artificially, he required to know the composition of the natural mineral; before he could form a portion

[1] At present aluminium cannot be profitably extracted from clay. On a large scale the metal is usually obtained from the minerals, *cryolite* and *bauxite*. The latter, which is essentially a compound of oxide of aluminium, oxide of iron and water, is the source of the greater part of the aluminium produced by Messrs Bell Brothers of Newcastle. Another metal which was regarded as a scientific curiosity a few years ago has lately become an article of commerce. We refer to *magnesium*, the base of the earth, magnesia. This metal when heated to redness in the air burns with a dazzling light which has the photographic power of sunlight. An improved method of preparing it was introduced by Mr Sonstadt in 1863, and the combustion of a few inches of magnesium-wire is now a common experiment.

of lapis lazuli, it was necessary that he should pull another portion to pieces for a pattern. This preliminary operation was soon performed, and the chief constituents of lapis lazuli were found to be silica, alumina, and soda, three colourless bodies, with sulphur and a trace of iron, neither of which is blue. The chemist was not a whit disheartened at the absence of any bright-coloured ingredient, as he knew that it was impossible to account for the colour of most chemical compounds. He now combined the five constituents of the mineral in their proper proportions, and saw, to his great delight, that the compound assumed the matchless hue of ultramarine. The artificial ultramarine is even more beautiful than the natural, while for the price of a single ounce of the latter we may obtain many pounds of the former.

Surely our modern alchemists have discovered the true philosopher's stone, for with the comparatively valueless substances, flint, clay, soda, sulphur, and iron, they form a mineral which was formerly much dearer than gold!

Let us just glance at a few of the new bodies which the adepts have derived from coal. Here is *paraffin*, a beautiful crystalline translucent body, which is now largely used in place of wax or spermaceti as a material for candles. Here is *benzol*, a limpid colourless liquid which readily dissolves india-rubber and gutta-percha, the fixed and volatile oils, sulphur, camphor, wax, and mastic. Here is *rosaniline* or *magenta*, the queen of crimson dyes; and here are her lovely sisters, *aniline-purple* or *mauve*, *aniline-green* and *aniline-yellow*. While such things can be obtained from such a substance as coal-tar, our alchemists are not likely to waste much time in attempting to make gold.

The extraction of aluminium from clay, the manufacture of ultramarine, and the formation of the aniline dyes are examples of chemical analysis, synthesis, and substitution, but not of transmutation. Let us now examine the opinions entertained by the alchemists of to-day on the subject of the transmutation of elementary bodies.

The ancients believed the metals to be compounds, and this view may be correct. They are now considered to be simple substances, not because they are known to be undecomposable, but because they have never yet been decomposed. Sixty years ago upwards of a dozen bodies were regarded as elements which are now known to be compounds of metals with oxygen.

Who can tell what another period of sixty years may do for alchemy? It is quite possible that at the end of that time the sixty-two so-called simple bodies may be found to be mere modifications of three or four elements, or perhaps of one primordial substance.

These considerations lead us to reflect on the curious transformations which occur in the properties of certain elementary bodies, and which must be regarded as actual instances of transmutation. Now, a difference in the properties of two compounds having the same composition, may arise from a difference in the arrangement of their ultimate particles; but how is it with the different forms assumed by a simple body? A mass of phosphorus is supposed to be an aggregate of similar atoms, yet this and many other substances of a simple nature, are liable to strange variations of condition which we are as yet unable to explain.

The element carbon exists in many different states. This irregular lump of charcoal, this light powder called lamp-black, and this hard semi-crystalline mass of coke, are mere modifications of one substance.

Again, this piece of graphite is chemically the same substance, as it is simply an aggregate of carbon atoms; but it has none of the properties of charcoal. It has a metallic leaden-grey lustre, whence its familiar name of *black-lead.* It burns with great difficulty; it is greasy to the touch, and it leaves dark traces when rubbed upon paper.

But the most remarkable form assumed by carbon is that of the diamond. This precious gem occurs in nature in regular crystals, usually colourless, but sometimes yellow and brown. Now, we are convinced that this brilliant and transparent body is made up of the very same atoms as those which go to form the dull black mass of charcoal! The alchemist has not yet succeeded in making diamonds, but he has already transmuted diamonds into coke. Who knows but what he may reverse this transmutation before long!

When we find a single element assuming these Protean shapes, we must admit that the notions of the old alchemists were far from being extravagant. To a person ignorant of chemistry it would appear much more probable that the metals are modifications of one substance, than that the diamond is merely crystallized charcoal.

Sulphur may be obtained in various forms. The roll-sulphur or *brimstone*, and the fine powder called *flowers of sulphur*, are probably the only forms known to the reader. The alchemist, however, procures sulphur in beautiful semi-transparent crystals; in needle-like prisms of a brownish-yellow colour; and in a soft and sticky mass, which may be drawn out into elastic threads, and which greatly resembles shoemaker's wax.

Phosphorus is equally changeable, and may be obtained in no less than five different forms. Let us compare ordinary phosphorus with its most striking modification, which has been designated *amorphous phosphorus*. Ordinary phosphorus is a colourless waxy-looking solid; the amorphous phosphorus is opaque, and of a brownish-red colour. The former is easily fusible, very inflammable, and luminous in the dark; the latter may be heated in the open air without change, until the temperature reaches 500°, when it is converted into ordinary phosphorus. Great caution is required in handling the ordinary phosphorus, as the heat of the hand is sometimes sufficient to inflame it; but the philosopher who discovered the amorphous phosphorus[1] is in the habit of carrying this variety loose in his pocket. Common phosphorus dissolves in bisulphide of carbon; the altered phosphorus is insoluble in that liquid. The former is very poisonous; the latter, in the same dose, has no effect on the animal system.

These marvellous differences are inexplicable. We are able to change the ordinary phosphorus into the amorphous variety by means of heat, without adding to it any new substance; therefore we are quite sure that the soft translucent solid that takes fire so easily is chemically the same substance as that uninflammable solid which looks like a piece of common red bottle-wax. Were we unable to effect this strange transmutation, we should doubtless regard these two modifications of phosphorus as distinct elements.[2]

The invisible gas, oxygen, can be made to assume a very strange condition, by transmitting through it a succession of electric sparks. This altered oxygen, which has received the name of *ozone*, exhibits some very striking properties. It has a powerful odour,

[1] Schrötter.

[2] The amorphous phosphorus occurs in commerce as a chocolate-red powder. It is largely used for preparing the surfaces upon which the new 'patent safety matches' are ignited. The matches are tipped with a composition that cannot be ignited by friction on any unprepared rough surface.

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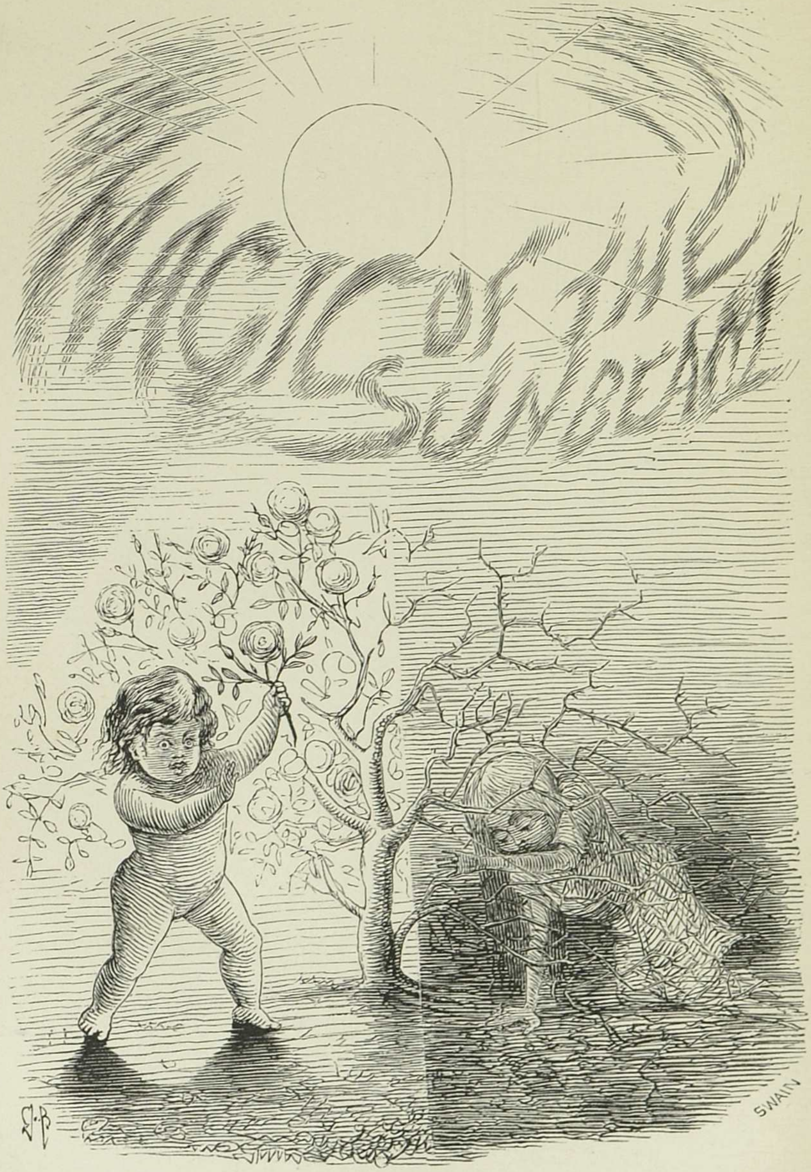
whereas ordinary oxygen is destitute of the slightest smell. It possesses considerable bleaching powers, corrodes organic matters, and acts as a powerful oxidizing agent. It seems to be much more active than ordinary oxygen, and might easily be taken for a distinct element by those ignorant of the fact that its active character can be destroyed by heat.

These instances of actual transmutation will suffice to convince the reader that alchemy still exists. He will see that our modern alchemists are true descendants of the ancient gold-seekers, though they no longer believe in the philosopher's stone. He will be less disposed to ridicule the idea of the transmutation of metals, and will be able to form some conception of the wonderful products of modern alchemy.


MAGIC OF THE
SUNBEAM
SWAIN

The Magic of the Sunbeam.

'The glorious sun
Stays in his course, and plays the alchemist.'—
King John.

WHEREVER the Sunbeam falls we find life and motion; elsewhere, death and stillness. Under its influence the seed germinates, the stem sends forth branches, the leaf bursts from the bud, the flower unfolds its petals, and the fruit grows and ripens.

This subtle agent plays an important part in many of the fairy tales of science. The philosopher has conducted it into his dark laboratory, and by twisting and torturing it with cunningly devised instruments, has forced it to reveal so many wonderful truths, that the mind, in attempting to grasp them, is fairly bewildered. The Magic of the Sunbeam is indeed an inexhaustible theme, and we can only touch upon a few of its mysteries.

Every sunbeam consists of luminous, heating and chemical rays. At present we will confine our attention to the light of the Sunbeam.

What is light? This is one of those unanswerable questions that meet us on the threshold of every science. According to the 'theory of emission,' light consists of tiny particles of matter thrown off from a luminous body with prodigious velocity in all directions. According to the 'theory of undulations,' it is the effect of vibrations excited by luminous bodies in an elastic medium called the *ether*, which is believed to pervade all space. The latter theory gives the most satisfactory explanation of the phenomena of light, and is now universally accepted.

Whether a ray of light be a stream of inconceivably minute particles of matter, or a succession of waves in an ethereal medium, we are quite certain that it travels at the rate of nearly two hundred thousand miles in a single second. But such is the disporportion between the distances of the celestial bodies, that light must be about eight and a quarter minutes in reaching us from the sun; more than four hours in coming from the planet Neptune; about ten years from the nearest fixed star; and probably centuries from the nebulæ! When we look up at the heavens, we do not see the stars as they are now, but as they were many years ago, for the light which now renders them visible must have left them long before we were born!

Rays of light are emitted, under ordinary circumstances, in direct lines; they will not pass through a bent tube, nor turn a corner. Bodies through which light passes freely are called transparent, and those which do not admit it to pass, opaque. When light falls upon an opaque surface, a portion is absorbed and another portion reflected; when the reflected portion is considerable, the surface appears *white*, and *black* when the portion is inappreciable.

We have said that a sunbeam brings us light, heat, and chemical force. These three forms of energy differ only in intensity; but to simplify our language, we shall regard them as distinct agents.

Light acts upon the organs of vision, and enables us to distinguish external objects. Heat regulates the solid, liquid, and aëriform states of matter, and maintains this planet in the condition which is essential to the well-being of its inhabitants. The chemical powers of the sunbeam bring about those wonderful chemical changes which are constantly occurring in nature. The three kinds of solar radiations unite to form our magic sunbeam, just as three chemical elements unite to form a compound.

How can we decompose a sunbeam? How can we separate those forces which are linked together in such a mysterious manner? Easily enough; for by the instrumentality of a triangular bar of transparent glass, called a prism, the beam can be instantly resolved into its components.

If a sunbeam, admitted into a dark chamber by a small hole in the window-shutter, be allowed to fall on a prism, its subtle constituents are mysteriously disturbed, and precipitate themselves at different distances on a white tablet, or screen, placed to receive them. What marvellous change is this! A moment since the beam formed a bright spot on the screen, but now in place of the spot we see a lengthened band of variegated colours! On one side of the prism a pencil of brilliant white sunlight falls upon the surface of the glass; on the other the pencil spreads out and paints upon the screen a ribbon whose beauteous hues infinitely surpass the colours that lie on the artist's palette! Examine these colours attentively. At the bottom of the band we find red, above it orange, then yellow, green, blue, indigo, and lastly violet. These colours pass by insensible gradations into each other, so that it is impossible to say where one colour ends and another begins.

We have thus decomposed the light of the sunbeam into its elementary colours, for our readers must know that white is a compound of seven hues. The natural colours of bodies depend entirely upon the manner in which they decompose the sunbeams. A rose is red because its petals have the property of absorbing all the elementary colours of light except red, which it reflects. The pigments used by the artist are not in themselves colours; they are merely substances that absorb certain rays and reflect others. Our readers will now understand how it is that a body which reflects most of the light that falls upon it appears perfectly white.

But we have not yet done with the variegated band, or *prismatic spectrum*, as it has been termed. If a highly sensitive finger were held in the yellow rays of the spectrum, a degree of warmth would be felt, greater than if it were held in the violet rays. But if it were removed to the extreme red rays, a great deal more heat would be perceived than in either of the former cases. Now, we have imagined the existence of a finger far more sensitive to slight variations of temperature than ordinary fingers are, but these results have been obtained by means of very delicate thermometers, or heat measurers.

Let us now take a piece of paper, prepared for the photographic process, and place it upon the screen so that it may receive the rainbow-like colours upon its sensitive surface. On removing it, it will be found to be blackened at a point beyond the violet rays of the spectrum. The blackening of the prepared paper is effected by the chemical force of the sunbeam.

From these experiments we learn that the sunbeam is an ethereal band of different rays, which may be separated by the instrumentality of the prism. We learn that heat rays are less refracted, or bent, by the glass than the others, as we find them but slightly thrown out of the right line which the beam would have taken had it not been interrupted by the prism. We discover that luminous rays are subject to greater refraction as the seven colours are thrown upon the screen above the maximum point of the heat rays. Lastly, we find that chemical rays are more refrangible than either those of heat or light, as we know that their power is most strikingly manifested in the upper part of the spectrum at a point where light rapidly diminishes, and where scarcely any heat can be detected.

The analysis of the sunbeam by means of the prism must excite our wonder. Who could imagine that a simple wedge-shaped piece of glass would be able to separate those imponderable agents which reach us after having travelled ninety-five millions of miles together?

We can isolate each kind of solar radiation without the aid of a prism. The crystal called *black mica* does not admit light to pass through it, but it is freely penetrated by heat; and, on the other hand, glass stained green by oxide of copper, offers scarcely any impediment to the passage of light, though it effectually stops the rays of heat. Again, a yellow transparent glass obstructs the chemical radiations, while a dark blue medium, which arrests nearly all the light, allows them to pass.[1]

Let us now consider the magic influences of this sunbeam over the animal and vegetable kingdoms. The luminous rays first demand our attention; for

[1] Professor Tyndall in his researches on radiation used an opaque solution of iodine in bisulphide of carbon, contained in a cell of rock salt, to separate the invisible and visible rays of the electric light. With a concave mirror behind the electric lamp and the solution in front, he produced a large invisible cone of heat, at the apex of which various substances could be kindled as if by magic.

although we are told that they are less abundant than either the calorific or the chemical rays, we cannot help regarding them as the sunbeam's chief element. Light is of the highest importance to the health and well-being of animals, as may be inferred from the fact that animal life ceases in situations from which light is totally excluded. The case of the *Proteus anguinus* appears to be exceptional, and therefore deserves some notice.

This extraordinary little creature is found in some of the gloomy caverns of Illyria, into which the magic sunbeam never penetrates. 'At first view,' says Sir Humphry Davy, 'you might suppose this animal to be a lizard, but it has the motions of a fish. Its head, and the lower part of its body, and its tail, bear a strong resemblance to those of the eel; but it has no fins, and its curious bronchial organs are not like the gills of fishes. They form a singular vascular structure, almost like a crest, round the throat, which may be removed without occasioning the death of the animal, who is likewise furnished with lungs. With this double apparatus for supplying air to the blood, it can live either below or above the surface of the water. Its fore feet resemble hands, but they have only three claws or fingers, and are too feeble to be of use in grasping or supporting the weight of the animal. The hinder feet have only two claws or toes, which, in the larger specimens, are found so imperfect as to be almost obliterated. It has small points in place of eyes, as if to preserve the analogy of nature. It is of a fleshy whiteness and transparency in its natural state; but when exposed to light, its skin gradually becomes darker, and at last assumes an olive tint. Its nasal organs appear large; and it is abundantly furnished with teeth, from which it may be concluded that it is an animal of prey, yet in its confined state it has never been known to eat, though it has been kept alive for many years by occasionally changing the water in which it was placed.' This strange creature, whose life is passed in total darkness, has long been a puzzle to philosophers, as all the facts revealed by science go to prove that light is indispensable to organization.

The dependence of animal life upon light is beautifully exhibited in the ocean. Water is not absolutely translucent, and it has been calculated that light must lose all its influence at the depth of a very few hundred feet in the ocean, even under the tropics. Now, although some humble marine creatures have been found at vast depths, it has been satisfactorily proved that life gradually diminishes as we descend into the ocean, and that at a comparatively moderate depth the higher forms of life disappear altogether. But this is not all, for besides being much more numerous, the shells of the different mollusca are much more brightly coloured in the upper regions of the ocean than in the lower, in fact, a regular gradation of tints may be traced, as the shells grow deeper in hue as they approach the light.

Man himself is highly susceptible to the influence of light, and pines and sickens in darkness. Those persons who dwell in dark streets and alleys are far more subject to disease than those who reside in open places. Again, those who take no heed of the old proverb about going early to bed, seldom find themselves healthy; and though they may be wealthy, they cannot be deemed wise!

Light is absolutely necessary to vegetable life, for under its influence the plant separates carbon from the air and secretes it within its tissues. Every one must have observed how plants grow towards the light, especially when confined in a room; how blanched and sickly they become in dark situations, and how speedily they recover when exposed to full sunlight. When a potato germinates in a dark cellar, it puts forth long pallid shoots in quest of a stray sunbeam; but let it be exposed to the light for a few days, and these shoots will become dark and green.

Flowers are more sensitive to the influence of light than leaves; indeed almost every flower has a particular degree of light requisite for its full expansion. So regular are the periods of opening and shutting with some flowers, that they enable us to tell the hour of the day with tolerable accuracy. The great naturalist, Linnæus, made a list of no less than thirteen flowers that open and shut at different hours, and designated them by the fanciful title of 'Flora's clock.'

Having said enough to prove that there exists a mysterious bond of union between organization and light, let us now examine some of the effects of heat.

The present condition of our earth is directly dependent upon the amount of heat we receive from the sun. If it were possible to move this planet nearer that orb, the quantity of heat would be much increased, and all the present races of plants and animals must perish; the same result would happen were the two bodies to be separated by a greater distance, owing to a deficiency of the genial influence. In the former case the world would be much too hot to hold us, and in the latter we should be regularly frozen out!

The rays that are emitted from the sun are partly absorbed by the atmosphere, which acts as a screen, and shields the earth's inhabitants from the full and perhaps destructive influence of the sun's heat. The quantity of heat received by us in one year is prodigious, for it has been calculated that it would suffice to melt a shell of ice thirty-five yards in thickness, and covering every part of the globe. The heat-rays striking the earth, become dispersed in a variety of ways. Some are reflected, others are absorbed. Some of the rays warm the earth, and then warm the overlying air, and expanding it, rise with it to the upper regions of the atmosphere. But by far the greater number of heat-rays penetrate the earth, and descend to a considerable depth. In winter this stored-up heat partly returns to the surface, and ultimately becomes dissipated into the air, and from the air into infinite space.

Heat, like light, is absorbed in different degrees by different substances. The colour and condition of surface seems to exert a great influence on its absorption; thus a black body absorbs more heat than a white one, and a rough surface more than a smooth one. 'Every tree,' says Mr Hunt, 'spreading its green leaves to the sunshine, or exposing its brown branches to the air, every flower which lends its beauty to the joyous earth, possesses different absorbing and radiating powers. The chalice-like cup of the pure white lily floating on the lake, the variegated tulip, the brilliant anemone, the delicate rose, and the intensely-coloured peony or dahlia, have each powers peculiar to themselves, for drinking in the warming life-stream of the sun, and for radiating it back again to the thirsting atmosphere.'

It is impossible to enumerate the wonderful offices performed by heat in the economy of nature. By the influence of heat, water is vaporized and raised into the air, thence to be precipitated in refreshing showers. The atmospheric currents are caused by heat; the trade-wind, that blows from the same quarter throughout the year, the periodical monsoon, the gentle breeze, the boisterous gale, and the devastating hurricane, are alike manifestations of the activity of this mighty principle.

Let us now glance at that mysterious element of the sunbeam which cannot be detected by the senses.

To modern science is entirely due the knowledge we have gained of the chemical powers of the sunbeam. The old alchemists, indeed, were acquainted with the isolated fact that a white substance called *horn silver* was blackened by exposure to the sun's rays, but it never struck them to investigate the cause of this curious phenomenon. It was reserved for modern philosophers to prove that no substance can be exposed to the sun's rays without undergoing a chemical change.

The blackening of horn silver is but a single instance of a vast number of effects produced by that mysterious agent which is associated with light and heat in the sunbeam. All bodies are influenced by the chemical force of the sunbeam, and undergo a molecular disturbance. The rock and the mountain, as well as the animal and the plant, are destructively acted upon during the hours of sunshine, and would soon perish under the delicate touch of the chemical rays, were it not for the counteracting influence of darkness. At night, the chemical disturbances are undone, and inorganic bodies as well as organized beings may be said to sleep!

The influence of the chemical rays upon germination is very remarkable, as seeds will not germinate in light from which these rays are separated. But, after the leaves are formed, a larger amount of light than of chemical energy is necessary to enable the plant to separate carbon from the atmosphere and form wood. Again, the flowering and fruiting of a plant is more closely connected with the heat of the sunbeam than with its light or its chemical action. Nature has amply provided for the varying wants of plants; in the spring we may detect an excess of chemical energy in the solar rays, in the summer an excess of light, and in the autumn an excess of heat.

We have said that all bodies undergo a chemical disturbance when exposed to the solar rays, but it must not be supposed that this disturbance always manifests itself in a blackening, as in the case of horn silver. If a polished plate of metal, of glass, of marble, or even a polished surface of wood, be in part exposed to the influence of sunshine, it will, when breathed upon, exhibit the fact that a disturbance of some kind has taken place upon the portions illuminated, whereas no change can be detected upon the parts kept in the dark. But if we expose a chemically prepared tablet to the sunbeam in a similar manner, we may by a certain process render the effect produced on its surface permanent, and thus as it were fix a shadow.

The beautiful art of photography, or light-drawing, is based upon this marvellous fact. Everybody is familiar with the grand results of this art. Everybody possesses some of those wondrous pictures which neither pencil, brush, nor hand has touched, but which have been delicately traced by the magic sunbeam. We have ceased to look upon these pictures with astonishment, just as we have ceased to wonder at the locomotive, the electric telegraph, and the steamship. But in times gone by, had any one asserted that he could compel the sunbeam to paint a portrait, he would in all probability have been burned as a wizard; indeed, not many years ago a gentleman was thought to be disordered in his intellect, because he deemed it possible to fix the fleeting pictures seen in the camera obscura.

We cannot enter further into the Magic of the Sunbeam without leading our readers into the mystic regions of mathematics. We have already said that the subject is an inexhaustible one, and we are more convinced of this than ever when we find what a comparatively small number of facts relating to the wonderful band of forces called the sunbeam, we have been able to set before the reader. But though so much is known about the sunbeam, how much still remains obscure! It is only since the commencement of the present century that the chemical action of the sunbeam has attracted notice; and who can tell what forces may still be hidden in the beam—what unknown powers may yet be discovered by our laborious truth-seekers?

Two Eyes are better than One.

'Mine eyes are made the fools o' the other senses.'
MACBETH.

THE old proverb which heads this chapter is suggestive of many wonderful truths connected with vision. Science has demonstrated that two eyes are better than one, for many reasons. We require two eyes to estimate distances, and to obtain a true idea of the roundness, relief, and solidity of natural objects. Those ugly one-eyed fellows who helped Vulcan to forge the thunderbolts, must have been clumsy workmen, in spite of what the ancient writers say to the contrary.

Before we consider the use of two eyes, let us examine the structure of a single organ. The eye has often been compared with the camera obscura, that dark box in which an image is formed of external objects, by means of an arrangement of glass lenses. The eye is, indeed, a dark chamber furnished with lenses, but here the likeness ceases, as its marvellous arrangements are infinitely more beautiful than those of any optical instrument devised by the ingenuity of man.

The human eyeball is a globular mass, somewhat flattened in front, and about the size of a walnut. The white part surrounding the centre is called the *sclerotic* coat, deriving its name from a Greek word expressive of hardness. This white coat is continued round the back of the eyeball, and forms a sort of strong bag for containing the other parts of the eye. As it is perfectly opaque, it is not continued over the front of the eye, but joins the beautiful transparent membrane called the *cornea*, or horny coat, which bulges forward a little, and forms that wonderful bow-window through which the rays of light pass to the brain. Within or behind the cornea may be perceived the *iris*, a sort of coloured fringe which assumes different hues in different eyes, being dark brown, blue, hazel, or grey, and, in exceptional cases, red. When we speak of blue eyes or hazel eyes, we refer to the colour of this remarkable fringe or curtain. In the centre of the eye, surrounded by the iris, is a dark circular space of variable dimensions, called the *pupil*, which is in fact the opening through which light passes into the dark chamber of the eye.

The internal structure of this wonderful organ is very complicated. The hard white membrane is lined by a coat called the *choroid*, which is covered on the inside with a perfectly black pigment, and this again with a delicate network of nerves called the *retina.* The cavity surrounded by these coats is filled by three substances, called humours. Behind the cornea or bow-window is the *aqueous humour*, a perfectly limpid liquid resembling water; the second in situation is the *crystalline humour*, which is a little capsule of transparent membrane, holding a small quantity of fluid; and the third, termed the *vitreous humour*, is a transparent jelly which fills the inner chamber of the eye, and contributes chiefly to preserve the globular figure of the organ.

Each eye is placed in a basin-shaped cavity in the skull, called the orbit, and there are various muscles attached to different parts of the orbit, which by their contraction give a lateral or rolling motion to the eyeball, and thus assist in directing the sight towards particular objects. Eyelids, also moved by muscles, and fringed by the eyelashes, serve to guard the eyes from dust, and to screen them from the access of too intense a light.

So much for the anatomy of the eye; let us now consider its functions. As already observed, the eye may be compared to a camera obscura, for the rays of light from any object entering the pupil form an image on the retina, just as the picture is painted on the ground glass of the camera. The various humours of the eye form a wonderful compound lens, far excelling the achromatic lenses of the opticians. The seat of vision is generally supposed to be the retina, though some philosophers regard the choroid coat as the sensitive tablet upon which the impression is made. We may trace the phenomena of vision up to this point, but no further. We know that a distinct image is formed upon one or other of the delicate coats of the eye, but the manner in which the sensation is conveyed to the brain is an inscrutable mystery. 'It is the boast of science,' says Herschel, 'to have been able to trace so far the refined contrivances of this most admirable organ, not its shame to find something still concealed from scrutiny; for, however anatomists may differ on points of structure, or physiologists dispute on modes of action, there is that in what we *do* understand of the formation of the eye so similar, and yet so infinitely superior to a product of human ingenuity,—such thought, such care, such refinement, such advantage taken of the properties of natural agents, used as mere instruments for accomplishing a given end, as force upon us a conviction of deliberate choice and premeditated design, more strongly, perhaps, than any single contrivance to be found, whether in art or nature, and renders its study an object of the greatest interest.'

The Cyclops had each a single eye stuck in the centre of the forehead, but we are provided with a pair of these matchless instruments. Each eye receives an impression of an object; nevertheless we do not see the object double. So long as each image falls exactly on the same part of each sensitive surface, the mind will perceive but one object, and the muscles which move the eyes act in such perfect unison that this result is constantly attained.

If we look at a candle placed at a distance of about ten feet, we see it distinctly as one object, because our eyes are so adjusted that the image of the candle is projected on similar parts of each retina. But if we now hold up a finger about ten inches from the eyes, and look steadily at it, the candle will be seen on both sides of the finger. The eyes are now adjusted to the finger, and the image of the candle no longer falls on the same parts of the two retinæ. Again, if the eyes be directed to the light, the finger will be seen double, because the optic axes are now adjusted to perceive objects at a distance of ten feet. Similar effects may be produced by pressing one eyeball with the finger so as to displace its optical axis, or by getting intoxicated, an experiment which we trust our readers will never perform.

We make use of our two eyes as a pair of compasses to measure distances; for we involuntarily associate the idea of smallness with the convergence of the visual axis, and that of vastness with its divergence. We feel that an object is near or remote, small or large, by opening and shutting our magic compasses, the legs of which are imaginary lines passing through the eyeballs. A person suddenly deprived of one eye estimates the distance of objects with the greatest difficulty; but after some time, experience teaches the one eye to measure distance by the change of focus alone.

Let the reader close one eye, and try to snuff a candle, he will then see the import of the old proverb, 'Two eyes are better than one.'

We have said that two eyes are required in order to form a new conception of solidity ; this point we now proceed to consider. If the reader will look at any near object,—a book placed on end, for instance, —he will at once perceive that it is a real book and not a picture of one ; he will see that it has a certain relief, that one portion of it is nearer to him than another ; in a word, that it is solid. Now, by closing each eye in turn, the reader will find that one eye will see round one side of the object, and the other round the other side, two different impressions being obtained. Every solid object, therefore, is seen differently by the two eyes, and it has been found that the effect of solidity is produced by the combination of these different impressions in the mind. Two eyes are better than one, not merely because they give symmetry to the face, but because they act together in producing on the inner or mental eye a perfect and instantaneous impression of the form and position of objects.

This important truth has been revealed by the beautiful and well-known instrument called the *stereoscope*, which, however, is much better known than understood. Some account of this magic instrument certainly merits a place amongst the fairy tales of science.

The stereoscope, in its most popular form, is simply a small wooden box, furnished with two lenses, like an opera-glass. A double picture, say a photograph of a statue, is placed at the bottom of the box, and viewed with both eyes, by means of the lenses. The effect is truly marvellous, for the design immediately appears in relief—the picture becomes a piece of sculpture! This illusion is so perfect, and the means by which it is produced so simple, that we cannot wonder at the popularity which the stereoscope has so rapidly attained.

The term *stereoscope* is derived from two words in the Greek language, the first signifying *a solid body*, and the latter *vision*; it may therefore be freely translated as 'that which shows every object in relief.' Our readers will admit that the name is a good one, and perfectly descriptive of the powers of the instrument.

Let us now consider how the wonderful illusions of the stereoscope are effected. We shall not require diagrams to make our meaning clear, since every one must be familiar with the construction of the magic instrument.

The two pieces of glass that are placed in the front of the stereoscope are wedge-shaped, that is to say, their outer edges are a little thicker than their inner edges. These glasses act like prisms, and by bending the rays of light that proceed from the double picture, they cause the two halves to combine, and appear as a single picture occupying a central position between the eyes. Two distinct images are thus formed in the eyes, but in consequence of the bending of the rays of light, they are projected upon similar parts of the two retinæ, and seem to be produced by a single object. Whether the two impressions are made by the double picture or by a single solid, the same sensation is produced, as in either case the mind combines the two impressions into the idea of solidity. The stereoscope, therefore, enables us to give a true notion of the form and position of objects from two flat representations on paper or glass; in fact, we may see the objects quite as well as if they stood before us.

Although the stereoscope was discovered nearly thirty years ago, it has only lately become popular. So long as mere drawings by hand were used as stereoscopic slides, only regular bodies, such as crystals and geometric solids, could be represented; but now, by the aid of photography, we may obtain pictures of any natural or artistic objects.

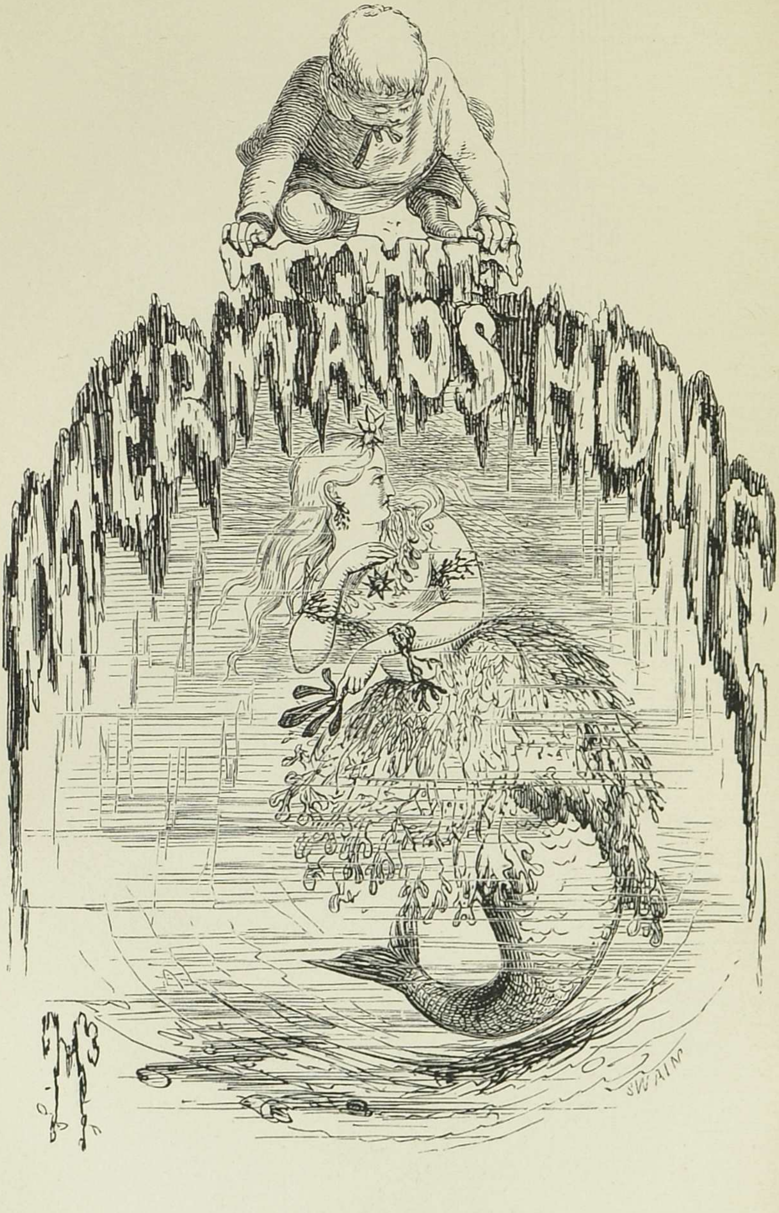
When we look at a double photograph in the stereoscope, the picture to the right is seen by the right eye only, and that to the left, by the left eye. The two pictures are taken from different points of view, and are exactly similar to the views we obtain of solid objects, by alternately closing the right and left eyes. There is, therefore, no longer any doubt as to the use of two eyes, since by the aid of photography we may obtain pictures similar to those which the eyes receive, and these pictures combine to produce the effect of solidity.

We are indebted to Professor Wheatstone for the discovery of the stereoscope, a discovery which Herschel has truly characterized as 'one of the most curious and beautiful for its simplicity in the entire range of experimental optics.' The original form of the instrument has been considerably modified by Sir David Brewster, who may indeed be regarded as the inventor of the refracting or popular stereoscope.

We will not attempt to describe the innumerable family groups, landscapes, portraits, and Alpine views, that photography has furnished for the stereoscope. Our readers are doubtless familiar with them, as the stereoscope has become quite a fashionable instrument, and is to be found upon almost every drawing-room table.

Two eyes are unquestionably better than one; nevertheless persons with but one eye are able to see distinctly. This fact does not refute what we have said about double vision. A person with one eye judges of the relief of an object from the distribution of light and shade, but his perceptions are much less vivid than those of a person with two eyes. It has, moreover, been remarked that a one-eyed person when looking at a solid object is constantly changing the position of the head from side to side, and by this means he obtains with one eye the same result that is obtained by two eyes with the head stationary.

Our readers will now understand why they have two eyes instead of one, and will be able to expound the mysteries of that magic spy-glass, the stereoscope.


THE
SWAIN

The Mermaid's Home.

'Oh, what an endless work have I in hand,
To count the sea's abundant progeny!'—SPENSER.

FORTUNATE youth! What would we not give for a glimpse of a live mermaid, especially if she happened to be as beautiful as the submarine lady portrayed by our artist! We do not wonder to see you peering over the rocks so earnestly, but we entreat you to be careful, lest you tumble into the water. The belle of the sea is prettily dressed in her robe of sea-weed, and the star-fish on her forehead is a most becoming ornament. But how would you look in the sea with your clean blouse and collar all wet and limp, with your trousers shrunk up to your knees, and your boots full of water? Hold tight to the rock then, inquisitive youth, for we fear you would look a pitiable object as a sea-boy!

Would the reader like to take a peep at the home of the mermaid? If so, let him follow us in imagination to the bottom of the sea. We cannot promise him a sight of the mermaid herself, but we can show him some of the inhabitants of the deep that are scarcely less wonderful. Candidly speaking, we do not believe in the existence of the fair lady with the fishy tail; but for the sake of our fairy tale, we will assume that she does exist, but is so excessively shy that she makes a point of concealing herself at the approach of strangers.

The mermaid's home is beneath the wave, but we must not suppose that it is situated at an unfathomable depth in the ocean. The lady is far too fond of life and light to reside in a region beyond the reach of the genial influence of the sunbeam. Depend upon it, she has selected some quiet bay, guarded by impassable rocks, for her habitation—a bay whose waters are not too deep nor yet too shallow.

Here is just such a bay as a mermaid might choose as a safe abode. Look how snugly the rocks shut it in on either side: a sea-nymph might pass her days here without fear of molestation. Let us walk to the end of yonder jutting rock. Now, if you wish to visit the mermaid's home, prepare for a dive; so—one, two, three—and in you go head foremost!

We are now safe on land; not on dry land, be it understood, but on the floor of the sea, with a good many feet of water overhead. We have ceased to be human beings subject to death by drowning, and have become the heroes of a fairy tale whom the elements cannot harm.

Looking around, we perceive a host of wonders. We are in a new world, whose plants and animals have no resemblance to those of the world we have just quitted. Dense forests of many coloured algæ are outspread before us; uncouth creatures crawl at our feet, and fairy-like forms flit around us.

If we wish to obtain a correct impression of these submarine wonders, we must examine them separately in regular order. We will therefore confine our attention at present to the beautiful herbs that grow in the mermaid's garden, and the miniature trees of her parks and forests.

This lovely group of algæ, misnamed weeds, will afford us ample types of marine vegetation. One of these plants has broad leaves of a beautiful emerald-green, as thin as the finest cambric, and strangely puckered and folded at their edges.[1] The mermaid doubtless makes use of these delicate leaves in place of silk or muslin, unless indeed she eats them as a salad. Beside this flimsy plant we see a cluster of crimson leaves, some five or six inches long, and of a most graceful form.[2] The mermaid must take some pains to cultivate this herb, as its gorgeous colouring renders it a striking feature in her garden. Here is a tuft of what seems to be fine grass; here a group of rosy leaves; and here a tiny tree of a beautiful purple hue.

In this little parterre we may find all the colours of the rainbow, and a wonderful variety of forms;

[1] Green Laver or Ulva. [2] Delesseria.

some of the plants are cut into fringes, some are spread out like fans, and others are divided into as many segments as are the graceful ferns of our woods. None of the marine plants in this group bear flowers; but nature has given them such brilliant hues that this fact might easily have escaped our notice.

Let us now glance at some of the mermaid's subjects, assuming the invisible lady to be the queen of these submarine realms.

Among the 'happy living things' of the sea, the fishes occupy the foremost rank; but we cannot bestow much time upom them, as we have to examine many less familiar creatures. But here comes one little fish whose strongly marked peculiarities at once attract our attention. His body is of a pale brown colour, with drab clouds, and patches of white specks. He looks a terrible fellow, in spite of his mild eyes, which are light blue, and closely resemble turquoises.[1] Now he hides beneath a broad frond of sea-weed, but we can see his wicked face projecting from the covert. We will watch this gentleman closely, as we half suspect that there is some mischief brewing. Another fish now appears upon the scene, a gentle and an unsuspicious fish to judge from his expression, a fish who would not hurt a fly—unless he happened to be hungry. Now this simple-minded creature approaches the place where he with the turquoise eyes waits in ambush. Assassin-like,

[1] The Black Goby.

the blue-eyed monster darts from his hiding-place, seizes his victim by the tail, and swallows him alive! Just look at the cannibal now: his distended body has become almost black, and bears witness to the blackness of his crime! How can the mermaid tolerate such a subject in her dominions!

As we stand on the sea-floor, the fishes that dart through the pale green atmosphere of water seem to be birds. That shoal overhead looks very like a flight of swallows; and these restless little fishes, who are perpetually quarrelling and chasing each other, remind us forcibly of sparrows. What grace and symmetry belong to the forms of these finny inhabitants of the deep, and what exquisite hues gleam from their resplendent coats of mail!

See, here come emissaries from the Court of Oberon! No, they are merely shrimps and prawns, though their transparency and lightness, their graceful gliding movements, and the long and slender wands they wave, entitle them to be considered the fairies of the sea. Those who are only familiar with these creatures in their boiled condition, can form no adequate conception of their appearance during life. In the mermaid's garden these fairy-like beings take the place of moths and butterflies.

Look at this little fellow, who moves about by discharging jets of water from a small tube or siphon—a mode of progression not uncommon among marine organisms. He hovers over a clear patch of sand, as though about to settle, while by means of his magic siphon he blows the sand from under him until a slight hollow is formed. Now he settles, but it is quite evident that his siphon is still at work, for the sand issues from all sides of his globular body in a little cloud, and he gradually sinks till nothing can be seen of him save his straggling arms and curious eyes. The mermaid has many expert miners in her service, but none to excel this cunning little well-sinker.[1]

These submarine regions are thickly populated by wondrous beings so transparent that they can only be distinguished by the flashes of light that gleam from their surfaces. Their substance is gelatinous, and, strange as it may appear, consists chiefly of sea-water. Let us now examine a few of these living bubbles with the superior powers of vision which we possess as heroes of a fairy tale.

How can we doubt the existence of mermaids, when we find animals assuming the forms of umbrellas, goblets, and bells! Look! here comes a living umbrella, moving through the water by opening and shutting itself. Now, reader, it flaps itself under your very nose, and you may inspect it narrowly. You will perceive, that it is rather an uncommon sort of umbrella, as it has four sticks instead of one, and is furnished with a number of tendril-like appendages. You will also see that it is neither made of silk nor gingham, but of a deli-

[1] The Cuttle.

cate transparent jelly.[1] This living umbrella may be taken as a type of the numerous gelatinous parachutes, bells, vases, and cups that glide through the sea.

But here is a little object which deserves a separate notice, for it bears no outward resemblance to the bell-shaped creatures, though closely related to them. It is not easy to distinguish the form of this living lump of jelly. Now you may see it, though, if you look closely as the light just catches its surface. See, it is a little egg-shaped ball of crystal, marked with longitudinal bands of the prismatic colours. Two long threads, that look like spun glass, may be seen depending from its exterior, and these threads, if examined attentively, will be found to be fringed with yet finer threads or tendrils. Now this creature vanishes, and we are left to wonder how so much beauty could be compressed into so small a compass! [2]

Many of these gelatinous little creatures, which have been learnedly named *Acalephæ*, are phosphorescent, and at night they cause the sea to assume the appearance of liquid fire. How beautiful must be the mermaid's home, when illuminated by myriads of these living lamps!

Suppose we now take a peep at some of the creatures that dwell in the crannies of these jagged rocks and wander through these miniature forests. We shall find them to be quite as remarkable as

[1] A Medusa or Jelly-fish. [2] Cydippe.

the free-swimming inhabitants of these submarine regions. The members of the great crab family are very conspicuous objects. They scuttle about in all directions, and their little bony eyes squint at us from out of every cranny. There goes a monster belonging to the edible species: take care of his formidable nippers, or perhaps you will have cause to repent your visit to the home of the mermaid. Now he passes edgewise through a narrow chink in the rocks, and so disappears. We are not sorry to be rid of such an ugly customer.

Look at that funny little fellow sitting on that large stone. He is a crab with some points that suggest the notion of a lobster—fringed swimming plates on the last joint of the body, large foot-jaws, and very long feelers. Now he jumps off the stone, and by flapping his tail, swims just enough to enable himself to reach the sandy bottom slantwise, instead of going straight down like some of his clumsier brethren. He now crawls about the sea-floor, evidently in search of something, and now he disappears beneath a loose stone. He does not want much space, for he is as flat and thin as if he had been trodden upon.

The naturalist has brought to light some strange facts illustrative of the domestic economy of this little crab. He usually clings to the under side of some flat stone or ledge of rock, and takes in the food that is brought to his door. His long feelers are constantly groping about for provender, which he fishes in with his outer foot-jaws. Each of these jaws is like a sickle, composed of five joints beset with parallel bristles. When the jaw is straightened, the bristles stand apart and let the water flow freely between them; when the joints are bent to a curve, the bristles overlap and form a net or hair spoon. This net is the more perfect because each bristle itself is feathered with two rows of hair. After a haul, the little fisherman picks what he likes to eat out of his net, and casts again. He throws his net out, with the claws extended, and the meshes consequently open, so that all rejected particles are washed away; then he again makes for himself a spoon wherewith to pick up victuals.

In addition to his nippers this crab has four pairs of legs; but only three pairs are at first sight visible. The fourth is a very tiny pair, folded down in a groove beneath the edges of the shell. Each of these little legs has at the end a pair of fingers and a little brush of hairs. With the two brushes he scrubs and cleanses his whole body, and with the two pairs of fingers—each being more properly comparable to a finger and a thumb—he picks off any dirt that cannot be removed by brushing.[1]

But who is that long-legged little gentleman with the crusty and prickly body? He is another member of the prolific crab family, and is perhaps one of the most valuable servants in the mermaid's employ. He fulfils the important duties of a scavenger,

[1] The Porcelain Crab.

and takes care that no decaying vegetable or animal matter shall remain long enough to be prejudicial to the purity of the sea. Instead of carting away the offal, this extraordinary little fellow crams it into his stomach, and appears to think it peculiarly palatable.[1]

Look at those shells that are moving about so clumsily among the pebbles. They are the habitations of the soft-tailed crabs, who being unprovided with defensive armour are forced to seek shelter in the empty shells of different mollusca. There is a tolerably large specimen of these creatures inhabiting a whelk-shell. Look how awkwardly his claws, legs, and feelers loll out of the mouth of the shell! you would almost think that such a strange bunch of limbs would be utterly useless to the imprisoned creature. Here comes another, dragging a still larger shell after him; so prepare to witness a battle, for these creatures are terribly pugnacious. Now they meet and begin to fight in earnest, tossing their legs and claws about in a most excited manner. Look how clumsily they tumble over each other, and you must confess that a more comical duel never took place either above or below the wave. But see, the larger crab appears to have got the worst of the fight, for he is scrambling off as fast as his legs can carry him. These humorous creatures must afford the mermaid considerable amusement; indeed, it is highly probable that they are the jesters of her court.[2]

[1] The Spider Crab. [2] The Hermit Crabs.

So many strange forms meet our vision in these submarine realms, that we are puzzled as to which we ought to select for examination. Look at all these richly-coloured and gracefully-formed shells: each has its peculiar tenant, about which many wonderful things might be related. The shells, though beautiful themselves, are not to be compared with some of their inhabitants. Look at that periwinkle, for instance, who is now devouring the tender shoots of that plant; you must own that his zebra stripes and netted markings are exceedingly ornamental. But the periwinkle is not nearly so attractive as some of the fleshy creatures that may be seen protruding from their shells, and which have the richest hues imaginable.

Again, just glance at those sea-slugs.[1] How can we describe their various forms and colours? Here is one of a bright lemon colour, with a beautiful plume of feathers springing from his back; here another of a pearly white, wearing numerous club-like ornaments; and here a third, of a dingy grey, but furnished with a pretty little bouquet of flowers. The reader will perhaps be surprised when we tell him that these plumes, and clubs, and flowers enable the sea-slugs to breathe; yet such is the fact, for all these ornamental appendages perform the same functions as our lungs.

Here is a curious creature, closely resembling those we have just examined, in form and substance,

[1] The Nudibranch Mollusca.

but belonging to a totally different class of beings. It looks like a milk-white slug; but if we inspect it carefully, we shall find that it is provided with five rows of delicate sucking arms, by means of which it clings firmly to the surface of the rock. It also has a chocolate-coloured head, tipped with a ring of feathery gills of white and primrose. Those naturalists who have studied the habits of marine creatures, inform us that this white slug will throw away its inside when irritated, the body remaining but an empty sac; yet in a month or so the creature will begin to eat as greedily as ever, a fresh set of digestive organs having grown in the interim.[1]

Our artist has furnished his mermaid with a couple of star-shaped ornaments, and here we may see plenty of similar stars in motion. Whether we regard their symmetrical forms or their brilliant hues, we must admit these living stars to be the most remarkable inhabitants of these realms of wonder. Even this dusky red one[2] possesses great beauty, though its flaming relatives throw it into the shade. You see it has five broad rays, but you must not suppose that these rays fulfil the office of legs, for the creature's legs, if so we may call them, are thousands of tiny suckers, protruding through holes in its under surface. Another member of the starry family may be seen clinging to the smooth surface of yonder rock,—a twelve-rayed sun of the

[1] The Holothuria. [2] Five-finger Star.

richest scarlet.[1] Here is another, a pentagonal disk of scarlet and orange;[2] and here again another, a little flower-like disk with five long prickly arms, that move about in a graceful serpentine manner.[3] The last-named creature is extremely sensitive to insult; and were you to handle him too roughly, he would probably commit deliberate suicide by breaking himself into little bits.

But how did that little hedgehog find his way hither? Examine him closely, and you will see that he is not an ordinary hedgehog. He is certainly covered over with prickles; but these, instead of being of a dark brown, are of a pretty violet colour. Again, his form is much more regular than that of his terrestrial namesake, and he has neither head nor legs. He is a distant relative of the living stars, though you would hardly think so, judging from his external appearance.[4]

Look at these stony tubes twisted so curiously into a tangled group. These are the habitations of some of the mermaid's subjects. See! from the mouth of one of these tubes a conical stopper of a bright scarlet colour emerges, and now a row of feathery objects which slowly spread themselves out into an elegant scarlet plume. Now another little stopper makes its appearance; another and another; and now each tube is crowned with its lovely tuft of feathers. Presto! they have disappeared, plumes

[1] Sun-star.
[2] Bird's-foot Star.
[3] Brittle-star.
[4] Echinus, or Sea-urchin.

and stoppers vanished like magic as a large fish passed over them.[1]

This rock is studded over with tiny conical shells, each of which contains a living creature, quite as wonderful as the tube-inhabiting worm. If you make good use of your 'microscopic eye,' you will see that each little shell opens at the tip, and that a delicate white feathery object is alternately protruded and withdrawn through the aperture. This tiny white feather is a veritable casting net, and every time it is spread out it catches some invisible particles of food.[2]

We have glanced at a few of the mermaid's subjects; to count them all would indeed be 'an endless task.' In another chapter we shall describe at length some of the marvellous flowers that bloom in these submarine regions. Would that we could introduce the reader to the mermaid herself; but we sadly fear that she will never figure in the fairy tales of science. We are rather inclined to think that she ceased to exist with the dragons and griffins of that marvellous age known as 'once upon a time.' But perhaps she does exist after all, and only keeps out of the way of the naturalist, for fear he should bestow upon her some hard Latin name. However this may be, it is quite certain that the naturalist has never caught a glimpse of this mysterious being, though he has discovered many objects in the sea quite as extraordinary. And now, reader, we will once more become air-breathers, and bid farewell to the Mermaid's Home.

[1] Serpulæ. [2] Balanus, or Acorn-shell.

Animated Flowers.

'Here, too, were living flowers,
Which, like a bud, compacted
Their purple cups contracted;
And now in open blossom spread,
Stretch'd, like green anthers, many a seeking head.'—
SOUTHEY.

THE flowers of the sea far surpass those of the land in splendid and gorgeous colouring. In the 'gardens of Nereus' there are anemones of the richest crimson, purple, and orange; chrysanthemums, beautifully striped and variegated; carnations, whose petals are exquisitely cut and fringed; and dahlias, so perfect in form that they could not fail to win the admiration of enthusiastic flower-fanciers.

But these flowers are not only beautiful. Nature has endowed them with wonderful powers. They fold and expand their petals at will: some of them can move from place to place; and others are so peculiarly sensitive, that the slightest touch will cause them to shrink into shapeless lumps of jelly.

What are these extraordinary beings? Are they plants or animals, or do they stand upon some debateable ground between the two great kingdoms of organic nature? In ancient times they were doubtless regarded as sea-nymphs metamorphosed into flowers; but we fear that this opinion would have little weight in the present age of science. Expound the riddle, good naturalist, and tell us all about these animated flowers.

Well, to put an end to the reader's suspense, we will at once inform him that these magic flowers are true animals. Nor will this statement surprise him, since he has already seen what marvellous forms may be endowed with animal life. He has seen living plumes, living stars, and living umbrellas, all of which are quite as wonderful as these living flowers.

The sea-anemones are by far the most conspicuous of the wild-flowers of the deep, and we will therefore give them the precedence in our examination. If we wander about the sea-beach at low tide, we may find plenty of these creatures attached to the rocks and stones left bare by the receding waves. The commonest are those known as the Smooth anemones, which seem, when out of the water, to be mere knobs of jelly. On touching them you find that they are tough and leathery, though you would never have imagined so from their appearance. These little knobs are variously coloured, but different shades of green and red are their prevailing hues.

When the sea comes up and covers the anemones, they assume the most lovely shapes. Each lump of jelly expands into a beautiful flower, having somewhat the form of a chrysanthemum, but a far more brilliant colour. When fully expanded, each flower displays a ring of turquoise beads, whose pure blue forms a beautiful contrast to the crimson, purple, and orange tints of the petals.

These jewelled flowers are not to be compared with their aristocratic relations, the Thick-horned anemones. Words can convey no idea of the beauty of these creatures. They are much larger than the last species, and some of them, when expanded, are four or five inches across. Their petals, which are very thick in proportion to their length, are delicately transparent, and prettily striped and ringed with various brilliant colours. These animated flowers have been well likened to quilled dahlias; but to complete the simile, we must suppose that the terrestrial flowers have petals of gelatine.

The Daisy anemone is another beautiful species. They may be found in abundance upon some coasts, in the tide-pools and hollows. In the sunshine of a fair day they expand beautifully, and you may see them studding the face of the rock just beneath the surface of the water, from the size of a shilling to that of a crown-piece. If you touch one of these sensitive daisies, its circular disk will at once begin to curl and pucker at its margin, and soon take the form of a cup; if further annoyed, the rim of this cup will contract more and more, until it closes.

The diameter of the disk is nearly four times that of the body at the point from which it expands. The petals are very small, but numerous, and are arranged on the disk in about six rows. As for colouring, the daisy is not surpassed by any flower of the deep; for though its tints are less brilliant than those of the living chrysanthemums and dahlias, they are so beautifully blended into one another, that they cause the little creature to appear quite as lovely as its flaring cousins. The upper surface of the disk is of a rich amber brown, merging into lavender colour towards the edge; the petals brown, blotched and speckled with white; and the base white, passing into pink, then lilac, and becoming purple as it joins the disk.

But of all the flowers that bloom in the sea, perhaps the Plumose anemone is the most magnificent. It is much taller than any of the creatures we have described, and excels them in delicacy of colouring; pure white, pearly grey, or faint rose, taking the place of scarlet, olive, or brown. It is indeed a creature of surpassing loveliness, and has justly been styled the maiden queen of all the beautiful tribe.

The sea-anemones are terribly voracious, devouring everything that comes within their reach. We are not romancing, dear reader: these flowers of the sea have wonderful appetites, and are endowed with digestive powers that the human *gourmand* might well covet. If we examine the internal structure of these anomalous beings, we shall be able to account for their voracity.

A sea-anemone may be likened to a double bag; the outer bag forming the exterior of the animal, and the inner one its stomach; the intervening space being divided into numerous chambers by vertical partitions, which pass in a radiating direction between the outer surface of the stomach and the general integument. The arms or tentacles of the anemone, which we have hitherto spoken of as petals, are hollow, and communicate with the internal chambers. These chambers are always filled with water, and by the contraction of the walls, water is forced into the hollow tentacles. The tentacles are also provided with small orifices at the extremity, that can be opened or closed by the animal. Water is taken in by these orifices, so as to distend the radiating chambers and tentacles, and is ejected with considerable violence through the same apertures whenever the creature is alarmed. The tentacles are placed in rows round the mouth, which is usually circular or oval.

Although the anemone is a mere membraneous bag distended with sea-water, it is endowed with powers that render it more than a match for many animals occupying a much higher position in the scale of being. No sooner does a small fish, a crab, or a shelled mollusk come within reach of its tentacles, than it is seized by them, and drawn to the gaping mouth of the greedy flower, the tentacles closing upon it on all sides. After a while the tentacles again expand, and an empty crust or shell is ejected through the mouth, the nourishing contents having been mysteriously extracted in the stomach of the anemone.

And now, abstemious reader, can you wonder at the voracity of these strange creatures? If you had a stomach of proportional capacity, a mouth equally extensive, and a hundred arms constantly picking up dainties, depend upon it you would be quite as greedy.

The anemone attaches itself to the rock by means of a sucking base, but it seldom remains long in the same place. In travelling it pushes forward one portion of the base, and having fixed it firmly, draws the remaining portion after it,—a mode of progression very similar to that adopted by the snail. There are many more wonderful things connected with the sea-anemones which we cannot stop to consider, as we must now pass on to another kind of living flower.

The Madrepore is allied to the anemones, but differs from them in many important points. This beautiful little flower of the sea has a stony skeleton, consisting of a number of thin chalky plates, standing up edgewise, and arranged in a radiating manner round a low centre. We have informed the reader that the interior of an anemone is divided into numerous chambers by perpendicular veils of membrane. If he will now imagine that every one of these membranes is turned into stone, he will understand the formation of the madrepore's skeleton, and its relations to the soft investing flesh.

Mr Gosse, the naturalist, to whom we are indebted for many striking facts relating to the beautiful inhabitants of the sea, has given a charming description of the living madrepore in one of his pleasant books. 'Let it,' he says, 'after being torn from the rock, recover its equanimity; then you will see a pellucid gelatinous flesh emerging from between the plates, and little exquisitely formed and coloured tentacles, with white clubbed tips fringing the sides of the cup-shaped cavity in the centre, across which stretches the oval disk, marked with a star of some rich and brilliant colour, surrounding the central mouth, a slit with white crenated lips, like the orifice of one of those elegant cowry-shells which we put upon our mantle-pieces. The mouth is always more or less prominent, and can be protruded and expanded to an astonishing extent. The space surrounding the lips is commonly fawn-colour or rich chesnut brown; the star, or vandyked circle, rich red, pale vermilion, and sometimes the most brilliant emerald green, as brilliant as the gorget of a humming-bird.'

The madrepores are quite as greedy as their wandering friends the anemones, and the presence of food stimulates them to more active efforts and the display of greater intelligence than we should give them credit for. Mr Gosse relates a very amusing anecdote about feeding a madrepore. He once put a minute spider, as large as a pin's head, into the water, pushing it down with a bit of grass to a coral, which was lying with partially exposed tentacles. The instant the insect touched the tip of the tentacle it adhered, and was drawn in with the surrounding tentacles between the plates, near their inward margin. Watching the animal with a lens, he saw the small mouth slowly open, and move over to that side, the lips gaping unsymmetrically; while at the same time, by a movement as imperceptible as that of the hour-hand of a watch, the tiny prey was carried along between the plates towards the corner of the mouth. The latter, however, moved most, and at length reached the edges of the plates, and gradually took in and closed upon the insect; after which it slowly returned to its usual place in the centre of the disk. After some quarter of an hour Mr Gosse caught a house-fly, and taking hold of its wings with a pair of pliers, plunged it under water. The tentacles held it at the first contact as before, and drew it down upon the mouth, which instantly began to gape in expectation. But the struggles of the fly's legs perhaps tickled the coral's tentacles in an unwonted manner, for they shrank away, and presently released the intended victim, which rose to the surface like a cork; only, however, to become the breakfast of an expectant daisy, which was much too wise to reject or let slip so dainty a prey. The poor coral evidently regretted the untoward necessity of letting it go, for his mouth kept gaping for some time after the escape.[1]

The animated flowers of the tropical seas far surpass those that bloom on our own shores. In the Red Sea, for instance, branching corals, madrepores, anemones of the most brilliant hues, flourish in such luxuriance as to form a submarine garden of unparalleled magnificence. 'Where is the paradise of flowers,' exclaims a German naturalist, 'that can rival in variety and beauty these living wonders of the ocean?'

And these gardens of Nereus, through the introduction of the aquarium, may be brought into our homes. The brilliant and sparkling hues of the marine creatures will prove equally attractive in the tiny vase and in the boundless ocean, the more so as we may be fettered to bricks and mortar, shut in our town prison, or hemmed round by stern duties which we cannot elude; so the deep sea may roar a bluff greeting, but we hear it not! Let us consider how one of these mimic oceans may be formed. We procure a tank of plate glass, and cover its slate bottom with a layer of sand from the sea-beach, or even well-washed river sand. But perhaps the best of all materials for forming a bottom are broken granite and coarse shingle. Rock-work must now be introduced, so as to provide shady nooks for those delicate creatures that shun the light or are of a retiring disposition. We may

[1] *A Naturalist's Rambles on the Devonshire Coast.*

fashion the rock-work into a rude arch, or three large pieces of stone may be built up in the form of a table or druidical *cromlech.*

The aquarium having been filled with sea-water, is now ready for stocking with marine plants and animals. The plants render the water fit for the maintenance of animal life, while the animals check the too rapid increase of vegetation. Thus the success of our aquarium will depend upon the proper balance of animal and vegetable life. We select the green and red reeds, as the brown and olive are apt to discolour the water. Sea-plants have no roots, but adhere by minute disks to the surface of the rock; a piece of stone has accordingly to be knocked off with each plant, in order that it may be removed to our glass tank.

Some days should be allowed to elapse before the animals are introduced, so that the plants may have time to impregnate the water with their minute spores. Among the finny inhabitants of the mermaid's home the little mullets rank first, then the blennies and gobies; but many other kinds of fish may find a place in our mimic ocean. The common periwinkle is essential to the aquarium, as it fulfils the duties of a scavenger, and carefully removes the green film that sometimes forms upon the glass. The star-fishes, crabs, serpulæ, and the prawns are favourites with aquarian naturalists; but the lovely sea-anemones are the crowning glories of the glass tank. We must carefully remove all dead plants and animals from our aquarium. It is indispensable that there should be a free access of light; but we must not expose our tank to the full glare of the sun's rays, or the water will become heated, and its delicate inhabitants will surely die. These tanks require constant attention, but their beauty will more than repay us for any amount of trouble. They have been beautifully described as 'flowery-gardens, which never wither; fairy lakes of perpetual calm, which no storm blackens.'


METAMORPHOSES
SWAIN

Metamorphoses.

'There is a difference between a grub and a butterfly; yet your butterfly was a grub.'—*Coriolanus.*

ONCE upon a time an aged butterfly, with wings all crumpled and torn, crawled up the stem of a willow, and seated himself on the nearest leaf.

'My last moments are drawing near,' said he; 'but I do not repine, for life has become a burden to me. My wings are useless, my joints stiff and rheumatic, and my antennæ have long since lost their exquisite sensibility. It is quite evident that my flying days are over; but so much happiness has fallen to my share, that I have no right to complain.' The butterfly had scarcely finished this soliloquy, when a large tiger-moth alighted on a leaf close by.

'Ah, my friend!' exclaimed the moth, 'I am truly glad to see you. I have not many hours to live, and I wish to make you my executor. Do not start, my friend; I am old and decrepit, and you shall see me meet death with becoming resignation.'

The butterfly smiled sadly, and declined the proffered executorship, explaining to the venerable tiger-moth that he himself was about to die.

Now, by one of those wonderful coincidences peculiar to fairy tales, a dragon-fly, a gnat, and two small flies, all bowed down by weight of years, settled in the neighbourhood of the two lepidoptera.[1] After much mutual condolence, the six insects began to quarrel about their respective adventures, each bragging that he had seen far more wonderful things than had any of his companions. The dragon-fly became very much excited, and though very feeble, he clashed his mandibles together in a manner that filled the smaller insects with dismay. The butterfly, who was an insect of a very superior turn of mind, put an end to this disagreeable scene.

'My friends,' he exclaimed, in a solemn voice, 'is it wise to waste the few short hours that remain to us in vain discussion? Would it not be more becoming in old insects like us to sit down quietly, and relate our adventures without quarrelling? Depend upon it, Nature has not formed us differently, and endowed us with distinct faculties, for a mere freak, but because we may be better fitted to enjoy the sweets of life in our separate spheres. Consider, my dear Dragon, what pitiable objects you and I would be were we to exchange wings! How could you support your long body with my

[1] The order *Lepidoptera*, or scaly wings, includes butterflies and moths.

painted wings, and how could I work your gauzy pinions with my feeble muscles? Instead of boasting about your superior strength and prowess, you ought to accept your gifts with a humble thankfulness, as you must be aware that you are far inferior in point of intellect to the sober bee or the tiny ant.'

'Do not be too hard upon me, Mr Butterfly,' said the great insect. 'I own myself in the wrong, and am quite willing to adopt any suggestion you may make with regard to the manner of passing our last hours.' The two little flies, on hearing their dreaded enemy speak so rationally, instantly recovered their self-possession, and the gnat actually ventured within the reach of his formidable mandibles.

'Well, then,' said the butterfly, 'let each relate his history in as few words as possible, describing the metamorphoses he has undergone, and the wonderful things that have fallen within the sphere of his observation.'

This proposition was received with unanimous approbation, and it was speedily determined that the butterfly should tell the first story.

We will now lay before the reader a true report of the conversation that ensued, adding such explanatory remarks as may be necessary to make the speeches of the insects intelligible.

'I am generally known as the cabbage-butterfly,' said the first speaker; 'and although my wings are now in a very dilapidated condition, I think you must admit that the dark spots upon the white ground produce a very pretty effect. I need not tell you that I originally came from an egg, which my maternal parent, guided by an unerring instinct, had deposited upon a leaf capable of affording me proper and sufficient nourishment in my caterpillar state. And a beautiful little egg it was, shaped like a flask, marked with fifteen ribs, converging towards the smaller end, and having a delicate yellow colour.

'I was a very little fellow when I made my escape from the egg; but having a tremendous appetite, I grew rapidly, and soon became a handsome caterpillar. Nature had furnished me with sixteen feet, and had dressed me in a coat of bluish grey, having a bright yellow line down the back, and another on each side. I am fairly shocked when I think of my voracity, for I frequently devoured double my own weight of cabbage in twenty-four hours. At length, when I had attained my full size, I felt that I was about to undergo a wonderful metamorphosis. Accordingly, I stole away from the plant on which I had been feeding, and found a secluded corner where I could perform unmolested the tedious and painful operation of wriggling out of my skin.

'Having thrown off my grey coat, and with it my sixteen legs, I became a *chrysalis*,[1]—a mere mummy,

[1] A Greek term, signifying *golden*, applied to pupæ on account of the golden lustre which they sometimes exhibit.

in fact, having neither limbs, eyes, nor mouth. My second metamorphosis was even more extraordinary than this. I broke through the mummy cloth as a perfect insect. My wings were at first moist and shrunken, but in an hour or so they spread out to their full extent. I will not attempt to describe the rapture which I experienced in my first flight through the air. My former life seemed to be an ugly dream; and as I flew from flower to flower, sipping ambrosial sweets, I could hardly realize the fact that I had once been a crawling caterpillar, with an insatiable craving for cabbage. The longest life must have an end; and you now see me patiently awaiting death, or some new metamorphosis of which my instinct gives me no warning.'

The reader will doubtless be astonished to hear that the butterfly exists in the caterpillar, and has been detected in it by expert anatomists. 'In order,' says Swammerdam, 'to discover plainly that a butterfly is enclosed and hidden in the skin of the caterpillar, the following operation must be performed. One must kill a full-grown caterpillar, tie a thread to its body, and dip it for a minute or two into boiling water. The outer skin will, after this, easily separate, because the fluids between the two skins are by this means rarefied and dilated, and therefore they break and detach both the vessels and the fibres wherewith they were united together. By this means the outer skin of the caterpillar, being separated, may be easily drawn off from the butterfly which is contained and folded up in it. This done, it is clearly and distinctly seen that, within this skin of the caterpillar, a perfect and real butterfly was hidden; and therefore the skin of the caterpillar must be considered only as an outer garment, containing in it parts belonging to the nature of a butterfly, which have grown under its defence by slow degrees, in like manner as other sensitive bodies increase by accretion.

'But as these limbs of the butterfly which lie under the skin of a caterpillar cannot without great difficulty be discovered, unless by a person accustomed to such experiments,—because they are then very soft, tender, and small, and are moreover complicated or folded together, and enclosed in some membraneous covering,—it is therefore necessary to defer the operation just now proposed until the several parts of the butterfly become somewhat more conspicuous than at first, and are more increased and swelled under the skin by the force of the intruded blood and aqueous humour. This is known to be the case when the caterpillar ceases to eat, and its skin on each side of the thorax, near under the head, is then observed to be more and more elevated by the increasing and swelling limbs, and shows the appearance of two pairs of prominent tubercles.' Before this beautiful discovery was made, the wildest theories were propounded to explain insect metamorphoses.

When the butterfly had finished his story, the tiger-moth addressed his friends in the following manner: 'I fear that my history will afford you but little interest, as I have undergone a series of changes of precisely the same character as those which have just been described by our friend. In my youthful days I was quite as voracious as the butterfly, but my favourite food was the nettle. My body was covered with long hairs of a dark-brown colour. This woolly coat was of immense service to me; for, besides keeping me warm, it saved me many a bruise by breaking my fall when I tumbled off a leaf or branch. Before changing into a chrysalis, I spun for myself a snug little silken hammock, in which I might repose in peace until my final metamorphosis into a moth. There, I have finished my brief narrative, and am now longing to hear the dragon-fly's story, as I suspect it will be very wonderful.'

'My early days,' said the dragon-fly, 'were spent in the water. I was then furnished with six feet, but I did not use them for walking so much as for capturing my prey. I moved through the water by means of a wonderful hydraulic engine, which nature had given me. With this engine I was able to eject a stream of water to the distance of several inches; and this jet propelled me through the water, in consequence of its being resisted by the stationary mass of the fluid behind. I was the terror of all the inhabitants of the pond, for I was dread-fully rapacious, devouring every living thing that came within my reach. In surprising my prey, I approached it very stealthily, and pounced upon it suddenly. I was so artful, that insects, and even small fishes, found it difficult to elude my attacks.

'My first metamorphosis was inconsiderable, as my appearance underwent very little alteration, and I still retained my six legs, and had the same carnivorous propensities as formerly. At length I felt that the term of my aquatic existence had expired, and I therefore crawled up the stem of a water-plant into the air. Having selected a dry spot, I pushed my sharp claws into the soft stem, and awaited my final transformation. By the swelling of the upper part of my body, the outer skin was greatly distended, and was eventually rent asunder on the back of the head and shoulders. Through this opening I escaped as a perfect fly, leaving the empty slough fixed to the aquatic plant. Old age has now come upon me, and I require no further nourishment; but I must confess that I never lost my rapacious instincts. Instead of seeking an innocent nutriment in the pulp of fruits, or the nectar of flowers, I hovered in the air, only to pounce upon other insects, and crush them with my powerful mandibles. I have exterminated innumerable gnats and flies in my latter days, and have even caused the death of several moths and butterflies.'

This confession so alarmed the gnat, that he flew at once to another leaf, so as to be at a safe distance from the splendid blue monster, for whom he had hitherto entertained so little fear. 'Do not run away,' exclaimed the dragon-fly, in a very jocular tone. 'I shall not eat you until I have heard your story, provided you sit still; but if you attempt to leave this tree, I shall be very much offended, and will not answer for the consequences.'

'Oh, sir!' exclaimed the gnat, 'how could you suppose that I should run away from you, the handsomest, the best, and the most magnanimous insect that ever breathed? I moved from the leaf upon which you were sitting, because I felt my own unworthiness so keenly, and feared that my presence might cause you some uneasiness. If you would like to hear the story of my life, I shall be most proud to relate it to you, and to the other illustrious insects that are here assembled.

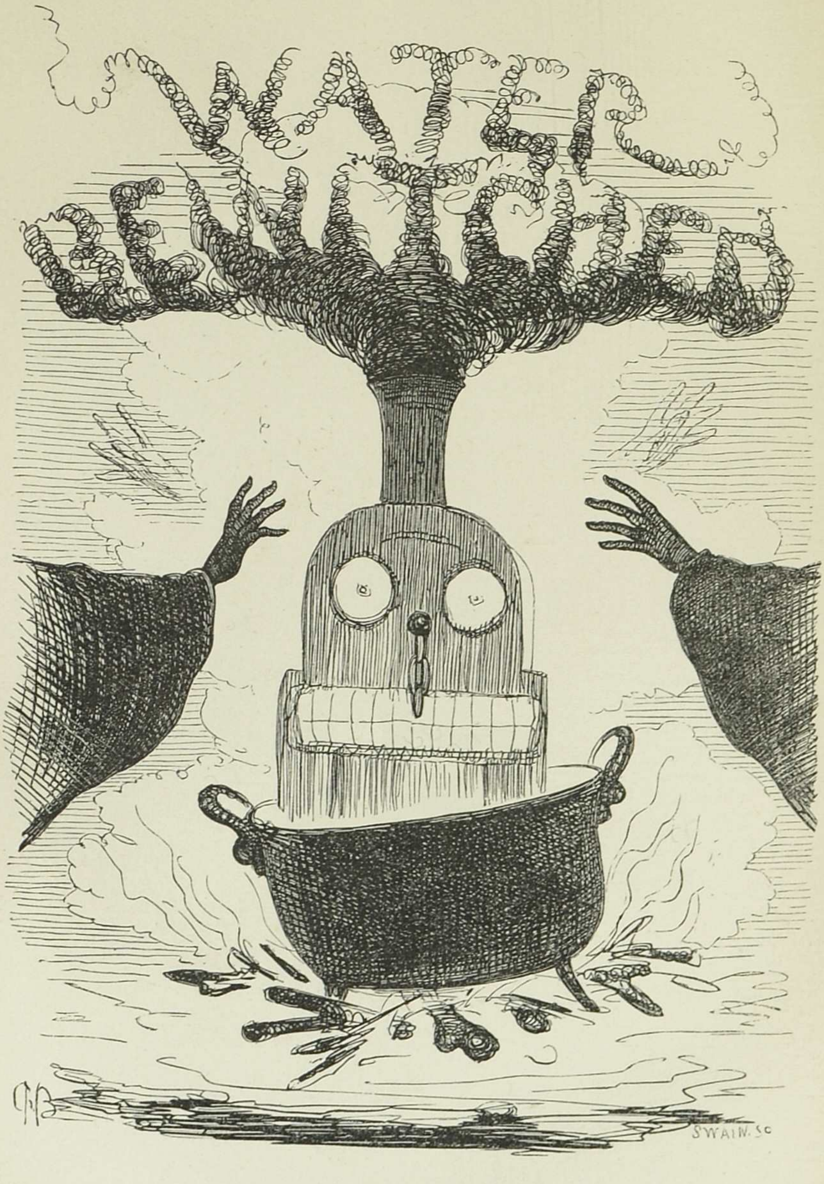
'I was originally produced from a tiny egg, shaped like a bottle. My mother knew that her offspring would pass the greater portion of their time in water, and she therefore deposited her eggs upon the surface of a pond. Now, as each egg was heavy enough to sink if dropped into water, she glued some three hundred of them together into the form of a boat, which floated so safely that the most violent agitation of the water could not sink it; and, what was still more extraordinary, it never became filled with water, even though exposed to the heavy rains. When hatched, I took the form of a minute, whitish, semi-transparent grub. I usually swam near the surface of the water, with my head downwards and my tail in the air; for my breathing organs were situated in the tail, and not along the sides, as in caterpillars. In course of time I underwent a semi-transformation, like that of our noble friend the dragon, and ten days after I broke through the skin that covered me, and winged my way through the air.'

The reader would probably like to hear how the gnat escapes from its envelope, without wetting its wings. The most important, and indeed indispensable part of the mechanism, is the maintaining of its upright position while extricating itself from the skin. The envelope, as it is thrown off, forms a life-boat, and supports the gnat until it gets its wings set at liberty and trimmed for flight. The body of the insect serves this little boat for a mast. 'When the naturalist,' says Réaumur, 'observes how deep the prow of the tiny boat dips into the water, he becomes anxious for the fate of the little mariner, particularly if a breeze ripple the surface, for the least agitation of the air will waft it rapidly along, since its body performs the duty of a sail as well as of a mast; but as it bears a much greater proportion to the little bark than the largest sail does to a ship, it appears in great danger of being upset, and once laid on its side, all is over. I have sometimes seen the surface of the water covered with the bodies of gnats which have perished in this way; but for the most part all terminates favourably, and the danger is instantly over.' When the gnat has extricated all but the tail, it stretches out its two fore-legs, and then the middle pair, bending them down to feel for the water, upon which it is able to walk as upon dry land,—the only aquatic faculty which it retains after having winged its way above the element where it spent the first stages of its existence.

The larger of the two flies came forward as soon as the gnat had done speaking, and gracefully waving his antennæ, addressed the assembled insects as follows: 'I am a water-fly, and, like the last two speakers, I spent my youth at the bottom of a pond. Having a very soft body, which required some protection from the rapacity of fishes and carnivorous insects, I enclosed myself in a case formed of bits of straw and wood, pebbles, and tiny shells bound together by silken threads, which I spun from my mouth. While I remained in the grub state, this case afforded me sufficient protection; but as soon as I felt a change approaching which I knew would render me helpless and inactive, I thought it advisable to contrive additional security. I therefore wove a silken grating at the entrance of my little gallery. This grating was marvellously strong, for I crossed and recrossed the threads until a thickish circular plate of brown silk was formed, which became as hard as gum. Of course I left a number of openings in this plate, for the purpose of breathing. In this case I reposed in peace until just before my final metamorphosis, when I gnawed my way through the grating with a pair of mandibles specially provided for that one object. I then swam to the surface, and underwent my change into a perfect insect.'

'It is my turn now,' said the other fly, a tiny creature with a black body and yellow legs; 'and although I am so small, I think I may safely say that I have led a stranger life than any of you. I did not pass my time, when in my caterpillar state, in looking out for food; yet I lived on the fat of the land. I am the dreaded ichneumon-fly, and the egg from which I was produced was deposited by my mother in the soft body of a cabbage-caterpillar, the brother probably of our friend here with the ragged wings. My kind parent settled upon the caterpillar's back, and pierced the skin in about thirty places, depositing an egg in each wound. When we were all hatched, we set to work devouring the fatty portions of the caterpillar, who continued to eat as usual, though his food did not afford him much nourishment. When full grown, we ate our way through the skin of the unfortunate cabbage-feeder, and immediately spun for ourselves a number of little silken cocoons of a bright yellow colour, in which to pass the winter. In one of these little cocoons I underwent my transformations, and when I escaped I had the form which you now behold.'

Such, reader, is the subject of a conversation which took place, or might have taken place, on the leaves of the willow, between six of our commonest insects. The metamorphoses of insects surely deserve a place in the fairy tales of Science, as they are far more wonderful, because true, than any of the metamorphoses that we read of in the fairy tales of Greece and Rome.


WATER BEWITCHED
SWAIN. SC

Water Bewitched.

'Fire burn, and cauldron bubble!'—*Macbeth.*

THE vapour that escapes from the spout of an ordinary tea-kettle, is a much more wonderful emanation than any of those flimsy spirits which the weird sisters summoned from their magic cauldron. Those deluded old ladies, who wasted so much time in collecting disgusting ingredients for their infernal broth, in dancing wildly around their cooking utensils, and in breaking-in and training broomsticks, have happily disappeared from the face of this beautiful earth. As we cannot look into their magic cauldron, let us peep into the homely kettle.

Science has revealed so many beautiful truths concerning boiling water, that we deem it advisable to devote an entire chapter to their consideration. The reader must not think that we have chosen a trivial subject. It has been well said, that there is no great and no small in nature, and that the force which shapes the world gives form to the dew-drop. To this remark we may add a similar one—namely, that some of the grandest phenomena in nature are represented on a small scale in a kettle of boiling water.

'Mary, bring the kettle!'

Heat, by entering bodies, expands them through a range which includes, as three successive stages, the forms of solid, liquid, and air, or gas; becoming thus in nature the grand antagonist and modifier of that attraction which holds corporeal particles together, and which, if acting alone, would reduce the whole material universe to one solid, lifeless mass.

The influence of heat on the dimensions of material substances affords a convenient method of estimating the relative quantity of heat which will produce a given effect; for since it appears that a certain increase of temperature will invariably be accompanied by a certain degree of expansion of bulk, it follows that, if we can estimate the degree of expansion in any given case, we may thence infer the amount of temperature. Upon this principle depends the utility of those philosophical instruments called thermometers, or heat-measures. As we shall frequently have to refer to the indications of the thermometer, we will describe the construction of this beautiful little instrument.

The mercurial thermometer consists essentially of a fine glass tube with a bulb at one extremity, and which, having been filled with hot mercury or quicksilver, introduced through the open extremity, has been hermetically sealed while full, so that no air can possibly enter. As the tube and mercury in it gradually cool, the enclosed fluid contracts and consequently sinks, leaving above it a vacant space or vacuum, through which it may again expand on the application of heat.

To such a tube it is necessary to add a scale, showing at what height the mercury will stand at any given temperature; for a tube of mercury without a scale would be just as useless as a balance without weights. Now, to form a scale that shall agree with other scales, we must find two fixed points, and then divide the intervening space into a given number of equal parts, or degrees. These fixed points are the temperatures of melting snow or ice, called the *freezing-point*, and of pure boiling water, named the *boiling-point.* The first is found by plunging the instrument into melting ice, and then, after the temperature of the bath is attained, marking the position of the mercury upon the tube; it is now placed in a deep metallic vessel nearly filled with water, which is heated until rapid ebullition ensues, and in this manner the position of the boiling-point is ascertained. Fahrenheit's scale being the standard generally adopted in England, it is usual to divide the space between the two points into 180 degrees, the freezing-point being marked 32°, and the boiling-point 112°. In the Centigrade thermometer, which is used on the Continent, the space is divided into 100 equal parts, the two points being marked respectively 0° and 100°. The reader will understand that a degree of heat is a mere arbitrary division, and that 212° Fahr. and 100° Cent. indicate the same temperature. We shall adopt the unphilosophical but convenient scale of Fahrenheit throughout this chapter.

No indication is afforded by the thermometer of the absolute quantity of heat contained in any substance, but merely of the amount of free or sensible heat capable of producing a certain degree of expansion in a column of mercury. If a quantity of ice, at the temperature of zero, or 0°, be placed in a warm room, it will immediately begin to melt, and a thermometer plunged into it will soon indicate 32°, though at first the column of mercury stood at zero. But, strange to say, the mercury will remain stationary at the freezing-point until the whole of the ice has passed into the liquid form. Thus we see that a large quantity of heat is absorbed by the ice in the act of thawing, so as to be no longer appreciable by the thermometer.

Again, if an open vessel containing ice-cold water be placed upon a fire, the temperature of the liquid will rapidly rise to 212°, but at this point it will remain stationary until the whole of the water is converted into steam. The heat thus lost or absorbed during liquefaction and vaporization is called *hidden* or *latent* heat, in contradistinction to the heat of temperature.

But we must not forget our kettle. The stream of vapour now issuing from the spout reminds us of the Arabian fable of the genie, who escaped from the fisherman's bottle in the form of a column of smoke. But the genie of the tea-kettle is infinitely more powerful than the genie of the bottle, who was, moreover, a stupid, blustering fellow, quite unlike our faithful servant, Steam. Let us see how our mighty genie may be evoked; in other words, let us ascertain the conditions under which vaporization takes place. Vapours, of which steam is the most familiar to us, are light, expansible, and generally invisible gases, resembling air completely in their mechanical properties while they exist, but subject to be condensed into liquids or solids by cold Steam is perfectly invisible; but as soon as it comes into contact with the cold air, it is condensed into a white cloud, which consists of minute liquid particles.

When converted into steam, water undergoes a great expansion, a cubic inch becoming under ordinary circumstances a cubic foot of steam; or, to be exact, one cubic inch of water expands, when sufficiently heated, into 1,694 cubic inches of steam.[1] We have already shown that this change, like the liquefaction of solids, is effected by the addition of heat to the water. But a much larger quantity of heat enters into vapours than into liquids—into steam than into water. If over a steady fire a certain quantity of ice-cold water requires one hour to bring it to the boiling-point, it will require a

[1] At the temperature of 212°, under the atmospheric pressure of 15 pounds to the square inch.

continuance of the same heat for five hours more to boil it off entirely. Yet liquids do not become hotter after they begin to boil, however long or with whatever violence the boiling is continued. This fact is of importance in domestic economy, particularly in cookery, and attention to it would save much fuel. Soups made to boil in a gentle way by the application of a moderate heat, are just as hot as when they are made to boil on a strong fire with the greatest violence. Again, when water in a copper is once brought to the boiling-point, the fire may be reduced, as having no further effect in raising its temperature.

If a thermometer be plunged into the steam that fills the upper part of the kettle, it will indicate 212°. The steam is thus found to be no hotter than the water itself. What then becomes of all the heat that passes into the kettle, since it is neither discovered in the water nor in the steam? It becomes latent—that is to say, it enters into the water and converts it into steam without raising its temperature. As much heat disappears in the vaporization of a single pint of water as would suffice to raise the temperature of 1,000 pints by one degree! But the reader will be able to form a more adequate conception of the latent heat of steam, from the fact that one gallon of water converted into steam will, by condensation, raise five gallons and a half of ice-cold water to the boiling-point!

Could we see through the sides of the kettle, we should observe so many strange movements in the liquid that we might easily persuade ourselves that we were peering into some magic cauldron. By substituting a thin glass flask for the kettle, the whole process of boiling may be seen to perfection. On gradually heating water in such a vessel, we first observe the formation of tiny air-bubbles, which dart through the liquid with marvellous rapidity. As the temperature increases, these 'beaded bubbles winking at the brim' give place to much larger bubbles, which are formed at the bottom of the vessel, and which rise a little way in the liquid, and then contract and disappear in a most mysterious manner, producing a hissing or simmering sound. But as the heating goes on, these bubbles, which consist of steam, rise higher and higher in the liquid, till at last they reach the surface and escape, producing a bubbling agitation, or the phenomena of *ebullition.* It may now be remarked that steam itself is invisible, as the upper part of the flask appears quite empty; but when it escapes into the cold air, it is condensed into a white cloud of minute drops of water.

It was first remarked by Gay-Lussac, an illustrious French chemist, that liquids are converted more easily into vapour when in contact with angular and uneven surfaces, than when the surfaces which they touch are smooth and polished. He also remarked that water boils at a temperature two degrees higher in glass than in metal; so that if into water in a glass flask which has ceased to boil, a twisted piece of cold iron wire be dropped, the boiling is instantly resumed.

Solid bodies having different temperatures will, if kept in contact, gradually change until they all acquire the same temperature. But this diffusion does not take place instantaneously, or there would be no such thing as difference of temperature. The rapidity with which heat is *conducted* varies in different substances; for example, if we place a silver spoon and a wooden one in boiling water, the handle of the former will become too hot to be held before that of the wooden one is sensibly warmed. Silver is, therefore, a good conductor and wood a bad conductor of heat.

Liquids conduct heat very slowly and imperfectly. If mercury be poured into a jar, and boiling water be poured over it, the metallic fluid will receive heat but slowly from the water. A thermometer let down a few feet below the surface of a pond or of the sea, would, on being drawn up, indicate a lower temperature than that of the surface water; for the latter, heated by the rays of the sun, communicates little or no heat to the water below. Indeed it may be questioned whether water has any conducting power.

It may be reasonably inquired how it happens that water is made to boil so readily by the application of heat. A little consideration will show that the effect, in a great measure, depends on the manner in which the liquid is heated, by placing it above the source of heat. If we require boiling water, we must place the kettle on the fire, and not in the ash-hole. When heat is applied to a vessel of water in the ordinary way, the fluid particles near the bottom of the vessel, being heated first and expanding, become specifically lighter and ascend; colder particles occupy their place, and ascend in their turn; and thus a current is established, the heated particles rising up through the centre, and colder particles descending at the sides. This is evidently a very different process from conduction. In the case of a solid the heat is conducted from particle to particle; but in liquids there can be no change of temperature without a displacement of particles. Each particle, as soon as it receives a fresh accession of heat, starts off with it, and conveys it to a distance, displacing other and colder particles in its progress. This process has received the name of *convection*.

The more a liquid is expanded by a given change of temperature, the greater will be the difference of specific gravity between the part which is heated and the rest of the mass, and the more rapid, therefore, will be the circulation from the change. Any tenacity or viscosity in the liquid will impede its motion, and when water is thickened with flour, or other farinaceous substances, it parts with its acquired heat very slowly. Many a person has burned his mouth with hot porridge and expressed his surprise at the slowness with which it cools, without being able to assign the philosophical reason of the phenomenon.

The currents that exist in the ocean are produced by convection, and are quite as easily accounted for as the currents in the heated water of our tea-kettle. The oceanic currents are of great constancy and regularity, but they are modified in their direction by the general distribution of land and water on the earth's surface. That part of the ocean which is immediately under the tropics, and between the eastern and western hemispheres, for example, becomes highly heated. The water being greatly expanded, flows off on either side towards the poles, acquiring a westerly direction as it passes south of the coast of Guinea, and striking the promontory of Cape St Roque, on the South American coast, is split into two streams. The smaller one continues southwards towards Cape Horn; while the larger current maintains a north-westerly course into the Gulf of Mexico, where it receives further accessions of heat, and is gradually changed in its direction. It now passes along the southern shores of North America, and finally emerges northward in the narrow channel between the peninsula of Florida and the Bahama Islands, where it assumes the name of the Gulf Stream. The temperature of this current is found to be nine or ten degrees higher than that of the neighbouring ocean. This current passes on, gradually widening and becoming less marked, till it is lost on the western shores of Europe. A less accurately defined under-current from the poles is constantly setting in towards the equator, to supply the place of the heated water which takes the course already described. Besides rendering important aid to the navigator, these oceanic currents assist in maintaining an equilibrium of temperature on the earth, moderating the severity of the polar frosts, and tempering the sultry heats of the tropics.[1]

Among the circumstances which materially affect the vaporization of liquids, one of the most important is atmospheric pressure. We have said that water boils at 212°, but this statement requires some qualification, as the boiling-point of water will vary according to the pressure of the atmosphere as indicated by the barometer. The aërial ocean which envelopes this planet presses upon the surface of the liquid ocean with a force equal to nearly fifteen pounds on every square inch; in other words, a column of air an inch square, extending from the level of the sea to the top of the atmosphere, weighs between fourteen and fifteen pounds. The elastic force of air is necessarily equal to its pressure. Let us try to make this point intelligible to the reader. If the mercury of a barometer stands at a height of about thirty inches in the open air, indicating a pressure of fifteen pounds, it will stand at exactly the same height in a close room from which all communication with the external air has been cut

[1] Professor Miller.

off. The lowest stratum of the atmosphere is pressed upon by the strata above it, and being highly elastic, it assumes the condition of a bent spring. The confined air of the room is therefore able to support thirty inches of mercury by the elasticity which it acquired before the doors and windows were closed.

We shall now be able to understand the relation that subsists between the phenomenon of ebullition and atmospheric pressure. Water evaporates, or is converted into steam at all temperatures, until the whole space above it is filled with watery vapour of a certain elasticity. This is a wise provision of nature; for if water obstinately retained its liquid form at all temperatures below 212°, the moisture that descended to the earth in the form of rain would never be evaporated during the hottest summers. But there is a difference between evaporation at low temperatures and ebullition or boiling. Water must be heated until its vapour acquires an elasticity equal to that of the atmosphere before ebullition can take place. At 212° the elastic force of steam will support a column of mercury thirty inches high, and at this temperature the steam-bubbles acquire the power of breaking through the surface of the heated water, provided the barometer stands at thirty inches.

Were we to carry our kettle to the summit of a high mountain, we should find that the water would boil at a very low temperature, and never become hot enough to make a decent cup of tea. Thus at the town of Potosi, on the Andes, where the superincumbent pressure of air will only support some eighteen inches of mercury, water boils at 188°. Again, were we to carry our kettle to the bottom of a deep mine, we should have to heat the water to a point considerably higher than 212° before it would boil, owing to the increased height of the column of air pressing upon its surface.

We now turn to the examination of another interesting point connected with the boiling of water. The reader will doubtless imagine that the hotter a vessel is into which water is poured, the sooner the liquid will boil. This is far from being the case, as may be proved by pouring a small quantity of water into a silver basin heated to redness. Instead of flashing into steam, as might be expected, the water will gather itself into a globule and dance about on the hot surface as if bewitched. The liquid is in a state of incessant motion: sometimes it elongates itself into an oval in one direction; then, drawing itself up, it stretches out in a cross direction; and these changes take place so rapidly, that a star-shaped figure or rosette is often the result. While the drop is in this spheroidal condition, as it has been called, let the lamp which heats it be withdrawn: the basin gradually cools, and after a short time the drop loses its spheroidal form, spreads out on the metallic surface, and is instantly thrown into violent ebullition. This striking phenomenon is generally known as Leidenfrost's experiment.

All volatizable liquids under similar circumstances behave as water does. Liquid sulphurous anhydride, for instance, when poured into a red-hot silver or platinum crucible, retains its spheroidal state; its temperature never rising beyond its boiling-point. Now, as the boiling-point of this liquid is 14°, and therefore much below the *freezing*-point of water, we can actually freeze water in a red-hot crucible by pouring it into the sulphurous anhydride! The same thing occurs with a mixture of ether and solid carbonic anhydride when introduced into a red-hot metallic vessel. The mixture requires for its conversion into gas as much time as it would in the air at the ordinary temperature. If we introduce into this mixture a small tube containing a little mercury, the liquid metal instantly congeals into a solid![1] Again, in the place of a metallic basin or crucible, water near its boiling-point may be made use of to support a drop of ether. Instead of mixing with the hot water, the ether gathers itself up into a globule and rolls about upon the surface of the other liquid.

Let us confine our attention to the original experiment, to the dancing drop in the red-hot basin. By a series of beautiful experiments it has been satisfactorily proved that the spheroidal drop never touches the heated surface, but is separated from it by a considerable interval. To what, then, is this interval due? Let us quote the words of a clever writer to whom we are indebted for many of the facts contained in this chapter:—

[1] Liebig.

'At an early period of railway history, it was proposed by that original genius George Stephenson to substitute for ordinary steel springs, in the case of locomotives, springs of elastic steam. It was proposed to convey the steam into cylinders in which pistons should move steam-tight; these pistons, supported by the steam beneath them, were to bear the weight of the locomotive. Now what the great engineer proposed for the locomotive, the spheroidal drop effects for itself—it is borne upon a cushion of its own steam. The surface must be hot enough to generate steam of sufficient tension to lift the drop. The body which bears the drop must be of such a nature as to yield up readily a supply of heat; for the drop evaporates and becomes gradually smaller, and to make good the heat absorbed by the vapour, the substance on which the drop rests must yield heat freely; in other words, it must be a good conductor of heat.

'It is to the escape of steam in regular pulses from beneath the drop that the beautiful figures which it sometimes exhibits are to be referred. By using a very flat basin over which the spheroidal drop spreads itself widely, we render it difficult for the vapour to escape from the centre to the edges of the drop; and this resistance may be increased till the vapour finds it easier to break in bubbles through the middle of the drop than to escape laterally.

'All these facts are in perfect harmony with the explanation, that it is the development and incessant removal of a steam-spring at the lower surface of the drop which keeps the liquid from contact with the metal and shields it from the communication of heat by contact. Owing to this, indeed, the liquid in the spheroidal condition never reaches its boiling temperature. If you plunge a thermometer into a spheroid of water in a red-hot vessel, its temperature will be found to be several degrees under 212°. When the lamp is withdrawn and the basin cools, the tension of the steam underneath the drop becomes gradually feebler. The spring loses its force, the drop sinks and finally comes in contact with the metal. Heat is then suddenly imparted to the liquid, which immediately bursts into ebullition.'[1]

It is well known that we may introduce the hand, if moist, into melted lead, nay, into white-hot melted copper or iron, and move it slowly about in these liquids, not only without burning the hand, but without even feeling the intense heat of the melted metals; whereas iron or copper at a heat far below redness, instantly causes a blister or burn. This apparent anomaly is easily explained. The intense heat of the melted metal instantly vaporizes the moisture of the hand, and the experimentalist receives no injury, as his hand is protected by a thick glove of non-conducting steam.

It is highly probable that the priests of old were acquainted with this fact, and made good use of it

[1] From the 'Westminster Review.'

in the ordeal of fire. When a person was accused of some crime which could not be proved against him, he was subjected to the fiery ordeal, that is to say, he had to plunge his arm into molten lead or walk barefooted over red-hot ploughshares. If he passed through the ordeal scathless, his innocence was held to be satisfactorily established. Now the reader need not be told that the safety of the suspected person did not depend on his freedom from guilt, but on the moisture of his arm or feet and the heat of the metal. The greatest criminal might walk over hot ploughshares, provided they were hot enough to give him sandals of vapour.

Truly the humble tea-kettle is wonderfully suggestive. We had almost forgotten that it forms the text of the present chapter; but just now the water boiled over and reminded us that we had not touched upon those grand kettles of nature, the Geysers, or intermittent boiling fountains of Iceland.

The Geysers, of which there are a considerable number, are springs of hot water holding a large quantity of silex or flint in solution, which issue from the beds of lava of which the wonderful volcanic island is chiefly composed. A jet of boiling water, accompanied with a great evolution of vapour, first appears, and is ejected to a considerable height; a dense volume of steam succeeds, and is thrown up with prodigious force, and a terrific noise like that produced by the escape of vapour from the boiler of a steam-engine. Nature's cauldron boils over!

This operation sometimes lasts for more than an hour; and after an interval of repose of uncertain duration, the same phenomena are repeated.

The Great Geyser is the most celebrated of these boiling fountains. Sir George Mackenzie, who was the first to describe it, states that its eruptions were preceded by a sound resembling the distant discharge of heavy ordnance, and the ground shook sensibly. The sound was rapidly repeated, when the water in the basin, after heaving several times, suddenly rose in a large column, accompanied by clouds of steam, to the height of ten or twelve feet. The column then seemed to burst, and sinking down, produced a wave, which caused the water to overflow the basin. A succession of eighteen or twenty jets now took place, some of which rose to a height of from fifty to ninety feet. The last eruption was the most violent. This being over, the water suddenly disappeared from the basin, and sunk down a pipe in the centre to a depth of ten feet; but in the course of a few hours the phenomena were repeated with increased energy. The basin of the Great Geyser is an irregular oval, about fifty-six feet by forty-six, formed of a mound of flinty deposits about seven feet high. The channel through which the water is ejected is about sixteen feet in diameter at the opening, but it contracts to ten feet lower down; its depth is estimated at sixty feet.

From experiments made by the Chevalier Bunsen, in 1846, it appears that the Geysers are irregular tubes fed with rain and snow-water, and that their peculiar form favours the heating of the lower portions of the contained water, by the subterranean fires, to a degree far above the boiling-point. The eruption of one of these Geysers is explained by supposing that when the whole of the contained water is sufficiently heated to allow of ebullition towards the upper part of the tube, portion after portion of the highly heated water successively bursts into steam as the pressure is diminished by the removal of the upper portion of the aqueous column.

That this is the true explanation of the phenomena is highly probable, since artificial Geysers have been constructed of iron tubes, which being filled with water, and heated near the lower extremity by burning charcoal, eject little columns of boiling water, and mimic all the phenomena presented by the natural Geysers.

Let us now ring the bell, and tell Mary to take away the tea-kettle, for there is no knowing what abstruse subjects it may suggest, as it sits on the hob, singing its peculiar version of 'Home, sweet home!' The reader must admit that the title we have chosen for this chapter is the only term that would embrace all the wonderful facts we have related. The bubbles and currents of boiling water, the dancing and ever-changing globule, and the huge cauldrons of Iceland, fall quite naturally under the indefinite heading of 'Water Bewitched.'


A FLIGHT THROUGH SPACE

A Flight through Space.

'We fly by night.'—*Macbeth.*

WITH the genius of Astronomy for our guide, we propose to travel, on the wings of thought, as far as we may, into the limitless space by which we are surrounded, and to survey the wonderful system of systems that forms the visible universe. On a clear night, when the moon's face is in shadow, a part of this vast scheme is revealed, and we behold thousands of bright orbs disposed in clusters and figures of great beauty. By scanning the heavens, we learn that the immense majority of the celestial bodies give a twinkling light, and retain the same relative position to each other, whilst the remainder, very few in number, shine with steady radiance, and change their places continually, returning at given periods in the same paths. The former are popularly called *fixed stars;* but this term, in its strictest acceptation, is not applicable to them, as they all move in definite courses through the abyss of space. The latter are called *erratic stars*, or, more commonly, *planets*, from a Greek word signifying 'a wanderer.' These move round the Sun as their common centre, or focus, in obedience to the universal law of gravitation, revealed to us by the genius of Newton, and constitute the *Solar System*, which includes our own globe. This group of worlds, though but an infinitesimal part of the universe, is naturally regarded by us with special interest. Each member of the system is comparatively near to us, and is obviously related to our mother Earth, while the fixed stars, which are separated from us by immeasurable distances, seem to be aliens. Let us therefore take a rapid survey of the solar system, before proceeding to the contemplation of the 'world of worlds' beyond.

By a long series of patient observations of a most delicate kind, aided by the magic powers of the telescope and other marvellous instruments, and by refined combinations of theoretical reasoning and logical induction, man has succeeded in measuring the dimensions, gauging the contents, and weighing the mass, not of our Earth alone, but of every other planet, and of the great Sun himself.

The *Earth* is a spheroid, not a perfect sphere, its equatorial diameter being 7,926, and its polar diameter 7,899, miles; it revolves with a velocity of seventeen miles a minute at the equator, and moves in its orbit round the Sun at a rate of more than 1,100 miles a minute. Its mean distance from the solar centre is about 95,000,000 miles.[1]

[1] Foucalt's experimental determination of the velocity of light, and Winnecke's recent observations of the parallax of Mars,

The *Moon*, the satellite of the Earth, sweeps round our planet in 27 days, 7 hours, 43 minutes, and 11 seconds, at the distance of some 238,000 miles. Her diameter is about 2,160, consequently her *bulk* or *volume* is only one-fiftieth that of the Earth. The latter, however, is made of heavier stuff, and eighty-eight moons would be needed to make up its *mass*, or quantity of gravitating matter.

Two planets revolve round the solar centre within the orbit of the Earth; the rest move in external paths.

Mercury is the innermost planet of our system, his distance from the Sun being less than 37,000,000 miles. The period of his revolution, or, in other words, the length of his year, is about 88 of our days. His diameter is some 3,200 miles; his mass, about one-fourteenth that of the Earth. The heat borne by this child of the Sun has from six to seven times the intensity of that which we receive.

At a distance of some 69,000,000 miles from the centre we discover *Venus*, the queen of the heavens, our beautiful 'morning' and 'evening star.' This planet has a diameter of about 8,000 miles, which only slightly exceeds that of the Earth. The resemblance between the two orbs is not confined to size; their masses are nearly equal, and they rotate on their axes with about the same velocity, the day of Venus

seem to show that this distance ought to be reduced to less than 93,000,000 miles. We must wait, however, for the next transits of Venus, in 1874 and 1882, for the exact determination of this important distance, which is the unit employed in measuring the diameters of the planetary orbits.

being only thirty-nine minutes shorter than our own. Moving in a smaller orbit than that of her sister planet, Venus performs her journey round the Sun in less than 225 of our days. She intercepts nearly twice as much light and heat as our globe receives; but the dense, cloudy atmosphere with which she is enveloped must moderate to some extent the effects of the solar rays.

Pursuing our outward course we cross the orbit of the Earth, and reach that of *Mars* at the distance of some 144,000,000 miles from the Sun. Mars is comparatively a small planet, his diameter being only about 4,500 miles, and his mass less than one-seventh that of our globe. He performs his journey round the solar centre in 687 of our days. His day exceeds ours by thirty-seven minutes. Seen through a powerful telescope, his disk presents a vague delineation of seas and continents, with patches of white at the poles, denoting the existence of snow-covered regions. The seasons are beautifully indicated by the alternate increase and decrease of these snow-masses. Though Mars does not get half so much heat from the Sun as the Earth receives, he seems to enjoy a temperate climate, as a very large portion of his surface is always free from patches of snow, large enough to catch the eye of the observer. This temperate climate is undoubtedly dependent on the vaporous atmosphere which surrounds the planet.

Beyond the path of Mars, at a mean distance from the Sun of about 250,000,000 miles, we encounter a host of little worlds called *planetoids* or *asteroids*. The principal members of this group are *Juno*, *Ceres*, *Vesta* and *Pallas;* but even these are too small to be seen from the Earth without the aid of the telescope.[1]

Leaving the minor planets, and continuing our journey towards the confines of our system, we reach the orbit of *Jupiter* at the distance of some 495,000,000 miles from the Sun. Jupiter is the largest of all the planets. With a diameter of about 90,000 miles, he exceeds our globe in bulk in the proportion of about 1,400 to 1; but owing to his inferior density, his mass is not quite 340 times that of the earth. He spins on his axis with marvellous rapidity, his time of rotation being less than ten hours. He performs his journey round the solar centre in 4,333 days, consequently his year is nearly twelve times as long as ours. The solar rays that reach Jupiter, have only one-twenty-eighth the intensity of those which fall upon the Earth. Attending this king of planets are *four satellites* or *moons*, which revolve round him at different distances. The smallest of these secondary planets is very nearly as large as our Moon; the largest surpasses the planet Mercury in bulk.

The next world we meet is *Saturn*, placed at the distance of some 900,000,000 miles from the solar centre, round which he revolves in a period exceeding twenty-nine of our years. In bulk he is second

[1] The *eighty-fourth* planet of this group was discovered by Dr Luther of Dusseldorf in August 1865.

only to Jupiter, his diameter being about 77,000 miles; and though his density is less than that of any other planet, his mass is a hundred times as great as that of our globe. This stupendous planet, besides being attended by *eight satellites*, is surrounded by three, if not four, flat, rotating concentric *rings*. The interval between the planet and the inner ring is some 19,000 miles, and the breadth of the whole system of rings is about 30,000 miles.

Up to the close of the eighteenth century, the mighty orbit of Saturn was supposed to form the boundary of the solar system; but we now know that it is encircled by the orbits of at least two great globes. The first of these is *Uranus*, whose distance from the Sun is twice that of Saturn, and whose year, or period of revolution, equals 84 of ours. His diameter is about 35,000 miles; his mass about sixteen times that of the Earth. At least *four satellites* are known to revolve around him, and others probably exist.

Far beyond Uranus, at the immense distance of some 2,850,000,000 miles from the solar centre, we find *Neptune*, another huge globe, with a diameter of about 39,000 miles. He is probably attended by satellites, and performs his mighty journey round the Sun in 84 years, travelling at the rate of about 200 miles a minute.[1]

[1] Sir John Herschel, in his *Outlines of Astronomy*, makes the following remarks on the discovery of this planet:—'The discovery of Neptune marks in a signal manner the maturity of

Having reached the known limits of our system, we will now retrace our course through space, to contemplate the great central body which keeps the revolving planets in their orbits, and illuminates and vivifies them with its glorious rays. The stupendous globe which we call the *Sun*, has a diameter of 882,000 miles, and is consequently more than 1,380,000 times as large as the Earth. Its mass, estimated by its attractive force, is, however, only about 355,000 times that of our globe; hence we conclude that its density is very low. It turns on its axis in 25 days, 7 hours, and 48 minutes. The Sun *apparently* moves through the heavens in a great circular orbit called the *ecliptic;* but this apparent motion is simply the effect of the real motion of our Earth.

A general impression of the relative magnitudes and distances of the principal parts of the planetary system may be obtained from the ingenious illus-

astronomical science. The proof, or at least the urgent presumption of the existence of such a planet, as a means of accounting (by its attraction) for certain small irregularities observed in the motions of Uranus, was afforded almost simultaneously by the independent researches of two geometers, Messrs Adams of Cambridge and Leverrier of Paris, who were enabled *from theory alone* to state whereabouts it ought to appear in the heavens, the places independently calculated agreeing surprisingly. *Within a single degree* of the place assigned by M. Leverrier's calculations, and by him communicated to Dr Galle of the Royal Observatory at Berlin, and within two and a half from that indicated by Mr Adams, it was actually found by Dr Galle, on the very first night (Sept. 23, 1846) after the receipt of M. Leverrier's communication, on turning a telescope on the spot, and comparing the stars in its immediate neighbourhood with those previously laid down in a zodiacal chart.

tration devised by Sir John Herschel. Let a globe, two feet in diameter, be placed on a level plain to represent the *Sun. Mercury* will then be represented by a grain of mustard-seed, on the circumference of a circle 164 feet in diameter for his orbit. *Venus* will appear as a pea, on a circle 284 feet in diameter. The *Earth* will also be represented by a pea, on a circle of 430 feet; *Mars* by a rather large pin's head, on a circle of 654 feet; the principal *planetoids* by grains of sand, in orbits of from 1,000 to 1,200 feet; *Jupiter* by a moderate-sized orange, on a circle nearly half a mile across; *Saturn* by a small orange, on a circle of four-fifths of a mile; *Uranus* by a small plum, upon the circumference of a circle of more than a mile and a half; and *Neptune* by a good-sized plum, on a circle about two miles and a half in diameter.

As a planet, our Earth presents no striking peculiarities. Its orbit embraces the paths of some of the planets, and is environed by the orbits of the others. It is neither the largest nor the smallest of the Sun's dependants; neither the fleetest nor the slowest; neither the warmest nor the coldest. In fine, the Earth holds a place in the grand series of revolving orbs which seems to prove that it is in no respect an extraordinary part of the solar system. If we accept this conclusion, and consider how the one globe is crowded with living beings, we cannot doubt that most, if not all, of the larger planets are habitable and inhabited worlds. Many of the conditions under which life flourishes on the Earth are known to exist in Mars. Both planets enjoy the same alternations of light and darkness, the same pleasing succession of seasons, the same diversity of climate; their surfaces are similarly divided into continents and oceans, and their polar regions have similar snowy coverings, derived from atmospheres which probably have nearly the same composition. Bearing in mind these essential analogies between the Earth and Mars, we may reasonably suppose that the latter planet is the abode of sentient beings, who share with ourselves the love and care of the Great Maker of the Universe.

In regarding the planets as inhabited worlds, we must recollect that they are placed at different distances from the Sun, and that their masses and densities are dissimilar; for these differences are necessarily productive of great diversity in the provisions by which the life of their inhabitants is supported. Thus, the intensity of the solar heat and light on the innermost planet, Mercury, must be nearly seven times greater than on the Earth, and some 5,600 times greater than on the remote world Neptune! Unless, therefore, there be some provision for equalizing the influence of the solar rays, life, as we know it, could not exist on either of the planets named. Not a living thing now found on our globe would remain were the Sun to be septupled, or were its actual heating and illuminating powers to be diminished in the proportion of 900 to 1.

Again, the intensity of the gravity, or its efficacy in counteracting muscular and repressing animal activity, on Jupiter is nearly two and a half times that on the Earth, while on Mars it is not more than one-half. Lastly, the density of Saturn is only about one-ninth of the Earth's, so that it must consist of materials not heavier, on the average, than some of our lighter woods.

Recent discoveries tend to increase the probability of the planets being inhabited. For instance, by a series of beautiful experiments, Dr Tyndall has proved that aqueous vapour stops the heat-rays emanating from bodies only slightly warmed, but not those emitted by the Sun. Hence, a vaporous atmosphere surrounding a planet must act like warm clothing in preventing the waste of heat by radiation into space. The Sun's rays would pass freely through such an atmosphere, but would lose their penetrating power on reaching the surface of the planet. The mild climate which Mars seems to enjoy may reasonably be ascribed to this provision, for the snow which collects at the poles of this planet proves that it has an atmosphere containing aqueous vapour.

In the case of the Moon, we infer from the unearthly ruggedness of her surface, and the absence of all indications of an atmosphere, that she is *not* inhabited by organized beings. We must not forget, however, that we see only half of the Moon's surface, and that any arguments we may adduce against the existence of Selenites must necessarily be *one-*

sided. The satellites of the other planets appear as mere dots in the field of the telescope, and present no features from which we may draw conclusions respecting their habitability. Again, the planetoids or asteroids offer none of the essential analogies to our globe that are observed in the larger planets. They may be compact little inhabited worlds, but many considerations bring them before the mind as the rough fragments of an exploded planet.

As we intend to devote a separate chapter to those 'strange wanderers of the sky,' *comets*, we will now wing our flight beyond the comparatively narrow limits of the solar system to the confines of the visible universe—to the threshold of the abyss of space beyond.

The innumerable multitude of celestial bodies, which seemingly preserve from age to age the same relative situation in the heavens, and are therefore popularly called *fixed stars*, were classified by the ancients into fanciful groups called *constellations*, to which names were assigned, either from some supposed resemblance of the outlines of the group to figures of men, animals, or other objects—for example, Ursa Major, Ursa Minor, Draco, Aquila, Cygnus, Serpens, and the well-known Signs of the Zodiac; or by way of a special tribute of veneration to some departed hero or heroine, as Hercules, Perseus, Andromeda, Cassiopeia. A few names, moreover, may be traced to grovelling adulation; a striking example being afforded by Coma Berenices, the name bestowed upon a constellation above Leo. Berenice, daughter of Magas of Cyrene, and wife of Ptolemy III., king of Egypt, rejoiced in an abundance of very beautiful hair, of which she was inordinately vain ; a portion of this had been suspended in a temple, from which it was suddenly missed one day, to the great consternation of the courtiers, who had reason to dread the anger of the bereaved beauty. However, Conon the astronomer, a sharp fellow in his way, luckily bethought himself of the notable expedient of looking for the missing locks in the heavens, where, sure enough, he beheld them quite plain, the same having been 'translated' to that exalted position by the gods, evidently on account of their surpassing loveliness. The delicate flattery succeeded to the fullest extent ; the queen was more than satisfied, and the Coma Berenices shines down on us to the present day! The catalogue of stars which forms part of the famous 'Almagest' of Ptolemy of Alexandria, an astronomer who flourished in the second century after Christ, contains upwards of a thousand stars, arranged in forty-eight such constellations.[1] Although these fanciful divisions and classifications of the stars would seem, as Sir John Herschel truly and pertinently observes, to have been purposely named and delineated to cause as much confusion as possible, yet the general convenience which they

[1] This catalogue of stars was founded upon that which had been drawn up about B.C. 125 by the illustrious Hipparchus, the greatest astronomer of antiquity.

afford is so great, and the stars have in process of time become so intensely identified with their names, that they have for ages been permitted, and must even in our own days still be permitted, to retain them.

A much more rational division of the stars, however, is that into classes, according to their apparent brightness. These classes astronomers term *magnitudes.* The brightest stars are said to be of the *first* magnitude; those next in brightness, of the *second* magnitude, and so forth. The stars down to the sixth or seventh magnitude are visible to the naked eye; those of lower magnitudes cannot be discerned without the aid of the telescope. Astronomers enumerate only 23 or 24 stars of the first magnitude; from 50 to 60 of the second; about 200 of the third, and so on, the numbers increasing rapidly as we descend in the scale of brightness. The whole number of stars already registered, down to the seventh magnitude inclusive, amounts to from 12,000 to 15,000. The number that can be seen with the aid of the telescope is incalculable. Sir William Herschel, by counting the stars which appeared together in the field of his powerful instrument, was led to conclude that 50,000 had passed under his notice, in a zone only two degrees in breadth, during a single hour's observation. The Milky-Way, that great luminous band which stretches across the heavens, is resolved by the telescope into countless millions of distinct stars. Though the most remote star of this wondrous zone is separated from us by an inconceivable distance, it does not mark the boundary of the visible universe. Far beyond the limits of our vast stellar system there are other systems which the telescope brings into view as minute luminous clouds. Thousands of these *nebulæ*, or star-clouds, have been catalogued by our great countrymen, the Herschels; and some of them have actually been resolved into separate stars.[1] What an inexhaustible field of speculation and conjecture is opened here to the imagination! The mind of man, with its limited comprehensive powers, is bewildered and lost in the interminable range of system upon system, firmament upon firmament, of stars, each of them a sun, and probably in its sphere the presiding centre round which planetary worlds may

[1] Sir William Herschel was enabled, by the powers of his large reflecting telescope, to divide and arrange the nebulous masses of light discovered by him in his general sweep of the northern heavens, into the following six classes:—1. Distinct clusters of separate stars; 2. Resolvable nebulæ, or such as, though not distinctly resolved, yet clearly indicate that their resolution may be accomplished by more powerful optical instruments; 3. Nebulæ showing no trace of resolution; 4. Planetary nebulæ, or such as have the appearance of planets; 5. Stellar nebulæ; 6. Nebulous stars. Many of the nebulæ which could not be resolved into separate stars by Sir W. Herschel's telescope have since yielded to the powers of Lord Rosse's gigantic six-feet reflector, and the great refractor of the observatory at Cambridge, U. S. The results recently obtained by Mr Huggins and Professor W. A. Miller, in an examination of the light emitted by the nebulæ, seem to prove that many of these celestial objects are really enormous masses of luminous gas, and that the bright points supposed to be stars are not solid bodies.

be revolving, the dwelling-places, perchance, of intelligent beings.

The classification of stars into magnitudes by estimation of their relative brightness, although unquestionably much more rational than the unmeaning division into constellations, is, however, entirely arbitrary. As we can only judge of the brightness of a star by the total impression made by its light upon the eye, it is quite evident that the assumed magnitude will depend, in the first place, on its distance from us; secondly, on the absolute extent of its luminous surface; and lastly, on the intrinsic brightness of that surface: but of these data we know nothing, or next to nothing. Up to a recent period we only knew that the nearest fixed stars could not possibly be placed at a distance *so small* as 19,595,175,000,000, or nearly twenty billions of miles from the Sun; but certain most admirable observations and measurings, commenced by the illustrious Bessel, and carried on by Struve, Henderson, and Peters, have since given us the actual distances of several of the stars, and we now know that the fixed star[1] placed nearest to our solar system, is separated from it by more than 20,000,000,000,000 miles—a distance utterly inconceivable by the human mind. Light travelling, as it is well known, at

[1] This is the star *Alpha* in the constellation Centaurus or the Centaur. It is the nearest star which has yet been found. The star 61 in Cygnus, the Swan, which is placed at the distance of over 56,000,000,000,000 miles from our system, was formerly considered the nearest star.

the rate of 192,000 miles per second, would take about three years and four months to pass from this nearest star to the Earth! But if this nearest and comparatively trifling distance is sufficient to appal the human understanding, what shall we say or think of the immeasurably greater distances which separate us from the remoter stars, and from the most distant visible nebulæ, whose light, it has been calculated, will take at least a million years to reach our Earth! To arrive at some approximate estimation of the real magnitude of the stars, the light which they shed on us, and the most imperfect and as yet still almost entirely negative knowledge which we have obtained respecting their distances, must be our only guide. Now, direct photometrical[1] experiments have shown that the light of *Sirius*, the most brilliant of the fixed stars, is, at equal distances, nearly 394 times more intense than that of our Sun, and that it would accordingly require a collection of about 394 suns to shed a ray of light on our Earth like that of Sirius, supposing the two bodies to be placed at the same distance from us.

Several among the stars exhibit the most remarkable phenomenon of a regular periodical increase and diminution of lustre, involving, in some rare instances, an alternate total extinction and revival. These are called *periodical* or *variable stars*. One of the most remarkable is the star *Omicron*, in the constellation Cetus, which has a period of about 331

[1] Light-measuring.

days. It remains about a fortnight at its greatest brightness, equal to a large star of the second magnitude; it then decreases during about three months until it disappears altogether: after remaining invisible during about five months, it reappears again, and continues increasing in brilliancy during the remainder of its period. It shows, however, occasionally considerable irregularity in its phases, and has actually been known on one occasion to remain altogether invisible during more than four years (between October 1672 and December 1676). Another remarkable specimen of a variable star is *Algol* or *Beta*, in the constellation of Perseus. The whole period of change of this star is about 2 days 20 hours and 49 minutes, during which time it varies in brightness from the second magnitude to the fourth: its changes are confined, however, to a few hours, as it continues for rather more than 2 days and 13 hours at its state of greatest brightness.

Stars have also occasionally appeared suddenly in various parts of the heavens, blazing forth for a time with extraordinary lustre, and after remaining awhile apparently immovable, have gradually decreased in brightness, and finally altogether vanished. These are properly termed *temporary stars.* Thus there suddenly appeared in the time of Tycho Brahe (1572, 11th November), in the constellation of Cassiopeia, a most lustrous star, equalling Sirius in brightness; it continued increasing in brilliancy up to December 1572, when it actually surpassed Jupiter and Venus when nearest to the earth, and was visible at mid-day. From this period forward it began to diminish rapidly, and in March 1574 it had completely disappeared from the heavens. Another equally brilliant star burst forth on the 10th October 1604, in the constellation of Serpentarius, and continued visible till October 1605. The fact of the sudden appearance and subsequent disappearance of such temporary stars affords an irrefragable indication that there must exist also in space immense *dark bodies*, absolutely invisible to us, and of which accordingly we cannot possibly have any knowledge, as light is the only means of communication between the stars and the earth.

There remains now for us still to consider another marvel of the heavens—the *double* and *multiple stars*. The telescope has revealed to us that several thousands of stars which appear single to the naked eye, consist in reality of two or more luminous bodies placed in close proximity to each other. The observations and researches made principally by Sir William and Sir John Herschel, and the great Russian astronomer Struve, have placed it beyond doubt that the proximity of some of these stars to each other is by no means accidental, but that they are physically connected together by the tie of gravity, and revolve round each other as the planets do round the sun, and in obedience to the same law of attraction and gravitation which governs the motions of the solar system.[1] Many of the double stars of unequal magnitude exhibit the beautiful phenomenon of complementary colours. Thus, if the larger star be of a ruddy or orange hue, the smaller one will appear blue or green; if the larger star appear yellow, the smaller will appear blue; if the light of the brighter star incline to crimson, that of the other will incline to green. 'It may be easier suggested in words than conceived in imagination,' observes Sir John Herschel, 'what variety of illumination *two suns*—a red and a green, or a yellow and a blue one—must afford a planet circulating about either; and what charming contrasts and graceful vicissitudes—a red and a green day, for instance, alternating with a white one and with darkness—might arise from the presence or absence of one or other, or both, above the horizon.' In connection with this subject we may here remark, that in many parts of the heavens isolated stars have been observed of a red colour, almost as deep as blood. Thus, *Arcturus*, *Aldebaran* (in the Bull), *Antares* (in the Scorpion), are red stars; and what is more curious still, *Sirius*, whose light is now, and has been for several centuries, of the purest white, is mentioned by Ptolemy and all other astronomers of antiquity as a *red* star. There is no instance of an isolated blue or green star. In the remote clusters or resolved nebulæ, the minute stars usually shed a faint blue light.

[1] Upwards of 100 double stars of this kind were enumerated by Madler in 1841.

Thus far have we winged our daring flight to the utmost confines of the visible heavens—to the Ultima Thule of the starry world. But beyond, into the endless realms of space, we may not soar. Here Almighty Wisdom has fixed a barrier, sealed to the finite intellect of man. The superior intelligences of higher spheres may perchance pass beyond into the immensity of God's creation, to stand in their turn on the confines of another immensity, into which even *they* may not enter—and so on in endless succession!

A Tale of a Comet.

'I *could* a tale unfold.'—*Hamlet.*

IN our Flight through Space we disregarded those strange celestial wanderers called comets, as a consideration of the marvellous facts connected with them would have delayed us too long in our journey from the Sun to the Nebulæ. We now place some of these facts before our readers in a separate article, which takes the form of a Comet's Tale:—

. . . .

'So you want to know all about me and my eccentric brethren?—What we are? What we are made of? How many there are of us? Where we come from and where we go to? What position we hold, and what purpose we subserve in the great celestial scheme?—Well, you *are* inquisitive! You will, however, get but little information out of me, my terrestrial friends, on most of these points. Still, I cannot but admire the indomitable perseverance with which you are prying into the abyss of space, seeking to fathom the secrets of the universe; and although some of you have of late rather offended the dignity of our great family by calling us "visible nothings," and exaggerating our avowed flimsiness and want of gravity,[1] I will bear no malice, and will endeavour, not indeed to satisfy your curiosity in all matters concerning me and my brethren, but to give you some few scraps of information and stray hints about us, leaving you to make the best use of them you may, in your interminable cruise on the endless sea of speculation.

'Well, then, I am one of a most numerous family. Johannes Kepler—one of those bright intellectual stars that adorn and illumine your microscopic mite of a sphere, and render it interesting even to the giants of creation—had very good reasons for declaring that there were more comets in space than fishes in the ocean. A kindred spirit of the present age, Arago, has informed you that we number some three and a half millions at the lowest computation, and possibly twice as many. Thousands of my brethren have passed near to you, but have escaped observation, because their paths traversed that part of your heavens which is above the horizon at daytime. One of these invisible travellers was revealed

[1] M. Babinet, in his '*Etudes et Lectures sur les Sciences d' Observation*,' is indeed rather hard upon the poor comets. He calls them mere gatherings of vapour, visible *nothings*, incapable of doing either good or harm, and useful simply through enabling us to verify Newton's law of attraction, and explore the regions of heaven far beyond the limits of the solar system.

to the inhabitants of your globe by the total eclipse of the sun in the year 62 B.C. We are of all sizes and magnitudes, from the incredibly immense down to the minutest telescopic. I myself may boast of a respectable bulk, as my head alone has a diameter of some 100,000 miles, to say nothing of the millions of miles overreached by my tail.[1] I am, however, a mere pigmy compared with my mighty brother who visited you in 1811. The essential part of each of us is the *nucleus*, which sometimes appears as a bright stellar point, and sometimes rather gives the notion of a planetary disk, seen through a nebulous haze. My own nucleus is about the size of your globe. What is generally called the *head*, is simply this nebulous haze which surrounds the nucleus. The train of illuminated vapour which is often, though by no means always, attached to the head, is usually termed by you the *tail*, though, allow me to observe, rather improperly, since this appendage often precedes us in our motions, as it is invariably thrown out in a direction opposite to that in which the sun is situated. The inhabitants of that portion of your sphere which is designated in your maps by the name of China—who, though certainly a little pigheaded, and strangely averse to progress in arts and sciences, are yet very careful, and, moreover, much more ancient observers of the starry heavens than you Europeans—have bestowed

[1] The celestial story-teller is Comet V. of 1858, better known as 'Donati's Comet.'

upon this occasional appendage the much more appropriate and significant name of *brush* or *pencil* of light. The nebulous haze which invariably surrounds the nucleus of members of our family is called the *coma*, from a Greek word signifying hair: some fancied resemblance of the nebulous matter composing this coma and the tail, has gained us the name of *comets*, or *hairy stars*. Now, though rather put out by your astronomers' statements respecting the extreme flimsiness of our material structure, I am yet bound to confess that there is unfortunately a great deal of truth in them. Leaving altogether out of the question the physical constitution of what is termed our tail, I must even plead guilty to the charge of extreme "light-headedness" brought against us. I would repel it if I could; but as the faintest stars can often be distinctly seen, without any perceptible diminution of their lustre, through our enormous heads, I feel it would be useless to make any pretensions to solidity. I acknowledge, therefore, that even our most compact parts are composed of matter possessing an extreme degree of tenuity. If additional proof were required of this patent fact, it might be found in the almost imperceptible power of attraction which we, even of the largest magnitudes, exercise upon Jupiter and other planets, or even upon their satellites, and those mites of worlds the planetoids, when we accidentally cross them in their orbits. Jupiter, more especially, who seems to have a peculiar knack of being always, somehow or other, in the way of some of us, seems never to be in the least affected by the attraction of our immense bodies, and actually often manages to thrust us right out of our orbits—a feat which even the wretched little planetoids, of whom myriads might find room in the head, millions in the tail, of one of us, have sometimes succeeded in performing. I would not, however, have you believe that we are mere "visible nothings"—the "airy offspring of vapour and the sun;" for however so attenuated the material composing us may be, still it is ponderable matter; and there can be no doubt but that in some of us at least, the *nucleus* consists of a substance of appreciable density, a direct collision with which no planet would care to court. Not that I want to frighten you about the possibility of such a collision with your Earth; your wise men have cleverly calculated that there are about 300,000,000 chances against a contingency of the kind. Moreover, depend upon it, none of us is likely ever to seek the chance of a brush against your Earth or any other planet—and that for a sufficient reason of our own. Your famous George Stephenson, whose genius has enabled you, his brother mites, to move a little faster than of old over the surface of your cheese, once said, in reply to a question addressed to him as to whether it might not be awkward if a cow were to happen to stray on a line of rails, right in the way of a rapidly advancing train, "Yes, very awkward—for the *coo!*" Experience has since but too often and too clearly proved that an event of the kind may be equally "awkward" for the train as for the cow; and we, who are much wiser in our generation, have really no notion of tempting the chances of a collision that might prove equally fatal to the two bodies.

'I may here briefly observe, that the material of which we are composed is not luminous in itself, but is illuminated by the sun of this, or, in the case of those of us who soar into the immensity of space, some other solar system.

'We are most capricious and mutable in the forms which we assume, though, as a general rule, our heads mostly affect the globular or spheroidal shape. The magnificent luminous appendages or tails which many of us proudly display, are sometimes straight, and sometimes curved like a scimitar. With some of us this vapoury train of light attains an immense apparent length. Thus, for instance, my brother comet of 1811 was provided with a tail upwards of a hundred millions of miles in length, covering some 25 degrees of the heavens. My own, when developed to the fullest extent, stretched over more than 30 degrees; that of my brother of 371 B.C., Aristotle tells you, occupied some 60 degrees of the heavens, or a third of the hemisphere; that of the comet of 1680 covered between 70 and 90 degrees; and that of the comet of 1618 is stated to have extended to 104 degrees in length!

Some of us exhibit more than one tail. My brother of 1744, for instance, had no less than six, spread out like an immense fan; again, my brother of 1843, not contented with the splendid cone of light which gained him so much fame, shot out an additional tail in the form of a lateral streamer, which extended over nearly 100 degrees of the heavens in a single day!

'You are already aware, so I need hardly tell you, that we are all most eccentric in our motions. To superficial observation we would indeed seem to be careering with mad capriciousness along the great highway of space. But if you watch our motions more closely, you will find that there is the strictest method in our apparent madness, and that we obey the same universal law of attraction and gravitation as the other celestial bodies—some of us moving about the sun in parabolic orbits, or at least in ellipses of various degrees of eccentricity, and returning in determinate periods in the same path (unless disturbed); others running off in hyperbolic orbits, to visit other systems in the immensity of space.[1] Most of us come, in fact, into this solar system from parts of the universe extending to enormous distances beyond its limits, and after approaching more or less near to the sun, start off again on our

[1] We must here assume the reader to know that an ellipse whose major axis is of infinite length, is said to degenerate into a *parabola*. The parabola is that conic section which forms the limit between the ellipse on the one hand, which returns into itself, and the hyperbola on the other, which runs out to infinity.

journey to distances not less remote. I may perhaps be permitted here to observe that, with all due deference to those astronomers who entertain a somewhat contemptuous opinion of us and our uses, I can safely affirm that we subserve some better and higher purpose in the great economy of the universe than enabling your astronomers to verify certain natural laws, and to pry into the mysteries of heaven. You will not, of course, expect me to tell you what these purposes may happen to be; depend upon it, you will find them out all in good time, by the unaided efforts of that marvellous intelligence with which you have been endowed. This much, however, you may take for granted even now, that we serve as means of communication between system and system.

'It seems hardly credible now that our apparition in the heavens should ever, at any period of time, have been almost universally regarded with feelings of awe and terror, and that to us should have been ascribed the most malignant influences, and a most astonishing diversity of effects, physical, physiological, social, and political. And passing strange that even men like Kepler should not have been entirely free from this weakness! Seneca alone among ancient philosophers dared to oppose his powerful logic to the superstitious ideas which his age, and the ages that had preceded it, entertained with regard to us. He declared that we moved regularly in orbits fixed by natural laws; and expressed his conviction that posterity would one day stand aghast at the blindness of his age, which could ignore or disregard facts so clear and palpable.

'One of the brightest of our family—so bright, indeed, as to be plainly visible in the daytime—happening to make its appearance in the year 43 B.C., a short time after the assassination of Cæsar, was supposed to be connected in some way with that event, and was pointed to by the poets as the soul of the dictator taking its place among the divinities.

'Another comet—the first whose orbit was calculated, in 1682, by your illustrious Edmund Halley, whose name it bears, and will hand down to the remotest ages—had, at one of its former appearances, in June 1456, spread terror throughout Europe. It was regarded as a most powerful ally of the Turkish Sultan, Mohammed II., who had taken Constantinople, and threatened to overrun Christian Europe with his victorious armies. The thunders of the Vatican were launched against this celestial visitor, who thereupon disappeared from the heavens, in due course of time, to reappear when his definite journey through space had been completed. Another of my brethren—the very one, in fact, whom you have been so anxiously expecting to reappear ever since 1848—terrified the Emperor Charles V., in 1556, into consummating the abdication of all his earthly crowns, and retirement to a monk's cell in the cloister of St Justus in Spain.

'But enough of these instances of the presumption and folly of your kind,—which yet are, perhaps, less insulting after all to the dignity of our family than the notion that we occasionally take a delight in killing cats and blinding flies, in oppressing poor Whitechapel shoemakers with four babies at a birth, knocking down steeples, and in executing other undignified vagaries! Even so recently as 1829, an English physician named Forster vilified us in a most shameful manner, by ascribing to our malignant influence many of the assumed ills that flesh is heir to, —such as epidemic diseases of all kinds, earthquakes, volcanic eruptions, floods, droughts, and famines!

'Now, you may believe me, my little friends, we are entirely innocent of these dreadful charges brought against us; and I grieve to add, we cannot properly claim credit either for the glorious seasons that will occasionally coincide with our appearance, and for the splendid harvests of corn and wine produced therein. It would unquestionably have been a proud distinction for me to have had my name associated, as was that of my illustrious predecessor of 1811, with the wine of the abundant year 1858; but truth will not be trifled with: careful statistical researches and comparisons of thermal and cometary observations, extending over a period of a century, have but too fully established the conclusion, that we can claim no influence whatsoever on the temperature of the seasons. It is your Arago who has dealt us this heavy blow.

'I will now give you a little special information respecting a few of my brethren, whose periods have been fixed by your astronomers, with more or less precision.

'The most remarkable of these is the one known as Halley's Comet, from the circumstance of that illustrious geometer having predicted its return. The immortal Newton having demonstrated the possibility of any conic section whatever being described about the sun by a body revolving under the dominion of the law of gravitation, applied his theory to my great brother of 1680 with the most complete success. He ascertained that this comet described about the sun, as its focus, an elliptic orbit of such exceeding eccentricity as to degenerate into a parabola, and that its motion in this orbit was strictly comparable with the motion of the planets in their ellipses. Some years after, Halley, guided by Newton's observations and deductions, calculated with great care the elements of the orbit in which my brother of 1682 travelled, and, by a diligent study of old records, discovered a remarkable coincidence between the calculated period and the nearly equal periods which separated several famous cometary visits: thus there was a great comet in 1456, another in 1531, and another in 1607. After mature consideration, Halley concluded that these comets must be identical, returning at certain fixed periods, and ventured to *predict* another return at the close of 1758 or beginning of 1759. Clairaut, an eminent mathematician of the period, undertook to calculate the delay which the return of this comet would experience from the disturbing influence exercised upon its orbit by the larger planets, and fixed the return for spring 1759. True to the appointment, Halley's Comet made its reappearance, passing the perihelion[1] on the 12th March of that year; and once more in 1835, when it was found in the heavens at the exact spot indicated by the calculations of several of your eminent mathematicians. Assuming seventy-six years to be the mean time which elapses between its successive appearances at its perihelion, it will be seen again in 1911.

'Some of our family revolve in comparatively short periods round the sun. The most remarkable member of this group is the little body called Encke's Comet—so named from Professor Encke, of Berlin, who first ascertained its periodical return. This revolves round the sun in the short period of about 1211 days, or three years and one-third, and has been observed at every successive return since 1822. Your cunning astronomers have discovered a strange circumstance connected with this comet, which I must not omit to notice. They have found that its periods of revolution are gradually but regularly decreasing; a circumstance, it has been observed, which forebodes its ultimate fall into the sun, unless

[1] The extremity of the major axis of a comet's or planet's orbit which is nearest the sun is called the *perihelion;* the opposite extremity, the *aphelion.*

it should previously be dissipated altogether—a termination of its career by no means unlikely.

'Another comet of short period is the one called after Professor Biela, of Josephstadt, who, at its apparition in 1826, identified it with comets that had appeared in 1772 and 1805. The period of its revolution is about 2410 days, or six years and seven months. Since 1826 it has regularly reappeared at its appointed times. By a remarkable coincidence, its orbit very nearly intersects that of the Earth; and in 1832, the comet passed close to the point which was reached by your globe a month later. In 1846 a part of this comet seceded from the main body, to the great astonishment of your astronomers, and since then two comets have reappeared instead of a single body.[1]

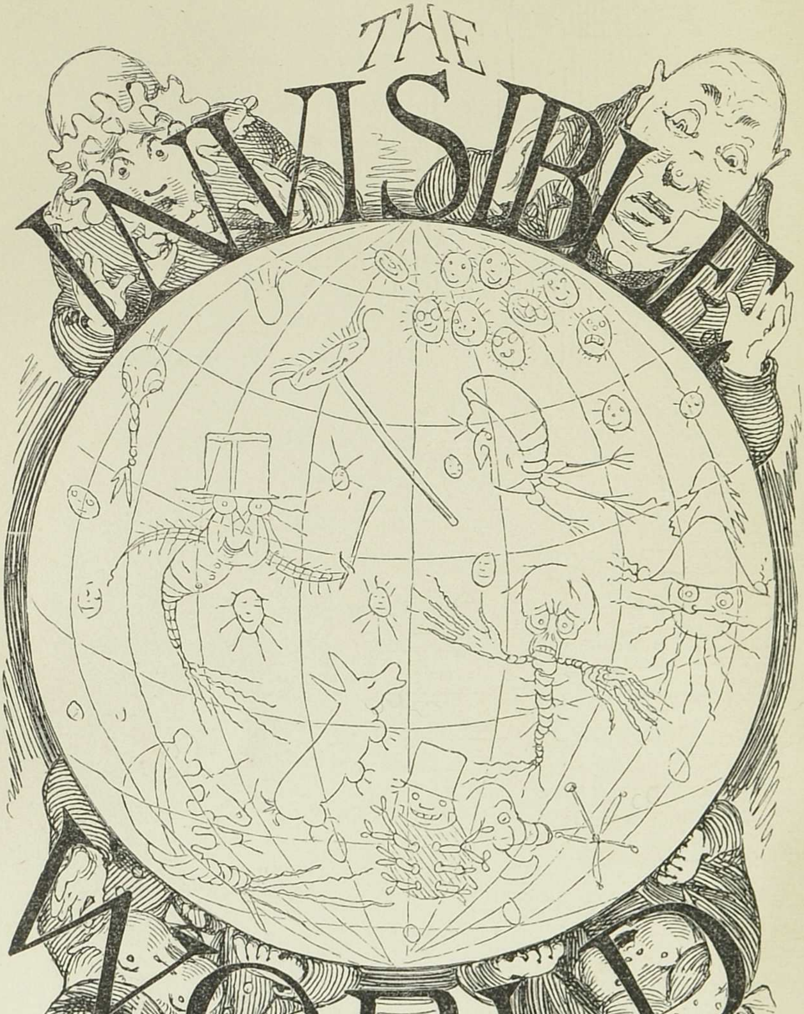
'Four other comets of short periods are known to your astronomers, and their regular reappearance proves that we are not the lawless wanderers that we were once thought to be.

'Before I take my final leave of you, I may men-

[1] The separation of Biela's Comet into two distinct comets is an inexplicable phenomenon. The comet appeared at first, as usual, as a single body; but on its approach towards perihelion, it was, on the 13th January 1846, for the first time, seen to be attended by another comet considerably fainter, at a distance of about 2′. This distance continued steadily to increase, with a corresponding change in the comparative brightness of the two comets, till the companion comet became as bright as the original, and subsequently brighter, exhibiting a star-like nucleus. A very short time after, however, the original comet gained again in brilliancy on its companion, which finally disappeared some time before the other ceased to be observed.

tion that I enjoy the reputation of being the third great comet revealed to you during the present century. When first seen by Professor Donati, of Florence, in June 1858, I appeared as a mere hazy speck on the field of the telescope, and was some 230,000,000 miles distant from the Earth. I became visible to the naked eye in the September following; and in October, my beautiful plume-like tail and brilliant head rendered me a conspicuous ornament of your heavens. Since I left the neighbourhood of your solar system, I learn that you have been visited by another member of my family, who displayed a tail of unprecedented magnitude. Doubtless this comet of 1861 was a very fine fellow, but I think you must admit that I surpassed him in brightness and elegance. I am now on my way to a point in space billions of miles away from your system; but you may be quite sure that I will come back to you, probably in about 2500 years from the present time!

'And now, farewell till our next meeting! Methinks I hear you exclaim, that this is scant and meagre information indeed. Patience, my little friends: at my next appearance I trust I may be in a position to tell a different and more circumstantial and satisfactory Tale of a Comet.'


THE
INVISIBLE
WORLD

The Invisible World.

'Nor is the stream
Of purest crystal, nor the lucid air,
Though one transparent vacancy it seems,
Void of their unseen people.'—THOMSON.

THE revelations of the telescope are not more astounding than those of the microscope. The human eye can only range over a finite portion of the universe; but aided by these magic instruments, its sphere of research is greatly augmented. The one unveils the marvels of a world of inconceivable vastness, while the other discloses the wonders of a world of inconceivable minuteness.

Single microscopes,[1] in the form of glass globes containing water, were used by the ancients, and in course of time these crystal bubbles gave place to hemispheres of glass, and these in their turn to lenses. The compound microscope, consisting essentially of two lenses placed at a distance, so that the

[1] The term *microscope* is derived from two Greek words, the first signifying a *small object*, and the latter *to see* or *examine*.

one next the eye magnifies the enlarged image of any object placed in front of the other, was invented by a spectacle-maker at Middleburg in Holland, about the year 1590. This Dutch microscope, rudely formed of two lenses and a wooden tube, was the germ of the beautiful and complex instrument of modern times. Let us now peep through this wondrous spy-glass into the invisible world.

A single drop of water taken from a stagnant ditch is found to be crowded with living organisms, both animal and vegetable, whose eccentric forms and movements baffle description. Strange Protean monsters continually changing shapes, gliding symmetrical figures of exquisite beauty, rolling globes, restless little bodies of various forms, active pear-shaped and spindle-shaped creatures, whose internal organs are plainly discernible, and other wondrous minute tabernacles of life, pass in turn across the magic circle to which our exalted vision is confined. To those who have not explored the 'invisible world,' these objects are incomprehensible; but to the microscopic naturalist they appear as familiar animals and plants, with intelligible structures and functions. These minute organisms are called *Infusoria*, from the fact that they were first observed in infusions of vegetable matter. This term is, however, a very vague one, as the objects detected in a single drop may represent many widely separated links in the great chain of life.

The infusorial animals, with few exceptions, belong to the sub-kingdom *Protozoa*,[1] or the lowest division of animated nature. The humblest of them all is the *Amœba*, a creature destitute of special organs, yet capable of performing the functions of locomotion and digestion. Under the microscope this initial form of animal existence presents the appearance of a globular mass of semi-transparent jelly. At first this mass may seem inert and lifeless, but its vital activity is soon made manifest by the movements which it executes. To supply its want of special organs, the amœba pushes out portions of its gelatinous substance in various directions; and with the aid of these finger-like prolongations, it roams about in search of food. Its mode of progression is peculiar. A finger of jelly is put forth in the line of motion, and then gradually distended, until it contains the entire substance of the amœba. By thus carrying, as it were, the whole island into a single cape, the creature changes its place. After a short time another finger is put forth, and expanded till it becomes the body. When the amœba in the course of its progress meets with a nutritive particle, its gelatinous body spreads itself over and around the precious morsel, so as to envelope it completely. The substance thus enveloped undergoes a rude digestive process, the nutritive matter being extracted, and the indigestible remains being, as it were, squeezed out of

[1] A Greek compound, signifying *first animals*.

the body. Compared with this minute speck of living jelly,—which can get along without legs, and convert any portion of its substance into a stomach, —the other Protozoa are highly organized creatures. Most of them have symmetrical bodies, which in some cases are protected by horny, flinty, or shelly armour. The movements of all the more active infusorial animals are ascribed to the vibratory motion of peculiar hair-like appendages called *cilia*.

The *Rotifera* occupy a higher position in the great scheme of life than any of the Protozoa. These wonderful little creatures are commonly found in water taken from exposed ponds and cisterns. They have usually an elongated form, and are perfectly symmetrical on the two sides. Near the mouth we observe one or two rows of delicate cilia, which are frequently arranged in a circular manner; and when they are in motion, an appearance of revolving wheels is produced, from which the class derives its appellation. The common *wheel animalcule* was long a puzzle to philosophers, who were forced to invent many marvellous hypotheses to explain the motion of the pair of paddle-wheels with which this little creature is furnished. We must not always believe our own eyes; for the two little wheels on the anterior part of the body of this rotifer, which seem to be always turning round on their axes, are really stationary. The motion is now allowed to be an optical illusion, produced by the motion of the long cilia which fringe the margins of two disk-like lobes situated on the fore part of the body. These cilia lash the surrounding waters into a miniature whirlpool, into which innumerable animalcules are drawn, to be swallowed by the voracious rotifer, who is provided with a formidable set of crushing teeth, and a most efficient digestive apparatus. The movements of these strange animals are active and varied. Sometimes they will attach themselves by the tail to a fixed object, and set their cilia in motion to entrap unwary infusoria; then they will pack up their wheels and swim freely through the water, or crawl along a solid surface after the manner of a leech. Some of the *rotifera* may be completely dried up and preserved for an indefinite time, without the loss of their vitality. But put one of these withered animalcules in water, and in an hour's time you will see him return to life, though he may have been apparently dead for many years! The multiplication of the rotifera is extremely rapid, twenty-four hours being a sufficient period for an individual to be born, be developed, and to become itself a parent! The reader must not forget that all these wonderful facts are related of a living being not quite the thirty-sixth part of an inch in length,—a mere speck in the visible world!

Let us pause for a moment in our examination, to reflect upon these marvellous revelations. How perfect are the works of the Divine Hand! Not long since we allowed our imagination to penetrate the unfathomable ocean of space, wherein 'God's name is writ in worlds;' and now, as we peep into a drop of water, we find in the structure of its marvellous inhabitants evidences of the same Infinite Wisdom that conceived the harmonious arrangement of the celestial orbs. It has been truly said, that the smallest living object in the world is in itself, and for the part it is destined to perform in nature, as perfect as the largest.

The plants of the invisible world outvie the animals in strangeness and beauty. We call them plants, though they are utterly unlike the vegetable forms of the visible world. Most of them are endowed with powers of motion, and were, until quite recently, regarded as animals. In nature there is no line of demarcation between the two organic kingdoms; and these moving plants seem to form the link which renders the chain of being complete.

The beautiful *Volvox*, now regarded as a plant, is so animal-like in its movements, that it was formerly known as the *globe animalcule.* It is not uncommon in fresh-water ponds; and is large enough to appear to the naked eye as a speck of green. Under the microscope this speck becomes a magnificent hollow sphere of pellucid matter, studded at regular intervals with minute green spots, from each of which proceed two long cilia, so that the entire surface is beset with these vibratile filaments.

Within this beautiful globe we find other globes of darker colour and of varying sizes. The movements of this remarkable plant, or congeries of plants, never fail to excite admiration. Its onward motion is usually of a rolling kind; but sometimes it glides smoothly along without turning on its axis; and sometimes it may be seen spinning like a top without changing its position. To increase our wonder, the little volvoces often revolve by the agency of their own cilia within the investing sphere.

The *Diatomaceæ* or *diatoms* are interesting and beautiful forms of microscopic vegetation. They may be described as simple vegetable cells, with external flinty coatings. In many species each cell or frustule enjoys a free and independent existence: in some, the frustules are fixed by stalks; and in others, many frustules are united by their sides or corners, so as to form chains. The free diatoms move spontaneously through the water, although they have no visible motile organs. All these organisms are remarkable for their symmetrical forms and elegant sculptured markings.

The diatoms are characterized by the presence of a large proportion of silica or flint in their external coats. This peculiarity gives them great importance. The trees of the forest, having passed through their successive stages of development, undergo the process of decay, their constituents being dissipated as invisible gases; but the tiny diatoms are virtually indestructible, and their constantly accumulating skeletons are gradually being deposited in beds beneath the waters which cover nearly three-fourths of the surface of this planet.

'At first,' remarks a well-known microscopist, 'the effect produced by things so small—thousands of which might be contained in a drop, and millions packed together in a cubic inch—may appear of trifling moment, when speaking of so grand an operation as the deposition of submarine strata. But each moment has its value in the measurement of time, to whatever extent of ages the succession may be prolonged; so each of these atoms has a definite relation to space, and their constant production and deposition will at length result in mountains. The examination of the most ancient of the stratified rocks, and of all others in the ascending scale, and the investigation of deposits now in the course of formation, teach us that, from the first dawn of animated nature up to the present hour, this prolific family has never ceased its activity. England may boast that the sun never sets upon her empire; but here is an ocean-realm whose subjects are literally more numerous than the sands of the sea. We cannot count them by millions simply, but by hundreds of thousands of millions. Indeed, it is futile to speak of numbers in relation to things so uncountable. Extensive rocky strata, chains of hills, beds of marl, almost every description of soil, whether superficial or raised from a great depth, contain the remains of these little plants, in greater or less abundance. Some tracts of country are literally built up of their skeletons. No country is destitute of such monuments; and in some they constitute the leading features in the structure of the soil. The world is a vast catacomb of Diatomaceæ; nor is the growth of those old dwellers on the earth diminished in its latter days.'[1]

Whether living or dead, diatoms are very beautiful objects under the microscope; but it is impossible to convey by written descriptions a distinct idea of their beautiful forms and delicate sculptured markings. A splendid diatom found in guano and attached to sea-weeds, from different parts of the world, appears under the microscope as a perfect circle with fine markings, suggestive of the threads of a spider's web. Another circular form in the infusorial earth of Bermuda exhibits radial divisions of two distinct patterns. A diatom found in the mud of the Thames presents the appearance of a triangular honey-comb, or, if its side is turned towards us, an oblong piece of lacework. Another diatom appears as a chain of oblong tablets, joined together in some inexplicable manner at their corners.

The boat-shaped diatoms, or *Naviculæ*, are perhaps the most beautiful of this minute family. One of them, an unnamed variety, has been thus described by an anonymous writer: 'The tiny

[1] Dr Harvey.

bark is a boat of cut rock-crystal, fit to float across a sea of light; itself might almost be believed to be fashioned out of solidified light. The central line must be the keel; the translucent planking is clearly visible; and around the sides are cut symmetrical notches, to serve as rullocks for ethereal rowers to navigate this brilliant gondola.' In Thames water, naviculæ exist in great abundance, the most common form being that of an Indian canoe, with a gracefully curved prow.[1]

The flint which forms the skeleton of the diatom, and the armour of the animalcule, is withdrawn from its solution in the waters inhabited by these minute organisms by some mysterious operation of the vital force. So prolific are these tiny forms of life, that it has been estimated that a single animalcule can increase to such an extent during one month, that its entire descendants can form a bed of silica or flint twenty-five square miles in extent, and one foot and three-quarters thick! 'As a parallel to Archimedes,' says Bischof, 'who declared he could move the earth if he had a lever long enough, we may say: Give us a mailed animalcule, and with it we will in a short time separate all the carbonate of lime and silica from the ocean!'

This leads us to consider more minutely the part played by the animals and plants of the invisible world in the formation of the beds of rock which form the solid crust of our globe. The recent

[1] *Navicula hippocampus.*

discoveries of the microscope have shown that many accumulations of whitish mud in lakes and estuaries are almost wholly composed of the silicious and calcareous coverings of infusorial plants and animals, and that the 'mountain-meal' of the Swedes, the edible clay of the South American Indians, and the polishing slate of Tripoli and Bohemia, are analogous deposits of earlier date. Sometimes these infusorial deposits are of great depth. Many years ago a mass of light silicious earth, more than twenty feet in thickness, was found at Ebsdorf in Hanover, and, on examination by the microscope, it appeared that this earth consisted entirely of the minute shields of invisible infusoria. Again, the beds of silicious marls upon which the towns of Richmond and Petersburg in Virginia are built, are now known to be almost wholly made up of the skeletons of diatomaceæ. The forms that predominate are elegant saucer-shaped shields, elaborately ornamented with hexagonal spots disposed in curves, and resembling the engine-turned sculpturing on a watch. They vary in size from the one-hundredth to the one-thousandth of an inch in diameter.[1]

We need not carry our microscope out of England to discover the remains of infusoria in the earth's crust. The white chalk which underlies or forms the surface of the south-eastern part of England, is a mere aggregation of microscopic shells and corals, so minute that upwards of a million of the former

[1] Dr Mantell.

are contained in a single cubic inch of this well-known substance. These little shells, which remind us of those of the nautili, are the calcareous envelopes of the animalcules termed *foraminifera*, which abound in modern seas, and are constantly contributing to the amount of sediment now forming in the bed of the ocean. The beautiful white stone called *calcaire grossier*, which furnishes the inhabitants of Paris with a cheap and inexhaustible supply of building material, has almost the same structure as chalk; and Professor Ansted has observed that the capital of France, as well as the towns and villages of the neighbouring departments, are almost entirely built of foraminifera.

These stupendous results, produced by the agency of creatures that are separately invisible to the naked eye, direct our thoughts to the Creator who has thought fit to endow these living atoms with powers that render them such important instruments in effecting the changes in the earth's surface, which His infinite wisdom has planned.

Let us quit the infusoria, and glance with our microscopic eye at some other marvellous objects belonging to the invisible world. If we look through our magic tube at the downy mould formed upon any decaying substance, a wonderful forest of delicate thread-like plants will be revealed. These beautiful fungi will be seen to multiply and grow, to swell and finally to burst, scattering their invisible spores into the surrounding air.

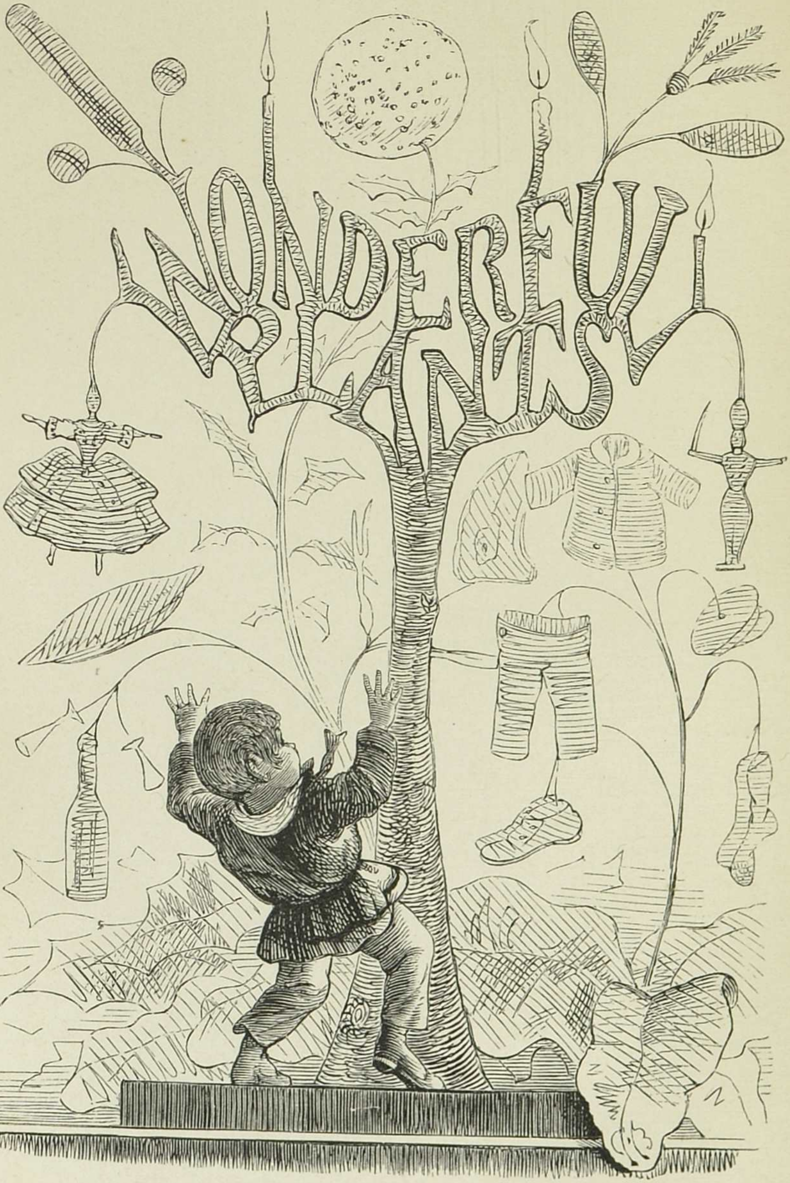
If we make use of our microscope to examine the eggs of insects, we shall have cause to wonder at their elaborate carving and beautiful forms. It is impossible to convey to the reader an adequate idea of the elegant design and delicate sculpturing of some of these insect-eggs; few of which, be it observed, are what is commonly termed egg-shaped. It is impossible to account for the strange diversities of form in these egglets; thus, in the small and great peacock butterflies, which differ in little but size, the egg of the first is a cylinder with eight prominent ribs, while that of the latter is shaped like a Florence flask and has no ribs. Why the little peacock should escape from a barrel, and the big one from a bottle, is a problem as yet unsolved. Here are the eggs of four different members of the butterfly family. To the unaided eye they appear mere uninteresting dots, about the size of a pin's head; but if we examine them microscopically, we shall find that nature has spared no pains in decorating these minute objects. One of these eggs is an elegant turban, having a round button in the centre of the depressed crown; another is a very elaborate pound-cake; the third a fairy foot-ball, covered with a network of extremely minute hexagonal meshes; and the fourth is a little spherical summer-house of rustic-work roofed with flat tiles. The last simile is a little strained, as it is not easy to imagine a rustic arbour shaped like a balloon; but we must remind the reader that we meet with forms in the invisible world that cannot be likened to any object that exists within the sphere of unaided vision. The smaller insects deposit eggs that are still more curious than those of the butterflies and moths. The egg of the lace-fly is like an unripe cherry with a long white transparent stem; that of the blow-fly like a white cucumber with longitudinal stripes; and that deposited by the bug has been well compared to a circular game-pie with a standing crust, the lid of which is lifted when the young one makes its exit after hatching.

The microscope reveals many wonderful peculiarities of structure in the beings whose eggs we have just examined. The coloured dust of the butterfly's wing turns out to be feathery scales of a tapering form, with deeply cut notches at their broad end. The hairs of the bee are seen to be thickly beset with still finer hairs. The smallest fly is found to possess an elaborate pumping apparatus or trunk, compared with which the pumps constructed by man are clumsy and inefficient. The eyes of insects are composite, each visible eye being made up of thousands that are invisible; no less than twenty thousand of these minute organs have been detected by means of the microscope in the head of the hawk-moth. But our space is limited, and we dare not enter any further into the subject of insect anatomy.

The dust of the butterfly's wing is remarkable enough; but the fertilizing dust or pollen that covers the stamens of flowers, appears still more curious to the microscopic eye. Pollen varies greatly in different plants. An author, who seems to have a happy knack of finding similes for indescribable objects, says that the rose and poppy have pollen like grains of wheat magnified into semi-transparent weavers' shuttles; that of the mallow, he tells us, resembles cannon-balls covered with spikes; the fuchsia has pollen like bits of half-melted sticky sugar-candy, with which a small quantity of horse-hair has become entangled; and the passion-flower has pollen grains resembling Chinese carved ivory balls.

The microscope has revealed strange little fissures and cavities in minerals, the latter containing fluids, groups of crystals, and floating balls. Even the diamond, topaz, garnet, and other precious stones, have these minute cavities.

Here we must stop, or our fairy tale will wear out the patience of the reader. We have glanced at a few of the marvels of the invisible world through that wonderful spy-glass which science has recently brought to a high state of perfection, and which day by day adds to our knowledge of minute things. Our examination has necessarily been imperfect, for it would be an easier task to enumerate all the visible objects upon the face of the earth, than to describe the countless forms that exist in the invisible world.


WONDERFUL
PLANTS

Wonderful Plants.

> 'Give me to drain the cocoa's milky bowl,
> And from the palm to draw its freshening wine.'—
>
> THOMSON.

THE wonderful plants portrayed by our artist are scarcely more wonderful than some of the vegetable productions of this bounteous earth. The little boy may well be astonished to see such a rare crop of good things; but if he will only stop and think a little, he will find that plum-puddings, mince-pies, and wearing apparel do really grow, or, more strictly speaking, they spring from the wonderful plants which actually exist. Consider the composition of that famous pudding which crowns the fanciful group on the preceding page. The currants and raisins, the sugar, almonds, and candied lemon-peel, which are its principal ingredients, are all vegetable productions; and the suet and eggs may be described as animalized grass and barley, for they are formed out of the vegetable food of the ox and the hen. The plum-pudding tree is not half so preposterous a conception as it appears to be at the first glance.

In the present chapter we propose to consider some of the most striking productions of the vegetable kingdom. We shall not attempt to preserve any sort of order in our rapid review, but will jump from one country to another, and throw aside all the elaborate systems of classification that have been devised by botanists. We will promise to bring some wonderful plants before the reader's notice, but we will not bind ourselves to any scientific rules.

The imaginary plum-pudding tree naturally suggests the bread-fruit of the islands of the Pacific, that wonderful plant that bears a crop of penny rolls. The bread-fruit[1] is a beautiful as well as a useful tree. Its trunk rises to a height of about forty feet, and when full grown is from a foot to fifteen inches in diameter. The branches come out in a horizontal manner, becoming shorter and shorter as they near the top. The leaves are of a rich green, are nearly two feet long, and deeply gashed or divided at the edges.

As for its marvellous fruit, we cannot do better than quote the words of Captain Dampier, who first described it in 1688. 'The fruit,' says this celebrated navigator, 'grows on the boughs like apples; it is as big as a penny loaf when wheat is at five shillings the bushel; it is of a round shape, and hath a thick tough rind. When the fruit is ripe, it

[1] *Artocarpus incisa.*

is yellow and soft, and the taste is sweet and pleasant. The natives use it for bread. They gather it when full grown, while it is green and hard; then they bake it in an oven which scorcheth the rind and maketh it black; but they scrape off the outside black crust, and there remains a tender, thin crust; and the inside is soft, tender, and white, like the crumb of a penny loaf. There is neither seed nor stone in the inside, but all of a pure substance like bread. It must be eaten now, for if it be kept above twenty-four hours, it grows harsh and choky; but it is very pleasant before it is too stale. This fruit lasts in season eight months in the year, during which the natives eat no other sort of bread.' This quaint description is singularly accurate, and has been confirmed by many modern travellers. The timber of the bread-fruit, though soft, is much used by the natives in the construction of houses and boats; the flowers, when dried, form a sort of tinder; the viscous fluid that oozes from the trunk serves for bird-lime and glue; the leaves are used for towels; and from the inner bark a coarse kind of cloth is made. Thus we see that food and raiment grow on this wonderful plant.

The cabbage-palm of Surinam[1] is another of our wonderful plants. This gigantic tree has a stem about seven feet in circumference at the base, which ascends straight and tapering to a vast height, and bears a plume of graceful foliage. The cabbage lies

[1] *Areca oleracea.*

concealed within the leaves that surround the top of the trunk. It is about two or three feet long and as thick as a man's arm. When eaten raw, it greatly resembles the almond in flavour, but is much more tender and delicious. It is generally cut into pieces, boiled, and served up with meat.

'To obtain this small portion,' says Dr Lankaster, 'borne on the pinnacle of the tree, and hidden from the eye of man, the axe is applied to the stately trunk, and this majestic lord of the mountain-top is laid low, to furnish a small quantity of vegetable matter, which is eaten like cauliflower, and which receives its distinctive name from our lowly cabbage. Surely this rivals the tales handed down to us of Roman epicurism!'

The reader has doubtless heard of the cow-tree of South America,[1] which yields an abundant supply of milk to the Indian of the Cordilleras, and flourishes at a vast height amid arid mountains where no cattle can pasture. This wonderful plant has been described by Humboldt with his characteristic spirit and accuracy. 'On the side of a thirsty rock,' says the great traveller, 'grows a tree whose leaves are dry and husky. Its large roots penetrate with difficulty through the stony soil. During many months of the year not a shower waters its foliage; the branches appear withered and dead; but when its trunk is pierced, a sweet and nourishing milk flows from the wound. It is at the rising of the

[1] *Brosimum utile.*

sun that this vegetable aliment is most plentiful. The natives and the black slaves then gather together from all parts with large wooden vessels to catch the milk, which as it flows becomes yellow, and thickens on the surface. Some make their abundant meal at the foot of the tree which supplies it; others carry their full vessels home to their children.'

Our reader will not question the utility of writing-paper, though he may possibly deem this substance of inferior importance to either bread, cabbage, or milk. The poets and sages of antiquity did not write their immortal works upon 'foolscap,' but upon natural paper, furnished by the papyrus[1]—a reed-like plant, growing in the waters of the Nile. The stem of this wonderful plant is triangular, and shoots up gracefully to the height of some fifteen or twenty feet, its slender top bearing a tuft of thread-like leaves.

The inner bark of the stem was divided into thin plates or pellicles, each as large as the plant would admit. These plates, which were necessarily very narrow, were then laid side by side, with their edges touching, on a smooth hard surface; and then other pieces were laid across them, so as to form a sheet of many pieces, which required adhesion to become one united substance. The whole was then moistened with Nile water, and subjected to pressure; and in this manner the sheet was

[1] *Papyrus antiquorum.*

formed, for the glutinous sap contained in the plant sufficed to cement the various pieces together. The plates procured from the central portions of the stem were the most valuable, and were used to form varieties of paper equivalent to our 'cream-laid' and 'satin-wove' post. The papyrus must look down upon its aquatic companions with supreme contempt; for it can boast of a long line of ancestors, whose delicate under-skins served to perpetuate the sublime thoughts conceived by the giant intellects of the past.

The fan palm of Ceylon[1] is another paper-tree. Its stem attains a great height, and is surmounted by many large palmated leaves, the lobes or divisions of which are very long, and are arranged round a foot-stalk, like the ribs of an umbrella. Indeed, these compound leaves are actually used as umbrellas by the Cingalese, a single out-spreading leaf affording ample shelter for seven or eight people. All the religious books of the Cingalese are written, or rather engraved, on tablets plucked from this wonderful palm, the leaves of the book being simply the leaflets of the tree.

The palms are all wonderful plants, from whatever point of view we may regard them. The services they render man are incalculable. The date palm[2] gives him its nourishing fruit, the cocoa palm[3] its milky nuts, the sago palms[4] their farina-

[1] *Corypha umbraculifera.*
[2] *Phœnix dactylifera.*
[3] *Cocos mucifera.*
[4] *Sagus lævis*, *S. genuina*, etc.

ceous pith, and the Palmyra palm[1] its sweet juice, which becomes wine by fermentation. Then, as for useful things that are neither eatable nor drinkable, the palm tribe furnishes vegetable oil, wax, and ivory, fibres that may be formed into cordage, leaves that may be used for thatching, and timber that may be applied to a hundred different purposes.

The wax-bearing palm is called the pashiuba, and its peculiar form, were it remarkable for nothing else, would entitle it to a place among our wonderful plants. Its slender stem shoots up to the height of some fifty or sixty feet, and is strangely supported by a tall open cone of roots.

'But what most strikes attention in this tree, and renders it so peculiar, is, that the roots are almost entirely above ground. They spring out from the stem, each one at a higher point than the last, and extend diagonally downwards till they approach the ground, when they often divide into many rootlets, each of which secures itself in the soil. As fresh ones spring out from the stem, those below become rotten and die off; and it is not an uncommon thing to see a lofty tree supported entirely by three or four roots, so that a person may walk erect beneath them, or stand with a tree seventy feet high growing immediately over his head. In the forests where these trees grow, numbers of young plants of every age may be seen, all miniature copies of their parents, except that

[1] *Borassus flabelliformis.*

they seldom possess more than three legs, which give them a strange and almost ludicrous appearance.'[1]

These aërial roots are not peculiar to the pashiuba palm. In the mangrove,[2] a wonderful plant that grows on the sea-shore in tropical countries, the trunk springs from the union of a number of slender arches formed by the roots, whose extremities penetrate into the muddy soil. 'The larger arches,' says Mr Gosse, 'send out secondary shoots from their sides, which take the same curved form, but in a direction at right angles to the former; and thus a complex array of vaulted lines is formed, which to the crabs that run beneath, if they were able to institute the comparison, must be like the roof-groins of some Gothic church, supposing the interspaces to be open to the sky.'

But the wonder of wonders in this shore-loving plant, is the premature germination of its long club-shaped seeds. Each seed begins to grow while hanging from the twig, gradually lengthening until the tip reaches the soft soil, which it penetrates, and thus roots itself. The seeds which depend from the higher branches cannot stretch themselves out to a sufficient length to reach the mud; they therefore drop as soon as they feel themselves strong enough to commence an independent existence. In this manner a dense forest of mangroves is speedily

[1] Wallace's *Palms of the Amazons.*
[2] *Rhizophora mangle.*

produced from a single trunk. Dampier has described such a forest with his usual accuracy.

'The red mangrove,' he says, 'groweth commonly by the sea-side, or by rivers or creeks. It always grows out of many roots, about the bigness of a man's leg, some bigger, some less, which at about six, eight, or ten feet above the ground, join into one trunk or body, that seems to be supported by so many artificial stakes. Where this sort of tree grows, it is impossible to march by reason of these stakes, which grow so mixed one among another, that I have, when forced to go through them, gone half a mile, and never set my foot on the ground, stepping from root to root.'

There is a species of cane that must surely be considered a wonderful plant; for, though no thicker than the little finger, it is sometimes a quarter of a mile in length. This vegetable cord is studded with sharp prickles, by means of which it is enabled to cling to the leaves and branches of the various trees which it encounters in its serpentine course.

The gum-trees[1] of the Australian forests resemble our own timber trees in form; but their leaves, instead of being extended horizontally so as to catch the falling rain, are placed edgewise, and thus allow the rain-drops and the sun's rays to pass between them. Near these wonderful trees, which afford no shelter, may be found the grass-tree,[2] displaying what seems to be an immense tuft of wiry grass

[1] *Eucalypti.* [2] *Xanthorrhæa arborea.*

elevated on the summit of a dark ungainly trunk. A number of tall spikes of blossom, resembling bulrushes, spring from the centre of the grassy crown, and render this wonderful plant still more anomalous.

The famous banyan-tree[1] must not be omitted, for it would be difficult to find a plant to which the epithet 'wonderful' could be applied with greater propriety. This sacred tree of the Hindoos attains a prodigious size, sometimes covering an area of nearly 2000 square yards; for its lateral branches send down shoots which take root, till, in course of time, a single tree becomes a vast umbrageous tent, supported by numerous columns. The poet has thus described this marvel of the vegetable kingdom:—

'Branching so broad along, that in the ground
The bending twigs take root, and daughters grow
About the mother tree; a pillar'd shade
High over-arch'd, with echoing walks between.
There oft the Indian herdsman, shunning heat,
Shelters in cool; and tends his pasturing herds
At loop-holes cut through thickest shade.'

Turn we now to plants much smaller but not less wonderful than those we have mentioned. The mean-looking little plant called the Fly-trap of Venus, is gifted with sensation, which compensates for its want of beauty. Each leaf is formed into two halves, which move on a central hinge, and fold up and contract on the slightest contact. The

[1] *Ficus indica.*

edges are beset with spines, and the whole surface is covered with a sticky mucilage. No sooner does an unfortunate fly alight on one of these ticklish leaves than the two halves spring together, and the insect is made a prisoner. There are other irritable plants, which ought to be mentioned here. The leaves of the sensitive mimosa shrink from the slightest touch; while those of the *Hedysarum gyrans* have a spontaneous motion, and appear to dance about from pure buoyancy of spirits.

The pitcher-plant, with its marvellous lidded goblet, is another member of the class wonderful; so is the caricature-plant, whose spotted leaves bear such a striking resemblance to human faces. The orchids, whose flowers mimic the forms of various insects, and the cacti, whose quaint shapes render them so remarkable, ought to be included in our review of wonderful plants; but this list must necessarily be imperfect, as the wonders of the vegetable world are innumerable. We have merely selected a few striking forms of vegetable life, to show the reader that botany, as well as the other sciences, has its marvels.

But are not all plants wonderful? If we examine minutely the structure of the humblest moss, we may discover wonders which fill the mind with admiration and astonishment. We may fitly conclude this rambling chapter with an anecdote related by one of the earliest African explorers, who found consolation, when in the depth of misery, in the contemplation of one of the wonderful plants with which the Creator has been pleased to deck this beautiful earth.

'In this forlorn and almost helpless condition,' writes Mungo Park, 'when the robbers had left me, I sat for some time looking around me with amazement and terror; whatever way I turned, nothing appeared but danger and difficulty. I found myself in the midst of a vast wilderness, in the depth of the rainy season, naked and alone, surrounded by savage animals, and by men still more savage. I was five hundred miles from any European settlement. All these circumstances crowded at once on my recollection, and I confess that my spirits began to fail me; I considered my fate as certain, and that I had no alternative but to lie down and perish.

'The influence of religion, however, aided and supported me. I reflected that no human prudence or foresight could possibly have averted my present sufferings. I was indeed a stranger in a strange land, yet I was still under the protecting eye of that God who has condescended to call himself the stranger's Friend. At this moment, painful as my reflections were, *the extraordinary beauty of a small moss caught my eye;* and though the whole plant was not larger then the top of one of my fingers, I could not contemplate the delicate conformation of its roots, leaves, and fruit without admiration.

'Can that Being, thought I, who planted, watered, and brought to perfection, in this obscure part of the world, a thing which appears of so small importance, look with unconcern upon the situation and sufferings of creatures formed after His own image? Surely not! Reflections like these would not allow me to despair. I started up, and disregarding both hunger and fatigue, travelled onwards, assured that relief was at hand; and I was not disappointed.'


MOVING LANDS

Moving Lands.

'The ice is here, the ice is there,
The ice is all around;
It cracks and growls, and roars and howls,
Like noises in a swound.'—COLERIDGE.

THE attention of scientific men has of late been directed to the structure and movement of glaciers, those vast accumulations of ice that fill up the deep valleys of mountains whose summits are covered by perpetual snow. These glaciers form the moving lands which we are about to consider for the edification of our reader. The facts that we have to bring forward relating to these 'gigantic icicles' will doubtless be new to the majority of our readers, as they have not yet found their way into elementary scientific treatises. In selecting our fairy tales from the copious budget of science, we have never lost sight of novelty, but have endeavoured to elucidate the most recent discoveries.

As we ascend a lofty mountain, the air becomes colder and colder, and at a certain elevation we enter the regions of eternal snow. The vegetation that clothes the slopes undergoes a corresponding change, and at the margin of the snow we find plants resembling those of the arctic circle.

In the upper regions of the ice-world, water descends from the clouds in the form of snow, but never in the form of rain. The average fall of snow in the region of the Swiss Alps, from 8000 to 10,000 feet above the level of the sea, has been estimated at sixty feet; that is to say, sufficient snow descends in one year to form a bed of this thickness. What becomes of all this frozen water? How is it that the mountains do not become top-heavy? Be patient, gentle reader, we shall be in a position to answer these momentous questions soon, but at present we must confine our attention to the structure of the snow-beds that are formed on the vast tablelands of these elevated regions.

The snow-bed is generally called the *névé*, and is formed of layers of more or less crystalline snow, which diminish in thickness as their depth increases; in other words, each layer is thinner than that immediately above it. At a certain depth these layers can scarcely be distinguished one from another; and still lower the substance of the *névé* passes into clear ice. The separate layers represent each considerable fall of snow that has taken place, and their gradual consolidation arises from the percolation of water coming from above, and the pressure of fresh strata of snow which continually accumulate overhead.

The deep valleys that radiate from the central mass of a great mountain are invariably filled with frozen water, and are the outlets of the frozen snow-fields; or, in the words of a clever writer, 'the glacier is a river of ice, and the *névé* its source.' Glaciers sometimes fill up a valley twenty miles long by three or four broad, to the depth of six hundred feet. Although apparently solid and stationary, they really move slowly down the valley, and carry with them, either on the surface, frozen into their mass, or grinding and rubbing along the bottom, all the fragments, large and small, from blocks many tons in weight, down to the finest sand and mud, that rain and ice, and the friction of the moving glacier itself, detach from the adjacent rocks.

The glaciers of the Alps, and probably those of other regions, descend to a vertical depth of nearly 4000 feet below the line of perpetual snow, and into a climate much warmer than that of our own island, before they finally melt away, and leap forth as rivers of running water. The heap of materials of all sorts and sizes which they deposit at their melting extremity is called the *moraine*, a term which is also applied to the lines of blocks that are being carried along on the surface of the glacier, the floating sticks and straws of the solid river.

Strange to say, the simple fact of the motion of glaciers was not admitted until a comparatively recent date, though it was well known that the lower end of a glacier, in spite of its rapid thawing, remained year after year at about the same point. Were we to attempt to describe the various observations that have been made with a view to determine the rate of glacial movement, we fear we should tax our reader's patience. Let us mention one or two illustrative facts. In the year 1827, M. Hugi built a very solid hut on the glacier of the lower Aar. In 1841 this hut was 1562 yards farther down the valley. Again, Professor Forbes gives an interesting account of a knapsack lost by a guide who fell into a *crevass*, one of those great chasms which are often observed in glaciers, which was recovered, ten years after, 4300 feet lower down. These facts, were there no others, would suffice to prove that the glaciers move onward at a slow but steady pace.

The surface of the glacier is rough and crumbling, and the traveller can walk upon it without fear of slipping; in some parts it is unbroken and undulating, but in others it is rent by yawning fissures many hundred feet in depth, one set of fissures sometimes crossing another at right angles, and so cutting up the ice in fantastic pinnacles and towers, that occasionally topple over with a terrific crash. The noises that proceed from the glacier cannot be properly described; and we can only vaguely compare the mysterious rumblings, growls, and cracklings, that salute the traveller's ear, to 'noises in a swound.'

Various theories have been advanced to account for the motion of glaciers. Saussure, who was the first to observe these wonderful ice-rivers with any attention, asserted that they advance by sliding along their beds, which are constantly lubricated by the melting of the lower strata of ice. But this explanation is far from being satisfactory. Ice is undoubtedly a very slippery substance, but it is scarcely credible that a solid mass of ice some twenty miles in length should glide along by reason of its slipperiness.

To move the *Great Eastern*, our engineers had to make use of the most powerful machines ever constructed, before they could overcome the friction between the mighty ship and the surface upon which it rested. But the mass of the *Great Eastern* is immeasurably small compared with that of the glacier; indeed, the river of ice might support a number of such ships, and still move onward at its usual speed. Now, in spite of the lubricating fluid which Saussure imagined to exist between the glacier and its rocky bed, the friction must be immense, and we can scarcely reconcile the steady movement of the frozen mass with the operation of such a powerful retarding force.

Again, it may be asked, how does the huge icicle adapt itself to the irregular form of the valley through which it travels? A solid mass of ice, however large, might possibly slide along a perfectly straight channel, but mere slipperiness would not enable it to pass through a tortuous valley. The diameter of the great basin of the Glacier de Telèfre, on the range of Mont Blanc, is six times as great as the outlet through which the frozen stream eventually squeezes itself. Saussure's explanation throws no light upon this point, and it is quite plain that the philosopher had failed to hit upon the true theory of glacier motion.

We will pass over the theory of M. Agassiz, which was founded on a radical error, and proceed to consider that advanced by Professor James Forbes of Edinburgh. In 1842 this celebrated geologist undertook an extensive series of observations, from which dates the commencement of all sound and accurate knowledge respecting our moving lands. The laws of glacier motion were established by a few simple observations. He showed that the glacier moves onward with such regularity that it is almost possible to tell the hour by the progress of a point placed on the surface; but that the motion is less rapid in summer than in winter, in damp than in dry weather, at night than during the day. The different parts of the same glacier do not advance at a uniform rate, and the centre invariably moves more rapidly than the sides. If a series of points be laid out in a straight line across the glacier, they will be rapidly bent into the form of a regular curve, by the gradual decrease of velocity from the centre to the sides. Further observations in subsequent seasons proved that the upper part of the glacier moves faster than that near to the bottom.

These observations established the strange and unexpected conclusion, that the ice of glaciers, though apparently hard and brittle, can be bent and moulded under the enormous pressure of its own weight, and that instead of moving like an ordinary solid, it flows down the valley just as a viscous substance, such as partially melted pitch, would flow. Professor Forbes actually attributed this manner of motion to a slight degree of plasticity or a *demi-semi-fluidity* in the ice mass, and announced his new theory of glacier motion in these words: 'A glacier is an imperfect fluid, or a viscous body, which is urged down slopes of a certain inclination by the mutual pressure of its parts.'

Our moving lands are thus robbed of their solidity, and become mere sluggish rivers of a marvellous sticky fluid, which we are unable to define with anything like accuracy.

> 'For the ice it isn't water, and the water isn't free,
> And we cannot say that anything is as it ought to be.'

But are we quite sure that the viscous theory is the only possible explanation of glacier motion? It is quite certain 'that the manner of movement of the surface of a glacier coincides with the manner of motion of a viscous or semi-fluid body,' but we have many reasons for doubting the viscosity of glacier ice. The yawning *crevasses*, the fantastic towers, and the perpetual crackling noise of a glacier, would seem to prove that it is formed of a very brittle material. But a substance cannot be brittle and viscous at the same time, and we are quite at a loss to explain how it is that the motion of a mass of ice conforms to that of an imperfect fluid.

Professor Tyndall has recently cleared up the mystery, and has shown that ice may be plastic without being viscous. Some time ago, Professor Faraday discovered that two pieces of ice when placed in contact would freeze together, even under hot water; and that any number of fragments would unite into a solid mass, provided sufficient pressure were applied to bring their surfaces together. The plasticity of ice has since been established beyond all question by the beautiful experiments of the younger philosopher. Spheres of ice have been flattened into cakes, cakes have been formed into transparent lenses, a block of ice has been moulded into a crystal cup, and a straight bar six inches long has been bent into a semi-ring. Ice can be forced into a mould and made to take what shape we please, not because it is an imperfect fluid like plaster of Paris, but because it possesses the peculiar property of reuniting by the contact of adjoining surfaces, after having been broken into fragments. In forcing a cube of ice into a cup-shaped mould, we crush it to a powder, but the particles composing this powder immediately freeze together again into a solid and transparent cup. The plasticity of ice may therefore be explained as the effect of breakage and re-freezing; or, in scientific language, *fracture* and *regelation.*

This strange property of ice fully accounts for its obedience to the law of glacier motion discovered by Professor Forbes. 'All the phenomena of motion,' says Tyndall, 'on which the idea of viscosity has been based, are brought by such experiments as the above into harmony with the demonstrable property of ice. In virtue of this property, the glacier accommodates itself to its bed, while preserving its general continuity; *crevasses* are closed up; and the broken ice of a cascade, such as that of the Talèfre or the Rhone, is re-compacted into a solid continuous mass.

'But if the glacier accomplishes its movements in virtue of the incessant fracture and regelation of its parts, such a process will be accompanied by a crackling noise, corresponding in intensity to the nature of the motion, and which would be absent if the motion were that of a viscous body. It is well known that such noises are heard, from the rudest crashing and quaking down to the lowest decrepitation, and they thus receive a satisfactory explanation.' The reader will now be able to comprehend the wonderful phenomena presented by our moving lands. A glacier does not slide along its bed like a launching ship along her ways, nor does it flow, in virtue of any viscous quality, like thick mud or melted pitch; but its motion is the result of the minute, almost molecular, fracture and regelation of the ice particles, which move as if they were sand, continually thawing and re-freezing.

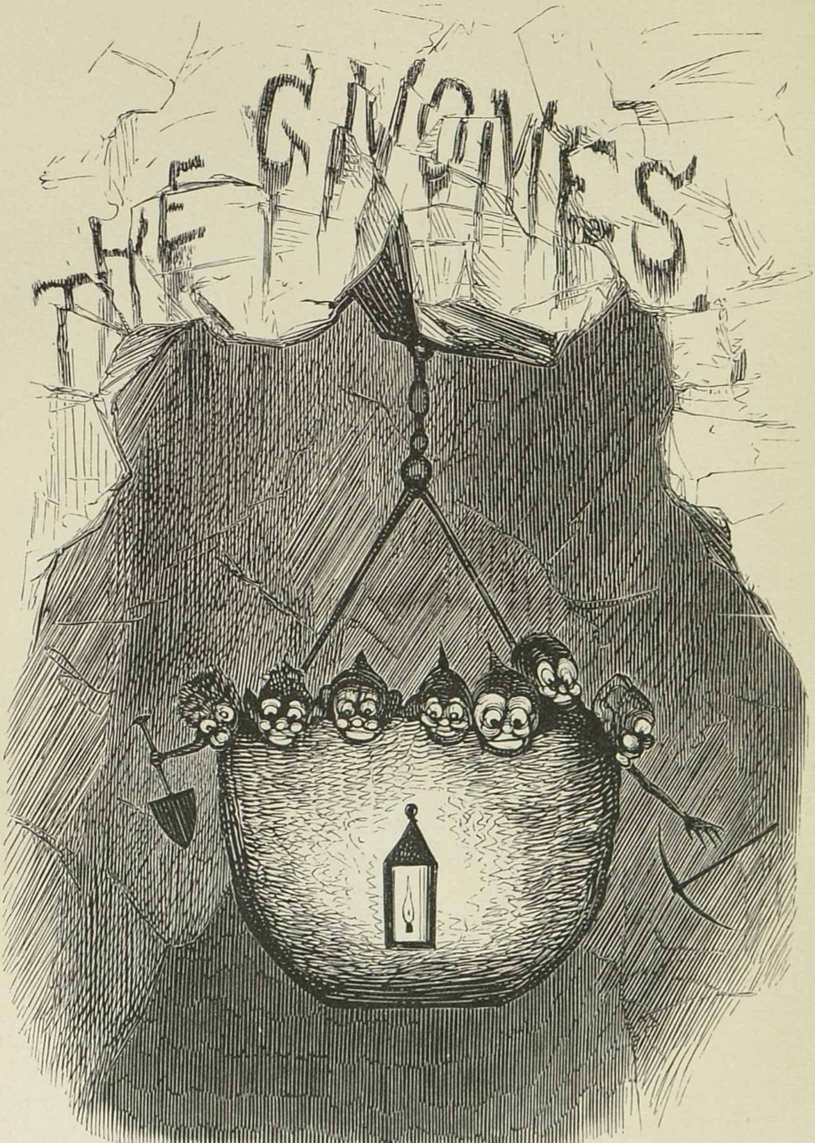
We have said that glaciers generally carry large fragments of rock, which they deposit in confused heaps at their lower extremities. It sometimes happens, however, that a glacier descends into a lake, or into the sea, before it melts, and large masses of it, or icebergs, are floated off with their freight of rock fragments. These loaded icebergs are sometimes carried great distances before they entirely dissolve, and in this manner large unworn angular blocks of rock may be dropped on the bed of the sea hundreds of miles from their original site.

In many parts of Great Britain the geologist finds heaps of gravel and sand containing large fragments of rock, which exactly resemble the terminal heaps or *moraines* of modern glaciers. He also finds huge blocks of rock or boulders resting upon the bare surface of rocks of quite a different character. One of the largest of the boulders is situated at the head of the Devil's Glen, in the county of Wicklow, its dimensions being twenty-seven feet long by eighteen wide, and fifteen high. It consists of granite, and rests upon a bed of slate six or eight miles from the granite district, a wide shallow valley intervening. Another large boulder of granite was discovered some years ago in the chalk near Croydon, and geologists have come to the conclusion that this mass of rock must have wandered hither from the North of Europe.

These curious heaps and boulders prove that 'once upon a time' the glens of our present mountains were encumbered with glaciers, and that our lowlands were entirely submerged. By the action of these glaciers the rocks were scored and rounded, polished and grooved, and masses of rock carried down and heaped into *moraines;* while great blocks were transported on fragments of these glaciers which dipped into the sea and formed icebergs, being often carried far over the shallow seas and dropped many miles from their parent sites, generally on the banks and shallows (now the hill-tops) which arrested the laden icebergs in their course.[1]

We have said that our moving lands advance with great regularity. Let the reader glance at the illustration which precedes this chapter, and he will find that our artist has represented this motion by the figure of Time using his scythe as an *alpenstock*, and sliding along with the glacier upon which he stands.

[1] Professor Jukes.


THE GNOMES

The Gnomes.

'Far removed from the dazzling light,
That blazes around earth's rugged shell,
In caves and burrows as dark as night,
Thousands and thousands of little men dwell.'—
From the German.

REPAIR we to the home of the Gnomes—to the stalactite cavern, where Fancy may revel and Imagination soar,—where every hue of the rainbow, every sparkle of the gem, and every metal's sheen shall be reflected in the light of the torch we bear in our hands!

Before us, a perspective of brilliancy; a crystalline canopy overhead, which, in the torch-flame, sparkles with a myriad diamond rays, and upon whose surface multitudes of sparry globules rival the charms of burnished gold.

Beauty and grace displayed everywhere: in the architecture of the stalactite columns which support the roof; in the simulated forms of altars, trees, and stony organ-barrels which meet our gaze on every side; and in the grouping of the transparent tubes which depend from the ceiling, now hanging singly like monster icicles, now clustering into elegant chandeliers, and now twirling in spiral and festoon, imitating the most elaborate Gothic tracery.

Passing onward through antechambers and corridors of seeming porphyry and jasper, our ears are saluted by the trickle and fall of large heavy drops of water, the only sounds to be heard in this vast and wonderful Gnome Palace. Now we reach a vaulted chamber, the roof of which is sustained by arches springing from pillars of every form and colour. The floor is inlaid with chequered slabs; the walls are composed of broken and detached masses of rock piled one upon another in picturesque irregularity; while high above us fantastic forms of stalactite are arranged with a grandeur beyond the workmanship of mortal.

We enter another apartment still more magnificent. Its walls are of purple marble, embellished with branching sprays of rock crystal, which, on the purple ground, assume the hue of the amethyst. The festoons of jewelled flowers, and the brilliant scroll-work of the ceiling, the cascades of crystal suddenly arrested into rigidity, and the uneven pavement of gold and red, green and azure, underneath our feet, combine to produce an effect of unparalleled grandeur. Our eyes are dazzled by the scene, and our footsteps are arrested by a vague terror born of so much weird beauty, while our mind is enthralled by its presence.

We are deep deep down in the bowels of the earth, trespassers in the land of the 'little men.' Shall we extinguish our torch, and so allow the thick darkness to fall upon us like a pall? Shall we restore to these subterranean chambers their native gloom? And shall we invoke, by such an act, the presence of those weird beings who are scared away by the light?

The consequence of our deed would be, not an apparition of the gnomes, but the loss of the track by which we entered these gorgeous caverns, now grim and gloomy. Our danger would thus be in the absence of living creatures, and not in their presence. Science, which wars against ignorance on the earth above, has descended to these depths to strike the sceptre from the hand of the Gnome King, and to banish his subjects to the mysterious regions of No-man's-land, leaving only these jewelled caves to astonish and delight us.

The old story-tellers, whose rich and active fancy peopled the air with sylphs, and the waters with nymphs, created the gnomes to be the guardians of the untold wealth of these subterranean realms. Queer little fellows were these underground people, and wonderful stories have been related of them. In the night, when mortals were fast asleep, they would sometimes ascend to the moon-lit surface of the earth, and dance about the hills till cock-crow. Some say that they had no music but howling and whimpering, and that the sounds which proceeded from their midnight assemblies were often mistaken for the cries of children and the mewing of cats. They were jet black and hideously ugly, having misshapen bodies, large heads, and great round eyes, always red as if from weeping; nor was their ill-favoured appearance redeemed by a sweetness of disposition, as they were invariably crabbed and malicious. We are told that they were cunning workers in metals, and that the swords manufactured by them were as flexible as rushes, and as hard as diamonds. The gnomes figured in our illustration must be the last of their race; indeed, we are inclined to believe that those quaint dwarfs are merely creations of our artist's fancy.

The reader, however, must not suppose that the description we have given of the Gnome Palace is the offspring of imagination. Such caverns do really exist beneath the surface of this planet, and their fantastic architecture is the result of the percolation of water through limestone; their pillars, arches, and stony icicles having been moulded out of the calcareous matter which the fluid dissolved while infiltrating through the fissures and cavities of overlying beds of rock.

The Grotto of Antiparos, in the Grecian Archipelago, is a gnome palace quite as wonderful as that we have just pictured. Countless stalactites depending from above, together with an indescribable accumulation of crystallized masses on the walls, ornament a chamber with an arched roof upwards of one hundred and twenty feet in length. The floor of this cavern is paved with polished marble of a delicate green colour, and the columns which appear to support the roof seem to be formed of a deep burning-red porphyry. But this cavern is merely the entrance-hall of the subterranean palaces; the principal apartment, or throne-room, is incomparably more gorgeous. At a depth of fifteen hundred feet below the surface of the earth, the traveller finds himself in a grotto whose height is one hundred feet, while it extends to a length of three hundred and forty feet. Here the pillars are of yellow marble; petrifactions resembling snakes, trees, and shrubs abound; and in some places icicles of pure white glistening marble depend from the roof, to a length of ten feet. The tales told of this awe-inspiring gnome palace have assumed the tone of the wildest romance; and its diamond-spangled caves and walls of ruby have been described with all the vividness of over-wrought imagination. Nevertheless, all this wondrous architecture—all these wild and fantastic forms, and every phenomenon attending the production of the roof, sides, and floors of these caverns—can be accounted for, as we have said, by the percolation of water, clear as crystal, but charged with calcareous material.

In these caverns we discover stalactites in every stage of growth, and are thus enabled to conceive how a single specimen is formed. A drop of water holding a quantity of limestone in solution hangs from the roof, and as the fluid evaporates, the calcareous matter is left behind. In course of time a little conical button of spar is formed; and as fresh matter is constantly being deposited from the water which trickles over it, this button gradually assumes the form of a long stony icicle. Again, the water that falls upon the floor of the cavern, instead of hollowing out a cup-shaped cavity by its continued action during long ages, gradually builds up the accumulation termed the stalagmite, which, rising from the floor, eventually meets the descending stalactite, and thus helps to form a graceful column. When the lapidifying water oozes through a long joint or crevice in the roof, it forms a beautiful transparent curtain of spar; and when it percolates through the sides of the cave, it deposits its calcareous particles in the form of a frozen cascade.

All the sparry ornaments of these underground palaces were formerly held to be the handiwork of the gnomes; and in the present day, those 'vacant of our glorious gains' in knowledge, would doubtless regard this opinion with more favour than that which ascribes the fantastic architecture of the caverns to the formative power of a myriad trickling drops of water.

Out of Gnome-land, solid marble is deposited by exactly the same process, wherever water holding carbonate of lime in solution is brought into circumstances favourable to rapid evaporation. Sticks and twigs hanging over brooks often become coated with calcareous matter; and the incrustation of birds' nests, medallions, moss, and even old wigs, by the action of the petrifying springs of Derbyshire, is known to every one who has visited that romantic and interesting county.

In Italy large masses of solid and beautiful *travertine*[1] are deposited by some of the springs; and in the famous Lake of the Solfatara, the formation of this stone is so rapid, that insects as well as the plants and shell-fish are frequently incrusted and destroyed. A considerable number of edifices in Italy, both ancient and modern, are constructed of stone thus formed. The Cyclopean walls and temples of Pæstum, and the Colosseum at Rome, are built of huge blocks of travertine, which must have been deposited, particle by particle, in lakes similar to that of the Solfatara.

But the most remarkable instance of the rapid formation of marble occurs in Persia. The beautiful transparent stone called Tabreez marble is formed by deposition from the water of a celebrated spring which rises near Maragha. Here the process of petrifaction may be traced from its first beginning to its termination. In one part the water is perfectly clear; in another, dark, muddy, and stagnant; in a third it is quite black, and very thick; while in the last stage it is as white as snow. The petrified ponds look like frozen water; a stone thrown upon

[1] The term *travertine* is derived from the Tiber, its literal signification being *Tiber-stone*.

them breaks the crust, and a black fluid exudes through the opening; but when the process of petrifaction has reached a certain stage, a man may walk upon the surface without wetting his shoes. The stony mass is finely laminated, and a section of it resembles an accumulation of sheets of coarse paper. Such is the constant tendency of this water to solidify, that the very bubbles on its surface become hard, as if, by a stroke of magic, they had been arrested and metamorphosed into marble.

Return we to our subterranean regions, promising that we will not ascend to the surface again unless such a course should appear absolutely necessary to the elucidation of our subject. In Gnome-land there are other wonders besides the capacious caverns, with their glancing roofs and walls and clustering stalactite columns. The hidden treasures of the earth—or, in more ordinary language, 'the bowels of the earth'—are only to be exceeded in their wondrous accumulation and occurrence by their vastness and value. The gnomes were formerly held to be the legitimate guardians of these treasures; and for the sake of our fairy tale, we will suppose this view to be founded on facts. As mere story-tellers, we may create just as many giants, fairies, or gnomes as we please, even though we think fit to destroy them afterwards. Let us therefore people our stalactite cavern with elves like those to which our artist's fancy has given birth.

What a wonderful scene meets our mental vision!

The grotto is filled with active little beings, all busily employed in different operations connected with mining and metallurgy. On every side there are miniature forges, and the ceaseless clatter of innumerable tiny hammers is absolutely deafening. Each little smith wields his sledge with a superhuman energy, and never seems to require rest. Some of the gnomes are digging holes in the marble floor, and others are carrying away the excavated material in little wheelbarrows, the like of which would make a toyman's fortune. In one part of the cave a crowd of miners are very hard at work with spade and pickaxe, while others near them are turning a windlass, by the action of which a little tram is drawn up from the floor of the cavern to the roof, and probably much higher, as it passes through a fissure and remains out of sight for some time. When it descends, it is either empty or freighted with gnomes who come to relieve their brethren at the windlass. Some of these underground people are chipping shapeless minerals into regular geometric crystals; others are polishing fragments of spar; others are casting metals into beautiful arborescent forms. To describe all the various occupations of these elves would take up too much time, and we are therefore compelled to leave much to the reader's imagination.

Though the little men dread the light of day, their homes are not so dark as the poet imagines. The cavern is illuminated not by torches or candles, but by the crystals with which its walls and roof are studded. Each crystal is a lamp, every cluster a dazzling chandelier, and the scintillation of myriads of these natural lamps produces an effect of indescribable brilliancy.

But see, here comes an aristocratic gnome, arrayed in a tunic of asbestos, and wearing a cap formed of precious stones. He sits on a little stalagmite, and looks up at us with an impudent air, as though he thought us very inferior beings. This conceited little jackanapes has evidently something to say to us, so we will assume a becoming gravity, and endeavour to become attentive listeners.

'I am the chief guardian of the jewels. To me is entrusted the care of the sparkling diamond, the flaming ruby, the cerulean sapphire, the green emerald, the yellow topaz, the purple-streaming amethyst, and all the precious stones which you mortals prize so highly.' His small mightiness pauses for a moment, probably to give us time to form an adequate idea of his immense importance.

'As you have been permitted to enter our abode,' he continues, 'I will reveal to you a few secrets concerning the treasures I guard. You are doubtless aware that the diamond is merely a bit of crystallized charcoal; but I trust you do not think meanly of this princely gem on that account. Were you to estimate the value of things by their composition, the finest marble and the coarsest chalk would be placed on an equality; or to choose an example from human nature, the wisest philosopher would be no better than the greatest dunce. The diamond is my most precious charge. It surpasses all other gems in hardness and lustre, and its beauty and rarity have rendered it peculiarly attractive to you men. My richest diamond-beds are situated in the Brazils and in Bengal, but I have scattered these gems over many parts of the world. They may be found in alluvial deposits of sand and gravel, lying in detached octohedral crystals, sometimes with plain, but more frequently with rounded surfaces. When perfectly pure, a diamond is as transparent as a drop of the purest water, in which state it is known to you who live overhead as a diamond of the first water; and in proportion as it falls short of this perfection it is said to be of the second, third, or fourth water, till it becomes a coloured one. Coloured diamonds are brown, yellow, green, blue, or red; the deeper the colour the more valuable they are, though still inferior to those absolutely colourless. Many of my largest diamonds have fallen into the hands of man. The famous Koh-i-noor, or Mountain of Light, was removed from the mines of Golconda more than three hundred years ago; but, though it was thus taken out of my keeping, I never lost sight of it, and I was extremely pleased to see it pass into the possession of the Queen of England.

'A slight sketch of the history of this remarkable jewel may perhaps be interesting to you. It was first brought to light by the miners of Golconda in the year 1550, and became the property of the reigning prince. When the Mogul princes extended their pretensions to the sovereignty of the Deccan, the Koh-i-noor passed from Golconda to Delhi, where it was seen in 1665 by the French traveller Tavernier, who, by the extraordinary indulgence of Aurungzebe, was permitted to handle, examine, and weigh it. In the year 1739, Nadir Shah, the Persian invader, seized the precious jewel and carried it back with him; but it was destined to pass from Persia as quickly as that ephemeral supremacy in virtue of which it had been acquired. Soon after his return the Persian conqueror was assassinated by his own subjects, and the great diamond was carried off by Ahmed Shah.

'At the commencement of the present century, the treasures of Ahmed were vested in Zemaun Shah, who was deposed and imprisoned by his brother, Shah Shuja. For some time the Koh-i-noor was missing, but at length it was discovered ingeniously secreted in the walls of Zemaun Shah's prison. When Shah Shuja was expelled from Cabul by the British, he contrived to make this far-famed diamond the companion of his flight. He found refuge at the court of Runjeet Singh, who demanded the jewel in return for his protection; and thus the great diamond of the Moguls became the property of the warlike chief of the Sikhs. You must be aware that the Koh-i-noor formed part of the spoil taken by the English in the Sikh war, that it was one of the chief attractions of your Great Exhibition in 1851, and that it has since been re-cut and placed among the jewels of your queen.

'Such is the history of that marvellous gem which, in point of size, is still without a rival, though cutting has reduced it to little more than one-eighth of its original weight.[1] You would probably like to know something about the previous history of this stone. I could tell you how it was originally formed, and how it came to be deposited with the gravel and sand of Golconda, but I have my own reasons for keeping these matters secret. Science will one day enable you to solve many problems connected with the formation of gems, and will perhaps teach you how to manufacture Koh-i-noors from coal or charcoal. Till then I shall keep my own counsel.

'Many of the jewels under my care are composed of alumina, and bear the same relation to clay that the diamond bears to coal. Of these aluminous gems the rubies are the most valuable, on account of their extreme rarity, their matchless hues, and the brilliant stars of light which they exhibit when viewed in certain directions. The sapphire, another of my precious charges, is merely a blue variety of the same substance as that which, when red, is called ruby.

'Flint, or silica, forms the base of innumerable

[1] In its rough state the Koh-i-noor is said to have weighed nearly 800 carats—a carat being $3\frac{1}{6}$ troy grains. Its present weight is $102\frac{1}{2}$ carats.

mineral treasures. Quartz is formed of pure silica, and is often found crystallized in beautiful six-sided prisms, ending in six-sided pyramids. When coloured by slight admixtures of other substances, such as iron and manganese, quartz goes under various names, according to the variety and arrangement of colours, crystalline form, and state of transparency. When purple, it is called amethyst, and is highly prized by you mortals; smoky quartz is called cairngorm; when blue, it is known as siderite; and when yellow, as Scotch or Bohemian topaz. Agate, jasper, carnelian, onyx, chalcedony, and opal, are merely varieties of the same abundant substance. The emerald, again, one of the most esteemed gems, is nothing but transparent flint, coloured green by oxide of chromium.

'My time is precious, and although I have given you but an imperfect idea of the mineral treasures that I have to guard, I must now leave you, as my presence is required at the diamond mines of Brazil. The inferior gnomes under my control are continually engaged in building up new minerals, in filling empty veins with spar, in polishing crystals, and in performing a thousand mysterious processes of a chemical or electrical nature. It is no easy task, I can assure you, to superintend these countless operations, and I need scarcely tell you that my time is fully occupied—so, farewell!' The gnome takes off his jewelled cap, makes a low bow, and disappears.

But here comes another little fellow, in far more splendid habiliments than those of the guardian of the gems. He wears a complete suit of armour, every plate of which is formed of a different metal. His helmet is of gold, and surmounted by a graceful plume, formed entirely of the finest conceivable silver wire. Everything about him is metallic, and so highly polished that our eyes are fairly dazzled by the apparition. As he walks towards us, his armour makes a pleasant jingling noise; and as he sits down on the stalagmite vacated by his brother gnome, we hear such a crash, that we half expect to see the elaborate suit of metal tumble into pieces.

'I come to speak to you of the real treasures of the earth, and not of those useless bodies misnamed precious stones. I am the keeper of the metals, those wonderful substances which have been such important aids to human progress, and without which, indeed, any high degree of civilisation were impossible. Unlike the jewels guarded by the boastful gnome who vanished as I approached, the metals are not merely ornamental; for you must be aware that they are essential to every process connected with the tilling of the soil, the building of houses and temples, the construction of roads, the manufacture of clothing, the navigation of seas—to every art, in fine, which elevates man above the condition of the brute.

'I will not attempt to describe the properties of the various metals confided to my care, nor will

I speak of the uses to which they are applied by man; for surely you ought to know more about human works than a gnome. I shall merely allude to the states in which the metals occur in these subterranean regions, for you must know that they are seldom to be met with in a state of purity.' The little man of metal now takes off his helmet, and, drawing his tiny legs under him into a comfortable position, speaks as follows:—

'The metals nearly always occur in the crude state of ores. These ores are sulphides, oxides, and carbonates mingled with earthy impurities, generally situated in fissures or rents in the rocks, which are called veins or lodes. I may as well inform you at once, that these fissures are produced by the upheaval and depression of the rocks which they traverse. The internal fires of this wonderful planet sometimes exert a force sufficient to raise vast masses of rock, of unknown but immense thickness, from the bottom of the sea high into the air, in order to form dry land; you may easily imagine, therefore, that this force is also sufficient to crack and rend the earth's crust in every direction, and thus form the veins in which the metallic ores are deposited.

'The respective metals do not always lie in separate veins; for though one metal generally predominates, three, four, or even more metals may be strangely combined and intermixed in the same veinstone: thus the vein which contains lead as the principal metal, frequently contains small quantities of silver, zinc, and cobalt; manganese is often associated with iron, while platinum is usually mixed with gold. Besides the ores of metals, these veins almost always contain quartz, fluorspar, crystalline carbonate of lime, and other spars.

'Ores and spars, however, are not confined to the deep fissures that occur in the earth's crust. They find their way into all kinds of cracks and cavities, whatever may have been the cause of the hollows, and even into detached holes, often no larger than your fist, and completely surrounded by solid rock. Wherever, indeed, permanent hollows and interstices of any kind, size, shape, or origin exist in hard rocks, crystallized minerals, spars, and ores may be formed in them.

'How do these matters reach the cavities, is a problem which you will perhaps expect me to solve, but if so, you will be disappointed. A number of clever mortals are striving to arrive at the true solution of this mysterious question; and were I to tell you all I know, I should be robbing some future philosopher of the fame that will accrue from a great discovery. I will, however, give you one or two hints, which may help you to form some conception of the mode in which the veins and isolated cavities may be filled.

'Look around at these walls of crystal, these pillars of porphyry, this floor of marble, and these hanging stalactites! All these things have been formed since this cavern was hollowed out by the disturbing forces of nature. How did they find their way hither? you will perhaps ask. They came by water, not in large masses, but particle by particle, dissolved in the minute drops of fluid which percolated through the rocks overhead. May not the minerals have been introduced into the rock cavities by water also? May not each detached and isolated nest of minerals be a miniature stalactite cavern?

'If the mineral contents of veins have not been deposited from aqueous solutions, they may have been introduced by sublimation. Many of the metals can be converted into vapour by intense heat; and provided it be possible for mineral vapours to gain access to fissures in rocks, it is not impossible for some of them to be condensed and deposited on the sides of the lodes.

'Gold ranks first among the metals, though its rarity renders it of less importance to man than some of the less perfect ones. This kingly metal occurs in almost every quarter of the globe, and is obtained by the miner either in the metallic or native state, from alluvial sands and gravels, or from veins in combination with silver, and often mixed with sulphides of other metals. In its native state it occurs in small crystals, in threads or granular fragments, and in curiously shaped nuggets.

'Silver is a still more widely disseminated product of nature, occurring in veins in granitic mountains, and in the most ancient sedimentary rocks. It is sometimes found in a native state, though less frequently than gold.

'Iron is far more valuable than either of the so-called precious metals, and its ores are scattered over the crust of the globe with a beneficent profusion proportionate to the utility of the metal. One of your best authors has well remarked, that he who first made known the use of iron may be truly styled the father of arts and author of plenty.

'What miserable creatures you mortals would be without this marvellous substance! Banish the ploughshare, the anchor, and the needle from the world, and there would be an end to agriculture, to navigation, and to the fashioning of clothes. You would be reduced to the state of barbarism; and in your naked and forlorn condition your time would be fully occupied in seeking your scanty meal of acorns, and in paddling about in your rude canoe, intent upon spearing a stray fish with your wooden lance. You would cease to be interested in "the fairy tales of science," and "the long result of time" could have no possible attraction for a hungry savage like you.

'Copper, lead, and tin are also estimable treasures; indeed, there is not a single metal which has not contributed, or at any rate may not contribute, to man's comfort and happiness. Look upon me as the friend of the human race, for it is I who superintend the filling of the veins with ores, and all the metallurgical operations of nature's laboratory. But here is another gnome who, despite his ugliness, has quite as great a claim to your respect as I have. I leave you with him.' So saying, the armour-clad spirit vanishes in a most mysterious manner, before we can shape our grateful thoughts into words.

The gnome who now seats himself on the sparry throne is a sombre-looking little imp, with something so repulsive, and at the same time something so ludicrous, in his whole appearance, that we are undecided whether we ought to run away or burst out laughing. His ugly face wears a very comical expression, and is as black as jet. His crooked body is clothed in a suit of shining black; his legs are black, his feet are black; in fine, he is black all over. But what renders this strange being so terrible, is a circle of flames which surrounds his head and forms a sort of fiery crown.

'I am the gnome of the coal-measures,' says the little blackamoor; 'those wondrous accumulations of ancient vegetable matter that abound in these subterranean realms. I need not tell you that coal is one of the greatest treasures hidden in the bowels of the earth. By it man heats his apartments, cooks his food, fuses the metals, and produces steam, which sets all kinds of machinery in motion. With it he feeds his iron horses, which drag him from place to place with the velocity of the wind; and with it he raises an agent that propels his ships along the pathless deep against wind and tide.

'You are familiar with the general aspect and nature of coal, and are doubtless aware that it is almost wholly composed of the element, carbon.

Were I to describe the immense varieties of coal that occur in nature, you would not thank me for my trouble, and would probably fall asleep long before I reached the end of my list. These different varieties of coal may, however, be grouped under three heads: anthracite, ordinary or pit coal, and brown coal or lignite.

'Anthracite is a natural coke or charcoal, and may be regarded as the most completely mineralized form of coal. If you handle a piece of this substance, you will find that it does not soil the fingers like ordinary coal, that it is much heavier, and that it has a glistening and semi-metallic aspect. It is not easily ignited, but when burning gives out a fierce heat, and neither flames nor smokes.

'Ordinary coal has many varieties, which, however, may be classified into four kinds. The first kind is called caking-coal, from its fusing or running together on the fire, so as to form clinkers. Splint or hard coal comes next, which is not easily broken, nor is it easily kindled, though it affords a clear and lasting fire when once ignited. Cherry or soft coal is an abundant and beautiful kind, and highly prized by mortals. It does not cake when heated; it can be broken with ease; and it readily catches fire, requiring but little stirring, and giving out a cheerful flame and heat. Another kind is called cannel coal. It is always compact, and does not soil the fingers. It varies much in appearance, from a dull earthy to a lustrous wax-like substance. The bright shining varieties often burn away like wood, leaving scarcely any cinders and only a little white ash, while the duller kinds leave white masses of ash, almost equal in size and shape to the original lumps of coal. Jet, of which you make necklaces and bracelets, is merely an extreme variety of cannel coal.

'Brown coal, or lignite, is a substance of comparatively recent formation, and it sometimes exhibits the structure of the plants from which it is derived, the trunks and branches being plainly perceptible. This brown coal is only had recourse to where there are no older beds beneath, or where they are too far down to be reached by the miner.

'Although you mortals are constantly consuming vast quantities of coal in your stoves, fire-places, and engine-furnaces, I give you my word that there is quite enough in the earth's crust to supply all your wants for thousands of years to come. Many of the great coal-fields are as yet untouched; for until the wood of a new country is used, and civilisation has made some progress, man never dreams of looking for his fuel in Gnome-land.'[1]

Where have we been? To Gnome-land or to dream-land? The cavern and all its weird inhabitants have vanished. We are sitting at our desk, with a text-book of mineralogy open before us, the source from which our fairy tale proceeded.

[1] Mr Edward Hull, of the Geological Survey, calculates that there is enough coal within reach in Great Britain, to last for eight centuries, even though the consumption be estimated at one hundred millions of tons a year.


SWAIN Sc

Pluto's Kingdom.

'To the sad realm of shades, where Pluto sits enthroned,
In gloomy majesty, grim King of Death;
And Phlegethontic rills roll waves of lurid fire—
There will I lead, an thou wilt follow me.'—

KLOPSTOCK.

THEY were brethren three, sons of Old Time, who shared among them the dominion of the world. Jupiter, the eldest of them, assumed the supreme rule of heaven and earth; to Neptune was given the empire of the sea; Pluto had assigned to his sway the interior of the earth—the realm of death.

The name of Pluto is taken from a Greek word signifying *wealth*, and was therefore most appropriately given to the master of all the hidden treasures of the earth.

The gate to the dominions of Pluto was guarded by the many-headed dog Cerberus. To get there, you had to pass the famous River Styx, or the sad river. Over this you were ferried by Charon, the son of Tartarus and Night, for the small consideration of an obolus,[1] which the ancients, for this reason, used to put in the mouths of the dead. But woe unto those shadows whose bodies had had no burial! For a hundred years had they to wander by the side of the river, before they could hope to induce the grim ferryman to carry them over. And grim he was, this ferryman, and far from prepossessing, if the portrait drawn of him by Virgil may be considered a correct likeness: a frightfully ugly old man, with glaring eyes and a bushy matted beard; a dirty dark-coloured mantle, fastened with a knot, hanging down from his left shoulder. The River Styx, or the Stygian Lake, as it was also called, encircled Pluto's Kingdom, in a sevenfold embrace. There dwelt a marvellous power in the name, to which even the highest divinities were subject. If any of the gods swore falsely by it, a hundred years' exile from heaven, with loss for that time of all the rights and privileges of divinity, punished the perjurer. Four other rivers, besides Styx, flowed through the sad realms of Death—the Acheron, the Cocytus, the Phlegeton, and the Lethe. The Phlegeton was a lake of liquid fire: whoever drank of the waters of Lethe forgot all that was past. According to the doctrine of the transmigration of souls taught by Pythagoras in the sixth century B.C., the souls of the departed were made to drink the waters of Lethe, when quitting the infernal regions to return to the surface of the earth to animate new bodies there.

[1] An Athenian coin, worth about five farthings of our money.

Pluto, the supreme lord and ruler over this subterranean realm, sat here enthroned in gloomy majesty, on a seat of ebony, a crown of the same wood encircling his 'portentous brow,' and a two-pronged sceptre in his right hand. On voyages of inspection through his dominions, he rode in a chariot of dark hue, drawn by four jet-black steeds. No temples nor altars were ever raised to *him* by man; no hymns ever chanted in *his* praise; and strange enough, from some tacit understanding among the learned of all nations, evidently dictated by some universal intuitive sense of the 'fitness of things,' the starry heavens are, even to the present day, left without a representative of his name. Yet was he acknowledged to be a powerful god, and trembling man would not dare to withhold from him the propitiatory sacrifice: the blood of black rams, spilt in a pit, was the peace-offering presented to him.

Pluto's lord high-treasurer and secretary of state for the financial department was Plutus, the god of Wealth, son of Jasius and Ceres. We find that the ancient Greeks imputed to this god blindness and folly, which in fact would appear to have been the chief qualifications that recommended him for his high office. He was depicted lame in his approach, winged in his departure. Among the other high functionaries in Pluto's court, were the three fatal sisters—Clotho, who held the spindle, and drew the thread of man's life; Lachesis, who spun it; and

Atropos, who cut it asunder with her relentless scissors;—and the three infernal judges—Minos, the son of Jupiter and Europa, whilom king and law-giver of the Cretans; Æacus, the son of Jupiter and Ægina; and Rhadamanthus, also a Cretan lawgiver. Before the dread judges all the shades of the departed had to appear, with the knowledge that there was no appeal from *their* decrees. The officials upon whom devolved the execution of the sentences passed by this dark tribunal, were presided over by three most unamiable females, holding lighted torches in their hands, and with a fanciful arrangement of snakes dangling round their heads, in lieu of hair—Alecto, the never resting; Megæra, the type of envy; Tisiphone, the avenger of blood.

The empire of the dead was divided into two parts—Tartarus and Elysium.

Tartarus was the place of punishment assigned to the criminals. Here might be seen the Titans and the Giants who had dared to 'war 'gainst heaven's king.' Here the robber Sisyphus toiled at his eternal fruitless task of rolling to the top of a high mountain an immense round stone, which always rolled backward with irresistible force when it came close to the summit. Here the giant Tityus lay stretched upon nine acres of ground with vultures perpetually devouring his ever-growing liver. Here might be seen Ixion tied with serpents to a wheel which revolved incessantly; here Tantalus, condemned to stand for ever chin-deep in water with an abundance of pleasant fruit just at his lips, without the power of even once satisfying his hunger or quenching his thirst; here the forty-nine wicked daughters of Danaus, condemned to pour water eternally and incessantly into a tub full of holes.

Elysium, on the other hand, the placid abode of peace and contentment, was assigned for the habitation of the souls of good and virtuous men, those who had distinguished themselves by heroic deeds, and those who had rendered important services to humanity. Here the spirits of the blessed wandered in serene happiness, under a sunny and star-spangled sky, in a pure atmosphere, over ever-blooming fields, and through ever-green laurel groves, continuing those pursuits and occupations in which they had delighted most during their terrestrial career.

Now although this pleasant little retreat formed part of Pluto's kingdom, it would appear that none of the goddesses could be persuaded by the grizzly monarch to share his throne. Finding the honour of his alliance everywhere 'declined, with thanks,' he took at last the desperate step of carrying off to his subterranean realm Proserpine, the daughter of Jupiter and Ceres. The bereaved mother lighted torches on Mount Etna, and incessantly, both by day and night, sought for her daughter all over the world, but in vain. At last, having been put on the right track by the nymph Arethusa, she descended to the infernum to claim the restitution of her child, as she decidedly objected to brimstone matches. But Proserpine, won over, most likely, to Pluto by the splendour of his throne, showed no great eagerness to comply with her mamma's peremptory request to instantly return to Olympus; and poor Ceres was obliged, as a last resource, to appeal to the justice and power of Jupiter. He decreed that Proserpine should return, provided she had tasted nothing in the infernal regions; but, unfortunately, one of those busybodies who are always poking their noses into other people's affairs, one Ascalaphus, son of Acheron and Orphne, stood forward as witness on Pluto's behalf, deposing that he had seen the lady eating seven pomegranate seeds, as she walked in Pluto's orchard. Whereupon, all hope of a return being gone, the angry mother touched the luckless Ascalaphus with her magic wand, and enriched the tribe of owls by a new species. It would, however, appear that Jupiter, afterwards yielding to the deep grief and the incessant lamentations of Ceres, granted that her daughter should only live six months in the year with her husband below, and the other six months with the gods above.

Such as we have here endeavoured to sketch it, in a few rapid outlines, was the kingdom of Pluto, in the ideal conception of the ancient Greeks, that nation of poets. To us, the sons of a hard, stern, matter-of-fact age, a very different image presents itself. We still make use of the *name*, indeed; but the *god*, with all that pertained unto him, has departed for ever and for evermore. Our 'Pluto's Kingdom' is the mass of liquid fire that constitutes the inner kernel of the earth. To us, he is the great Fire-King, and he and his realm are *one.*

Many astronomers and geologists countenance the notion, that the matter composing this solid globe of ours once existed in the gaseous state, and was subsequently, by the chemical combination of its different elements, and consequent evolution of heat, gradually condensed into a glowing, fusing mass, which being whirled round in space, ultimately assumed, under the conjoint action of gravity and the rotatory projecting impulse inherent in it, its present state and orange-shaped form, the surface or 'crust' gradually cooling and hardening in process of time.

If you wish to form some intelligible conception of the state and condition of the earth, you need simply go to a foundry, and watch the cooling of a cannon-ball heated to redness: as it cools you see the surface becoming gradually covered with pellicles, or flakes of oxide of iron, whilst a touch will speedily convince you that the heat beneath the surface continues still unabated; and it is only after a certain time, when the process of cooling has extended to the inner part, that you may take up the ball without burning your fingers. Now proceed a little further: take up a mass of cinder, or scoria, that has cooled, and break it to pieces; you will find that the inside shows streaks and veins of different materials, and presents many cavities or holes, called by foundrymen 'honeycomb.' Reflect now that these cavities were formed in the cinder while yet in the liquid state, either by air or by other gases. Remember that the mass of cinder when first formed contained a core of molten matter. Now bring your imagination into play, and let that cinder represent the earth; the cavities, subterranean caverns of many hundred square miles; and the molten core, an immense mass of liquid fire, enlarging the caverns, melting away parts of the crust nearest to it, or swelling it up until it cracks, and forms crevices and fissures for the escape of smoke, flames, and fused matter. Here you have at once an intelligible theory of earthquakes and volcanic eruptions.

It has been demonstrated by numerous observations made in mines and Artesian wells in various countries, that at a certain depth in the crust of the earth the temperature remains stationary, being uninfluenced by the heat of summer or the cold of winter, and that this depth varies between 60 to 90 feet according to the nature of the material passed through. Below this 'stratum of invariable temperature' it has been found, that a rise of one degree of Fahrenheit's thermometer takes place for every 55 or 60 feet of descent. Assuming this rate of increase to remain constant, a temperature of 2400° Fahrenheit would be reached at a depth of about 25 miles—a temperature sufficient to keep in fusion such rocks as basalt, greenstone, and porphyry. At the same rate of increase, or even admitting, as some contend, that the thermometer only rises one degree for every 90 feet, we would, at a depth of 150 miles, arrive at a temperature sufficiently high to vaporize the most refractory rocks. We know little, however, of the effects of heat upon matter under such a pressure as must exist at these depths; but we have every reason to believe, that the solid part of our globe forms only a comparatively thin rind or crust, and that the great interior mass is liquid and incandescent. The process of cooling from the crust downwards is, of course, still going on, but, as has been demonstrated by Fourier, at a less rate than was formerly the case. According to the same authority, it will require 30,000 years to reduce the increase of temperature on descending into the interior of the earth, from its present rate of one degree Fahrenheit for every 60 feet in descent, to one half degree. Some geological chemists have calculated from the known laws of radiation of heat, that it would take 200,000,000 years to cool the earth to its centre!

Another point to consider is the *density* of the earth. The density of the crust is about $2\frac{1}{2}$ times that of water; but we know, from most careful and accurate pendulum experiments, that the average density of the bulk of the earth is about $5\frac{1}{2}$ times that of water. It is quite evident, therefore, that the ponderable matter of the interior must be very much denser than that of the crust. The generally received notion is that, assuming the radius of the earth to measure 4000 miles in round numbers, and dividing it into ten equal parts of 400 miles each, the density of the materials severally constituting the ten divisions increases in an arithmetical progression by about 1·5 for each part, which, taking the density of the first annular space of 400 miles at 2·7, gives for the second 4·2, for the third 5·7, and so on, the density of the central portion being about 16·2.

In Cordier's purely thermometrical theory as to the nature and mode of action of the great elevating force that has at successive periods raised and broken the earth's crust, lifting up various igneous or plutonic rocks, and forcing them into the cracks and fissures, the central nucleus of the earth is considered in the light of an immense sea of molten mineral matter. As the solid crust continues to contract as its temperature decreases in a greater ratio than the central mass, and the velocity of rotation increases as the diameter of the globe shortens, a tendency will necessarily be induced to additional divergence from the spherical form, and the fluid matter within will accordingly press against the contracting crust, and thus produce volcanic eruptions. M. Cordier has calculated that a contraction of $\frac{1}{12350}$ of an inch in the mean radius of the earth would be sufficient to force out the matter of a volcanic eruption. Every volcano acts as a safety-valve by affording an outlet to the molten matter, and Man ought to feel rather thankful when he beholds the flaming head of the Fire-King towering above the crater. Earthquakes surely are much more terrible and destructive than volcanic eruptions.

A *volcano* may be defined as a perpendicular tunnel in the earth's crust, through which heated matter from below is thrown up to the surface. The matter thrown up may be in the form of lava, scoriæ, ashes, or mud. The tunnel or fissure is generally called the chimney, vent, or chasm of the volcano. The upper part of the chimney is called the *crater:* it always presents the form of an inverted cone, or the shape of a funnel with the broad part upward. A distinction is made between so-called *craters of eruption* and *craters of elevation.*

Craters of eruption are formed by the boiling streams of lava, the floods of hot mud, or *tuf*, and the showers of ashes and cinders gathering or falling around the mouth of the vent or chimney of a volcano. In proportion to the continuance of the eruption, and its repetition, successive beds of volcanic products will accumulate round the mouth, and form themselves into the shape of a sugar-loaf or cone.[1]

Craters of elevation, on the other hand, are formed by the matter of the volcanic eruption lifting the horizontal strata in which the crater is formed, until the beds snap, and rest in highly inclined planes about the mouth of the fissure.

[1] Most volcanic cones appear to have been formed in this manner.

The lava in a crater may be burning and boiling for years, without either an eruption of scoriæ or an overflow of lava taking place: a multitude of small conical vents are formed, however, in such cases, which rise out of the cooled surface of the melted lava, and incessantly emit volumes of smoke and sulphurous vapour. A vent of this kind is called in Europe a *fumerole* or *moffet*, and in Mexico a *hornito*, or small oven. Other vents also are produced occasionally on the walls of the crater, or on the sides of the mountain, by the jets of scoriæ thrown up accumulating in falling round the mouth of the vent.

The number of volcanoes is very great, more than 300 of them being known to exist in the world at the present time; of which 24 are in Europe, 11 in Africa, 46 in Asia, 114 in America, and 108 in Oceania. Most of the islands of the Pacific, and many isles of the Atlantic and Indian Oceans, are also volcanic, or else composed of volcanic rocks.

The most ancient volcanoes known are Mount Vesuvius in Italy, Mount Etna in Sicily, and Stromboli, one of the Lipari Islands, near Sicily. The latter seems to be continually belching forth fire, and is called 'the great lighthouse of the Mediterranean.'

Mount Vesuvius gave its first notice of action in A.D. 73, when it did much injury to houses and villages upon its flanks. From 73 to 79 there were several small shocks; and in August of the latter year occurred that awful eruption of ashes which destroyed the cities of Herculaneum, Pompeii, and Strabiæ, and caused the death of the elder Pliny. From 79 to 1036, six other eruptions of ashes, sand, and shattered fragments of lava took place: in the latter year occurred the first authentic overflow of lava, which was repeated in 1049 and 1138. After this the mountain rested for one hundred and sixty-eight years. Another great eruption then took place in 1306, and a slight one in 1500, followed by another repose, which lasted till 1631, when a fearful eruption took place, blowing up into the air the forest of brushwood that covered the sides of the mountain, and the luxuriant grassy plain at the bottom. Passing over several other eruptions of the mountain, we come to the one in October 1822, which lasted nearly a month, and was attended by a series of loud detonations and explosions. Between 1800 and 1822, the vast crater formed in 1631 was gradually getting filled up with lava, cinders, and ashes, the bottom presenting a rugged, rocky plain, covered with scattered blocks of lava and heaps of cinders. In this eruption of October 1822, the force from below broke up this aggregation of lava blocks at the bottom, and hurled them all into the air, leaving behind a tremendous chasm, above three miles long, and three-fourths of a mile across. The depth of this chasm was at first about 2000 feet, but as the walls of the crater continued to fall in, it became eventually reduced to less than half that depth. Previous to this eruption, the summit of the cone round the crater had been 4200 feet high; after the eruption its elevation was found to be reduced to 3400 feet. Another eruption took place in 1833; and since 1857, Mount Vesuvius has given uncomfortably convincing indications that it continues as much 'alive' as ever.

Mount Etna in Sicily rises 10,874 feet above the level of the sea, of which the lower or bottom part, to the extent of some three thousand feet, consists of calcareous beds, associated with lavas and clays; the remaining 7000 or 8000 feet have been formed by successive eruptions from the volcano. The upper 1100 feet consist of the cone of the crater, which rises from an irregular plain, about nine miles in its circumference. The great crater in the summit of this cone is perpetually emitting sulphurous vapours. Etna, like Vesuvius, has been particularly active during the past two years.

One of the most remarkable volcanoes is that of Kilauea in the Sandwich Islands, which burns continually, and whose crater contains a sea of red-hot melted lava, sometimes several miles in diameter.

The loftiest volcanoes known are those of Orizaba in Mexico, and Antisana and Aconagua in South America, which are from three to five miles in height.

Mount Jorullo in Mexico affords a curious illustration of volcanic action combined with extensive elevation. This vast mountain rises in the great plain of Malpays, which, up to June 1759, was never suspected to be the site of a volcano, although the basaltic hills of the neighbourhood clearly indicate that the district had at some very early period been the theatre of volcanic eruptions, which had filled up the original valleys. In the month of June 1759, hollow murmurings began to be heard, speedily attended by earthquakes, which followed each other in rapid succession up to the month of September. The surface-soil at last swelled up like a large bladder, three or four miles square; it finally burst open in various parts, flames issuing forth through the fissures, and burning fragments of rocks being thrown up high into the air. Six conical vents were thus formed in different parts of the area, of which the lowest was 800 feet high. Besides these, thousands of small cones or bosses arose, which cracking, subsequently emitted aqueous and sulphurous vapours. These bosses are called in the country hornitos, or small ovens. Towards the close of the month of September, the vast mountain Jorullo was pushed up bodily in a few days, by the subterranean force, to an elevation of 1682 feet above what had been a plain up to the preceding month of June. The crater of Jorullo threw out immense streams of basaltic lava, which continued to flow till February 1760, after which the district resumed its former stability, though it still remained far too hot to be habitable. In 1780, twenty years after the outburst, the heat of the hornitos was still so great that a cigar could readily be lighted by plunging it two or three inches into one of the lateral cracks. When Humboldt visited Jorullo in 1803, forty-three years after the eruption, he found around the base of the great cone a mass of matter, of convex form, about 500 feet high near the cone, but sloping gradually as it receded from it: this mass, which covered to the extent of four square miles, was then still in a heated state. And twenty-two years later, in 1825, Mr Bullock found the cones still smoking.

Previous to the outburst, two purling streams had watered the plain of Malpays, the Cutimbo and the San Pedro. These two rivers ran into the crater, and lost themselves below at the *eastern* limit of the plain, but reappeared afterwards on the *western* limit as hot springs.

Among the productions of volcanoes, emitted or ejected through their craters and vents, may be enumerated various gases—such as hydrochloric acid gas, carbonic anhydride, sulphuretted hydrogen, and gases formed by the several combinations of sulphur with oxygen; aqueous vapour, lava, minerals, cinders, stones, sand, water, mud, and ashes—which latter probably consist simply of pulverized lava.

The quantity of ashes discharged by volcanoes must be immense. During an eruption of Mount Cosiguiana, a volcano in the Gulf of Fonseca, on the shores of the Pacific, ashes fell as far as Truxillo, on the shores of the Gulf of Mexico; also on board a ship at the time some 1200 miles westward of the volcano; and four days after the eruption, at Kingston in Jamaica, 700 miles eastward from it, having travelled there by an upper current of west wind, at the rate of 170 miles a day. For about thirty miles to the south of this volcano, ashes covered the ground three yards and a half deep; and thousands of cattle, wild animals, and birds perished under them.

One of the most curious productions of a volcano is *mud*. The aqueous vapour emitted by the crater being condensed by the cold atmosphere, heavy rains are produced, which, falling upon the volcanic dust on the sides of the mountain, form a current of mud, generally called *aqueous lava*, which is more dreaded by those dwelling in the vicinity of a volcano than a stream of melted lava. But, after all, as this muddy stream is not actually ejected from the crater, but simply formed on the surface of volcanoes by the action of water upon the erupted matter, the term 'mud volcano' is not exactly applicable in such cases.

However, in some volcanic districts mud is occasionally found to ooze from the ground; and there are also, in different parts of the globe, *real mud volcanoes*,—as, for instance, the mud volcano of Jokmali, on the peninsula of Abscheron, in the Caspian Sea; that of Damak, in the province of Samarang, in the island of Java; and the Salses of Girgenti in Sicily, and Sassueto in Northern Italy.

One of the most remarkable of this class is the one described by Humboldt. This is situated at Turbaco, near Carthagena, in New Grenada, South America. It consists of some fifteen or twenty cones from nineteen to twenty-five feet high, and measuring round the base from seventy-eight to eighty-five feet each. These cones, or *Volcancitos*, as they are called in the language of the country, have a hollow on the top, measuring from fifteen to thirty inches in diameter, and filled in the driest seasons with muddy water, through which air-bubbles are constantly escaping: the temperature of the water is not higher than that of the surrounding atmosphere.

Earthquakes are intimately connected with volcanoes: they often precede volcanic eruptions, and arise from the same cause—viz. from the movement of matter in the interior of the earth; only that their action is much more formidable and destructive, and the changes produced by them in the globe are much more varied and extensive. Landslips on the sides of mountains are most frequently attributable to them: they give rise to the formation of new lakes, and cause old ones to disappear; islands are swallowed up by them, and new ones arise in the sea as by magic; parts of continents subside and sink, and others are elevated; the relative positions of sea and land are changed; and rivers quit their former courses and ancient beds, seeking other channels and forming new beds.

The action or movement of earthquakes is threefold—*vertical*, *horizontal*, and *gyratory* or *circular*.

The *vertical* movement proceeds from below upwards, and may be likened to the explosion of a mine in a stone quarry. It produces cracks and fissures in the earth's crust. In many instances, the earth opens and closes rapidly; in others, portions of the crust slip down into the chasm, and disappear for ever. It was by a vertical earthquake movement that the city of Messina in Sicily was destroyed in the year 1783. These vertical movements are felt even at sea. Thus, for instance, during the celebrated earthquake at Lisbon in 1755, many ships at considerable distances from the actual focus of the movement were violently shaken; the concussion in one ship far out in the Atlantic being so great, that the men were tossed up into the air a foot and a half perpendicularly from the deck.

In the *horizontal* movement the shock is propagated in a linear direction, producing undulations in the surface of the earth, bearing some resemblance to the waves of the sea, and the sight of which, curious enough, causes a swimming in the head, like sea-sickness.

These undulatory shocks in a linear direction must, of course, be understood to move in waves of great breadth as well as length. The horizontal earthquake movement which visited Syria in 1837, was felt in a line five hundred miles long by ninety miles wide.

In accordance with a general law in mechanics, the undulations of horizontal earthquake movements finish by cracking the superficial soil and strata of the earth's crust. In the earthquake which in 1811 convulsed the district of New Madrid, South Carolina, the surface-earth between New Madrid and Little Prairie rose in great undulations to a considerable height, till the earth waves burst, when volumes of water and sand, and masses of pit-coal, were hurled up through the crevices high into the air; large lakes of twenty miles in extent were on this occasion formed in the course of a single hour, whilst some of the ancient lakes of the district were drained and completely dried up.

As a general rule, horizontal shocks, proceeding onward unresisted, are not considered to be very dangerous. The most terrible horizontal earthquakes are those where the shocks, proceeding from two different foci of action, happen to cross each other. A town standing on the ground at the point of intersection of the two waves has little chance indeed of escaping the crash and crush produced by their meeting.

In the *circular or gyratory* movement, the earthquake action moves in a circuit, sometimes very extensive, in other, but rare instances, of very small compass; in the latter case, the movement proves generally most dangerous and destructive, of which the earthquakes at Quito in 1797, and in Calabria in 1783, afford convincing illustrations. In cases of this description it has happened that solid walls have changed their place, with the masonry perfectly undisturbed; rows of trees, straight and parallel, have been inflected; and, more remarkable still, entire fields, with different sorts of grain growing in them, have exchanged places and crops! Humboldt tells us that at Riobamba, South America, destroyed by the terrific convulsion of 1797, he was shown a place among the ruins where the whole furniture of one house had been carried bodily by the movement of the earthquake under the roof of another.

As an illustration of a circular movement upon an immense scale, may be instanced the famous earthquake which destroyed Lisbon in November 1755, and afforded the great Pombal the opportunity of erecting those solid wooden-framed stone buildings that have so gloriously withstood later shocks, even up to periods so recent as November 1855 and November 1858. The shock, in this instance, was felt in many parts of Europe, and on the north coast of Africa, as well as in North America and the West Indies.

As has already been intimated, earthquakes are generally attended with more or less extensive elevation or subsidence of land. We will here give a few instances in illustration.

In the earthquake which visited Jamaica in 1692, several large storehouses in the harbour of Port Royal subsided to a depth of between twenty-four and forty-eight feet under water, apparently without disturbing the masonry, as the buildings remained standing, with the tops of the chimneys erect above the water. A large tract of land around the town, about 1000 acres in extent, subsided in less than a minute, and was covered over by the waters of the sea.

The fearful shock which destroyed Lima in Peru in 1746, submerged the entire coast near Callao, converting it into a bay of the sea.

In the great earthquake of 1755, the new quay at Lisbon, then recently built of massive and solid marble, on which a vast number of people had collected for safety, sank suddenly down with its living load, and not one of the bodies ever rose to the surface again; and, more extraordinary still, a number of boats and ships lying at anchor a little distance off the quay, went suddenly down with the body of water beneath them as into a whirlpool, and not a fragment of the wrecks was ever after seen: upon sounding the spot afterwards, it was ascertained to be some 600 feet deep.

Before the earthquake which visited Messina in 1783, the ground along the port of that city was perfectly level; after the shock it was found to slope considerably towards the sea, the latter itself getting deeper and deeper as the distance from the shore increased,—an indication that the sloping of the coast continued far under the water, and that accordingly the bottom of the sea must have sunk as well as the shore.

During the same earthquake, many houses in the streets in the town of Terra Nova in Calabria were raised above their usual level, others sank down in the ground. Near the town was a circular tower of solid masonry: part of this tower remained undestroyed, but one side of it was lifted up by the action of the earthquake much above the other, the foundations of the upraised portion being laid bare to the view; though, strange to say, the divided walls were found to adhere throughout as firmly to each other, and to fit as closely, as if they had been so constructed on purpose, and cemented together from the beginning.

Towards the close of last century a remarkable subsidence took place in North America, just above the falls of the Columbia River. In 1807, American travellers found here a forest of pines under water, standing erect in the body of the river.

The most extensive elevation of land by earthquake is that which took place in 1822, on the coast of Chili, South America, in which an area of about 100,000 square miles was raised three, four, six, and seven feet above the former level.

In 1819, a great subsidence of land took place at the mouth of the river Indus in Hindostan, the bed of the river sinking eighteen feet: the sea rushing into the mouth of the Indus, in a few hours converted a tract of land, of some 2000 square miles area, into an inland sea. To the north-west of the subsided district, and running in a parallel direction with it, one of the level plains about this region, some fifty miles in length from east to west, and about sixteen miles wide from north to south, was uniformly raised ten feet above the level of the delta.

We will now dismiss this part of the subject with a mere passing allusion to the well-known changes of level of the celebrated temple of Puzzuoli, near Naples; the rising and sinking of the land in Scandinavia; and submarine forests and raised beaches on the shores of England, France, North America, and other countries; and will conclude this chapter with a few brief remarks about submarine volcanoes and extinct volcanoes.

The subterranean fires, the source and cause of volcanic eruptions and earthquakes, act also on the beds which form the bottom of the sea. When the vents formed by volcanic action lie beneath the waters of the ocean, they are called *submarine volcanoes.* The existence and action of submarine volcanoes, long suspected and conjectured, has since the beginning of this century been clearly proved, by the formation of new islands above the waters of the ocean.

The first well-ascertained instance of the elevation of a new island by a submarine eruption occurred in 1811, near St Michael, in the Azores. Various eruptions had at different times taken place in the neighbourhood. During the latter half of 1810, several minor shocks had been felt; but on the 31st of January and 1st of February 1811, the convulsion reached the highest point, when sulphurous vapours were seen to rise out of the sea, about two miles from the coast, and spread in all directions; jets of flame attended the rising of these vapours, which were speedily followed by columns of volcanic ashes, and other erupted materials: in about eight days this eruption terminated, when it was found that the bottom of the sea, previously from 300 to 500 feet deep in this spot, had been lifted up nearly to a level with the surface of the water. About four months after, on the 13th of June 1811, another eruption took place about two miles and a half from the scene of the former, which reached its greatest violence on the 17th of June, columns of ashes and smoke being whirled up many hundred feet high above the sea. At the close of the eruption an island became visible, which gradually rose to a height of three hundred feet above the sea. Captain Tillard, of the *Sabrina*, visited the island, which he found rather too hot to walk on, and gave it the name of his vessel. It presented at one end a conical hill, and at the other a deep crater, which sent forth jets of flames, though it was under water at full tide. The continued eruptions of hot stones, sand, and ashes from the crater, raised the conical hill at the one side of the island eventually six hundred feet above the sea. However, in the last days of February 1812, the entire island sank into the sea, and disappeared without leaving a vestige behind.

In July 1818, violent spoutings and jettings of steam and water were observed at a spot some thirty miles to the south-west of Sicily, where the sea was known to be 600 feet deep. On the 18th of the month a small island made its appearance, with a burning crater in the centre of it, ejecting ashes, cinders, and thick volumes of smoke, and covering the sea around with floating cinders, and shoals of dead fishes.

The new island rose gradually to an elevation of nearly 200 feet above the sea; it measured about three miles round at the base. The crater, in its centre, constituted a basin 600 feet in diameter, full of dingy red water, boiling.

After having continued above the sea for nearly three months, the island, now generally known in the books by the name of Graham Island, sank gradually back into the sea: towards the end of October it was again nearly on a level with the surface of the water: it disappeared eventually altogether, leaving behind, however, a most dangerous roof of hard volcanic rock, just eleven feet under water, encompassed by shoals, consisting of cinders and sand.

Another volcanic island rose on the coast of Iceland, during the tremendous eruption of Skaptaar Jokul in 1783. This island also, which was called Nyöe, sank afterwards down again into the sea.

Some of these volcanic islands are of a more permanent character; as, for instance, the island of New

Kameni, near Santorin, in the Grecian Archipelago, which was raised up by a submarine volcanic eruption in 1707, and continues to the present day above water.

There are many mountains whose summits and depressions, though now covered with herbage, and in some instances, the sites of villages and cities, bear a close resemblance to the cones and craters of active volcanoes, and whose constituent rocks are decidedly volcanic. Geologists apply to such mountains the term *extinct volcanoes*, which, however, is intended to signify simply that no eruption has taken place from them for ages; but by no means implies that they will never be active again. Mount Vesuvius, which at some geological era had clearly been an active volcano, had slumbered for ages in a state of apparent extinction, when the terrible eruption that buried Herculaneum and Pompeii under a sea of volcanic ashes, revealed once more the true nature of the mountain.

In certain localities are found vents which emit only gaseous exhalations and aqueous vapour. Such vents, or *solfataras*, as they are usually called, are properly looked upon in the light of half-extinct volcanoes, which may at any time suddenly burst forth again with all the terrific violence of true volcanic eruptions.

Extinct volcanoes are found not only in volcanic regions, but also in places presenting, with the exception of hot wells and mineral springs, no traces of volcanic activity within historical periods.

Among extinct volcanoes, those of Central France have attracted most attention. In the districts of Auvergne, Velay, and the Vivarais, there are seen several hundred volcano-shaped conical hills, with more or less perfectly formed craters on their tops. These conical hills are called in the language of the country *Puys*, which means mountain-peaks. They are all of them dome-shaped, varying in height from 500 feet to 2800 feet above the level of the plain from which they rise in an irregular chain, thirty miles in length and two miles in breadth; the plain itself, some forty-five miles long and twenty miles wide, is 1200 feet above the level of the sea.

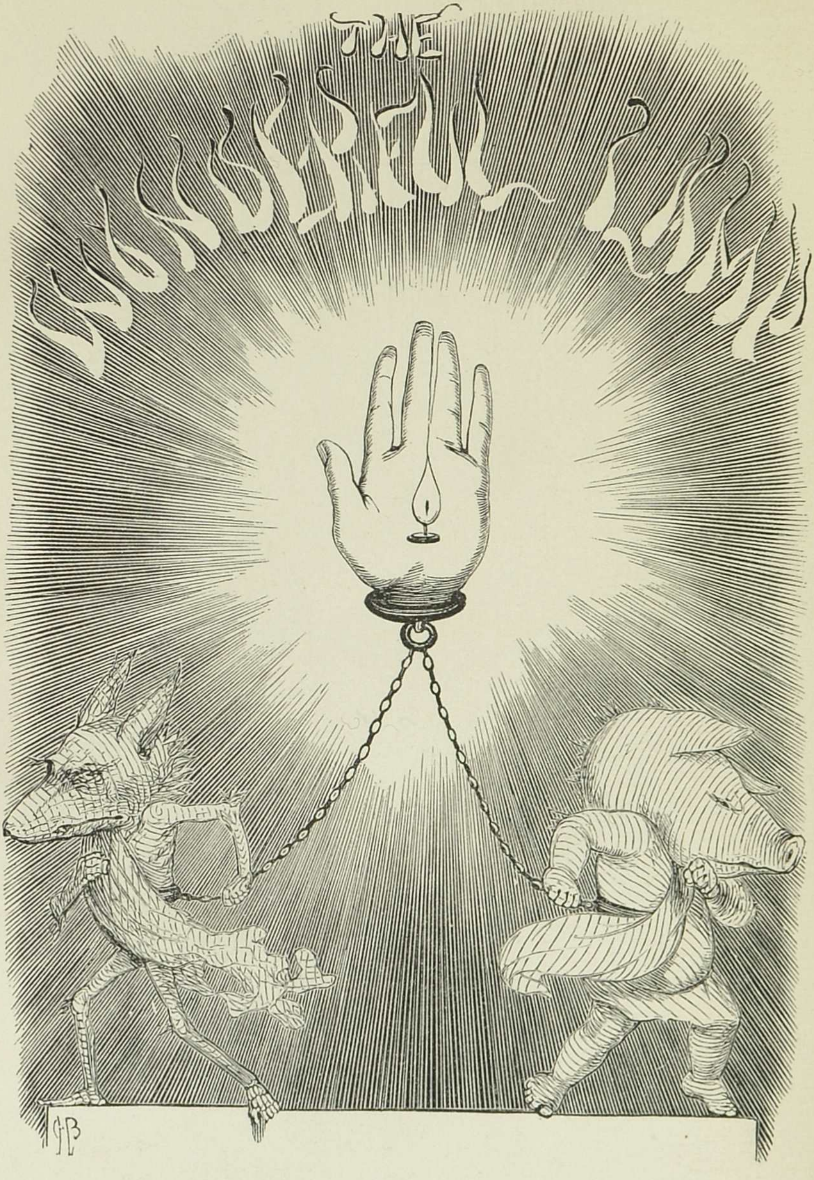
All the cones are formed of volcanic materials, such as lava, sand, and cinders; and in many of them are found well-defined craters. The highest of these is called *Puy de Dome.* It is 4000 feet above the level of the sea: it is composed entirely of volcanic materials, and has a regular crater, measuring fifteen hundred feet round, and three hundred feet deep.

On the top of another of these remarkable cones, called the *Puy de Pariou,* there is a very deep extinct crater, a mile round, which is now closed in, and covered with turf and grass. From the lower part of this conical hill a stream of lava has issued, which lies there now, rugged and black, covering the plain with volcanic cinders to the depth of about twenty feet.

Similar extinct volcanoes are found in the south of Sicily, the neighbourhood of Naples, Hungary, the lower provinces of the Rhine, and the north of Spain.

In England, Scotland, and Ireland, although no such specimens of extinct volcanoes, in the form of hills with cones and craters, are found, yet rocks of volcanic origin abound; and there can be no doubt but that the remarkable basaltic rocks of Staffa and the Giant's Causeway are the productions of an extinct volcano.

The absence of cones and craters, and of streams of cooled lava issuing from the bases of the basaltic hills of the British Isles, is owing simply to the circumstance that the eruption of these volcanoes, in the period of their activity, took place under the bed of the ocean.


THE
WONDERFUL LAMP

The Wonderful Lamp.

'Know the great genius of this land
Has many a light aërial band,
Who, all beneath his high command,
Harmoniously,
As arts or arms they understand,
Their labours ply.'—Burns.

GENII, afrits, and ghouls have long since lost their terrors; but the wonderful stories told about them will continue to charm the youthful mind for centuries to come. Chief among these stories is that of Aladdin, the poor boy, who became the fortunate possessor of a wonderful lamp, which gave him control over a powerful race of genii. By merely rubbing the lamp he summoned these superhuman servants, who waited on him, hand and foot, brought him untold wealth, transported him from place to place, and fulfilled his wildest desires. Upon this beautiful Arabian romance we ground our concluding fairy tale of science.

Our wonderful lamp is merely a poetical image of Science. The lamp of science dispels intellectual darkness, and floods the world with its all-penetrating light. The night-prowling ghouls, Ignorance and Superstition, dare not encounter its glancing rays, and descend shrieking into the abyss; while Industry toils in the glare, and seems to acquire new vigour whenever the flame increases in brilliancy.

The attendant genii of this wonderful lamp are those powers of the material world which have been subjugated by man—the Aladdin of our story.

Among these genii, the almost omnipotent agent Steam ranks first. The miracles wrought by this slave of the lamp transcend all the wonders conceived by the oriental romancists. 'By its agency,' says Dr Lardner, 'coal is made to minister in a variety of ways to the uses of society. By it coals are taught to spin, weave, dye, print, and dress silks, cottons, woollen, and other cloths; to make paper, and print books on it when made; to convert corn into flour; to press oil from the olive and wine from the grape; to draw up metal from the bowels of the earth; to pound and smelt it, to melt and mould it, to forge it, to roll it, and to fashion it into every form that the most wayward caprice can desire. Do we traverse the deep? they lend wings to the ship, and bid defiance to the natural opponents, the winds and the tides! Does the wind-bound ship desire to get out of port to start on her voyage? steam throws its arms around her, and places her in the open sea! Do we traverse the land? steam is harnessed to our chariot, and we outstrip the flight of the swiftest bird, and equal the fury of the tempest!'

We may form an idea of the versatile powers of steam if we consider the manufacture of this volume. It was printed by steam, upon paper made by steam. The rags of which the sheets were formed were woven by steam, their separate threads having been previously spun by steam. Moreover, by steam the types were cast in metal that the same agent had raised from the mine; by steam, too, the mill-board and cloth which form the cover were fabricated, and the thread which fastens the sheets together was twisted.

Many striking illustrations of the power of steam have been given by the author of the passage quoted above. Some of these, slightly altered, we now bring before our reader:—A train of coaches weighing about 80 tons, and transporting 240 passengers with their luggage, has been taken from Liverpool to Birmingham, and back from Birmingham to Liverpool; the trip each way taking about four hours and a quarter, stoppages included. The distance between these places by railway is 95 miles. The double journey of 190 miles was effected by the mechanical force produced in the combustion of four tons of coke, the value of which is about five pounds. To carry the same number of passengers daily between the same places by stage-coaches on a common road, would require twenty coaches and an establishment of 3800 horses, with which the journey in each direction would be performed in about twelve hours, stoppages included.

The circumference of the earth measures some 25,000 miles; if it were begirt with an iron railway, such a train as above described, carrying 240 passengers, would be drawn round it by the combustion of about thirty tons of coke, and the circuit would be accomplished in five weeks.

In the drainage of the Cornish mines, a bushel of coals usually raises 40,000 tons of water a foot high; but it has on some occasions raised 60,000 tons of water the same height. Let us take its labour at 49,000 tons raised one foot high. According to Boulton and Watt, a horse of average strength can draw 125 pounds twenty-four miles in one day; his work is therefore equivalent to 7000 tons raised one foot. A bushel of coals consequently, as used in Cornwall, performs as much labour as a day's work of seven such horses.

The Great Pyramid of Egypt stands upon a base measuring 700 feet each way, and is 500 feet high, its weight being 12,760 millions of pounds. Herodotus states, that in constructing it 100,000 men were constantly employed twenty years. The materials of this Pyramid would be raised from the ground to their present position by the combustion of about 480 tons of coal.

The Menai Bridge consists of about 2000 tons of iron, and its height above the level of the water is 120 feet. Its mass might be lifted from the level of the water to its present position by the combustion of four bushels of coal. The reader will hardly require to be informed that the above illustrations show what might be done by the steam generated during the combustion of certain quantities of coal, provided its entire strength could be applied to the fulfilment of the required results.

Let us now briefly consider some of the achievements of Steam, and other genii, over which man, as the holder of the lamp of science, has absolute control.

Our great iron ships, which rival the wondrous palaces described by the Sultana Scheherazade, could not be constructed without the aid of the slaves of the lamp. The giant Steam forges the huge engine-shafts, rolls the iron plates, and punches the rivet-holes as quickly and as noiselessly as a lady punches card-board for a fancy ornament. Urged by this potent genii, steel shows its mastery over iron in the great lathes and planing machines employed for fashioning the various parts of the ship's engines. Heat, the father of Steam, lends his aid in joining the plates. When the holes in the plates to be held together have been brought into exact opposition, bolts at a white heat are one by one introduced, and firmly riveted by three men, one holding the bolt in its position by placing a hammer against its head on the inside of the ship, whilst the other two with alternate blows produce the rivet-head on the outside. The rivets contract in cooling, and draw the plates together with the force of a vice. Before the *Great Eastern* could swim, no less than two millions of these bolts had to be made secure.

One of the mighty tools used by the giant Steam deserves special notice, as it was called into existence by the agency of the lamp of science. This tool is known by the name of 'Nasmyth's Steam-hammer,' and is now universally used in the manufacture of heavy articles in wrought-iron, such as anchors and large engine-cranks. This machine is a direct-acting steam-engine, in which the cylinder is inverted, and the piston-rod connected with a ponderous mass of iron having a steel face, which impinges on an anvil placed beneath it. The steam-pressure being sufficient to lift the hammer, will, when admitted above the piston, cause it to descend with at least double the accelerating force of gravity; and hence the powerful effect which it is capable of producing. So completely is the tremendous power of this machine within the control of the engineer, that a nut may be cracked on the anvil without bruising the kernel, and the next minute a huge mass of red-hot iron may be flattened.

On all sides we see the subjugated powers of nature, the genii of our wonderful lamp, performing their Cyclopean labours for man's benefit. Here we find them helping him to convert the muddy shores of a great river into a noble embankment. Here we see them boring a tunnel through nearly eight miles of solid rock. Here they are draining a great marsh. In fine, wherever the lamp of science is fed and trimmed, the genii may be seen at work.

We will not attempt to enumerate the great achievements of modern engineers, but will confine our attention to one work which has excited the admiration of the whole civilized globe. We refer to the Britannia Bridge across the Menai Straits.

The deep chasm which separates the Isle of Anglesey from the mainland had long been a serious obstacle to the modern Aladdin, who could not brook the delay which attended the use of ferry-boats. He could not rest satisfied until he had bridged-over the intervening strip of sea; and he therefore summoned the potent genii of the lamp, who helped him to form a magical roadway in mid-air. This cobweb-like structure is known as the Suspension Bridge of Telford. In course of time, however, Aladdin began to wish for a more substantial fabric, across which he might urge his steam-drawn chariot. To obtain such a bridge as he desired, he sought the aid of a potent magician, who had long been famed for his power over the genii of the lamp.

In plain language, a railway bridge across the Menai Straits was required, and its construction was left to Mr Robert Stephenson.

The twelve labours of Hercules were insignificant tasks compared with that which the railway authorities set before the great engineer, perfectly satisfied that he would accomplish it by some means or other. Yet the difficulties which Stephenson had to contend with seemed insurmountable, and a less daring genius would have shrunk from encountering them.

Those captive princesses of fairy lore who were doomed to draw water from a well without a bucket, to catch fish without a net, and to spin a thread without either wheel or distaff, were not more unfortunately situated than was Robert Stephenson, though he has never yet been made the hero of a romantic story.

'You must build a bridge,' said his employers, 'that the heaviest trains may pass over in safety at any speed. This bridge may have any form you please; but we wish you to remember, that its rupture would be attended with most disastrous consequences, and we therefore urge upon you the necessity of making it strong enough to resist every strain.'

'If you build a railway bridge across the Straits,' said the Lords of the Admiralty, 'you must not interfere with the navigation. Your viaduct must be at least one hundred feet above the level of the water, so that ships may pass beneath, and it must be constructed without the aid of scaffolding.'

Even the elements seemed to set their face against the proposed bridge. The Straits are above twelve miles in length, the shores throughout being rocky and precipitous. The water that fills the passage is never at rest, and the fall of the tide is from twenty to twenty-five feet. Moreover, the wind blows through the Straits with such violence that a bridge must be strong indeed to withstand its rude shocks.

Imagine an enchanted engineer with such a task before him as the construction of a bridge a hundred feet above the tumultuous waters, without scaffolding of any kind, and you will be able to get a faint idea of the difficulties which he had to overcome before a railway train could pass from Carnarvon to Anglesey.

We will not allude to the various plans which Stephenson conceived and discarded before the idea of a tubular bridge took possession of his mind. This last project, destined to prove so successful, has been well compared to a beam along which a man scrambles when escaping from a fire. Stephenson was bent upon crossing the Straits; but as he could not build an ordinary bridge, when under such extraordinary restrictions, he resolved to span the waters with a huge makeshift, in the shape of a hollow beam of iron. Each tube of the Britannia Bridge is literally a beam, so constructed that it combines the maximum of strength with the minimum of weight; in other words, it is a beam from which every portion of metal that does not add to its strength has been carefully removed.

We will now endeavour to explain the simple principle upon which a beam, whether of wood or iron, is enabled to support the weight imposed upon it.

For want of a few moments' reflection, most people, in looking up at a common ceiling-girder, consider that its upper and lower parts suffer equally in bearing the weight of the roof; but these upper and lower strata suffer from causes as diametrically opposite to each other as the climates of the pole and of the equator. The top of the beam throughout its whole length suffers from severe compression, the bottom from severe extension; and thus, while the particles of the one are violently jammed together, the particles of the other are on the point of separation: in short, the difference between the two is precisely that which exists between the opposite punishments of vertically crushing a man to death under a heavy weight, and of horizontally tearing him to pieces by horses.

This theory, confused as it may appear in words, can at once be simply and most beautifully illustrated by any small straight stick freshly cut from a living shrub.

In its natural form the bark or rind around the stick is equally smooth throughout; but if the little bough, held firmly in each hand, be bent downwards so as to form a bow, or in other words to represent a beam under heavy pressure, two opposite results will instantly appear. The rind in the centre of the upper part of this stick will be crumpled up, while that on the opposite side will be severely distended; thus denoting, or rather demonstrating, what we have stated—namely, that beneath the rind, the wood of the upper part of the stick is severely compressed, while that underneath is as violently stretched ; indeed, if we continue to bend the bow until it breaks, the splinters of the upper fracture will be seen to interlace or cross each other, while those beneath will be divorced by a chasm.

But it is evident, on reflection, that these opposite results of compression and extension must, as they approach each other, respectively diminish in degree, until in the middle of the beam, termed by mathematicians its neutral axis, the two antagonist forces, like the celebrated Kilkenny cats, destroy each other. It therefore appears that the main strength of a beam consists in its power to resist compression and extension, and that the middle is comparatively useless, so that to obtain the greatest amount of strength, the given quantity of material to be used should be accumulated at the top and bottom, where the strain is greatest; or, in plain terms, the middle of the beam, whether of wood or iron, should be bored out. All iron girders, all beams in houses,—in fact all things in domestic or naval architecture that bear weight,—are subject to the same law.

A hollow beam of iron having been fixed upon as the form which the projected bridge should take, an extensive series of experiments were undertaken with a view to ascertain the shape capable of sustaining the greatest weight. A rectangular tube, with a height considerably greater than its breadth, and strengthened at the top and bottom, was eventually selected. The genii of the lamp were now set to work, and the quiet folk of North Wales were disturbed by the din of an unfamiliar industry. The principal tubes were constructed on piles at high-water mark, and were formed of wrought-iron plates riveted together with white-hot iron bolts.

A system of longitudinal tubes or cells gave the required strength to the top and bottom of each fabric, these cells being quite as effectual as solid metal. Every means was taken to make the tubes as light as possible, as it was known that the strength of the bridge depended on its lightness. This fact sounds rather paradoxical; but if the reader will reflect a moment, he will find that a bridge has to support itself, as well as the things passing over it. A beam of solid iron, of the dimensions of the Britannia Bridge, would be useless if placed across the Straits, as it would infallibly break down under the enormous pressure of its own weight. Stephenson's beam, as we have already intimated, has all the elements of strength, but none of the elements of weakness of a common beam.

While the monster tubes were being constructed, the masons were heaping up sandstone and marble into the huge piers upon which they were to rest. The central pier or tower was built upon a little rock in the middle of the stream. This rock, which was only exposed at low water, had long been a trouble to sailors and nothing else; but it is now world-famous as the Britannia Rock, the chief support of Stephenson's magic aërial galleries. Two other piers were constructed, one on the Anglesey and the other on the Carnarvon shore, each at a distance of 472 feet from the Britannia tower.

The bridge was to consist of two tubes, placed side by side, one for the down and the other for the up trains. Each tube was formed in four lengths, and when completed these lengths had to be joined together, like the pieces of a huge dissected puzzle. A huge puzzle indeed! When these immense tubes were finished, how could they be thrown across the Straits a hundred feet above the level of the water? The reader will open his eyes in astonishment when we inform him that the four principal tubes, each 472 feet in length, were *floated* into the centre of the Strait, and then *pumped* up to their present elevated position. Said we not that science had brought the powers of nature under man's control—that the genii of the lamp had become the willing slaves of the modern Aladdin?

Each tube was supported on pontoons,—huge life-buoys if you will,—and dragged from its resting-place by chains connected with a monster windlass stationed on the opposite bank. This operation was performed at high-tide; and when the water sank, the delighted spectators beheld the tube resting in its proper position, between its two towers. We need scarcely say that we refer to the direction of the tube, but not to its height, when we here speak of its proper position. The mass of iron had yet to be lifted high into the air.

Among the genii of the lamp there is one called Fluid Pressure, and to this power the task of raising the tubes was committed. The hydraulic-press gave direction to the mighty efforts of this genius. This engine consists essentially of a strong metallic cylinder, in which is inserted a solid piston or ram, and a pump, by means of which water can be forced into the main cylinder. Many of these machines were employed in raising the different lengths of the bridge; but one of them deserves particular mention on account of its stupendous magnitude.

The cylinder of this Cyclopean engine was nine feet long, twenty-two inches in internal diameter, ten inches thick, and weighed fifteen tons. Allowing for the waste, twenty-two tons of fluid incandescent iron were required for this enormous casting. After having been left for seventy-two hours in the mould in which it was cast, the mould was detached from it. It was still red-hot! It was then left to cool, but it was ten days before it was sufficiently cool to be approached by operatives well-inured to heat, in order to detach from it some of the sand of the mould which still adhered to it.

This vast machine was fixed upon an iron stage, near the summit of one of the towers, and to the cross-head of the ram were attached massive chains, which descended to the level of the water, and embraced the tube to be raised.

The greatest weight lifted by the press was 1144 tons, but it was capable of raising 2000 tons. The quantity of water injected into the great cylinder, in order to raise the ram six feet, was 81½ gallons. When a lift of six feet was effected, the lifting chains were seized by a set of clamps, under the lowest point to which the cross-head descended, and while they were thus held suspended, the water was discharged from the great cylinder, and the ram, with its cross-head, made to descend. Meanwhile, the lengths of the chain above the clamps were removed, and the chains thus shortened attached to the cross-head by other clamps, and all was prepared for another lift. In the practical operation of the machine, each lift of six feet occupied from thirty to forty-five minutes.[1]

The towers were formed of three massive piers of solid masonry, so that each tube just filled up the space between the inner and an outer pier. As the tubes were elevated by the action of the press, the vacant spaces beneath were closely packed with blocks of wood. It was very fortunate that this course was adopted, as an accident occurred which must have resulted in the destruction of one of the tubes had the packing process been omitted. The water contained in one of the presses, not content with lifting the tube, thought fit to make a display of its power by thrusting the bottom out of the cylinder, thereby killing an unfortunate workman.

[1] Dr Lardner.

The monster tube *fell one inch*, but was prevented from falling any farther by the packing beneath; had it fallen six feet, it would have been shivered into atoms.

When all the tubes were elevated to their permanent position the great work was completed, and Aladdin gazed at the new wonder with delighted eyes. These aërial galleries, nearly fifteen hundred feet in length, are marvellously strong, each being capable of bearing, spread over its whole surface, the enormous weight of 4000 tons—a weight nine times greater than it can ever be required to sustain. The hollow beam is not deflected more than an inch from the horizontal line by the passage of the heaviest luggage-train, and it is scarcely affected at all by the highest wind.

The enchanted engineer, whom we whilom saw beset with difficulties of no ordinary kind, can now point to the twin tubes across the Menai Straits, and say proudly, 'My task is performed; the bridge has been constructed without scaffolding; and little Mona is no longer separated from her mighty sister.'

We need scarcely say that the engineer is treated quite as badly as the ogre-guarded princess; for no sooner has he performed one task, than the ogre called 'Nineteenth Century' finds him another still more impossible to all appearances than the last.

Let us not forget that although the human mind may plan a Britannia Bridge or a *Great Eastern*, the human hands could never construct such wonderful fabrics without the assistance of those mighty powers of the material world which man, by industry and patient observation, has succeeded in enslaving. Steam, heat, light, electricity—indeed, every agent that is known to exert power in the natural world, can be made to labour in the world of art. These forces, then, are the genii that attend the lamp of science. This lamp, like that of Aladdin, must be rubbed before the genii will appear; in plain language, science will not reveal its mighty powers unless the student works diligently.

Our artist has pictured the lamp of science as a luminous hand. What is the meaning of this curious emblem? Reflect for a moment, and you will detect a deep truth hidden in this fancy. Science, dear reader, is the magical hand that points out truth and strikes down falsehood; and, more than that, it is the magical hand which fashions the crude materials of the world in objects of beauty, which constructs and moves all kinds of machinery, which performs Herculean feats of strength, and executes works of marvellous delicacy.

But what has science to do with the wolf and the hog at the bottom of the emblem? Nothing indeed, except to keep them out of mischief! The wolf stands for the lawless man, who preys upon his fellow-mortals and lives by crime; the hog for the ignorant glutton, who wallows in the mire of indolence, devouring everything that comes in his way. We trust that these brutes in human form will one day become extinct, and that the chains which depend from our wonderful lamp will be no longer needed: at present, however, it is absolutely necessary to restrain the wolf from interfering with those who labour in the light of science, and the hog from devouring their well-earned food.

Having thus 'pointed a moral' in the emblem that 'adorns our concluding tale,' we have now to bid the reader farewell.

An unpleasant task is the leave-taking, dear reader. We have journeyed together for some time, and now we feel as though we were parting from an old friend. We have treated you very rudely, we fear. We have dragged you hither and thither, without once asking you whether you liked such wandering habits. We have led you through the ancient forests; have soared with you to the confines of space; have plunged with you into the sea; and, in fine, have taken you everywhere. We trust that you bear us no malice, and will not think that time wasted which was spent in listening to our FAIRY TALES OF SCIENCE.

THE END.

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