THE SEVEN FOLLIES OF SCIENCE

To which is added a Small Budget of Interesting Paradoxes, Illusions, Marvels, and Popular Fallacies.

A

POPULAR ACCOUNT OF THE MOST FAMOUS

SCIENTIFIC IMPOSSIBILITIES

AND THE ATTEMPTS WHICH HAVE BEEN MADE TO SOLVE THEM.

WITH NUMEROUS ILLUSTRATIONS

BY

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PREFACE

In the following pages I have endeavored to give a simple account of problems which have occupied the attention of the human mind ever since the dawn of civilization, and which can never lose their interest until time shall be no more. While to most persons these subjects will have but an historical interest, yet even from this point of view they are of more value than the history of empires, for they are the intellectual battlefields upon which much of our progress in science has been won. To a few, however, some of them may be of actual practical importance, for although the schoolmaster has been abroad for these many years, it is an unfortunate fact that the circle-squarer and the perpetual-motion-seeker have not ceased out of the land.

In these days of almost miraculous progress it is difficult to realize that there may be such a thing as a scientific impossibility. I have therefore endeavored to point out where the line must be drawn, and by way of illustration I have added a few curious paradoxes and marvels, some of which show apparent contradictions to known laws of nature, but which are all simply and easily explained when we understand the fundamental principles which govern each case.

In presenting the various subjects which are here discussed, I have endeavored to use the simplest language and to avoid entirely the use of mathematical formulae, for

I know by large experience that these are the bugbear of the ordinary reader, for whom this volume is specially intended. Therefore I have endeavored to state everything in such a simple manner that any one with a mere common school education can understand it. This, I trust, will explain the absence of everything which requires the use of anything higher than the simple rules of arithmetic and the most elementary propositions of geometry. And even this I have found to be enough for many lawyers, physicians, and clergymen who, in the ardent pursuit of their professions, have forgotten much that they learned at college. And as I hope to find many readers amongst intelligent mechanics, I have in some cases suggested mechanical proofs which any expert handler of tools can easily carry out.

As a matter of course, very little originality is claimed for anything in the book, — the only points that are new being a few illustrations of well-known principles, some of which had already appeared in "The Young Scientist" and "Self-education for Mechanics." Whenever the exact words of an author have been used, credit has always been given; but in regard to general statements and ideas, I must rest content with naming the books from which I have derived the greatest assistance. Ozanam's "Recreations in Science and Natural Philosophy," in the editions of Hutton (1803) and Riddle (1854), has been a storehouse of matter. Much has been gleaned from the "Budget of Paradoxes" by Professor De Morgan and also from Professor W. W. R. Ball's "Mathematical Recreations and Problems." Those who wish to inform themselves in regard to what has been done by the perpetual-motion-mongers must consult Mr. Dirck's two volumes entitled "Perpetuum

Mobile" and I have made free use of his labors. To these and one or two others I acknowledge unlimited credit.

Some of the marvels which are here described, although very old, are not generally known, and as they are easily put in practice they may afford a pleasant hour's amusement to the reader and his friends.

JOHN PHIN

Paterson, N. J., July, 1905.

PREFACE TO SECOND EDITION

THE notable favor with which the first edition of this work has been received has encouraged the author to enlarge it by the addition of some new problems and the discussion of an entirely new department of popular misconception and error. The numerous personal letters which he has received convince him that a book which gave a simple and popular view of the old so-called "scientific impossibilities" was needed, for very many of those who had heard of the problems discussed in these pages had the most erroneous ideas as to their real nature, although the principles involved in most of them are the foundation of almost all our scientific knowledge.

And so the author hopes that the subjects which have been added to this edition will be as useful and as interesting as those already presented.

JOHN PHIN

Paterson, N. J., March 20, 1911.

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THE SEVEN FOLLIES OF SCIENCE

THE difficult, the dangerous, and the impossible have always had a strange fascination for the human mind. We see this every day in the acts of boys who risk life and limb in the performance of useless but dangerous feats, and amongst children of larger growth we find loop-the-loopers, bridge-jumpers, and all sorts of venture-seekers to whom much of the attraction of these performances is undoubtedly the mere risk that is involved, although, perhaps, to some extent, notoriety and money-making may contribute their share. Many of our readers will doubtless remember the words of James Fitz-James, in "The Lady of the Lake":

> Or, if a path be dangerous known
> The danger's self is lure alone.

And in commenting on the old-time game laws of England, Froude, the historian, says: "Although the old forest laws were terrible, they served only to enhance the excitement by danger."

That which is true of physical dangers holds equally true in regard to intellectual difficulties. Professor De Morgan tells us, in his "Budget of Paradoxes," that he once gave a lecture on "Squaring the Circle" and that a gentleman who was introduced to it by what he said, remarked loud enough to be heard by all around: "Only prove to me that it is impossible and I will set about it this very evening."

Therefore it is not to be wondered at that certain very difficult, or perhaps impossible problems have in all ages had a powerful fascination for certain minds. In that curious *olla podrida* of fact and fiction, "The Curiosities of Literature," D'Israeli gives a list of six of these problems, which he calls "The Six Follies of Science." I do not know whether the phrase "Follies of Science" originated with him or not, but he enumerates the Quadrature of the Circle; the Duplication, or, as he calls it, the Multiplication of the Cube; the Perpetual Motion; the Philosophical Stone; Magic, and Judicial Astrology, as those known to him. This list, however, has no classical standing such as pertains to the "Seven Wonders of the World," the "Seven Wise Men of Greece," the "Seven Champions of Christendom," and others. There are some well-known follies that are omitted, while some authorities would peremptorily reject Magic and Judicial Astrology as being attempts at fraud rather than earnest efforts to discover and utilize the secrets of nature. The generally accepted list is as follows:

1. The Quadrature of the Circle or, as it is called in the vernacular, "Squaring the Circle."
2. The Duplication of the Cube.
3. The Trisection of an Angle.
4. Perpetual Motion.
5. The Transmutation of the Metals.
6. The Fixation of Mercury.
7. The Elixir of Life.

The Transmutation of the Metals, the Fixation of Mercury, and the Elixir of Life might perhaps be properly classed as one, under the head of the Philosopher's Stone, and then Astrology and Magic might come in to make up the mystic number Seven.

The expression "Follies of Science" does not seem a very appropriate one. Real science has no follies. Neither can these vain attempts be called *scientific* follies because their very essence is that they are unscientific. Each one is really a veritable "Will-o'-the-Wisp" for unscientific thinkers, and there are many more of them than those that we have here named. But the expression has been adopted in literature and it is just as well to accept it. Those on the list that we have given are the ones that have become famous in history and they still engage the attention of a certain class of minds. It is only a few months since a man who claims to be a professional architect and technical writer put forth an alleged method of "squaring the circle," which he claims to be "exact"; and the results of an attempt to make liquid air a pathway to perpetual motion are still in evidence, as a minus quantity, in the pockets of many who believed that all things are possible to modern science. And indeed it is this false idea of the possibility of the impossible that leads astray the followers of these false lights. Inventive science has accomplished so much — many of her achievements being so astounding that they would certainly have seemed miracles to the most intelligent men of a few generations ago — that the ordinary mind cannot see the difference between unknown possibilities and those things which well-established science pronounces to be impossible, because they contradict fundamental laws which are thoroughly established and well understood.

Thus any one who would claim that he could make a plane triangle in which the three angles would measure more than two right angles, would show by this very claim that he was entirely ignorant of the first principles of geometry. The same would be true of the man who would claim that he could give, in exact figures, the diagonal of a square of which the side is exactly one foot or one yard, and it is also true of the man who claims that he can give the exact area of a circle of which either the circumference or the diameter is known with precision. That they cannot both be known exactly is very well understood by all who have studied the subject, but that the area, the circumference, and the diameter of a circle may all be known with an exactitude which is far in excess of anything of which the human mind can form the least conception, is quite true, as we shall show when we come to consider the subject in its proper place.

These problems are not only interesting historically but they are valuable as illustrating the vagaries of the human mind and the difficulties with which the early investigators had to contend. They also show us the barriers over which we cannot pass, and they enforce the immutable character of the natural laws which govern the world around us. We hear much of the progress of science and of the changes which this progress has brought about, but these changes never affect the fundamental facts and principles upon which all true science is based. Theories and explanations and even practical applications change or pass away, so that we know them no more, but nature remains the same throughout the ages. No new theory of electricity can ever take away from the voltaic battery its power, or change it in any respect, and no new discovery in regard to the constitution of matter can ever lessen the eagerness with which carbon and oxygen combine together. Every little while we hear of some discovery that is going to upset all our preconceived notions and entirely change those laws which long experience has proved to be invariable, but in every case these alleged discoveries have turned out to be fallacies. For example, the wonderful properties of radium have led some enthusiasts to adopt the idea that many of our old notions about the conservation of energy must be abandoned, but when all the facts are carefully examined it is found that there is no rational basis for such views. Upon this point Sir Oliver Lodge says:

"There is absolutely no ground for the popular and gratuitous surmise that radium emits energy without loss or waste of any kind, and that it is competent to go on forever. The idea, at one time irresponsibly mooted, that it contradicted the principle of the conservation of energy, and was troubling physicists with the idea that they must overhaul their theories — a thing which they ought always to be delighted to do on good evidence — this idea was a gratuitous absurdity, and never had the slightest foundation. It is reasonable to suppose, however, that radium and the other like substances are drawing upon their own stores of internal atomic energy, and thereby gradually disintegrating and falling into other and ultimately more stable forms of matter."

One would naturally suppose that the extensive diffusion of sound scientific knowledge which has taken place during the century just past, would have placed these problems amongst the lumber of past ages; but it seems that some of them, particularly the squaring of the circle and perpetual motion, still occupy considerable space in the attention of the world, and even the futile chase after the

"Elixir of Life" has not been entirely abandoned. Indeed certain professors who occupy prominent official positions, assert that they have made great progress towards its attainment. In view of such facts one is almost driven to accept the humorous explanation which De Morgan has offered and which he bases on an old legend relating to the famous wizard, Michael Scott. The generally accepted tradition, as related by Sir Walter Scott in his notes to the "Lay of the Last Minstrel," is as follows:

"Michael Scott was, once upon a time, much embarrassed by a spirit for whom he was under the necessity of finding constant employment. He commanded him to build a 'cauld,' or dam head across the Tweed at Kelso; it was accomplished in one night, and still does honor to the infernal architect. Michael next ordered that Eildon Hill, which was then a uniform cone, should be divided into three. Another night was sufficient to part its summit into the three picturesque peaks which it now bears. At length the enchanter conquered this indefatigable demon, by employing him in the hopeless task of making ropes out of sea-sand."

Whereupon De Morgan offers the following exceedingly interesting continuation of the legend:

"The recorded story is that Michael Scott, being bound by contract to procure perpetual employment for a number of young demons, was worried out of his life in inventing jobs for them, until at last he set them to make ropes out of sea-sand, which they never could do. We have obtained a very curious correspondence between the wizard Michael and his demon slaves; but we do not feel at liberty to say how it came into our hands. We much regret that we did not receive it in time for the British Association. It appears that the story, true as far as it goes, was never finished. The demons easily conquered the rope difficulty, by the simple process of making the sand into glass, and

spinning the glass into thread which they twisted. Michael, thoroughly disconcerted, hit upon the plan of setting some to square the circle, others to find the perpetual motion, etc. He commanded each of them to transmigrate from one human body into another, until their tasks were done. This explains the whole succession of cyclometers and all the heroes of the Budget. Some of this correspondence is very recent; it is much blotted, and we are not quite sure of its meaning. It is full of figurative allusions to driving something illegible down a steep into the sea. It looks like a humble petition to be allowed some diversion in the intervals of transmigration; and the answer is:

" 'Rumpat et serpens iter institutum'

a line of Horace, which the demons interpret as a direction to come athwart the proceedings of the Institute by a sly trick."

And really those who have followed carefully the history of the men who have claimed that they had solved these famous problems, will be almost inclined to accept De Morgan's ingenious explanation as something more than a mere "skit." The whole history of the philosopher's stone, of machines and contrivances for obtaining perpetual motion, and of circle-squaring, is permeated with accounts of the most gross and obvious frauds. That ignorance played an important part in the conduct of many who have put forth schemes based upon these pretended solutions is no doubt true, but that a deliberate attempt at absolute fraud was the mainspring in many cases cannot be denied. Like *Dousterswivel* in "The Antiquary," many of the men who advocated these delusions may have had a sneaking suspicion that there might be some truth in the doctrines which they promulgated; but most of them knew that their particular claims were groundless, and that they were put forward for the purpose of deceiving some confiding patron from whom they expected either money or the credit and glory of having done that which had been hitherto considered impossible.

Some of the questions here discussed have been called "scientific impossibilities" — an epithet which many have considered entirely inapplicable to any problem, on the ground that all things are possible to science. And in view of the wonderful things that have been accomplished in the past, some of my readers may well ask: "Who shall decide when doctors disagree?"

Perhaps the best answer to this question is that given by Ozanam, the old historian of these and many other scientific puzzles. He claimed that "it was the business of the Doctors of the Sorbonne to discuss, of the Pope to decide, and of a mathematician to go straight to heaven in a perpendicular line!"

In this connection the words of De Morgan have a deep significance. Alluding to the difficulty of preventing men of no authority from setting up false pretensions and the impossibility of destroying the assertions of fancy speculation, he says: "Many an error of thought and learning has fallen before a gradual growth of thoughtful and learned opposition. But such things as the quadrature of the circle, etc., are never put down. And why? Because thought can influence thought, but thought cannot influence self-conceit; learning can annihilate learning; but learning cannot annihilate ignorance. A sword may cut through an iron bar, and the severed ends will not reunite; let it go through the air, and the yielding substance is whole again in a moment."

I.

SQUARING THE CIRCLE

UNDOUBTEDLY one of the reasons why this problem has received so much attention from those whose minds certainly have no special leaning towards mathematics, lies in the fact that there is a general impression abroad that the governments of Great Britain and France have offered large rewards for its solution. De Morgan tells of a Jesuit who came all the way from South America, bringing with him a quadrature of the circle and a newspaper cutting announcing that a reward was ready for the discovery in England. As a matter of fact his method of solving the problem was worthless, and even if it had been valuable, there would have been no reward.

Another case was that of an agricultural laborer who spent his hard-earned savings on a journey to London, carrying with him an alleged solution of the problem, and who demanded from the Lord Chancellor the sum of one hundred thousand pounds, which he claimed to be the amount of the reward offered and which he desired should be handed over forthwith. When he failed to get the money he and his friends were highly indignant and insisted that the influence of the clergy had deprived the poor man of his just deserts!

And it is related that in the year 1788, one of these deluded individuals, a M. de Vausenville, actually brought an action against the French Academy of Sciences to recover a reward to which he felt himself entitled. It ought to be needless to say that there never was a reward offered for the solution of this or any other of the problems which are discussed in this volume. Upon this point De Morgan has the following remarks:

"Montucla says, speaking of France, that he finds three notions prevalent among the cyclometers [or circle-squarers]: 1. That there is a large reward offered for success; 2. That the longitude problem depends on that success; 3. That the solution is the great end and object of geometry. The same three notions are equally prevalent among the same class in England. No reward has ever been offered by the government of either country. The longitude problem in no way depends upon perfect solution; existing approximations are sufficient to a point of accuracy far beyond what can be wanted. And geometry, content with what exists, has long pressed on to other matters. Sometimes a cyclometer persuades a skipper, who has made land in the wrong place, that the astronomers are in fault for using a wrong measure of the circle; and the skipper thinks it a very comfortable solution! And this is the utmost that the problem ever has to do with longitude."

In the year 1775 the Royal Academy of Sciences of Paris passed a resolution not to entertain communications which claimed to give solutions of any of the following problems: The duplication of the cube, the trisection of an angle, the quadrature of a circle, or any machine announced as showing perpetual motion. And we have heard that the Royal Society of London passed similar resolutions, but of course in the case of neither society did these resolutions exclude legitimate mathematical investigations — the famous computations of Mr. Shanks, to which we shall have occasion to refer hereafter, were submitted to the Royal Society of London and published in their Transactions. Attempts to "square the circle," when made intelligently, were not only commendable but have been productive of the most valuable results. At the same time there is no problem, with the possible exception of that of perpetual motion, that has caused more waste of time and effort on the part of those who have attempted its solution, and who have in almost all cases been ignorant both of the nature of the problem and of the results which have been already attained. From Archimedes down to the present time some of the ablest mathematicians have occupied themselves with the quadrature, or, as it is called in common language, "the squaring of the circle"; but these men are not to be placed in the same class with those to whom the term "circle-squarers" is generally applied.

As already noted, the great difficulty with most circle-squarers is that they are ignorant both of the nature of the problem to be solved and of the results which have been already attained. Sometimes we see it explained as the drawing of a square inside a circle and at other times as the drawing of a square around a circle, but both these problems are amongst the very simplest in practical geometry, the solutions being given in the sixth and seventh propositions of the Fourth Book of Euclid. Other definitions have been given, some of them quite absurd. Thus in France, in 1753, M. de Causans, of the Guards, cut a circular piece of turf, squared it, and from the result deduced original sin and the Trinity. He found out that the circle was equal to the square in which it is inscribed, and he offered a reward for the detection of any error, and actually deposited 10,000 francs as earnest of 300,000. But the courts would not allow any one to recover.

In the last number of the Athenæum for 1855 a correspondent says "the thing is no longer a *problem* but an *axiom*." He makes the square equal to a circle by making each side equal to a quarter of the circumference. As De Morgan says, he does not know that the area of the circle is greater than that of any other figure of the same circuit.

Such ideas are evidently akin to the poetic notion of the quadrature. Aristophanes, in the "Birds," introduces a geometer, who announces his intention to make a *square circle*. And Pope in the "Dunciad" delivers himself as follows:

> Mad Mathesis alone was unconfined,
> Too mad for mere material chains to bind,—
> Now to pure space lifts her ecstatic stare,
> Now, running round the circle, finds it square.

The author's note explains that this "regards the wild and fruitless attempts of squaring the circle." The poetic idea seems to be that the geometers try to make a square circle.

As stated by all recognized authorities, the problem is this: To describe a square which shall be exactly equal in area to a given circle.

The solution of this problem may be given in two ways: (1) the arithmetical method, by which the area of a circle is found and expressed numerically in square measure, and (2) the geometrical quadrature, by which a square, equal in area to a given circle, is described by means of rule and compasses alone.

Of course, if we know the area of the circle, it is easy to find the side of a square of equal area; this can be done by simply extracting the square root of the area, provided the number is one of which it is possible to extract the square root. Thus, if we have a circle which contains 100 square feet, a square with sides of 10 feet would be exactly equal to it. But the ascertaining of the area of the circle is the very point where the difficulty comes in; the dimensions of circles are usually stated in the lengths of the diameters, and when this is the case, the problem resolves itself into another, which is: To find the area of a circle when the diameter is given.

Now Archimedes proved that the area of any circle is equal to that of a triangle whose base has the same length as the circumference and whose altitude or height is equal to the radius. Therefore if we can find the length of the circumference when the diameter is given, we are in possession of all the points needed to enable us to "square the circle."

In this form the problem is known to mathematicians as that of the rectification of the curve.

In a practical form this problem must have presented itself to intelligent workmen at a very early stage in the progress of operative mechanics. Architects, builders, blacksmiths, and the makers of chariot wheels and vessels of various kinds must have had occasion to compare the diameters and circumferences of round articles. Thus in I Kings, vii, 23, it is said of Hiram of Tyre that "he made a molten sea, ten cubits from the one brim to the other; it was round all about * * * and a line of thirty cubits did compass it round about," from which it has been inferred that among the Jews, at that time, the accepted ratio was 3 to 1, and perhaps, with the crude measuring instruments of that age, this was as near as could be expected. And this ratio seems to have been accepted by the Babylonians, the Chinese, and probably also by the Greeks, in the earliest times. At the same time we must not forget that these statements in regard to the ratio come to us through historians and prophets, and may not have been the figures used by trained mechanics. An error of one foot in a hoop made to go round a tub or cistern of seven feet in diameter, would hardly be tolerated even in an apprentice.

The Egyptians seem to have reached a closer approximation, for from a calculation in the Rhind papyrus, the ratio of 3.16 to 1 seems to have been at one time in use. It is probable, however, that in these early times the ratio accepted by mechanics in general was determined by actual measurement, and this, as we shall see hereafter, is quite capable of giving results accurate to the second fractional place, even with very common apparatus.

To Archimedes, however, is generally accorded the credit of the first attempt to solve the problem in a scientific manner; he took the circumference of the circle as intermediate between the perimeters of the inscribed and the circumscribed polygons, and reached the conclusion that the ratio lay between $3\frac{1}{7}$ and $3\frac{10}{71}$, or between 3.1428 and 3.1408.

This ratio, in its more accurate form of 3.141592 . . is now known by the Greek letter π (pronounced like the common word *pie*), a symbol which was introduced by Euler, between 1737 and 1748, and which is now adopted all over the world. I have, however, used the term ratio, or value of the ratio instead, throughout this chapter, as probably being more familiar to my readers.

Professor Muir justly says of this achievement of Archimedes, that it is "a most notable piece of work; the immature condition of arithmetic, at the time, was the only real obstacle preventing the evaluation of the ratio to any degree of accuracy whatever."

And when we remember that neither the numerals now in use nor the Arabic numerals, as they are usually called, nor any system equivalent to our decimal system, was known to these early mathematicians, such a calculation as that made by Archimedes was a wonderful feat.

If any of my readers, who are familiar with the Hebrew or Greek numbers, and the mode of representing them by letters, will try to do any of those more elaborate sums which, when worked out by modern methods, are mere child's play in the hands of any of the bright scholars in our common schools, they will fully appreciate the difficulties under which Archimedes labored.

Or, if ignorant of Greek and Hebrew, let them try it with the Roman numerals, and multiply XCVIII by MDLVII, without using Arabic or common numerals. Professor McArthur, in his article on "Arithmetic" in the Encyclopædia Britannica, makes the following statement on this point:

"The methods that preceded the adoption of the Arabic numerals were all comparatively unwieldy, and very simple processes involved great labor. The notation of the Romans, in particular, could adapt itself so ill to arithmetical operations, that nearly all their calculations had to be made by the abacus. One of the best and most manageable of the ancient systems is the Greek, though that, too, is very clumsy."

After Archimedes, the most notable result was that given by Ptolemy, in the "Great Syntaxis." He made the ratio 3.141552, which was a very close approximation.

For several centuries there was little progress towards a more accurate determination of the ratio. Among the Hindoos, as early as the sixth century, the now well-known value, 3.1416, had been obtained by Arya-Bhata, and a little later another of their mathematicians came to the conclusion that the square root of 10 was the true value of the ratio. He was led to this by calculating the perimeters of the successive inscribed polygons of 12, 24, 48, and 96 sides, and finding that the greater the number of sides the nearer the perimeter of the polygon approached the square root of 10. He therefore thought that the perimeter or circumference of the circle itself would be the square root of exactly 10. It is too great, however, being 3.1622 instead of 3.14159. . . The same idea is attributed to Bovillus, by Montucla.

By calculating the perimeters of the inscribed and circumscribed polygons, Vieta (1579) carried his approximation to ten fractional places, and in 1585 Peter Metius, the father of Adrian, by a lucky step reached the now famous fraction $\frac{355}{113}$, or 3.14159292, which is correct to the sixth fractional place. The error does not exceed one part in thirteen millions.

At the beginning of the seventeenth century, Ludolph Van Ceulen reached 35 places. This result, which "in his life he found by much labor," was engraved upon his tombstone in St. Peter's Church, Leyden. The monument has now unfortunately disappeared.

From this time on, various mathematicians succeeded, by improved methods, in increasing the approximation. Thus in 1705, Abraham Sharp carried it to 72 places; Machin (1706) to 100 places; Rutherford (1841) to 208 places, and Mr. Shanks in 1853, to 607 places. The same computer in 1873 reached the enormous number of 707 places.

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the giant must make. He will not succeed, unless his microscopes be much better for his size than ours are for ours."

It would of course be impossible for any human mind to grasp the range of such an illustration as that just given. At the same time these illustrations do serve in some measure to give us an impression, if not an idea, of the vastness on the one hand and the minuteness on the other of the measurements with which we are dealing. I therefore offer no apology for giving another example of the nearness to absolute accuracy with which the circle has been "squared."

It is common knowledge that light travels with a velocity of about 185,000 miles per second. In other words, light would go completely round the earth in a little more than one-eighth of a second, or, as Herschel puts it, in less time than it would take a swift runner to make a single stride. Taking this distance of 185,000 miles per second as our unit of measurement, let us apply it as follows:

It is generally believed that our solar system is but an individual unit in a stellar system which may include hundreds of thousands of suns like our own, with all their attendant planets and moons. This stellar system again may be to some higher system what our solar system is to our own stellar system, and there may be several such gradations of systems, all going to form one complete whole which, for want of a better name, I shall call a universe. Now this universe, complete in itself, may be finite and separated from all other systems of a similar kind by an empty space, across which even gravitation cannot exert its influence. Let us suppose that the imaginary boundary of this great universe is a perfect circle, the extent of which is such that light, traveling at the rate we have named (185,000 miles per second), would take millions of millions of years to pass across it, and let us further suppose that we know the diameter of this mighty space with perfect accuracy; then, using Mr. Shanks' 707 places of decimal fractions, we could calculate the circumference to such a degree of accuracy that the error would not be visible under any microscope now made.

An illustration which may impress some minds even more forcibly than either of those which we have just given, is as follows:

Let us suppose that in some titanic iron-works a steel armor-plate had been forged, perfectly circular in shape and having a diameter of exactly 185,000,000 miles, or very nearly that of the orbit of the earth, and a thickness of 8000 miles, or about that of the diameter of the earth. Let us further assume that, owing to the attraction of some immense stellar body, this huge mass has what we would call a weight corresponding to that which a plate of the same material would have at the surface of the earth, and let it be required to calculate the length of the side of a square plate of the same material and thickness and which shall be exactly equal to the circular plate.

Using the 707 places of figures of Mr. Shanks, the length of the required side could be calculated so accurately that the difference in weight between the two plates (the circle and the square) would not be sufficient to turn the scale of the most delicate chemical balance ever constructed.

Of course in assuming the necessary conditions, we are obliged to leave out of consideration all those more refined details which would embarrass us in similar calculations on the small scale and confine ourselves to the purely mathematical aspect of the case; but the stretch of imagination required is not greater than that demanded by many illustrations of the kind.

So much, then, for what is claimed by the mathematicians; and the certainty that their results are correct, as far as they go, is shown by the predictions made by astronomers in regard to the moon's place in the heavens at any given time. The error is less than a second of time in twenty-seven days, and upon this the sailor depends for a knowledge of his position upon the trackless deep. This is a practical test upon which merchants are willing to stake, and do stake, billions of dollars every day.

It is now well established that, like the diagonal and side of a square, the diameter and circumference of any circle are incommensurable quantities. But, as De Morgan says, "most of the quadrators are not aware that it has been fully demonstrated that no two numbers whatsoever can represent the ratio of the diameter to the circumference, with perfect accuracy. When, therefore, we are told that either 8 to 25 or 64 to 201 is the true ratio, we know that it is no such thing, without the necessity of examination. The point that is left open, as not fully demonstrated to be impossible, is the *geometrical* quadrature, the determination of the circumference by the straight line and circle, used as in Euclid."

But since De Morgan wrote, it has been shown that a Euclidean construction is actually impossible. Those who desire to examine the question more fully, will find a very clear discussion of the subject in Klein's "Famous Problems in Elementary Geometry." (Boston, Ginn & Co.)

There are various geometrical constructions which give approximate results that are sufficiently accurate for most practical purposes. One of the oldest of these makes the ratio $3\frac{1}{7}$ to 1. Using this ratio we can ascertain the circumference of a circle of which the diameter is given by the following method: Divide the diameter into 7 equal parts by the usual method. Then, having drawn a straight line, set off on it three times the diameter and one of the sevenths; the result will give the circumference with an error of less than the one twenty-five-hundredth part or one twenty-fifth of one per cent.

If the circumference had been given, the diameter might have been found by dividing the circumference into twenty-two parts and setting off seven of them. This would give the diameter. A more accurate method is as follows:

Given a circle, of which it is desired to find the length of the circumference: Inscribe in the given circle a square, and to three times the diameter of the circle add a fifth of the side of the square; the result will differ from the circum-

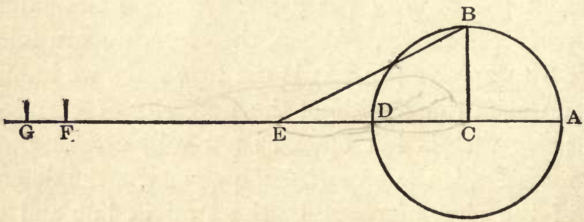


Fig. 1.

ference of the circle by less than one-seventeen-thousandth part of it. Another method which gives a result accurate to the one-seventeen-thousandth part is as follows:

Let AD, Fig. 1, be the diameter of the circle, C the center, and CB the radius perpendicular to AD. Continue AD and make DE equal to the radius; then draw BE, and in AE, continued, make EF equal to it; if to this line EF, its fifth part FG be added, the whole line AG will be equal to the circumference described with the radius CA, within one-seventeen-thousandth part.

The following construction gives even still closer results: Given the semi-circle ABC, Fig 2; from the extremities A and C of its diameter raise two perpendiculars, one of them CE, equal to the tangent of 30°, and the other AF, equal to three times the radius. If the line FE be then

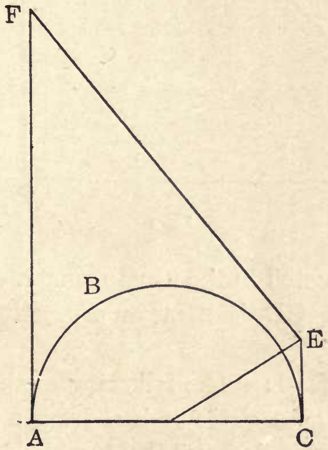


Fig. 2.

drawn, it will be equal to the semi-circumference of the circle, within one-hundred-thousandth part nearly. This is an error of one-thousandth of one per cent, an accuracy far greater than any mechanic can attain with the tools now in use.

When we have the length of the circumference and the length of the diameter, we can describe a square which shall be equal to the area of the circle. The following is the method:

Draw a line ACB, Fig. 3, equal to half the circumference and half the diameter together. Bisect this line in O, and with O as a center and AO as radius, describe the semicircle ADB. Erect a perpendicular CD, at C, cutting the arc in D; CD is the side of the required square which can

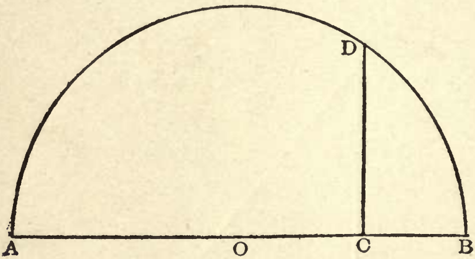


Fig. 3.

then be constructed in the usual manner. The explanation of this is that CD is a mean proportional between AC and CB.

De Morgan says: "The following method of finding the circumference of a circle (taken from a paper by Mr. S. Drach in the 'Philosophical Magazine,' January, 1863, Suppl.), is as accurate as the use of eight fractional places: From three diameters deduct eight-thousandths and seven-millionths of a diameter; to the result, add five per cent. We have then not quite enough; but the shortcoming is at the rate of about an inch and a sixtieth of an inch in 14,000 miles."

For obtaining the side of a square which shall be equal in area to a given circle, the empirical method, given by Ahmes in the Rhind papyrus 4000 years ago, is very simple and sufficiently accurate for many practical purposes. The rule is: Cut off one-ninth of the diameter and construct a square upon the remainder.

This makes the ratio 3.16.. and the error does not exceed one-third of one per cent.

There are various mechanical methods of measuring and comparing the diameter and the circumference of a circle, and some of them give tolerably accurate results. The most obvious device and that which was probably the oldest, is the use of a cord or ribbon for the curved surface and the usual measuring rule for the diameter. With an accurately divided rule and a thin metallic ribbon which does not stretch, it is possible to determine the ratio to the second fractional place, and with a little care and skill the third place may be determined quite closely.

An improvement which was no doubt introduced at a very early day is the measuring wheel or circumferentor. This is used extensively at the present day by country wheelwrights for measuring tires. It consists of a wheel fixed in a frame so that it may be rolled along or over any surface of which the measurement is desired.

This may of course be used for measuring the circumference of any circle and comparing it with the diameter. De Morgan gives the following instance of its use: A squarer, having read that the circular ratio was undetermined, advertised in a country paper as follows: "I thought it very strange that so many great scholars in all ages should have failed in finding the true ratio and have been determined to try myself." He kept his method secret, expecting "to secure the benefit of the discovery," but it leaked out that he did it by rolling a twelve-inch disk along a straight rail, and his ratio was 64 to 201 or 3.140625 exactly. As De Morgan says, this is a very creditable piece of work; it is not wrong by 1 in 3000.

Skilful machinists are able to measure to the one-five-thousandth of an inch; this, on a two-inch cylinder, would give the ratio correct to five places, provided we could measure the curved line as accurately as we can the straight diameter, but it is difficult to do this by the usual methods. Perhaps the most accurate plan would be to use a fine wire and wrap it round the cylinder a number of times, after which its length could be measured. The result would of course require correction for the angle which the wire would necessarily make if the ends did not meet squarely and also for the diameter of the wire. Very accurate results have been obtained by this method in measuring the diameters of small rods.

A somewhat original way of finding the area of a circle was adopted by one squarer. He took a carefully turned metal cylinder and having measured its length with great accuracy he adopted the Archimedean method of finding its cubical contents, that is to say, he immersed it in water and found out how much it displaced. He then had all the data required to enable him to calculate the area of the circle upon which the cylinder stood.

Since the straight diameter is easily measured with great accuracy, when he had the area he could readily have found the circumference by working backward the rule announced by Archimedes, viz: that the area of a circle is equal to that of a triangle whose base has the same length as the circumference and whose altitude is equal to the radius.

One would almost fancy that amongst circle-squarers there prevails an idea that some kind of ban or magical prohibition has been laid upon this problem; that like the hidden treasures of the pirates of old it is protected from the attacks of ordinary mortals by some spirit or demoniac influence, which paralyses the mind of the would-be solver and frustrates his efforts.

It is only on such an hypothesis that we can account for the wild attempts of so many men, and the persistence with which they cling to obviously erroneous results in the face not only of mathematical demonstration, but of practical mechanical measurements. For even when working in wood it is easy to measure to the half or even the one-fourth of the hundredth of an inch, and on a ten-inch circle this will bring the circumference to 3.1416 inches, which is a corroboration of the orthodox ratio (3.14159) sufficient to show that any value which is greater than 3.142 or less than 3.141 cannot possibly be correct.

And in regard to the area the proof is quite as simple. It is easy to cut out of sheet metal a circle 10 inches in diameter, and a square of 7.85 on the side, or even one-thousandth of an inch closer to the standard 7.854. Now if the work be done with anything like the accuracy with which good machinists work, it will be found that the circle and the square will exactly balance each other in weight, thus proving in another way the correctness of the accepted ratio.

But although even as early as before the end of the eighteenth century, the value of the ratio had been accurately determined to 152 places of decimals, the nineteenth century abounded in circle-squarers who brought forward the most absurd arguments in favor of other values. In 1836, a French well-sinker named Lacomme, applied to a professor of mathematics for information in regard to the amount of stone required to pave the circular bottom of a well, and was told that it was impossible "to give a correct answer, because the exact ratio of the diameter of a circle to its circumference had never been determined"! This absolutely true but very unpractical statement by the professor, set the well-sinker to thinking; he studied mathematics after a fashion, and announced that he had discovered that the circumference was exactly $3\frac{1}{8}$ times the length of the diameter! For this discovery (?) he was honored by several medals of the first class, bestowed by Parisian societies.

Even as late as the year 1860, a Mr. James Smith of Liverpool, took up this ratio $3\frac{1}{8}$ to 1, and published several books and pamphlets in which he tried to argue for its accuracy. He even sought to bring it before the British Association for the Advancement of Science. Professors De Morgan and Whewell, and even the famous mathematician, Sir William Rowan Hamilton, tried to convince him of his error, but without success. Professor Whewell's demonstration is so neat and so simple that I make no apology for giving it here. It is in the form of a letter to Mr. Smith: "You may do this: calculate the side of a polygon of 24 sides inscribed in a circle. I think you are mathematician enough to do this. You will find that if the radius of the circle be one, the side of the polygon is .264, etc. Now the arc which this side subtends is, according to your proposition, $\frac{3.125}{12} = .2604$, and, therefore, the chord is greater than its arc, which, you will allow, is impossible."

This must seem, even to a school-boy, to be unanswerable, but it did not faze Mr. Smith, and I doubt if even the method which I have suggested previously, viz., that of cutting a circle and a square out of the same piece of sheet metal and weighing them, would have done so. And yet by this method even a common pair of grocer's scales will show to any common-sense person the error of Mr. Smith's value and the correctness of the accepted ratio.

Even a still later instance is found in a writer who, in 1892, contended in the New York "Tribune" for 3.2 instead of 3.1416, as the value of the ratio. He announces it as the re-discovery of a long lost secret, which consists in the knowledge of a certain line called "the Nicomedean line." This announcement gave rise to considerable discussion, and even towards the dawn of the twentieth century 3.2 had its advocates as against the accepted ratio 3.1416.

Verily the slaves of the mighty wizard, Michael Scott, have not yet ceased from their labors !

THE DUPLICATION OF THE CUBE

THIS problem became famous because of the halo of mythological romance with which it was surrounded. The story is as follows:

About the year 430 B.C. the Athenians were afflicted by a terrible plague, and as no ordinary means seemed to assuage its virulence, they sent a deputation of the citizens to consult the oracle of Apollo at Delos, in the hope that the god might show them how to get rid of it.

The answer was that the plague would cease when they had doubled the size of the altar of Apollo in the temple at Athens. This seemed quite an easy task; the altar was a cube, and they placed beside it another cube of exactly the same size. But this did not satisfy the conditions prescribed by the oracle, and the people were told that the altar must consist of one cube, the size of which must be exactly twice the size of the original altar. They then constructed a cubic altar of which the side or edge was twice that of the original, but they were told that the new altar was eight times and not twice the size of the original, and the god was so enraged that the plague became worse than before.

According to another legend, the reason given for the affliction was that the people had devoted themselves to pleasure and to sensual enjoyments and pursuits, and had neglected the study of philosophy, of which geometry is one of the higher departments — certainly a very sound reason, whatever we may think of the details of the story. The people then applied to the mathematicians, and it is supposed that their solution was sufficiently near the truth to satisfy Apollo, who relented, and the plague disappeared.

In other words, the leading citizens probably applied themselves to the study of sewerage and hygienic conditions, and Apollo (the Sun) instead of causing disease by the festering corruption of the usual filth of cities, especially in the East, dried up the superfluous moisture, and promoted the health of the inhabitants.

It is well known that the relation of the area and the cubical contents of any figure to the linear dimensions of that figure are not so generally understood as we should expect in these days when the schoolmaster is supposed to be "abroad in the land." At an examination of candidates for the position of fireman in one of our cities, several of the applicants made the mistake of supposing that a two-inch pipe and a five-inch pipe were equal to a seven-inch pipe, whereas the combined capacities of the two small pipes are to the capacity of the large one as 29 to 49.

This reminds us of a story which Sir Frederick Bramwell, the engineer, used to tell of a water company using water from a stream flowing through a pipe of a certain diameter. The company required more water, and after certain negotiations with the owner of the stream, offered double the sum if they were allowed a supply through a pipe of double the diameter of the one then in use. This was accepted by the owner, who evidently was not aware of the fact that a pipe of double the diameter would carry *four* times the supply.

A square whose side is twice the length of another, and a circle whose diameter is twice that of another will each have an area four times that of the original. And in the case of solids: A ball of twice the diameter will weigh eight times as much as the original, and a ball of three times the diameter will weigh twenty-seven times as much as the original.

In attempting to calculate the side of a cube which shall have twice the volume of a given cube, we meet the old difficulty of incommensurability, and the solution cannot be effected geometrically, as it requires the construction of two mean proportionals between two given lines.

III

THE TRISECTION OF AN ANGLE

THIS problem is not so generally known as that of squaring the circle, and consequently it has not received so much attention from amateur mathematicians, though even within little more than a year a small book, in which an attempted solution is given, has been published. When it is first presented to an uneducated reader, whose mind has a mathematical turn, and especially to a skilful mechanic, who has not studied theoretical geometry, it is apt to create a smile, because at first sight most persons are impressed with an idea of its simplicity, and the ease with which it may be solved. And this is true, even of many persons who have had a fair general education. Those who have studied only what is known as "practical geometry" think at once of the ease and accuracy with which a right angle, for example, may be divided into three equal parts. Thus taking the right angle ACB, Fig. 4, which may be set off more easily and accurately than any other angle except, perhaps, that of 60°, and knowing that it contains 90°, describe an arc ADEB, with C for the center and any convenient radius. Now every schoolboy who has played with a pair of compasses knows that the radius of a circle will "step" round the circumference exactly six times; it will therefore divide the 360° into six equal parts of 60° each. This being the case, with the radius CB, and B for a center, describe a short arc crossing the arc ADEB in D, and join CD. The angle DCB will be 60°, and as the angle ACB is 90°, the angle ACD must be 30°, or one-third part of the whole. In the same way lay off the angle ACE of 60°, and ECB must be 30°, and the remainder DCE must also be 30°. The angle ACB is therefore easily divided

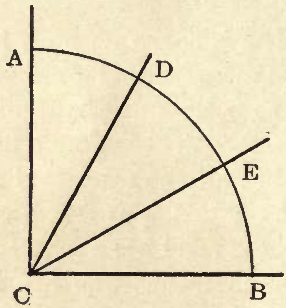


Fig. 4.

into three equal parts, or in other words, it is trisected. And with a slight modification of the method, the same may be done with an angle of 45°, and with some others. These however are only special cases, and the very essence of a geometrical solution of any problem is that it shall be applicable to *all* cases so that we require a method by which *any* angle may be divided into three equal parts by a pure Euclidian construction. The ablest mathematicians declare that the problem cannot be solved by such means, and De Morgan gives the following reasons for this conclusion: "The trisector of an angle, if he demand attention from any mathematician, is bound to produce from his construction, an expression for the sine or cosine of the third part of any angle, in terms of the sine or cosine of the angle itself, obtained by the help of no higher than the square root. The mathematician knows that such a thing cannot be; but the trisector virtually says it can be, and is bound to produce it to save time. This is the misfortune of most of the solvers of the celebrated problems, that they have not knowledge enough to present those consequences of their results by which they can be easily judged."

De Morgan gives an account of a "terrific" construction by a friend of Dr. Wallich, which he says is "so nearly true, that unless the angle be very obtuse, common drawing, applied to the construction, will not detect the error." But geometry requires *absolute* accuracy, not a mere approximation.

IV

PERPETUAL MOTION

IT is probable that more time, effort, and money have been wasted in the search for a perpetual-motion machine than have been devoted to attempts to square the circle or even to find the philosopher's stone. And while it has been claimed in favor of this delusion that the pursuit of it has given rise to valuable discoveries in mechanics and physics, some even going so far as to urge that we owe the discovery of the great law of the conservation of energy to the suggestions made by the perpetual-motion seekers, we certainly have no evidence to show anything of the kind. Perpetual motion was declared to be an impossibility upon purely mechanical and mathematical grounds long before the law of the conservation of energy was thought of, and it is very certain that this delusion had no place in the thoughts of Rumford, Black, Davy, Young, Joule, Grove, and others when they devoted their attention to the laws governing the transformation of energy. Those who pursued such a will-o'-the-wisp, were not the men to point the way to any scientific discovery.

The search for a perpetual-motion machine seems to be of comparatively modern origin; we have no record of the labors of ancient inventors in this direction, but this may be as much because the records have been lost, as because attempts were never made. The works of a mechanical inventor rarely attracted much attention in ancient times, while the mathematical problems were regarded as amongst the highest branches of philosophy, and the search for the philosopher's stone and the elixir of life appealed alike to priest and layman. We have records of attempts made 4000 years ago to square the circle, and the history of the philosopher's stone is lost in the mists of antiquity; but it is not until the eleventh or twelfth century that we find any reference to perpetual motion, and it was not until the close of the sixteenth and the beginning of the seventeenth century that this problem found a prominent place in the writings of the day.

By perpetual motion is meant a machine which, without assistance from any external source except gravity, shall continue to go on moving until the parts of which it is made are worn out. Some insist that in order to be properly entitled to the name of a perpetual-motion machine, it must evolve more power than that which is merely required to run it, and it is true that almost all those who have attempted to solve this problem have avowed this to be their object, many going so far as to claim for their contrivances the ability to supply unlimited power at no cost whatever, except the interest on a small investment, and the trifling amount of oil required for lubrication. But it is evident that a machine which would of itself maintain a regular and constant motion would be of great value, even if it did nothing more than move itself. And this seems to have been the idea upon which those men worked, who had in view the supposed reward offered for such an invention as a means for finding the longitude. And it is well known that it was the hope of attaining such a reward that spurred on very many of those who devoted their time and substance to the subject.

There are several legitimate and successful methods of obtaining a practically perpetual motion, provided we are allowed to call to our aid some one of the various natural sources of power. For example, there are numerous mountain streams which have never been known to fail, and which by means of the simplest kind of a water-wheel would give constant motion to any light machinery. Even the wind, the emblem of fickleness and inconstancy, may be harnessed so that it will furnish power, and it does not require very much mechanical ingenuity to provide means whereby the surplus power of a strong gale may be stored up and kept in reserve for a time of calm. Indeed this has frequently been done by the raising of weights, the winding up of springs, the pumping of water into storage reservoirs and other simple contrivances.

The variations which are constantly occurring in the temperature and the pressure of the atmosphere have also been forced into this service. A clock which required no winding was exhibited in London towards the latter part of the eighteenth century. It was called a perpetual motion, and the working power was derived from variations in the quantity, and consequently in the weight of the mercury, which was forced up into a glass tube closed at the upper end and having the lower end immersed in a cistern of mercury after the manner of a barometer. It was fully described by James Ferguson, whose lectures on Mechanics and Natural Philosophy were edited by Sir David Brewster. It ran for years without requiring winding, and is said to have kept very good time. A similar contrivance was employed in a clock which was possessed by the Academy of Painting at Paris. It is described in Ozanam's work, Vol. II, page 105, of the edition of 1803.

The changes which are constantly taking place in the temperature of all bodies, and the expansion and contraction which these variations produce, afford a very efficient power for clocks and small machines. Professor W. W. R. Ball tells us that "there was at Paris in the latter half of last century a clock which was an ingenious illustration of such perpetual motion. The energy, which was stored up in it to maintain the motion of the pendulum, was provided by the expansion of a silver rod. This expansion was caused by the daily rise of temperature, and by means of a train of levers it wound up the clock. There was a disconnecting apparatus, so that the contraction due to a fall of temperature produced no effect, and there was a similar arrangement to prevent overwinding. I believe that a rise of eight or nine degrees Fahrenheit was sufficient to wind up the clock for twenty-four hours."

Another indirect method of winding a watch is thus described by Professor Ball:

"I have in my possession a watch, known as the Lohr patent, which produces the same effect by somewhat different means. Inside the case is a steel weight, and if the watch is carried in a pocket this weight rises and falls at every step one takes, somewhat after the manner of a pedometer. The weight is moved up by the action of the person who has it in his pocket, and in falling the weight winds up the spring of the watch. On the face is a small dial showing the number of hours for which the watch is wound up. As soon as the hand of this dial points to fifty-six hours, the train of levers which wind up the watch disconnects automatically, so as to prevent overwinding the spring, and it reconnects again as soon as the watch has run down eight hours. The watch is an excellent timekeeper, and a walk of about a couple of miles is sufficient to wind it up for twenty-four hours."

Dr. Hooper, in his "Rational Recreations," has described a method of driving a clock by the motion of the tides, and it would not be difficult to contrive a very simple arrangement which would obtain from that source much more power than is required for that purpose. Indeed the probability is that many persons now living will see the time when all our railroads, factories, and lighting plants will be operated by the tides of the ocean. It is only a question of return for capital, and it is well known that that has been falling steadily for years. When the interest on investments falls to a point sufficiently low, the tides will be harnessed and the greater part of the heat, light, and power that we require will be obtained from the immense amount of energy that now goes to waste along our coasts.

Another contrivance by which a seemingly perpetual motion may be obtained is the dry pile or column of De Luc. The pile consists of a series of disks of gilt and silvered paper placed back to back and alternating, all the gilt sides facing one way and all the silver sides the other. The so-called gilding is really Dutch metal or copper, and the silver is tin or zinc, so that the two actually form a voltaic couple. Sometimes the paper is slightly moistened with a weak solution of molasses to insure a certain degree of dampness; this increases the action, for if the paper be artificially dried and kept in a perfectly dry atmosphere, the apparatus will not work. A pair of these piles, each containing two or three thousand disks the size of a quarter of a dollar, may be arranged side by side, vertically, and two or three inches apart. At the lower ends they are connected by a brass plate, and the upper ends are each surmounted by a small metal bell and between these bells a gilt ball, suspended by a silk thread, keeps vibrating perpetually. Many years ago I made a pair of these columns which kept a ball in motion for nearly two years, and Professor Silliman tells us that "a set of these bells rang in Yale College laboratory for six or eight years unceasingly." How much longer the columns would have continued to furnish energy sufficient to cause the balls to vibrate, it might be difficult to determine. The amount of energy required is exceedingly small, but since the columns are really nothing but a voltaic pile, it is very evident that after a time they would become exhausted.

Such a pair of columns, covered with a tall glass shade, form a very interesting piece of bric-a-brac, especially if the bells have a sweet tone, but the contrivance is of no practical use except as embodied in Bohnenberger's electroscope.

Inventions of this kind might be multiplied indefinitely, but none of these devices can be called a perpetual motion because they all depend for their action upon energy derived from external sources other than gravity. But the authors of these inventions are not to be classed with the regular perpetual-motion-mongers. The purposes for which these arrangements were invented were legitimate, and the contrivances answered fully the ends for which they were intended. The real perpetual-motion-seekers are men of a different stamp, and their schemes readily fall into one of these three classes: 1. ABSURDITIES, 2. FALLACIES, 3. FRAUDS. The following is a description of the most characteristic machines and apparatus of which accounts have been published.

I. ABSURDITIES

In this class may be included those inventions which have been made or suggested by honest but ignorant persons in direct violation of the fundamental principles of mechanics and physics. Such inventions if presented to any expert mechanic or student of science, would be at once condemned as impracticable, but as a general rule, the inventors of these absurd contrivances have been so confident of success, that they have published descriptions and sketches of them, and even gone so far as to take out patents before they have tested their inventions by constructing a working machine. It is said, that at one time the United States Patent Office issued a circular refusal to all applicants for patents of this kind, but at present instead of sending such a circular, the applicant is quietly requested to furnish a *working* model of his invention and that usually ends the matter. While I have no direct information on the subject, I suspect that the circular was withdrawn because of the amount of useless correspondence, in the shape of foolish replies and arguments, which it drew forth. To require a working model is a reasonable request and one for which the law duly provides, and when a successful model is forthcoming, a patent will no doubt be granted; but until that is presented the officials of the Patent Office can have no positive information in regard to the practicability of the invention.

The earliest mechanical device intended to produce perpetual motion is that known as the overbalancing wheel. This is described in a sketch book of the thirteenth century by Wilars de Honecourt, an architect of the period, and since then it has been reinvented hundreds of times. In its simplest forms it is thus described and figured by Ozanam:

"Fig. 5 represents a large wheel, the circumference of which is furnished, at equal distances, with levers, each bearing at its extremity a weight, and movable on a hinge so that in one direction they can rest upon the circumference, while on the opposite side, being carried away by the weight at the extremity, they are obliged to arrange themselves in the direction of the radius continued. This being supposed, it is evident that when the wheel turns in the direction ABC, the weights A, B, and C will recede from the center; consequently, as they act with more force, they will carry the wheel towards that side; and as a new lever

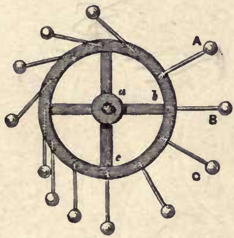


Fig. 5.

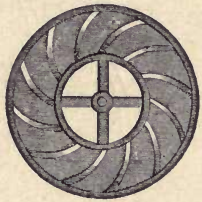


Fig. 6.

will be thrown out, in proportion as the wheel revolves, it thence follows, say they, that the wheel will continue to move in the same direction. But notwithstanding the specious appearance of this reasoning, experience has proved that the machine will not go; and it may indeed be demonstrated that there is a certain position in which the center of gravity of all these weights is in the vertical plane passing through the point of suspension, and that therefore it must stop."

Another invention of a similar kind is thus described by the same author:

"In a cylindric drum, in perfect equilibrium on its axis, are formed channels as seen in Fig. 6, which contain balls of lead or a certain quantity of quicksilver. In consequence of this disposition, the balls or quicksilver must, on the one side, ascend by approaching the center, and on the other must roll towards the circumference. The machine ought, therefore, to turn incessantly towards that side."

In his "Course of Lectures on Natural Philosophy," Dr. Thomas Young speaks of these contrivances as follows:

"One of the most common fallacies, by which the superficial projectors of machines for obtaining perpetual motion have been deluded, has arisen from imagining that any

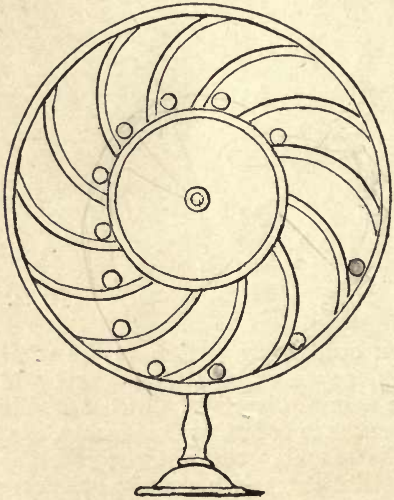


Fig. 7.

number of weights ascending by a certain path, on one side of the center of motion and descending on the other at a greater distance, must cause a constant preponderance on the side of the descent: for this purpose the weights have either been fixed on hinges, which allow them to fall over at a certain point, so as to become more distant from the center, or made to slide or roll along grooves or planes which lead them to a more remote part of the wheel, from whence they return as they ascend; but it will appear on the inspection of such a machine, that although some of the weights are more distant from the center than others,

yet there is always a proportionately smaller number of them on that side on which they have the greatest power, so that these circumstances precisely counterbalance each other."

He then gives the illustration (Fig. 7), shown on the preceding page, of "a wheel supposed to be capable of producing a perpetual motion; the descending balls acting at a greater distance from the center, but being fewer in number than the ascending. In the model, the balls may be kept in their places by a plate of glass covering the wheel."

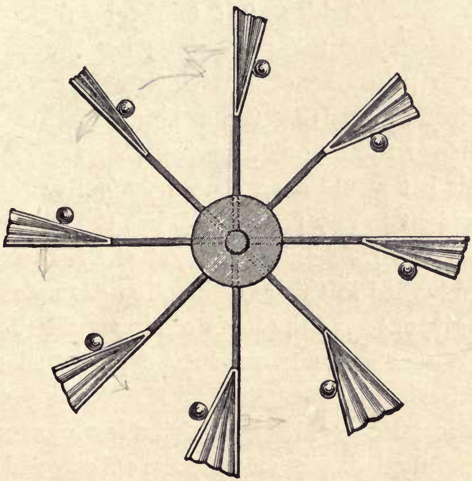


Fig. 8.

A more elaborate arrangement embodying the same idea is figured and described by Ozanam. The machine, which is shown in Fig. 8, consists of "a kind of wheel formed of six or eight arms, proceeding from a center where the axis of motion is placed. Each of these arms is furnished with a receptacle in the form of a pair of bellows: but those on the opposite arms stand in contrary directions, as seen in the figure. The movable top of each receptacle has affixed to it a weight, which shuts it in one situation and opens it in the other. In the last place, the bellows of the opposite arms have a communication by means of a canal, and one of them is filled with quicksilver.

"These things being supposed, it is visible that the bellows on the one side must open, and those on the other must shut; consequently, the mercury will pass from the latter into the former, while the contrary will be the case on the opposite side."

Ozanam naïvely adds: "It might be difficult to point out the deficiency of this reasoning; but those acquainted with the true principles of mechanics will not hesitate to bet a hundred to one, that the machine, when constructed, will not answer the intended purpose."

That this bet would have been a perfectly safe one must be quite evident to any person who has the slightest knowledge of practical mechanics, and yet the fundamental idea which is embodied in this and the other examples which we have just given, forms the basis of almost all the attempts which have been made to produce a perpetual motion by purely mechanical means.

The hydrostatic paradox by which a few ounces of liquid may apparently balance many pounds, or even tons, has frequently suggested a form of apparatus designed to secure a perpetual motion. Dr. Arnott, in his "Elements of Physics," relates the following anecdote: "A projector thought that the vessel of his contrivance, represented here (Fig. 9), was to solve the renowned problem of the perpetual motion. It was goblet-shaped, lessening gradually towards the bottom until it became a tube, bent upwards at *c* and pointing with an open extremity into the goblet again. He reasoned thus: A pint of water in the goblet *a* must more than counterbalance an ounce which the tube *b* will contain, and must, therefore, be constantly pushing the ounce forward into the vessel again at *a*, and keeping up a stream or circulation, which will cease only when the water dries

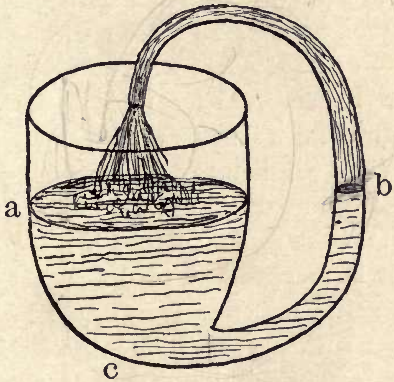


Fig. 9.

up. He was confounded when a trial showed him the same level in *a* and in *b*."

This suggestion has been adopted over and over again by sanguine inventors. Dircks, in his "Perpetuum Mobile," tells us that a contrivance, on precisely the same principle, was proposed by the Abbé de la Roque, in "Le Journal des Sçavans," Paris, 1686. The instrument was a U tube, one leg longer than the other and bent over, so that any liquid might drop into the top end of the short leg, which he proposed to be made of wax, and the long one of iron. Presuming the liquid to be more condensed in the metal than the wax tube, it would flow from the end into the wax tube and so continue.

This is a typical case. A man of learning and of high position is so confident that his theory is right that he does not think it worth while to test it experimentally, but rushes into print and immortalizes himself as the author of a blunder. It is safe to say that this absurd invention will do more to perpetuate his name than all his learning and real achievements. And there are others in the same predicament — circle-squarers who, a quarter of a century hence, will be remembered for their errors when all else connected with them will be forgotten.

To every miller whose mill ceased working for want of water, the idea has no doubt occurred that if he could only pump the water back again and use it a second or a third time he might be independent of dry or wet seasons. Of course no practical miller was ever so far deluded as to attempt to put such a suggestion into practice, but innumerable machines of this kind, and of the most crude arrangement, have been sketched and described in magazines and papers. Figures of wheels driving an ordinary pump, which returns to an elevated reservoir the water which has driven the wheel, are so common that it is not worth while to reproduce any of them. In the following attempt, however, which is copied from Bishop Wilkins' famous book, "Mathematical Magic" (1648), the well-known Archimedean screw is employed instead of a pump, and the naïveté of the good bishop's description and conclusion are well worth the space they will occupy.

After an elaborate description of the screw, he says: "These things, considered together, it will hence appear how a perpetual motion may seem easily contrivable. For, if there were but such a waterwheel made on this instrument, upon which the stream that is carried up may fall in its descent, it would turn the screw round, and by that means convey as much water up as is required to move it; so that the motion must needs be continual since the same weight which in its fall does turn the wheel, is, by the turning of the wheel, carried up again. Or, if the water, falling upon one wheel, would not be forcible enough for this effect, why then there might be two, or three, or more, according as the length and elevation of the instrument will admit; by which means the weight of it may be so multiplied in the fall that it shall be equivalent to twice or thrice that quantity of water which ascends; as may be more plainly discerned by the following diagram (Fig. 10):

"Where the figure LM at the bottom does represent a wooden cylinder with helical cavities cut in it, which at AB is supposed to be covered over with tin plates, and three waterwheels, upon it, HIK; the lower cistern, which contains the water, being CD. Now, this cylinder being turned round, all the water which from the cistern ascends through it, will fall into the vessel at E, and from that vessel being conveyed upon the waterwheel H, shall consequently give a circular motion to the whole screw. Or, if this alone should be too weak for the turning of it, then the same water which falls from the wheel H, being received into the other vessel F, may from thence again descend on the wheel I, by which means the force of it will be doubled. And if this be yet insufficient, then may the water, which falls on the second wheel T, be received into the other vessel G, and from thence again descend on the third wheel at K; and so for as many other wheels as the instrument is capable of. So that besides the greater distance of these three streams from the center or axis by which they are made so much heavier; and besides that the fall of this outward water is forcible and violent, whereas the ascent of that within is natural — besides all this, there is twice as much water to turn the screw as is carried up by it.

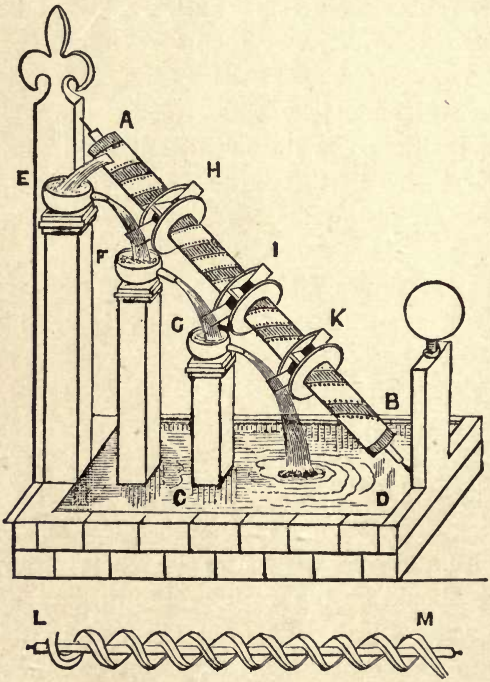


Fig. 10.

"But, on the other side, if all the water falling upon one wheel would be able to turn it round, then half of it would serve with two wheels, and the rest may be so disposed of in the fall as to serve unto some other useful, delightful ends.

"When I first thought of this invention, I could scarce forbear, with Archimedes, to cry out 'Eureka! Eureka!' it seeming so infallible a way for the effecting of a perpetual motion that nothing could be so much as probably objected against it; but, upon trial and experience, I find it altogether insufficient for any such purpose, and that for these two reasons:

1. The water that ascends will not make any considerable stream in the fall.

2. This stream, though multiplied, will not be of force enough to turn about the screw."

How well it would have been for many of those inventors, who supposed that they had discovered a successful perpetual motion, if they had only given their contrivances a fair and unprejudiced test as did the good old bishop!

A modification of this device, in which mercury is used instead of water, is thus described by a correspondent of "The Mechanic's Magazine." (London.)

"In Fig. 11, A is the screw turning on its two pivots GG; B is a cistern to be filled above the level of the lower aperture of the screw with mercury, which I conceive to be preferable to water on many accounts, and principally because it does not adhere or evaporate like water; c is a reservoir, which, when the screw is turned round, receives the mercury which falls from the top; there is a pipe, which, by the force of gravity, conveys the mercury from the reservoir c on to (what for want of a better term may be called) the float-board E, fixed at right angles to the center [axis] of the screw, and furnished at its circumference with ridges or floats to intercept the mercury, the moment and weight of which will cause the float-board and screw to revolve, until, by the proper inclination of the floats, the mercury falls into the receiver F, from whence it again falls by its spout into the cistern G, where the constant revolution of the screw takes it up again as before."

He then suggests some difficulties which the ball, seen just under the letter E, is intended to overcome, but he confesses that he has never tried it, and to any practical mechanic it is very obvious that the machine will not work.

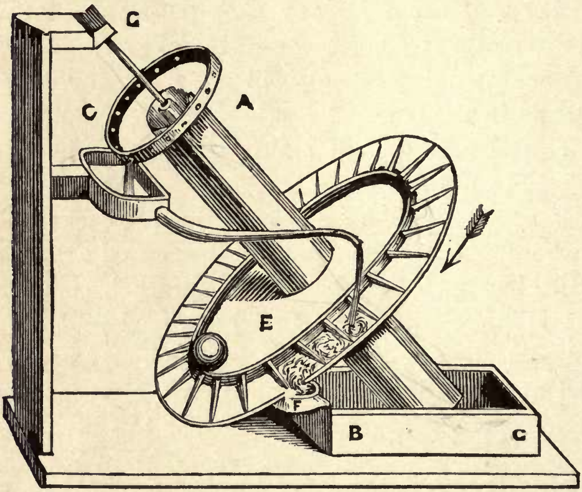


Fig. 11.

But we give the description in the language of the inventor, as a fair type of this class of perpetual-motion machines.

In the year 1790 a Doctor Schweirs took out a patent for a machine in which small metal balls were used instead of a liquid, and they were raised by a sort of chain pump which delivered them upon the circumference of a large wheel, which was thus caused to revolve. It was claimed for this invention that it kept going for some months, but any mechanic who will examine the Doctor's drawing must see that it could not have continued in motion after the initial impulse had been expended.

That property of liquids known as capillary attraction has been frequently called to the aid of perpetual-motion seekers, and the fact that although water will, in capillary tubes and sponges, rise several inches above the general level, it will not overflow, has been a startling surprise to the would-be inventors. Perhaps the most notable instance of a mistake of this kind occurred in the case of the famous Sir William Congreve, the inventor of the military rockets that bore his name, and the author of certain improvements in matches which were called after him. It was thus described and figured in an article which appeared in the "Atlas" (London) and was copied into "The Mechanic's Magazine" (London) for 1827:

"The celebrated Boyle entertained an idea that perpetual motion might be obtained by means of capillary attraction; and, indeed, there seems but little doubt that nature has employed this force in many instances to produce this effect.

"There are many situations in which there is every reason to believe that the sources of springs on the tops and sides of mountains depend on the accumulation of water created at certain elevations by the operation of capillary attraction, acting in large masses of porous material, or through laminated substances. These masses being saturated, in process of time become the sources of springs and the heads of rivers; and thus by an endless round of ascending and descending waters, form, on the great scale of nature, an incessant cause of perpetual motion, in the purest acceptance of the term, and precisely on the principle that was contemplated by Boyle. It is probable, however, that any imitation of this process on the limited scale practicable by human art would not be of sufficient magnitude to be effective. Nature, by the immensity of her operations, is able to allow for a slowness of process which would baffle the attempts of man in any direct and simple imitation of her works. Working, therefore, upon the same causes, he finds himself obliged to take a more complicated mode to produce the same effect.

"To amuse the hours of a long confinement from illness, Sir William Congreve has recently contrived a scheme of perpetual motion, founded on this principle of capillary attraction, which, it is apprehended, will not be subject to the general refutation applicable to those plans in which the power is supposed to be derived from gravity only. Sir William's perpetual motion is as follows:

"Let ABC, Fig. 12, be three horizontal rollers fixed in a frame; aaa, etc., is an endless band of sponge, running round these rollers; and bbb, etc., is an endless chain of weights, surrounding the band of sponge, and attached

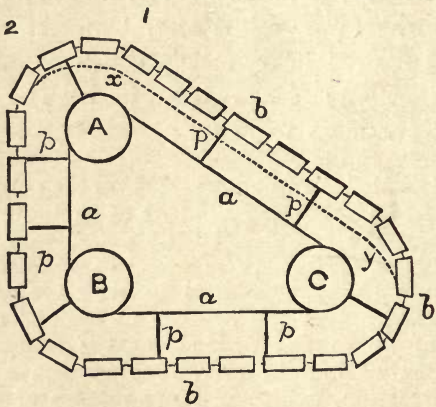


Fig. 12.

to it, so that they must move together; every part of this band and chain being so accurately uniform in weight that the perpendicular side AB will, in all positions of the band and chain, be in equilibrium with the hypothenuse AC, on the principle of the inclined plane. Now, if the frame in which these rollers are fixed be placed in a cistern of water, having its lower part immersed therein, so that the water's edge cuts the upper part of the rollers BC, then, if the weight and quantity of the endless chain be duly proportioned to the thickness and breadth of the band of sponge, the band and chain will, on the water in the cistern being brought to the proper level, begin to move round the rollers in the direction AB, by the force of capillary attraction, and will continue so to move. The process is as follows:

"On the side AB of the triangle, the weights bbb, etc., hanging perpendicularly alongside the band of sponge, the band is not compressed by them, and its pores being left open, the water at the point x, at which the band meets its surface, will rise to a certain height y, above its level, and thereby create a load, which load will not exist on the ascending side CA, because on this side the chain of weights compresses the band at the water's edge, and squeezes out any water that may have previously accumulated in it; so that the band rises in a dry state, the weight of the chain having been so proportioned to the breadth and thickness of the band as to be sufficient to produce this effect. The load, therefore, on the descending side AB, not being opposed by any similar load on the ascending side, and the equilibrium of the other parts not being disturbed by the alternate expansion and compression of the sponge, the band will begin to move in the direction AB; and as it moves downwards, the accumulation of water will continue to rise, and thereby carry on a constant motion, provided the load at xy be sufficient to overcome the friction on the rollers ABC.

"Now to ascertain the quantity of this load in any particular machine, it must be stated that it is found by experiment that the water will rise in a fine sponge about an inch above its level; if, therefore, the band and sponge be one foot thick and six feet broad, the area of its horizontal section in contact with the water would be 864 square inches, and the weight of the accumulation of water raised by the capillary attraction being one inch rise upon 864 square inches, would be 30 lb., which, it is conceived, would be much more than equivalent to the friction of the rollers."

The article, inspired no doubt by Sir William, then goes on to give elaborate reasons for the success of the device, but all these are met by the damning fact that the machine never worked. Some time afterwards Sir William, at considerable expense, published a pamphlet in which he explained and defended his views. If he had only had a working model made and the thing had continued in motion for a few hours, he would have silenced all objectors far more quickly and forcibly than he ever could have done by any amount of argument.

And in his case there could have been no excuse for his not making a small machine after the plans that he published and even patented. He was wealthy and could have commanded the services of the best mechanics in London, but no working model was ever made. Many inventors of perpetual-motion machines offer their poverty as an excuse for not making a model or working machine. Thus Dircks, in his "Perpetuum Mobile" gives an account of "a mechanic, a model maker, who had a neat brass model of a time-piece, in which were two steel balls A and B; — B to fall into a semicircular gallery C, and be carried to the end D of a straight trough DE; while A in its turn rolls to E, and so on continuously; only the gallery C not being screwed in its place, we are desired to take the will for the deed, until twenty shillings be raised to complete this part of the work!"

And Mr. Dircks also quotes from the "Builder" of June, 1847: "This vain delusion, if not still in force, is at least as standing a fallacy as ever. Joseph Hutt, a framework knitter, in the neighborhood of the enlightened town of Hinckley, professes to have discovered it [perpetual motion] and only wants twenty pounds, as usual, to set it agoing."

The following rather curious arrangement was described in "The Mechanic's Magazine" for 1825.

"I beg leave to offer the prefixed device. The point at which, like all the rest, it fails, I confess I did not (as I do now) plainly perceive at once, although it is certainly very obvious. The original idea was this — to enable a body which would float in a heavy medium and sink in a lighter one, to pass successively through the one to the other, the continuation of which would be the end in view. To say that valves cannot be made to act as proposed will not be to show the *rationale* (if I may so say) upon which the idea is fallacious."

The figure is supposed to be tubular, and made of glass, for the purpose of seeing the action of the balls inside, which float or fall as they travel from air through water and from water through air. The foot is supposed to be placed in water, but it would answer the same purpose if the bottom were closed.

DESCRIPTION OF THE ENGRAVING, FIG. 13. No. 1, the left leg, filled with water from B to A. 2 and 3, valves, having in their centers very small projecting valves; they all open upwards. 4, the right leg, containing air from A to F. 5 and 6, valves, having very small ones in their centers; they all open downwards. The whole apparatus is supposed to be air and water-tight. The round figures represent hollow balls, which will sink one-fourth of their bulk in water (of course will fall in air); the weight therefore of three balls resting upon one ball in water, as at E, will just bring its top even with the water's edge; the weight of four balls will sink it under the surface until the ball immediately over it is one-fourth its bulk in water, when the under ball will escape round the corner at C, and begin to ascend.

"The machine is supposed (in the figure) to be in action, and No. 8 (one of the balls) to have just escaped round the corner at C, and to be, by its buoyancy, rising up to valve No. 3, striking first the small projecting valve in the center, which when opened, the large one will be raised by the buoyancy of the ball; because the moment the small valve in the center is opened (although only the size of a pin's head), No. 2 valve will have taken upon itself to sustain the whole column of water from A to B. The said ball (No. 8) having passed through the valve

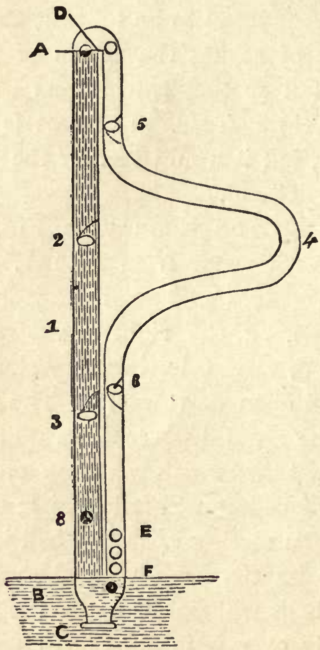


Fig. 13.

No. 3, will, by appropriate weights or springs, close; the ball will proceed upwards to the next valve (No. 2), and perform the same operation there. Having arrived at A, it will float upon the surface three-fourths of its bulk out of water. Upon another ball in due course arriving under it, it will be lifted quite out of the water, and fall over the point D, pass into the right leg (containing air), and fall to valve No. 5, strike and open the small valve in its center, then open the large one, and pass through; this valve will then, by appropriate weights or springs, close; the ball will roll on through the bent tube (which is made in that form to gain time as well as to exhibit motion) to the next valve (No. 6), where it will perform the same operation, and then, falling upon the four balls at E, force the bottom one round the corner at C. This ball will proceed as did No. 8, and the rest in the same manner successively."

That an ordinary amateur mechanic should be misled by such arguments is perhaps not so surprising, when we remember that the famous John Bernoulli claimed to have invented a perpetual motion based on the difference between the specific gravities of two liquids. A translation of the original Latin may be found in the Encyclopædia Britannica, Vol. XVIII, page 555. Some of the premises on which he depends are, however, impossibilities, and Professor Chrystal concludes his notice of the invention thus: "One really is at a loss with Bernoulli's wonderful theory, whether to admire most the conscientious statement of the hypothesis, the prim logic of the demonstration — so carefully cut according to the pattern of the ancients — or the weighty superstructure built on so frail a foundation. Most of our perpetual motions were clearly the result of too little learning; surely this one was the product of too much."

A more simple device was suggested recently by a correspondent of "Power." He describes it thus:

The J-shaped tube A, Fig. 14, is open at both ends, but tapers at the lower end, as shown. A well-greased cotton rope C passes over the wheel B and through the small opening of the tube with practically little or no friction, and also without leakage. The tube is then filled with water. The rope above the line WX balances over the pulley, and so does that below the line YZ. The rope in

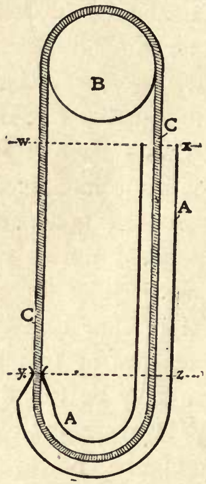


Fig. 14.

the tube between these lines is lifted by the water, while the rope on the other side of the pulley between these lines is pulled downward by gravity.

The inventor offers the above suggestion rather as a kind of puzzle than as a sober attempt to solve the famous problem, and he concludes by asking why it will not work?

In addition to the usual resistance or friction offered by the air to all motion, there are four drawbacks:

1. The friction in its bearings of the axle of the wheel B.

2. The power required to bend and unbend the rope.

3. The friction of the rope in passing through the water from z to x and its tendency to raise a portion of the water above the level of the water at x.

4. The friction at the point *y*, this last being the most serious of all. An "opening of the tube with practically little or no friction, and also without leakage" is a mechanical impossibility. In order to have the joint water-tight, the tube must hug the rope very tightly and this would make friction enough to prevent any motion. And the longer the column of water xz, the greater will be the tendency to leak, and consequently the tighter must be the joint and the greater the friction thereby created.

A favorite idea with perpetual-motion seekers is the utilization of the force of magnetism. Some time prior to the year 1579, Joannes Taisnierus wrote a book which is now in the British Museum and in which considerable space is devoted to "Continual Motions" and to the solving of this problem by magnetism. Bishop Wilkins in his "Mathematical Magick" describes one of the many devices which have been invented with this end in view. He says: "But amongst all these kinds of invention, that is most likely, wherein a loadstone is so disposed that it shall draw unto it on a reclined plane a bullet of steel, which steel as it ascends near to the loadstone, may be contrived to fall down through some hole in the plane, and so to return unto the place from whence at first it began to move; and, being there, the loadstone will again attract it upwards till coming to this hole, it will fall down again; and so the motion shall be perpetual, as may be more easily conceivable by this figure (Fig. 15):

"Suppose the loadstone to be represented at AB, which, though it have not strength enough to attract the bullet C directly from the ground, yet may do it by the help of the plane EF. Now, when the bullet is come to the top of this plane, its own gravity (which is supposed to exceed the strength of the loadstone) will make it fall into that hole at E; and the force it receives in this fall will carry it with such a violence unto the other end of this arch, that it will open the passage which is there made for it, and by its return will again shut it: so that the bullet (as at the

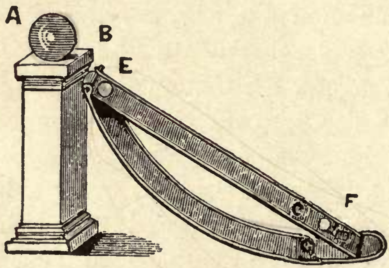


Fig. 15.

first) is in the same place whence it was attracted, and, consequently must move perpetually."

Notwithstanding the positiveness of the "must" at the close of his description, it is very obvious to any practical mechanic that the machine will not move at all, far less move perpetually, and the bishop himself, after carefully and conscientiously discussing the objections, comes to the same conclusion. He ends by saying: "So that none of all these magnetical experiments, which have been as yet discovered, are sufficient for the effecting of a perpetual motion, though these kind of qualities seem most conducible unto it, and perhaps hereafter it may be contrived from them."

It has occurred to several would-be inventors of perpetual motion that if some substance could be found which would prevent the passage of the magnetic force, then by interposing a plate of this material at the proper moment, between the magnet and the piece of iron to be attracted, a perpetual motion might be obtained. Several inventors have claimed that they had discovered such a non-conducting substance, but it is needless to say that their claims had no foundation in fact, and if they had discovered anything of the kind, it would have required just as much force to interpose it as would have been gained by the interposition. It has been fully proved that in every case where a machine was made to work apparently by the interposition of such a material, a fraud was perpetrated and the machine was really made to move by means of some concealed springs or weights.

A correspondent of the "Mechanic's Magazine" (Vol. xii, London, 1829), gives the following curious design for a "Self-moving Railway Carriage." He describes it as a machine which, were it possible to make its parts hold together unimpaired by rotation or the ravages of time, and to give it a path encircling the earth, would assuredly continue to roll along in one undeviating course until time shall be no more.

A series of inclined planes are to be erected in such a manner that a cone will ascend one (its sides forming an acute angle), and being raised to the summit, descend on the next (having parallel sides), at the foot of which it must rise on a third and fall on a fourth, and so continue to do alternately throughout.

The diagram, Fig. 16, is the section of a carriage A, with broad conical wheels *a, a,* resting on the inclined plane *b.* The entrance to the carriage is from above, and there are ample accommodations for goods and passengers. "The most singular property of this contrivance is, that its speed increases the more it is laden; and when checked on any part of the road, it will, when the cause of stoppage is removed, proceed on its journey by mere power of gravity. Its path may be a circular road formed of the inclined planes. But to avoid a circuitous route, a double road ought to be made. The carriage not having a retrograde motion on the inclined planes, a road to set out upon, and another to return by, are indispensable."

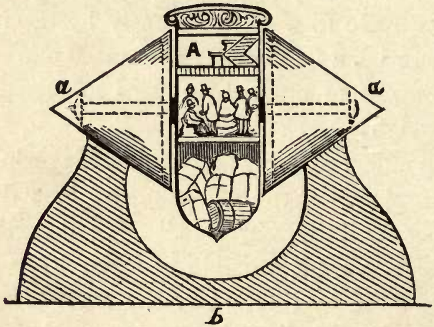


Fig. 16.

How any one could ever imagine that such a contrivance would ever continue in motion for even a short time, except, perhaps, on the famous *decensus averni*, must be a puzzle to every sane mechanic. I therefore give it as a climax to the absurdities which have been proposed in sober earnest. As a fitting close, however, to this chapter of human folly, I give the following joke from the "Penny Magazine," published by the Society for the Diffusion of Useful Knowledge.

"'Father, I have invented a perpetual motion!' said a little fellow of eight years old. 'It is thus: I would make a great wheel, and fix it up like a water-wheel; at the top I would hang a great weight, and at the bottom I would hang a number of little weights; then the great weight

would turn the wheel half round and sink to the bottom, because it is so heavy: and when the little weights reach the top they would sink down, because they are so many; and thus the wheel would turn round for ever.'

The child's fallacy is a type of all the blunders which are made on this subject. Follow a projector in his description, and if it be not perfectly unintelligible, which it often is, it always proves that he expects to find certain of his movements alternately strong and weak — not according to the laws of nature — but according to the wants of his mechanism.

2. FALLACIES

Fallacies are distinguished from absurdities on the one hand and from frauds on the other, by the fact that without any intentionally fraudulent contrivances on the part of the inventor, they seem to produce results which have a tendency to afford to certain enthusiasts a basis of hope in the direction of perpetual motion, although usually not under that name, for that is always explicitly disclaimed by the promoters.

The most notable instance of this class in recent times was the application of liquid air as a source of power, the claim having been actually made by some of the advocates of this fallacy that a steamship starting from New York with 1000 gallons of liquid air, could not only cross the Atlantic at full speed but could reach the other side with more than 1000 gallons of liquid air on board — the power required to drive the vessel and to liquefy the surplus air being all obtained during the passage by utilizing the original quantity of liquid air that had been furnished in the first place.

That this was equivalent to perpetual motion, pure and simple, was obvious even to those who were least familiar with such subjects, though the idea of calling it perpetual motion was sternly repudiated by all concerned — the term "perpetual motion" having become thoroughly offensive to the ears of common-sense people, and consequently tending to cast doubt over any enterprise to which it might be applied.

That liquid air is a real and wonderful discovery, and that for a certain small range of purposes it will prove highly useful, cannot be doubted by those who have seen and handled it and are familiar with its properties, but that it will ever be successfully used as an economical source of mechanical power is, to say the least, very improbable. That a small quantity of the liquid is capable of doing an enormous amount of work, and that under some conditions there is *apparently* more power developed than was originally required to liquefy the air, is undoubtedly true, but when a careful quantitative examination is made of the outgo and the income of energy, it will be found in this, as in every similar case, that instead of a gain there is a very decided and serious loss. The correct explanation of the fallacy was published in the "Scientific American," by the late Dr. Henry Morton, president of the Stevens Institute, and the same explanation and exposure were made by the writer, nearly fifty years ago, in the case of a very similar enterprise. The form of the fallacy in both cases is so similar and so interesting that I shall make no apology for giving the details.

About the year 1853 or 1854, two ingenious mechanics of Rochester, N. Y., conceived the idea that by using some liquid more volatile than water, a great saving might be effected in the cost of running an engine. At that time gasolene and benzine were unknown in commerce, and the same was true in regard to bisulphide of carbon, but as the process of manufacturing the latter was simple and the sources of supply were cheap and apparently unlimited, they adopted that liquid. The name of one of these inventors was Hughes and that of the other was Hill, and it would seem that each had made the invention independently of the other. They had a fierce conflict over the patent, but this does not concern us except to this extent, that the records of the case may therefore be found in the archives of the Patent Office at Washington, D.C. Hughes was backed by the wealth of a well-known lawyer of Rochester, whose son subsequently occupied a high office in the state of New York, and he constructed a beautiful little steam-engine and boiler, made of the very finest materials and with such skill and accuracy that it gave out a very considerable amount of power in proportion to its size. The source of heat was a series of lamps, fed, I think, with lard oil (this was before the days of kerosene), and the exhibition test consisted in first filling the boiler with water, and noting the time that it took to get up a certain steam pressure as shown by the gage. After this test, bisulphide of carbon was added to the water, and the time and pressure were noted. The difference was of course remarkable, and altogether in favor of the new liquid. The exhaust was carried into a vessel of cold water and as bisulphide of carbon is very easily condensed and very heavy, almost the entire quantity used was recovered and used over and over again.

But to the uninstructed onlooker, the most remarkable part of the exhibition was when the steam pressure was so far lowered that the engine revolved very slowly, and then, on a little bisulphide being injected into the boiler, the pressure would at once rise, and the engine would work with great rapidity. This seemed almost like magic.

The same experiment was tried on an engine of twelve horse-power, and with a like result. When the steam pressure had fallen so far that the engine began to move quite slowly, a quantity of the bisulphide would be injected into the boiler and the pressure would at once rise, the engine would move with renewed vigor, and the fly-wheel would revolve with startling velocity. All this was seen over and over again by myself and others. At that time the writer, then quite a young man, had just recovered from a very severe illness and was making a living by teaching mechanical drawing and making drawings for inventors and others, and in the course of business he was brought into contact with some parties who thought of investing in the new and apparently wonderful invention. They employed him to examine it and give an opinion as to its value. After careful consideration and as thorough a calculation as the data then at command would allow, he showed his clients that the tests which had been exhibited to them proved nothing, and that if a clear proof of the value of the invention was to be given, it must be after a run of many hours and not of a few minutes, and against a properly adjusted load, the amount of which had been carefully ascertained. This test was never made, or if made the results were not communicated to the prospective purchasers; the negotiations fell through, and the invention which was to have revolutionized our mechanical industries fell into "innocuous desuetude."

That the inventors were honest I have no doubt. They were themselves deceived when they saw the engine start off with tremendous velocity as soon as a little bisulphide of carbon was injected into the boiler, and they failed to see that this spurt, if I may use the expression, was simply due to a draft upon capital previously stored up. The capacity of bisulphide of carbon for heat is quite low, when compared with that of water; its vaporizing point is also much lower and consequently, an ordinary boiler full of hot water contains enough heat to vaporize a considerable quantity of bisulphide of carbon at a pretty high pressure.

In even a still greater measure the same is true of liquid air, and this was the underlying fallacy in the case of the tests made with liquid-air motors.

3. FRAUDS

But while the inventors of these schemes may have been honest, there is another class who deliberately set out to perpetrate a fraud. Their machines work, and work well, but there is always some concealed source of power, which causes them to move. As a general rule, such inventors form a company or corporation of unlimited "lie-ability," as De Morgan phrases it, and then they proceed by means of flaring prospectuses and liberal advertising, to gather in the dupes who are attracted by their seductive promises of enormous returns for a very small outlay. Perhaps the most widely known of these fraudulent schemes of recent years was the notorious Keeley motor, the originator of which managed to hoodwink a respectable old lady, and to draw from her enormous supplies of cash. At his death, however, the absolutely fraudulent nature of his contrivances was fully disclosed, and nothing more has been heard of his alleged discovery. But, while he lived and was able to put forward claims based upon some apparent results, he found plenty of fools who accepted the idea that there is nothing impossible to science.

It is true that the Keeley motor was examined by several committees and some very respectable gentlemen acted in such a way as to give a seeming endorsement of the scheme, but it must not be supposed for an instant that any well-educated engineers and scientific men were deceived by Mr. Keeley's nonsense. The very fact that he refused to allow a complete examination of his machine by intelligent practical men, ought to have been enough to condemn his scheme, for if he had really made the discovery which he claimed there would have been no difficulty in proving it practically and thoroughly, and then he might have formed company after company that would have rewarded him with "wealth beyond the dreams of avarice."

The Keeley motor was not put forward as a perpetual motion; in these days none of these schemes is admitted to be a perpetual motion, for that term has now become exceedingly offensive and would condemn any invention; but the result is the same in the end, and the whole history of perpetual motion is permeated with frauds of this kind, some of them having been so simple that they were obvious to even the most unskilled observer, while others were exceedingly complicated and most ingeniously concealed. Many years ago a number of these fraudulent perpetual-motion machines were manufactured in America and sent over to Great Britain for exhibition, and quite a lucrative business was done by showing them in various towns. But the fraud was soon detected and the British police then made it too warm for these swindlers.

Mr. Dircks, in his "Perpetuum Mobile," has given accounts of quite a number of these impostures. The following are some of the most notable:

M. Poppe of Tübingen tells of a clock made by M. Geiser, which was an admirable piece of mechanism and seemed to have solved this great problem in an ingenious and simple manner, but it deceived only for a time. When thoroughly examined inwardly and outwardly, some time after his death, it was found that the center props supporting its cylinders contained cleverly constructed, hidden clock-work, wound up by inserting a key in a small hole under the second-hand.

Another case was that of a man named Adams who exhibited, for eight or nine days, his pretended perpetual motion in a town in England and took in the natives for fifty or sixty pounds. Accident, however, led to a discovery of the imposture. A gentleman, viewing the machine took hold of the wheel or trundle and lifted it up a little, which probably disengaged the wheels that connected the hidden machinery in the plinth, and immediately he heard a sound similar to that of a watch when the spring is running down. The owner was in great anger and directly put the wheel into its proper position, and the machine again went around as before. The circumstance was mentioned to an intelligent person who determined to find out and expose the imposture. He took with him a friend to view the machine and they seated themselves one on each side of the table upon which the machine was placed. They then took hold of the wheel and trundle and lifted them up, there being some play in the pivots. Immediately the hidden spring began to run down and they continued to hold the machine in spite of the endeavors of the owner to prevent them. When the spring had run down, they placed the machine again on the table and offered the owner fifty pounds if it could then set itself going, but notwithstanding his fingering and pushing, it remained motionless. A constable was sent for, the impostor went before a magistrate and there signed a paper confessing his perpetual motion to be a cheat.

In the "Mechanic's Magazine," Vol. 46, is an account of a perpetual motion, constructed by one Redhoeffer of Pennsylvania, which obtained sufficient notoriety to induce the Legislature to appoint a committee to enquire into its merits. The attention of Mr. Lukens was turned to the subject, and although the actual moving cause was not discovered, yet the deception was so ingeniously imitated in a machine of similar appearance made by him and moved by a spring so well concealed, that the deceiver himself was deceived and Redhoeffer was induced to believe that Mr. Lukens had been successful in obtaining a moving power in some way in which he himself had failed, when he had produced a machine so plausible in appearance as to deceive the public.

Instances of a similar kind might be multiplied indefinitely.

The experienced mechanic who reads the descriptions here given of the various devices which have been proposed for the construction of a perpetual-motion machine must be struck with the childish simplicity of the plans which have been offered; and those who will search the pages of the mechanical journals of the last century or who will examine the two closely printed volumes in which Mr. Dircks has collected almost everything of the kind, will be astonished at the sameness which prevails amongst the offerings of these would-be inventors. Amongst the hundreds, or, perhaps, thousands, of contrivances which have been described, there is probably not more than a dozen kinds which differ radically from each other; the same arrangement having been invented and re-invented over and over again. And one of the strange features of the case is that successive inventors seem to take no note of the failure of those predecessors who have brought forward precisely the same combination of parts under a very slightly different form.

It is true that we occasionally find a very elaborate and apparently complicated machine, but in such cases it will be found, on close examination, to owe its apparent complexity to a mere multiplication of parts; no real inventive ingenuity is exhibited in any case.

Another singular characteristic of almost all those who have devoted themselves to the search for a perpetual motion is their absolute confidence in the success of the plans which they have brought forth. So confident are they in the soundness of their views and so sure of the success of their schemes that they do not even take the trouble to test their plans but announce them as accomplished facts, and publish their sketches and descriptions as if the machine was already working without a hitch. Indeed, so far was one inventor carried away with this feeling of confidence in the success of his machine that he no longer allowed himself to be troubled with any doubts as to the machine's *going* but was greatly puzzled as to what means he should take to *stop* it after it had been set in motion!

These facts, which are well known to all who have been brought into contact with this class of minds, explain many otherwise puzzling circumstances and enable us to place a proper value on assertions which, if not made so positively and by such apparently good authority, would be at once condemned as deliberate falsehoods. That falsehood, pure and simple, has formed the basis of a good many claims of this kind, there can be no doubt, but at the same time, it is probable that some of the claimants really deceived themselves and attributed to causes other than radical errors of theory, the fact that their machines would not continue to move.

While many have claimed the actual invention of a perpetual motion it is very certain that not one has ever succeeded. How, then, are we to explain the statements which have been made in regard to Orffyreus and the claims of the Marquis of Worcester? For both of these men it is claimed that they constructed wheels which were capable of moving perpetually and apparently strong testimony is offered in support of these assertions.

In the famous "Century of Inventions," published by the Marquis in 1663, four years before his death, the celebrated 56th article reads as follows (*verbatim et literatim*):

"To provide and make that all the Weights of the descending side of a Wheel shall be perpetually further from the Centre, then those of the mounting side, and yet equal in number and heft to the one side as the other. A most incredible thing, if not seen, but tried before the late king (of blessed memory) in the *Tower*, by my directions, two Extraordinary Embassadors accompanying His Majesty, and the Duke of *Richmond* and Duke *Hamilton*, with most of the Court, attending Him. The Wheel was 14. Foot over, and 40. Weights of 50. pounds apiece. Sir *William Balfore*, then Lieutenant of the *Tower*, can justifie it, with several others. They all saw, that no sooner these great Weights passed the Diameter-line of the lower side, but they hung a foot further from the Centre, nor no sooner passed the Diameter-line of the upper side, but they hung a foot nearer. Be pleased to judge the consequence."

Such is the account given by the Marquis himself, and that he exhibited such a wheel at the time and place which he names, I have not the least doubt. And that some of the weights on one side hung a foot further from the center than did weights on the other side is also no doubt true, but, as the judging of the "consequence" is left to ourselves we know that after the first impulse given to it had been expended, the wheel would simply stand still unless kept in motion by some external force.

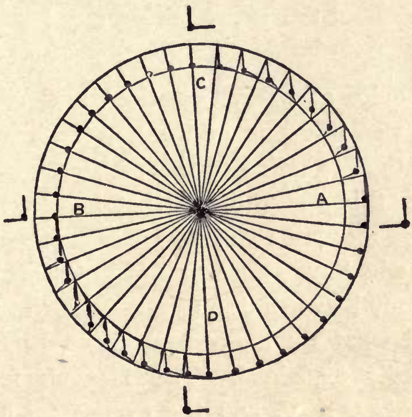


Fig. 17.

Mr. Dircks in his "Life, Times and Scientific Labours of the Second Marquis of Worcester," gives an engraving of a wheel which complies with all the conditions laid down by the Marquis and which is thus described:

" Let the annexed diagram, Fig. 17, represent a wheel of 14 feet in diameter, having 40 spokes, seven feet each, and with an inner rim coinciding with the periphery, at one foot distance all round. Next provide 40 balls or weights, hanging in the center of cords or chains two feet long. Now, fasten one end of this cord at the top of the center

spoke C, and the other end of the cord to the next right-hand spoke one foot below the upper end, or on the inner ring; proceed in like manner with every other spoke in succession; and it will be found that, at A, the cord will have the position shown outside the wheel; while at B, C, and D, it will also take the respective positions, as shown on the outside. The result in this case will be, that all the weights on the side A, C, D, hang to the great or outer circle, while on the side B, C, D, all the weights are suspended from the lesser or inner circle. And if we reverse the motion of the wheel, turning it from the right to the left hand, we shall reverse these positions also (the lower end of the cord sliding in a groove towards a left-hand spoke), but without the wheel having any tendency to move of itself."

But it is quite as likely that the wheel constructed by the Marquis was like one of the "overbalancing" wheels described at the beginning of this article.

It is upon this "scantling" that has been based the claim that the Marquis really invented a perpetual motion, but to those who have seen much of inventors of this kind, the discrepancy between the suggested claim made by the Marquis and what we know must have been the actual results, is easily explained. The Marquis felt sure that the thing *ought to work*, and the excuse for its not doing so was probably the imperfect manner in which the wheel was made. Only put a little better work on it, says the inventor, and it will go.

Caspar Kaltoff, mechanician to the Marquis, probably got the wheel up in a hurry so as to exhibit it on the occasion of the king's visit to the tower. If he only had had a little more time he would have made a machine that would have worked. (?) I have heard the same excuse under almost the same circumstances, scores of times.

The case of Orffyreus was very different. The real name of this inventor was Jean Ernest Elie-Bessler, and he is said to have manufactured the name Orffyreus by placing his own name between two lines of letters, and picking out alternate letters above and below. He was educated for the church, but turned his attention to mechanics and became an expert clock maker. His character, as given by his contemporaries was fickle, tricky, and irascible. Having devised a scheme for perpetual motion he constructed several wheels which he claimed to be self-moving. The last one which he made was 12 feet in diameter and 14 inches deep, the material being light pine boards, covered with waxed cloth to conceal the mechanism. The axle was 8 inches thick, thus affording abundant space for concealed machinery.

This wheel was submitted to the Landgrave of Hesse who had it placed in a room which was then locked, and the lock secured with the Landgrave's own seal. At the end of forty days it was found to be still running.

Professor 'sGravesande having been employed by the Landgrave to make an examination and pronounce upon its merits, he endeavored to perform his work thoroughly; this so irritated Orffyreus that the latter broke the machine in pieces, and left on the wall a writing stating that he had been driven to do this by the impertinent curiosity of the Professor!

I have no doubt that this was a clear case of fraud, and that the wheel was driven by some mechanism concealed in the huge axle. As already stated, Orffyreus was at one time a clock maker; now clocks have been made to go for a whole year without having to be rewound, so that forty days was not a very long time for the apparatus to keep in motion.

Professor 'sGravesande seems to have had some faith in the invention, but then we must remember that it would not have been very difficult to deceive an honest old professor whose confidence in humanity was probably unbounded. The crowning argument against the genuineness of the motion was the fact that the inventor refused to allow a thorough examination, although a wealthy patron stood ready with a large reward if the machine could be proved to be what was claimed.

And now comes up the question which has arisen in regard to other problems, and will recur again and again to the end of the chapter: Is a perpetual motion machine one of the scientific impossibilities?

The answer to this question lies in the fact that there is no principle more thoroughly established than that no combination of machinery can create energy. So far as our present knowledge of nature goes we might as well try to create matter as to create energy, and the creation of energy is essential to the successful working of a perpetual-motion machine because some power must always be lost through friction and other resistances and must be supplied from some source if the machine is to keep on moving. And since the law of the conservation of energy makes it positive that no more power can be given out by a machine than was originally supplied to it, it seems as certain as anything can be that the construction of a perpetual-motion machine is one of the impossibilities.

V

TRANSMUTATION OF THE METALS

THE "accursed thirst for gold" has existed from the earliest ages and, as the apostle says, "is the root of all evil." Those who have a greed for power, a craving for luxury, or a fever for lust, all think that their wildest dreams might be realized if they could only command sufficient gold. Never was there a more lurid picture of a mind inflamed with all these evil passions than that set forth by Ben Jonson in the Second Act of "The Alchemist," and who can doubt but that such desires and dreams spurred on many, either to engage in an actual search for the philosopher's stone, or to become the dupes of what Van Helmont calls "a diabolical crew of gold and silver sucking flies and leeches."

As we might naturally expect, the early history of alchemy is shrouded in myths and fables. Zosimus the Panapolite tells us that the art of Alchemy was first taught to mankind by demons, who fell in love with the daughters of men, and, as a reward for their favors, taught them all the works and mysteries of nature. On this Boerhaave remarks:

"This ancient fiction took its rise from a mistaken interpretation of the words of Moses, 'That the sons of God saw the daughters of men that they were fair, and they took them wives of all which they chose.'[1] From whence it was inferred that the sons of God were dæmons, consisting of a soul, and a visible but impalpable body, like

[1] Genesis vi, 2.

the image in a looking-glass (to which notion we find several allusions in the evangelists); that they know all things, appeared to men and conversed with them, fell in love with women, had intrigues with them and revealed secrets. From the same fable probably arose that of the Sibyl, who is said to have obtained of Apollo the gift of prophecy, and revealing the will of heaven in return for a like favor. So prone is the roving mind of man to figments, which it can at first idly amuse itself with, and at length fall down and worship."

This idea of the supernatural origin of the arts permeates the ancient mythology which everywhere teaches that men were taught the sacred arts of medicine and chemistry by gods and demigods.

Modern science discards all these mythological accounts. Whatever knowledge the ancients acquired of medicine and chemistry was, no doubt, reached along two lines — pharmacy and metallurgy. That the pharmacist or apothecary exercised his calling at a very early period we have positive knowledge; thus in the Book of Ecclesiastes we are told that "dead flies cause the ointment of the apothecary to send forth a stinking savor," and that men at a very early day found out the means of working iron, copper, gold, silver, etc., is evident from the accounts given of Vulcan and Tubalcain, as well as from the remains of old tools and weapons. And that Alchemy, as it is generally understood, is a comparatively modern outgrowth of these two arts, is pretty certain. No mention of the art of converting the baser metals into gold, and no account of a universal medicine or elixir of life is to be found in any of the authentic writings of the ancients. Homer, Aristotle, and even Pliny are all silent on the subject, and those writings which treat of the art, and which claim an ancient origin, such as the books of Hermes Trismegistus, are now regarded by the best authorities as spurious — the evidence that they were the work of a far later age being irrefragable.

Several writers have taken the ground that the alchemical treatises which have come down to us from the early writers on the subject, are purely allegorical and do not relate to material things, but to the principles of a higher religion which, in those days, it was dangerous to expound in plain language. One or two elaborate works and several articles supporting this view have been published, but the common-sense reader who will glance through the immense collection of alchemical tracts gathered together by Mangetus in two folio volumes of a thousand pages each, will rise from such examination, very thoroughly convinced that it was the actual metal gold, and the fabled universal medicine that these writers had in view.

There can be little doubt that Geber, Roger Bacon, Albertus Magnus, Raymond Lully, Helvetius, Van Helmont, Basil Valentine, and others, describe very substantial things with a minuteness of detail which leaves no room for doubt as to their materiality though we cannot always be sure of their identity.

Some confusion of thought has been caused by the difference which has been made between the terms alchemy and chemistry and their applications. The word *alchemy* is simply the word chemistry with the Arabic word *al*, which signifies *the*, prefixed, and the history of alchemy is really the history of chemistry — wild and erratic in its beginnings, and giving rise to strange hopes and still stranger theories, but ever working along the line of discovery and progress. And, although many of the professional chemists or alchemists of the middle ages were undoubted charlatans and quacks, yet did we not have many of the same kind in the nineteenth century? We may use the word alchemist as a term of reproach, and apply it to these early workers because their theories appear to us to be absurd, but how do we know that the chemists of the twenty-second century will not regard us in a similar light, and set at naught the theories we so fondly cherish?

Only seven out of the large number of metals now catalogued by us were known to the ancients; these were gold, silver, mercury, copper, tin, lead, and iron. And as it happened that the list of so-called planets also numbered exactly seven, it was thought that there must be a connection between the two, and, consequently, in the alchemical writings, each metal was called by the name of that one of the heavenly bodies which was supposed to be connected with it in influence and quality.

In the astronomy of the ancients, as is generally known, the earth occupied the center of the universe, and the list of planets included the sun and moon. After them came Mercury, Venus, Mars, Jupiter, and Saturn. To the metal gold was given the name of Sol, or the sun, on account of its brightness and its power of resisting corroding agents; hence the compounds of gold were known as solar compounds and solar medicines. As might have been expected, silver was assigned to Luna or the moon, and in the modern pharmacopœia such terms as lunar caustic and lunar salts still have a place. Mercury was, of course, appropriated to the planet of that name. Copper was named after Venus, and cupreous salts were known as venereal salts. Iron, probably from its being the metal chiefly used for making arms and armor, was dedicated to Mars, and we still speak of martial salts. Tin was named after Jupiter from his brilliancy, the compounds of tin being called jovial salts. The dull, leaden color of Saturn, with his apparently heavy and slow motion, seemed to fit him for association with lead, and we still have the saturnine ointment as a reminder of old alchemical times.

Of these metals gold was supposed to be the only one that was perfect, and the belief was general that if the others could be purified and perfected they would be changed to gold. Many of the old chemists worked faithfully and honestly to accomplish this, but the path to wealth seemed so direct and the means for deception were so ready and simple, that large numbers of quacks and charlatans entered the field and held out the most alluring inducements to dupes who furnished them liberally with money and other necessaries in the hope that when the discovery was made they would be put in possession of unbounded wealth. These dupes were easily deceived and led astray by simple frauds, which scarcely rose to the level of amateur legerdemain. In the "Memoirs of the Academy of Sciences" for 1772, M. Geoffroy gives an account of the various modes in which the frauds of these swindlers were carried on. The following are a few of their tricks: Instead of the mineral substances which they pretended to transmute they put a salt of gold or silver at the bottom of the crucible, the mixture being covered with some powdered crucible and gum water or wax so that it might look like the bottom of the crucible. Another method was to bore a hole in a piece of charcoal, fill the hole with fine filings of gold or silver, stopping it with powered charcoal, mixed with some agglutinent so that the whole might look natural. Then when the charcoal burned away, the silver or gold was found in the bottom of the crucible. Or they soaked charcoal in a solution of these metals and threw the charcoal, when powdered, upon the material to be transmuted. Sometimes they whitened gold with mercury and made it pass for silver or tin, and the gold when melted was exhibited as the result of transmutation. A common exhibition was to dip nails in a liquid and to take them out apparently half converted into gold; these nails consisted of one-half iron neatly soldered to the other half, which was gold, and covered with something to conceal the color. The paint or covering was removed by the liquid. A very common trick was the use of a hollow, iron stirring rod; the hollow was filled with gold or silver filings, and neatly stopped with wax. When used to stir the contents of the crucible the wax melted and allowed the gold or silver to fall out.

These frauds were rendered all the more easy because of certain statements which were current in regard to successful attempts to convert lead and other metals into gold. These accounts were vouched for by well-known chemists and others of high standing. Perhaps the most famous of these is that given by Helvetius in his "Brief of the Golden Calf; Discovering the Rarest Miracle in Nature; how by the smallest portion of the Philosopher's Stone, a great piece of common lead was totally transmuted into the purest transplendent gold, at the Hague in 1666." The following is Brande's abridgment of this singular account.

"The 27th day of December, 1666, in the afternoon, came a stranger to my house at the Hague, in a plebeick habit, of honest gravity and serious authority, of a mean stature and a little long face, black hair not at all curled, a beardless chin, and about forty-four years (as I guess) of age and born in North Holland. After salutation, he beseeched me with great reverence to pardon his rude accesses, for he was a lover of the Pyrotechnian art, and having read my treatise against the sympathetic powder of Sir Kenelm Digby, and observed my doubt about the philosophic mystery, induced him to ask me if I really was a disbeliever as to the existence of an universal medicine which would cure all diseases, unless the principal parts were perished, or the predestinated time of death come. I replied, I never met with an adept, or saw such a medicine, though I had fervently prayed for it. Then I said, 'Surely you are a learned physician.' 'No,' said he, 'I am a brass-founder, and a lover of chemistry.' He then took from his bosom-pouch a neat ivory box, and out of it three ponderous lumps of stone, each about the bigness of a walnut. I greedily saw and handled for a quarter of an hour this most noble substance, the value of which might be somewhere about twenty tons of gold; and having drawn from the owner many rare secrets of its admirable effects, I returned him this treasure of treasures with a most sorrowful mind, humbly beseeching him to bestow a fragment of it upon me in perpetual memory of him, though but the size of a coriander seed. 'No, no,' said he, 'that is not lawful, though thou wouldest give me as many golden ducats as would fill this room; for it would have particular consequences, and if fire could be burned of fire, I would at this instant rather cast it all into the fiercest flames.' He then asked if I had a private chamber whose prospect was from the public street; so I presently conducted him to my best furnished room backwards, which he entered, says Helvetius (in the true spirit of Dutch cleanliness), without wiping his shoes, which were full of snow and dirt. I now expected he would bestow some great secret upon me; but in vain. He asked for a piece of gold, and opening his doublet showed me five pieces of that precious metal which he wore upon a green riband, and which very much excelled mine in flexibility and color, each being the size of a small trencher. I now earnestly again craved a crumb of the stone, and at last, out of his philosophical commiseration, he gave me a morsel as large as a rape-seed; but I said, 'This scanty portion will scarcely transmute four grains of lead.' 'Then,' said he, 'Deliver it me back:' which I did, in hopes of a greater parcel; but he, cutting off half with his nail, said: 'Even this is sufficient for thee.' 'Sir,' said I, with a dejected countenance, 'what means this?' And he said, 'Even that will transmute half an ounce of lead.' So I gave him great thanks, and said I would try it, and reveal it to no one. He then took his leave, and said he would call again next morning at nine. I then confessed, that while the mass of his medicine was in my hand the day before, I had secretly scraped off a bit with my nail, which I projected on lead, but it caused no transmutation, for the whole flew away in fumes. 'Friend,' said he, 'thou art more dexterous in committing theft than in applying medicine; hadst thou wrapt up thy stolen prey in yellow wax, it would have penetrated and transmuted the lead into gold.' I then asked if the philosophic work cost much or required long time, for philosophers say that nine or ten months are required for it. He answered, 'Their writings are only to be understood by the adepts, without whom no student can prepare this magistery. Fling not away, therefore, thy money and goods in hunting out this art, for thou shalt never find it.' To which I replied, 'As thy master showed it thee so mayest thou perchance discover something thereof to me who know the rudiments, and therefore, it may be easier to add to a foundation than begin anew.' 'In this art,' said he, 'it is quite otherwise, for unless thou knowest the thing from head to heel, thou canst not break open the glassy seal of Hermes. But enough; tomorrow at the ninth hour I will show thee the manner of projection.' But Elias never came again; so my wife, who was curious in the art whereof the worthy man had discoursed, teazed me to make the experiment with the little spark of bounty the artist had left me; so I melted half an ounce of lead, upon which my wife put in the said medicine; it hissed and bubbled, and in a quarter of an hour the mass of lead was transmuted into fine gold, at which we were exceedingly amazed. I took it to the goldsmith, who judged it most excellent, and willingly offered fifty florins for each ounce."

Such is the celebrated history of Elias the artist and Dr. Helvetius.

Helvetius stood very high as a man and chemist, but in connection with this and some other narratives of the same kind, it may be well to remember that something over a hundred years before that time the celebrated Paracelsus had introduced laudanum.

The following is another history of transmutation, given by Mangetus, on the authority of M. Gros, a clergyman of Geneva, "of the most unexceptionable character, and at the same time a skilful physician and expert chemist."

"About the year 1650 an unknown Italian came to Geneva and took lodgings at the sign of the Green Cross. After remaining there a day or two, he requested De Luc, the landlord, to procure him a man acquainted with Italian, to accompany him through the town and point out those things which deserved to be examined. De Luc was acquainted with M. Gros, at that time about twenty years of age, and a student in Geneva, and knowing his proficiency in the Italian language, requested him to accompany the stranger. To this proposition he willingly acceded, and attended the Italian everywhere for the space of a fortnight. The stranger now began to complain of want of money, which alarmed M. Gros not a little, for at that time he was very poor, and he became apprehensive, from the tenor of the stranger's conversation, that he intended to ask the loan of money from him. But instead of this, the Italian asked him if he was acquainted with any goldsmith, whose bellows and other utensils they might be permitted to use, and who would not refuse to supply them with the different articles requisite for a particular process which he wanted to perform. M. Gros named a M. Bureau, to whom the Italian immediately repaired. He readily furnished crucibles, pure tin, quicksilver, and the other things required by the Italian. The goldsmith left his workshop, that the Italian might be under the less restraint, leaving M. Gros, with one of his own workmen as an attendant. The Italian put a quantity of tin into one crucible, and a quantity of quicksilver into another. The tin was melted in the fire and the mercury heated. It was then poured into the melted tin, and at the same time a red powder enclosed in wax was projected into the amalgam. An agitation took place and a great deal of smoke was exhaled from the crucible; but this speedily subsided, and the whole being poured out, formed six heavy ingots, having the color of gold. The goldsmith was called in by the Italian and requested to make a rigid examination of the smallest of these ingots. The goldsmith not content with the touch-stone and the application of aquafortis, exposed the metal on the cupel with lead and fused it with antimony, but it sustained no loss. He found it possessed of the ductility and specific gravity of gold; and full of admiration, he exclaimed that he had never worked before upon gold so perfectly pure. The Italian made him a present of the smallest ingot as a recompense and then, accompanied by M. Gros, he repaired to the mint, where he received from M. Bacuet, the mint-master, a quantity of Spanish gold coin, equal in weight to the ingots which he had brought. To M. Gros he made a present of twenty pieces on account of the attention that he had paid to him and after paying his bill at the inn, he added fifteen pieces more, to serve to entertain M. Gros and M. Bureau for some days, and in the meantime he ordered a supper, that he might, on his return, have the pleasure of supping with these two gentlemen. He went out, but never returned, leaving behind him the greatest regret and admiration. It is needless to add that M. Gros and M. Bureau continued to enjoy themselves at the inn till the fifteen pieces which the stranger had left, were exhausted."

Narratives such as these led even Bergman, a very able chemist of the period, to take the ground that "although most of these relations are deceptive and many uncertain, some bear such character and testimony that, unless we reject all historical evidence, we must allow them entitled to confidence."

A much more probable explanation is that the relators were either dreaming or deceived by clever legerdemain.

Of the possibility or impossibility of converting the more common metals into gold or silver, it would be rash to give a positive opinion. To say that gold, silver, lead, copper, etc., are elements and cannot be changed, is merely to say that we have not been able to decompose them. Water, potash, soda, and other substances, were at one time considered elements, and resisted all the efforts of the older chemists to resolve them into their components, but with the advent of more powerful means of analysis they were shown to be compounds, and it is not impossible that the so-called elements into which they were resolved may themselves be found to be compounds. This has happened in regard to some substances which were at one time announced as elements, and it is not impossible that it may happen in regard to others. The ablest chemists of the present day recognize this fully and are prepared for radical changes in our knowledge of the nature and constitution of matter. Amongst the new views is the hypothesis of Rutherford and Soddy, which, as given by Sir William Ramsay, in a recent article contributed by him to "Harper's Magazine," is that,

"atoms of elements of high atomic weight, such as radium, uranium, thorium, and the suspected elements polonium and actinium, are unstable; that they undergo spontaneous change into other forms of matter, themselves radioactive and themselves unstable; and that finally elements are produced, which, on account of their non-radioactivity, are as a rule, impossible to recognize, for their minute amount precludes the application of any ordinary test with success. The recognition of helium however, which is comparatively easy of detection, lends great support to this hypothesis."

At the same time we must not lose sight of the fact that the substances which we now recognize as elements have not only resisted the most powerful analytical agencies and dissociating forces, but have maintained their elemental character in spectrum analysis, and shown their presence as distinct elements in the sun and other heavenly bodies where they must have been subjected to the action of the most energetic decomposing forces. So that in the present state of our knowledge the near prospect of successful transmutation does not seem to be very bright, although we cannot regard it as impossible. In the article from which we have already quoted, Sir William Ramsay, after discussing the bearing of certain experiments in regard to the parting with and absorbing of energy by certain elements, says: "If these hypotheses are just, then the transmutation of the elements no longer appears an idle dream. The philosopher's stone will have been discovered, and it is not beyond the bounds of possibility that it may lead to that other goal of the philosophers of the dark ages — the *elixir vitæ.* For the action of living cells is also dependent on the nature and direction of the energy which they contain; and who can say that it will be impossible to control their action, when the means of imparting and controlling energy shall have been investigated!"

In the event of the discovery of a cheap method of producing gold, the change which would certainly occur in our financial or currency system would be important, if not revolutionary. It has become the fashion at present with certain writers to scout the so-called "quantitative theory" of money as if it were an exposed fallacy. Now the quantitative theory of money rests on one of the most well-grounded and firmly established principles in political economy: the trouble is that the writers in question do not understand it or even know what it is. At present, the production of gold barely keeps pace with the increasing demand for the metal as currency and in the arts, but if that production were increased ten-fold, the value of gold would decline and prices would go up astonishingly.

One of the objects which the better class of alchemists had in view was the making of gold to such an extent that it might become quite common and cease to be sought after by mankind. One alchemical writer says: "Would to God that all men might become adepts in our art, for then gold, the common idol of mankind, would lose its value and we should prize it only for its scientific teaching."

VI

THE FIXATION OF MERCURY

THIS is really one of the processes supposed to be involved in the transmutation of the metals and might, therefore, perhaps, with propriety, be included under that head. But as it has received special attention in the apocryphal works of Hermes Trismegistus, who is generally regarded as the Father of Alchemy, it is frequently mentioned as one of the old scientific problems. Readers of Scott's novel, "Kenilworth," may remember that Wayland Smith, in his account of his former master, Demetrius Doboobius, describes him as a profound chemist who had "made several efforts to fix mercury, and judged himself to have made a fair hit at the philosopher's stone." Hermes, or, rather, those who wrote over his name, speaks in the jargon of the adepts, about "catching the flying bird," by which is meant mercury, and "drowning it so that it may fly no more." The usual means for effecting this was amalgamation with gold, or some other metal or solution in some acid.

To the ancient chemists mercury must have been one of the most interesting of objects. Its great heaviness, its metallic brilliancy, and its wonderful mobility, must all have combined to render it a subject for deep thought and an attractive object for experiment and investigation.

Living in a warm climate, as they did, there was no means at their command by which its fluidity could be impaired. This subtle substance seemed to defy the usual attempts to grasp it; it rolled about like a solid sphere, but offered no resistance to the touch, and when pressed it split up into innumerable smaller globules so that the problem of "fixing" it must have had a strange fascination for the thoughtful alchemist, especially when he found that, on subjection to a comparatively moderate degree of heat, this heavy metal disappeared in vapor and left not a trace behind.

I have often wondered what the old alchemists would have said if they had seen fluid mercury immersed in a clear liquid and brought out in the form of a lump of solid, bright metal. For, although this is not in any sense a solution of the problem, yet it is a most curious sight and one which was rarely seen before the discovery of the liquefaction of the gases. To Geber, Basil Valentine, Van Helmont, Helvetius, and men of their day, living in their climate, this startling phenomenon would have seemed nothing short of a miracle.

In modern times the solidification of mercury had been frequently witnessed by these who dwelt in northern climates and by the skilful use of certain freezing mixtures made up of ordinary salts, it is not difficult to exhibit this metal in the solid state at any time. But it was not until the discovery of the liquefaction of carbonic acid, nitrous oxide, and other gases by Faraday, about 1823, that the freezing of mercury became a common lecture-room experiment.

In the year 1862 the writer delivered a course of lectures on chemistry, in the city of Rochester, N. Y., and during the progress of these lectures he reduced carbonic acid first to the liquid, and then to the solid state, in the form of a white snow. The temperature of this snow was about —80° Cent. (—176° Fahr.) and when it was mixed with ether and laid on a quantity of mercury, the latter was quickly frozen. In this way it was easy to make a hammer-head of frozen mercury and drive a nail with it.

Another very interesting experiment was the freezing of a slender triangular bar of mercury which might be twisted, bent, and tied in a knot. This was done by folding a long strip of very stiff paper so as to make an angular trough into which the mercury was poured. This trough was then carefully leveled and a mixture of solid carbonic acid and ether was placed over the metal in the usual way. In a few seconds the mercury was frozen quite solid so that it could be lifted out by means of two pairs of wooden forceps and bent and knotted at will. But the most striking part of the experiment was the melting of this bar of mercury by means of a piece of ice. The moment the ice touched the mercury, the latter melted and fell down in drops in the same way that a bar of lead or solder melts when it is touched with a red-hot iron.

The melted mercury was allowed to fall into a tall ale-glass of water, the temperature of which had been reduced as nearly as possible to the freezing point. When the mercury came in contact with the cold water, the latter began to freeze and by careful manipulation it was possible to freeze a tube of ice through the center of the column of water. The effect of this under proper illumination was very striking.

Owing to the fact that the specific heat or thermal capacity of mercury is only about one-thirtieth of that of water, it requires a considerable amount of melted mercury to produce the desired result.

But these processes do not enable us to fix mercury in the alchemical sense; the accomplishment of that still remains an unsolved problem, and it is more than likely that it will remain so.

VII

THE UNIVERSAL MEDICINE AND THE ELIXIR OF LIFE

LOVE of life is a characteristic of all animals, man included, and notwithstanding the fact that an occasional individual becomes so dissatisfied with his environment that he commits suicide, and also in the face of the poet's assertion that

> "protracted life is but protracted woe"

most men and women are of the same way of thinking as Charmian, the attendant on Cleopatra, and "love long life better than figs." And the force of this general feeling is appealed to in the only one of the Mosaic commandments to which a promise is attached, the inducement for honoring father and mother being "that thy days may be long in the land that the Lord thy God giveth thee."

No wonder then that the old alchemists dreamed of a universal medicine that would not only prevent or cure sickness but that would renew the youth of the aged and the feeble, for in this, as in most other attempts at discovery, the wish was father to the thought. That the renewal of youth in the aged was supposed to be within the ability of the magicians and gods of old, we gather from the stories of Medea and Aeson and the ivory shoulder of Pelops, as referred to in Shakespeare, and explained in the "Shakespeare Cyclopaedia."

Of the form of this supposed elixir we know very little for the language of the alchemists was so vague and mystical that it is often very difficult to ascertain their meaning with any approach to certainty. The following, which is a fair sample of their metaphorical modes of expressing themselves, is found in the works of Geber. In one of his writings, he exclaims: "Bring me the six lepers that I may cleanse them." Modern commentators explain this as being his mode of telling his readers that he would convert into gold the six inferior or, as they were called by the alchemists, the six imperfect metals. No wonder that Dr. Johnson adopted the idea that the word *gibberish* (anciently written *geberish*) owed its origin to an epithet applied to the language of Geber and his tribe.

Some have claimed that the elixir and the philosopher's stone were one and the same thing, and some of the writings of the old alchemists would seem to confirm this view. Thus, at the close of a formula for preparing the philosopher's stone, Carolus Musitanus gives the following admonition:

"Thus friend, you have a description of the universal medicine, not only for curing diseases and prolonging life, but also for transmuting all metals into gold. Give therefore thanks to Almighty God, who, taking pity on human calamities, has at last revealed this inestimable treasure, and made it known for the benefit of all."

And Brande tells us that "nearly all the alchemists attributed the power of prolonging life either to the philosopher's stone or to certain preparations of gold, imagining possibly that the permanence of that metal might be transferred to the human system. The celebrated Descartes is said to have supported such opinions; he told Sir Kenelm Digby that although he would not venture to promise immortality, he was certain that life might be lengthened to the period of that of the Patriarchs. His plan, however, seems to have been the very rational one of limiting all excess of diet and enjoining punctual and frugal meals."

It is an old saying that history repeats itself. About forty years ago certain medical practitioners strongly urged the use of salts of gold in the treatment of disease, and great hopes were entertained in regard to their efficacy. And the Keeley gold cure for drunkards is strongly in evidence, even at the present day.

On the other hand, some have held that the elixir was quite distinct from the stone by which metals might be transmuted into gold. In the second part of "King Henry IV," Falstaff (Act III, Scene 2, line 355), says of Shallow: "it shall go hard but I will make him a philosopher's two stones to me," and this saying of his has given considerable trouble to the commentators.

Warburton's explanation of this expression is, that "there was two stones, one of which was a universal medicine and the other a transmuter of base metals into gold." And in Churchyard's "Discourse and Commendation of those that can make Gold," we read of Remundus, who

> Wrate sundry workes, as well doth yet appeare
> Of stone for gold, and shewed plaine and cleare
> A stone for health.

Johnson and some others have objected to this explanation, but it seems to be evident that Falstaff meant that he would get health and wealth from Shallow. He got the wealth to the extent of a thousand pounds.

The intense desire which exists in the human bosom for an elixir that will cure all diseases, and prolong life has made itself evident, even in recent times, and has called forth serious efforts on the part of men occupying prominent positions in the scientific world. Both in Europe and in this country suggestions have been made of fluids which, when injected into the veins of the old and the feeble, would renew youth and impart fresh strength. But alas! the results thus far attained have been anything but gratifying, and the probabilities against success in this direction are very strong.

The latest gleam of light comes from discoveries in connection with the radioactive elements, as the reader will find, on referring to Sir William Ramsay's utterance, which is given at the close of the article on the "Transmutation of the Metals," on a preceding page.

ADDITIONAL "FOLLIES"

In addition to the seven "Follies," of which an account has been given in the preceding pages, there are a few which deserve to be classed with them, although they do not find a place in the usual lists. These are known as

Perpetual Lamps.
The Alkahest or Universal Solvent.
Palingenesy.
The Powder of Sympathy.

PERPETUAL OR EVER-BURNING LAMPS

PART of the sepulchral rites of the ancients consisted in placing lighted lamps in the tombs or vaults in which the dead were laid, and, in many cases, these lamps were carefully tended and kept continually burning. Some authors have claimed, however, that these men of old were able to construct lamps which burned perpetually and required no attention. In number 379 of the "Spectator" there is an anecdote of some one having opened the sepulcher of the famous Rosicrucius. There he discovered a lamp burning which a statue of clock-work struck into pieces. Hence, says the writer, the disciples of this visionary claimed that he had made use of this method to show that he had re-invented the ever-burning lamps of the ancients. And Fortunio Liceti wrote a book in which he collected a large number of stories about lamps, said to have been found burning in tombs or vaults. Ozanam fills eight closely printed pages with a discussion of the subject.

Attempts have been made to explain many of the facts upon which is based the claim that the ancients were able to construct perpetual lamps by the suggestion that the light sometimes seen on the opening of ancient tombs may have been due to the phosphorescence which is well known to arise during the decomposition of animal and vegetable matter. Decaying wood and dead fish are familiar objects which give out a light that is sufficient to render dimly visible the outlines of surrounding objects, and such a light, seen in the vicinity of an old lamp, might give rise to the impression that the lamp had been actually burning and that it had been blown out by sudden exposure to a draft of air.

Another supposition was that the flame, which was supposed to have been seen, may have been caused by the ignition of gases arising from the decomposition of dead bodies, and set on fire by the flambeaux or candles of the investigators, and it is quite possible that the occurrence of each of these phenomena may have given a certain degree of confirmation to preconceived ideas.

After the discovery of phosphorus in 1669, by Brandt and Kunckel, it was employed in the construction of luminous phials which could be carried in the pocket, and which gave out sufficient light to enable the user to see the hands of a watch on a dark night. Directions for making these luminous phials are very simple, and may be found in most of the books of experiments published prior to the introduction of the modern lucifer match. They were also used for obtaining a light by means of the old matches, which were tipped merely with a little sulphur, and which could not be ignited by friction. Such a match, after being dipped into one of these phosphorus bottles, would readily take fire by slight friction, and some persons preferred this contrivance to the old flint and steel, partly, no doubt, because it was a novelty. But these bottles were not in any sense perpetual, the light being due to the slow oxidation of the phosphorus so that, in a comparatively short time, the luminosity of the materials ceased. Nevertheless, it has been suggested that some form of these old luminous phials may have been the original perpetual lamp.

After the discovery of the phosphorescent qualities of barium sulphate or Bolognian phosphorus, as it was called, it was thought that this might be a re-discovery of the long-lost art of making perpetual lamps. But it is well known that this substance loses its phosphorescent power after being kept in the dark for some time, and that occasional exposure to bright sun-light is one of the conditions absolutely essential to its giving out any light at all. This condition does not exist in a dark tomb.

A few years ago phosphorescent salts of barium and calcium were employed in the manufacture of what was known as luminous paint. These materials shine in the dark with brilliancy sufficient to enable the observer to read words and numbers traced with them, but regular exposure to the rays of the sun or some other bright light is absolutely necessary to enable them to maintain their efficiency.

More recently it has been suggested that the ancients may have been acquainted with some form of radio-active matter like radium, and that this was the secret of the lamps in question. It is far more likely, however, that the reports of their perpetual lamps were based upon mere errors of observation.

The perpetual lamp is, in chemistry, the counterpart of perpetual motion in mechanics — both violate the fundamental principle of the conservation of energy. And just as suggestions of impossible movements have been numerous in the case of perpetual motion, so impossible devices and constructions have been suggested in regard to perpetual lamps. Prior to the development, or even the suggestion of the law of the conservation of energy, it was believed that it might be possible to find a liquid which would burn without being consumed, and a wick which would feed the liquid to the flame without being itself destroyed. Dr. Plott suggested naphtha for the fluid and asbestos for the wick, but since kerosene oil, naphtha, gasolene, and other liquids of the kind have become common, every housewife knows that as her lamp burns, the oil, of whatever kind it may be, disappears.

Under present conditions the construction of a perpetual lamp is not a severely felt want; for constancy and brilliancy our present means of illumination are sufficient for almost all our requirements. Whether or not it would be possible to gather up those natural currents of electricity, which are suspected to flow through and over the earth, and utilize them for purposes of illumination, however feeble, it might be difficult to decide. But such means of perpetual electric lighting would be similar to a perpetual motion derived from a mountain stream. Such natural means of illumination already exist, and have existed for ages in the fire-giving wells of naphtha which are found on the shores of the Caspian sea, and in other parts of the east, and which have long been objects of adoration to the fire-worshippers.

As for the outcome of present researches into the properties of radium, polonium, and similar substances, and their possible applications, it is too early to form even a surmise.

THE ALKAHEST OR UNIVERSAL SOLVENT

fluorine, even the platinum electrodes were corroded and destroyed. Vessels of pure silver and of lead served tolerably well, but Davy suggested that the most scientific method of constructing a containing vessel would be to use a compound in which fluorine was already present to the point of saturation. As there is a limit to the amount of fluorine with which any base can combine, such a vessel would be proof against its solvent action. I am not aware, however, that the suggestion was ever carried into actual practice with success.

PALINGENESY

THIS singular delusion may have been partly due to errors of observation, the instruments and methods of former times having been notably crude and unreliable. This fact, taken in connection with the wild theories upon which the natural sciences of the middle ages were based, is a sufficient explanation of some of the extraordinary statements made by Kircher, Schott, Digby, and others.

By palingenesy these writers meant a certain chemical process by means of which a plant or an animal might be revived from its ashes. In other words a sort of material resurrection. Most of the accounts given by the old authors go no further than to assert that by proper methods the ashes of plants, when treated with water, produce small forests of ferns and pines. Thus, an English chemist, named Coxe, asserts that having extracted and dissolved the essential salts of fern, and then filtered the liquor, he observed, after leaving it at rest for five or six weeks, a vegetation of small ferns adhering to the bottom of the vessel. The same chemist, having mixed northern potash with an equal quantity of sal ammoniac, saw, some time after, a small forest of pines and other trees, with which he was not acquainted, rising from the bottom of the vessel.

And Kircher tells us in his "Ars Magnetica" that he had a long-necked phial, hermetically sealed, containing the ashes of a plant which he could revive at pleasure by means of heat; and that he showed this wonderful phenomenon to Christina, Queen of Sweden, who was highly delighted with it. Unfortunately he left this valuable curiosity one cold day in his window and it was entirely destroyed by the frost. Father Schott also asserts that he saw this chemical wonder which, according to his account, was a rose revived from its ashes. And he adds that a certain prince having requested Kircher to make him one of the same kind, he chose rather to give up his own than to repeat the operation.

Even the celebrated Boyle, though not very favorable to palingenesy, relates that having dissolved in water some verdigris, which, as is well known, is produced by combining copper with the acid of vinegar, and having caused this water to congeal, by means of artificial cold, he observed, at the surface of the ice, small figures which had an exact resemblance to vines.

In this connection it is well to bear in mind that in Boyle's time almost all vinegar was really what its name implies — *sour wine* (*vin aigre*) — and verdegris or copper acetate was generally prepared by exposing copper plates to the action of refuse grapes which had been allowed to ferment and become sour. Therefore to him it might not have seemed so very improbable that the green crystals which appeared on the surface of the ice were, in reality, minute resuscitated grape-vines.

The explanation of these facts given by Father Kircher is worthy of the science of the times. He tells us that the seminal virtue of each mixture is contained in its salts and these salts, unalterable by their nature, when put in motion by heat, rise in the vessel through the liquor in which they are diffused. Being then at liberty to arrange themselves at pleasure, they place themselves in that order in which they would be placed by the effect of vegetation, or the same as they occupied before the body to which they belonged had been decomposed by the fire; in short, they form a plant, or the phantom of a plant, which has a perfect resemblance to the one destroyed.

That the operators have here mistaken for true vegetable growth the fern-like crystals of the salts which exist in the ashes of all plants is very obvious. Their knowledge of plant structure was exceedingly limited and their microscopes were so imperfect that imagination had free scope. As seen under our modern microscopes, there are few prettier sights than the crystallization of such salts as sal ammoniac, potassic nitrate, barium chloride, etc. The crystals are actually seen to grow and it would not require a very great stretch of the imagination to convince one that the growth is due to a living organism. Indeed, this view has actually been taken in an article which recently appeared in a prominent magazine. The writer of that article sees no difference between the mere aggregation of inorganic particles brought together by voltaic action and the building up of vital structures under the influence of organic forces. This is simply materialism run mad.

Perhaps the finest illustration of such crystallization is to be found in the deposition of silver from a solution of the nitrate as seen under the microscope. A drop of the solution is placed on a glass slide and while the observer watches it through a low power, a piece of copper wire or, preferably, a minute quantity of the amalgam of tin and mercury, such as is used for "silvering" cheap looking glasses, is brought into contact with it. Chemical decomposition at once sets in and then the silver thus deposited forms one element of a very minute voltaic couple and fresh crystals of silver are deposited upon the silver already thrown down. When the illumination of this object under the microscope is properly managed, the appearance, which resembles that shown in Fig. 18, is exceedingly brilliant, and beautiful beyond description.

That imagination played strange pranks in the observations of the older microscopists is shown by some of the engravings found in their books. I have now before me a

Fig. 18.

thick, dumpy quarto in which the so-called seminal animalcules are depicted as little men and women, and I have no doubt that, to the eye of this early observer, they had that appearance. But the microscopists of to-day know better.

Sir Kenelm Digby, whose name is associated with the Sympathetic Powder, tells us that he took the ashes of burnt crabs, dissolved them in water and, after subjecting the whole to a tedious process, small crabs were produced in the liquor. These were nourished with blood from the ox, and, after a time, left to themselves in some stream where they throve and grew large.

Now, although Evelyn, in his diary, declares that "Sir Kenelm was an errant mountebank," it is quite possible that he was honest in his account of his experiments and that he was merely led astray by the imperfection of his instruments of observation. It is more than likely that the creatures which Digby saw were entomostraca introduced in the form of ova which, unless a good microscope be used, are quite invisible. These would develop rapidly and might easily be mistaken for some species of crab, though, when examined with proper instruments, all resemblance vanishes. When let loose in a running stream it would evidently be impossible to trace their identity and follow their growth.

But while some of these stories may have originated in errors of observation this will hardly explain some of the statements made by those who have advocated this strange doctrine. Father Schott, in his "Physica Curiosa," gives an account of the resurrection of a sparrow and actually gives an engraving in which the bird is shown in a bottle revived!

Although the subject, of itself, is not worthy of a moment's consideration, it deserves attention as an illustration of the extraordinary vagaries into which the human mind is liable to fall.

THE POWDER OF SYMPATHY

THIS curious occult method of curing wounds is indissolubly associated with the name of Sir Kenelm Digby (born 1603, died 1665), though it was undoubtedly in use long before his time. He himself tells us that he learned to make and apply the drug from a Carmelite, who had traveled in the east, and whom he met in Florence, in 1622. The descendants of Digby are still prominent in England, and O. W. Holmes, in his "One Hundred Days in Europe," tells us that he had met a Sir Kenelm Digby, a descendant of the famous Sir Kenelm of the seventeenth century, and that he could hardly refrain from asking him if he had any of his ancestor's famous powder in his pocket.

Digby was a student of chemistry, or at least of the chemistry of those days, and wrote books of Recipes and the making of "Methington [metheglin or mead?] Syder, etc." He was, as we have seen in the previous article, a believer in palingenesy and made experiments with a view to substantiate that strange doctrine. Evelyn calls him an "errant quack," and he may have been given to quackery, but then the loose scientific ideas of those days allowed a wide range in drawing conclusions which, though they seem absurd to us, may have appeared to be quite reasonable to the men of that time.

From his book on the subject,[1] we learn that the wound

[1] Touching the Cure of Wounds by the Powder of Sympathy. With Instructions how to make the said Powder. Rendered faithfully out of French into English by R. White, Gent. London, 1658.

was never to be brought into contact with the powder. A bandage was to be taken from the wound, immersed in the powder, and kept there until the wound healed.

This beats the absent treatment of Christian Science!

The powder was simply pulverized vitriol, that is, ferric sulphate, or sulphate of iron.

There was another and probably an older method of using sympathetic powders and salves; this was to apply the supposed curative to the weapon which caused the wound, instead of the wound itself. In the "Lay of the Last Minstrel," Scott gives an account of the way in which the Lady of Buccleuch applied this occult surgery to the wound of William of Deloraine:

"She drew the splinter from the wound,
  And with a charm she stanched the blood.
  She bade the gash be cleansed and bound:
  No longer by his couch she stood;
But she has ta'en the broken lance.
  And washed it from the clotted gore,
  And salved the splinter o'er and o'er.
William of Deloraine, in trance,
Whene'er she turned it round and round
Twisted as if she galled his wound.
  Then to her maidens she did say,
That he should be whole man and sound,
  Within the course of a night and day.
Full long she toiled, for she did rue
  Mishap to friend so stout and true."[1]

That no direct benefit could have been derived from such a mode of treatment must be obvious, but De Morgan very plausibly claims that in the then state of surgical and medical knowledge, it was really the very best that could have been adopted. His argument is as follows: "The

[1] Canto III. Stanza 23.

sympathetic powder was that which cured by anointing the weapon with its salve instead of the wound. I have been long convinced that it was efficacious. The directions were to keep the wound clean and cool, and to take care of diet, rubbing the salve on the knife or sword. If we remember the dreadful notions upon drugs which prevailed, both as to quantity and quality, we shall readily see that any way of *not* dressing the wound, would have been useful. If the physicians had taken the hint, had been careful of diet, etc., and had poured the little barrels of medicine down the throat of a practicable doll, *they* would have had their magical cures as well as the surgeons. Matters are much improved now; the quantity of medicine given, even by orthodox physicians, would have been called infinitesimal by their professional ancestors. Accordingly, the College of Physicians has a right to abandon its motto, which is, *Ars longa, vita brevis*, meaning, *Practice is long, so life is short.*"

As set forth by Digby and others, the use of the Powder of Sympathy is free from all taint of witchcraft or magic, but, in another form, it was wholly dependent upon incantations and other magical performances. This idea of sympathetic action was even carried so far as to lead to attempts to destroy or injure those whom the operator disliked. In some cases this was done by moulding an image in wax which, when formed under proper occult influences, was supposed to have the power of transferring to the victim any injuries inflicted on the image. Into such images pins and knives were thrust in the hope that the living original would suffer the same pains and mutilations that would be inflicted if the knives or pins were thrust into him, and sometimes the waxen form was held before the fire and allowed to melt away slowly in the hope that the prototype would also waste away, and ultimately die. Shakespeare alludes to this in the play of King John. In Act v., Scene 4, line 24, Melun says:

> "A quantity of life
> Which bleeds away, even as a form of wax,
> Resolveth from his figure 'gainst the fire?"

And Hollinshed tells us that "it was alleged against Dame Eleanor Cobham and her confederates that they had devised an image of wax, representing the king, which, by their sorcerie, by little and little consumed, intending thereby, in conclusion, to waste and destroy the king's person."

In these cases, however, the operator always depended upon certain occult or demoniacal influences, or, in other words, upon the art of magic, and therefore examples of this kind do not come within the scope of the present volume. In the case of the Powder of Sympathy the results were supposed to be due entirely to natural causes.

A SMALL BUDGET OF PARADOXES, ILLUSIONS AND MARVELS

THE FOURTH DIMENSION AND THE POSSIBILITY OF A NEW SENSE AND NEW SENSE-ORGAN

THIS subject has now found its way not only into semi-scientific works but into our general literature and magazines. Even our novel-writers have used suggestions from this hypothesis as part of the machinery of their plots so that it properly finds a place amongst the subjects discussed in this volume.

Various attempts have been made to explain what is meant by "the fourth dimension," but it would seem that thus far the explanations which have been offered are, to most minds, vague and incomprehensible, this latter condition arising from the fact that the ordinary mind is utterly unable to conceive of any such thing as a dimension which cannot be defined in terms of the three with which we are already familiar. And I confess at the start that I labor under the superlative difficulty of not being able to form any conception of a fourth dimension, and for this incapacity my only consolation is, that in this respect I am not alone. I have conversed upon the subject with many able mathematicians and physicists, and in every case I found that they were in the same predicament as myself, and where I have met men who professed to think it easy to form a conception of a fourth dimension, I have found their ideas, not only in regard to the new hypothesis, but to its correlations with generally accepted physical facts, to be nebulous and inaccurate.

It does not follow, however, that because myself and some others cannot form such a clear conception of a fourth dimension as we can of the third, that, therefore, the theory is erroneous and the alleged conditions non-existent. Some minds of great power and acuteness have been incapable of mastering certain branches of science. Thus Diderot, who was associated with d'Alembert, the famous mathematician, in the production of "L'Encyclopedie," and who was not only a man of acknowledged ability, but who, at one time, taught mathematics and wrote upon several mathematical subjects, seems to have been unable to master the elements of algebra. The following anecdote regarding his deficiency in this respect is given by Thiébault and indorsed by Professor De Morgan: At the invitation of the Empress, Catherine II, Diderot paid a visit to the Russian court. He was a brilliant conversationalist and being quite free with his opinions, he gave the younger members of the court circle a good deal of lively atheism. The Empress herself was very much amused, but some of her councillors suggested that it might be desirable to check these expositions of strange doctrines. As Catherine did not like to put a direct muzzle on her guest's tongue, the following plot was contrived. Diderot was informed that a learned mathematician was in possession of an algebraical demonstration of the existence of God and would give it to him before all the court if he desired to hear it. Diderot gladly consented, and although the name of the mathematician is not given, it is well known to have been Euler. He advanced toward Diderot, and said in French, gravely, and in a tone of perfect conviction: "*Monsieur,*

$\frac{a + b^n}{n} = x$, *therefore, God exists; reply!*" Diderot, to whom algebra was Hebrew, was embarrassed and disconcerted, while peals of laughter rose on all sides. He asked permission to return to France at once, which was granted.

Even such a mind as that of Buckle, who was generally acknowledged to be a keen-sighted thinker, could not form any idea of a geometrical line — that is, of a line without breadth or thickness, a conception which has been grasped clearly and accurately by thousands of school-boys. He therefore asserts, positively, that there are no lines without breadth, and comes to the following extraordinary conclusions:

"Since, however, the breadth of the faintest line is so slight as to be incapable of measurement, except by an instrument under the microscope, it follows that the assumption that there can be lines without breadth is so nearly true that our senses, when unassisted by art, can not detect the error. Formerly, and until the invention of the micrometer, in the seventeenth century, it was impossible to detect it at all. Hence, the conclusions of the geometrician approximate so closely to truth that we are justified in accepting them as true. The flaw is too minute to be perceived. But that there is a flaw appears to me certain. It appears certain that, whenever something is kept back in the premises, something must be wanting in the conclusion. In all such cases, the field of inquiry has not been entirely covered; and part of the preliminary facts being suppressed, it must, I think, be admitted that complete truth be unattainable, and that no problem in geometry has been exhaustively solved."[1]

The fallacy which underlies Mr. Buckle's contention is thus clearly exposed by the author of "The Natural History of Hell."

[1] "History of Civilization in England." American edition, Vol. II, page 342.

"If it be conceded that lines have breadth, then all we have to do is to assign some definite breadth to each line — say the one-thousandth of an inch — and allow for it. But the lines of the geometer have no breadth. All the micrometers of which Mr. Buckle speaks depend, either directly or indirectly, upon lines for their graduations, and the positions of these lines are indicated by rulings or scratches. Now, in even the finest of these rulings, as, for example, those of Nobert or Fasoldt, where the ruling or scratching, together with its accompanying space, amounts to no more than the one hundred and fifty thousandth part of an inch, the scratch has a perceptible breadth. But this broad scratch is not the line recognized by the microscopist, to say nothing of the geometer. The true line is a line which lies in the very center of this scratch and it is certain that this central line has absolutely no breadth at all." [1]

It must be very evident that if Mr. Buckle's contention that geometrical lines have breadth were true, then some of the fundamental axioms of geometry must be false. It could no longer hold true that "the whole is equal to all its parts taken together," for if we divide a square or a circle into two parts by means of a line which has breadth, the two parts cannot be equal to the whole as it formerly was. As a matter of fact, Mr. Buckle's lines are saw-cuts, not geometrical lines. Geometrical points, lines, and surfaces, have no material existence and can have none. An ideal conception and a material existence are two very different things.

A very interesting book [2] has been written on the movements and feelings of the inhabitants of a world of two dimensions. Nevertheless, if we know anything at all, we know that such a world could not have any actual existence

[1] "The Natural History of Hell," by John Phillipson, page 37.
[2] "Flatland," by E. A. Abbott. London, 1884.

and when we attempt to form any mental conception of it and its inhabitants, we are compelled to adopt, to a certain extent, the idea of the third dimension.

But at the same time we must remember that since the ordinary mechanic and the school-boy who has studied geometry, find no difficulty in conceiving of points without magnitude, lines without breadth, and surfaces without thickness — conceptions which seem to have been impossible to Buckle, a man of acknowledged ability — it may be possible that minds constituted slightly differently from that of myself and some others, might, perhaps, be able to form a conception of a fourth dimension.

Leaving out of consideration the speculations of those who have woven this idea into romances and day-dreams we find that the hypothesis of a fourth dimension has been presented by two very different classes of thinkers, and the discussion has been carried on from two very different standpoints.

The first suggestion of this hypothesis seems to have come from Kant and Gauss and to have had a purely metaphysical origin, for, although attempts have been made to trace the idea back to the famous phantoms of Plato, it is evident that the ideas then advanced had nothing in common with the modern theory of the existence of a fourth dimension. The first hint seems to have been a purely mathematical one and did not attract any very general attention. It was, however, seized upon by a certain branch of the transcendentalists, closely allied to the spiritualists, and was exploited by them as a possible explanation of some curious and mysterious phenomena and feats exhibited by certain Indian and European devotees. This may have been done merely for the purpose of mystifying and confounding their adversaries by bringing forward a striking illustration of Hamlet's famous dictum — "

> "There are more things in heaven and earth, Horatio,
> Than are dreamt of in your philosophy."

A very fair statement of this view is thus given by Edward Carpenter:[1]

"There is another idea which modern science has been familiarizing us with, and which is bringing us towards the same conception — that, namely, of the fourth dimension. The supposition that the actual world has four space-dimensions instead of three makes many things conceivable which otherwise would be incredible. It makes it conceivable that apparently separate objects, e. g., distinct people, are really physically united; that things apparently sundered by enormous distances of space are really quite together; that a person or other object might pass in and out of a closed room without disturbance of walls, doors or windows, etc., and if this fourth dimension were to become a factor of our consciousness it is obvious that we should have means of knowledge which, to the ordinary sense, would appear simply miraculous. There is much, apparently, to suggest that the consciousness attained to by the Indian gñanis in their degree, and by hypnotic subjects in theirs, is of this fourth dimensional order.

"As a solid is related to its own surface, so, it would appear, is the cosmic consciousness related to the ordinary consciousness. The phases of the personal consciousness are but different facets of the other consciousness; and experiences which seem remote from each other in the individual are perhaps all equally near in the universal. Space itself, as we know it, may be practically annihilated in the consciousness of a larger space, of which it is but the superficies; and a person living in London may not unlikely find that he has a back door opening quite simply and unceremoniously out in Bombay."

On the other hand, the mathematicians, looking at it as a purely speculative idea, have endeavored to arrive at

[1] "From Adam's Peak to Elephanta — " page 160.

definite conclusions in regard to what would be the condition of things if the universe really exists in a fourth, or even in some higher dimension. Professor W. W. R. Ball tells us that

"the conception of a world of more than three dimensions is facilitated by the fact that there is no difficulty in imagining a world confined to only two dimensions — which we may take for simplicity to be plane — though equally well it might be a spherical or other surface. We may picture the inhabitants of flatland as moving either on the surface of a plane or between two parallel and adjacent planes. They could move in any direction along the plane, but they could not move perpendicularly to it, and would have no consciousness that such a motion was possible. We may suppose them to have no thickness, in which case they would be mere geometrical abstractions; or we may think of them as having a small but uniform thickness, in which case they would be realities."

. . . .

"If an inhabitant of flatland was able to move in three dimensions, he would be credited with supernatural powers by those who were unable so to move; for he could appear or disappear at will; could (so far as they could tell) create matter or destroy it, and would be free from so many constraints to which the other inhabitants were subject that his actions would be inexplicable to them."

. . . .

"Our conscious life is in three dimensions, and naturally the idea occurs whether there may not be a fourth dimension. No inhabitant of flatland could realize what life in three dimensions would mean, though, if he evolved an analytical geometry applicable to the world in which he lived, he might be able to extend it so as to obtain results true of that world in three dimensions which would be to him unknown and inconceivable. Similarly we cannot realize what life in four dimensions is like, though we can use analytical geometry to obtain results true of that world, or even of worlds of higher dimensions. Moreover, the analogy of our position to the inhabitants of flatland enables us to form some idea of how inhabitants of space of four dimensions would regard us."

. . . .

"If a finite solid was passed slowly through flatland, the inhabitants would be conscious only of that part of it which was in their plane. Thus they would see the shape of the object gradually change and ultimately vanish. In the same way, if a body of four dimensions was passed through our space, we should be conscious of it only as a solid body (namely, the section of the body by our space) whose form and appearance gradually changed and perhaps ultimately vanished. It has been suggested that the birth, growth, life, and death of animals, may be explained thus as the passage of finite four-dimensional bodies through our three-dimensional space."

Attempts have been made to construct drawings and models showing a four-dimensional body. The success of such attempts has not been very encouraging.

Investigators of this class look upon the actuality of a fourth dimension as an unsolved question, but they hold that, provided we could see our way clear to adopt it, it would open up wondrous possibilities in the way of explaining abstruse and hitherto inexplicable physical conditions and phenomena.

There is obviously no limit to such speculations, provided we assume the existence of such conditions as are needed for our purpose. Too often, however, those who indulge in such day-dreams begin by assuming the impossible, and end by imagining the absurd.

We have so little positive knowledge in regard to the ultimate constitution of matter and even in regard to the actual character of the objects around us, which are revealed to us through our senses, that the field in which our imagination may revel is boundless. Perhaps some day the humanity of the present will merge itself into a new race, endowed with new senses, whose revelations are to us, for the present, at least, utterly inconceivable.

The possibility of such a development may be rendered more clear if we imagine the existence of a race devoid of the sense of hearing, and without the organs necessary to that sense. They certainly could form no idea of sound, far less could they enjoy music or oratory, such as afford us so much delight. And, if one or more of our race should visit these people, how very strange to them would appear those curious appendages, called ears, which project from the sides of our heads, and how inexplicable to them would be the movements and expressions of intelligence which we show when we talk or sing? It is certain that no development of the physical or mathematical sciences could give them any idea whatever of the sensations which sound, in its various modifications, imparts to us, and neither can any progress in that direction enable us to acquire any idea of the revelations which a new sense might open up to us. Nevertheless, it seems to me that the development of new senses and new sense organs is not only more likely to be possible, but that it is actually more probable, than any revelation in regard to a fourth dimension.

HOW A SPACE MAY BE APPARENTLY ENLARGED BY CHANGING ITS SHAPE

THE following is a curious illustration of the errors to which careless observers may be subject:

Draw a square, like Fig. 19, and divide the sides into 8 parts each. Join the points of division in opposite sides so as to divide the whole square into 64 small squares. Then draw the lines shown in black and cut up the drawing into four pieces. The lines indicating the cuts have been made quite heavy so as to show up clearly,

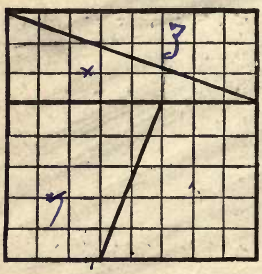


Fig. 19.

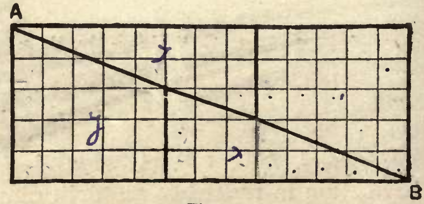


Fig. 20.

but on the actual card they may be made quite light. Now, put the four pieces together, so as to form the rectangle shown in Fig. 20. Unless the scale, to which the drawing is made is quite large and the work very accurate, it will seem that the rectangle contains 5 squares one way and 13 the other which, when multiplied together, give 65 for the number of small squares, being an apparent gain of one square by the simple process of cutting.

This paradox is very apt to puzzle those who are not familiar with accurate drawings. Of course, every person of common sense knows that the card or drawing is not made any larger by cutting it, but where does the 65th small square come from?

On careful examination it will be seen that the line AB, Fig. 20, is not quite straight and the three parts into which it is divided are thus enabled to gain enough to make one of the small squares. On a small scale this deviation from the straight line is not very obvious, but make a larger drawing, and make it carefully, and it will readily be seen how the trick is done.

CAN A MAN LIFT HIMSELF BY THE STRAPS OF HIS BOOTS?

I THINK it was the elder Stephenson, the famous engineer, who told a man who claimed the honor of having invented a perpetual motion, that when he could lift himself over a fence by taking hold of his waist-band, he might hope to accomplish his object. And the query which serves as a title for this article has long been propounded as one of the physical impossibilities. And yet, perhaps, it might be possible to invent a waist-band or a boot-strap by which this apparently impossible feat might be accomplished!

Travelers in Mexico frequently bring home beans which jump about when laid on a table. They are well-known as "jumping beans" and have often been a puzzle to those who were not familiar with the facts in the case. Each bean contains the larva of a species of beetle and this affords a clue to the secret. But the question at once comes up: "How is the insect able to move, not only itself, but its house as well, without some purchase or direct contact with the table?"

The explanation is simple. The hollow bean is elastic and the insect has strength enough to bend it slightly; when the insect suddenly relaxes its effort and allows the bean to spring back to its former shape, the reaction on the table moves the bean. A man placed in a perfectly rigid box could never move himself by pressing on the sides, but if the box were elastic and could be bent by the strength of the man inside, it might be made to move.

A somewhat analogous result, but depending on different principles, is attained in certain curious boat races which are held at some English regattas and which is explained by Prof. W. W. Rouse Ball, in his "Mathematical Recreations and Problems." He says that it

"affords a somewhat curious illustration of the fact that commonly a boat is built so as to make the resistance to motion straight forward less than that to motion in the opposite direction.

"The only thing supplied to the crew is a coil of rope, and they have (without leaving the boat) to propel it from one point to another as rapidly as possible. The motion is given by tying one end of the rope to the afterthwart, and giving the other end a series of violent jerks in a direction parallel to the keel.

"The effect of each jerk is to compress the boat. Left to itself the boat tends to resume its original shape, but the resistance to the motion through the water of the stern is much greater than that of the bow, hence, on the whole, the motion is forwards. I am told that in still water a pace of two or three miles an hour can be thus attained."

HOW A SPIDER LIFTED A SNAKE

ONE of the most interesting books in natural history is a work on "Insect Architecture," by Rennie. But if the architecture of insect homes is wonderful, the engineering displayed by these creatures is equally marvellous. Long before man had thought of the saw, the saw-fly had used the same tool, made after the same fashion, and used in the same way for the purpose of making slits in the branches of trees so that she might have a secure place in which to deposit her eggs. The carpenter bee, with only the tools which nature has given her, cuts a round hole, the full diameter of her body, through thick boards, and so makes a tunnel by which she can have a safe retreat, in which to rear her young. The tumble-bug, without derrick or machinery, rolls over large masses of dirt many times her own weight, and the sexton beetle will, in a few hours, bury beneath the ground the carcass of a comparatively large animal. All these feats require a degree of instinct which in a reasoning creature would be called engineering skill, but none of them are as wonderful as the feats performed by the spider. This extraordinary little animal has the faculty of propelling her threads directly against the wind, and by means of her slender cords she can haul up and suspend bodies which are many times her own weight.

Some years ago a paragraph went the rounds of the papers in which it was said that a spider had suspended an unfortunate mouse, raising it up from the ground, and leaving it to perish miserably between heaven and earth. Would-be philosophers made great fun of this statement, and ridiculed it unmercifully. I know not how true it *was*, but I know that it *might have been* true.

Some years ago, in the village of Havana, in the State of New York, a spider entangled a milk-snake in her threads, and actually raised it some distance from the ground, and this, too, in spite of the struggles of the reptile, which was alive.

By what process of engineering did the comparatively small and feeble insect succeed in overcoming and lifting up by mechanical means, the mouse or the snake? The solution is easy enough if we only give the question a little thought.

The spider is furnished with one of the most efficient mechanical implements known to engineers, viz., a strong elastic thread. That the thread is strong is well known. Indeed, there are few substances that will support a greater strain than the silk of the silkworm, or the spider; careful experiment having shown that for equal sizes the strength of these fibers exceeds that of common iron. But notwithstanding its strength, the spider's thread alone would be useless as a mechanical power if it were not for its elasticity. The spider has no blocks or pulleys, and, therefore, it cannot cause the thread to divide up and run in different directions, but the elasticity of the thread more than makes up for this, and renders possible the lifting of an animal much heavier than a mouse or a snake. This may require a little explanation.

Let us suppose that a child can lift a six-pound weight one foot high and do this twenty times a minute. Furnish him with 350 rubber bands, each capable of pulling six pounds through one foot when stretched. Let these bands be attached to a wooden platform on which stand a pair of horses weighing 2,100 lbs., or rather more than a ton. If now the child will go to work and stretch these rubber bands, singly, hooking each one up, as it is stretched, in less than twenty minutes he will have raised the pair of horses one foot!

We thus see that the elasticity of the rubber bands enables the child to divide the weight of the horses into 350 pieces of six pounds each, and at the rate of a little less than one every three seconds, he lifts all these separate pieces one foot, so that the child easily lifts this enormous weight.

Each spider's thread acts like one of the elastic rubber bands. Let us suppose that the mouse or the snake weighed half an ounce and that each thread is capable of supporting a grain and a half. The spider would have to connect the mouse with the point from which it was to be suspended with 150 threads, and if the little quadruped was once swung off his feet, he would be powerless. By pulling successively on each thread and shortening it a little, the mouse or snake might be raised to any height within the capacity of the building or structure in which the work was done. So that to those who have ridiculed the story we may justly say: "There are more things in heaven and earth than are dreamed of in *your* philosophy."

What object the spider could have had in this work I am unable to see. It may have been a dread of the harm which the mouse or snake might work, or it may have been the hope that the decaying carcass would attract flies which would furnish food for the engineer. I can vouch for the truth of the snake story, however, and the object of this article is to explain and render credible a very extraordinary feat of insect engineering.

HOW THE SHADOW MAY BE MADE TO MOVE BACKWARD ON THE SUN-DIAL

IN the twentieth chapter of II Kings, at the eleventh verse we read, that "Isaiah the prophet cried unto the Lord, and he brought the shadow ten degrees backward, by which it had gone down in the dial of Ahaz."

It is a curious fact, first pointed out by Nonez, the famous cosmographer and mathematician of the sixteenth century, but not generally known, that by tilting a sun-dial through the proper angle, the shadow at certain periods of the year can be made, for a short time, to move backwards on the dial. This was used by the French encyclopædists as a rationalistic explanation of the miracle which is related at the opening of this article.

The reader who is curious in such matters will find directions for constructing "a dial, for any latitude, on which the shadow shall retrograde or move backwards," in Ozanam's "Recreations in Science and Natural Philosophy," Riddle's edition, page 529. Professor Ball in his "Mathematical Recreations," page 214, gives a very clear explanation of the phenomenon. The subject is somewhat too technical for these pages.

HOW A WATCH MAY BE USED AS A COMPASS

SEVERAL years ago a correspondent of "Truth" (London) gave the following simple directions for finding the points of the compass by means of the ordinary pocket watch: "Point the hour hand to the sun, and south is exactly half way between the hour hand and twelve on the watch, counting forward up to noon, but backward after the sun has passed the meridian."

Professor Ball, in his "Mathematical Recreations and Problems," gives more complete directions and explanations. He says:

"The position of the sun relative to the points of the compass determines the solar time. Conversely, if we take the time given by a watch as being the solar time (and it will differ from it only by a few minutes at the most), and we observe the position of the sun, we can find the points of the compass. To do this it is sufficient to point the hour-hand to the sun and then the direction which bisects the angle between the hour and the figure XII will point due south. For instance, if it is four o'clock in the afternoon, it is sufficient to point the hour-hand (which is then at the figure IIII) to the sun, and the figure II on the watch will indicate the direction of south. Again, if it is eight o'clock in the morning, we must point the hour-hand (which is then at the figure VIII) to the sun, and the figure X on the watch gives the south point of the compass.

"Between the hours of six in the morning and six in the evening the angle between the hour and XII, which must be bisected is less than 180 degrees, but at other times the angle to be bisected is greater than 180 degrees; or perhaps it is simpler to say that at other times the rule gives the north point and not the south point.

"The reason is as follows: At noon the sun is due south, and it makes one complete circuit round the points of the compass in 24 hours. The hour-hand of a watch also makes one complete circuit in 12 hours. Hence, if the watch is held with its face in the plane of the ecliptic, and the figure XII on the dial is pointed to the south, both the hour-hand and the sun will be in that direction at noon. Both move round in the same direction, but the angular velocity of the hour-hand is twice as great as that of the sun. Hence the rule. The greatest error due to the neglect of the equation of time is less than 2 degrees. Of course, in practice, most people would hold the face of the watch horizontal, and in our latitude (that of London) no serious error would thus be introduced.

"In the southern hemisphere, or in any tropical country where at noon the sun is due north, the rule will give the north point instead of the south."

MICROGRAPHY OR MINUTE WRITING AND MICROPHOTOGRAPHY

MINUTE works of art have always excited the curiosity and commanded the admiration of the average man. Consequently Cicero thought it worth while to record that the entire Illiad of Homer had been written upon parchment in characters so fine that the copy could be enclosed in a nutshell. This has always been regarded as a marvelous feat.

There is in the French Cabinet of Medals a seal, said to have belonged to Michael Angelo, the fabrication of which must date from a very remote epoch, and upon which fifteen figures have been engraved in a circular space of fourteen millimeters (.55 inch) in diameter. These figures cannot be distinguished by the naked eye.

The Ten Commandments have been engraved in characters so fine that they could be stamped upon one side of a nickle five-cent piece, and on several occasions the Lord's Prayer has been engraved on one side of a gold dollar, the diameter of which is six-tenths of an inch. I have also seen it written with a pen within a circle which measured four-tenths of an inch in diameter.

In the Harleian manuscript, 530, there is an account of a "rare piece of work, brought to pass by Peter Bales, an Englishman, and a clerk of the chancery." Disraeli tells us that it was "The whole Bible in an English walnut, no bigger than a hen's egg. The nut holdeth the book: there are as many leaves in his little book as in the great Bible, and he hath written as much in one of his little leaves as a great leaf of the Bible."

By most people, such achievements are considered marvels of skill, and the newspaper accounts of them which are published always attract special attention. And it must be acknowledged that such work requires good eyes, steady nerves, and very delicate control of the muscles. But with ordinary writing materials there are certain mechanical limitations which must prevent even the most skilful from going very far in this direction. These limitations are imposed by the fiber or grain of the paper and the construction of the ordinary pen, neither of which can be carried beyond a certain very moderate degree of fineness. Of course, the paper that is chosen will be selected on account of its hard, even-grained surface, and the pen will be chosen on account of the quality of its material and its shape, and the point is always carefully dressed on a whetstone so as to have both halves of the nib equal in strength and length, and the ends smooth and delicate. When due preparation has been made, and when the eyes and nerves of the writer are in good condition, the smallness of the distinctly readable letters that may be produced is wonderful. And in this connection it is an interesting fact that in many mechanical operations, writing included, the hand is far more delicate than the eye. That which the unaided eye can see to write, the unaided eye can see to read, but the hand, without the assistance or guidance of the eye, can produce writing so minute that the best eyes cannot see to read it, and yet, when viewed under a microscope, it is found to compare favorably with the best writing of ordinary size. And those who are conversant with the more delicate operations of practical mechanics, know that this is no exceptional case. The only aid given by the eye in the case of such minute writing is the arrangement of the lines, otherwise the writing could be done as well with the eyes shut as open.

Since the mechanical limitations which we have noted prevent us from going very far with the instruments and materials mentioned, the next step is to adopt a finer surface and a sharper point. These conditions may be found in the fine glazed cards and the metal pencils or styles used by card writers. In these cards the surface is nearly homogeneous, that is to say, free from fibers, and the point of the metal pencil may be made as sharp as a needle, but to utilize these conditions to the fullest extent, it is necessary to aid the eye, and a magnifier is, therefore, brought into use. Under a powerful glass the hand may be so guided by the eye that the writing produced cannot be read by the unaided vision.

The specimens of fine writing thus far described have been produced directly by the hand under the guidance either of a magnifier or the simple sense of motion. Just how far it would be possible to go by these means has never been determined, so far as I know, but those who have examined the specimens of selected diatoms and insect scales in which objects that are utterly invisible to the naked eye are arranged with great accuracy so as to form the most beautiful figures, can readily believe that a combination of microscopical dexterity and skill in penmanship might easily go far beyond anything that has yet been accomplished in this direction, either in ancient or modern times.

But by means of a very simple mechanical arrangement, the motion of the hand in every direction may be accurately reduced or enlarged to almost any extent, and it thus becomes possible to form letters which are inconceivably small. The instrument by which this is accomplished is known as a pantagraph, and it has, within a few years, become quite popular as a means of reducing or enlarging pictures of various kinds, including crayon reproductions of photographs. Its construction and use are, therefore, very generally understood. It was by means of a very finely-made instrument embodying the principles of the pantagraph that the extraordinarily fine work which we are about to describe was accomplished.

It is obvious, however, that in order to produce very fine writing we must use a very fine pen or point and the finer the point the sooner does it wear out, so that in a very short time the lines which go to form the letters become thick and blurred and the work is rendered illegible. As a consequence of this, when the finest specimens of writing are required, it is necessary to abandon the use of ordinary points and surfaces and to resort to the use of the diamond for a pen, and glass for a surface upon which to write. One of the earliest attempts in this direction was that of M. Froment, of Paris, who engraved on glass, within a circle, the one-thirtieth of an inch in diameter, the Coat of Arms of England — lion, unicorn, and crown — with the following inscription, partly in Roman letters, partly in script: "*Honi soit qui mal y pense*, Her Most Gracious Majesty, Queen Victoria, and His Royal Highness, Prince Albert, *Dieu et mon droit*. Written on occasion of the Great Exhibition, by Froment, à Paris, 1851."

The late Dr. Barnard, President of Columbia College, had in his possession a copy of the device borne by the seal of Columbia College, New York, executed for him by M.

Dumoulin-Froment, within a circle less than three one-hundredths of an inch in diameter, "in which are embraced four human figures and various other objects, together with inscriptions in Latin, Greek, and Hebrew, all clearly legible. In this device the rising sun is represented in the horizon, the diameter of the disk being about three one-thousandths of an inch. This disk has been cross-hatched by the draughtsman in the original design from which the copy was made; and the copy shows the marks of the cross-hatching with perfect distinctness. When this beautiful and delicate drawing is brought clearly out by a suitably adjusted illumination, the lines appear as if traced by a smooth point in a surface of opaque ice."

Lardner, in his book on the "Microscope," published in 1856, gives a wood cut which shows the first piece of engraving magnified 120 diameters, but he said that he was not at liberty to describe the method by which it was done. As happens in almost all such cases, however, the very secrecy with which the process was surrounded naturally stimulated others to rival or surpass it, and Mr. N. Peters, a London banker, turned his attention to the subject and soon invented a machine which produced results far exceeding anything that M. Froment had accomplished. On April 25, 1855, Mr. Farrants read before the Microscopical Society of London a full account of the Peters machine, with which the inventor had written the Lord's Prayer (in the ordinary writing character, without abbreviation or contraction of any kind), in a space not exceeding the one hundred and fifty-thousandth of a square inch. Seven years later, Mr. Farrants, as President of the Microscopical Society, described further improvements in the machine of Mr. Peters, and made the following statement: "The

Lord's Prayer has been written and may be read in the one-three hundred and fifty-six thousandth of an English square inch. The measurements of one of these specimens was verified by Dr. Bowerbank, with a difference of not more than one five-millionth of an inch, and that difference, small as it is, arose from his not including the prolongation of the letter *f* in the sentence 'deliver us from evil'; so he made the area occupied by the writing less than that stated above."

Some idea of the minuteness of the characters in these specimens may be obtained from the statement that the whole Bible and Testament, in writing of the same size, might be placed twenty-two times on the surface of a square inch. The grounds for this startling assertion are as follows: "The Bible and Testament together, in the English language, are said to contain 3,566,480 letters. The number of letters in the Lord's Prayer, as written, ending in the sentence, 'deliver us from evil,' is 223, whence, as 3,566,480 divided by 223, is equal to 15,922, it appears that the Bible and Testament together contain the same number of letters as the Lord's Prayer written 16,000 times; if then the prayer were written in 1-16,000 of an inch, the Bible and Testament in writing of the same size would be contained by one square inch; but as 1-356,000th of an inch is one twenty-secondth part of 1-15,922 of an inch, it follows that the Bible and Testament, in writing of that size, would occupy less space than one twenty-secondth of a square inch."

It only now remains to be seen that, minute as are the letters written by this machine, they are characterized by a clearness and precision of form which proves that the moving parts of the machine, while possessing the utmost delicacy of freedom, are absolutely destitute of shake, a union of requisites very difficult of fulfilment, but quite indispensable to the satisfactory performance of the apparatus.

I have no information in regard to the present whereabouts of any of the specimens turned out by Mr. Peters, and inquiry in London, among persons likely to know, has not supplied any information on the subject.

There was, however, another micrographer, Mr. William Webb, of London, who succeeded in producing some marvellous results. Epigrams and also the Lord's Prayer written in the one-thousandth part of a square inch have been freely distributed. Mr. Webb also produced a few copies of the second chapter of the Gospel, according to St. John, written on the scale of the whole Bible, to a little more than three-quarters of a square inch, and of the Lord's Prayer written on the scale of the whole Bible eight times on a square inch. Mr. Webb died about fifteen years ago, and I believe he has had no successor in the art. Specimens of his work are quite scarce, most of them having found their way into the cabinets of public Museums and Societies, who are unwilling to part with them. The late Dr. Woodward, Director of the Army Medical Museum, Washington, D.C., procured two of them on special order for the Museum. Mr. Webb had brought out these fine writings as tests for certain qualities of the microscope, and it was to "serve as tests for high-power objectives" that Dr. Woodward procured the specimens now in the microscopical department of the Museum. I am so fortunate as to have in my possession two specimen's of Mr. Webb's work. One is an ordinary microscopical glass slide, three inches by one, and in the center is a square speck which measures 1-45th of an inch on the side. Upon this square is written the whole of the second chapter of the Gospel according to St. John — the chapter which contains the account of the marriage in Cana of Galilee.

In order to estimate the space which the whole Bible would occupy if written on the same scale as this chapter, I have made the following calculation which, I think, will be more easily followed and checked by my readers, than that of Mr. Farrants.

The text of the old version of the Bible, as published in minion by the American Bible Society, contains 1272 pages, exclusive of title pages and blanks. Each page contains two columns of 58 lines each, making 116 lines to the page. This includes the headings of the chapters and the synopses of their contents, which are, therefore, thrown in to make good measure. We have, therefore, 1272 pages of 116 lines each, making a total of 147,552 lines.

The second chapter of St. John has 25 verses containing 95 lines, and is written on the 1–2025th of an inch, or, in other words, it would go 2025 times on a square inch. A square inch would, therefore, contain 95 × 2025 or 192,375 lines. This number (192,375), divided by the number of lines in the Bible (147,552), gives 1.307, which is the number of times the Bible might be written on a square inch in letters of the same size. In other words, the whole Bible might be written on .77 inch, or very little more than three-quarters of a square inch.

Perhaps the following gives a more impressive illustration: The United States silver quarter of a dollar is .95 inch in diameter, so that the surface of each side is .707 of a square inch. The whole Bible would, therefore, very nearly go on one side of a quarter of a dollar. If the blank spaces at the heads of the chapters and the synopses of contents were left out, it would easily go on one side.

The second specimen, which I have of Mr. Webb's writing, is a copy of the Lord's Prayer written on a scale of eight Bibles to the square inch. According to a statement kindly sent me by the superintendent of the United States Mint at Philadelphia, the diameter of the last issued gold dollar, and also of the silver half-dime, is six-tenths of an inch. This gives .2827+ of a square inch as the area of the surface of one side, and, therefore, the whole Bible might be written more than two and a quarter times on one side of either the gold dollar or the silver half dime.

Such numerical and space relations are far beyond the power of any ordinary mind to grasp. With the aid of a microscope we can see the object and compare with other magnifications the rate at which it is enlarged, and a person of even the most ordinary education can follow the calculation and understand why the statements are true, but the final result, like the duration of eternity or the immensity of space, conveys no definite idea to our minds.

But at the same time we must carefully distinguish between our want of power to grasp these ideas and our inability to form a conception of some inconceivable subject, such as a fourth dimension or the mode of action of a new sense.

Wonderful as these achievements are, there is another branch of the microscopic art which, from the practical applications that have been made of it, is even more interesting. This is the art of microphotography.

About the middle of the last century Mr. J. B. Dancer, of Manchester, England, produced certain minute photographs of well-known pictures and statues which commanded the universal attention of the microscopists of that day, and for a time formed the center of attraction at all microscopical exhibitions. They have now, however, become so common that they receive no special notice. Mr. Dancer and other artists also produced copies of the Lord's Prayer, the Creed, the Declaration of Independence, etc., on such a scale that the Lord's Prayer might be covered with the head of a common pin, and yet, when viewed under a very moderate magnifying power, every letter was clear and distinct. I have now before me a slip of glass, three inches long and one inch wide, in the center of which is an oval photograph which occupies less than the 1-200th of a square inch. This photograph contains the Declaration of Independence with the signatures of all the signers, surrounded by portraits of the Presidents and the seals of the original thirteen States. Under a moderate power every line is clear and distinct. In the same way copies of such famous pictures as Landseer's "Stag at Bay," although almost invisible to the naked eye, come out beautifully clear and distinct under the microscope, so that it has been suggested that one might have an extensive picture gallery in a small box, or pack away copies of all the books in the Congressional Library in a small handbag. With such means at our command, it would be a simple matter to condense a bulky dispatch into a few little films, which might be carried in a quill or concealed in ways which would have been impossible with the original. If Major André had been able to avail himself of this mode of reducing the bulk of the original papers, he might have carried, without danger of discovery, those reports which caused his capture and led to his death. And hereafter the ordinary methods of searching suspected spies will have to be exchanged for one that is more efficient.

The most interesting application of microphotography, of which we have any record, occurred during the Franco-Prussian war in 1870–71.

On September 21, 1870, the Germans so completely surrounded the French capitol, that all communication by

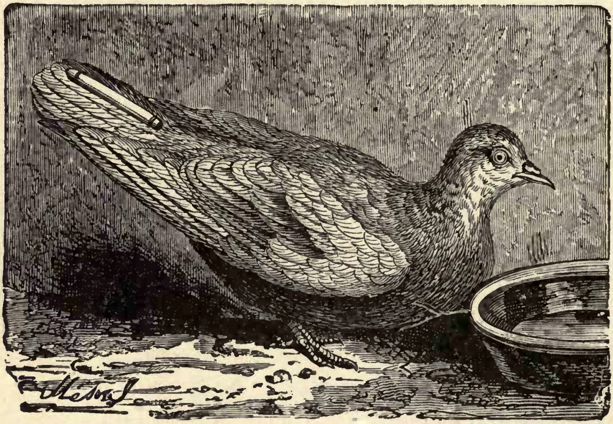


Fig. 21.

roads, railways, and telegraphs, was cut off and the only way of escape from the city was through the air. On April 23, the first balloon left Paris, and in a short time after that, a regular balloon post was established, letters and packages being sent out at intervals of three to seven days. In order to get news back to the city, carrier pigeons were employed, and at first the letters were simply written on very thin paper and enclosed in quills which were fastened to the middle tail-feather of the bird, as shown in the engraving, Fig. 21. It is, of course, needless to say, that the ordinary pictures of doves with letters tied round their necks or love-notes attached to their wings, are all mere romance. A bird loaded in that way would soon fall a prey to its enemies. As it was, some of the pigeons were shot by German gunners or captured by hawks trained by the Germans for the purpose, but the great majority got safely through.

Written communications, however, were of necessity, bulky and heavy, and therefore M. Dagron, a Parisian photographer, suggested that the news be printed in large sheets of which microphotographs could be made and transferred to collodion positives which might then be stripped from the glass and would be very light. This was done; the collodion pellicles measuring about ten centimeters (four inches) square and containing about three thousand average messages. Eighteen of these pellicles weighed less than one gramme (fifteen grains) and were easily carried by a single pigeon. The pigeons having been bred in Paris and sent out by balloons, always returned to their dove-cotes in that city.

M. Dagron left Paris by balloon on November 12, and after a most adventurous voyage, being nearly captured by a German patrol, he reached Tours and there established his headquarters, and organized a regular system of communication with the capitol. The results were most satisfactory, upwards of two and a half millions of messages having been sent into the city. Even postal orders, and drafts were transmitted in this way and duly honored.

And thus through the pigeon-post, aided by microphotography, Paris was enabled to keep in touch with the outer world, and the anxiety of thousands of families was relieved.

It is not likely, however, that the pigeon-post will ever again come into use for this purpose; our interest in it is now merely historical, for in the next great siege, if we ever have one, the wireless telegraph will no doubt take its place and messages, which no hawks can capture and no guns can destroy, will be sent directly over the heads of the besiegers.

But let us hope and pray, that the savage and unnecessary war which is now being waged in the east will be the last, and that in the near future, two or more of the great nations of the globe will so police the world, that peace on earth and good will toward men will everywhere prevail.

ILLUSIONS OF THE SENSES

OUR senses have been called the "Five Gateways of Knowledge" because all that we know of the world in which we live reaches the mind, either directly or indirectly, through these avenues. From the "ivory palace," in which she dwells apart, and which we call the skull, the mind sends forth her scouts — sight, hearing, feeling, taste, and smell — bidding them bring in reports of all that is going on around her, and if the information which they furnish should be untrue or distorted, the most dire results might follow. She, therefore, frequently compares the tale that is told by one with the reports from the others, and in this way it is found that under some conditions these reporters are anything but reliable; the stories which they tell are often distorted and untrue, and in some cases their tales have no foundation whatever in fact, but are the "unsubstantial fabric of a vision."

It is, therefore, of the greatest importance to us, that we should find out the points on which these information bearers are most likely to be deceived so that we may guard against the errors into which they would otherwise certainly lead us.

All the senses are liable to be imposed upon under certain conditions. The senses of taste and of smell are frequently the subject of phantom smells and tastes, which are as vivid as the sensations produced by physical causes acting in the regular way. Even those comparatively new senses[1] which have been differentiated from the sense of touch and which, with the original five, make up the mystic number seven, are very untrustworthy guides under certain circumstances. Thus we all know how the sense of heat may be deceived by the old experiment of placing one hand in a bowl of cold water and the other in a bowl of hot water, and then, after a few minutes, placing both hands together in a bowl of tepid water; the hand, which has been in the cold water will feel warm, while that which has just been taken from the hot water, will feel quite cold.

We have all experienced the deceptions to which the sense of hearing exposes us. Who has not heard sounds which had no existence except in our own sensations? And every one is familiar with the illusions to which we are liable when under the influence of a skilful ventriloquist.

Even the sense of touch, which most of us regard as infallible, is liable to gross deception. When we have "felt" anything we are always confident as to its shape, number, hardness, etc., but the following very simple experiment shows that this confidence may be misplaced:

Take a large pea or a small marble or bullet and place it

[1] The old and generally recognized list of the senses is as follows: Sight, Hearing, Smell, Taste, and Touch. This is the list enumerated by John Bunyan in his famous work, "The Holie Warre." It has, however, been pointed out that the sense which enables us to recognize heat is not quite the same as that of touch and modern physiologists have therefore set apart, as a distinct sense, the power by which we recognize heat.

The same had been previously done in the case of the sense of Muscular Resistance but, as the author of "The Natural History of Hell" says, "when we differentiate the 'Sense of Heat,' and the 'Sense of Resistance' from the Sense of Touch, we may set up new signposts, but we do not open up any new 'gateways'; things still remain as they were of old, and every messenger from the material world around us must enter the ivory palace of the skull through one of the old and well-known ways."

on the table or in the palm of the left hand. Then cross the fingers of the right hand as shown in the engraving, Fig. 22, the second finger crossing the first, and place them on the ball, so that the latter may lie between the fingers,

Fig. 22.

as figured in the cut. If the pea or ball be now rolled about, the sensation is apparently that given by two peas under the fingers, and this illusion is so strong that it cannot be dispelled by calling in any of the other senses (the sense of sight for example) as is usually the case under similar circumstances. We may try and try, but it will only be after considerable experience that we shall learn to disregard the apparent impression that there are two balls.

The cause of this illusion is readily found. In the ordinary position of the fingers the same ball cannot touch at the same time the exterior sides of two adjoining fingers. When the two fingers are crossed, the conditions are exceptionally changed, but the instinctive interpretation remains the same, unless a frequent repetition of the experiment has overcome the effect of our first education on this point. The experiment, in fact has to be repeated a great number of times to make the illusion become less and less appreciable.

But of all the senses, that of sight is the most liable to error and illusion, as the following simple illustrations will show.

In Fig. 23 a black spot has been placed on a white

Fig. 23.

Fig. 24.

ground, and in Fig. 24 a white spot is placed on a black ground; which is the larger, the black spot or the white one? To every eye the white spot will appear to be the largest, but as a matter of fact they are both the same size. This curious effect is attributed by Helmholtz to what is called irradiation. The eye may also be greatly deceived even in regard to the length of lines placed side by side.

Thus, in Fig. 25 a thin vertical line stands upon a thick horizontal one; although the two lines are of precisely the same length, the vertical one seems to be considerably longer than the other.

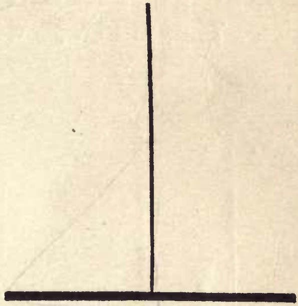


Fig. 25.

In Figs. 26 and 27 a series of vertical and horizontal lines are shown, and in both forms the space that is covered seems to be longer one way than the other. As a matter of fact the space in each case is a perfect square, and the apparent difference in width and height depends upon whether the lines are vertical or horizontal.

Advantage is taken of this curious illusion in decorating rooms and in selecting dresses. Stout ladies of taste avoid dress goods having horizontal stripes, and

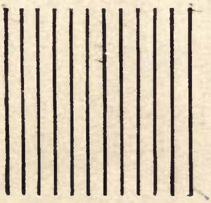


Fig. 26.

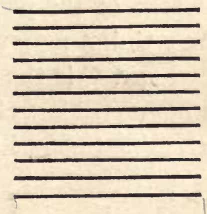


Fig. 27.

ladies of the opposite conformation avoid those in which the stripes are vertical.

But the greatest discrepancy is seen in Figs. 28 and 29, the middle line in Fig. 29 appearing to be much longer than in Fig. 28. Careful measurement will show that they are both of precisely the same length, the apparent difference being due to the arrangement of the divergent lines at the ends.

Converging lines have a curious effect upon apparent size. Thus in Fig. 30 we have a wall and three posts, and

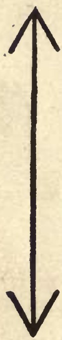


Fig. 28.

Fig. 29.

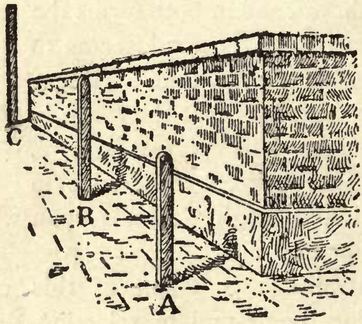


Fig. 30.

if asked which of the posts was the highest, most persons would name C, but measurement will show that A is the highest and that C is the shortest.

A still more striking effect is produced in two parallel lines by crossing them with a series of oblique lines as seen

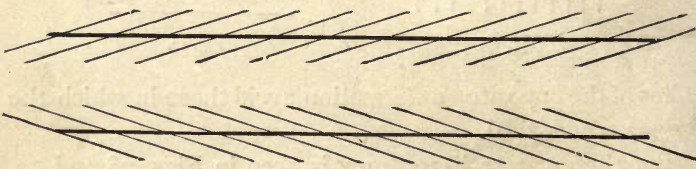


Fig. 31.

in Figs. 31 and 32. In Fig. 31 the horizontal lines seem to be much closer at the right-hand ends than at the left, but accurate measurement will show that they are strictly parallel.

By changing the direction of the oblique lines, as shown in Fig. 32, the horizontal lines appear to be crooked although they are perfectly straight.

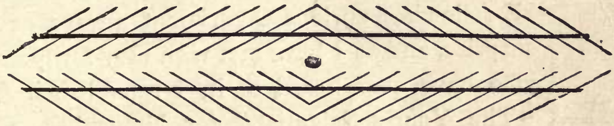


Fig. 32.

All these curious illusions are, however, far surpassed by an experiment which we will now proceed to describe.

OBJECTS APPARENTLY SEEN THROUGH A HOLE IN THE HAND

THE following curious experiment always excites surprise, and as I have met with very few persons who have ever heard of it, I republish it from "The Young Scientist," for November, 1880. It throws a good deal of light upon the facts connected with vision.

Procure a paste-board tube about seven or eight inches

Fig. 33.

long and an inch or so in diameter, or roll up a strip of any kind of stiff paper so as to form a tube. Holding this tube in the left hand, look through it with the left eye, the right eye also being kept open. Then bring the right hand into the position shown in the engraving, Fig. 33, the edge opposite the thumb being about in line with the right-hand side of the tube. Or the right hand may rest against the right-hand side of the tube, near the end farthest from the eye. This cuts off entirely the view of the object by the right eye, yet strange to say the object will still remain apparently visible to both eyes through a hole in the hand, as shown by the dotted lines in the engraving! In other words, it will appear to us as if there was actually a hole through the hand, the object being seen through that hole. The result is startlingly realistic, and forms one of the simplest and most interesting experiments known.

This singular optical illusion is evidently due to the sympathy which exists between the two eyes, from our habit of blending the images formed in both eyes so as to give a single image.

LOOKING THROUGH A SOLID BRICK

A VERY common exhibition by street showmen, and one which never fails to excite surprise and draw a crowd, is the apparatus by which a person is apparently enabled to look through a brick. Mounted on a simple-looking stand are a couple of tubes which look like a telescope cut in two in the middle. Looking through what most people take for a telescope, we are not surprised when we see clearly the people, buildings, trees, etc., beyond it, but this natural expectation is turned into the most startled surprise when it is found that the view of these objects is not cut off by placing a common brick between the two parts of the telescope and directly in the apparent line of vision, as shown in the accompanying illustration, Fig. 34.

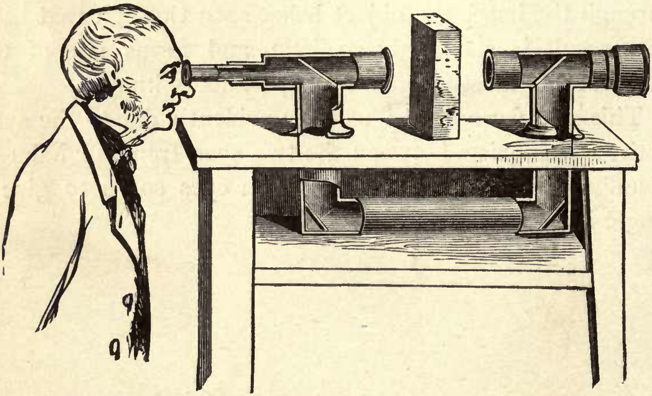


Fig. 34.

In truth, however, the observer looks *round* the brick instead of through it, and this he is enabled to do by means of four mirrors ingeniously arranged as shown in the engraving. As the mirrors and the lower connecting tube are concealed, and the upright tubes supporting the pretended telescope, though hollow, appear to be solid, it is not very easy for those who are not in the secret to discover the trick.

Of course any number of "fake" explanations are given by the showman who always manages to keep up with the times and exploit the latest mystery. At one time it was psychic force, then Roentgen or X-rays; lately it has been attributed to the mysterious effects of radium!

This illustration is more properly a delusion; there is no illusion about it.

CURIOUS ARITHMETICAL PROBLEMS

THE CHESS-BOARD PROBLEM

AN Arabian author, Al Sephadi, relates the following curious anecdote:

A mathematician named Sessa, the son of Dahar, the subject of an Indian Prince, having invented the game of chess, his sovereign was highly pleased with the invention, and wishing to confer on him some reward worthy of his magnificence, desired him to ask whatever he thought proper, assuring him that it should be granted. The mathematician, however, only asked for a grain of wheat for the first square of the chess-board, two for the second, four for the third, and so on to the last, or sixty-fourth. The prince at first was almost incensed at this demand, conceiving that it was ill-suited to his liberality. By the advice of his courtiers, however, he ordered his vizier to comply with Sessa's request, but the minister was much astonished when, having caused the quantity of wheat necessary to fulfil the prince's order to be calculated, he found that all the grain in the royal granaries, and even all that in those of his subjects and in all Asia, would not be sufficient.

He therefore informed the prince, who sent for the mathematician, and candidly acknowledged that he was not rich enough to be able to comply with his demand, the ingenuity of which astonished him still more than the game he had invented.

It will be found by calculation that the sixty-fourth term of the double progression, beginning with unity, is

9,223,372,036,854,775,808,

and the sum of all the terms of this double progression, beginning with unity, may be obtained by doubling the last term and subtracting the first from the sum. The number, therefore, of the grains of wheat required to satisfy Sessa's demand will be

18,446,744,073,709,551,615.

Now, if a pint contains 9,216 grains of wheat, a gallon will contain 73,728, and a bushel (8 gallons) will contain 589,784. Dividing the number of grains by this quantity, we get 31,274,997,412,295 for the number of bushels necessary to discharge the promise of the Indian prince. And if we suppose that one acre of land is capable of producing in one year, thirty bushels of wheat, it would require 1,042,499,913,743 acres, which is more than eight times the entire surface of the globe; for the diameter of the earth being taken at 7,930 miles, its whole surface, including land and water, will amount to very little more than 126,437,889,177 square acres.

If the price of a bushel of wheat be estimated at one dollar, the value of the above quantity probably exceeds that of all the riches on the earth.

THE NAIL PROBLEM

A GENTLEMAN took a fancy to a horse, and the dealer, to induce him to buy, offered the animal for the value of the twenty-fourth nail in his shoe, reckoning one cent for the first nail, two for the second, four for the third, and so on. The gentleman, thinking the price very low, accepted the offer. What was the price of the horse?

On calculating, it will be found that the twenty-fourth term of the progression 1, 2, 4, 8, 16, etc., is 8,388,608, or $83,886.08, a sum which is more than any horse, even the best Arabian, was ever sold for.

Had the price of the horse been fixed at the value of all the nails, the sum would have been double the above price less the first term, or $167,772.15.

A QUESTION OF POPULATION

THE following note on the result of unrestrained propagation for one hundred generations is taken from "Familiar Lectures on Scientific Subjects," by Sir John F. W. Herschel:

For the benefit of those who discuss the subjects of population, war, pestilence, famine, etc., it may be as well to mention that the number of human beings living at the end of the hundreth generation, commencing from a single pair, doubling at each generation (say in thirty years), and allowing for each man, woman, and child, an average space of four feet in height and one foot square, would form a vertical column, having for its base the whole surface of the earth and sea spread out into a plane, and for its height 3,674 times the sun's distance from the earth! The number of human strata thus piled, one on the other, would amount to 460,790,000,000,000.

In this connection the following facts in regard to the present population of the globe may be of interest:

The present population of the entire globe is estimated by the best statisticians at between fourteen and fifteen hundred millions of persons. This number would easily find standing-room on one half of Long Island, in the State of New York. If this entire population were to be brought to the United States, we could easily give every man, woman, and child, one acre and a half each, or a nice little farm of seven acres and a half to every family, consisting of a man, his wife, and three children.

This question has also an important bearing on the preservation of animals which, in limited numbers, are harmless and even desirable. In Australia, where the restraints on increase are slight, the rabbit soon becomes not only a nuisance but a menace, and in this country the migratory thrush or robin, as it is generally called, has been so protected in some localities that it threatens to destroy the small fruit industry.

HOW TO BECOME A MILLIONAIRE

MANY plans have been suggested for getting rich quickly, and some of these are so plausible and alluring that multitudes have been induced to invest in them the savings which had been accumulated by hard labor and severe economy. It is needless to say that, except in the case of a few stool-pigeons, who were allowed to make large profits so that their success might deceive others and lead them into the net, all these projects have led to disaster or ruin. It is a curious fact, however, that some of those who invested in such "get-rich-quickly" schemes were probably fully aware of their fraudulent character and went into the speculation with their eyes open in the hope that *they* might be allowed to become the stool-pigeons, and in this way come out of the enterprise with a large balance on the right side. No regret can be felt when a bird of this kind gets plucked.

But by the following simple method every one may become his own promoter and in a short time accumulate a respectable fortune. It would seem that almost any one could save one cent for the first day of the month, two cents for the second, four for the third, and so on. Now if you will do this for thirty days we will guarantee you the possession of quite a nice little fortune. See how easy it is to become a millionaire on paper, and by the way, it is only on paper that such schemes ever succeed.

If, however, you should have any doubt in regard to your ability to lay aside the required amount each day, perhaps you can induce some prosperous and avaricious employer to accept the following tempting proposition:

Offer to work for him for a year, provided he pays you one cent for the first week, two cents for the second, four for the third, and so on to the end of the term. Surely your services would increase in value in a corresponding ratio, and many business men would gladly accept your terms. We ourselves have had such a proposition accepted over and over again; the only difficulty was that when we insisted upon security for the last instalment of our wages, our would-be employers could never come to time. And we would strongly urge upon our readers that if they ever make such a bargain, they get full security for the last payment for they will find that when it becomes due there will not be money enough in the whole world to satisfy the claim.

The entire amount of all the money in circulation among all the nations of the world (not the *wealth*) is estimated at somewhat less than $15,000,000,000, and the last payment would amount to fifteen hundred times that immense sum.

The French have a proverb that "it is the first step that costs" (*c'est le premier pas qui coute*) but in this case it is the last step that costs and it costs with a vengeance.

While on this subject let me suggest to my readers to figure up the amount of which they will be possessed if they will begin at fifteen years of age and save ten cents per week for sixty years, depositing the money in a savings bank as often as it reaches the amount required for a deposit, and adding the interest every six months. Most persons will be suprised at the result.

THE ACTUAL COST AND PRESENT VALUE OF THE FIRST FOLIO SHAKESPEARE

SEVEN years after the death of Shakespeare, his collected works were published in a large folio volume, now known as "The First Folio Shakespeare." This was in the year 1623. The price at which the volume was originally sold was one pound, but perhaps we ought to take into consideration the fact that at that time money had a value, or purchasing power, at least eight times that which it has at present; Halliwell-Phillips estimates it at from twelve to twenty times its present value. For this circumstance, however, full allowance may be made by multiplying the ultimate result by the proper number.

This folio is regarded as the most valuable printed book in the English language — the last copy that was offered for sale in good condition having brought the record price of nearly $9,000, so that it is safe to assume that a perfect copy, in the condition in which it left the publisher's hands, would readily command $10,000, and the question now arises : What would be the comparative value of the present price, $10,000, and of the original price (one pound) placed at interest and compounded every year since 1623 ?

Over and over again I have heard it said that the purchasers of the "First Folio" had made a splendid investment and the same remark is frequently used in reference to the purchase of books in general, irrespective of the present intellectual use that may be made of them. Let us make the comparison.

Money placed at compound interest at six per cent, a little more than doubles itself in twelve years. At the present time and for a few years back, six per cent is a high rate, but it is a very low rate for the average. During a large part of the time money brought eight, ten, and twelve per cent per annum, and even within the half century just past it brought seven per cent during a large portion of the time. Now, between 1623 and 1899, there are 23 periods, of 12 years each, and at double progression the twenty-third term, beginning with unity, would be 8,388,608. This, therefore, would be the amount, in pounds, which the volume had cost up to 1899. In dollars it would be $40,794,878.88. An article which costs forty millions of dollars, and sells for ten thousand dollars, cannot be called a very good financial investment.

From a literary or intellectual standpoint, however, the subject presents an entirely different aspect.

Some time ago I asked one of the foremost Shakesperian scholars in the world if he had a copy of the "First Folio."

His reply was that he could not afford it; that it would not be wise for him to lose $400 to $500 per year for the mere sake of ownership, when for a very slight expenditure for time and railway fare he could consult any one of half-a-dozen copies whenever he required to do so.

ARITHMETICAL PUZZLES

A GOOD-SIZED volume might be filled with the various arithmetical puzzles which have been propounded. They range from a method of discovering the number which any one may think of to a solution of the "famous" question: "How old is Ann?" Of the following cases one may be considered a "catch" question, while the other is an interesting problem.

A country woman, carrying eggs to a garrison where she had three guards to pass, sold at the first, half the number she had and half an egg more; at the second, the half of what remained and half an egg more; at the third the half of the remainder and half an egg more; when she arrived at the market-place she had three dozen still to sell. How was this possible without breaking any of the eggs?

At first view, this problem seems impossible, for how can half an egg be sold without breaking any? But by taking the greater half of an odd number we take the exact half and half an egg more. If she had 295 eggs before she came to the first guard, she would there sell 148, leaving her 147. At the next she sold 74, leaving her 73. At the next she sold 37, leaving her three dozen.

The second problem is as follows: After the Romans had captured Jotopat, Josephus and forty other Jews sought shelter in a cave, but the refugees were so frightened that, with the exception of Josephus himself and one other, they resolved to kill themselves rather than fall into the hands of their enemies. Failing to dissuade them from this horrid purpose, Josephus used his authority as their chief to insist that they put each other to death in an orderly manner. They were therefore arranged round a circle, and every third man was killed until but two men remained, the understanding being that they were to commit suicide. By placing himself and the other man in the 31st and 16th places, they were the last that were left, and in this way they escaped death.

ARCHIMEDES AND HIS FULCRUM

NEXT to that of Euclid, the name of Archimedes is probably that which is the best known of all the mathematicians and mechanics of antiquity, and this is in great part due to the two famous sayings which have been attributed to him, one being "Eureka" — "I have found it," uttered when he discovered the method now universally in use for finding the specific gravity of bodies, and the other being the equally famous dictum which he is said to have addressed to Hiero, King of Sicily, — "Give me a fulcrum and I will raise the earth from its place."

That Archimedes, provided he had been immortal, could have carried out his promise, is mathematically certain, but it occurred to Ozanam to calculate the length of time which it would take him to move the earth only one inch, supposing his machine constructed and mathematically perfect; that is to say, without friction, without gravity, and in complete equilibrium, and the following is the result:

For this purpose we shall suppose that the matter of which the earth is composed weighs 300 pounds per cubic foot, this being about the ascertained average. If the diameter of the earth be 7,930 miles, the whole globe will be found to contain 261,107,411,765 cubic miles, which make 1,423,499,120,882,544,640,000 cubic yards, or 38,434,476,-263,828,705,280,000 cubic feet, and allowing 300 pounds to each cubic foot, we shall have 11,530,342,879,148,611,-584,000,000 for the weight of the earth in pounds.

Now, we know, by the laws of mechanics, that, whatever be the construction of a machine, the space passed over by the weight, is to that passed over by the moving power, in the reciprocal ratio of the latter to the former. It is known also, that a man can act with an effort equal only to about 30 pounds for eight or ten hours, without intermission, and with a velocity of about 10,000 feet per hour. If then we suppose the machine of Archimedes to be put in motion by means of a crank, and that the force continually applied to it is equal to 30 pounds, then with the velocity of 10,000 feet per hour, to raise the earth one inch the moving power must pass over the space of 384,344,762,-638,287,052,800,000 inches; and if this space be divided by 10,000 feet or 120,000 inches, we shall have for a quotient 3,202,873,021,985,725,440, which will be the number of hours required for this motion. But as a year contains 8,766 hours, a century will contain 876,600; and if we divide the above number of hours by the latter, the quotient, 3,653,745,176,803, will be the number of centuries during which it would be necessary to make the crank of the machine continually turn in order to move the earth only one inch. We have omitted the fraction of a century as being of little consequence in a calculation of this kind. The machine is also supposed to be constantly in action, but if it should be worked only eight hours each day, the time required would be three times as long.

So that while it is true that Archimedes could move the world, the space through which he could have moved it, during his whole life, from infancy to old age, is so small that even if multiplied two hundred million times it could not be measured by even the most delicate of our modern measuring instruments.

AN INTERESTING EGG PROBLEM

A PARTY of young people going on an excursion proposed to take with them some cold, hard-boiled eggs for lunch. Just as they were about to set out, an addition was made to their number and more eggs were needed. A young boy was sent to the cellar to bring some, which he did, but unfortunately he carelessly placed the raw eggs amongst the boiled ones, and as they were all cold and about the same temperature an interesting problem arose: How could they distinguish and separate them?

One of the party solved the puzzle very easily and quickly. He placed one of the eggs on a table and taking it between his thumb and fingers he tried to twirl it as one would twirl a teetotum. It would not spin and he pronounced it raw. Taking another and treating it in the same way he found that it would spin like a top and he said it was boiled. Testing all the eggs in this way he soon picked out the raw ones, and when they came to use them his companions found that he had not made a single mistake.

This is a very pretty experiment and one that does not seem to be generally known. It is easily tried at the breakfast table whenever boiled eggs form part of the bill of fare.

And a good deal of fun may be had by providing two or three eggs, some boiled hard and some raw and all cold and asking some one to pick out the boiled from the raw. Very probably the candle test will be the one that first suggests itself, and it is amusing to watch how many failures result. When the simple method here described is shown it always causes a good deal of surprise to those who have not seen it before.

The reason why the raw egg will not spin is obvious: The time during which the fingers act on the egg is not long enough to impart motion to the contents if they are liquid; when the contents are solid, the movement of the fingers is imparted to the whole egg from the very start, and when let go, the entire mass continues to rotate like a top.

SOME NOTES
ON
POPULAR FALLACIES AND COMMON ERRORS

NOTES ON A FEW POPULAR FALLACIES AND COMMON ERRORS

WHEN a fallacy or an error becomes embodied in a proverb or woven into the texture of a language, its vitality and power of diffusion seem almost inexhaustible. It will require a long course of education to destroy the force of the proverb, "Lightning never strikes twice in the same place," or to eradicate from the popular mind the idea that black lead is related to the metal lead. Nevertheless the time will surely come when such crude notions will be abandoned by even the least educated. Of course there will always be errors and mistakes which will have a vogue amongst the unthinking, but such gross fables as were accepted by our forefathers are now entirely abandoned and no one can be found who now believes in the vampire, the phœnix, the salamander, the centaur, or any of the other fabulous products of the human imagination. But even down to the time of Shakespeare it was generally held that such creatures did exist or might have existed, the most elementary principles of biology not being generally known and even not yet discovered. Shakespeare's works are full of erroneous statements in regard to matters of natural history, and it is not long since a writer for the press published an elaborate article accusing him of ignorance or faking, the truth of the matter being that Shakespeare took his natural history from those works which in his time were considered standard authorities, just as the writer of the article in question takes ninety-nine per cent of his information from the generally accepted books of the day. When Shakespeare speaks of things which come within the sphere of his own observation he is almost always correct, but when he accepts the ideas and beliefs which prevailed amongst the authors of his time he is frequently wrong. Like all the men of his time he believed in a king bee, and his description of the government of the hive ("King Henry V," Act I, Scene 2, line 188), as he understood it, is one of the most beautiful and most frequently quoted passages in his works, though as a statement of the true natural history of the bee and the economy of the hive it is pure fiction. So too the reference to "the kind life-rendering pelican," in "Hamlet"[1] (Act IV, Scene 5, line 145), as well as in other plays, was in strict accord with the notions that were then accepted and that were portrayed in numerous pictures and engravings as well as in the crest and scutcheon of many noble families. This matter has been well discussed by Professor Dowden of the University of Dublin in the Introduction to "The Shakespeare Cyclopedia."

Even Izaac Walton, who from his many opportunities for observation in country fields and by riversides might have been expected to be accurate in his knowledge of facts, accepts many of the crude notions and erroneous statements made by the writers who preceded him.

[1] Some of our readers will no doubt be surprised when told that in the first collected edition of Shakespeare's works, generally known as the "First Folio," the words are "Kinde Life-rendering Politicean," — a curious typographical mistake which has given rise to some interesting lucubrations. If this were the true reading the politicians of Hamlet's time must have been very different from those of our day. But the word is *pelican* in the quartos, and the same alleged characteristic of the pelican is referred to in Richard II and King Lear so that there can be no doubt that the modern text is correct.

It is now rather more than two centuries and a half since Sir Thomas Browne published his "Pseudodoxia Epidemica," or "Vulgar Errors," a curious and interesting work which throws much light on some of the extraordinary beliefs of his day. The last edition that was issued during his life now lies before me, and it is interesting to note the absurdities which seem to have been generally accepted by even the best educated people of his time. But most of them have been discarded owing to the increase and diffusion of knowledge in natural history and the physical sciences. A few, however, still remain, and some brief notes on those which are most prominent can hardly fail to interest the readers of this book.

THAT MOST GREAT DISCOVERIES HAVE BEEN MADE BY ACCIDENT

NOTHING appeals more strongly to the mind of the average man than accounts of great results which have been achieved by means which were apparently totally inadequate to effect the purpose intended. When he is told that Sir Isaac Newton made some of his great discoveries by means of a child's toy — the soap bubble — he is not only interested but amazed, forgetting the long course of deep mathematical study which enabled Newton to derive such important conclusions from such apparently trivial phenomena. And there is a good story told of two old ladies who lived opposite the great mathematician and who after watching him for some time came to the conclusion that he was weak-minded. One day they mentioned the matter to their physician, a well-informed man, and expressed their pity and sympathy for the poor old gentleman. They were much astonished when they were told that the supposed imbecile was none other than the great philosopher Sir Isaac Newton, who was then deeply engaged in the study of certain abstract problems in regard to light and was using the soap bubbles to verify practically his purely mathematical deductions. This particular story may not be true (very few such stories are), but it has an air of probability about it and there have been hundreds of actual cases just like it.

Very few great discoveries or inventions were ever made by mere accident and when such has apparently been the case, the mind that was able to seize the new idea and adapt it to the required conditions must have been prepared to recognize its significance and the relation which it bore to these conditions. The discovery of phosphorus seems to have been made by accident; the discoverer, Brandt, was looking for something entirely different. He thought that in certain liquids derived from the human organism he ought to find the philosopher's stone; he did not find the stone, but he did find phosphorus. But it is very certain that he would not have obtained the phosphorus if he had not been prepared to do so by long experience in earnest chemical work.

A few years ago an article on this subject went the rounds of the press and in it we were told that among other accidental discoveries "the attraction of gravitation was suggested to Sir Isaac Newton by the fall of an apple; that Galileo got his first hint of the pendulum from the swinging of a chandelier in a cathedral; that Madame Galvani, being an invalid, had frog soup prescribed for her, and while the frogs were being prepared she noticed certain twitchings in the dead animals and called the attention of her husband to the matter, and that owing to this accident Galvani was led to make his great discoveries. Also that the power of steam was first discovered by the oscillations of the lid of a teakettle; and to these instances were added numerous other historic fables which have long been exploded.

In the case of Newton, he did not discover "the attraction of gravitation"; what he did discover was that the same force which caused stones, etc., to fall to the earth when left unsupported, also retained the moon in her orbit; and this he proved by comparing the rate of falling bodies on the earth, as determined by Galileo, with the rate at which the moon deviated from the straight line which she would have pursued if no extraneous force had acted on her. The story of the falling apple had no foundation in fact; this was amply proved by Sir David Brewster in his life of Sir Isaac Newton.

Galileo had long been engaged in investigations relating to falling bodies and had fully proved the absolute regularity of their motion when he suggested the use of the pendulum as a time measurer. Very probably he may have watched the swinging chandelier and used it as an illustration, but it was his previous studies and earnest thought and not the mere swinging of the chandelier that pointed to the utility of the pendulum.

The story about Madame Galvani and her frog soup, as given in popular books on electricity and in many old textbooks, is a fabrication of Alibert, an Italian writer of no repute. It is completely disproved by the fact that at the time his wife's health failed Galvani had been engaged for eleven years in a series of experiments in which he had used frogs' legs as electroscopes.

The power of steam was known long before teakettles had come into use; and as the case of Watt and his inventions affords a very good example of the erroneous ideas so generally entertained on such subjects, it may be well to consider it at length.

THAT THE IDEA OF THE STEAM ENGINE WAS SUGGESTED TO JAMES WATT BY THE ACTION OF THE STEAM ON THE LID OF HIS MOTHER'S TEAKETTLE

THERE is a large and elaborate engraving of James Watt as a boy standing before a fire on which a teakettle is boiling while he watches the lid jump up and down. On one side is an elderly woman (mother or grandmother) earnestly watching the boy. Young Watt is dressed in the height of the fashion of the period — knee breeches, powdered wig, and other habiliments such as no Scottish lad of his station in life ever wore. This engraving has had a large circulation and has no doubt impressed the minds of many with the truth of the story that Watt's great invention was due to the accident of his watching the motion of the kettle lid as the steam rose from the boiling water.

The incident which the engraving is supposed to represent is pure fiction. The power of steam was well known long before the days of Watt. Hero of Alexandria, 130 years before the Christian era, had applied steam to the production of motion, and the number of the inventors who had devoted themselves to the improvement of the steam engine was very large — Battista della Porta, Branca, Solomon de Caus, the Marquis of Worcester, Savery, and many others had all invented engines of various types. Indeed the engines of Newcomen were then in practical operation in the mines and had in many cases displaced horses. So that Watt was not the inventor of the first steam engine that did practical work, and that such engines were in use was known to every intelligent mechanic.

But that Watt was the inventor of the first engine that was commercially successful as a motive power for machinery is true beyond all question, and this success was not due to any happy accident, but was the result of long-continued and earnest study and investigation. This is not the place for even a brief history of Watt and his inventions, but as the prominent incidents which led to his final success afford a most valuable illustration of the great truth that almost all inventions and discoveries are the result of hard and earnest work and not of mere accident, we may be pardoned for glancing at them.

Owing to the failure of his father in business, Watt was early thrown upon his own resources. He went to London and engaged as apprentice with a philosophical instrument maker, but as his health failed he was obliged to return home at the end of a year. During this year, however, he seems to have acquired unusual skill in the use of tools and a very thorough insight into the construction of apparatus, and through the influence of some of the professors in the University of Glasgow, with whom he had formed a friendship, he was employed to repair and adjust the apparatus used by them in their lectures. He even attempted to open a shop in the city of Glasgow, but the guilds refused their permission. Fortunately for Watt and for humanity the University authorities had complete control within their own grounds, so they assigned him a workroom and enabled him to set the guilds at defiance.

Amongst the apparatus which was sent to him to repair was a model of Newcomen's engine. Watt succeeded in putting it in working order, but was disgusted with the small result which it gave for the combustion of a large amount of fuel. Just about this time his friend Dr. Joseph Black, Professor of Chemistry in the University of Glasgow and the discoverer of carbonic acid, had made his celebrated investigations into latent heat, and this gave Watt accurate ideas in regard to the practical relations of steam. After much study and many experiments he worked out the condensing engine, which did an equal amount of work with less than one-fourth the fuel required by Newcomen's engine. This enabled the Cornish mine owners to carry on work in mines which otherwise must have been abandoned as unprofitable. Other improvements followed, and while the old engines were never used for any other purpose than pumping, the new engines of Watt were capable of being profitably employed for driving machinery and other kinds of work.

But at no stage of this progress could any advancement be said to have been due to mere accident; it was all the result of deep study and hard work.

THAT WHETSTONES ARE OILED TO LESSEN THE FRICTION OF THE METAL UPON THE STONE

THIS fallacy has become popular owing to a statement made by Professor Tyndall in his celebrated work, "Heat a Mode of Motion." In paragraph 9 occurs the following passage: "Whenever friction is overcome, heat is produced, and the heat produced is the exact measure of the force expended in overcoming the friction. The heat is simply the primitive force in another form, and if we wish to avoid this conversion, we must abolish the friction. We put oil upon the surface of a hone, we grease a saw, and are careful to lubricate the axles of our railway carriages."

Now since the application of grease to rubbing surfaces for the purpose of lessening friction has been practiced from time immemorial, it is not to be wondered at that Tyndall in his dragnet for instances should have caught the hone or whetstone amongst other things, because the application of oil to hones and whetstones is almost universal. And as his book is a standard authority in its department, this mistake has been quoted over and over again, the latest instance that has come to my notice being found in a most interesting and instructive book by the late Professor Tidy, "The Story of a Tinder-Box."

Those who are practically familiar with the use of hones and whetstones know that the chief use of the oil is not to lessen the friction but to prevent the metal from forming a glaze on the surface of the stone. When a steel blade is rubbed on a dry whetstone the minute particles that are torn from the metal attach themselves to the surface of the stone and are then burnished to a smoothness which greatly lessens the friction and prevents further abrasion. So that in reality the application of the oil to the whetstone actually increases the friction instead of lessening it.

Of course this does not apply to coarse-grained grindstones where the particles of metal that are removed from the tool are of considerable size and are torn off with great rapidity. In that case the combined friction and abrasion quickly heat the article to a degree which destroys its temper if it is made of steel, and to counteract this a stream of water is applied, but not for the purpose of lessening the friction.

It is a popular impression that friction is only a source of evil. It is regarded as the great agent in wasting power and destroying machinery which, if there were no friction, would last forever. But friction has its advantages as well as its disadvantages, and the former are quite as important as the latter. If it were not for friction no nail or screw would hold, and our buildings and machines, unless constructed after methods very different from those at present in use, would all fall to pieces. No knot could be made to hold; the first strain would cause it to slip. Without friction no locomotive could drag its train along, and even the horses would be unable to pull their loads. A striking example of this may be seen any day when the roads are covered with sheets of ice and men and horses are falling in every direction. Even while writing these lines I have received a notable object lesson in this direction, for I am held a close prisoner in the house of a friend because the whole region is coated with a sheet of ice over which it would be impossible for an elderly person to walk with safety. And all owing to the absence of friction between opposing surfaces.

THAT LIGHTNING NEVER STRIKES TWICE IN THE SAME PLACE

TYLOR, in his "Researches into the Early History of Mankind," traces this proverb to the mythology of India and notes a very curious connection between it and the old ceremonies of Easter eve, when new fire was obtained from flint and hallowed against all great dangers, and particularly against the lightning stroke, for the new fire was supposed to be akin to lightning, "which strikes no place twice."

But in these days it undoubtedly owes its general acceptance to a feeling that the place where lightning strikes is a matter of mere chance or at least as much a matter of chance as would be the location of a bullet fired by a poor shot at a large target from a considerable distance.

In purely mechanical or physical operations there is no such thing as chance. The poet very truly tells us:

> All nature is but Art unknown to thee;
> All Chance, Direction which thou canst not see.

In the toss of a penny or the throw of a die the result depends upon immutable laws; and if we could but know the action of the various forces at work, that is to say the direction, intensity, and the point of application of each, we could predict with absolute certainty which side of the penny or the die would turn up. In the case of lightning, conditions are liable to change; and while in former times lightning may have struck a given spot several times, the erection of lightning conductors, the growth of trees, and other changed conditions may have so altered the relation of a given spot to the clouds that the path of the discharge will be entirely changed. But that particular buildings and places have been struck by lightning time and again is a matter of unquestionable record, the following instances being well authenticated.

The Cathedral of St. Peter in Geneva, although so elevated as to be above all other buildings in the neighborhood, has for three centuries enjoyed perfect immunity from damage by lightning, while the tower of St. Gervaise, although much lower, has been frequently struck. Another instance is that of a church on the estate of Count Orsini, in Carinthia. This building is placed upon an eminence, and had been struck so often by lightning that it was deemed no longer safe to celebrate divine service within its walls. For two or three years after its erection the church of St. Michael's in Charlestown had been frequently damaged by lightning; a conductor was attached to it, and during the following fourteen years it was not injured. The steeple of St. Mark's in Venice has a height of 340 feet, and was frequently struck by lightning until a proper lightning conductor was attached to it, after which it remained uninjured.

THAT THE FIRST FIRE WAS PRODUCED BY THE FRICTION OF BRANCHES OF TREES MOVED BY THE WIND

THIS legend has been adopted from the works attributed to Sanchoniathon but now generally considered forgeries. The account is as follows: "And when there were violent storms of rain and wind the trees about Tyre, being rubbed against each other, took fire, and all the forest in the neighborhood was consumed." And then the unknown writer goes on to tell us that Usous consecrated two pillars to fire and wind and worshiped them.

This statement has been accepted as true by almost all modern writers, and even some of our recent scientific authors, who certainly ought to have known better, have quoted it as the origin of the primeval method of obtaining fire by rubbing two sticks together. We know that fire has been obtained in this way, for it was a common method amongst savages and was practiced by the Indians of this continent in early days. But that two branches moved by the intermittent action of the wind and cooled by both wind and rain could ever attain the temperature of the ignition point of wood is simply incredible. Almost all violent storms of wind and rain are accompanied by thunder and lightning, and it is quite possible that the lightning may have set fire to the dry rubbish lying at the foot of the tree that was struck. This has actually occurred in the forests of Maine.

This is not the place for a general discussion of the origin of fire, but it seems to me more than likely that man obtained his first practical knowledge of fire from the burning wells which abound in the neighborhood of the Caspian Sea, the acknowledged cradle of the human race. These wells could scarcely escape being struck and set on fire by lightning, and some of them have been burning for ages. The wonderful spectacle and the pleasant warmth of these burning wells would be sure to attract those who came near them, and this was no doubt the source from which men obtained their first knowledge of fire, an agent without which civilization would have been impossible.

THAT VOLCANOES ARE "BURNING" MOUNTAINS

THE term "burning mountain" is very apt to convey a wrong impression to the ordinary person; he thinks of it as he does of a fire in a stove or as a burning forest where combustible materials combine with the oxygen of the air to produce heat, flames, gas, and dust. In the eruption of a volcano none of these phenomena are caused to any considerable extent by combustion. The red-hot matter which is thrown out was probably "burned" ages ago, indeed long before this earth had taken on its present characteristics of oceans and continents with their mountain ranges, rivers, and lakes. The substances which are thrown out by a volcano are the ashes of long-past fires, and we might as well think of burning the ashes beneath our grates as to burn them.

The red-hot and sometimes white-hot material thrown out by the volcano is merely a sample of the internal contents of the globe, which is covered with a comparatively thin crust (from thirty to fifty miles thick) that has cooled off during past ages and is now in a condition in which organic beings can live upon its surface. A volcano is simply a hole in this crust through which the melted matter of the interior and the steam produced by the infiltration of water are ejected. Several causes may contribute to the ejection of this volcanic material, amongst the principal being the following:

1. The access of sea water through one or more fissures, thus producing enormous pressure, a pressure so great that dust and cinders have been projected to a height of 10,000 feet. That sea water is the cause of at least some eruptions is rendered probable by the large proportion of chlorides present in the ejected matter.

2. The pressure of deposits at the bottom of the ocean, these deposits consisting of material washed down from mountain ranges and other regions through which large rivers flow. For while the average pressure over the entire globe would not be disturbed by this action, it is very evident that large local deposits over a limited area might easily cause the comparatively slight disturbance which would be necessary to produce volcanic phenomena. These phenomena, when compared with the vast amount of material carried out to sea by some of our large rivers, are small. Of the amount of this material few people have any conception. The greatest works of man in moving rocks and earth are insignificant when compared with it. The weight of this material might easily cause a local sinkage of the crust quite sufficient to set a volcano in action or to open up a new vent at some distant point along the line of least resistance.

3. The gradual cooling of the earth and the consequent contraction of the crust, which would proceed more rapidly and to a greater extent than the contraction of the liquid interior. That the earth is gradually cooling is a fact which is generally accepted by scientific men. In other words, the earth radiates into space an amount of heat greater than that which it receives from the sun and stars. Consequently the crust becomes too small to contain the liquid contents of the globe and a portion of the latter is ejected at the point of least resistance, which may be either an old vent or a new opening. Cordier has calculated that a contraction of only the one-twenty-fifth of an inch would suffice to force out to the surface lava enough for 500 eruptions, allowing 1300 million cubic yards for each eruption. This cooling process is, however, very slow, so slow that it may not have been recognizable during the historic period. But we must remember that an amount which would be quite imperceptible by our most delicate instruments would be sufficient to produce all the volcanic phenomena with which we are familiar.

THAT THE FORCE OF DYNAMITE IS ALWAYS EXERTED IN A DOWNWARD DIRECTION

IT is a well-known fact that if a charge of dynamite be laid on the ground and exploded, it will make a deep hollow, and if it be placed on a slab of stone, even without any covering or tamping, as it is called, the stone will be broken into shivers. It was these facts that led to the belief that dynamite acted only in a downward direction, and as there were no visible effects *above* the charge (as, indeed, how could there be?) the theory was believed to have been proved beyond doubt.

But every engineer and miner knows that if the slab of stone were raised from the ground and supported on pillars, the dynamite if placed *under* it would shatter it as effectually as if it were laid on the top of it. The truth is that the expansive force of dynamite has no tendency to act in any one direction rather than in another. Numerous experiments prove this beyond any question.

The explanation of the apparent downward action of dynamite is quite simple. The destructive power of dynamite and similar explosives is due to the tremendous rapidity with which the resulting gases expand in *every* direction when exploded; indeed so rapid is this explosive action that neither solid nor aerial matter can get out of its way fast enough. Black gunpowder when burned on a stone slab (unless the quantity be very large) simply gives a slow puff and passes off in smoke. A little of it burned on the palm of the hand burns so slowly that it will scorch the flesh. But if we place a little fulminating mercury on the palm of the hand and touch it with a spark of fire it goes off with a sharp puff and burns so rapidly that there is no time for it to impart a perceptible amount of heat to the hand. It may even be burned on a pile of common black gunpowder without setting the latter on fire. If, however, we should select a still more rapidly expansive explosive, such as dynamite, and set that off on the hand, the hand would probably be torn to shreds.

Even when there is no solid material placed over the dynamite to concentrate the action of the expanding gases, there is always present the enormous pressure of the atmosphere, which, as a resisting medium, under some conditions, is almost as effective as so much sand. On a stone slab three feet square there rests a load of air weighing nearly nine tons. Now this air, if moved slowly, does not offer much resistance to the moving agent. The most delicate fan, if moved very slowly in the air, does not even bend. But if moved rapidly it bends very perceptibly, and if moved with great velocity it will be broken. We can easily see, therefore, that when an effort is made to move nine tons of air with the velocity of the gases evolved by exploded dynamite, the air will offer almost the resistance of a solid body, and a stone slab, though hard and strong, breaks under the blow.

THAT THE ART OF HARDENING COPPER IS LOST

AT short intervals there appears in our different periodicals an article telling us that somebody has found a lot of old copper tools hard enough to cut the hardest stone and bewailing the fact that the process by which these tools were hardened by some prehistoric race is now unknown and must be classed amongst the so-called "lost arts."

That the Egyptians and some other peoples knew how to harden copper is unquestionably true, but a chemical analysis of their tools quickly revealed the secret, and there has never been a time since then when we could not produce copper tools quite as good as those of the ancients, and probably better. During his investigations into metallic alloys suitable for cutlery, Faraday produced an alloy of copper which took an edge as keen and showed an endurance as great as that of anything left behind them by the ancients. Of this alloy a razor was made which proved quite serviceable but was not equal to finely tempered steel and consequently it offered no attraction to the modern artisan.

The art of hardening copper is not lost, but it has fallen into desuetude for two reasons: In the first place it is not as efficient as good steel, and, secondly, copper is too costly ever to take the place of the cheaper metal, iron, while the latter can be made to do equally good work. While copper is worth several cents per pound, iron is worth only a fraction of a cent. This fact is reason enough for driving copper out of use as a material for making cutting tools.

Careful observation shows that much of the fine stone-cutting work of the ancients was done by grinding rather than by cutting. I doubt very much if any tool made prior to the Christian era could stand the hard work to which the picks used by the miller in dressing his mill-stones are subjected.

This matter of the hardening of copper is a very fair sample of the erroneous ideas prevalent in regard to the "Lost Arts," a subject in regard to which the late Wendell Phillips was charmingly eloquent and woefully ignorant. All the arts which have fallen into disuse and so are said to have been lost, have been merely abandoned because they have been superseded by something greatly better.

THAT STEAM CAN BE SEEN

WHEN those who have not given special attention to the subject see a cloud of vapor floating away from a locomotive in action, the feeling is irresistible that they see the steam which causes the piston to move in the cylinder. This, however, is far from being the case What they really see is a collection of fine particles of water. If these particles had been in the state of *steam* they would have been in the form of an invisible gas.

The truth of this is easily proved. Pour a little water into a thin glass flask or a test tube and plug the mouth with a cork having a small hole passing through it. The hole should not be more than an eighth of an inch in diameter. Heat the water in the flask or test tube over a spirit lamp or gas flame until the steam rushes out of the hole in the cork with some force. The flask or test tube, although filled with steam, will be quite transparent; the steam will not be visible.

Or watch a jet of steam issuing from the cock of a steam boiler or the spout of a teakettle when the latter is boiling briskly; as the steam issues from the cock or jet it will be quite invisible for a short distance, but when cooled a little by contact with the air it becomes vapor and is easily seen, but then it is not steam.

THAT HANNIBAL USED VINEGAR TO CUT A PASSAGE FOR HIS ARMY ACROSS THE ALPS

THIS alleged fact forms a staple illustration in the literature of the eighteenth and nineteenth centuries, and I have recently seen an allusion to it in the work of an author from whom I should have expected better things. When we consider the enormous quantity of vinegar which would be required to remove even a few cubic yards of limestone or similar rock, the absurdity of the suggestion becomes apparent. Where could Hannibal have obtained enough vinegar to enable him to perform this feat?

A great deal of ink has been shed in the effort to explain and enforce this alleged historical fact and to prove that it might have been done, but the only satisfactory explanation is that it is a fiction pure and simple.

THAT LARGE LENSES ARE MORE POWERFUL THAN SMALL ONES

IN the mind of the ordinary person the idea of comparative power is almost always associated with that of comparative size. The largest and heaviest locomotive is always the most powerful and so, as a general rule, are the largest animals of the same species. And too often this same idea is applied to lenses or magnifying glasses.

Of course those who have even the slightest knowledge of optics and the construction of optical instruments can never make this mistake, but a very large majority of those whom we meet in daily life know nothing of these things, and unfortunately it does not follow because a boy at school has gone over the section on optics in his Natural Philosophy, that therefore he understands these things.

If by *power* we mean the extent to which a lens magnifies any object, then it will be found that the smallest lenses are the most powerful.

It is a very elementary truth that of two lenses composed of the same material that which has the sharpest curvature to its surfaces will magnify most. Now, on reflection it will be evident to even the least mathematical mind that lenses which have very sharp or "quick" curves must of necessity be small. Suppose that the curve which bounds the figure of a lens has a radius of half an inch; then it is evident that the largest lens which could be made with this curve would be one inch in diameter and then it would either be a perfect sphere or approaching a plano-convex. Most lenses, however, resemble thin slices cut off the spheres, either making a plano-convex lens or two such slices joined together, making a double convex lens, so that the diameter of the lens is in general much less than the diameter of the curves which form its surface. Therefore we see that all lenses of high power are of necessity small, and when lenses are required of very high power they become so minute that they can be handled only with great difficulty. Indeed, before the modern improvements in the microscope many of the lenses used by scientific men were nothing more than small globules of glass brought to a round form by fusion. And they were the most powerful microscopes then known.

The idea that large lenses are the most powerful is so very prevalent that "Send me one of your largest and most powerful magnifiers," is an order with which every optician is familiar, and yet such an order contains a positive contradiction in terms. A lens cannot possibly be very large and magnify greatly at the same time.

THAT THE SERPENT HAS A STING IN ITS TAIL

THIS curious belief, the falsity of which must have been known to every country boy, seems to have permeated our literature down to a period well along in the nineteenth century, and I do not know but that it prevails yet amongst the littérateurs of the day. In Shakespeare we find more than half a dozen passages in which the "sting" of the serpent is spoken of, and the Bible tells us that wine "stingeth like an adder." That the general impression derived from these expressions was that adders, snakes, and serpents had stings in their tails, is very evident, and this view is corroborated by a passage in Scott's novel "The Monastery"[1] in which the peddler says: "Now let us hurry down the hill; for to tell the truth a Scottish noble's march is like a serpent — the head is furnished with fangs, and the tail hath its sting; the only harmless point of access is the main body."

And as that which is unknown is generally more dreaded than that which is seen, the sting of the tail seems to have been more feared than the fangs of the head.

[1] Vol. II, Chap. XVIII. In some of the bastard editions where the chapters of both volumes are numbered consecutively this would be Chap. XXXV.

No snake or serpent has a sting in its tail. Its only offensive weapons (exclusive of its crushing power) are the fangs which are connected with certain poison glands in the head. All the other parts and organs of the animal are perfectly harmless.

THAT THE FORKED TONGUE OF THE SERPENT OR SNAKE IS A WEAPON OF OFFENSE

THE tongues of snakes and serpents are cleft at the end and have always been an emblem of double dealing, treachery, and falsehood. As a mere simile for a human being with a deceitful tongue, this is well enough and may pass without comment, but it will not serve as a suggestion for a truth in natural history, since it has no foundation in fact.

Nevertheless in all ages the tongue of the snake or serpent seems to have impressed humanity with a feeling of danger, and from the fact that when snakes are irritated they thrust out their forked tongues, these tongues have been regarded as a weapon of offense, something to be feared and avoided, so that when, in "Measure for Measure" (Act III, Scene 1, line 15), the Duke says:

> Thou art by no means valiant;
> For thou dost fear the soft and tender fork
> Of a poor worm,

Shakespeare puts into his mouth words which no doubt reflected a common feeling and belief. And in several other passages the forked tongue of the snake is referred to as a thing of danger. It was a popular fallacy. The serpent's tongue is quite harmless in comparison with the poisonous fangs of a venomous and treacherous poet.

THAT A HORSEHAIR WHEN PLACED IN A POOL OF WATER TURNS TO A SNAKE

IT would seem that this was formerly a very general article of belief among the country people of Great Britain and Ireland. Even Shakespeare seems to have accepted the current notion, for in "Antony and Cleopatra" (Act I, Scene 2, line 200) we find the following:

> Much is breeding,
> Which, like the courser's hair, hath yet but life
> And not a serpent's poison.

Even Sir Thomas Browne in his elaborate work on the "Vulgar Errors" of his time ("Pseudodoxia Epidemica") does not allude to this error in natural history, though we can scarcely believe that he was not familiar with the current notions on the subject, and therefore we are led to suspect that he accepted the popular view as being correct.

The error arose out of two very interesting facts. In the first place there is a species of threadworm (the *Gordius aquaticus*) which at one stage of its existence is parasitic but which develops in stagnant pools and so closely resembles an animated horsehair that it gave rise to the idea that it was really a horsehair which had fallen into the water and had become alive.

The other fact was that when a dry horsehair is placed in water it frequently moves, just as a thin shaving of wood will curl and move when laid on a damp surface or as the well-known toy called the artificial fish will flop its tail when after being well dried it is laid on the moist hand. In these cases we know that there is no animal life either in the shaving or in the fish, and the cause of the phenomenon is obvious and easily explained; but in the case of the hair, associated as it is with a real living worm of almost identical appearance, the ordinary mind is more easily deceived. The general impression amongst those who have not made a special study of the subject is that voluntary movement on the part of any organism implies the presence of animal life, and for a long time several microscopic plants which are now known to be true vegetables, were believed to be animals because they were seen to move about in the still water in which they floated. This was the case with many diatoms and desmids, and the beautiful *volvox globator*, which is unquestionably a vegetable, was long known as the "globe animalcule" and was believed to be an animal because it seemed to have the power of voluntary motion. Few sights are more strikingly beautiful than the appearance of a well-developed volvox passing across the field of view of a microscope with a steady rolling motion, thus giving one the impression of a large green globe obeying the instincts of animal life.

This free motion from place to place was of course seen to be very different from the movement of the sensitive plant or the movement of flowers under the action of the sun, and it was thought that it could only be attributed to animal life.

Of course in the present state of biological knowledge it would be futile to offer any arguments against this old belief. The microscope gives us ample assurance that it is false and the life history of the *Gordius* has been fully traced.

It may interest some of our younger readers to learn that these worms get the name *Gordius* because of their curious habit of coiling themselves into complicated knots — veritable "Gordian knots."

THAT HAIRS ARE TUBES

WHEN we look through a strong magnifying glass at a human hair it appears to the uneducated eye to be tubular and consequently the impression very generally prevails that hairs, like quills, are tubes. This fallacy is due to the fact that since the hair is nearly cylindrical there is generally a bright line of light reflected from the upper part of the surface, and as the edges are in shade and consequently dark, the resemblance to a tube is very strong. But if we place a bright metallic wire under a microscope and examine it as a dry and opaque object, the same bright central line and dark edges will appear and the wire will seem to be a tube, although we know that such is not the case. Of course the decisive test is to make a cross section of the hair and examine this under the microscope after it has been properly mounted. The interior substance of the hair will then be found to consist of a peculiar fibrous material with sometimes a central medullary portion composed of spheroidal cells.

The hairs of different mammals vary greatly in their structure. Those of the cat, squirrel, mouse, rabbit, and some others present very characteristic appearances. The large hairs of the deer are very peculiar when viewed as an opaque object. Indeed there are few more interesting objects for microscopical study than hairs with their various forms and structures.

THAT WORMS SHALL EAT OUR BODIES AFTER WE ARE DECENTLY BURIED

THIS is a very old belief. In the Book of Job (Chap. xix, v. 25) the prophet exclaims: "And though after my skin worms destroy this body, yet in my flesh shall I see God."

And Shakespeare makes Hamlet say (Act IV, Scene 3, line 28): "A man may fish with the worm that hath eat of a king, and eat of the fish that hath fed of that worm."

Rosalind also boldly avers that "men have died from time to time, and worms have eaten them, but not for love" ("As You Like It," Act. IV, Scene 1, line 107).

And all through our literature the same idea prevails. No wonder then that the popular mind is firm in the belief that it is the fate of humanity to be eaten by worms if not consumed by fire or consigned to the fishes. And the worm that is usually thought of in this connection is the common earthworm or angleworm as it is usually called.

Now in the first place the earthworm does not feed upon undecomposed flesh; I have never met them in a putrefying carcass. Their food consists chiefly of decaying vegetable matter; consequently the site of an old manure heap is a choice place to dig for them. And, secondly, earthworms are scarcely ever found at the depth to which a normal grave is sunk, that is, six feet. So that no one need fear that he will fall a prey to the ordinary garden or earth worm.

That an uncared-for corpse, left exposed on a summer day, would soon be flyblown and that the eggs deposited by the flies would develop into larvæ which would soon devour the body, is quite true. Linnæus tells us that the progeny of three blowflies would devour the carcass of an ox as quickly as would a lion. So that it is pretty certain that they would make quick work with an unprotected corpse. But such a condition never occurs in civilized life where death takes place amongst relatives and friends.

But while we do not stand in much danger of being eaten by earthworms or the larvæ of insects, it is very certain that every man carries into his grave those devouring agents which though invisible to ordinary sight will accomplish the destruction of his body quite as effectually as could those grosser creatures of which so many stand in dread. Unless destroyed by powerful embalming agents the microbes which cause putrefaction and which are always present in inconceivable numbers will sooner or later cause the materials of this worn-out garment which we call our body to return to the elements whence they came. From birth to death we have been continually borrowing, continually paying back. Part of our physical organization may have come from the fruits of the tropics, part from the mosses and lichens of the frozen north. We may hold in our bones, muscles, and brains, materials which once formed part of the gentle sheep or the ravenous wolf, and in all the millions of years during which the composition and decomposition of organic matter has gone on, it is quite probable that some portion of our physical system may have previously formed part of the material organization of thousands of other animals, men included. The imbecile may have in his body atoms which once formed part of Homer, of Plato, or of Archimedes. Into the wretched frame of the beggar may be built material which once formed part of Solomon in all his glory or of Crœsus with all his wealth, and some of the atoms which by their changes enabled such generals as Alexander, Cæsar, or Bruce to achieve their fame, may now form part of the body of a lazar. For all power is due to the energy derived from the change of material.

Even among the corporeal atoms which now make up our own bodies may be particles which helped to incarnate the person of Jesus Christ or which lent physical energy to the burning eloquence of Saint Paul.

Organic life has gone on unceasingly for untold ages in ever-recurring cycles and it will continue to go on while the earth endures. Not a single moment passes in which some part of every living organism does not die. We cannot move a muscle or give way to an emotion or even think a thought without burning up some part of our corporeal frame and the used-up material is speedily ejected and then transformed into the clothing of a new life.

THAT A DECAYING CARCASS BREEDS WORMS

THIS erroneous belief was much more prevalent half a century ago than it is to-day. In the olden time it was commonly held that all kinds of creatures might be "generated," as it was termed, out of decaying matter, and it was supposed that animals of even such a high degree of development as birds might be evolved in a single generation out of some lower form. Thus the barnacle goose was said to be a metamorphosed barnacle, the latter being a marine animal of no very high grade.

And Virgil in his poem on country matters gives minute directions for raising a swarm of bees out of a dead carcass. It is very certain, however, that no swarm was ever raised in this way.

So too Shakespeare makes Lepidus say: "Your serpent of Egypt is bred now of your mud by the operation of your sun; so is your crocodile" ("Antony and Cleopatra," Act II, Scene 7, line 29).

And his audiences probably did not doubt the statement even in regard to such a highly developed animal as the crocodile. But it is no wonder that such opinions should prevail generally amongst the people at large, for everywhere we see life developing under conditions and in ways which hide their origin from the ordinary observer because he has not been taught to direct his attention to them. He sees the larvæ or worms which are devouring the dead carcass, but he did not see the minute eggs from which the larvæ were developed simply because he did not look for them. Consequently it was the most natural thing in the world for him to suppose that they owed their origin to the putrefying action of the carcass itself. As we examine other forms of animal life the difficulty of ascertaining their origin becomes in many cases very great and in the case of some parasites it has required the laborious efforts of the ablest biologists to make out their life history. Until a few decades ago the different life stages of certain marine animals were regarded as entirely different species and each stage was classified as being an entirely distinct animal. And it is within the memory of living men that the parr, a small fish which swarms in all salmon rivers, was considered a distinct species and was allowed to be slaughtered without limit, whereas it is now known beyond the possibility of a doubt that it is the young of the salmon and is carefully protected.

And it is now very certain that no creatures which show distinct animal characteristics ever appear except as the progeny of animals of the same kind.

THAT SMALL FLIES ARE THE YOUNG OF LARGE FLIES

EVERY observing person must have noticed that the flies which infest our houses differ greatly in size, some being very small while others of similar general appearance are quite large. And it is a very common idea that these small flies are small simply because they are young and that if they are allowed to live they will grow larger. It is very natural that this mistake should be made by those who have never given special attention to the manner in which insects are developed from the egg. But it is a curious fact that flies, bees, wasps, butterflies, moths, etc., are as large at the time they emerge from the cocoon or cell as they ever are afterwards. All their growth is made while in the larval condition — that is as caterpillars or "worms." Hence the voracity of the caterpillar and the so-called "worms" of clothes moths. After the insect becomes mature it never changes, and the difference of size in the flies with which we are familiar is due to the fact that they are different kinds or species.

THAT DRAGON FLIES STING MEN AND OTHER ANIMALS

IT is an old saying, "You might as well hang a dog as give him a bad name." This is eminently true of the dragon fly, of which there are a vast number of species and to which many evil names have been given. Thus it has been called "the devil's darning needle," "the horse stinger," "the snake-feeder," and other vile names. And amongst children whose education in natural history has been neglected there is a very prevalent belief that the devil's darning needle can go in at one ear, pass through the head and come out at the other ear, and that various dire diseases are the result of this action on its part.

Now it is a well-ascertained fact that the dragon fly is one of our best friends; it has no sting and its biting apparatus is so feeble that one may be safely caught in the bare hand and held without injury to the captor.

The dragon fly lives entirely on flies, mosquitoes, and other insects which it captures on the wing, and when a room is so fortunate as to have a dragon fly for a visitor, all mosquitoes and flies are quickly removed. And yet, notwithstanding this well-known fact, let a dragon fly appear in an assembly of young people (or old ones either, for that matter) and there will be an intense commotion and every young man in the party will be put on his mettle in an effort to kill the terrible beast.

So well known to naturalists are the good offices of the dragon fly that some years ago an effort was made to propagate them as an enemy of the mosquito. It was found, however, that while the dragon flies were active destroyers of the mosquito they retired early in the evening, while the late evening and night is just the time when the mosquitoes are most active. In addition to this the larvæ of the dragon fly are very destructive to small fish, and these are well known to be the most efficient destroyers of the larvæ of the mosquito. A dozen small fish will clean out all the mosquito larvæ in a small pool of water, and what is more, they will keep it clear of these pests. And as the larvæ of the mosquito are almost always bred in stagnant pools, this is the most effective mode of getting rid of them.

The larvæ of the larger species of dragon fly are fierce, carnivorous creatures of which the common name is "the water-devil." They spare nothing that comes within their reach and that they can overcome — not even weaker individuals of their own species. But the mature insect is a harmless and indeed a beneficent creature and it never stings, for it has no sting.

THAT POWDERED GLASS IS A SECRET AND DEADLY POISON

THIS is a very old fallacy. It figures in the "Vulgar Errors" of Sir Thomas Browne and it survives even to this day amongst a certain class of pseudo-scientific writers. Even within two or three years a man was charged with committing murder by means of powdered glass and was tried for a capital offense. Of course the physicians who went on the witness stand scouted the idea of powdered glass acting as a virulent poison and one of them offered to swallow a tablespoonful of the stuff in open court. Sir Thomas Browne experimented with it on dogs and tells us that he gave "unto dogs above a dram thereof subtilely powdered in butter and paste, without any visible disturbance." Nevertheless he tells us that "glass grossly or coarsely powdered is mortally noxious, and effectually used by some to destroy mice and rats."

This idea that powdered glass is an efficient poison for rats and mice is quite prevalent, but it has been proved by recent experiments made under the direction of the United States Department of Agriculture that glass, whether coarsely or finely powdered, has no ill effects upon rats. Rats were fed for some time on food mixed with the glass and they did not seem to be injured by it. And when examined after being killed, the alimentary canal was found to be in normal condition. So that we may safely relegate the belief in powdered glass as a poison to the list of popular fallacies.

THAT A MAN BECOMES OF AGE ON HIS TWENTY-FIRST BIRTHDAY

THIS might be regarded rather as an error of speech than as a fallacy of thought were it not that the same erroneous idea has been carried into other conceptions and has given rise to serious error which has sometimes been of a practical nature.

When a man reaches his twenty-first birthday it is evident that he has lived only twenty full years. On his first birthday he was just beginning life and it was only on his second birthday that he reached the age of one year. The same difference between the number of his birthdays and the number of his years continues all his life, and it is only on his twenty-second birthday that he has lived out the twenty-one years which entitle him to vote in this country and which confer upon him all the rights and privileges of adolescence.

The same discrepancy appears in the numbering of the centuries and it is no uncommon thing to hear the seventeenth century spoken of as the sixteenth because it ran from 1601 to 1699, only the last year (1700) having 17 before the other two figures. Indeed I have seen in print, under the authorship of one who must certainly have known better, the seventeenth century named when the eighteenth was what was intended.

It was not until the close of 1900 that the nineteenth century rounded out its full quota of years, and it was with the beginning of 1901 that the twentieth century commenced its run. And although the attempt was actually made, yet all the edicts and laws of kings and Kaisers could not alter this mathematical fact.

THAT "THE EXCEPTION PROVES THE RULE"

THIS very common expression is a singular misconception as to the meaning of an old Latin proverb, *Exceptio probat regulam.* The word *probat* used here really means to test, but it may be translated *proves*, since the word *prove* also means to test, as is seen in its use in relation to the proving of cannon, the place where the guns are fired being called "proving" grounds, or in other words, testing grounds. Therefore the expression quoted at the head of this note does not mean that the exception confirms or ratifies the rule, but that it tests or tries it, and if the exception cannot be easily explained away, the rule breaks down.

For example: a somewhat positive person asserted that the only case in which the letter *s* had the sound *sh* when it preceded the vowel *u* was in the word *sugar*, and was at once met with the question: "Are you *sure?*" His rule, if rule it could be called, broke down on being proved or tested.

THAT CINDERELLA'S SLIPPER WAS OF GLASS

MOST people would think that glass as we know it, whether blown or cast, would not make a very serviceable slipper, and we have no reason to believe that it was made of spun glass. But all doubt in regard to the material of which the slipper was made is set at rest by referring to the original French version of the story, of which ours is a translation. There we are told that it was a slipper of *vair*, the French for *fur*. This word the translator mistook for *verre*, which means *glass*, and so it has come to pass that all English-speaking people believe that Cinderella's slipper was made of glass. In the German version the slipper is of gold.

The story is very old and a similar legend is told of Rhodope, the famous Egyptian courtesan who was said to have built the third pyramid. While she was bathing, her slipper was carried off by an eagle and dropped in the lap of the Egyptian king, who was so struck with its beauty that he sought out the owner and made her his queen. See "The Shakespeare Cyclopedia," page 258.

THAT GLASS IS VERY HARD

WE are led to believe that this error is very prevalent because the expression "as hard as glass" is used as a comparison by some manufacturing firms in their advertisements of goods in which hardness is a specially desirable quality. And we are confirmed in this view by the fact that the editor of one of our mechanical journals actually defended the implied statement on the ground that glass is very brittle!

Hardness, as we all know, is a comparative term. Copper is hard when compared with lead; it is soft when compared with brass, and brass is soft when compared with common iron. The latter is soft when compared with steel, and steel itself is soft when compared with iridium or with the diamond.

Glass, however, according to all the scientific tests used by the mineralogist and the physicist, is quite soft. It is easily scratched by flint and by several minerals of that grade, while flint is easily scratched by carborundum, ruby, and some other substances — the hardest material known being the diamond.

It is a curious fact that, next to the diamond, the hardest substance should be an artificial product — carborundum. It readily cuts the hardest materials, and is invaluable as an abrasive.

Different kinds of glass vary greatly in hardness, but they are all comparatively soft and may be cut by a good steel tool. It is a common practice amongst amateur opticians to shape pieces of glass into lenses in the turning lathe just as they would shape a piece of iron or steel. An ordinarily hard steel graver will cut glass as if the latter were cheese, and a bit of fine glass may soon be brought so nearly to the proper curve that it will require merely a little polishing to make a good magnifier. I have three or four lenses which were thus made and which are very convenient and serviceable.

It has been argued that glass must be hard because it is so brittle. But sugar is quite as brittle and it is certainly very much softer. Hardness and brittleness have no necessary relation to each other, although substances which by the usual process of hardening are made as hard as possible frequently become very brittle. This is true of steel and glass, both of which when unannealed are harder than usual and very brittle. But even the most brittle glass is comparatively soft.

If our advertising friends would say "as smooth as glass" their claims would probably be much more attractive and certainly far more accurate. Their goods being made of hardened steel are far harder than any glass that ever was produced.

THAT FRANKENSTEIN WAS A MONSTER

THIS atrocious literary blunder has become so common and has been so frequently accepted as true by writers of notable reputation that a correspondent of one of our literary journals actually defended the use of the expression, "the monster Frankenstein," on the ground that the idea had now become part of the mental furniture of the majority of literary men! The assertion that the majority of fairly well-read men, not to speak of men whose profession is literature, are ignorant of the general outlines of the story of Frankenstein is certainly incorrect, and to say that if we only give a mistake or a falsehood circulation enough it will be converted into a truth is to propound a system of ethics which few will be willing to accept.

"Frankenstein," as many of the readers of this page know, is the title of a romance written by Mrs. Mary Wollstonecraft Shelley, the wife of the famous poet. It was written under very peculiar circumstances, which Mrs. Shelley herself has detailed in the first and second prefaces to the book and which have been so frequently quoted that it is unnecessary to do more than allude to them here. Mrs. Shelley was but nineteen when she began this story, one of the most remarkable in the literature of the nineteenth century. The substance of it is as follows:

Frankenstein was a student of science at Ingolstadt, and the question "Whence did the principle of life proceed?" occupied his thoughts beyond any other. At length he thought he had solved it and he set about constructing a human being into which he could infuse life. To avoid the great difficulty of working on very minute organs he made his man eight feet high and large in proportion. After two years' hard work he finished the construction of this being and succeeded in vitalizing it. When he had accomplished his task and the creature showed signs of life he was horror-struck at the sight of the fearful monster he had created and he fled from it in terror. The monster escaped to the woods and was the terror of those who saw it, and the account which the creature afterwards gave to Frankenstein of the way in which he subsisted and how he learned to speak and to understand French showed wonderful imagination on the part of the authoress. And the account which the monster gave of the way in which he was treated by everybody and his woeful sense of isolation is very pathetic. But this expulsion from all association with any other being led him to entertain bitter and vengeful feelings against men in general and his creator in particular. He murdered the younger brother of Frankenstein and contrived to fix the crime on an innocent young girl who was executed for it. He found Frankenstein in the mountains and made him promise that he would create a mate for him, a female with whom he might associate in love and sympathy.

Frankenstein made the promise and set about the work, but before it was completed he repented and destroyed the creature he was making. Thereupon the monster appeared and threatened him with the most dire vengeance. He killed the dearest friend that Frankenstein had and swore that he would be with him on his wedding night. When that night came the monster murdered the bride of Frankenstein and then departed for the region of the north pole. Frankenstein attempted to follow for the purpose of destroying the demon, but in the northern seas he was picked up in an exhausted condition by a ship on board of which he expired after giving a full account of all that had happened. The monster fled towards the north with the expressed intention of immolating himself on an immense funeral pyre.

From this the reader will see that Frankenstein was not the monster and to the latter no name is given in the romance.

WORDS WHICH CONVEY ERRONEOUS IDEAS

IT is an unfortunate fact that many of the words in common use actually convey erroneous statements of fact. This arises partly from the corruption to which all words in common use are liable and partly from the changes which are constantly going on in every living language. A change of this kind is seen in the word *admire*, of which the old meaning was simply to wonder, and in this sense it was used by Shakespeare and Milton. But it carries a very different signification now. Again, take the word *vulgar*, which now conveys the idea of something offensive. Formerly it merely meant common, as when in "Twelfth Night" Shakespeare makes Viola say: "for 'tis a vulgar proof" (Act III, Scene 1, line 135). And in this sense it is still used in France, where they have a journal for the vulgarization of science ("Vulgarisation Scientifique"), or what we would call the popularization of science. As a matter of fact, however, the words *vulgarization* and *popularization* both come from roots which signify the common people.

So too the word *fond*, which now means *loving* or *affectionate*, formerly meant *foolish*, and is so used by Shakespeare in several passages, notably in "The Merchant of Venice," Act III, Scene 3, line 9, and other places in that play.

Perhaps the most curious transformation of meaning occurs in the word *telescope*, which literally means an instrument for seeing things afar off, and in this sense it is still used when speaking of the optical instrument. But from the fact that the mechanical portion of telescopes was generally made of two or more tubes sliding into each other the word came by analogy to be applied to any combination in which this mere mechanical feature was present, and now we speak of railroad cars "telescoping" when, in a collision, they slide one into the other. In this case optics or any of the features of *seeing* are entirely absent and the mere mechanical motion alone is considered.

Numerous instances might be cited where changes in the arts and in our customs give an apparently absurd meaning to old words. Thus in the olden time distances were marked by stones set up at regular intervals and called milestones; to-day these markers are sometimes of wood and sometimes of metal, but we still retain the old term, milestone, and then we have wooden milestones and iron milestones.

Again: The old-time pens were all made from the quills of geese, swans, and crows, and were called pens because that, in its Latin form, was the word for feathers. Now quills have gone out of use and we have gold and steel pens, — literally, gold and steel feathers.

Before the introduction of steel pens almost all writing in ink was done by means of quills. These wore out quite rapidly and upon the writing master and some of his most skillful pupils devolved the task of mending the pens used in the writing lessons of each day. This was done by means of an exceedingly sharp knife, and by practice some of the boys became very expert at the work. The knife used for this purpose was called a pen-knife, and we still retain the name though the term has entirely lost its significance. I remember well the time when steel pens were almost unknown, and when a boy I have made and mended hundreds if not thousands of quill pens.

The old alchemical nomenclature introduced several words which now are stumblingblocks to the ordinary reader of modern times. For example, silver nitrate got its old name of *lunar* caustic from the fact that the old alchemical name of silver was *luna* or the *moon*, and its compounds were known as *lunar* salts. The ancients were acquainted with seven metals and also with seven planets, for in their system the sun and moon were classed with the planets. This led to the theory that each metal had special associations with its own planet — iron with Mars, copper with Venus, lead with Saturn, and so on. This explains why salts of iron were called martial salts; salts of copper, venereal salts; compounds of lead, saturnine preparations, and so with the others.

The following list contains a few words which convey erroneous ideas; the number might be greatly enlarged.

Black Lead. — This well-known substance has no lead at all in its composition; it is simply a form of carbon, charcoal and the diamond being other forms. Another name for it is plumbago, but this is just as bad, for this word is derived from the Latin name for lead (*plumbum*). The proper name is *graphite*, or writing material. Black lead no doubt got its name from the fact that pencils were originally made of lead or of one of its alloys, and when graphite was substituted for the metal it was quite natural to call it black lead from its color. But nevertheless it is a misnomer.

Blind Worm. — Although not found in this country, the name of the creature is so often mentioned in English literature that it is worth while to note the fact that it is neither blind nor poisonous, qualities which are generally attributed to it by the ignorant. It is really a small lizard.

Its eyes are small but very bright and provided with lids.

Camel's-hair Brushes are not made from the hair of camels but from hair from the tails of Russian and Siberian squirrels. Did any one ever try to use the hairs of any of the large American or Canadian squirrels for this purpose?

Catgut. — This is never made from the intestines of cats but from those of sheep and sometimes of horses. It is a curious fact that the highly fed and fat sheep of the best farming countries do not yield materials that are fit for making catgut. The lean, hardy sheep of the north of Italy seem to furnish the best article.

Coddington Lens. — This very valuable improvement in magnifying glasses was invented by Sir David Brewster and it ought to be called the "Brewster lens" It is an inexpensive form of simple microscope, and although not equal to a well-made achromatic magnifier, it is very much cheaper and is greatly superior to the ordinary double convex lens. Coddington, who wrote several books on optics, never claimed to be the inventor of this form, but like many other inventions it has been credited to the wrong person.

Galvanic Battery. — This is a singular misnomer which for a time was applied to what really ought to be called the *voltaic* battery, since the combination of two metals and an acid (or their equivalents) was really invented by Volta. Galvani had been dead some years before the voltaic pile or battery was given to the world.

Foxglove. — The syllable *fox* in this word is a corruption of the word *folks*, meaning the fairies or "little folks." It should be folks' glove.

Hydrophobia is a very misleading term as applied to so-called mad dogs. A dog that is rabid does not dread water; he will lap it or even swim in it.

JERUSALEM ARTICHOKE. — This is a curious corruption of the Italian name, *girasole articiocco*, which means sunflower artichoke. It has no relation to the city of Jerusalem. The plant is a native of this continent.

RICE PAPER. — The well-known Chinese rice paper, as it is called, is not a paper at all but a thin slice of the pith of a herbaceous Chinese plant (the *Aralia papyrifera*). The pith forms a cylinder, and with a long and very sharp knife a slice is cut from the surface, the cut going round and round in a spiral. The moist slice of tissue is thus unrolled from the cylinder of pith and dried under slight pressure — just enough to cause it to remain flat. It cannot be written on with an ordinary pen and ink. The Chinese use fine brushes, and I have in my possession some beautiful water-color paintings done by a Chinese artist on this material. This "rice paper" forms a beautiful object under the microscope, as it shows the form and arrangement of the cells very clearly under a low power. Paper may be made and has been made from rice straw, but it is an article very different from the real Chinese "rice paper."

SEALING WAX. — Good sealing wax, as used now, contains no wax. But originally it consisted of almost pure wax, and the seal was not affixed to the document as is now done. The old seals were huge lumps of wax on which the seal was impressed, and they were attached to the document by means of a ribbon which passed through the seal. Our modern sealing wax is composed largely of shellac.

SPARROWGRASS. — This word is obviously a corruption of *asparagus*, but it has obtained such a hold upon the speech of the uneducated that the market gardeners actually contract it to "grass" and when speaking of asparagus they call it "grass" for short. It has no affinity to the true grasses, and sparrows do not seem to be particularly fond of it, though they will occasionally eat it as they do peas and many other green things in the spring.

WHALEBONE is not bone at all but a peculiar horny substance of which the scientific name is *baleen*.

WORMWOOD. — This is a corruption of the Anglo-Saxon *wermod* or *wermode*, which means the keeper or strengthener of the mind. It has nothing to do with worms or wood. The plant (*absinthe*) furnishes a powerful tonic. The word *vermuth* seems to be a form of *wermod*.

"KNOWLEDGE IS POWER"

NO proverb ever received more emphatic confirmation than that given to the above during the century just past. Whether the power be for good or for evil, knowledge is its source. A single modern battleship would be more than a match for all the fleets in existence three hundred years ago. And when we turn to the triumphs of peace we find ocean liners that can brave any storm; while such well-known inventions as railroads, telegraphs, telephones, fast printing presses and others which have changed all our social conditions, are all due to increased knowledge.

A few pages back we quoted the saying of Archimedes: "Give me a fulcrum and I will raise the world." There is a modern saying which has become almost as famous amongst English-speaking peoples as is that of Archimedes to the world at large. It is that which Bulwer Lytton puts into the mouth of Richelieu, in his well-known play of that name:

> "Beneath the rule of men entirely great
> THE PEN IS MIGHTIER THAN THE SWORD."

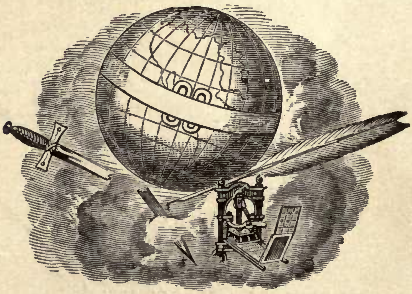
About thirty years ago it occurred to the writer that these two epigrammatic sayings — that of Archimedes and that of Bulwer Lytton — might be symbolized in an allegorical drawing which would forcibly express the ideas which they contain, and the question immediately arose — Where will Archimedes get his fulcrum and what can he use as a lever?

And the mental answer was: Let the pen be the lever and the printing press the fulcrum, while the sword, used for the same purpose but resting on glory, or in other words, having no substantial fulcrum, breaks in the attempt.

The little engraving which, with a new motto, forms a fitting tailpiece to this volume, was the outcome.

It is true that the pen is mighty, and in the hands of philosophers and diplomats it accomplishes much, but it is only when resting on the printing press that it is provided with that fulcrum which enables it to raise the world by diffusing knowledge, inculcating morality, and providing pleasure and culture for humanity at large.

When assigned to such a task the sword breaks, and well it may. But we have a well-grounded hope that through the influence of the pen and the printing press there will soon come an era of universal



Peace on Earth and Good Will toward Men.

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