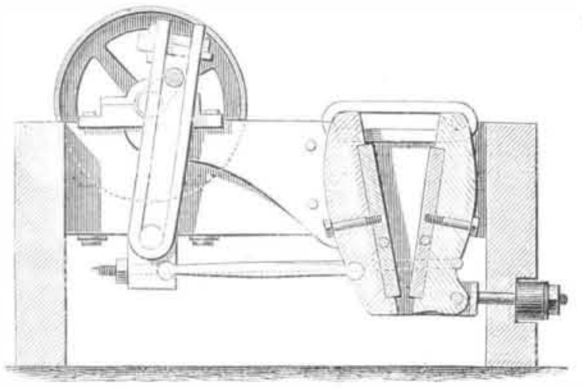
compose the levers at a right angle with the rod next to it. This lever is attached to the periphery of the wheel by the hinge joint, B, provided with the shoulder, to prevent its falling into any other than a right line from the center of the circumference of the wheel. The levers are furnished at their outer extremities with a bucket, or receiver, the bottom of which is sufficiently broad to retain the ball, C. The balls remain in the buckets till the buckets come into the position of the lever, D, when they are expected to roll out of the buckets on to the inclined plane, and by their own gravity roll to the other end of the inclined plane, ready to be again taken into the buckets.

QUARTZ CRUSHER.

In machines designed for breaking stones, crushing ores, etc., simplicity is absolutely essential. Pride and poverty are fully as congenial as rude work with complication in mechanism. The parts of such machines should therefore be few and massive, and be so put together thas even common laborers may be able to keep them in running order.

Messrs. Varney & Rix, of San Francisco, Cal., have patented a machine which seems, so far as simplicity is concerned, to answer the requirements of the case.

Our engraving is a representation of this machine. The power is transmitted from cranks on the shaft of a heavy fly wheel through a system of powerful links, or toggle bars,



to pivoted jaws, which thus approach each other with great force at each revolution of the fly wheel, compressing the quartz and thus crushing it. The general principle of the mastication of food by the jaws of animals is very nearly approached in this machine.

ACTION OF THE RECIPROCATING PARTS OF STEAM ENGINES, AND ITS INFLUENCE ON THE PROBLEM OF HIGH PISTON-SPEED.

Read before the Polytechnic Club of the American Institute, by Chas. T. Porter.

Your attention is invited to a proposition, which, on its bare statement, will probably strike many persons as absurd. It is, that a reciprocating engine is, with respect to the line of centers, identical with a rotary engine; reciprocation is, in the line of motion, identical with rotation; the reciprocating parts of an engine, at the instant when the direction of their motion is reversed, exert a force, which is precisely the same centrifugal force that would be exerted by them continually if they were revolving with the crank; so that reciprocation may properly be defined to be rotation in a straight line.

I am well aware that the doctrine that the reciprocating parts of an engine exert a force on the dead centers where they are at rest, when their motion in one direction has ceased and that in the opposite one has not yet begun, is rank heresy; as much so as was once the assertion that the earth revolves on its axis. It is, however, equally true. The demonstration of it is quite simple, and I do not doubt that at every step I shall have your entire and cordial concurrence. If we find ourselves on ground not before trodden, we shall nevertheless be sure that it is firm and solid ground.

It may be observed here, that the action which we are to investigate has no *necessary* connection with high piston-speed. Although it is what makes rapid speed practicable, and although a correct understanding of it wholly removes any theoretical objection to the employment of such speed, still it takes place at all speeds, varying only in the amount of centrifugal force developed, according to the law of central forces, namely: directly as the mass, directly as the diameter of the circle when the number of revolutions is constant, inversely as this diameter when the velocity is constant, and as the square of the speed in a given circle.

We know that the motion of a piston controlled by a crank is not uniform, but, commencing from a state of rest, it becomes at the mid stroke slightly in excess of that of the crank-pin, and at the termination of the stroke has been reduced back to nothing. In giving the piston-speed of an engine, we always name its mean speed, found by multiplying the length of the stroke, in feet, into the number of strokes made per minute; but the speed attained at the middle of each stroke is about 57 per cent greater than this, having the same relation to it that the semi-circumference bears to the diameter of a circle.

Let us take, for illustration, the case of a horizontal engine, of 16 in. diameter of cylinder, by 30 in. stroke, the reciprocating parts of which weigh 1200 lbs., and which makes 122·3 revolutions per minute. The mean piston-speed is 611·5 feet per minute, while that reached at the middle of each stroke is 960 feet per minute, or 16 feet per second.

The first question requiring to be answered is: What is the amount of accelerating force, constantly exerted through a distance of 15 inches, that is required to impart to a body of 1200 lbs. weight a velocity of 16 feet per second? We suppose the motion to be without friction, and are inquiring only for the force required to overcome the inertia of the mass. The laws of falling bodies will furnish the answer to our question.

The motion being horizontal, gravity has no effect, either to produce or to destroy it; but a force of 1200 lbs., equal to the weight of these parts, would, by being constantly exerted horizontally through a distance of 16·083 feet, give to them a velocity of 32·166 feet per second, this being the velocity imparted by gravity to a falling body.

But what velocity would this force impart, by acting through a distance of 1·25 feet? The velocity acquired by a body accelerated by a constant force, varies as the square roots of the distances through which the force acts. Thus, a falling body, to acquire a double velocity, must fall through four times the distance, and to acquire five-fold velocity, it must fall through twenty-five times the distance; and so the force equal to their weight, acting through 1·25 feet, would impart to the reciprocating parts a velocity of 8·968 feet per second.

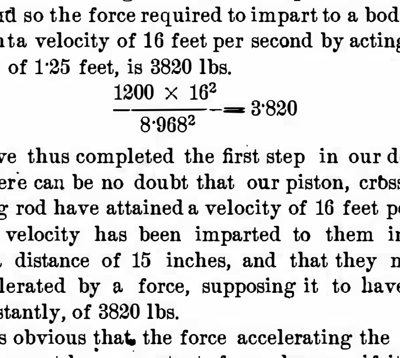
$$\frac{32{\cdot}166 \times \sqrt{1{\cdot}25}}{\sqrt{16{\cdot}083}} = 8{\cdot}968$$

But if 1200 lbs. will give a velocity of 8·968 feet per second, what force will be required to impart a velocity of 16 feet per second? The forces required to impart different velocities by acting through a given distance, must vary as the squares of the velocities imparted. Thus, to give to a body in moving through a distance of 16·083 feet, a velocity of 64·332 feet per second, or double that which gravity would impart, the accelerating force must be equal to four times its weight, and so the force required to impart to a body of 1200 lbs. weight a velocity of 16 feet per second by acting through a distance of 1·25 feet, is 3820 lbs.

$$\frac{1200 \times 16^2}{8{\cdot}968^2} = 3{\cdot}820$$

We have thus completed the first step in our demonstration. There can be no doubt that our piston, crosshead and connecting rod have attained a velocity of 16 feet per second, that this velocity has been imparted to them in moving through a distance of 15 inches, and that they must have been accelerated by a force, supposing it to have been exerted constantly, of 3820 lbs.

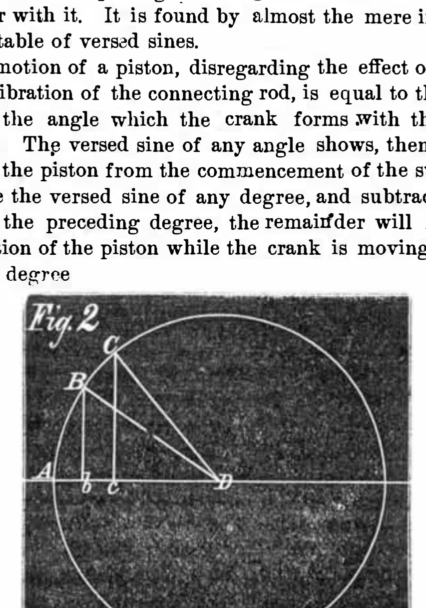
But it is obvious that the force accelerating the motion of a piston cannot be a constant force, because if it were so, then at the middle of the stroke, where acceleration ends, it must cease abruptly, and retardation must commence in the same manner, as would be illustrated by the two parallelograms, A B C D and C E F G, in the accompanying figure.



Now we know very well that, instead of this, acceleration passes at the mid-stroke into retardation, in a manner wholly insensible.

How shall this mystery be explained? There are various methods, more or less abstruse, of reaching the explanation, but there is one that is exceedingly simple, indeed so much so that it is surprising that engineers are not uniformly familiar with it. It is found by almost the mere inspection of the table of versed sines.

The motion of a piston, disregarding the effect of the angular vibration of the connecting rod, is equal to the versed sine of the angle which the crank forms with the line of centers. The versed sine of any angle shows, then, the motion of the piston from the commencement of the stroke. If we take the versed sine of any degree, and subtract from it that of the preceding degree, the remainder will represent the motion of the piston while the crank is moving through the last degree



Thus, in the above figure, while the crank is traversing the arc, A B, the piston is moving through a distance equal to A b, the versed sine of the angle, A D B, and so on.

The following table, which any one can complete, shows, in the first column, the versed sine, or total piston motion, for the first and last five degrees which the crank passes through while the piston is making a half stroke, and in the second column, obtained by subtraction as above, shows the motion for each one of these degrees.

The motion for each succeeding degree, of course, increases all the way, but in what ratio does it increase? This is the vital question. To answer it, we subtract from the motion for each degree that for the preceding one, and the difference shows the velocity imparted while the crank was moving through the last degree. In this manner we obtain the third column, showing at a glance the velocity imparted to the piston at each degree; and how wonderful is the revelation! The acceleration, at first nearly uniform, diminishes in an increasing ratio, which for the 90th degree is less than $\frac{1}{57}$ that for the first degree, and is just equal to the diminution in the acceleration for the 89th degree, showing how at the end of this degree it ceases altogether.

Degrees.	Versed sine, or total motion	Motion during each 1°.	Velocity imparted during each 1°.	Difference.
1	·0001523	·0001523	·0003046	
2	·0006092	·0004569	·0003046	0
3	·0013705	·0007613	·0003044	2
4	·0024359	·0010654	·0003041	3
5	.0038052	·0013693	·0003039	2
86	·9302435	·0173992	·0000265	
87	·9476640	·0174205	·0000213	52
88	·9651005	·0174365	·0000160	53
89	·9825476	·0174471	·0000106	54
90	1·0000000	·0174524	·0000053	53

The motion during the first two degrees seems to be uniformly accelerated; but if we should go to a sufficiently high place of decimals, we should find the acceleration absolutely greatest on the very dead center.

It will be interesting to compare this diminishing acceleration with the uniform acceleration of the motion of a falling body. The following table represents the latter; decimals are omitted for convenience, but this does not at all affect the table for the purpose of this comparison. The second and third columns are derived from the first by subtraction, in the same manner as above.

Seconds.	Total distance fallen through.	Distance fallen in each second.	Velocity in feet per second imparted during each second.
	ft.	ft.	
1	16	16	32
2	64	48	32
3	144	80	32
4	256	112	32
5	400	144	32
6	576	176	32

If now, at each degree, we draw an ordinate, perpendicular to the line of centers, and of a length proportionate to the acceleration at that degree, we shall find that a straight line connects all their extremities, showing the acceleration to be represented by the right-angled triangle, D C H, Fig. 1. This any one can verify.

It is thus revealed to us, that precisely on the dead center the acceleration of the piston's motion is double its mean acceleration, and the force required to produce it is twice that which would be constantly required; or, in the case we are considering, is 7640 lbs., equal to a pressure of 38 lbs. on each square inch of piston area.

The fact is so important, that it may be well to exhibit it also in another manner. We have seen that the motion of the piston is, for the first two degrees, accelerated in a manner which may be regarded as uniform. The distance moved through by a body uniformly accelerated, increases as the square of the time, as shown in the last table.

If, then, we take the coefficient of the motion for the first degree, ·0001523, and multiply it by the square of the number of degrees traversed by the crank in one second, we shall have the distance which the reciprocating parts would be moved in one second, at their original rate of acceleration, supposing it to be continued uniformly during that time, if the length of the crank equaled 1. This distance is 82·05254 feet, for the crank moves in one second through 734 degrees, and $734^2 \times {\cdot}0001523 = 82{\cdot}05254$. The length of the crank is, however, 1·25 feet, so that the distance moved through would be 102·5 feet. This distance, divided by 16·083, gives the quotient 6·37, which is the accelerating force in terms of the weight of the parts. But $1200 \times 6{\cdot}37 = 7644$, the same result as before.

The second point in our demonstration is now established that on the dead center, where motion begins to be imparted to the piston, it is imparted in double the average ratio, and the force required for this purpose is just twice as great as a uniform accelerating force would have to be, to give to it the velocity that it has at the mid-stroke.

The retardation of the motion of the piston by the crank, bringing it to rest at the end of the stroke, is the reverse of the acceleration, commencing insensibly at the middle, and culminating at the termination of the stroke, and is represented by the triangle, E, C, I, Fig. 1. This, to one who has clearly apprehended the acceleration, must be sufficiently obvious.

We are arrived now at our final proposition, that the resistance offered by the reciprocating parts to this alternate acceleration and retardation is, at its culminating point, the dead center, precisely the centrifugal force that the same weight would exert continually, if it were revolving with the crank pin.

Let us examine this action in the light that has now been thrown upon it. We will suppose the steam to be suddenly shut off, so that the acceleration, as well as the retardation, is effected through the crank. We note, first, this distinction, that while at the mid-stroke acceleration passes when diminished to nothing into retardation commencing at nothing; at the centers, on the contrary, retardation passes at its maximum into acceleration at *its* maximum. A closer examination shows, however, that while, in the first case, the direction of the force changes, in the latter it does not change. This direction must be reversed twice in each revolution, and this reversal takes place at the middle of each stroke, and not on the center. The crank begins, at each mid-stroke to retard the motion of the piston, and opposes to it a continually increasing resistance, retarding it more and more rapidly up to the center line, at which point it begins *by a continuance of the same force*, to urge it in the opposite direction. The strain of the piston on the crank, in either direction alternately, begins insensibly at the mid-stroke, culminates on the center, and diminishes to nothing at the mid-stroke again, and this resistance, at its culminating point, is the centrifugal force which the mass would exert, if it were revolving instead of reciprocating; and at every other point is the horizontal component of that force.

This is readily established. First, the direction of the force is radial. Second, the coefficient of centrifugal force is the decimal, ·000341, which is the centrifugal force (in decimals of a pound), of one pound, making one revolution per minute, in a circle of one foot radius. This coefficient shows the centrifugal force of 1200 pounds, making 122·3 revolutions per minute, in a circle of 1·25 feet radius, to be 7650 pounds.* Third, this identity is practically proved by the fact that the reciprocating parts are balanced, in the horizontal direction, by an equal weight, revolving opposite to the crank, and at the same distance from the center. Fourth, an examination into the nature of the force itself shows that it *is* centrifugal. What is centrifugal force? It is the resistance which a moving body offers to being deflected from a right line, or, as it is radially at rest, its right line of motion being across the radial line at right angles, it is its resistance to being put in motion, towards the center, from a state of rest, and the amount of this motion is the versed sine of the angle, a definition which exactly describes the force under consideration.

But what is the influence of this action upon the problem of high piston-speed?

We see that it makes any engine, in effect, a rotary engine if the steam be shut off, the crank passing the centers under the strain of the centrifugal force of the reciprocating parts. But at ordinary speeds this force is developed only in a small degree, varying from 2 pounds to 10 pounds for each square inch of piston area, and of course the force of the steam is only to this extent expended in overcoming it, the excess becoming, at the instant of its admission, effective against the crank.

Nor, at more rapid speed does it become of marked value, unless considerable weight in the reciprocating parts and a short stroke be employed, since it increases directly as the mass, and inversely as the diameter of the circle, with a given piston-speed. By combining, however, rapid speed and short stroke with considerable weight in these parts, their centrifugal force may be developed to whatever extent we choose; and if this be in excess of the force of the steam, the engine, with the steam turned on, becomes, in effect, a rotary engine. The crank passes the centers under a strain not wholly relieved; the force of the steam does not reach the crank at these points, but is absorbed in the mass, and is afterwards gradually imparted to the crank during the stroke.

It is certainly difficult to estimate too highly the value of this action. By means of it, the shock of the steam on the center may be avoided wholly, or in any degree; the excessively intermittent pressure caused by working steam at a high grade of expansion is transformed, as by magic, into a steady and uniform rotative pressure on the crank; the fly wheel is relieved of its most trying offices, and the shaft from the excessive torsion in alternate directions that is produced by its action; and a smooth and gliding movement is attained, with a closer approximation to uniform motion than the crank has been supposed to be capable of giving.

It is curious to observe how exactly opposite to the truth all the engineering traditions on this subject turn out to be. We have been taught that the reciprocating parts of an engine were passive on the centers, that the great difficulty encountered in the attempt to employ high speed was the necessity of reversing their motion, that they should therefore be made as light as possible, and long strokes should be employed, so that the changes in the direction of their motion might be as few as possible. Now we know that their centrifugal action on the centers is all important to a high speed engine, and that to render this most serviceable we must employ considerable weight and a short stroke.

The field is a very large one; I limit myself to the fundamental principle which I have endeavored to explain. This being established, all theoretical objection to the employment of high speed vanishes. When the dead center is stripped of its imaginary terrors, we must perceive the dawn of a new day in the history of the steam engine.

* This furnishes us a simple rule for calculating this force. Multiply together the weight of the reciprocating parts, the length of the crank in feet, and the square of the number of revolutions per minute, and multiply the product by the decimal ·000341.

Sulphuric Acid from Gypsum.

As is well known, numerous attempts have been made to procure sulphuric acid from the widely-distributed gypsum, or sulphate of lime; but hitherto without success. Some time ago it was stated that dolomite, a mineral consisting of carbonate of magnesia and lime, may be decomposed by gypsum—carbonate of lime and sulphate of magnesia (bitter salt) being produced when they are both mixed as fine powders and lixiviated with water. From the latter the sulphuric acid can be readily separated by chloride of sodium, the concentrated solution of both yielding sulphate of soda and chloride of magnesium. In the *Neue Jahrbuch für Pharmacie*, 1870, page 204, H. Reinsch denies that gypsum can be decomposed by dolomite. He prepared an intimate mixture of the powdered minerals, and treated it for three months with water, allowing the liquid to drop from a filter, but without even obtaining a trace of bitter salt. After this time he kept the mass boiling for three days, the waste of water by evaporation being constantly re-supplied. The filtered liquid, being boiled down, left a yellowish cake, consisting of two thirds gypsum and one third of other salts, as nitrate of magnesia, chloride of magnesium, nitrate of lime, and traces of bitter salt. Hereupon Reinsch made trials in another direction. He mixed two parts of powdered gypsum with one part of carbonate of ammonia, which contains one and a half equivalent of ammonia. Upon being triturated with water, a liberation of gas took place which lasted for several days, and as the liquid was ultimately heated to the boiling point, a very vivid disengagement of pure carbonic acid was produced. By this process, carbonate of lime, and sulphate of ammonia were formed, and part of the carbonic acid of the ammonia salt was disengaged as gas.

The gypsum was completely decomposed. At the ordinary temperature the decomposition takes place without interruption, but slowly, while at the boiling point it becomes very rapid. A very soft carbonate of lime is thereby obtained, which, in large quantities, might certainly be utilized. In order to separate the sulphuric acid from the ammonia salt, it would only be necessary to subject it to sublimation with common salt, and to convert the resulting chloride of ammonia with carbonate of lime into carbonate of ammonia. It is thought probable that this method of producing sulphuric acid may be carried out on a large scale, provided that the carbonate of lime formed during the first decomposition, and the chloride of calcium formed at the second one, can be utilized, of which, according to Reinsch, there cannot be any doubt.

The chloride of calcium, at least, has repeatly been recommended as a means for keeping streets free from dust. In this manner the inexhaustible sources of gypsum could be employed for the manufacture of sulphate of soda, which forms the basis of the fabrication of glass and soda.

Correspondence.

The Editors are not responsible for the opinions expressed by their Correspondents.

Beams and Girders.

MESSRS. EDITORS:—Mr. Severson, in the SCIENTIFIC AMERICAN of Dec. 10, last, criticised me freely on the subject of the strength and strain of beams, etc., which is all right; but I am sorry for the reputation of the profession to which he attaches himself, that he should make so many blunders in so short an article. He evidently does not belong to that class of engineers to which I referred in a former article, for he differs from all of them, in every point he advances.

It will be observed that, on page 307, SCIENTIFIC AMERICAN, Vol. XXIII., I assumed two positions, differing from those advanced by the *Builder*. The first, which was in relation to the strain to which a beam is subjected by a weight laid upon it at different points between the supports, is expressed by the following formula or general proportion:

A varies as BC×CD

in which A is the strain to which a beam is subjected, by a weight laid on it, at any point, and BC and CD are the segments of the beam between this point and the supports. For authority see "Gregory's Mathematics," art. 2, page 402; "Practical Book" of reference, by Chas. Hazlett, and Prof. Hackley, of Columbia College, page 265; "Scribner's Engineer's and Mechanic's Companion," page 129, Note 1.

The second relates to the strength of beams, and is expressed by the following general proportion:

$$S \text{ varies as } \frac{bd^2}{l}$$

in which S equals the strength of the beam, b the breadth, d the depth, and l the length. See "Scribner's Engineer's and Mechanic's Companion," page 127; "King's Notes on Steam," art. 3, page 207; "Gregory's Mathematics, art. 22, page 405; "Mahan's Engineering," first equation on page 387; reports of Du Hamet and M. de Buffon, to the French Government, as given by Robert Stuart in his "Cyclopedia of Architecture," article, "Mechanical Carpentry."

Yet, in the face of all this authority, our friend Benjamin Severson, mechanical and civil engineer, of Washington, D. C., is bold enough to tell us, with regard to the first of the above propositions, that the strain varies "inversely as the distances." And with regard to the second proposition, that "the positive statement of Mr. Pearson appears to be equally erroneous."

Again, in attempting to enlighten us upon the "strain of beams," resulting from a load laid evenly over the whole length, he says: "Under loads thus uniformly applied, the strains increase as the squares of the spans." While all the authorities above quoted unite in telling us that the strain at any point of a beam, resulting from a load thus evenly laid over its entire length, is only the half of that resulting from laying the entire load on that particular point.

Again, in relation to his hypothetical beam, it is no disparagement of the formula that the beam will not support its own weight. It will be seen that the element of weight varies directly as the length, while the element of strength varies inversely as the length, the other dimensions remaining constant, so that it is possible for a beam, having all the strength assigned to it by the formula, to fail of supporting its own weight.

Furthermore, it will be seen by reference to his article on page 372, Vol. XXIII., SCIENTIFIC AMERICAN, that all his deductions are from appearances. He does not give the result of any experiment, or any analytical investigation, or quote any author in support of his sayings. It takes something more than simple appearances to do away the results of profound research for ages. H. C. PEARSONS.

Ferrysburgh, Mich.

Fire Escapes.

MESSRS. EDITORS:—In a late issue of your valuable paper, one who signs himself "Humanity" suggests the idea of an apparatus to save persons from the horrible death of burning alive, as was the case at the burning of the Spotswood House, at Richmond.

The idea is a good one, but instead of a rope basket, as he suggests, two baskets, made of wire, should be used, one inside of the other. The outside one must be made of wire gauze $\frac{1}{20}$-inch mesh, or sufficiently fine to prevent a flame from passing through, yet, at the same time, allowed full circulation of air. The inside basket should be made less than the size of the outside one, allowing from two to three inches space between the two, and of wire $\frac{1}{2}$-inch mesh. Both should be placed on iron frames. To this should be attached a small iron chain, sufficiently long to be used by parties outside of the building, on the ground, in hoisting and lowering. A small pulley block and hook should be attached to the chain.

About the building in several places should be placed iron brackets with rings suspended to hook the blocks to in case of need. The principle of the basket is well understood to be that of Sir H. Davy's miners' lamp. It could be lowered through any amount of flame without the least fear of a person's clothes inside taking fire. These baskets would also be handy for firemen to use in case of fire, provided they were not wanted for other purposes; and the cost of placing them about a building would be merely nominal.

376 Broadway, Boston. M. H.

"Men of Progress."

MESSRS. EDITORS:—I feel I must acknowledge the receipt of the splendid steel engraving. For art and beauty, it far surpasses my expectations. I look on it as a piece of work pretty hard to beat.

I have been striving to establish the SCIENTIFIC AMERICAN in this place; and I think, henceforth, it will speak for itself. I have yet to hear any one say that the SCIENTIFIC AMERICAN is not a good paper. R. M. HUMPHREYS.

Tarentum.

Discovery and Invention.

The genius of the inventor is frequently undisciplined by culture; he is perhaps a workman of slender means and narrow views; hence the overpowering force with which his one idea seizes him. The discoverer, on the contrary, he who enlarges the boundaries of knowledge by important truths, must be both a genius and a scholar, a man of broad views, many-sided, healthy, up to the level of science in his time. Such conditions almost presuppose pecuniary independence. Hence, in reading the lives of the great lights of science—Pythagoras, Archimedes, Copernicus, Newton, etc.—we generally find them men of standing and influence, men who have leisure enough to devote themselves to science, and education enough to bring all varieties of existence within their ken. For want of this thorough scientific training, inventors are continually forced to test every step of their work; and it may be that only after hundreds of failures any success is achieved. Though, as Mr. Smiles says, "the steam engine was nothing until it emerged from the state of theory, and was taken in hand by practical mechanics," it must be remembered, also, that without theory it could never have been thought of, and that ignorance of scientific truths is often the most serious hindrance to practical men in their inventions. If Goodyear had known that oil of vitriol contained sulphur, he might have been able to utilize india-rubber in three years, instead of ten, after he had made that the purpose of his life. He found that oil of vitriol (he did not know it by the name of sulphuric acid) would sometimes produce upon the pure gum the very effect that he wanted, and he wasted time in numerous experiments trying to render that effect permanent, when a chemist would have suspected that the sulphur in the acid was the real agent, and have taken the steps at once that Goodyear took years later.

Perhaps the greatest, the most complete and powerful mind among men, is that of the man who is at once a great discoverer and great inventor. Archimedes, Newton, and Franklin are illustrious examples. The ancients attribute to Archimedes more than forty mechanical inventions, prominent among which is the endless screw, which he thought out while traveling in Egypt, reflecting on the necessity of raising the water of the Nile to points which the river did not reach. He likewise applied it as a pump to clear water out of the holds of vessels, to launching ships, and to propelling them through the water, a use which is still retained. The precision with which he directed his thoughts to the attainment of any desired result is well shown by his detection of the fraud practised on Hiero, King of Syracuse, by a goldsmith to whom the king had intrusted a certain weight of gold to be made into a crown. The king suspected, when he received the crown, that the gold had been adulterated, and he applied to Archimedes for a test. The difficulty was to measure the bulk of the crown without melting it into a regular figure. It was of the proper weight; hence, if any alloy had been substituted for a part of the gold, the bulk would be necessarily increased. Archimedes kept the subject continually in his thoughts, and the conditions of the problem became so clear to his mind that when he stepped into a bath one day, the vessel being full and water flowing over, he comprehended in an instant that the amount of water flowing over was equal in bulk to the body immersed. It followed at once that if the crown would displace more water than an equal weight of pure gold, it had been fraudulently adulterated. Without a moment's delay he jumped from the bath and ran to his own house, crying triumphantly, "Eureka! Eureka!" Yet, notwithstanding his ability in the application of scientific principles, he regarded his inven-