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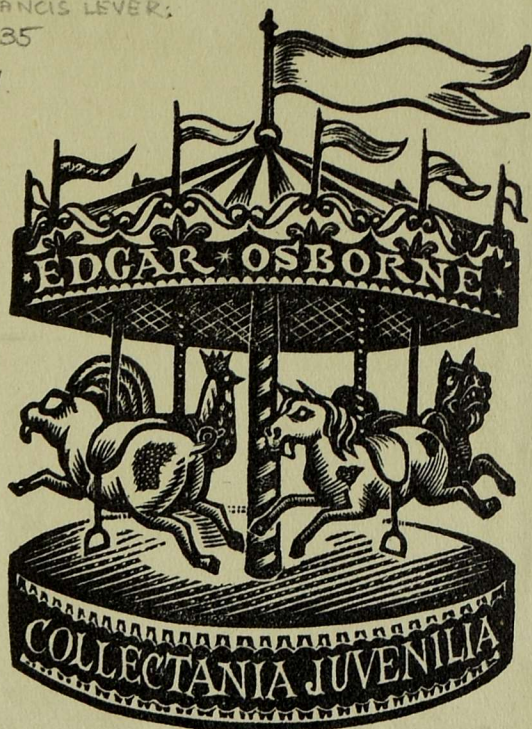
Francis Capel Mauley

William Campbell Manley
the gift of his Coffer^{to} Father
Jun. 4 1835

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FRANCIS LEVER;

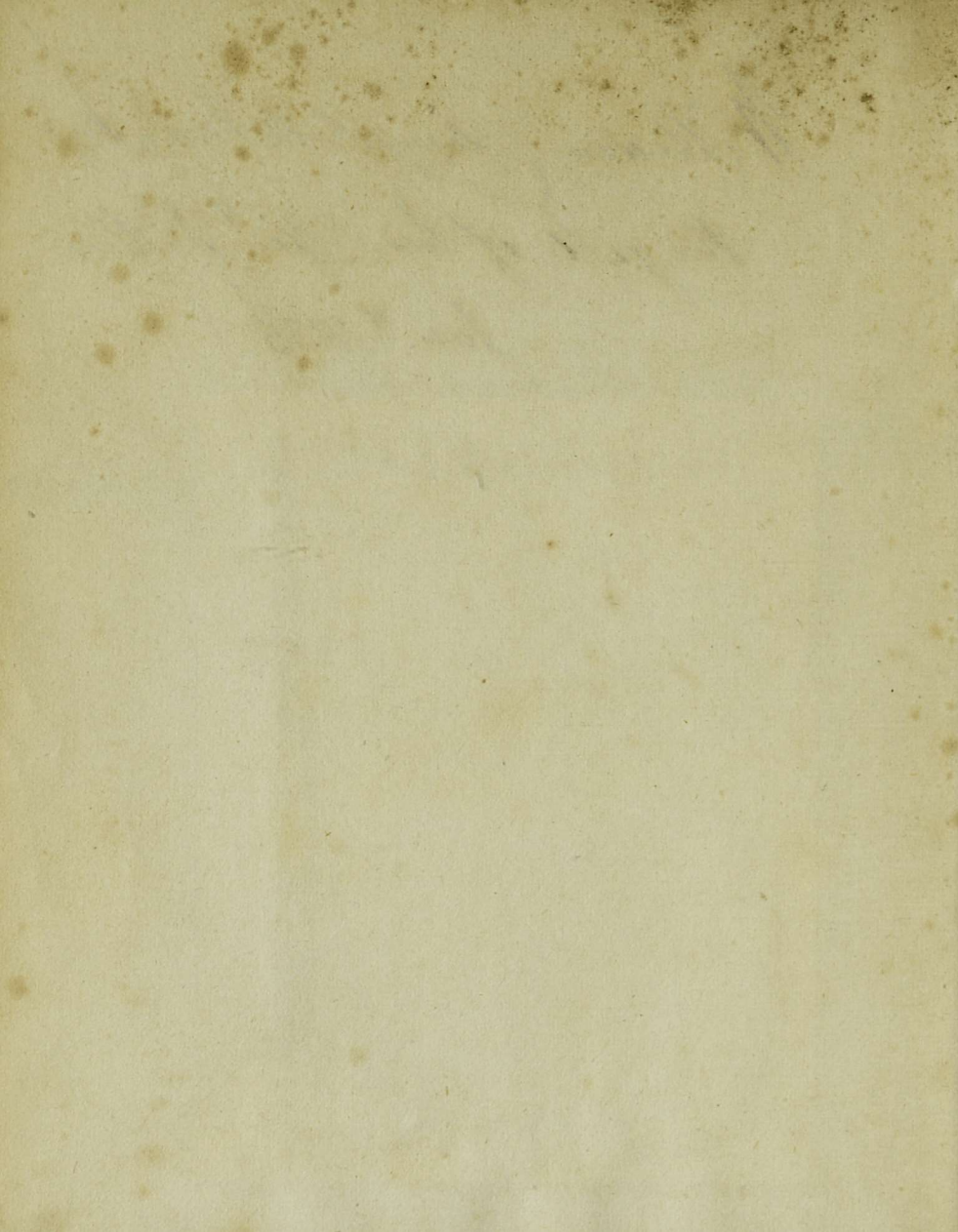
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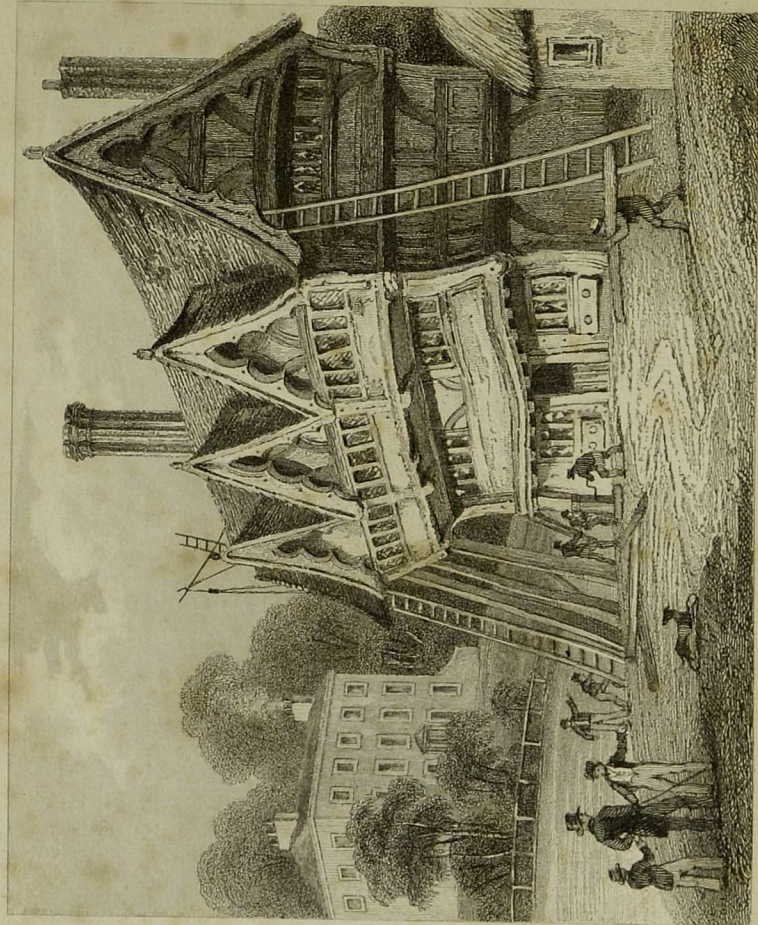


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FRANCIS LEVER,
THE YOUNG MECHANIC;
BEING
INCIDENTS AND LECTURES
EXPLANATORY OF
THE FIRST PRINCIPLES OF MECHANICS,
WITH SOME ACCOUNT OF
THE MOST CELEBRATED ENGINES,
ANCIENT AND MODERN.

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FRANCIS LEVER,

THE YOUNG MECHANIC.

CHAPTER I.

INCIDENTS AND OBSERVATIONS.

FRANK LEVER was a grave, steady lad, and very much given to fits of meditation, even when engaged in mere boyish sports.

An amusing instance of his peculiarity in this respect was observed one day, when our hero and his younger brother had placed themselves, one at each end of a long plank supported by a fallen tree; whereby, as my readers are aware, they obtained an alternate

elevation of several feet. Edward, having decidedly the worst place on this occasion, strenuously insisted on a re-adjustment of the plank, or a cessation of the motion. But Frank seemed to be deaf just then. It was not, however, the pleasure of looking twenty-nine times in a minute over Mr. Zimmerman's garden-wall, or the entertainment of seeing his helpless yet protesting companion plunged as often among the luxuriant nettles of the opposite bank, that shut the ears of our hero to the reasonable remonstrances of his little brother. He was merely pondering over the puzzle which the balanced plank afforded; and the subject of speculation was this:—Frank, though half as heavy again as Edward, was by the latter raised as easily as was Edward in his turn by Frank, when he descended.

With his head on one side and his arms akimbo, the elder lad had nearly found a

solution to the problem, before he replied to his brother's repeated and increasingly emphatic complaints: "Don't you like it, Edward?—well, then, we will soon give it up." But Edward was for *immediate emancipation*; and, seizing at the proper moment the boughs of a hazel-bush in the hedge, he safely gained the earth. His brother also exchanged the soaring throne he had so long enjoyed for the ground, which he reached from the height of a yard or two, and under circumstances of surprise and violence that completely broke the thread of his lengthened philosophical reasonings.

This was an impressive lesson in the doctrine of consequences, by which Frank was instructed to pay more attention to practice than to theory whilst performing an experiment. Rubbing his knees, with a face somewhat longer than usual, he retired from the spot; whilst Edward, whose temptation to

laugh was moderated by the smart of his own hands, which had been repeatedly and severely stung, also betook himself to the house.

“Well, Frank,” said his father, who soon perceived that no real injury had been occasioned by the fall; “what think you now of the attraction of gravity?”

The youth scarcely smiled; but it was not the remembrance of his disaster that occupied his thoughts so much as a new subject for inquiry. “Papa,” said he, “why did I strike the ground when I came down so much harder than Edward?”

“Because you deserved it,” interjected the last-named personage very promptly: “why did not you stop when I asked you?”

“I wished to see how high I could go,” replied Frank.

“And forgot how deeply your brother must be thrust amongst the nettles at the same

time," said his father: "however, I think the affair was pretty nearly *balanced*, all things considered. I will take another opportunity of replying to your question, Frank. Perhaps Edward will then have forgotten his tingling scratches, and I dare say you have already nearly lost the impression of your strains and bruises."

Amongst the various topics of conversation suggested by the character and rising stature of our hero, the inquiry respecting his future employment in life began, at about the twelfth year of his age, to assume an important aspect. Fond, yes, and proud as his mother was of the lad, she was somewhat disappointed to find that the process of early instruction was with him rather a difficult task; whilst Edward, who was to a considerable degree volatile and perverse, mastered his lessons generally with ease. It seemed strange that a boy, obedient, sedate, and thoughtful, as

Frank was, should be undeniably a dull scholar; and this fact was the more regretted, because a wish had been entertained to bring up the youth to the practice of a learned profession, and family connexions afforded facilities for such an arrangement.

But Mr. Lever and his lady at length saw the propriety of reserving their decision for the guidance of circumstances at the time when a choice must be taken. "I have my preferences, it is true," said his father; "but I would rather resign them all than place the boy in a situation where powers might be required of which he is not possessed, and where his own gifts, whatever they may be, could not assist him. I believe that society is encumbered with unsuccessful persons, and injured especially by the blunders of incompetent professional men, rather because abilities have been misapplied than on account of a positive deficiency of needful talent. Where

eminence has been attained, I think it will be found that individuals have been permitted to pursue the course to which Nature had originally directed them. Let us observe carefully the indications afforded by Frank's apparent capabilities and habits of mind, and then, whilst endeavouring to decide for him, we shall be in less danger of deciding unhappily against him to our mutual sorrow."

"And now, Frank," said his father to him, a day or two after the incident we have related; "what were you thinking of, whilst riding on the plank with Edward, last Tuesday?—something perplexed you, I suppose?"

"Yes, sir," said the lad. "I am heavier than Edward, and yet his weight raised me up."

"Did you sit quite at the end of the plank?"

"Yes, papa."

"And was it supported in the middle by the tree on which it turned?"

“No. I found that Edward could not raise me at all then; so I told him to draw the board farther to his side; I thought the weight of the timber would make up the difference between him and me.”

“That weight might help Edward in some degree,” replied Mr. Lever; “but the power he gained was chiefly from another cause. Did you never see men raise a weight by raising also a lever placed under it; in which case, you know, the *weight* of the instrument was *against* them?”

“I was thinking of that just before Edward jumped off,” said Frank. “After that, I wondered again that I came down, as though I became heavier the farther I had to fall.—I can jump from the timber log without hurting myself at all.”

“A result which you like much better, I doubt not,” said his father. “The power of the lever, and the increasing force acquired by

falling bodies, are two most important principles in MECHANICS."

"I should like to understand *mechanics*," said Frank: "then I could understand machines and engines. I—I—I think I should like to be—*an Engineer*."

"Ay! say you so?" replied his father, not a little pleased at this explicit declaration; "we will see whether that wish is to be a lasting one, and will endeavour to find out what real force and value there may be in it. I perceive you are not unwilling to *think* for yourself—are you willing to study the thoughts and acquire some of the knowledge possessed by others?—are you willing to read books, to work problems, to perform experiments, which require time and patience, and which at first will afford but little amusement?"

"I should like to try," said Frank. "But, papa, I have been reading about James Brindley."

“And what do you remember concerning that famous personage?”

“I find that he did not study books much,” said Frank: “his clever thoughts came from his own head.”

“True, Frank; and, if you had a head like Brindley’s on your shoulders, you might possibly succeed as he did. But even *he* would have done more with less labour of mind, he would have encountered fewer difficulties in his vast projects, if his education had not been neglected. Whatever may eventually be the turn and occupation of your mind, my boy, you will be glad of all the knowledge you can possess, and will have need of more. *Your* education, therefore, shall *not* be neglected whilst I have the means to carry it forward. You shall have the best advantages I can devise and afford. You will soon understand my purposes and wishes; I hope I shall be at no loss in understanding yours.”

The parents of our hero now called to mind several particulars of the boy's childish occupations, of which hitherto they had not taken much notice; regarding them as little more than the unaccountable whims of early years. When a heavy shower had sent a swollen stream through a sluice-way in the garden, it was with difficulty that little Frank was prevented from running out, even whilst the rain copiously descended, "*to take his mill to the river!*" This hydraulic engine—a mere wheel supported at its centre by a wire,—the child would hold with his two hands in the gliding flood for an hour at a time, if permitted, gazing sometimes with the fixed stare almost of apparent vacancy on the revolving toy. An attempt, which he more recently made, to construct a dam across this needful conduit, filled his father's cellars with water during one pouring night:—a result of which it was clear this juvenile Brindley had no expectation.

This his alarm sufficiently testified in exculpation of our hero. Indeed it was found, on a survey of the place, that Frank had merely attempted thereby to procure the power of an *overshot* water-wheel, and his simple apparatus was found actually running round between two sticks beneath the rushing fall.

There was a Dutch wooden clock, that had long been abandoned to the pleasure of the boys. Its hands were lost, its bell was cracked, and the weights were only such ponderous bodies as were to be obtained from a chest of old iron in the lumber-room. Edward, less habitually interested in such things, and better satisfied with the common implements of play, yielded to his brother almost the entire possession of these articles. And so it was, that the clock in question exhibited a greater variety of forms, functions, and motions, I may venture to say, than ever Tompion himself would have planned. At one

time its proper face was covered by a sheet of pasteboard of the largest size, and its lack of hands was supplied by substitutes as long nearly as Frank's own arms. The clock was then made to look forth from a windowless aperture in the gable-end of a loft above, in the manner of the village dial. Anon, the engine was withdrawn, and hung at the highest attainable point over a back staircase, in order to admit of experiments on a pendulum twenty feet long, which, but that it gave half-hours for minutes, and required the constant agency of the experimentalist to continue its vibrations, might have kept good time; whilst the clock would have required winding up perhaps but once a month.

But this celebrated clock was not long to remain, together with the ingenious contrivances of its present master, under the concealment of the domestic roof. Its former situation at the loft-gable was indeed a conspicuous one

from many parts of the premises, but it was invisible and unknown to the public at large. Frank now entertained the bolder thought of protruding his machine through the side of an outbuilding by the way-side, after the fashion of certain projecting dials appertaining to the steeples of country towns. Men were somewhat surprised one morning to see a Dutch clock, at the end of a pole, thrust through a hole in the barn, no operator being visible! However, they passed on; not so the boys of the neighbourhood. Before our young mechanic had nearly surmounted the difficulties of imparting motion to the wheel-work at that distance from the maintaining power, the process of *pelting* had commenced, so that this *striking* clock had to be withdrawn before it had announced the hour to an individual in the parish. Frank learned afterwards from his father that, though a *dial* is sometimes for public convenience placed so as

to project over a street, the clock itself always remains in the steeple, the hands being moved by connecting chains, passing through the hollow arm to the end of which the double face of the machine is attached.

Finally, this said hapless servant of Father Time, the Dutch clock, was adapted to the office of an early alarm, by contrivances of so peculiarly effective a kind, that the result exceeded the calculations and even the wishes of the ingenious inventor. Weights, levers, bells, iron plates, clock and all, suddenly forsook the wainscot of Frank's apartment one memorable night, and roused nearly the whole household with the apprehension of an assault from most outrageous thieves.

But a roasting-jack — one of the kind more frequently employed years ago — was the engine the functions of which had been most diligently examined, varied, and extended by our mechanical philosopher. Indeed, so much

had the process of cooking been embarrassed by the experiments of Frank on the weights, pulleys, and wheelwork of that machine, that the dame of the spit represented the absolute necessity of being provided with a substitute, which should be exempted from the like inconveniences. A vertical jack was therefore supplied, with which the boy was forbidden to meddle.

The construction of the old roaster, now given over to its fate, is explained by the annexed cut, in which,

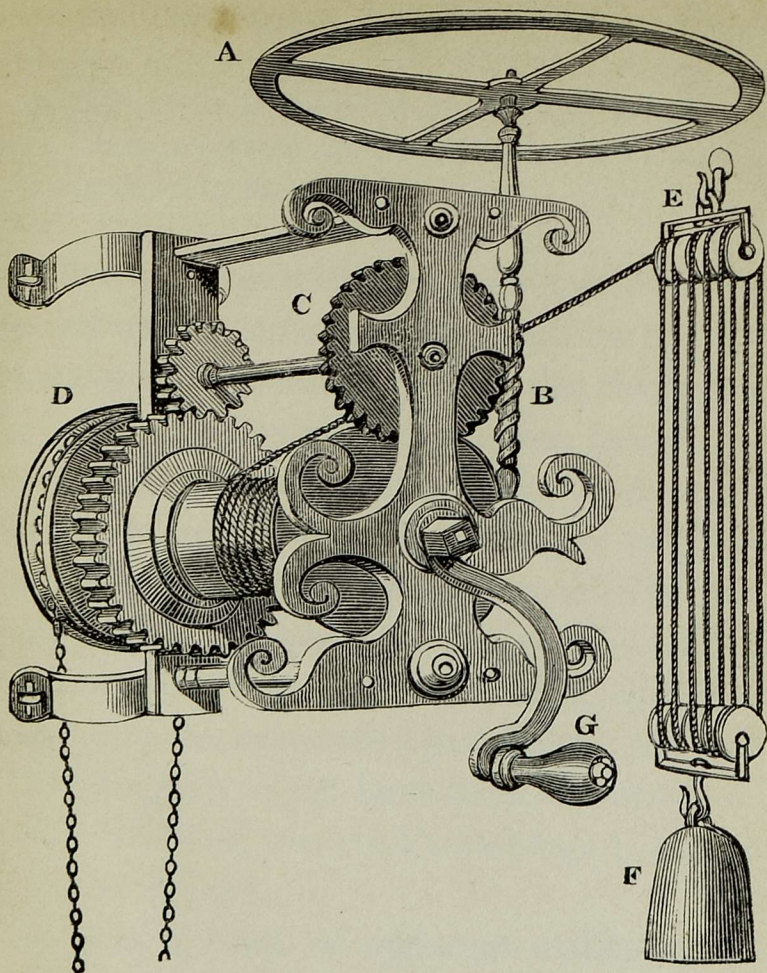
A, represents the fly-wheel, connected with the spindle of the endless screw, to keep the motion uniform.

B, the worm, or endless screw, consisting of two spiral threads.

C, the worm-wheel, generally containing thirty teeth.

D, the grooved wheel for the chain, on the axis of which turn the main-wheel and the barrel, round which the cord is wound.

E, the box of fixed pulleys round which the cord revolves, and which is attached to the corresponding one of moveable pulleys from which the weight is suspended.



F, the heavy weight suspended from the moveable pulleys.

G, the handle attached to the axis of the barrel and main-wheel, on which the cord is again wound back after it is run down by the weight.

I know not how many employments were required of this now jack-of-all-trades by its unconscionable possessor. Like the clock, it was for a period deprived of shelter, being placed on the top of a tall pump in the yard; having four sails attached in the manner of a mill; and, if the wind had been as invariable and as manageable a power as the weight, and the spit could have been conveniently, and to any good purpose, suspended just below, the labour of winding up might have been dispensed with, to the relief of the cook's assistant; but such was not the case.

A similar want of *apparent* utility attended various other efforts at re-construction and variation of design. The jack was made a

windlass to draw the garden-roller up an acclivity in the garden; nay, it became a crane to raise it from the ground! The blocks of pulleys, again, were the occasion of much reflection, contrivance, and laborious occupation, to the indefatigable boy. Reserved and taciturn regarding these his avocations, as he usually was, Frank could not help drawing his father's attention to the apparatus he had contrived, by which, with the agency of these pulleys, and seated in a sort of chair, he easily, though slowly, drew himself up, as he pulled the cord downward with his hands.

“See, papa!” said he; “now, *could* I raise myself so without the pulleys?”

“Certainly not with so little effort,” replied his father. “But observe how *slowly* you ascend—only six inches from the ground, yet you have drawn out some yards of line. I think you could reach the top of the shed much sooner by walking up a ladder.”

“O yes, sir, but then—”

“But then,” added Mr. Lever, “your exertion would, during the time of its continuance, be much greater; but, being over so quickly, it is in general best for such purposes to raise our bodies with the assistance only of our limbs. When, however, a weight is to be lifted or removed,—like a hogshead of sugar, for instance,—which can neither walk by itself, nor be carried on men’s shoulders, machinery is, indeed, of use.”

CHAPTER II.

RAISING THE HOUSE.—THE CATASTROPHE.

THERE was an old house adjoining the premises of Mr. Lever, which had long been in a ruinous, and had lately become in a decidedly dangerous, state. It was built in the manner so usual two or three hundred years ago. Each story projected beyond the one below, so that the highest rooms overhung the foundation in front seven feet or more. So long as that foundation, and the timbers upon it, remained sound and retained their proper position, the structure continued in its original circumstances of strength and security. But, of late, the corner-posts and under-beams had so far given way as to let down the front of the house several inches,

and thus the rooms above hung over more than ever; and, as the roof was uncommonly large and heavy, great fears were entertained that the whole building would descend in the same direction.

At length, the attention of the proprietor was very properly drawn to this house, which, though uninhabited, could not fall without hazard to the lives of many. A builder was sent for, one windy day, to give his advice or assistance: the consultation was held on the premises of Mr. Lever, who, indeed, had some interest in the proceedings; and so, apparently, had our friend Frank, who drew near with his father to the council.

“Well, Mr. Oakley,” said the landlord, “what are we to do with this old house?”

“Do?” said the builder, “I am just thinking what we *can* do, sir. You have no mind to take it down, and run up a nice tight little place—would let for twice as much?” This

appeal the builder made in a most insinuating tone, and with a fresh obeisance and adjustment of the hat, to Mr. Renton.

“Certainly not,” said that gentleman.

“There is stuff enough in it to build *two* good houses,” continued Mr. Oakley; “and I can’t exactly see how this can be made to stand much longer.”

“Then I had better sell the materials by auction,” replied Mr. Renton. “It will not cost much to take it down, and I have more houses already than I can let.”

“That would be a pity too,” said the builder: “it’s a noble old house, or has been. I’ll tell you *what* we can do, sir; we can *jack it up*, and make all good again to the first floor.”

“Indeed, I thought so from the first,” said Mr. Renton. “Hark you! Mr. Oakley; I have had some little experience in the repairs of houses, especially in the particular of pay-

ing builders' charges, and I have no money to trifle with here. You must jack this part of the house up to its proper level, under the first-floor beams: you must remove so much of the lath and plaster as to show us what is unsound; then, if needful, we can build an eighteen-inch wall underneath, and the house will be better than the two you would raise, and will not cost me a tenth part of the money. I wish you to commence these repairs on Monday morning, and you must place props under the eaves within an hour."

"Certainly, sir; that is all very correct, sir—we will lose no time."

"You see," said Mr. Renton, addressing Mr. Lever, when the builder was gone, "how easy it would be to spend a thousand pounds here, and wait seven years in vain for interest or rent."

"For my own part," said Mr. Lever, "I much prefer such a respectable and venerable

neighbour as this old mansion to the two carpenter's boxes proposed by Mr. Oakley. With regard to the supports needful in this gusty weather, I shall certainly be relieved from some anxiety when I see them applied."

"I will take care that the proper means are duly taken," said Mr. Renton. "In the mean time, I would advise that your young folks keep at a sufficient distance from the building. I am most apprehensive about that stack of chimneys at the end."

"The whole fabric has been condemned by a little unpaid surveyor at my side," said Mr. Lever, alluding to his son Frank. "He asked some months ago why the house did not fall, like anything else that leaned on one side so much."

Mr. Renton smiled, and said that he could scarcely answer so curious a question, and that he was persuaded the young gentleman had

drawn reasonable inferences from the premises before him.

“Now, Frank,” said his father, as they withdrew from the spot, “if you are interested in the mechanical powers, you will before long have an opportunity of observing some important applications of them. The house will be propped up for the present, to prevent its sinking more, and it will in a day or two be raised to its proper level by a simple engine contrived for that purpose. In the mean time, you may employ your own thoughts in devising probable means for accomplishing such a task.”

Frank promised he would think about it; and he *was* thinking about it accordingly, when the workmen entered the yard, with the timber needful to assist the old house, as with crutches, until its disease and weakness could be cured. Even this operation was not with-

out its interest to Frank, and he willingly suspended his theoretical speculations that he might attend to practical matters. His father re-appeared at this juncture, anxious lest his son's curiosity and inexperience should lead him into danger. Indeed, the workmen showed some hesitation in approaching the nodding fabric, and none of them cared to be under the eaves when a sudden gust assailed the house.

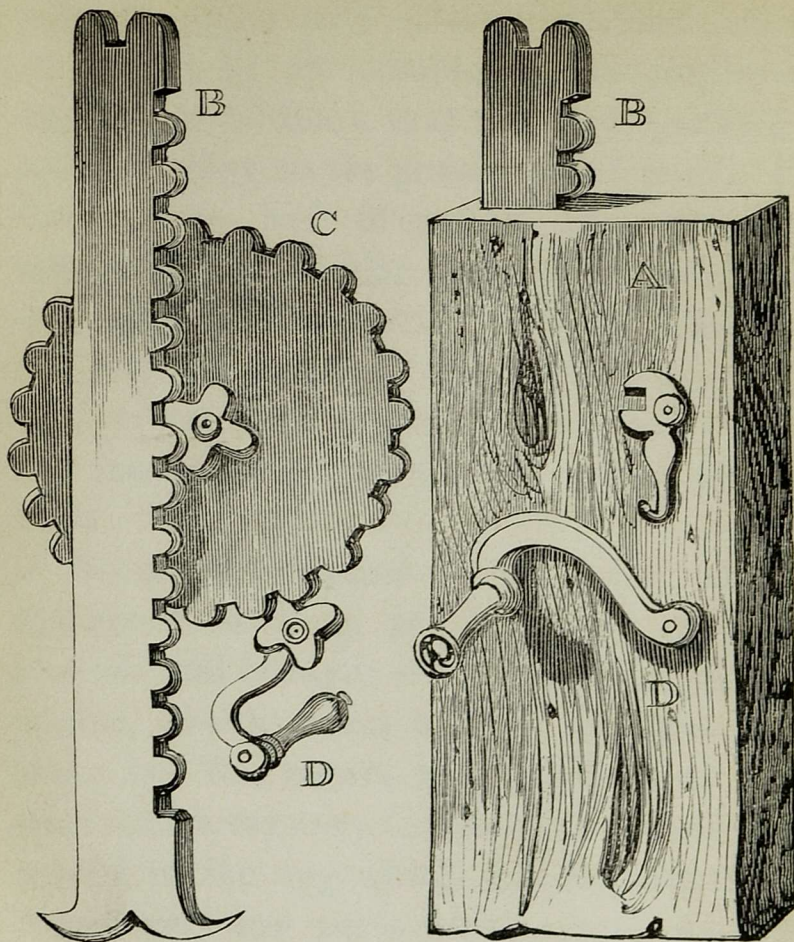
Mr. Oakley was a dexterous, ready man in the management of such an operation as this; and, with great judgment, he directed the instant application of several props or shores, not too heavy to be readily wielded, which, placed at different points, removed the apprehension of immediate danger. A ladder was now reared, and a stout pulley, with a hook to it, was hung near the top. A line passed over this was fastened to a weighty beam below, which, with the help of three or four

men, was thus raised until it rested under the plate-timbers of the roof, where, being duly adjusted, it remained, whilst the lower end was brought out and placed on a stout oaken plank laid on the ground. A few powerful blows, with the help now and then of a crow-bar, used as a lever, urged this foot of the beam forward. Of course, the upper end rose at the same time, and bore upward to some degree the enormous weight of the impending roof. In fact, the supports first applied now dropped away, superseded by the one now brought into action. They were, however, again tightened, for the sake of perfect security; and the men expressed their firm opinion, that the old house would as soon walk away as tumble down, with the help of the *stilts* they had placed beneath it.

Frank was wrapped in deep thought on the result of these operations. He plainly saw

that the upper part of the house had been in fact lifted by the simple means employed ; and began to think that this was "*jacking it up*," according to the phrase before used. His father, who had formed a plan for communicating a regular course of instruction on mechanical science, did no more, on the present occasion, than direct his attention to a few particulars, and left Frank to ruminate at leisure on what he had seen.

But more remained to be done. On the appointed morning, the workmen again appeared, and brought with them, in a cart, the engine, like so many others, denominated a jack, but the nature and functions of which were still a mystery to our hero. It is represented in the engraving, and apparently possessed very few parts which could entitle it to rank with important machines ; being a long and strong block of timber, with a winch, a



foot or claw, and a rack or toothed bar of iron, projecting from it.

The cut will furnish an accurate notion of this instrument, and its different parts.

A, a strong wooden stock or frame, containing the wheel and rack-work.

B B, the iron rack.

c, the great wheel, the axis of which revolves in the teeth of the rack.

D D, the handle of the pinion, the teeth of which move the large wheel, c.

“Can that machine lift the house?” inquired Edward.

“I should like to see it try, young mister,” replied one of the men.

“The machine and the men together, I suppose, can do it,” said Frank.

“You are right,” said his father. “When men use a machine of that sort, great things are done *slowly*. When they apply their own strength, without an engine, small things may be done *quickly*. A machine will not increase

power and speed at the same time.—Now, observe the process.”

By this time the heavy engine was placed beneath the beams of the first projecting floor. A stout piece of timber was sawed just to the length needful to reach from the foot, or lifting crow of the jack, to the part of the house above, and two of the men began to turn the winch.

Edward, I suppose, expected to see the house rise from the earth like an air-balloon, for he asked why it did not move? Frank, also, found his confidence in the potent functions of the jack sensibly weakened; for, whilst the men turned the winch, as if working at a grindstone, nothing else seemed to move. But patience and accurate observation were required. The operators presently found their labour so much increased, that an additional winder was fixed on the other side of the engine, by which means two more men added

their efforts to the work, and the result presently became sensible. A creaking sound proceeded from the timbers and boards of the old house; pieces of the mortar scaled off, and more even than was intended was accomplished by the next round: a window, nearly under which the power had been imprudently applied, suddenly discharged five or six of its panes, with all the jingling clatter usual with that kind of mischief.

Mr. Oakley, who, having been detained elsewhere, only then made his appearance, expressed some anger at this vexatious incident. He was bound to make all good at a certain price, and justly blamed the carelessness of his men in omitting to foresee so obvious a consequence.

He gave orders to lock the jack, by adjusting a click, or wedge of iron, which prevented the return of the winch, and released the men, that he might examine the progress made.

It appeared that so much of the building as was acted on by the jack had risen nearly two inches. The corner-post now hung suspended, with the ground-plate, or under beam, attached: the main-shore or prop, formerly applied, was also liberated, and the smaller ones, now considered quite useless, were taken out of the way. Frank was more than ever impressed with astonishment at the vast results attained by the mechanical powers, and felt a sort of reverence for those who thus enforced them.

“Which of you could have done as much?” said Mr. Lever to his boys, pointing to the work thus far accomplished.

“*I* could have broken the window,” said Edward; “I am sure of that.”

“I wish the window may be the worst part of this business,” said Mr. Oakley, in sudden alarm.—“*The click has sprung!* Take care all!—She comes! she comes!”

In an instant the ground was cleared, and by the time that the party could turn an eye behind them, it was perceived that the catch, which had detained the axis of the jack in a fixed position, had flown off. The winches now spun round with inconceivable rapidity, whilst the weight above slowly subsided. A cry of terror from the men now announced that the great beam, which just before was the main prop of the house, had fallen out of place so as to become entirely useless at this awful moment. The spectators had scarcely time to make another desperate rush from the line of danger, when an enormous stack of chimneys, with nearly one-third of the building, fell with a crash which was heard, or rather *felt*, at the distance of more than a mile!

As it is not my purpose in this little book to entertain my readers with a narrative apart from instruction, it will not be needful to

describe the scene that ensued, when the neighbours gathered round, and, with hands and brows uplifted, surveyed the ruins. No lives were lost, no limbs broken ; but Mr. Oakley and his men stood aghast, as if bereaved of sense and motion, at the sight before them. Altercation at length grew high between them, as the blame was laid by one on another, and as vehemently denied and retorted. Mr. Lever, who, with his boys, had just gained his own threshold when the fall took place, had enough to do to convince their terrified mother, who was just rushing out, that her children were really safe.

As for Frank, whose cogitations were thus, for the second time, interrupted in a most astounding manner, he began to look with caution on all processes the results of which he could not well foresee, and almost expected descending thunderbolts in the iron weights

which his own *jack* had enabled him to suspend on high.

The remaining part of the old house was eventually taken down, and the whole was entirely removed by Mr. Renton's orders.

CHAPTER III.

EDUCATION.—DR. KNOWLES.

WHERE there is an evident propensity in a child to the exercise of its mental powers, little doubt need be entertained that those powers will eventually prove to be of a superior kind. Habits of thought, and a frequent reference to the results of reason, are no signs of an understanding whose thoughts and reasonings are likely to be of an ordinary and inefficient kind. Mr. Lever was indeed pleased and relieved to find that his son Frank, although somewhat backward in the school-room, and far from bright in the eyes of casual observers, had undoubted tendencies of the kind just referred to, and that he was not burdened, as so many unhappily are, with a

feeble intellect and an inert frame, alike unfit for, and averse to, any successful and esteemed course of action in the world. Many a parent is distressed, year after year, unable to find a satisfactory answer to the question—"What is my son fit for?" Lively and quick, but volatile, capricious, and indisposed to any advantageous pursuit, many lads seem qualified for nothing but to play with a monkey all their lives. Others again, perverse, obstinate, stupid as scholars, churlish, perhaps awkward even as playmates, are seldom in favour with any but themselves, and will probably be as great encumbrances to society as idiots usually so called.

There is, however, a race more numerous, in whom powers of mind and qualities of disposition are neither altogether good nor bad, and it is the part of education to discern and distinguish, to aid or repress, as the signs of natural character promiscuously appear. Little

Edward, with whom we have not so much to do in this little work, was thought by many superficial observers to possess nearly *all the brains*; and, though somewhat pettish, and frequently mischievous, he was in general the favourite, as being by far the more amusing of the two children. Frank, who was thoroughly good-tempered and tranquil in his disposition, found no fault with the preference shown; contenting himself with his own cogitations and operations, even when means of recreation and indulgences the most prized by his fellows were within his reach.

Mr. Lever, however, had now reason to think that the scale of ability turned in favour of Frank, and reflected anew on the best means of bringing his natural powers into action. He determined, in the first place, that his son should not lie under the disadvantage—so seldom surmounted—of a neglected education. He believed that even

genius, with all its powers, was less able to proceed successfully without the guidance of knowledge, than was knowledge unassisted by the original force of genius ; and he considered mental *acquirements* as less likely to remain inactive and unprofitable for want of opportunity in life, than peculiar natural endowments.

Then arose the question respecting domestic and school tuition. The latter had been tried, but certainly with the least success ; but the parents of little Frank thought that the powers of the youth had been misunderstood and underrated by Mr. Frostick, with whom he had been placed. On the other hand, it was difficult to attain the same amount and an equal result of effort at home as at school. Family discipline is more frequently relaxed ; and, of necessity, it has never so grave an aspect under the parental roof as at a place where education is obviously the grand business of the community.

“ I confess,” said Mr. Lever to a friend one day, “ I am in doubt and difficulty : a *regular* education is scarcely to be attained at home, and general knowledge is scarcely attempted to be conveyed at school. What, then, is to be done ? must I abandon one advantage for the sake of the other ?”

“ By no means,” was the reply. “ Take my advice, sir,” added Mr. Renton ; “ send your son, not to a school kept by some needy adventurer—but to a man unquestionably qualified, conscientious, and successful as a tutor ; a man of intelligence and benignity—such a one I really know—I mean Dr. Knowles. His maxim is, that the boys should find a home at school, and a school at home ; and I think there is sense in it.”

“ The boy shall go to Dr. Knowles and make trial of the superior management you refer to,” said Mr. Lever. “ As for the latter part of his plan, making home to a certain extent a school

during the long holidays, I entirely approve it; and it agrees with the design I had entertained, and nearly adjusted in my own mind. Frank is thoughtful, inquiring, and, I think, ingenious; but he is not, even for his age, accomplished or well-informed. Dr. Knowles will, I trust, do his part; and, by the time the holidays arrive, I hope I shall be prepared to perform mine. What think you of '*Domestic Philosophical Lectures*,' enlivened by the company of as many of our young neighbours as may think proper to attend? For the familiar experiments required, very simple and homely apparatus may suffice."

"I have known the same thing done," said Mr. Renton, "and with the happiest effects: I could wish I were small enough to squeeze in among the youthful auditors."

"My first attempt will be directed to subjects connected with the mechanical powers," said Mr. Lever, "by any of which, however

unskilfully applied, I trust that the small resistance you will experience may be overcome."

But, in order at once to put in practice Mr. Renton's suggestion, and to allow time to prepare the materials for his own method of instruction, Mr. Lever placed his son with Dr. Knowles, and judged that he should thus prove the real strength and value of those powers and inclinations to which we have referred. These, if of a temporary and unsubstantial kind, would probably be displaced by new scenes and avocations—if otherwise, the habits as well as the matter of regular education would assist to secure a desired result.

Dr. Knowles was, indeed, a man on whose character, abilities, and temper, reliance might be placed. Many youths, of small promise when they came under his roof, left it in the end with high credit to themselves and him; and not a few of the Doctor's pupils became singularly eminent in after-life.

This gentleman was not very slow in forming opinions for his own guidance regarding the management of the various capacities and dispositions with which he had to deal; nor was he so hasty as to make up his mind in all cases with the same degree of observation. When he perceived, as in the case of Frank, that the mental powers were in operation, he was contented with small advances at first; and his experience led him often to prefer such, as scholars, to those whose progress was for a time more conspicuous and striking.

Poor Frank appeared to such disadvantage, during some weeks, among the boys, that, although not so soon moved as many by apparent mortifications, he really suffered to a considerable extent, and had very commonly tears on his cheek both in and out of the school-room. But his master's careful and benignant eye was upon him, and Frank speedily found a friend in the individual with whose

very name he had before associated nearly all the notions of dread and affliction which his imagination could supply. The Doctor would suffer no oppression of any kind or degree to be exercised over the younger or weaker lads by the others; and, without at all confusing the ranks naturally formed by years or acquirements, he maintained throughout his establishment a strict regard to the *natural* rights and feelings of each of his numerous pupils.

There was one particular in which Frank had a decided advantage above his fellows generally; — he was without conceit or selfishness, and possessed not that unhappy love of praise, by which the characters of so many otherwise promising young persons are nearly spoiled. Dr. Knowles could therefore without danger commend and encourage this modest, simple youth; and he could also administer the occasionally needful tokens of dissatis-

faction with his performances, and be in no danger of encountering in him that perverseness, pettishness, and obstinacy, which so frequently require punishment on their own account. The boy soon began to see the *reason* of things, and to dry his eye with the comfortable persuasion that he *could* see them, and that, therefore, his sorrows were matters, for the removal of which there was an open road in the paths of self-exertion and good conduct.

Had a less genial and discriminating mode of treatment been adopted in this school, such a youth as Frank would not probably have surmounted those early and important, though often unconsidered, hazards and difficulties of life. His slowly moving powers might not have gathered sufficient force to overcome so disastrous a check at first; and thus the actual powers of the intellectual machine would have remained inert, like those of an engine,

whose fly-wheel may be detained at rest by a cause incomparably less in power than that which could arrest it during its subsequent tremendous motions. Dr. Knowles considered that his duty to the community at large, as well as to those with whom he was by engagement connected, demanded all his care and efforts to preserve and to bring forward latent talent of all kinds and degrees amongst his pupils. To this end he modified and accommodated his various acts of sovereignty over his youthful subjects, and, by the guidance of such superior wisdom as results from discernment and benevolence united, he avoided much of that jarring collision with peculiar tempers, which too often renders education a season of punishment to all concerned.

Discipline, however, was by no means lax in this establishment. The school-room was the seat of power, and its regulations were laws, the sanctions of which were preserved

inviolable. Classes having been adjusted with judgment, pleas of incapacity for certain tasks were as vain as those of disinclination; appointed duties were to be accomplished or the consequences of failure to be endured, according to the ascertained measure of delinquency in the case: so that lads who had been transferred from other schools to Dr. Knowles's, found all the hopes of indolence withered in a day. Nothing unreasonable was required, nor, indeed, were school engagements regarded as hardships by the boys after the first few weeks of trial; and the periods of recreation were under few regulations but those of time and common good behaviour. Yet was the influence of the good Doctor as complete, whilst with kindly urbanity he witnessed the exuberant gaieties, or the whimsical labours of the boys, as when, from the high throne of legislation, he enforced the laws of grammars, quills, and slates.

The play-ground was not, as usual, an enclosed area, void of all materials for occupation; it was an irregular but somewhat extended domain, partly paved, partly sheltered by open buildings, having a considerable space beyond of *arable* land, laid out in separate *allotments*, for such as were disposed to agricultural pursuits. Here you might see oaks and cabbages, vines and mushrooms, in surprising intimacy mingling their forms and shades. Wheat just springing from the earth in August, and cucumbers in November, had been observed by more than one visitant of the spot; with other unexampled varieties of experimental farming and horticulture, whereby half a dozen crops were expected in succession from the same plot of ground in the course of a season, and as many different fruits from the grafts inserted in one hapless pear-tree stump, uprooted, it may be, more than twice in a week to obtain any advantage likely to arise from an improved

change of situation. Garden-rollers, gravel-barrows, casement-lights, watering-engines, scare-malkins, with the smaller implements of culture, occupied their several situations, right or wrong, according to the characteristic habits of their youthful owners. A few compartments of this curious domain showed knowledge, industry, neatness, and proportionate results of success and produce. Here no tools were lying about, no thistles or burdocks were suffered to insult the tulips with parasols; gravel was gravel, and lawn was lawn, as in the Doctor's own garden.

There was a large out-building, perfectly secured from weather, and supplied with all the tools and materials which ingenuity apart from mischief could require. Carpenter's tools, lengths of deal, cords, wires, chains, wheels, a long glazed window, and a fire-place, were here provided for the use, under certain regulations, of those young gentlemen

who had a mechanical turn. Dr. Knowles took an early opportunity to introduce Frank to this temple of Dædalus,* and observed in an instant that his new pupil thought himself *at home*, though a dozen miles from his father's house. "Oh, dear sir, may I come here sometimes?" inquired the lad with earnest eloquence, looking up to his instructor.

"Every day but Sunday, at proper hours," replied the Doctor; "but what would you do here?"

"Oh! I do so much want to make an Archimedes' crane, and a machine for lifting houses, and a perpetual motion," answered Frank. "I can get up very soon in the morning indeed, sir."

"You will need long days, I confess," said the Doctor, "if you perform these things in

* A clever and ingenious Athenian; he was a great mathematician, and first used the wedge as a mechanical power; he also invented sails for ships.

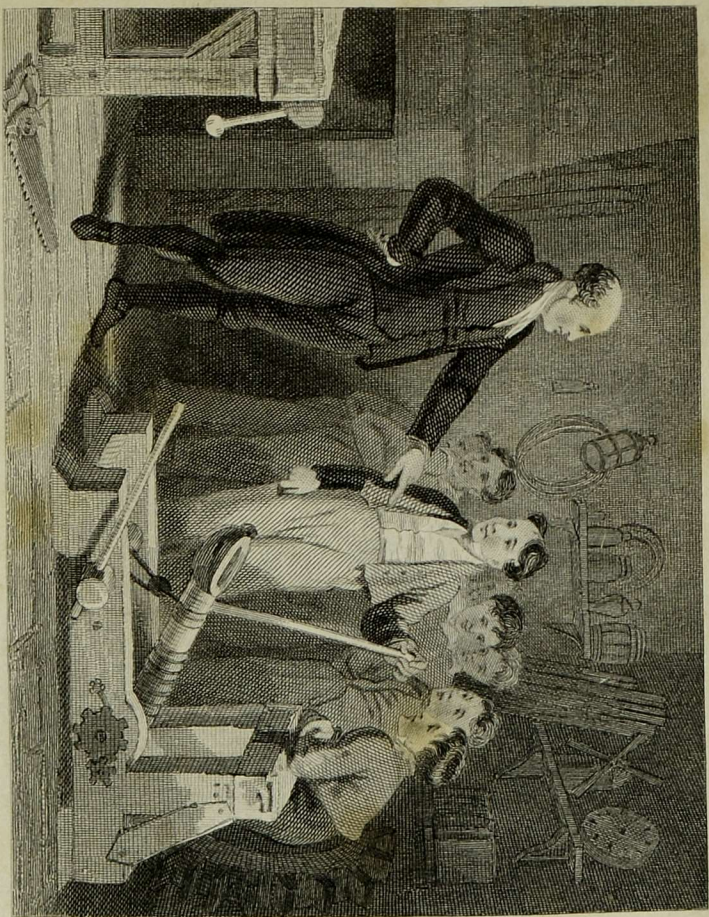
addition to your school business, which you know has no *ifs* belonging to it. But see, Master Rackwit has already attempted some of these things.—Here is the model of an engine which, if I am right, was to remove village churches into neighbouring towns, where they may be more wanted, by means of a flying car and hooked chains strong enough to bear the weight!—and I think he told me that this contrivance in the corner was intended for a perpetual mill, requiring only a place where it could be immoveably fixed, and a strap passing over this pulley, long enough to go round the world, which, as it revolves, you know, must in that case turn the mill! But I have not heard of its success at present: twenty-four thousand miles of leather or of cord would cost a great deal of money, and—— But what are you thinking about?”

“I was thinking, sir, that the earth *does* take the mill round every day without a cord.”

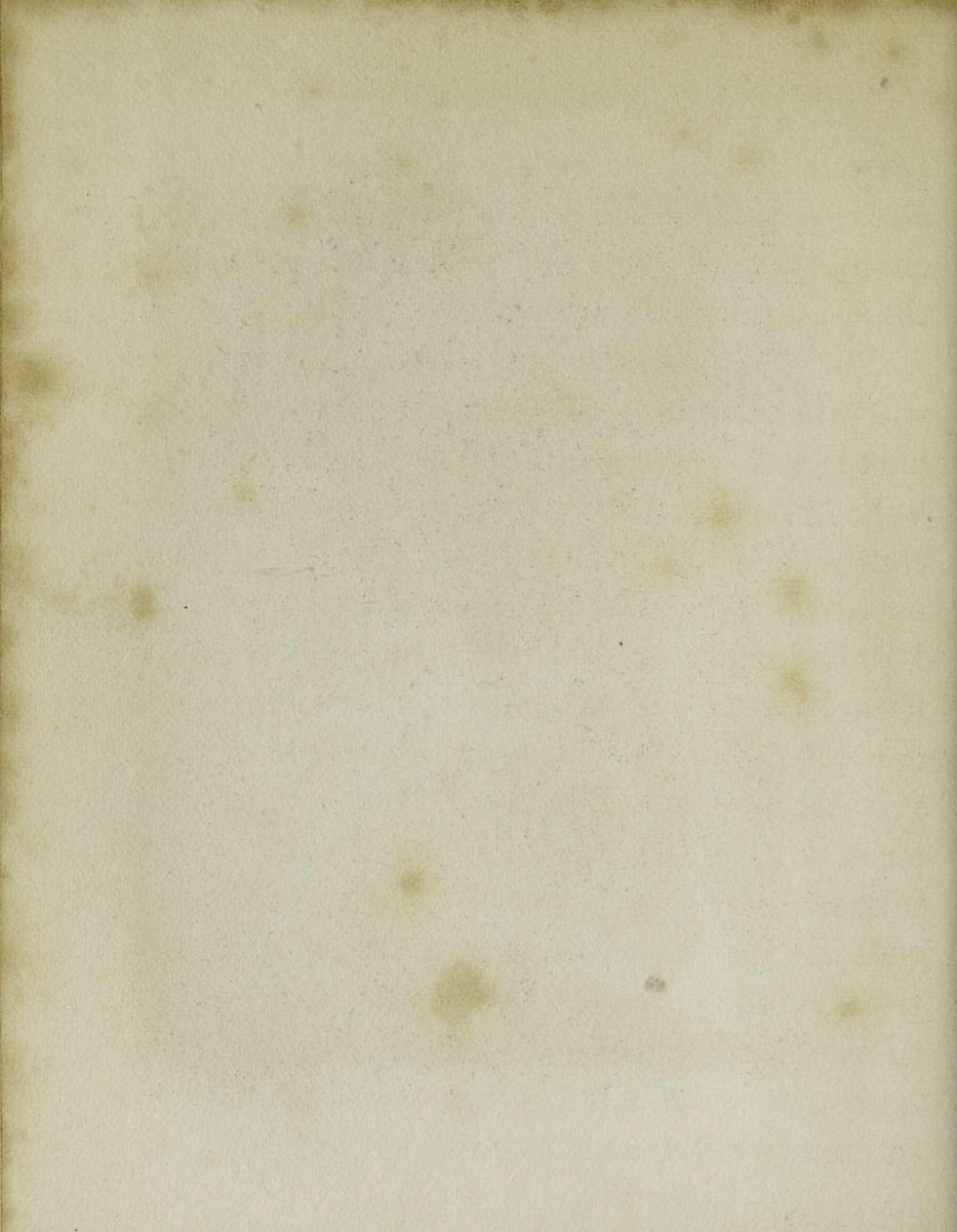
“And a great many other mills,” said the Doctor; “but their internal motions are not thereby accelerated.—Look! here is a *cata-pulta*, an engine which has, I see, operated sufficiently in breaking a square or two of glass; but has not yet, I am sorry to say, superseded manual labour in that department of juvenile occupation.”

“And then,” said Frank, in continuation of his train of reasoning on the globe-mill, “I do not know where a place could be found to *fix* the mill; for it must not touch the earth at all.”

“And a balloon would be too unsteady,” replied the Doctor. “On the whole, I am inclined to think that these *very* surprising thoughts are not so likely to be really useful as inventions of a less striking kind; and, though I allow of any experiments here which can be performed without danger or too much expense, I should rather recommend to young



Model of the Contagion, &c.



persons the study or the practice of things already understood by philosophers or mechanicians. I now leave you to your own thoughts till the school-bell rings."

Thus our hero found that an opportunity was afforded him of continuing his favourite pursuits, under certain limitations as to time ; but, otherwise, with better means of operation than under his father's roof. He found, too, an advantage accruing from his situation at Dr. Knowles's school, which he had not calculated upon ; but which, to his friends, was certainly more a cause of satisfaction than surprise :—his arithmetical and geometrical exercises enabled him to arrive at certain facts in mechanics by a much nearer road than that of ignorant conjecture or oft-repeated trials. He no longer measured the proportions of circles, diameters, levers, &c., by tapes and strings ; he could find out the proportions of quantities without scales and weights. He

began to see clearly that *some* things could not in possibility be done, for the accomplishment of which he had therefore laboured *needlessly* as well as in vain. On the other hand, for other undertakings he saw encouragement and assistance in the plain rules of numbers and of geometrical demonstration. The slate, therefore, and the case of instruments, were not laid aside when the requisitions of his masters had been satisfied: so that, whilst school aided his chosen pursuits, these in turn kept in ready use for school the rules and exercises practised there; and Frank in a few months took *precedence* of other lads, who had been longer under instruction, but who, by neglecting to *interest themselves* in their studies, gave dissatisfaction to their teachers, and made their tasks a double burden.

Frank did not, therefore, waste his leisure time in quite so many ingenious absurdities

as heretofore, nor ponder quite so long on principles and facts understood by almost all the world besides. His plans and operations were more reasonable, and their results more sightly, than they had been at home ; and, when a useful machine of simple construction, such as the garden-engine, needed repair, he could frequently accomplish it, instead of rendering repair necessary by injurious handling, as on former occasions.

But Frank once said he should like to be *an engineer*, and Dr. Knowles having been apprised of this, consulted the young professional gentleman on the practicability of conveying water from the stream which bounded his premises to the various domestic offices of the house.

“There are two ways, at least, in which water travels, I suppose,” said the Doctor ; “that is, by natural or artificial means.

Which of these, do you think, would best succeed in bringing the water from the brook this way ?”

Frank paused, and, with his head a little on one side, deliberated on the question. “ Perhaps,” said he, “ if the water is only wanted below stairs, a *canal* would bring it well enough ; but, if it must be carried higher, I should think a machine must be used.”

“ I should be content to have the water level with the ground-floor of the kitchen,” said Dr. Knowles ; “ but canals cannot take effect in all situations.”

“ True,” said Frank ; “ they will not run up hill ; and I remember now that the brook is in a lower situation than the land near it.”

“ A very common circumstance,” added the Doctor, “ and in the present case particularly observable. I should think that this house stands fifteen feet higher than the surface of

the brook. But is there no other objection to a canal from this spot to that?"

"Yes, sir: I had forgotten that the sheds and a barn stand nearly across the way; besides, there is a church-path at the farther end, and a great piece of Farmer Budgenot's meadow."

"Fatal objections, Frank, had the fall of ground been in our favour: we need not, therefore, calculate the expense of a canal a quarter of a mile in length, which would be considerable; and, after all, it would be unnecessary, for a pipe of an inch diameter would convey all the water we require, by means of a common pump. It is the business of an engineer to find out the readiest way of accomplishing his object, taking all circumstances into consideration. He must therefore acquaint himself with the laws of nature, by which knowledge he may avoid under-

taking impossibilities or absurdities ; he should also know what art and science have already performed, and adopt the latest improvements. If, for instance, it were needful to convey water from the top of one hill to the summit of another, he would not build an aqueduct across, as the ancients used to do ; but he would lay a pipe along the valley.”

“ I suppose the ancients did not understand these great works ?” said Frank.

“ We will inquire a little into some of their operations before we form an opinion of their merits,” said the Doctor. “ This evening we will devote an hour or two to the subject.”

CHAPTER IV.

OPERATIONS OF THE ANCIENTS.—BUILDINGS.—
AQUEDUCTS.—ENGINES.

DR. KNOWLES conveyed much general information by occasional conversation with the boys, which he conducted more in the manner of a father than a tutor, and thus he rendered those instructions at once suitable and interesting to the various understandings of his youthful auditors.

“You were observing, Frank,” said the Doctor, “that the ancients probably did not understand the execution of great works, such, perhaps, you mean as those which the moderns have accomplished. But attention to history, and what is even more convincing, a view of what now remains of their undertakings, would

rather lead us to say that, in comparison, the *moderns* do but little. The pyramids of Egypt are unquestionably the most surprising of all human operations, and would seem as impracticable to the powers and means of architects of the present day, as the erection of St. Paul's Cathedral to a common bricklayer. What think you of a stone building five hundred feet in height, and whose foundation covers eleven acres of ground ?

“ Here is a representation of the pyramids, with an obelisk and a sphinx in the foreground. The obelisks were formed of a single stone, eighty or a hundred feet high ; and the sphinx, which was an imaginary figure, having the head and bosom of a woman and the body of a lion, still to be seen near the foot of one of the pyramids of Ghiza, is also an enormous mass of one solid stone, but so buried in sand that only the top of the back, which is one hundred feet long, is visible. The head rises

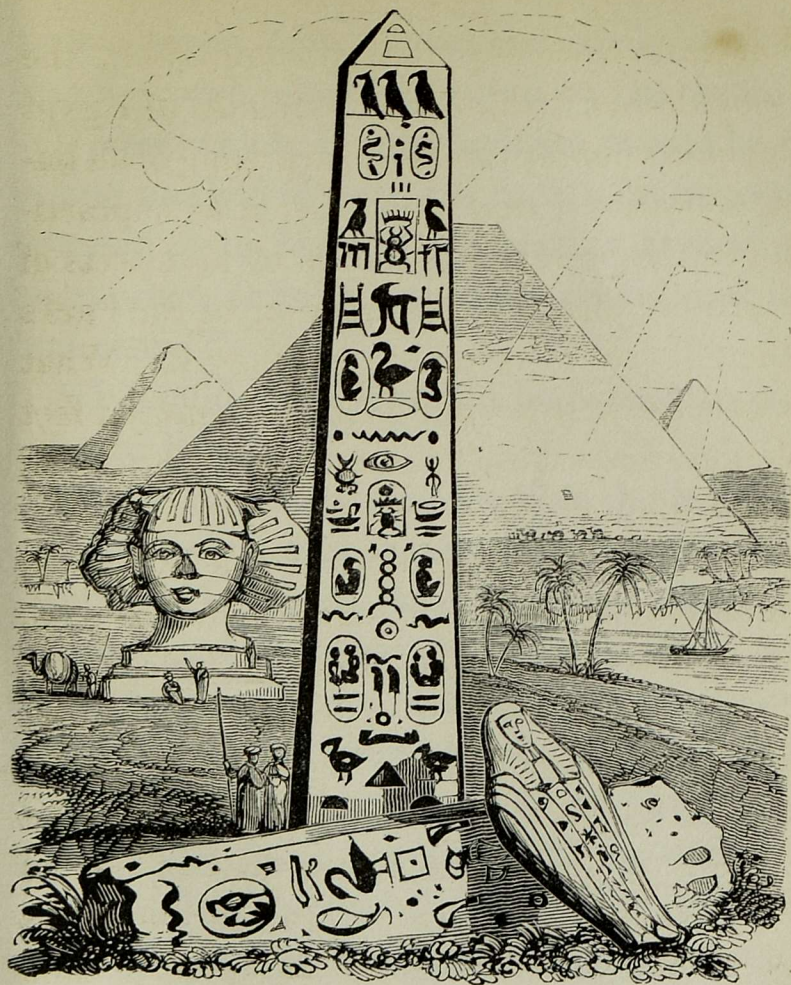


PLATE III.

to balance our wonder, by stating an amount of human labour, astonishing certainly, but which does not at all explain to us the scientific or mechanical means which enabled any number of men to rear such an edifice. It should also be borne in mind that these structures, which, at the present day remain uninjured by time, were completed in the infancy of the world, and when the discoveries of modern art are *supposed* to have been unknown.

“The lake *Mæris*, which is said to have been made by a king of that name in Egypt, we are told was two hundred miles in circumference, and was intended as a reservoir for the waters of the Nile after the inundations had filled it. It is more easy to conceive that mere labour could perform such a work as this with little help from science, than that the pyramids could have been so raised.”

“Is there any mountain near the lake *Mæris*?” inquired Frank.

“I am not aware that there is,” replied Dr. Knowles. “Why do you make that inquiry?”

“Because,” said Frank, “the earth removed from such a very large pit must, I should think, have made one.”

“And you think, probably, that if there is no such proof of the thing in question, it may be reasonably doubted. But it is not needful to suppose that a hole was dug as deep and as wide as the lake : partial excavations and embankments, in certain situations, would lay a country under water ; and the earth removed from one place would thus only ensure the required elevation in another. Still, it would be called a great work, such as the lake Mæris probably was ; yet not so astonishing as the pyramids, even though the lake were formed on a plain, and the earth distributed around it.

“You were talking of a canal from our

brook to the house ; but, on consideration, it appeared too great and difficult a work to dig a channel a few feet wide and four hundred and forty yards long. What do you think, then, of an artificial river one hundred miles long, and wide enough and sufficiently deep to be navigable for merchant ships passing to and fro ? The ancient Egyptians commenced, and other powers completed, a canal across the isthmus of Suez, whereby the Nile was united with the Red Sea. Of this work traces now remain ; it became choked up through neglect. On the whole, if we survey the ruins and consult the history of Egypt attentively, we shall see proofs of science, enterprise, and power, far surpassing that which any people of the present day can exhibit. In the finer arts, too, they excelled us. They had the secret of tempering steel to a degree of hardness which enabled them to execute enormous sculptures in porphyry, a substance on

which our present instruments scarcely make an impression. In painting, though we do not admire their manner of drawing the human figure, they had the advantage of possessing imperishable colours. Chambers in the solid rock, used as sepulchres, have been lately discovered, the walls of which are decorated with representations having all the freshness of new productions. Their knowledge of certain mixtures and processes, of which we now understand but little, gave them the power of preserving the bodies of their dead to this time. Embalmed corpses, called *mummies*, have been found entire in the vast subterranean recesses of Egypt, or the Catacombs, of which, I suppose, you have heard ?”

“Yes, sir,” said Frank ; — “but, about that canal—I think the Egyptian engineers did not finish their undertaking ?”

“No. They were afraid of inundating their country with the water of the Red Sea, which

they supposed to be much higher than Egypt; but it is possible that their science was not equal to their occasions on that point, and, in like manner, *ours* would most probably fail us in constructing pyramids such as theirs. The lake Mœris was formed to detain the waters of the overflowing Nile when needed: underground canals were also dug to drain off those lakes which the inundation naturally caused, and which were not desired; they were thus made to discharge themselves into the Mediterranean without occupying the surface of the earth."

"I think the Egyptians were a very clever people," said Frank.

"They were the first of astronomers, mathematicians, engineers, sculptors, painters, writers, and physicians," said Dr. Knowles. "Egypt is allowed to be the mother-country of the arts, and, although their performances were accomplished earlier, they have lasted

longer and are in better preservation than those of other nations. Of Babylon, the great wonder of history, scarcely any vestiges remain. The walls of that metropolis were almost incredibly vast; but these, with the buildings of the city, it seems, were formed of brick, and cemented by a kind of earthy pitch called bitumen. The gardens, reared on innumerable arches, the hundred brazen gates, the towers, the palaces, the surrounding moat—an immense artificial lake; all prove that here men were not obliged to content themselves with small things for want of capacity or power to execute prodigious works. Ancient writers agree in describing Babylon as a city of wonders; but, as I said before, Time has left us nothing but the page of history to attest these things of the renowned city we refer to.

“ In Egypt, and various other countries, we meet with erections of a most surprising kind, and the antiquity of which often exceeds our

knowledge. These are obelisks of monumental stones, generally consisting of one solid block set upright, but by what mechanical means we cannot easily conceive. There are porphyry obelisks in Egypt, from one to two hundred feet high, and weighing some hundreds of tons, which would seem to require a nation of giants to form and to elevate in that manner. Great Britain is not without examples, which make us ponder much on the science and powers of antiquity. Stonehenge, in Wiltshire, is an assemblage of stones of vast bulk, some raised on end, and others laid across at the top—in a way which, I say again, would greatly perplex our modern engineers.”

“ Well, but sir,” interrupted Frank, “ there is the Monument, in London, which I have seen—is not that as wonderful ?”

“ The Monument is a beautiful column, skilfully constructed,” replied the Doctor ; “ but there is nothing at all astonishing in it as an

erection, because it is composed of stones which are not so large but that pulleys and scaffolding would sustain them."

Frank, whose own thoughts sometimes wandered a little from the subject on which others were talking, suddenly expressed a wish to be informed respecting the Wall of China.

"You remind me of Doctor Johnson," said Dr. Knowles, "who thought so much of that wall, that he recommended his friend to go and see it; adding, that those children would be regarded with more honour whose parent had gone to view the Wall of China. It is not, however, so remote from our subject as from the limits of our probable travels.

"That wall is a sort of rampart, formed to protect the empire from the incursions of the Tartars. It is unquestionably amongst the most stupendous productions of human labour existing on the globe. It extends along a hilly surface fifteen hundred miles in length.

The breadth is such that six horsemen may ride abreast upon it with ease; and it has towers at the distance of one hundred and forty feet. The materials of which it is composed are so close and solid that it is yet almost entire, though built above two thousand years ago. But I am not sure that the Wall of China is more remarkable than the canals with which the ingenious and persevering people of that country have intersected their vast dominions. The Grand Canal of China surpasses any thing of that kind in the world. It exceeds a thousand miles in length, and connects one end of the empire with the other; besides this, there are innumerable other canals, many of them little inferior in extent, for the purposes of inland navigation. China is, in fact, the land of canals and other grand public works."

"Then, I suppose, I had better go to China to learn to be an engineer?" said Frank.

“I do not say so,” replied the Doctor : “the Chinese are an enterprising, ingenious, and indefatigable people in *their* way ; but their science and judgment we need not envy them. They would remove a mountain, it is true, if they determined on it, as ants would operate on a hillock in their path, without taking any quicker means than the labour of their limbs—nay, without perhaps reflecting whether the undertaking might not be accomplished with the hundredth part of the labour and loss of time. They will take a lump of ivory, and carve ball within ball with the point of a needle, with a degree of skill and patience absolutely incomparable ; yet the English excel them unquestionably as artists, and not less as engineers. A fortification, a steam-engine, a watch, or a telescope, the best of them could not produce, nor perhaps comprehend. They are not to be compared to the ancient Egyptians in any of the arts of

civilization, as far as we can judge. They have done great things, because they have been an undisturbed people, as regards their dwelling-place, in all known ages of time ; and their numbers exceed those of the inhabitants of any other country. The Wall of China had probably more men employed upon it than England can produce ; but I question if one in a thousand understood so much of mechanics as —whom shall I say ?— as Mr. Francis Lever !”

“ O sir !” said the boy, smiling and colouring too, “ I am sure I could not have helped to build the wall, or dig the Grand Canal !”

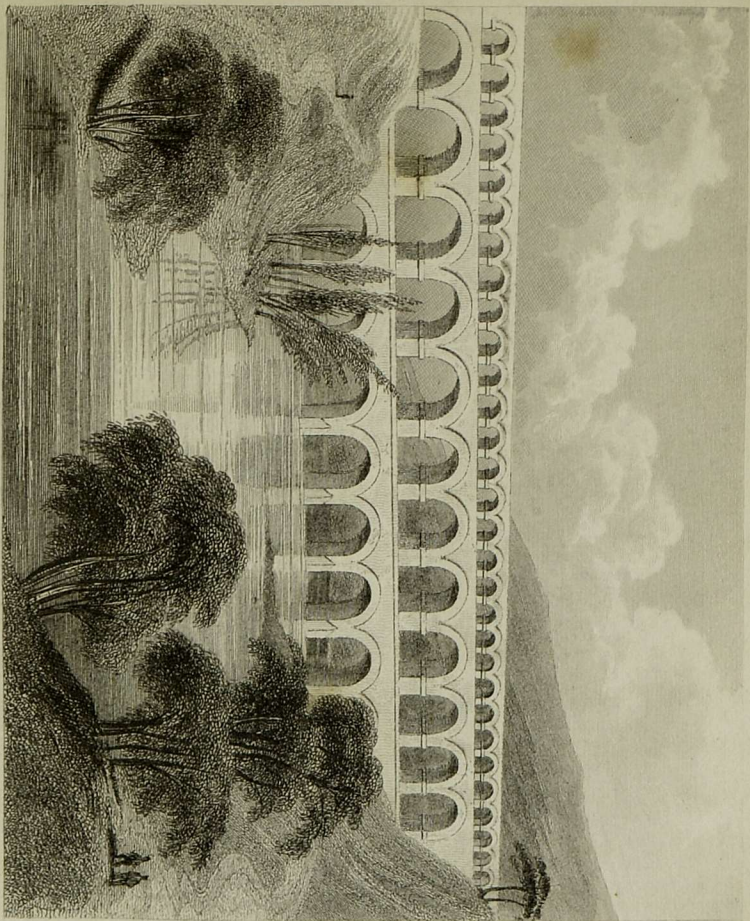
“ No ! Could you not have conveyed some of the bricks or earth in your wheelbarrow, or have helped to tread the mortar with your feet ? Had you been a Chinese two thousand years ago, you might in some such way have been employed ; but now you would endeavour to proceed in a more expeditious manner.”

“Pray, sir,” said Frank, “is a canal the same as an *aqueduct*?”

“As an aqueduct leads or conveys water, a canal, or a leaden pipe, may be so called,” replied the Doctor; “but we usually understand by an aqueduct an artificial channel for a considerable body of water to pass, either below the surface of the earth, or raised more than a little above it. Of the latter kind were the aqueducts most celebrated among the labours of the ancients, of which many very imposing remains exist. Some of these were built, as I mentioned before, to convey water across a valley, for the use of a city, by a series of stately arches supporting a channelled way on their summits. The ancients do not seem to have been aware that water will naturally rise to its own level, and that, if it runs *down* the side of one hill, it will run *up* the side of another to the exact height from which it issued, if not suffered to escape in other directions; so that

a pipe, or many pipes, laid along or beneath the ground, would answer all the purpose of a series of stone arcades of any length or height.

“ The ancient Romans were most celebrated for their aqueducts, and supplied their city through nine of these magnificent conduits with five hundred thousand hogsheads of water in twenty-four hours. The Romans constructed these stupendous works in other countries. The famous Pont du Gard, in France, was raised in the Augustan age by the Roman colony of Nismes, to convey a stream of water between two mountains, for the use of the city, and its remains, at the present day, form an object of great interest to travellers. It consists of three bridges, or rows of arches, one above another. The height is above one hundred and forty-nine feet, and the length extends to nearly eight hundred. The Roman aqueducts were, however, continued sometimes to the distance of a hundred miles, in the form



*Pont du Laid.
raised in the Augustan age by the Romans.*

of canals, sunk or raised to preserve the level ; and on some of these, vessels of large burden could sail over valleys, being suspended, as it were, in air ; and all this to save the water the trouble of mounting the required height, which it would have done just as well, had it been conducted first to any depth below : we know better now than to waste our time and materials in such works.”

“ Then, if I were to become the best engineer in the world, I should not be employed to build an aqueduct ?” said Frank.

“ You would be *the worst* in the world, to dream of such a thing,” said Doctor Knowles, “ unless the purpose were, indeed, to convey shipping from hill to hill, instead of from wave to wave. With regard to the Greeks and Romans, their works are beautiful and grand ; but not so amazing in their own nature as the Egyptian pyramids. We have, however, most elegant and majestic remains of their operations, and

our own island exhibits many proofs that here the Roman power existed. The military roads and fortifications of those ancient conquerors are traced with ease in certain places; and of their buildings, pavements, and utensils, it is not difficult to obtain a sight in or near most of our old towns."

"Did the ancients perform all these wonderful works without machines?" inquired Frank.

"You might as well suppose," answered the Doctor, "that a church-tower, if formed in one entire piece, could be reared on end like a ladder by men pushing beneath it. I have already mentioned the obelisks, which, though a hundred feet high and hewn in one block, stand erect, and were thus placed by *some* means. Of what kind the engines of the ancients were, capable of effecting *such* purposes, we do not now know; but we have the most convincing proofs of their abundant power, and may therefore conclude that they

had science to guide them. The most celebrated inventor of remote antiquity was Dædalus, an Athenian, concerning whom many fictions are related; but there is reason to believe that many of the common implements of labour were by him contrived. But the grand mechanician of ancient days was Archimedes, the Syracusan, of whom, I suppose, you have heard?"

"Yes, I have, indeed," said Frank, with emphasis; "but I should be glad to hear and know more about him."

"Archimedes was a famous geometrician of Syracuse, who lived about two thousand one hundred years ago. He invented a machine to represent the motions of the heavenly bodies, which we should now call an orrery. He must, therefore, have studied astronomy. When Marcellus, the Roman consul, besieged Syracuse, Archimedes exerted his powers as an engineer with surprising effect. Marcellus

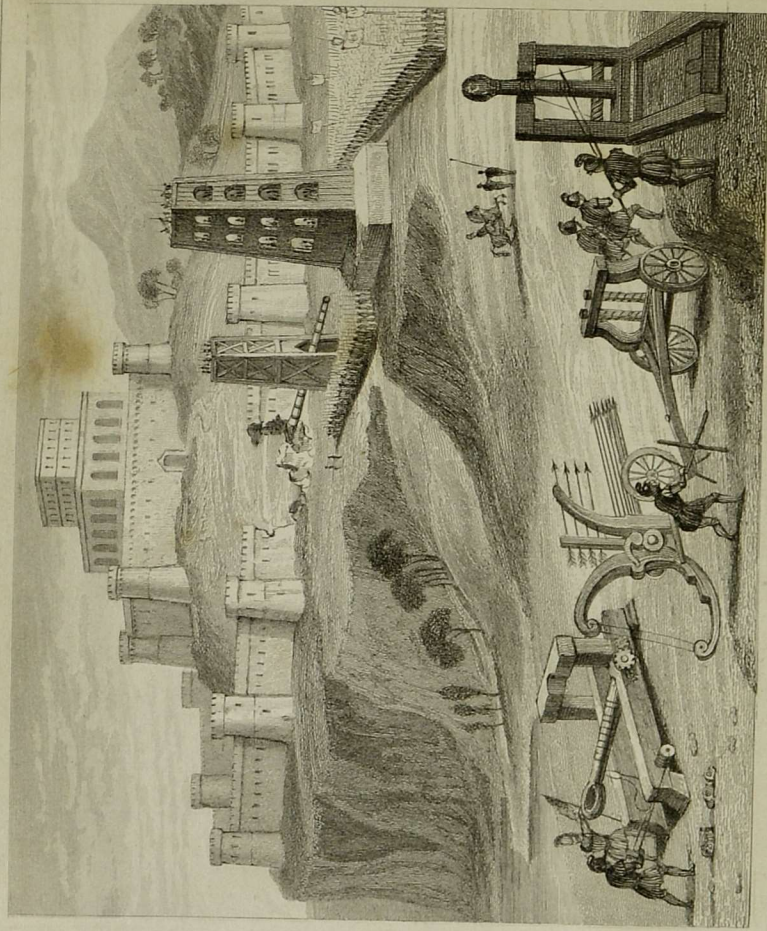
had prepared a machine, of great strength as he thought, for battering the walls; it was borne on eight ships fastened together; but, we are told that, whilst it was at a considerable distance from the walls, Archimedes discharged upon it stones of enormous weight, which shattered it to atoms. Besides engines for throwing stones, for which the ancients and *some other folks are famous*, the Syracusan engineer employed contrivances, by which he thrust hooks or grapples into the decks of the enemy's vessels, and, lifting them nearly out of the water, let them suddenly down, and thereby sunk them. Plutarch tells us, that in some instances the ships were seen suspended high above the sea, where they were whirled round until the men were thrown out, and that they were then dashed against the walls, or plunged beneath the waves!"

"Are we as sure of that, as we are that the pyramids were built?" said Frank.

“All history may be doubted,” replied the Doctor, “if we will believe nothing but that of which we can acquaint ourselves sufficiently *without* history. It is likely, however, that some of these narratives of the ancient writers may be mingled with uncertain matter; and, when we read that Archimedes made a burning-glass which consumed a whole fleet, we may be allowed to pass the story over without attention. There may be some exaggeration in the account of the freaks of Archimedes with the shipping; but remember that obelisks and other masses of stone, weighing *more* than a fleet of small vessels, *are now erect*, and therefore *were raised* by the science and enterprise of men of remote ages. This we know, that the operations of Archimedes compelled Marcellus to discontinue the siege, and to change his mode of attack. When that general had collected his troops, he smiled at the puny efforts of his

own engineers, and said to them in a bantering manner, ‘ Why do we not cease to contend with this mathematical Briareus, who, sitting on the shore, has baffled all our assaults, and, in striking us with such a multitude of bolts at once, exceeds even the hundred-handed giant mentioned in our fables?’ The Roman soldiers became so much terrified, that, if they saw but a rope or a stick put beyond the walls, they imagined that Archimedes was levelling his weapons at them, and instantly fled. The consequence was, that Marcellus was obliged to blockade the city, and afterwards he succeeded in taking the place by stratagem. Archimedes himself was slain, to the great regret of the Roman commander, who had much wished to spare his life.

“ And now we will just notice those of the ancient warlike engines of which we have any descriptions. You know that cities used com-



Battering-Ram, Catapult, Ballista, Trebuchet, &c.
p. 87.

monly to be enclosed by walls of great strength, to protect the inhabitants from their enemies ; besiegers, therefore, were obliged either to make a breach in the walls, or to climb over them. To batter them down was usually the first attempt, and to this end the famous *Aries*, or battering-ram, was employed. It is described as a vast beam, like the mast of a ship, strengthened and loaded at one end with a lump of iron something resembling the head of a ram, whence it took its name. This was suspended by the middle with ropes, to another beam, laid across two upright ones ; so it was balanced, and then a great number of men exerted their utmost strength to pull it backward, and, when drawn as far from the wall as possible, they suddenly released it, and thus it inflicted a tremendous blow on the building before it, which, being often repeated, at length produced the desired rupture of the wall.

“The *Balista* was a machine somewhat like a very large crossbow ; it was used to throw stones, darts, and javelins. It was fixed to stout posts, and several men were required to bend it ; when it sprung, missile weapons were thrown to a great distance. The *Catapulta* seems to have been like the *balista*, but on a larger scale. Elastic beams were bent by an engine made on purpose, and, on their being released by the blow of a hammer, stones of vast weight were projected from them ; and it is said that these made even more confusion in the enemy’s ranks than our modern cannon-balls ; but they were too cumbersome to be wheeled about like artillery.

“The *Scorpion* was an engine contrived to give sudden motion to a sling, containing a stone too heavy to be wielded by the human arm. Thus, the chief object of the ancient engineers in their warlike machines was to throw stones or sharp weapons amongst the

enemy, or to assault their walls. How would their renowned generals have been astonished to behold such a siege as that of Antwerp going on, when it would have appeared as though thunderbolts were hurled from the clouds by mortal men !”

Frank was now dismissed by his affable tutor, and joined his companions in various recreative exercises. The trap and ball he thought a *pelting engine*, which might be *improved* to accomplish some of the mischief unhappily required in battle. He revolved the question whether a gigantic automaton could not be constructed to bowl cannon-balls like an expert cricketer, and thus save powder and noise. In the course of three or four days, a battering-ram was erected against the wooden walls of Mr. Budgenot’s granary. Its numerous garrison, the rats, more than once evacuated the place ; but the youthful assailant was compelled to raise the siege on

the sudden appearance of Governor Budgenot himself, who peremptorily required a cessation of hostilities, refusing at the same time to name any terms of treaty for its surrender.

CHAPTER V.

THE PERPETUAL MOTION.

FRANK became more than ever silent and abstracted; an air of pensiveness, not to say of dejection, sat upon his brow; he discontinued those few engagements of sport with his companions, which at one time were indulged in by him. He spent his whole leisure time in a corner of the lumber-house before mentioned. Here he had boarded himself off a part, that he might be free from intrusion or remark. The sounds of the saw, the hammer, and the file, were sometimes heard; sometimes the dripping of water; anon the hard breathing of some incomparable pneumatic apparatus. Metal pipes, balls, wires, sheets of tin, chains, shot, bungs, bottles, and a thousand

other things, were seen to enter that replenished *sanctum* from time to time, but nothing came out, save the now lank and wan experimentalist, who issued punctually at every appointed summons—occasionally with a slight expression of satisfaction in an eye a little brightened, but more frequently with a lengthened visage and a sigh.

Dr. Knowles began to fear that the health of his pupil would suffer from the constant exercise of thought required for school business, and for those more harassing engagements in which the mind tasked itself without limit or mercy.

That infatuating problem of a perpetual motion, unlike any other constantly unsuccessful occupation—nay, unlike all the wheels and pinions that have been combined to accomplish it, continually supplies just such a balance of motive power from the last disappointment,

as keeps the mental machine still going. The wheel hangs at the wearisome point to which the perverse obstinacy of gravitation invariably brings it; but it revolves bravely in the mind: —“the weight was too heavy or too light—it was too near the centre—there was too much friction—the wheel was not properly made: all these faults of construction become sources of comfort: the very manner of the failure indicates eventual success—more lead, more oil, more wind or water—the least jerk in the world at that point would have given the long-sought inanimate self-mover to the world!”

My youthful reader, have you indeed entertained the thrilling hope of persuading a stock or a stone thus to oblige you by doing the very thing of all others which it most naturally refuses? I am not about to assert, what never can be proved, that a perpetual motion is im-

possible to be accomplished by human art, because some new principle in nature may be discovered, some independent power, such as magnetism, for instance, by which gravity may be counteracted or overcome; but I would suggest that every scheme which requires a weight to be lighter or heavier than itself, or to be heavier and lighter at the same time, is a cheat of an idle brain and a prevaricating judgment. You may nail a piece of lead to any part of the circumference of a wheel, and if you bring that weight to the point as nearly over the axis as possible, you will find on releasing it that it descends swiftly on one side, and rises—I admit—to a surprising height on the other, but it would not turn over again to favour Archimedes himself, were he to return to life and command it so to do. No: it would be needful that the lead, which weighed perhaps a pound whilst descending, should weigh but twelve or four-

teen ounces on rising from the bottom ; then, indeed, the force it had acquired might carry it over and over and round and round.

But Dr. Knowles confessed, when Frank admitted him to inspect some of his innumerable contrivances, that schemes far less obviously false and foolish than the common ones had been, with unusual ingenuity and admirable perseverance, pursued for his purpose, and it was by no means easy to point out in words the real fallacy of some of these combinations of mechanism. A wheel, partly wood and partly iron, had been constructed, which was to be suspended on its axis in water. With much cleverness, and a considerable measure of operative skill, Frank had so adjusted the parts, that the metal should continue on one side and the wood on the other *whilst turning*, by which an ascending power would be gained on one side, in addition to a descending force on the other. But

it was found that this wheel was *less revolutionary* in its tendencies than one composed of wood or iron alone, and nicely equipoised on its centre. Such a wheel many besides Frank have discovered to be *the* apparatus that will revolve the soonest, the longest, and with the smallest applied force of any. It will not, however, stir without *some* cause, commonly called *a maintaining power*, nor continue in motion longer than the influence of that power remains.

“Pray, sir,” said Frank, “what is the reason that this wheel, with something to draw it down and something to lift it up, will not turn more than half round?”

“Because, Frank,” said the Doctor, “the power required to keep this iron on one side and the wood on the other, as the wheel turns, is, in fact, as much as would be required to move them from one *part* to another if the wheel were fixed. Now, all that the metal

endeavours to do is to find the lowest place it can attain, and the wood in the water tries not to rise higher than the surface. If you had an independent power, like your own arm, these bodies might be continually displaced so as to serve your turn; but such a power would be more conveniently applied to a winch."

"Oh, sir!" said the boy sorrowfully, "I always find that these things want something just like my finger, which can move I cannot tell why."

"Just so," said the Doctor; "and, for want of some such thing, the wheel remains at rest, you *can* tell why.—But what have we here? Orfyreus's wheel, I declare!"

"Yes," said Frank, "I could not have invented that."

"You are not, therefore, answerable for its defects, nor to be ridiculed for its amazing absurdity," said Dr. Knowles: "indeed, I think

you have improved on all the plans I have seen of that tall child's rattle ; you have employed water in the hollow bent spokes of your wheel instead of cannon-balls."

"Yes," said Frank ; "but still I cannot bend the pipes so as to send the water where I want it timely enough : the water on one side will always balance that on the other before the wheel has turned half round."

"Do not you perceive, therefore," said the Doctor, "that all these various methods of placing weights on wheels come to the same thing ? Whatever power you employ on one part of the machine becomes a resistance equal to it on another. The weight which carries your apparatus at one time must itself be carried, or lifted, *with* the apparatus in return for that favour ; so you gain no power in the end. Pray, how did you become acquainted with the invention of Orfyreus ?"

Frank then drew from beneath a pile of books and papers on mechanical subjects, a number of a periodical work, in which was the following interesting paragraph, extracted, I believe, from an old encyclopædia.

“ORFYREUS'S *wheel*, in *mechanics*, is a machine so called from its inventor, which he imagined would produce A PERPETUAL MOTION. This machine, according to the account given of it by M. s'Gravesande, in his *Œuvres Philosophiques*, published by Allomand, Amsterdam, 1674, — consisted of a large circular wheel, or rather drum, twelve feet in diameter and fourteen inches in depth, and very light; as it was formed of an assemblage of deals, the intervals between which were covered with wax-cloth, in order to conceal the internal parts of it. The two extremities of an iron axis, on which it turned, rested in sockets well oiled. On giving the wheel a slight impulse in either direction, (*we are told*

that) its motion was gradually accelerated; so that, after two or three revolutions, it acquired so great a velocity as to make twenty-five or twenty-six turns in a minute! This rapid motion (*we are told*) it actually preserved during the space of *two months*! in a chamber of the Landgrave of Hesse, the door of which was kept locked, and sealed with the landgrave's own seal. At the end of that time, it was stopped, to prevent the wear of the materials!

The professor, who had been an eye-witness of all the circumstances, examined all the external parts of it, and was convinced that there could not be any communication between it and any neighbouring room. *Orfyreus*, however, was so incensed, that he broke the machine in pieces, and wrote on the wall that it was the impatient curiosity of Professor s'Gravesande which made him take this step. The Prince of Hesse, who had

seen the interior of this wheel, being asked by s'Gravesande, whether, after it had been in motion some time, there was any change observable in it, and whether it contained any pieces that indicated fraud or deception, answered both questions in the negative, and declared that the machine was of a very simple construction."

"And so is a grindstone," said Dr. Knowles, having perused this statement; "yet it will not turn alone, nor did that wheel, be assured. I have a drawing of it, more intelligible than the figure of it you possess, which will convince you at a glance that it could not turn perpetually, for though some of the weights are more distant from the centre than others, yet there is always a proportionably smaller number of them on the side at which they have the greatest power, so that these two circumstances precisely counterbalance each other."

“ Then you think, sir,” said Frank, with a deep-drawn sigh, “ that there is no use in attempting a perpetual motion ?”

“ I do not say so,” replied the Doctor ; “ on the contrary, I believe that much mechanical knowledge and many really good inventions have been the result of this otherwise fruitless inquiry. I only recommend *moderation* in the pursuit, and that you do not deprive yourself of the proper benefit of hard-earned experience by ever looking at the *facts* which counteract your wishes *in a wrong light*. When you see that the various results of your labours all tend *one* way, do not try to persuade yourself that they can tend the other ; and if you find *reason* to conclude that levers, wheels, and weights, hinder as much as they help in this business, throw them aside, and endeavour, if you would still persevere, to discover some substance which has power without weight, and some mechanical contrivance which

can increase power and speed at the same time!"

"I suppose," said Frank, "that if I could find a little fairy, who would not think it too much trouble to wind up my wheels and swing my pendulums for ever, I might make a machine for perpetual motion without being thought foolish?"

"Doubtless, Frank," said Dr. Knowles; "but consider: there are powers already known and in use which do things as apparently surprising as those related of all the fairies. GRAVITY draws things *one* way, and we cannot account for that: MAGNETISM gives motion to iron, hard and heavy as it is, in other directions, nor can we tell you why or how. There is no difficulty in finding out forces and influences in nature that are *unaccountable* to us; but still we cannot make them perform IMPOSSIBILITIES."

With these hints, Dr. Knowles left his

pondering pupil immersed in his books, papers, and apparatus, and neither encouraged nor altogether discouraged with regard to his bold undertaking.

“I tell you, Frank,” said one of a party of young gentlemen, who now entered the building, “it is all nonsense, you cannot do it.”

“Do what ?” inquired Frank.

“Make your wheels twirl, and your weights jump, and your pipes blow, and your water go, and your bars push, and your chains pull, after all you have done.”

“Dear me !” said Frank, “I did not know it would be so very difficult for *me* to do those things. See ! does not the wheel go round whilst I turn it, and then that weight goes where I throw it, and with this bar—look !—I push—the door open, and there *goes* that water,” added he, sprinkling a little in the face of one of the cavillers ; “and here, this chain,

Master Rackwit, will pull down the pulley you had fixed to receive a strap to go round the world.—What next *can't* I do?"

"You cannot do it by a perpetual motion," said one.

"What *is* a perpetual motion?" inquired Frank.

"Something that moves of itself," was the reply.

"And how does my body move?" rejoined Frank.

"Because it is alive," said a little respondent.

"And what *is* life?" demanded Frank; but the cleverest of the querists could reply no farther.

"I tell you how I think it is," added Frank. "Some machines want weights and springs, or water, or air, to move them; some require food and drink; and some, like Mr. Rackwit's very large circular engine,—I mean THE EARTH—

can move on for ever, without any help from such things."

"What a capital philosopher Frank is!" said George.

"He is Archimedes the second," said Charles Renton; "and yet he could not hinder my father's house from falling down. He stood gaping at it, like a trounced frog."

"You are very polite, Charles, I think," said Frank. "Pray, what did *you* look like when the bottom of the tub, in which you were sailing over the pond, came out?—not like a frog, for he would not have cared about the matter."

"Never mind that now," said the party referred to; "we want to see one of Frank's wheels turn round; and, if he cannot show us one going before the holidays, we will all say to everybody that Frank is no mechanician at all."

"Then I *will* show you one by that time,

depend on it," said Frank, "which *shall* turn round without wind, or water, or steam, or weights, or springs, or anything of the kind; and Dr. Knowles shall see that I do not wind it up, nor do anything of the sort to make it go!"

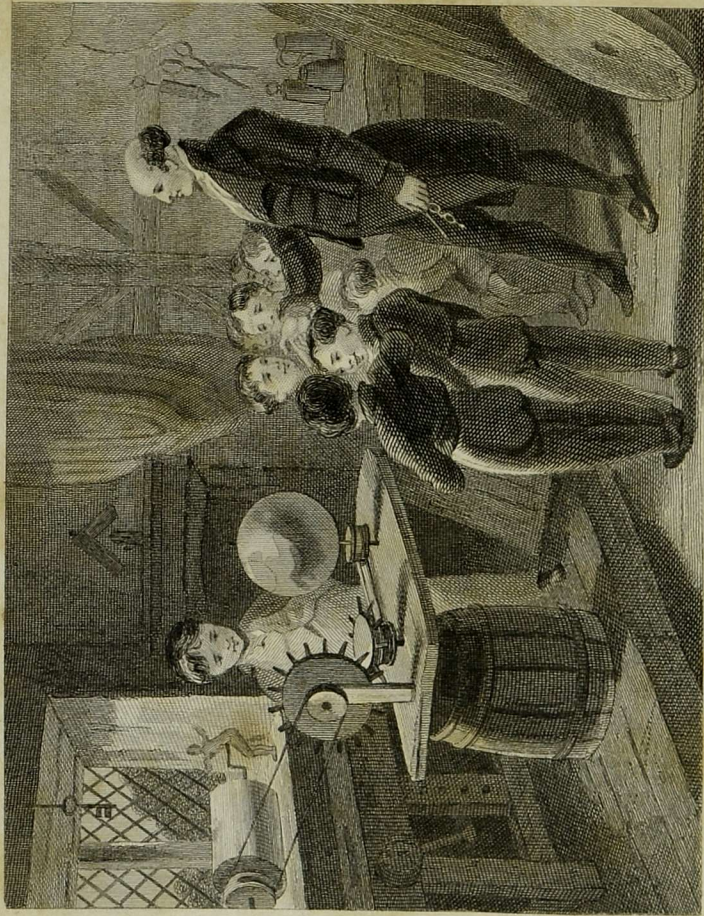
The Doctor was informed of this arduous undertaking, and was glad to find that so short a time as ten days was to put a successful close to the operations which had so long engrossed Frank's thoughts and energies, to the injury of his health, as he feared.

The 20th of December arrived, and our hero was bound by his agreement to produce his machine the next day. On the evening before, an unusual smile of placid confidence embellished the physiognomy of Francis Lever, the youthful mechanician.

On the appointed morning, our hero, to whose sole keeping the key of the engine-house had been confided, made several early

visits to the spot, and requested attention to a short speech when the breakfast was removed.

“ I never said that I was a mechanician,” he began ;—“ I never thought I was, and I don’t much think I ever shall be one. I never said that Master Rackwit or anybody else was *not* a mechanician—he may be one now ; and, if so, it is of no consequence whether we call him so or not : but I did say that by this time I would produce a machine that should turn round without those parts and those powers that keep other machines going. But pray, sir,” said Frank, addressing his observant tutor, “ will you call it fair if I enclose it in thin paper, so that paper and all may turn with it ? and will it not be a proof that I do not play any tricks to move it by anything outside, if I take it by its two wires and place it in its frame ? and, if it should not move for



Francis' contrivance.

some time after that, and then begins to spin round, and if it stops and then spins round again of itself, will not that make it more surprising still? and will you allow, if I should wish, a whole hour to my exhibition?"

The Doctor decided that all these things should be granted, if Frank would allow *him* to take the machine in his hands by its axis and to place it in its frame.

Frank agreed to this, somewhat to the surprise of his tutor. So the whole company marched forth to the scene of action. On entering the building, the party perceived that the young showman, like the rest of his craft, understood his business so far as to interpose a curtain between the vestibule or saloon of the theatre and the inner mysteries, towards which all eyes were now directed. Frank begged a moment's grace, and, gliding out of sight, soon pulled a string, when the curtain rose.

“Ha! a terrestrial globe, I declare!” said Doctor Knowles. “This, I am sure, Frank, you have executed extremely well.”

And certainly this was just praise. A paper sphere, about a foot in diameter, had been constructed, on which the terraqueous and geometric lines had been drawn with great precision. The land was duly coloured green and the water blue. One difficulty had been found insurmountable by Frank; the axis of the globe was not inclined. All drew near to examine and to pry. In crowding round for this purpose, the curtain was somewhat roughly pulled farther aside, when the piece of wood which had supported it fell down with some noise, and all were afraid that the globe would be demolished; but it tilted happily quite another way, and certainly did not touch it, yet, strange to say, the sphere immediately showed signs of motion. Frank stood the farthest off, and had evidently no hand in the revolution of

the sphere, which now gradually increased, in opposite directions, then suddenly stopped for an instant ; but, before this cessation could be spoken of, it as suddenly spun round again with a velocity which rendered land and water all one to the eye, and which made the paper rattle in the wind !

For a moment, wonder tied all tongues ; but this silence was soon followed by numerous and very lively expressions of surprise, admiration, certainty, and disbelief. “ I know this,” and, “ I am sure of that ” — “ I say he has *done* it ” — and, “ I say he has *not*,” formed the substance of the somewhat clamorous opinions which burst from the sundry disputants. Frank had his adversaries and he had also his partisans, and these last resolved to drown all cavils by three thundering claps and as many hearty huzzas, for which our hero no doubt thanked his friends ; but it happened somewhat remarkably, that the globe itself immediately stood

still, as if to listen to these wide-spreading acclamations.

Dr. Knowles now called silence, and begged to know whether he might now proceed to examine the external mechanism of Frank's contrivance.

"Oh yes, sir," said the youth. "You will see there are two things that turn round; I suppose there is no harm in that?"

"No harm in a thousand wheels and pinions," said the Doctor, "provided none of them are actuated by an external cause." Dr. Knowles then lifted the airy sphere fairly out of its support. Its axis was a mere wire, fixed to a small wooden hollow cylinder, at the lower or south pole, round which a tape travelled; the cylinder was then placed upon a pivot—and what next? This tape communicated by cogged wheels with the *primum mobile* at a short distance, and here the wonder of course remained. A cylinder, formed apparently of thin pellu-

cid paper, or, perhaps, merely covered with that material, was placed on the window-sill. It was about two feet long and one foot in diameter. The artist had evidently sported with his mechanism here, and had placed a card figure of a man turning a winch at one end, whilst the other, which by its little wheel gave motion to the strap, had cogs like those of a water-wheel. But the water, which was perfectly still, barely touched the mock floats before mentioned. All this Dr. Knowles perceived, when he had placed his glasses on his nose; for his own curiosity was not a little excited, especially when this cylinder now suddenly spun round, and so little affected by the agency of the paper man at the winch, that that frail effigy lost both its arms by this new movement, which arms now circulated by themselves, to the no small amusement of the spectators. A farther clue, but whether true or false did not appear, seemed to be afforded by a twanging

sound of wires or metal plates within; and Master Frank, if not yet installed as an engineer, was voted an undoubted conjurer of the first order. Dr. Knowles took the cylinder in his hands, convinced himself that the power was strictly internal which made it revolve, and declared it as his opinion that those who could not imagine and suggest any other cause for what they saw, than one equivalent to a perpetual motion, should allow it to be one, at least whilst their own ignorance remained.

Not one of the youths was able to name a cause which could be any evasion here. The Doctor did not state his own views at all; but merely said that, on any supposition, Frank was duly entitled to the reputation of an ingenious and skilful *mechanician*. Before I take leave of my readers, I may, perhaps, supply some incident, or venture a hint for their consideration, in solution of this difficulty.

CHAPTER VI.

THE HOLIDAYS.—DOMESTIC LECTURES.

A MACHINE of another sort, and the functions of which were less mysterious than the one we have just noticed, engaged the attention of young Francis on the morning of the ensuing day. It was his father's gig, which drove up to Dr. Knowles's; but not until the youth had spent an hour or two in watching, listening, and almost painful expectation.

Those who have never parted with their children, or been separated three days from their parents, cannot exactly appreciate the feelings of persons who thus meet after an interval of half a year. The interview between Frank and his father was unclouded

and satisfactory in every respect. The parent's face brightened, when he saw his son, and observed his improved air and the strengthened lines of intelligence which his countenance displayed. But how much more did the father's eye glisten, when Dr. Knowles, leading him aside, gave his opinion of the boy's capacity, attainments, and disposition. "Rest assured, my dear sir," said the Doctor, "that the boy is more than well provided for by nature, and his predilections, of which you are aware, have gained a settled direction and acquired vigour, with, I trust, some foundation for a superstructure of knowledge during the last six months ; but do not suffer the next six weeks to interrupt, so lamentably as that season usually does, the process which should be always going on with the young in one form or another — I mean that of instruction. If school conveys knowledge which is rarely attained at home, the paternal roof,

again, has the means of imparting various portions of essential information, but which it would be vain to attempt among the classes of a school. I know that many parents possess not either the materials or the inclination for domestic tuition; but to a scientific and a literary man there can be nothing but ease and satisfaction in the proceeding I recommend."

"I am ashamed to confess," said Mr. Lever, "that I have not seen this matter in its obvious aspect of importance by my own reflections on family duties. The suggestions of one friend confirmed by another will, I trust, have their due effect, and give us this winter something beneficial in exchange for our many idle evenings. Dr. Knowles, I thank you as emphatically as a man can do who perceives that he has benefited in his most dearly cherished interests." Mr. Lever in due time stepped with our young hero into his gig, and

an hour or two of young Lightfoot's exertions brought them safely home.

We must now attend more exclusively to the instructive portions of our present work. Indeed, the festivities of the holidays, especially those of Christmas, are, we doubt not, matters of such ample experience to our young friends, that we need not employ paper and ink in describing them. I shall not, therefore, relate the expressions of delight and affection which proceeded from Frank's kind and intelligent mother on receiving her son, and learning the highly encouraging opinion of Dr. Knowles concerning him. Edward, too, was as well pleased as anybody to see a brother, who had always been a kind and generous-tempered companion, and whose good qualities had been much better estimated in his absence than before. With eager impa-

tience Edward led his elder brother over the well-known domain, pointed out every alteration, apprised him of every purposed scheme for the future; and in the same breath with tidings relating to new repairs, new plantations, and even new implements for out-door or domestic use, introduced the *lectures*, the apparatus, and the various preparations, to the notice of his brother.

“The library is to be the lecture-room, Frank; and we have got printed cards, and papa has made large paper drawings, and everybody is to come, and your jack is to be there, and there is to be a great ball—a wooden one, I mean, and forms, and inclined planes, and an electrifying machine, and a skeleton, and a crane, and—oh! such a large pair of compasses!—Come and see!”

Frank needed no verbal representations to excite his attention on these subjects, especially when he was led into the library afore-

said, where a long table covered with baize was already spread with a most interesting assortment of philosophical implements and materials. The walls, too, were hung with diagrams and other scientific delineations; seats were arranged for more than a few besides the household; a small chandelier was suspended from the ceiling, and Frank showed as much satisfaction as his rather reserved habits would permit.

Mr. Lever, being well known in the neighbourhood as a gentleman of science and intelligence, found that his cards, which had been presented to the juvenile individuals of his acquaintance, were solicited by some other persons, who thought, perhaps, that their own information on certain subjects would admit of improvement or addition. Agreeably, however, to the object he had in view, his disquisitions were accommodated as much as possible to the supposed requirements of a juvenile

audience. Such an assembly he had before him, with a few older friends, on the evening of his first

LECTURE ON MATTER AND ITS LAWS.

After the greetings usual among friends, Mr. Lever, taking his station at the table, thus began :—

“ Ladies and gentlemen, my humble attempt this evening needs an apology ; for I have not made preparations suitable for so many intelligent and well-informed persons as I see before me. I do not suppose that to the youngest of my hearers the subjects to be brought before them will be entirely new ; far less do I imagine that they have not become occasions of reflection and inquiry to the greater number of the juvenile individuals present ; for what sort of a person must that be who makes no better use of his senses than to

perceive and forget, and whose understanding has nothing to do, whilst the eye, and the ear, and the touch, are surrounding it with materials for occupation ! I once heard a simple person say, that *she wondered whether her cat knew that it was a cat*; and we might in like manner, with regard to some beings of a higher order than quadrupeds, wonder whether they are aware of certain obvious things in philosophy : such a question would be entirely inappropriate in the case of any who now honour me with their attention.

“I must, however, begin at the beginning of my subject, though neither I nor any other man can ever probably arrive at its conclusion. WHAT IS MATTER ? Many would reply, it is metal, and wood, and earth, and air, and water, and fire, and so on. But this is only giving the same thing many different names ; as I may call the same person, George, Frederick, Alexander, Charles, Ernest, Augustus,

son of the Duke of Cumberland. I may make use of one term or half a dozen with regard to the thing meant, without describing that thing at all. Of matter, or substance, or body, then, there is only one thing I can think of to say that will apply to it and nothing else. It is that which either itself or by its effects is an object of perception to the senses of the body. This leaden ball, this bar of cedar wood, I can see them, I can feel them, I strike them together and my ears become witnesses to their existence, so also might my palate and nasal organs. But these five credible witnesses do not enable the *judgment* to pronounce WHAT IS MATTER. Each only says, it is that which I have seen, or heard, or handled, or smelt, or tasted; here their evidence begins and ends.

“Philosophers, therefore, have exerted their UNDERSTANDINGS, and this they did as long ago as the history of thought reaches, to ascertain

the *nature of matter*, but in vain, and so provokingly in vain, that not a few of them, as in a pet, have denied that matter *exists at all*—yes, they have in fact said that there is no such thing as *substance or body* in the universe—not *an atom* is anywhere in being!—I perceive my youngest auditors excited by mirth at this statement, which, however, has not been thought ridiculous by many a studious sage. We, therefore, had better content ourselves with inquiries respecting *the laws and properties* of matter; and, as these are facts communicated to the mind by observation, and entertained there with advantage by reflection, *we* shall not, I trust, inquire in vain.

“ One of the most evident, and yet the most curious properties or capabilities of matter is its *divisibility*. This piece of iron may be broken into bits, pounded to smaller fragments, filed into dust—nay, it may be reduced by heat or chemical processes till the particles are too fine

to be perceived ; yet the matter composing the lump would still exist. But here is the wonder ; that the *smallest* of these particles must be conceived of as possessing parts of its own ; say four quarters—How big are they ? I cannot tell : but I know that each of those quarters has four quarters of its own again, any one of which has without doubt as many quarters as—as the vast globe on which we live ; and though we might conceive of thus separating parts of particles for ever, yet, though this had been done a million of times, the portions remaining after the last division would still have parts ; for half of any one of them would be less than the whole ;—so that we are no nearer the end of that mental labour by commencing with a pin's head than if we began by dividing a mountain or a planet ! It is plain, therefore, that matter cannot be made an end of by subdivision ; nor can we conceive of particles so small that the

mind could not divide each into a million of parts again.

“But, perhaps, some would ask, are the parts of matter ever naturally so small as to excite this sort of wonder? I think they are, and shall mention LIGHT. To prove the extreme minuteness of the particles of light, let us consider that a candle when lighted is capable of filling a space five miles in diameter with its particles, which at any point can pass through the hardest substances, even the diamond itself. It seems, then, that the facts of nature exceed in wonder all that our thoughts can accomplish with regard to the divisibility of matter.

“My young friends, will allow me here to point out an excellent cure for that conceit of knowledge with which some persons please themselves, and displease others so often: it is the plain proof of ignorance which they may be compelled to exhibit when questioned

about the commonest objects around them. Is there anything wonderful in a lump of wood, or in a tallow-candle. ‘Wonderful! No,’ I think many a boy and girl would say, and so would many a one much older. To such I should reply—Well, take an atom of the dust of that wood, and halve it and its halves again and again till you can prove that *nothing* would remain; then, indeed, wonder itself might cease, for we could explain the whole substance of the thing away. And as to a common candle—I have now in my hand its form and body; it is of certain weight and dimensions, and its particles occupy a very small space; but I can do something to that candle by which these particles shall cause a globe of matter to exist five miles wide every way, and that before the candle is sensibly diminished. And, I would ask, is there nothing wonderful in thus disposing of a solid substance by *consuming* it, as we say? I should be

thought a conjurer if I could get rid of a rod of iron by a touch that should not move it, not impress it ; yet thus I do with a candle ; and till persons can inform me where and how that substance went—where and how it now exists—I must inform them that, however wise they seem to be on some subjects, they are IGNORANT with regard to the commonest things ; and this ignorance, if really wise, they will readily acknowledge. So much for the particles of matter, and the amazing fact that though they are infinitely too minute to be perceived by the body or conceived of by the mind, yet they form the vast globe on which we live, and the vaster spheres which revolve around us !

“ We are thus brought to consider another property of matter ; that is its *mobility*, or capability of being moved. Without this we cannot conceive of light, or heat, or sound, or animal existence, and we do not know of a

particle of matter in creation that cannot and that *does not* move. Yet matter cannot move *itself*, nor can it stop itself when once set going. One, at least, of my youthful auditors may feel surprise to hear me say this, when he knows — and I know it too — how many machines have stood still which were intended for nothing else but to accomplish *perpetual motions*! and that a pendulum *only* twenty feet long could not by the most *weighty* considerations be persuaded to vibrate except in diminishing degrees, until Patience herself was tired. But that pendulum would have vibrated until now, for the same reason that it did so at all, had it not been *forcibly* stayed by external causes. The resistance of the air through which the substance of a pendulum passes, and also the friction, or opposition of the parts at the point of suspension, although not sufficient to stop it instantly, have a constant and an unavoidable influence, which

certainly prevails at last, unless a superior influence be applied—that is, a maintaining power.

“I said that we do not *know* of a particle of matter in the universe which is not in motion. The earth and all planetary bodies perform vast and ceaseless circuits in the heavens, and with undiminished velocity. The stars we call fixed, because they appear thus to the eye; but we can by no means ascertain that they are really motionless; on the contrary, there is great reason to believe that these all revolve: some of them have been ascertained to do so. Yet it is quite true that, whilst matter continues moving, because it cannot stop itself, so it would remain at rest, because it cannot move itself, until acted upon by some external cause. Thus the feeblest understanding may perceive a proof of the existence and the power of Deity. Matter is in motion—worlds a hundred times the size of ours are

gliding through space with a swiftness we cannot follow with our thoughts: WHO gave these vast bodies this vast motion? GOD.

“That power or property of matter, by which it naturally continues in any state either of rest or motion in which it may happen to be, until acted upon from without, is called the *vis inertię* of matter;—a very useful principle; for if solid substances now at rest were, without any applied force, to leave their places, all the gravel-stones in the world might be about our ears in an instant;—again, if matter ceased to move the moment the force applied was withdrawn, the planets themselves would be arrested in their course;—and again, if the tendency of bodies to continue their imparted motion were not counteracted by various things on the surface of the earth, all the gravel-stones that ever had been thrown would continue to fly; millions of cannon-balls that have been discharged would revolve like so many perpetual

planets round the world ; nay, every particle of dust that has been moved since the creation would be travelling still.

“ These which I have been speaking of may be called *inactive* principles of matter. There are also *active* powers, which govern and influence it by mysterious and inviolable laws. What is it, think you, that causes the particles of which any substance is composed to combine together in a mass ? It is *attraction*, or the law of *cohesion*, that makes all the difference in this respect between a lump of iron and a quantity of sand. What is it that causes any substance to tend towards the earth, or *downwards*, as we say ? it is the attraction of *gravity*. What is it that causes the clouds in summer to assume that beautiful feathery form, stretching across the sky ?—it is electrical attraction. How is it that the loadstone draws iron towards itself, and that

the compass-needle indicates the north?—the attraction of *magnetism* it is which thus wonderfully acts. Then there is *chemical* attraction, a principle not so frequently under our notice, but as incomprehensible and as undeniable: but I must now explain by experiment.”

In order to exhibit some of the powers and operations of attraction, the lecturer now produced a polished iron ball an inch in diameter; it was suspended by a nearly invisible thread, and might well represent the earth as independent of external support.

“I may say first of this ball,” continued Mr. Lever, “that it exemplifies the attraction of *cohesion*; for, although it is composed of the same metal as these fine filings in the paper beneath, its particles are bound together so as to form a very hard substance and a regular and polished figure. The dust below cannot

be made to retain or to assume any such figure, because the particles cannot by pressure be placed sufficiently near each other to be thus attracted; and, therefore, although the weight of the filings is no more than that of the ball, the dust occupies evidently a much larger space, and cannot by any means be forced into this other *hollow* sphere, which, as you see, when opened, exactly contains the iron sphere. On the other hand, as many filings as this hollow ball would receive, I have had melted and cast into the form of another ball; you see it is less than half the size of the larger globe. The attraction of *cohesion*, therefore, detains the particles of matter in very close contact; but when those particles are forcibly separated, even though the distance be immeasurably small, the cohesion is destroyed.

“ But, whilst these atoms are thus mutually attracted towards each other by cohesion, they all obey another influence, that of *gravitation*

By this power all the bodies, compact or separated, in or on the earth, are constantly drawn towards its centre. This ball, therefore, and the filings also, are acted on by an influence which would remove them to that centre, if not obstructed in their progress thither. The attraction of cohesion, I have said, is destroyed by the smallest conceivable separation of parts; but that of gravity extends not only to all substances on or near the earth, but likewise evidently to the heavenly bodies, and thus it is that these are maintained in their appointed courses. I need scarcely remind any one present how necessary a principle the attraction of gravity is for our own planet; for, without this binding influence, the substances forming the earth would, as it swiftly revolves, fly off from it, as do the streams of water from a mop trundled on the arm.

“ This attraction, always towards the centre of the globe, explains to us the reason why

bodies on all parts of its surface press *on* that surface, even though as opposite as the antipodes to each other. Our feet, therefore, point to the feet of the New Zealanders; and if a hole were cut completely through the earth—if a well, for instance, were continued until an opening appeared on the other side of the globe—we should find ourselves with our head downwards, if we were to pass through with our bodies in their present position.

“The attraction of magnetism, however, will here make us better understand that of gravity. This iron ball, before mentioned, is itself a magnet; and now you see that the iron filings, when brought near it, place themselves thickly upon it, and adhere with some firmness to it, and, if these particles had the nature and form of men and animals, they would arrange themselves, of course with their feet to the surface, on all sides of the ball, as men and animals do now.

“Magnetism is a power that only acts on certain bodies, and is particularly observable in certain directions. I suppose all the present company are aware that the mariner’s compass is an instrument which depends on magnetism for its faculty of indicating the north. Many amusing and beautiful experiments may be performed with a piece of iron to which the magnetic influence has been communicated. Hence iron filings arrange themselves in streaming or branching figures, when placed on a paper under which the magnet is moved.

“Electric attraction,” added Mr. Lever, “you see, may be quickly excited by the simple process of rubbing a piece of rosin on my coat sleeve. There! you see now how it attracts the fleecy down of these feathers, which appear as if blown by the wind. The effects of electricity may be rendered visible in the form of sparks, with the aid of the electrical machine.

“The attraction of chemical affinity I think I can exhibit clearly to all my friends present by the mixture in this phial. You see it is of a clear blue colour : it is diluted nitrous acid, in which a portion of copper has been dissolved ; no remains of it however are to be discerned in the liquid, nor would any settlement of the metal take place in a hundred years. But now, observe ! I introduce this polished steel ball by means of a waxed thread, and by holding it immersed during half a minute it becomes — see ! — covered with a beautiful coat of bright copper, which may be easily detached in separate films like gold leaf !

“These,” said Mr. Lever, “are some of *the laws of nature* — so we speak — by which matter is constituted and governed. Of these laws, however — their cause or origin, I mean — philosophers can give no explanation at all without referring us to a FIRST CAUSE. It would indeed be quite as easy to account for

the flowing of a river *up* the side of a mountain as *down* the side of a mountain, by our own powers of reasoning. We could not understand the actual means of motion in one case more than in the other. We are too apt to forget this, and to think that every thing is made clear, when we find that any effect results from the influence of one or other of these appointments of Nature; whereas we are ignorant of every thing but the mere outside of the mystery in debate. Certain persons of whom I have heard were lately favoured with the exhibition of a revolving paper globe,—young gentlemen, I beg pardon if I startled you, but I am happy to see that I have awakened a sudden interest;—I say, the party in question viewed that revolving sphere with astonishment, unable to account for its motions; but presently a strap was discovered connected with a machine close by, and then, I understand, some appeared satisfied that the

wonder was at an end ; yet that second machine furnished no clue to its *own* motions—causes could be traced no farther. Now, suppose—[here Frank and his father exchanged a nod]—suppose that this machine enclosed within it a cylindrical cage of wire, such as I have frequently seen containing an imprisoned squirrel, whose sole labour or amusement consisted in mounting the yielding yet unvaried steeps before him, like a tread-mill felon ;—I say, if the party had made *this* discovery, they would have had more reason to say ‘the wonder is at an end!’ But philosophers have never yet removed the veil from the cause next beyond the natural fact before them ; and if they could, perhaps it would be found that the difficulty was only removed one step. The squirrel moves the cage—but what moves the squirrel ?

“Ladies and gentlemen, I feel honoured by your company and attention this evening.

Having taken some notice of the powers and laws of matter, I shall in my next lecture attempt to show the method of certain human operations upon it by means of THE MECHANICAL POWERS."

CHAPTER VII.

LECTURE ON THE MECHANICAL POWERS.

“THE subject to which we are to attend this evening,” said Mr. Lever, “forms the first chapter in experimental philosophy, which is learned by man either in the infancy of his own existence or in the early days of the community of which he is a member. The child finds out in practice, long before reason assists him to discern principles, that there is a way of handling substances in general which is calculated to effect his purposes, and a way which would disappoint him. His stick or his toy may displease him, and, in the determination to be rid of it, he flings it to a distance, and learns to impart more force in so doing than would be sufficient

to place it out of reach. His step fails him on one side, and he throws out his arm on the other; thus doing all that he can by weight and lever to restore the balance to his body. With his little hammer and a nail he exemplifies *more* than a philosopher could explain of the power derived from a travelled blow; and, in the various childish efforts at construction, he becomes to a certain extent a mechanician long before he has any knowledge of the theory of mechanics.

“And so, in the early ages of society, men are compelled to be mechanics and engineers to a certain extent, in order to supply the commonest wants of life. The tree must be riven by the wedge, raised or rolled by the lever, perhaps elevated as a roof-beam by the inclined plane, even though the operator be ignorant of those powers as such, and could in no way explain how the advantage was gained thereby. But, unless the understand-

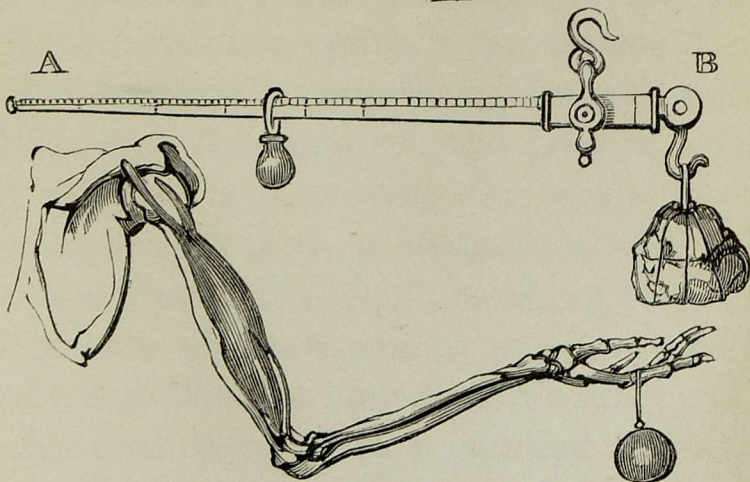
ing performs its part, the labour of the body is oppressively severe in accomplishing the simplest operations on hard or heavy masses : we see no signs of intellect or of civilization until *mechanics* has been to some considerable extent understood as well as practised by mankind.

“ But many persons pursue mechanics as an amusement, with a strange indifference towards the study of its principles. Ingenious youths will employ months, perhaps years, in the idle combination of wheels and weights and screws and bars, content with no other result than the whirl, the rattle, and the disappointment they occasion ; thus rendering their very ingenuity, which often is considerable, an occasion of loss to themselves, and of vexation, perhaps alarm, to their friends. The vain hope seems to be that some splendid *discovery* will be theirs, who take no pains to acquaint themselves with what is already known and

possessed by others, and who would not distinguish a pearl from a pebble if placed before them. I have not so much as hinted, that to *any* of my present company these remarks belong; but, if any of my young friends should see reason themselves to apply them, let me add, that the study of principles and of the reasons of things, *connected with practice*, has always been found more really agreeable, as well as more profitable, than the most curious operations of those who have wrought without knowledge and therefore without light, without study and therefore without a head!

“The first of the mechanical powers is always held to be THE LEVER, and it was probably the first instrument that was invented to aid the powers of man. A stout stick, a pole, a bar of wood, may readily become a *lever* in the hands of a man, and, thus furnished, he can perform alone a task which

twenty assistants perhaps would not be able to accomplish. A tree weighing many tons might lie across his path till his own last steps were taken, but for the aid afforded by a straight arm detached from its own branches. Levers are of three kinds, and we have all of them in common use without perhaps being aware of their importance. A lever of *the first order* is a bar of any kind supported *near* one end by a prop, block, or *fulcrum*, as it is called (see Plate 8); the resistance is then encountered at the end beyond the block, whilst the power is applied to the other extremity. Thus, a man digging with a spade, (see Plate 4,) having thrust the instrument into the earth, bears with a certain force on the handle: the ground behind the spade then becomes the *fulcrum*; the earth in front is the weight to be overcome, and the length of the tool forms the power of the lever; and, if the



length of the handle be six times that of the iron in the ground, the man will detach a mass which would require six times as much exertion on his part if his strength were applied without such aid. But a common pair of steel-yards will explain this easily and accurately to any who will take the trouble to consult them. An inconsiderable weight is there made to balance masses, which in common scales would outweigh it a hundred times; and thus a ball suspended by a hair might be made to uplift a house, could a lever of sufficient length be applied and supported well. But observe: the lever I have here adjusted will correct the mistake of supposing that it is *as speedy* as it is *powerful* in its operations; if a man's hand, by bearing with a force of three pounds on a lever, will sustain three hundred pounds at the other end, then his hand must move a hundred times as far as that weight is lifted, and of course,

therefore, it must move a hundred times as quick. See! here is a brass bar thirteen inches in length: at the distance of an inch from one end is a fulcrum or supporting pin; now, I hang a weight of one pound at the long end, and twelve pounds at the other shorter extremity; the bar is balanced with its load; and you will see by this index that, whilst the heavy weight rises one inch, the small one travels twelve inches when assisted by a small addition to make it preponderate. The *steel-yard*, represented in this cut (plate 4), is adapted for weighing meat, &c.; the short arm B, by an increase of size, is made to balance the longer one A; from the hook or point of suspension and motion, the bar is divided into equal parts, each part equal to the distance between B and the fulcrum. The weight of one pound will serve to weigh anything of its own weight, or of greater in proportion to the length of the graduated arm; if

one pound be placed at the first division on the longer arm, it will balance one pound at the shorter, and if farther removed to the second, third, or fourth division on the bar, it will weigh two, three, or four pounds at B.

“ A lever of the second order has the fulcrum at one *extremity* and the power at the other as before; the resistance then takes place at some point *between* the two ends; the effect is the same with regard to time and power as before: the less the distance is between the fulcrum and the resistance in proportion to the whole length of the lever, the greater is the power of the operation, and the longer is the time required. In removing timber logs of moderate size along the ground, a lever of the second order is *usually* employed, because it needs no block—the earth is the fulcrum when the bar is thrust beneath the tree (see the cut); and thus by successive inches a resistance is overcome, a work is accomplished,

by one man, which might have surpassed the mere muscular strength of a dozen. When a load therefore is supported on a pole between two persons, the strongest man should have the weight nearest to himself, as every inch of distance makes a sensible difference to the shoulders of the bearers.

“ But there are some cases in which it is needful to reverse the principle we have considered, to *gain* time at the expense of power, and to raise a weight of one pound twelve inches, by an exertion equal to that of twelve pounds moving one inch. In *human* contrivances this form of the lever is less frequently employed, because *time* and space are things of less importance generally in mechanics than power or force. But Nature operates in a different way, being able to communicate any needful degree of power ; and thus the limbs of animals are levers of the third order ; the fulcrum is at one end, the power is applied *very near*

it, and the weight to be raised is placed at the remote extremity. Here," said the lecturer, pointing to a diagram on the wall, "is a representation of the thing I mean. The bone of a man's arm is the lever, the elbow-joint is the fulcrum, the muscle drawn as a cord from the upper arm is the power, and a ball suspended from the fingers is the resistance to be overcome (see the cut). The muscles, by swelling in the middle, shorten in length, and thus move the bones in the direction needed ; and it has been calculated that the power exerted by this muscle, which bends the arm, in an ordinary man is equal to a resistance of three hundred pounds, whilst that of the lower jaw is much greater ! One man, a carpenter, celebrated for his strength, could readily lift eight hundred pounds. He rolled up a strong pewter dish with his fingers, and bent a poker an inch in diameter to a right angle — that is, so as to form two sides of a square — by striking

it on his arm ; and he repeatedly bent and unbent another about his neck ! Such is the machinery of the human frame.

“ The mechanical power next in order is the pulley ; an engine, though simple enough to us, yet not so likely to be contrived or formed as the lever, the wedge, and the inclined plane. It is a mere grooved wheel, called a sheave, moveable on an axis or gudgeon, and enclosed in a kind of case or block. A cord passed over this will only enable a man to draw up a weight equal to that which his own body supplies in pulling downwards. (The cut, plate 5, exhibits different kinds of pulleys, figs. 1. 2. 3.) Here is no increase of power or loss of time, but a mere convenience of operation, for a man’s own weight thereby assists his muscles in the task ; whereas by lifting the weight with his arms, his legs would have his own full weight and that of the lifted substance to support.

Fig. 1.

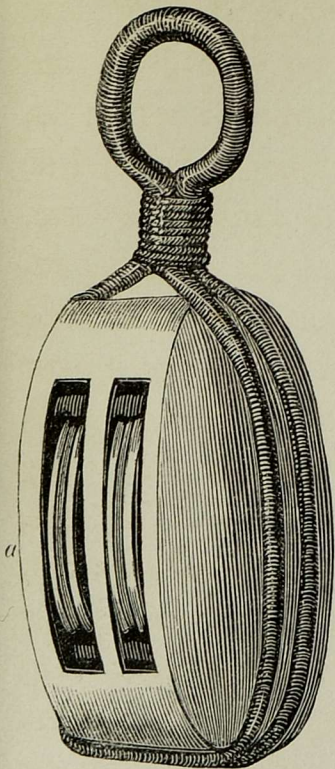


Fig. 2.

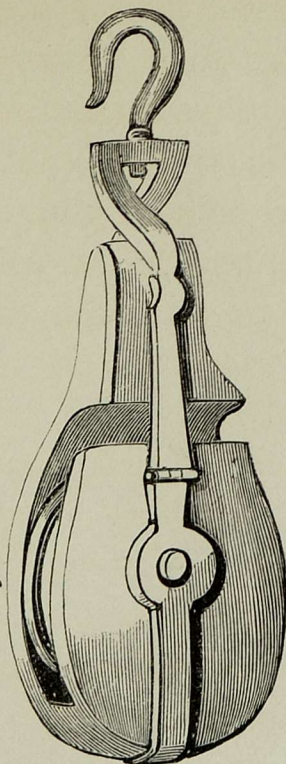
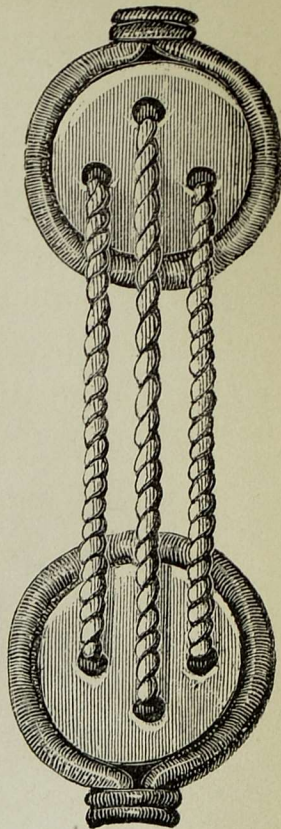
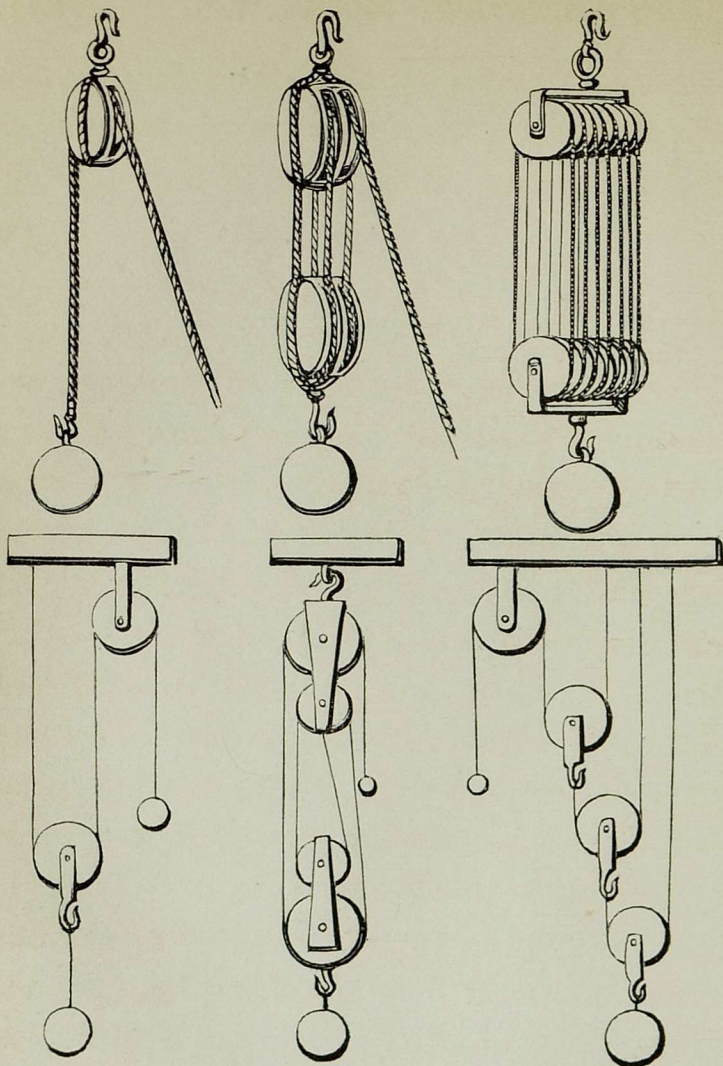
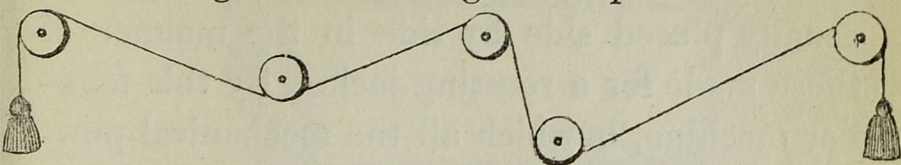


Fig. 3.





“The advantage of such pulleys is seen in fig. 4. as they alter the direction of the power, descending or ascending as required.

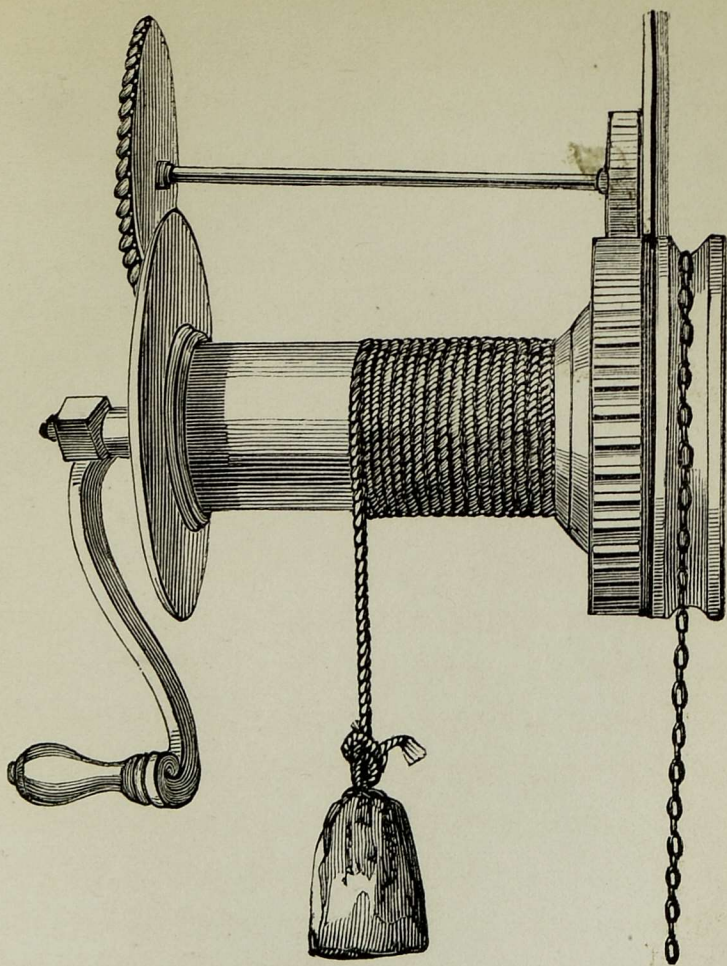


“If we combine a number of pulleys, we have as many assistants as there are wheels; and thus any weight, however large, might be raised by a weight however small, if our workmanship and materials were so perfect as to give the complete result. It is easy to see, for instance, why two pulleys placed thus should have double the force of one; because half the weight is sustained by the frame to which one end of the cord is attached, but then it requires *double the time* to do the work.

“By employing a series of moveable pulleys (see plate 6), a still greater mechanical advantage may be obtained; so that if four pulleys be connected by means of three different

cords, and a force of one pound exerted, the first will give two pounds, the second four, and the third eight pounds. But pulleys are usually placed side by side in the manner of those made for a roasting-jack. By this familiar machine, in which all the mechanical powers are brought together, a hundred weight of iron is raised by a winch which a child could turn with ease. Here the weight *ascends* slowly, but it *descends* far more slowly; thus the operation of the machine is protracted to save the trouble of renewing its power more frequently.

In illustration of the wheel and axle I have made a drawing, representing part of the old jack, the property of a certain philosopher (see plate 7). The wheel and axle is employed in numerous ways to serve the useful purposes of life; to this power we may refer all sorts of cranes, capstans, windlasses, &c. The advantage gained is in proportion as the circumfer-



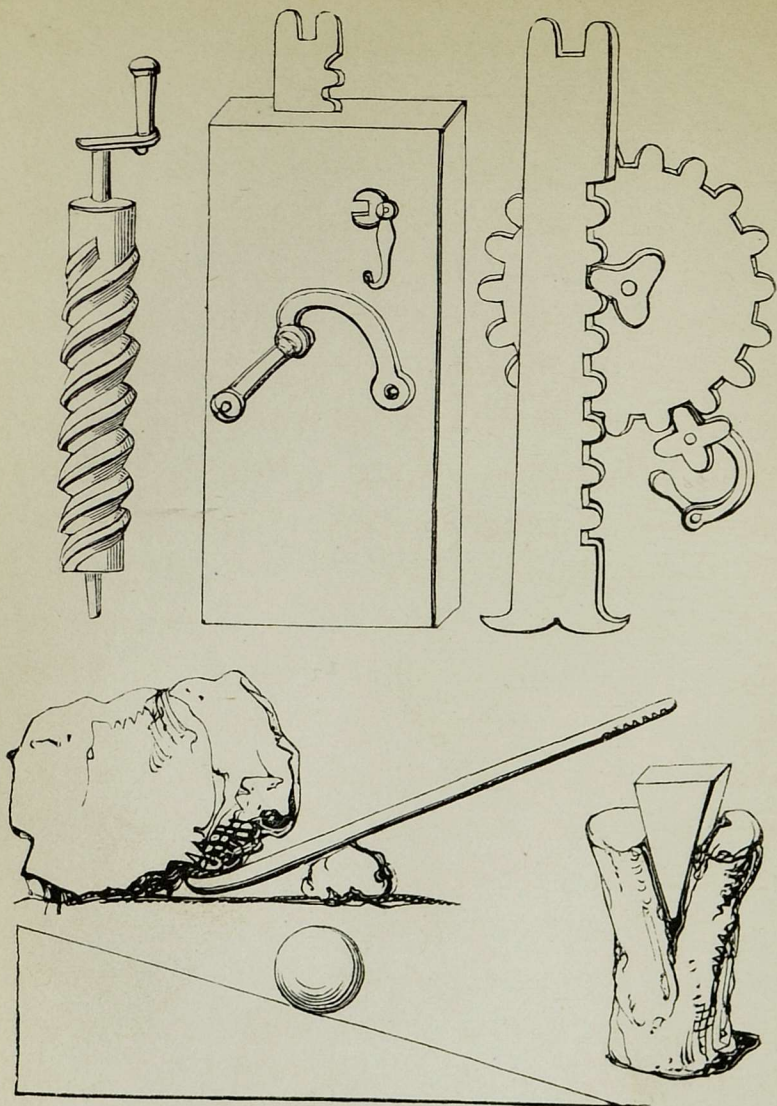


PLATE VIII.

LEVER OF THE FIRST ORDER.—INCLINED PLANE.—WEDGE.—SCREW.—JACK.

ence of the wheel exceeds that of the axle. In this design the rope coils on the axle, and we have a winch instead of a wheel; for in turning the winch the hand will describe a circle, and there is no difference in the result, whether an entire wheel be turning with the hand, or a single spoke of the wheel, which the winch, as a lever, here represents. If the proportion of power were three to one, then one pound at the winch would balance three in the bag.

“ The *timber-jack*, which some of us remember as the instrument by which even *houses* are raised, and through the failure of which they are sometimes brought to the ground, consists of a wheel and axis, acting however not by a cord, but by a toothed rack and pinion, like this (see plate 8), described before, page 29. The power of the lever is here very great, and it may be increased by additional wheels, until a child could raise a church; but the effect would be slow in proportion.

“ The *inclined plane* is reckoned the fourth mechanical power ; it forms simply a gradual and sloping, instead of a sudden and perpendicular ascent, by which heavy bodies may be raised to certain heights (see plate 8). Thus we raise our bodies with little sensible effort to an elevation of one or two hundred feet by walking up a hill a distance of half a mile ; but the same altitude, if direct, like the ascent by an upright ladder, would be an extremely laborious and painful task. It is more than probable that the vast buildings reared by the ancients were accomplished by the slow means afforded by sloping planes. The power necessary for raising a weight thus depends on the difference between the length of the plane and the height to be ascended. If the height is one-third of the length, then one pound will lift three times that amount.

“ The *wedge*, which is the fifth power, differs

not essentially from the inclined plane. It is like two inclined planes joined together at the base (see plate 8). The chief use of the wedge is in penetrating and separating hard and heavy bodies. The largest masses of timber may be by this means riven, and vessels of war, weighing many thousand tons, are lifted from their supports by the power of a few men exerted by blows on wedges inserted for that purpose.

“The *screw* (plate 8), is the last in order of the six mechanical powers, yet I might almost say, the first in utility and influence. It has been said that the screw has in fact an inclined plane coiled round a cylinder. It however admits of a continued circular motion, and has the advantage of a lever to turn it round, so that the power seems only limited by the strength of the frame in which it works. There is no mechanical implement as such that has so universal an application amongst artificers

as the screw. The tiny atoms of steel which are wrought into this form for watch-work would surprise many by the minute perfection of their execution. By these the artist binds his work securely together, or loosens it, at his pleasure. For purposes where a great amount of power is wanted, the screw is made of proportioned bulk and strength, and then it is almost irresistible in its effects when well lubricated with oil.

“And now,” continued Mr. Lever, “I must observe that these powers, as they are perhaps not quite correctly called, are as often misunderstood by those who superficially examine them, as by those who quite neglect them. If we form a right conception of them, we shall find that there are in general two methods of overcoming the gravity or other resistance of solid bodies ;—one is by a direct but difficult exertion of mere strength ; the other by an easier but slower and more conti-

nued employment of *strength* by the aid of implements or engines. A machine is not like a giant, who can carry great weights and take long steps at the same time. If a man wished to make or to remove a mountain of earth, he would gain nothing by employing engines to lessen the real amount of his operations. If he be even able to convey one hundred weight to a certain height in one minute, no mechanical engine will enable him to raise three hundred weight to the same height in the same time; but the machine would enable him to convey three hundred weight in three minutes. Thus every hundred weight would, as before, require a minute to convey it; but the advantage is this, that a machine, by taking as many minutes as there are hundred weight to be removed, can operate on masses which could not be divided into portions. A man, though he may raise the hundred weight in one minute, could not raise a thousand weight

in ten minutes, unless he could part it for his convenience.

“ The mistake of many, who have endeavoured to construct an engine which should have *perpetual motion*, seems to be this, that they imagine a real power may reside in a mere machine independent of any external cause. Such a power *does* reside in the animal machine, but it is THE POWER OF LIFE, the express gift of the Creator. It does *not* reside in the heavenly bodies, though they continually move, as we have seen before; they only revolve because they once received motion from some external cause, and they have no resistance to encounter: *they have not power to stop*.

“ The skill and the wants of man have, from age to age, combined and varied, improved and invented, implements and machines by which at length the vast demands of civilized society are nearly satisfied. The elements

which produce the food of man are detained till they have prepared it delicately for his use ; for the breeze and the flood fructify the blade, and they urge the groaning wheel, which grinds, and sifts, and fans the precious particles in the elaborate machinery of the mill. The reel and the loom add fibre to fibre, and thread to thread, of the stalk or the fleece, till Nature scarcely recognises her own production. Masses, which slept securely for ages in their rocky bed, have been riven from the quarry, uplifted, and conveyed on the bosom of the wave to climes the most distant : and thus the fair marble of the southern lands glistens on our rugged northern soil by the slow but mighty force of tools and engines. The waters now mount and flow at our bidding, and rivers rush upwards by the incomparable force of their own imprisoned vapours. Time himself has his portioned work, and is brought

to a reckoning for a second in a year by machines which traverse the globe and confront him with his ruling powers.

“Philosophy has indeed done wonders with her implements and machines : worlds of existence have been brought to our view by the lenses and the tubes of modern times ; worlds of atoms, teeming with life, have been discovered in the dust or the drop which the naked eye scarcely perceives ; and the tiny spark, which was for ages unnoticed in the dim horizon, has been expanded and defined, and registered, with its attendant worlds, in the many-leaved but yet imperfect book of human knowledge.”

Mr. Lever, having finished this lecture, announced his intention on the next occasion of addressing his young friends more at large on the nature, structure, powers, and uses of modern machinery.

CHAPTER VIII.

LECTURE ON MACHINES—MILLS, AND OTHER
ENGINES.

IN the former part of this little book we have endeavoured to give our readers some hints of various kinds connected with mechanical subjects, as the narrative gave us opportunity. The operations of men and of youths have been observed and noted, and these have given rise to conversations on scientific principles, and on the works of ancient philosophers, engineers, and mechanicians. We have listened to two of Mr. Lever's lectures on the nature and laws of matter and of motion, and the mechanical powers. That gentleman glanced at some of the amazing results of those powers when combined in the form

of compound engines, and referred to the uses which, through these contrivances, are derived from the movements of the elements around us. We must now attend, whilst he describes in a familiar manner a few of those celebrated machines to which society is most indebted.

“We are this evening,” said Mr. Lever, “to take some notice of those machines called MILLS, by the powerful operations of which those vast results are accomplished which are called for by the incessant wants of the individuals that compose a nation. The word *mill* properly denotes a machine for pulverizing or grinding such substances as corn or pulse; and thus two flat stones, moved by the hand, have borne the name, and in this way, in the early ages of the world, corn was actually prepared for use. We shall not have time to trace the progress of invention, whereby the task was performed with better success

and with less labour in succeeding times. Human or animal strength, we know, was long employed, and is now in some parts of the world, and in not a few places the toil is assigned to women. It was a noble exercise of mind which first produced the thought of employing the powers of nature to relieve the straining limbs of those who heretofore toiled, not less in preparing the grain for food, than in tilling, sowing, and reaping the spreading field. It was a profitable flood, a gainful blast, that first conveyed intelligence to man that the power by which his frail hut had been so often shaken, and perhaps borne to the earth, was equally able and ready to become an unwearied labourer in his service.

“Such, for instance, is the wind. Those swift currents of the fluid air, whose effects are so conspicuous around us in the flying clouds, the boisterous ocean, and the waving woods, are far more fitted for accomplishing the con-

tinued and powerful movements of machinery than are the united efforts of numerous kinds of cattle or companies of men. The same may be said of those numerous streams of water that urge their winding courses from the hill-sides to the sea. Man has but to prepare an engine to receive the impulse from these powers, and then he is not required to turn a single wheel by his own strength.

“ The manner in which the wind acts on the sails or vanes of a common windmill (see plate 9), is, I apprehend, not sufficiently understood by many persons. These four sails, it is known, face the wind, or very nearly. Now, how is it that the sails receiving the current of air in front, *turn round* in one direction, and do not, like some other things, proceed with or recoil from the blast? Those who have not yet attended to this subject may easily comprehend it by consider-



PLATE IX.

COMMON WINDMILL.

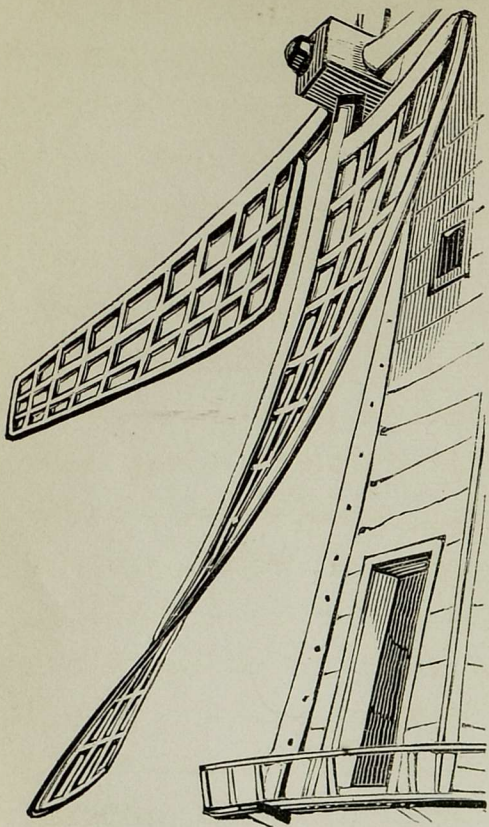
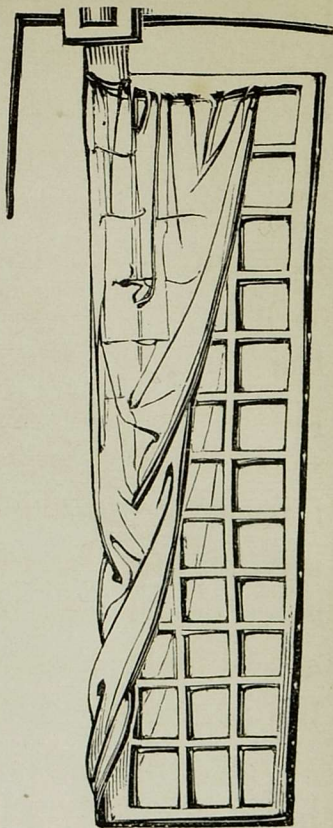


PLATE X.



Page 161.

WINGS OF A WINDMILL.

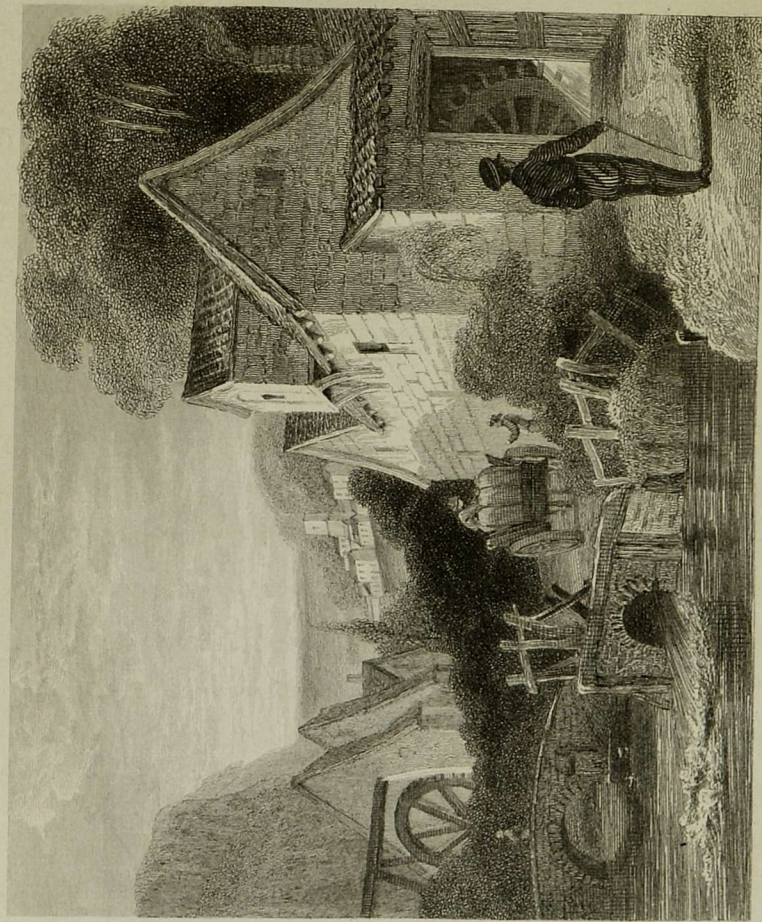
ing that the ladders on which the cloths of mill-sails expand are inserted in a slanting direction into the sail-beams, and thus the wind acts on inclined planes (see plate 10). These of course recede from the power in the only direction in which they can move at all; as the latch of a door, when it meets the inclined surface of the catch in the door-post, is thrown upwards by a power that would seem to act in a way to thrust the latch forward from the door. Thus vessels at sea are enabled to sail very well indeed with a side wind; the sails being set obliquely to act as inclined planes, sliding from the wind, but not following its course.

“It is evidently needful, however, that wind-mills, being thus constructed, should properly face the current of air from whatever quarter it may blow. The mill, therefore, or its head, is made to turn on an upright axis, or on rollers; and is either moved round by

force applied below on the mill-path, or it is adjusted without that trouble by a kind of fan behind. This has many vanes, and turns with a very slight breeze coming from either side: as it turns, it works the mill-head slowly but duly round by a toothed wheel and pinion, until the four sails are again in the required position.

“The action of a water-wheel for a water-mill is, perhaps, more readily comprehended. If any one will take the trouble to thrust a garden spade into a running stream, so that the water meets the broad surface of the implement, he will perceive that it requires a considerable exertion of strength to resist the force of the current, which would carry the spade iron before it.

“It is very easy to conceive, therefore, that if a number of arms or spokes, with float-boards at their extremities, are fixed in a cylinder or axis properly supported, the whole apparatus



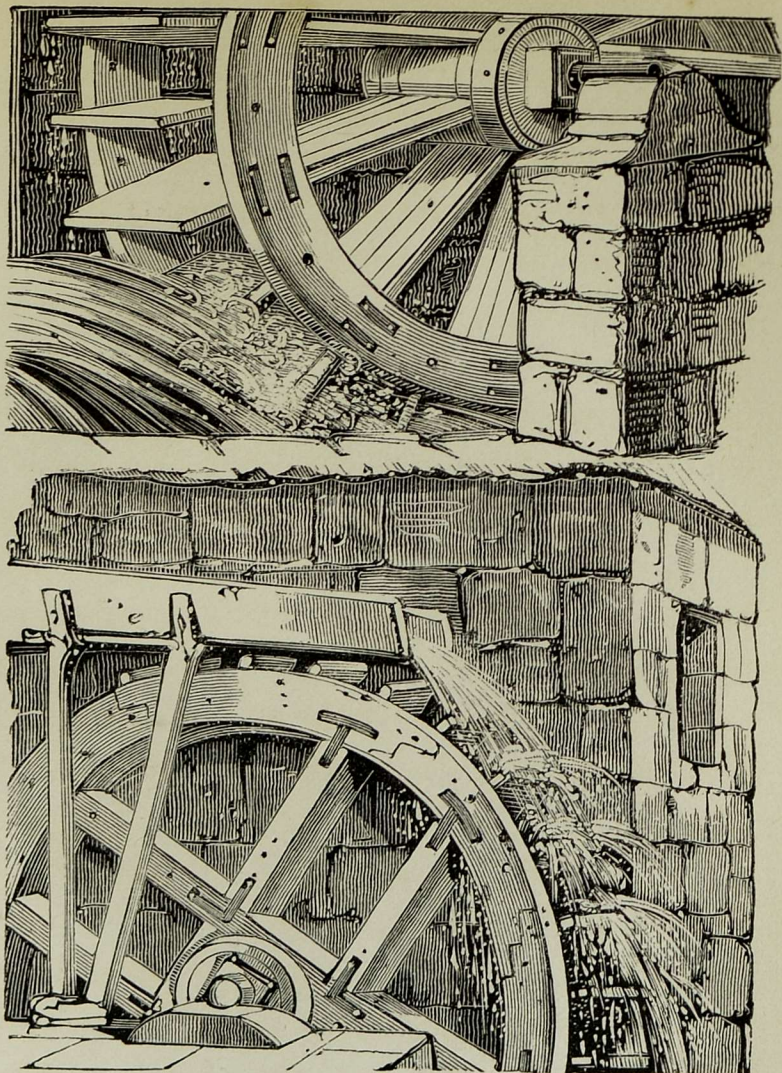
Undershot & Overshot Water Mills.

will revolve by the action of the water against those boards in succession. The force, quantity, and nature of the stream, however, being very different in different situations, wheels of various structure are required. These are chiefly of three kinds, named *breast-wheels*, *undershot-wheels*, and *overshot-wheels*. We can soon understand the distinction. In a breast-mill the water falls down upon the boards of the wheel from as great a height as can be obtained, by forming a dam or bank across the river, and allowing the water to flow over in one narrow place or sluice-way. I believe this is the most frequent form of water-mills; but it often happens that the stream being naturally insufficient to continue a constant discharge of the required power, the water must be detained occasionally by flood-gates, and it is only when these are drawn up to give a passage to the river that the mill goes. The more height the millwright can

obtain for the fall of water, the greater is its force in driving round the wheel.

“ When the stream is sufficiently copious and rapid, it will turn the wheel by merely having the float-boards immersed in it to a convenient depth. This is an *undershot*-mill (see fig. 1, plate 11). In an *overshot*-wheel, the water is poured over the top, and thus acts chiefly by its weight (plate 11, fig. 2).

“ And now, what I have to say respecting mills for grinding corn will apply equally to those driven by water and by wind. It must be borne in mind that the process of grinding is in these, as in ancient hand-mills, performed between two stones. Stone is a heavy material; and if it is to be moved with rapidity, and has needful dimensions, it requires a power greater perhaps than we may at first suppose. The two circular stones of a flour-mill are usually about six feet in diameter, and six or eight inches in thickness. The nether or under mill-



stone rests and is firmly fixed on its timber frame. The upper one, which is supported at a very small distance from it, revolves at the rate of about sixty or seventy times in a minute, and its weight is generally about nineteen thousand pounds! The circumference, therefore, of this ponderous mass travels at the rate of twelve or fourteen miles an hour, and would journey that distance in the time if it rolled upon its edge! Without this swiftness, or something near it, the grain, which is poured and jolted in from the top, would not find its way out at the edges, nor be reduced to meal. It is well, therefore, that adequate powers can be found and adapted for accomplishing such a motion.

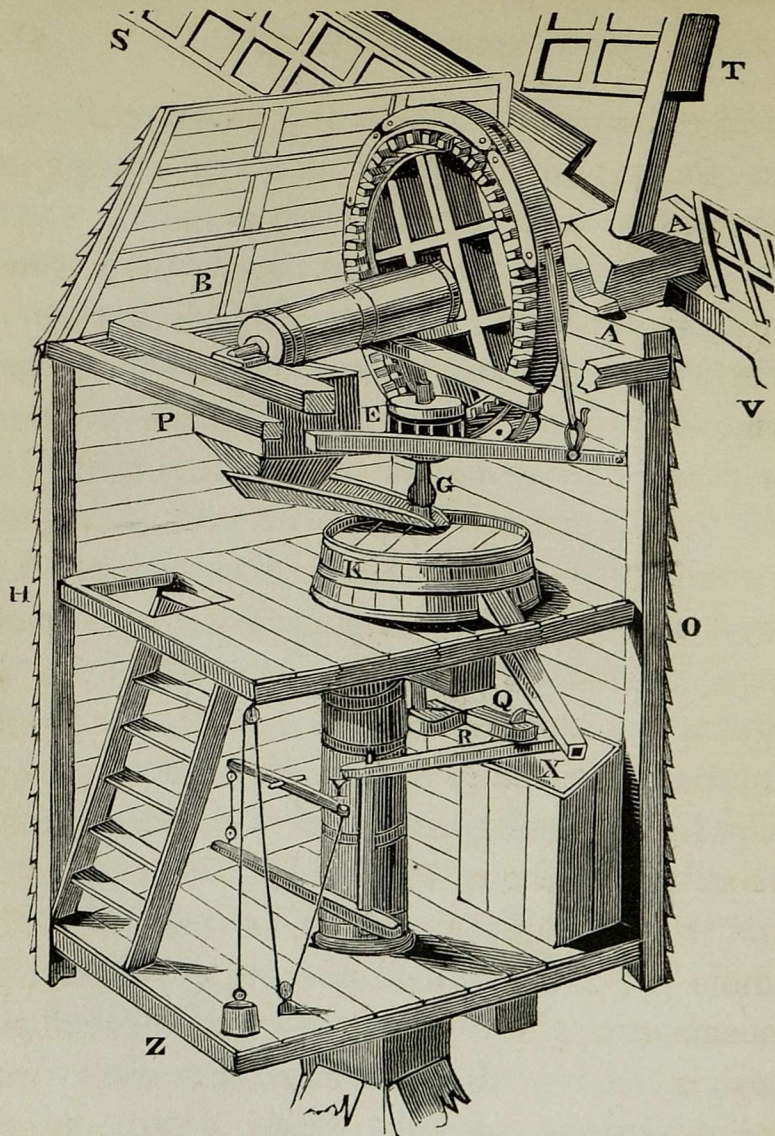
“ I must beg my young friends to examine with me the drawings here prepared — sections of the common water-mill, corn-mills, &c. This is a water-mill (plate 12) to drive only two pair of stones, others will drive three and even six pair

at once. The wheel marked A B is the great water-wheel; c, its shaft or axle; D, the outer wall; F, a wheel fixed upon the shaft c, containing ninety teeth or cogs, to drive the *pinion* G, as such a little wheel is called, having twenty-three teeth, and this is fastened on the upright axis, E. P is a wheel fixed upon the shaft E, containing eighty-two teeth; this wheel has fifteen teeth to act upon and drive round the pinion Q; the iron axle of the pinion supports and carries round the millstone at the rate I have mentioned. I is the beam that supports the frame on which the under millstone rests. There is a case or box to enclose the upper millstone. There should be about two inches distance from the stone to the box all round. K is the bearer, called a bridge, on which the under end of the iron spindle turns. This spindle passes upward through a hole in the middle of the lower millstone. The top end of the spindle fits into iron crosses fixed in

the upper stone, and thus it is sustained and turned round. *r s* is the feeder, which supplies the corn to the stone; this has a trough, *o*, also called a shoe, which is continually shaken by the four corners of the quickly-revolving spindle. Thus the grain is delivered according to the rate at which the mill goes.

“ So much for the grinding part of the mill. The meal produced from between the stones is however very far from being fit for use, according to our present notions. The husks of the grain are mixed with the flour, and must be separated by other means. The upright shaft has another toothed wheel fixed near its top, which turns a smaller one with great rapidity, having a horizontal axle, and at the other end a cylindrical box or drum. On this works a broad leathern strap, which extends for convenience to a distant part of the mill, where it gives swift motion to hollow cylinders of wire, canvass, or muslin.

These, as they circulate, have their sides beaten by projecting shelves of wood; and, the whole being enclosed in a sort of closet, the flour is detained, and the coarser parts are separated according to the degree required. I regret that our drawing does not show this part, or the apparatus in the roof of the mill contrived to draw up the sacks of corn from below. A long chain, to which the sack is fastened, goes round the roller on high, which is turned by a wheel brought in contact with the going parts of the mill by pulling a separate cord. When the sack arrives at the top, it pushes one end of a lever, and thus instantly prevents itself from being drawn too high: a man is waiting above to wheel the sacks to their destination on the mill floor, whilst another below wheels others under the chain and fastens them securely. There are grooves cut in certain directions on the grinding sides of the stones which exactly coincide when



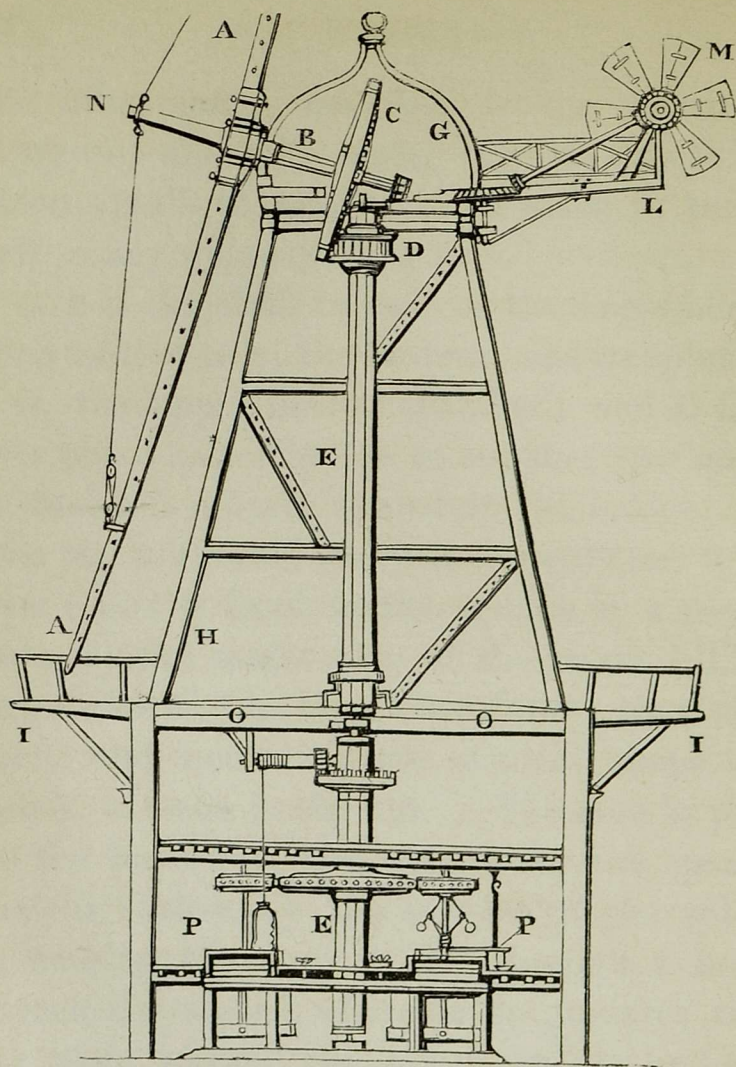
brought together. Thus the grain partly enters the various channels and is crushed against the corners before it can escape.

“These are the essential parts of a flour-mill, by whatever power it may be set in motion. Of course, there must be a somewhat different arrangement when wind, steam, or other means than water are employed.

“Plate 13 represents the interior of a post-windmill. A strong post is driven securely into the earth, and braced or supported with slanting timbers on all sides to within ten or twelve feet from the top; this post is rounded, and passed through the flooring of the lower part of the mill till it reaches the second floor; it is there fixed in a proper socket, and to a strong cross beam sustaining the whole weight of the mill-house, so that, by means of a pivot fastened on the part of the post which enters the socket, the whole mill can be moved to face the wind. There are

some other parts, not seen in the drawing, to prevent the mill being turned about by sudden squalls of wind, and to assist in turning it in any required direction.

“ A B is the shaft or axis of the cog-wheel, giving motion to E, the lantern, and its spindle G ; H, the upper floor or chamber ; and Z, the lower one. Q is a bridge to support the spindle, and R is a beam to sustain the bridge. K is the top millstone, which is the only one that moves ; and is fixed to the spindle by a piece of iron at the under side of the stone. The lower millstone is somewhat larger than the upper, and occasions the conical shape of the box, as seen in the cut. The corn is put into the hopper P, and runs along the spout, which is shaken by the motion of the spindle, causing the corn to fall through a hole between the stones, where it is ground ; the flour then passes the lower spout, and is deposited in the chest X. Y are levers which



may be connected with the stones to raise or lower them. s t v are the sails, which move in the order of the letters from s to v.

“Here (plate 14) is a vertical section of what is called a smock-mill, which is considered as the best kind of windmill. p p, the walls of the house; o o, strong timbers forming a roof to it; upon these are erected eight principal timbers, h h, to form an octagonal pyramid of carpentry, the sides of which are filled up by diagonal bracing and small uprights to nail the boarding to. The four sails, two of which only can be seen, marked a a, are fixed on an iron axis, b n, by screwing them to an iron cross formed at one end of it. Upon the axis, within the mill, the cog-wheel c is fixed, and this turns a trundle or lantern, d, fixed on the upper end of a strong vertical shaft, e e, extending from the top to the bottom of the mill, to turn

the machinery: on the lower end of it is a large wheel which turns two smaller ones upon the spindle of the millstones. Above this is a wheel upon the main axis, giving motion to a pinion on a horizontal shaft or roller, which has a rope wound round it to wind up the sacks of corn. The upper part of the mill, called the head or cap, is marked G. A small pair of sails or fans, M, fixed up in a frame, L, projecting from the back of the head, which can be turned by means of wheels, and at the same time moves the head of the mill slowly round. I I, is a circular gallery all round the mill, which enables the miller to take the cloth off the sails in high winds, or when the mill is to stop.

“ In the construction of mills great skill is requisite to direct and apply the power in a proper way; wheels, cogs, &c. of many

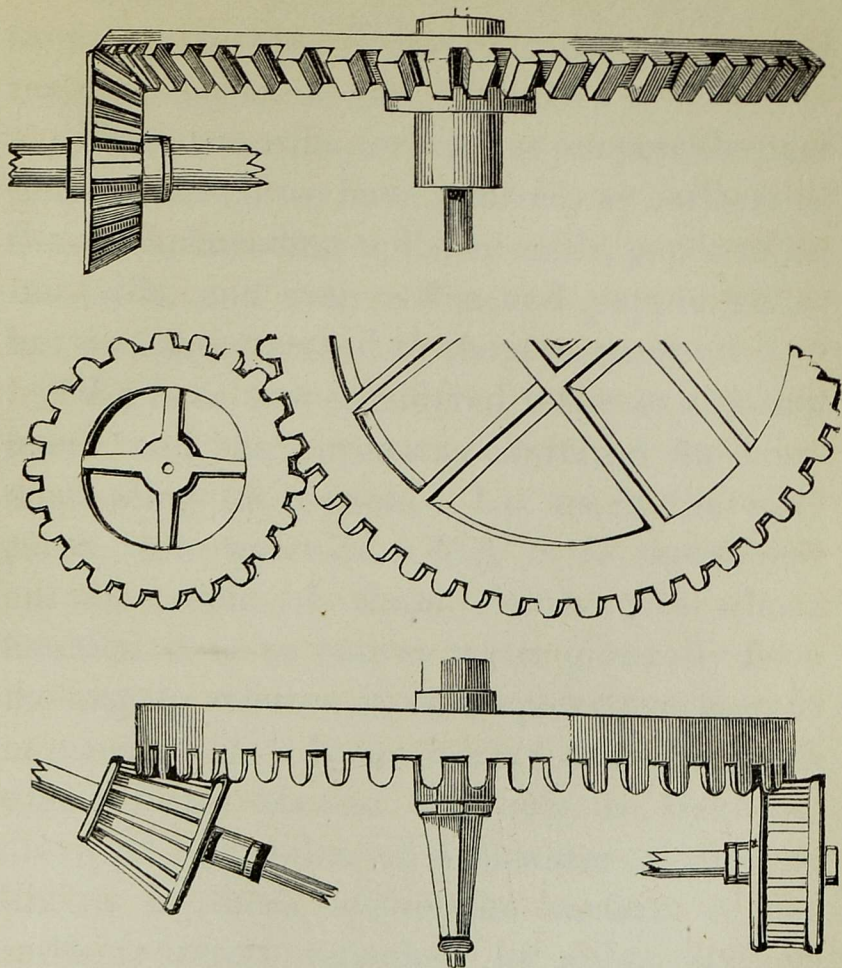


PLATE XV.

forms are in use. I have drawn one or two for your inspection (see plate 15).

“There are mills for various purposes besides those to which we have referred, as bark-mills, flax-mills, kneading-mills, oil-mills, paper-mills, saw-mills, and even coffee and pepper mills; but we cannot attend to them at present.

“We have now considered water *as a moving power*, and the apparatus contrived for communicating its motion. Let us, in the next place, view water *as a body to be moved*, and examine some of those contrivances whose function it is to convey water generally from the depths whence it is frequently necessary to procure it. In a country like England, where rivers abound and rain is frequent, the need and value of well-water cannot be felt as in lands where the surface of the earth is rarely refreshed by either streams or showers. However, so important a com-

modity is water, especially amongst a highly civilized people, that, even in Britain, numerous wells are dug, and therefore the methods of procuring their contents must be understood and practised to a great extent.

“We will then suppose that a well is sunk twenty feet deep, and that the crystal fountain bubbles from its bottom and rises a foot or two therein. It is sufficiently obvious that those who removed the earth from that depth by cords and baskets could also raise the water by cords and buckets; and the expedient of coiling the line round a roller was, there is no doubt, resorted to in very early ages, and with this method men were long contented. But, in process of time, it was discovered that water would rise by other means than the simple one of direct labour applied to lift it. The ancients had recourse to many curious inventions for the purpose of raising water. Hero of Syracuse contrived

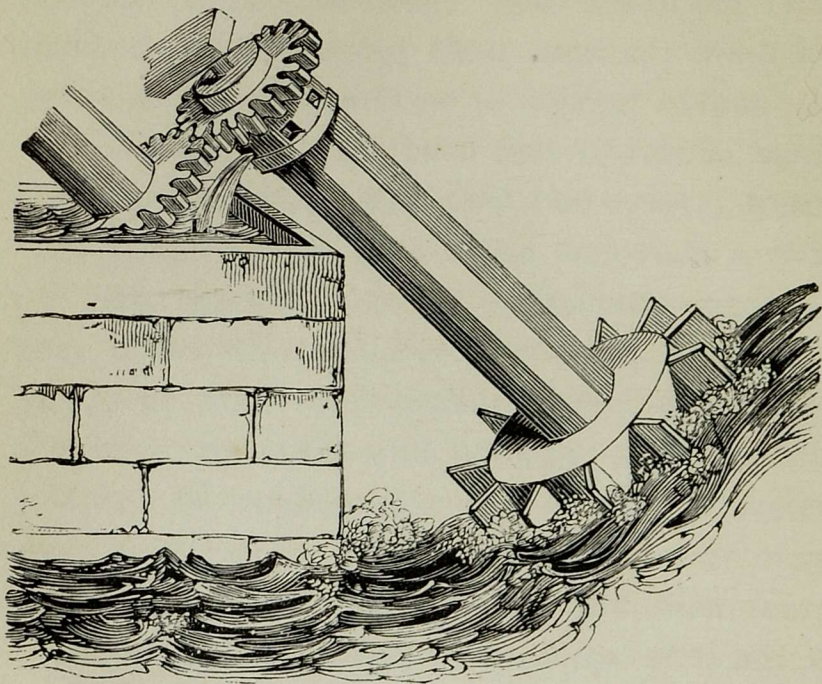


PLATE XVI.

Page 175.

ARCHIMEDES' SCREW.

an artificial fountain of great merit; and our old friend Archimedes showed his usual skill and knowledge here, by forming the water-screw which bears his name. This simple engine, called also the water-snail, may be at once understood by reference to the drawing (see plate 16); and indeed it may be readily made by any one who can bend a tube round a cylinder. For the same reason that a small weight, attached by a ring to the worm of a corkscrew, may be caused to ascend by turning the screw whilst it is held in an inclined position, water entering at the lower end of the hollow screw of Archimedes may be conveyed from the bottom to the top by turning the machine with a winch; or it may be made to perform this motion where there is a running stream, by placing float-boards near the lower end. The screw is not shown in the cut, but it is merely a tube winding round a common barrel cylinder.

“The ancients also used a machine called a *tympanum*, which was a great hollow wheel, divided into partitions from the centre to the circumference, where orifices were left for the water to enter. This wheel being fixed so as to dip a little in the water, it is evident that, on turning it round, the fluid would enter those cells and run out near the axis by a spout placed there; but here the weight will always be at the disadvantageous end of the lever, so that a common winch could not turn it. An eminent French geometriician has much improved upon this by making the water channels like hollow curved spokes, as you perceive in this representation (see plate 17), where you see the water would naturally find its way towards the centre, and at length issue thence. This drawing shows, indeed, almost three plans in one; for we see by the hollow rim of the wheel, and the float-boards attached to it, the nature

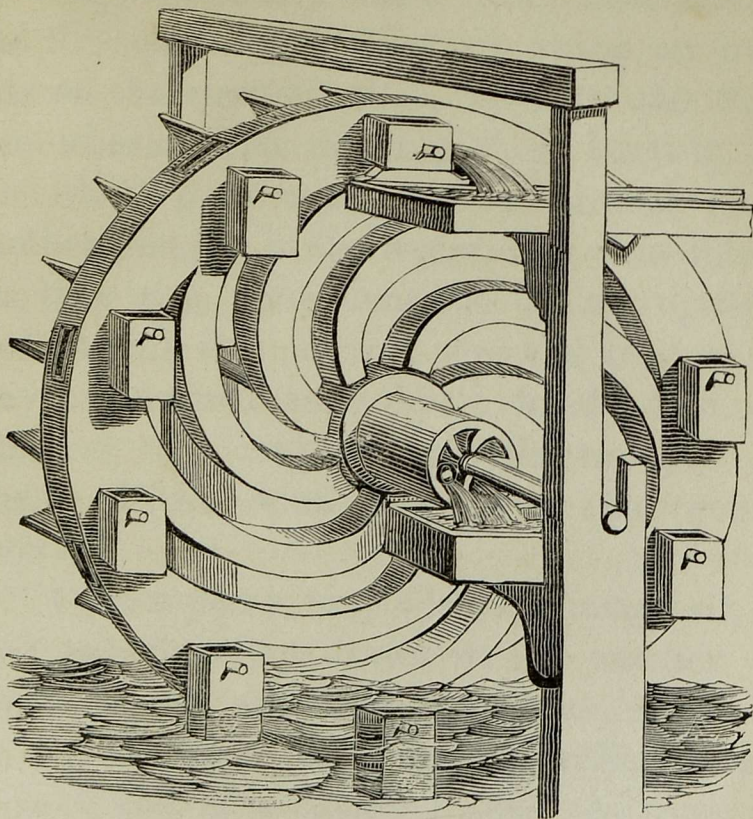


PLATE XVII.

WATER-WHEEL.

of the *tympanum*. The curved spokes exhibit the improvement I have just mentioned; and the square buckets, which swing on iron pins on the circumference, represent the Persian wheel. You see that these buckets, as the wheel goes round, must be one after another plunged in the water, and thus filled. As they rise, they continue in an upright position till they arrive near the top, when they are turned aside by a fixed catch or pin, and thus emptied into the trough. A wheel of this kind any clever lad could make.

“A chain-pump may be easily imagined, I have not therefore drawn it. A number of square boards are fixed at regular distances on a chain which turns on two rollers fixed at each end of a square trunk. As those in the water enter the trunk, they carry a portion of water with them, and thus drive the fluid up the required ascent. Sometimes,

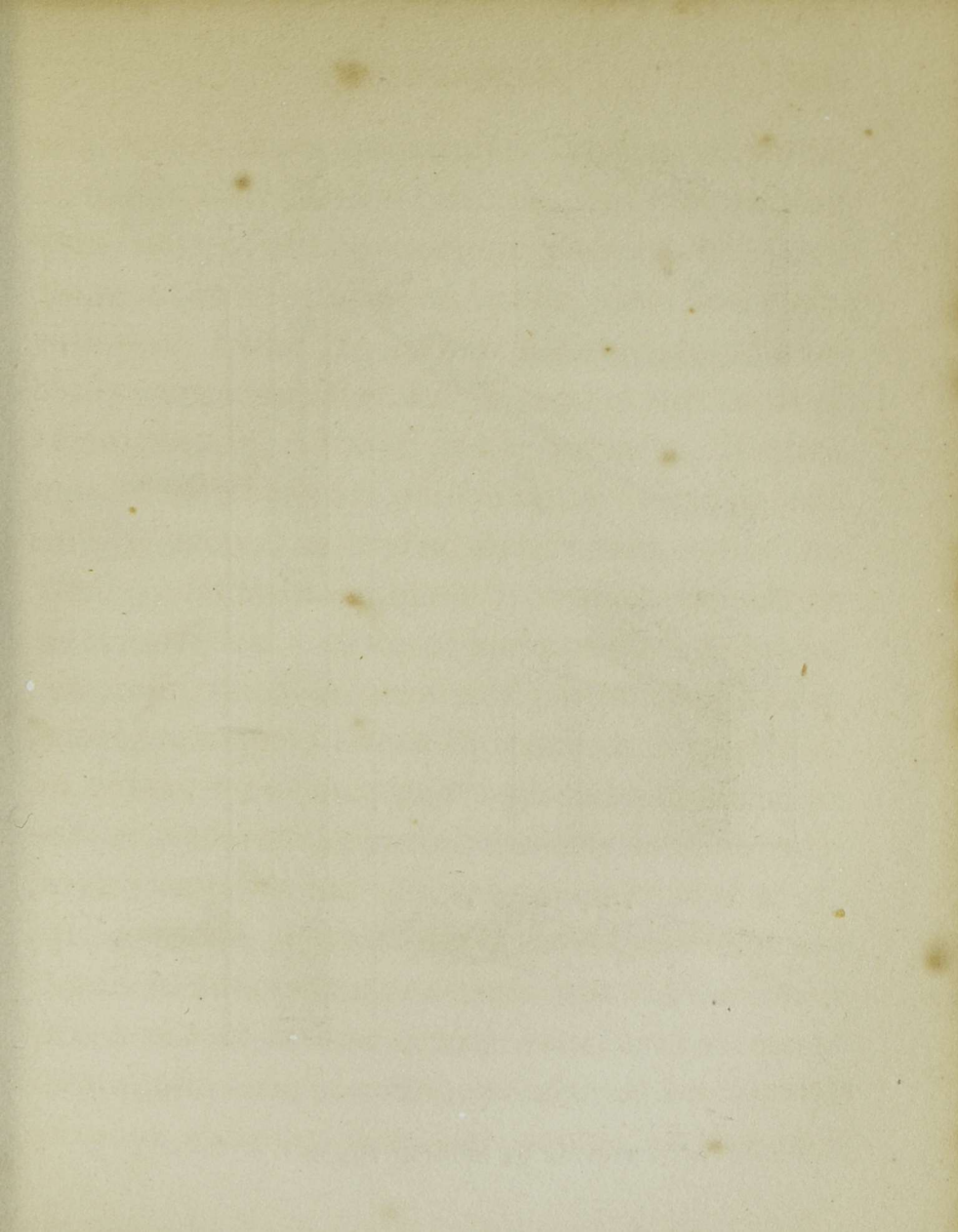
instead of mere boards, boxes are supplied, which dip into the water, empty on one side, and rise full on the other.

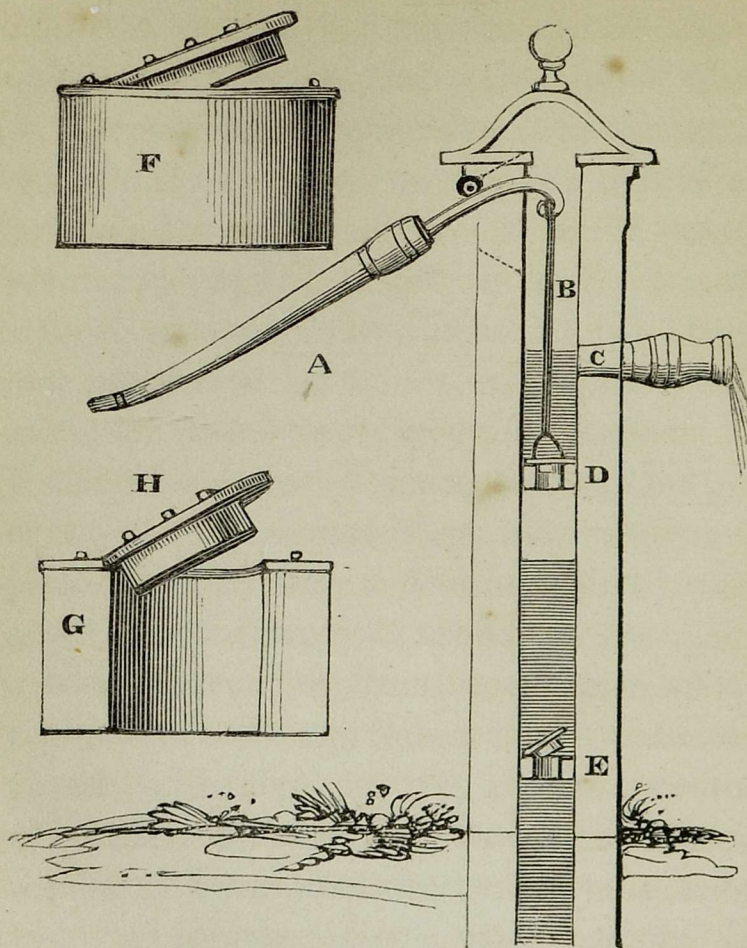
“But we must proceed to examine the nature of those more simple, useful, and therefore most common engines for raising water, called pumps, the greater number of which are known by the name of sucking-pumps (see plate 18). How is it that water can be made to rush up a tube from a depth of thirty feet by a power, applied, as it seems, not *beneath* but above the column of rising fluid? Let us bear in mind first, that water, like everything else on the surface of the globe, is constantly under the pressure of another fluid—lighter it is true, but still weighty—I mean air. Yes, air, which is supposed to extend to a height of fifty miles above us, bears with a great weight downwards by the force of gravity; and, acting thus on the surface of a vessel of water all over alike, we do not observe its effect: but if by



any contrivance we can remove the weight of air from any portion of that surface, the air pressing at the same time on every other part, do you think it likely that the water will still remain motionless ? Oh no ; the parts pressed down will sink, and the part not pressed will rise : no one can doubt or misunderstand so obvious a thing as this. Well, then ; I insert a tube in a vessel of water, which tube has a piston or plug tightly fitting it, previously thrust, we will say, nearly down to the bottom. Now, on drawing this piston up, of course it lifts the air in the tube above it, and none can enter below ; consequently the pressure of the air is removed from that portion of the water next to the bottom of the tube, and the fluid, thus relieved in that part, but pressed in every other, rises in the tube. Now, suppose that near the lower end of the pipe I fix a little valve or trap-door, which opens only upwards ; it will have permitted the water to rise, but will not

allow its return. Suppose, again, that the piston or plug has also a little valve fixed in it, opening only upwards; the piston may then be thrust down, and the column of water will be above both valves. If now I draw this piston up again, I lift with it the whole column of water above it, which will enter at any aperture in its course, whilst a new column of water rises from below as before. This is the principle of the common sucking-pump, of which a sectional view is here given (see plate 19), in such a form as to exhibit the action of the thing in a small compass. Here, A is the handle; a lever, you see, working on the central pin or fulcrum, attached to the piston or bucket B; D E are the two valves, or clacks, as they are called, opening upwards. I have also drawn them on a larger scale. F is the upper, and G H the lower one, and C the spout whence the water issues. It is not, however, possible to raise





water in this way above a certain height, which is about thirty-three feet ; for this reason, that a column of air has only a certain weight, and cannot lift a column of water that exceeds its weight. When, therefore, it is needful to procure water from a depth exceeding a little more than thirty feet, a forcing pump is often used. The principle of this is forcing one small column of water downwards, and thus lifting a tall column upwards, which is sustained at proper distances by the usual valves. This kind of pump is expensive, and requires a great power to work it.

“ The drawings usually given as illustrative of the action of the common and forcing pump, I will now produce. Models upon this plan are beautifully made of brass and glass for the lecture-room ; but, as they are expensive, I hope my explanations and drawings (see plate 20) may prove a sufficient substitute.

A represents the lower end of the suction-pump in

the water ; it is perforated with small holes to prevent gravel from getting into the pipe.

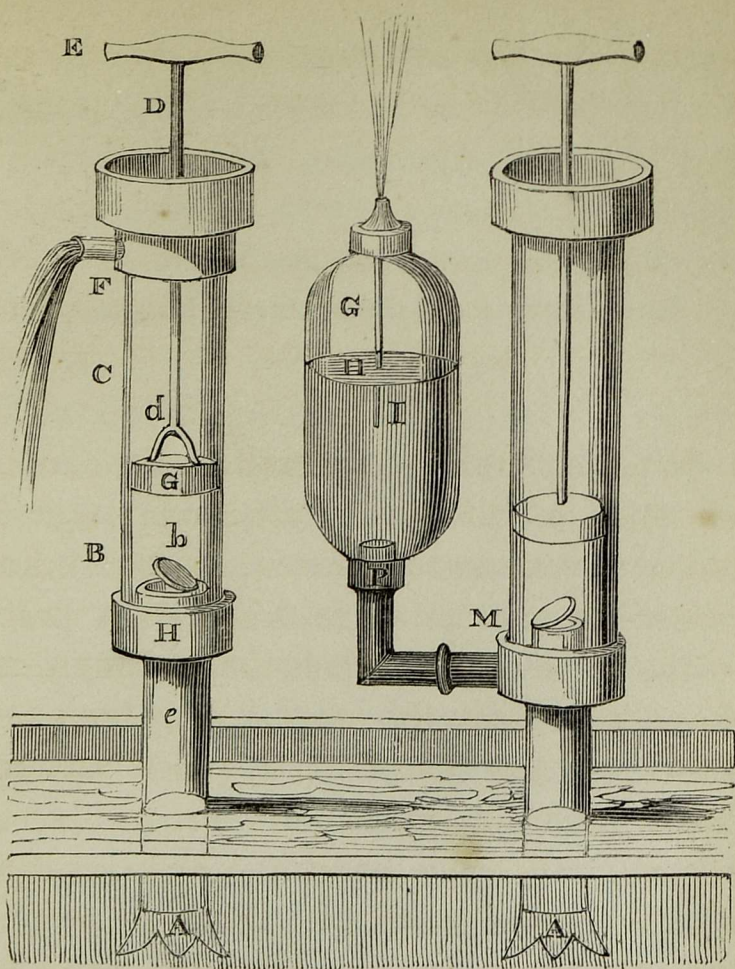
B c, the barrel larger than the lower part H, e, called the suction-pipe.

D, the piston rod.

E, the handle ; and, F, the spout.

G, the piston, made to fit air-tight in the barrel by means of leather, so as to prevent the air from passing by the edge into the lower part of the pipe.

“In the piston you observe a valve *d*, opening upwards to allow the air and water from below to pass and to prevent its descending, at *b* there is another valve, which acts precisely in the same way. When the piston, *G*, is put down close upon the valve *b*, they both remain closed. Raise the piston *G*, and a vacuum, or space free from atmospheric air, will be made : of course, the valve *b* will now open, as it meets with no resistance above, and is pushed up by the pressure of the air upon the water in the well through *e*, filling the vacant space above with water. If the piston is again depressed,



the water will push open the valve belonging to it, and, being thus above the piston without the opportunity of returning, it is lifted to the top and issues by the spout. The water continues to flow from the lower part, occupying the place of that which has passed away by the spout.

“The forcing-pump differs in its action from the common pump, chiefly by the piston or plunger having no valve. The parts for raising the water are the same as above described; but as the raised water cannot escape by an upper valve, when the piston is pushed down again, it is driven through the pipe *m*, which has a valve at *p*, opening upwards only. The air in the vessel *g* is by a continued influx of water very much compressed, and in that state, from its elastic property, presses with great force on the surface of the water in the vessel at *h*, driving it through the jet or pipe *i f*, which affords the only

passage for it. A column of water may by this contrivance be thrown to a great height and with great force ; the fire-engine is a striking example of the useful application of the forcing pump.

“The celebrated machine at Marly, in France, formed, I believe, the most extensive assemblage of pumps and waterworks in the world. It was constructed by one Rannequin, of Liege, and began to work in 1682. The purpose of this vast and complex engine was to raise water to the height of five hundred and thirty-three feet above the level of the river Seine ; and this it has done by means of fourteen great water-wheels, and two hundred and fifty-three pumps, that lift the water from stage to stage to its required height, for many years, at the rate of from forty to sixty thousand gallons in an hour. The King of Denmark, when he saw the magnificent extent of the machine, and judged what the whole and constant expense

must be, supposed that the water thus moved must cost as much as wine; but he was somewhat mistaken. The expense is about one farthing for ninety gallons! But Rannequin, eminent as he was as a wheel and pump maker, was not a man of much science; he has encumbered his engine with many useless parts, and often employed his power to the worst advantage: nevertheless, the machine at Marly is justly famous as a prodigious specimen of uneducated thought, ingenuity, and industrious and undaunted enterprise.

“We have now considered and examined flour-mills and certain water-engines—powerful and important machines to accomplish the purposes of civil society. There are however so many other contrivances whereby great results are gained, that it is difficult to make a selection, and say which shall be noticed first, and which left out of our present list. We have no present possibility of examining more than

a few of these very interesting objects, and must make the best choice we can amongst them, and content ourselves with merely a few hints on some of the commonest subjects. The LOOM alone might occupy an intelligent company a long time, merely to understand the chief functions of the various engines that go by that name. It must suffice us at present to advert to the weaving of plain cloths, where the threads cross each other in the way that a slight inspection explains. To adjust threads side by side one way, and insert threads equally close, over and under these, the other way, by the finger, would be an endless task; and there is reason to believe that a weaver's frame, similar to that which we now call a hand-loom, was in use at a remote period of antiquity. The weaver's loom and shuttle are mentioned in Scripture; and we find the garments of the embalmed Egyptian mummies consist of a fabric nearly resembling modern canvass. A

drawing cannot convey any correct idea of the art of weaving. The threads that go one way are mounted on frames moveable by a treadle with the foot, whilst those that cross them are supplied from an instrument called a shuttle, which with great rapidity delivers the material as the frames vibrate to and fro. Machinery of a very complex kind now supersedes the hand-loom in many places ; and *power-looms*, as they are called, worked by water, wind, or steam, fabricate much of those materials which now clothe British and foreign nations. The stocking-loom, invented, I think, by Bishop Blaize, weaves hosing, formerly the work of the fingers, in a manner truly surprising, and far too complex to be examined on this occasion. Silks, also, and carpeting, with the most beautiful flowered patterns, are produced by engines of the most intricate but accurate construction ; and the shining material of the simple cocoon assumes all the splendid

colours and elegant arrangements which human ingenuity and a refined and fertile taste can devise.

“But there is one machine that far transcends the most elaborate loom in variety of productions, and the most tremendous steam-engine in real power—I mean the printing-press. By means of such an apparatus as you see here represented, the great intercourse of mind is carried on. By this means the wisest of men, who have lived in remote ages, continue to exert their influence in the world. By the movements of that humble apparatus the vast produce of the human mind is distributed over the surface of the globe; and the new harvest, as it arises, is by the same means again stored up or spread abroad for use. The Chinese certainly have the advantage of us in this, the art of printing, as in many other inventions of great importance. But, without going into the history of letter-press printing,

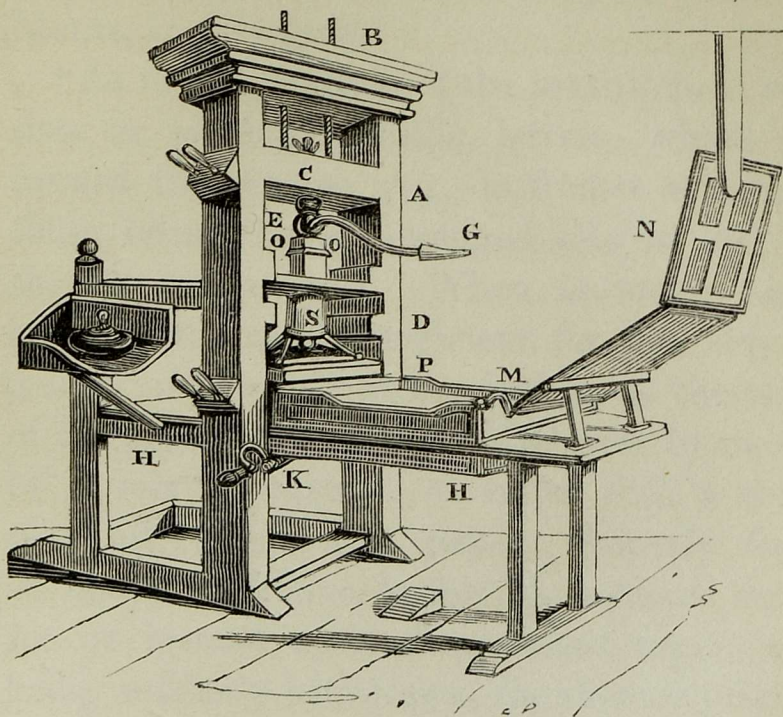


PLATE XXI.

I must just mention that printing, as an art for the purpose of multiplying copies of books, originated in the fifteenth century at, I believe, Mentz, in Germany.

“As to the principle of the invention, it consists in placing metallic letters, which are formed the reverse way, in frames or boxes; these letters being arranged side by side as the words are spelt. When as many pages are adjusted as are sufficient for one side of a sheet of paper, they are laid upon the table of the press, the whole is inked over by means of a sort of cushion or roller with a thick oily ink; then the paper, properly fixed in the press-frame, is forcibly screwed down for an instant upon these inked types, and being suddenly withdrawn, the sheet is printed on one side. I must describe more particularly the parts and action of the press. (See plate 21.)

A A, Two strong cheeks placed perpendicularly, joined

by five cross pieces; B, the cap; C, the head; D, the shelf; E, spindle and bar; G, the handle; H H, the carriage; K, rounce or handle; M, square frame or coffin, containing the form P; N, the tympan and frisket; O, body of the spindle.

COPPER-PLATE PRINTING-PRESS.

PLATE 22.

A B, cross levers of wood, the arms of which serve to turn the rollers.

D E, wooden cylinder; there is one of a similar size under the table.

H K L, the table, which is made to pass between the rollers by means of the cross levers turning the upper roller, then the lower or under one; by this motion drawing the table on which the copper or steel plate is placed forward and backward.

M, the stand. O O, perpendicular pillars to support the table.

P P, the cheeks or side-pieces of timber to hold the rollers and supports for table.

“ The method of taking an impression from an engraved plate, is first to place it over a charcoal fire to heat it, which makes it

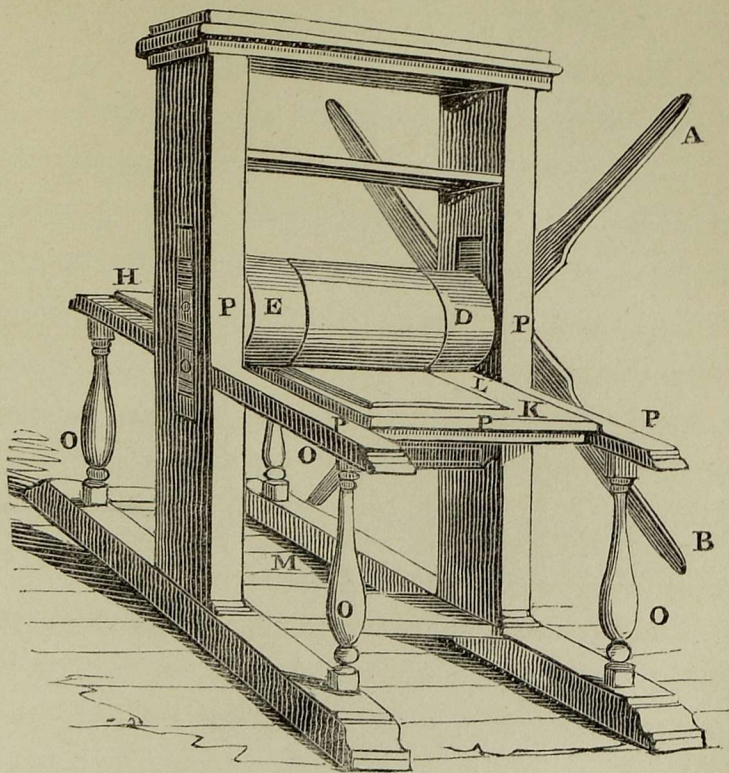


PLATE XXII.

receive the ink more easily into the finer lines. The ink is smeared over the plate with a rubber made of woollen rags, it is then wiped with canvass, and afterwards with the palms of the hands, which are dried often by rubbing them with whiting: great skill is necessary in the workmen to wipe the plate so as not entirely to remove the ink from the engraved lines. The plate thus prepared is laid on the table of the press, and over the plate is laid the paper, previously moistened; the arms of the press are then moved so as to draw the table between the rollers, which are covered with folds of flannel and cloth; it is pinched by them very strongly, but equally; the moistened paper is pressed into the lines of the engraving, absorbing the ink, and producing an impression or print.

“The discovery of this art has been claimed by the Germans and Italians of the fifteenth century. Mr. Roscoe, in his *Life of Leo*

the Tenth, states that Finiguerra, a goldsmith of Florence, being accustomed to engrave on different metals for the purpose of inlaying them, occasionally tried the effects of his work by taking off impressions, first on sulphur and afterwards on paper, by means of a roller, in such a manner that the figures seemed to have been traced with a pen. It does not appear that this Florentine applied this invention to any purpose out of his business ; but Baldini, another goldsmith, conceived that this discovery might be applied to more important purposes, and engraved on metals with a view of taking impressions from them. Botticello furnished him with drawings suitable to his purpose ; and the art was carried to greater perfection by Andrea Mantegna, of whose works many specimens remain. In the next century, Raimondi engraved and printed many of the rich and beautiful productions of Raffaello, with so great a degree

of accuracy as to call forth the praise of that great painter himself. From that period to the present the improvement has been great indeed; a taste for the fine arts has been widely diffused, and science made intelligible to all classes, by the illustrative aid of this valuable invention."

LECTURE ON HOROLOGY.

Mr. Lever, having obliged several of his young friends by allowing them a near inspection of the few pieces of mechanism connected with his present subject, thus commenced his lecture on clocks, watches, and other contrivances for measuring time.

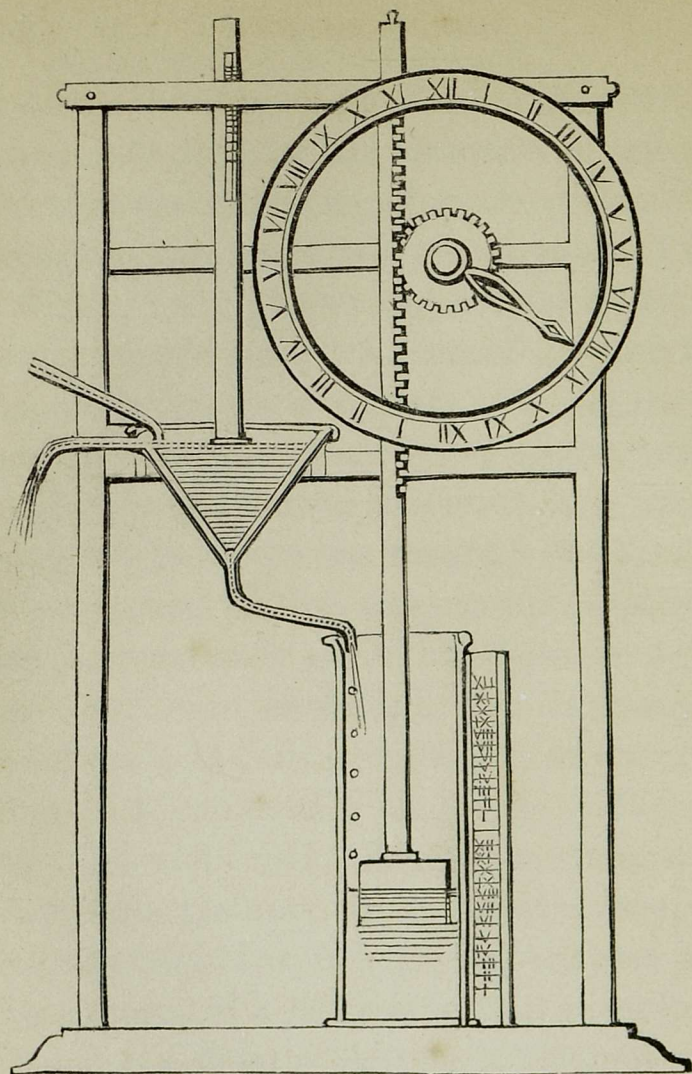
"I know not," said he, "whether the wisest of men would have had any notions at all of time, if the Creator had not commended it to the consideration of all mankind by the vast mechanism of the Heavens. Life

is itself a period, and one too important to be passed away under any such mistake as might have arisen from one continued undivided noon-day of existence. Time is exhibited to us, as the material of which life is made, by incessant movements and continually varying appearances around us. Thus, our first parent could scarcely have done more than glance successively at the new-born splendours around him, before the sun, sinking from his meridian height, poured his now golden beams between the distant mountain slopes, and presently disappeared behind them, leaving the solitary spectator to muse on this first great event of his existence, until the silvery lunar rays brightened the hill tops, and sparkled amidst the boughs of the opposite landscape. Yes—HE made the sun to rule by day, and the moon by night—HE made the stars also; and these in their courses remain, when sun and moon are unseen, to remind man that time still passes on, and that his hours are numbered.

“ But, though darkness and light marked successive days and nights, and the appearances of the moon measured longer periods of time, the position of the sun at noon indicating the progress of the year, the day itself required minute divisions of time, which man was left to arrange by his own contrivance and observation. There is no doubt that the progress of a shadow falling on a plane suggested the first artificial measurer of time by means of something resembling a dial. It was easy to mark the extent traversed by the shade of any fixed object in a day, and this could be divided into as many equal parts as were agreed upon and found convenient. Sun-dials are, we know, a very ancient invention, as we learn from Scripture. Some have supposed that various tall pillars and obelisks, and even the Pyramids of Egypt, had an intended use as measurers of time ; and in countries where the sun shone with such constancy, they supplied unvarying means of noting the exact pro-

gress of the day. Moon-dials also were constructed to register the moments of the night ; and thus those who cared to do so could easily enough observe and note the flight of Time.

“ But, for common and domestic use, some distinct contrivance was required ; and to tell the exact progress of day and night, where neither sun nor moon ever shone, was not possible, until human invention had been long exercised to devise the means. Water-clocks, or *clepsydræ*, as they are called, seem to have been in very early use. Of these many varieties have been described, and as many more could perhaps be contrived ; for, as water issues from an aperture in a vessel, its surface naturally descends, and this may be made to move a certain distance in a certain time, which distance and time being observed and known, the purpose of a clock is in part accomplished. The drops from a bucket, if they fell from a sufficient height on the vanes of a delicate

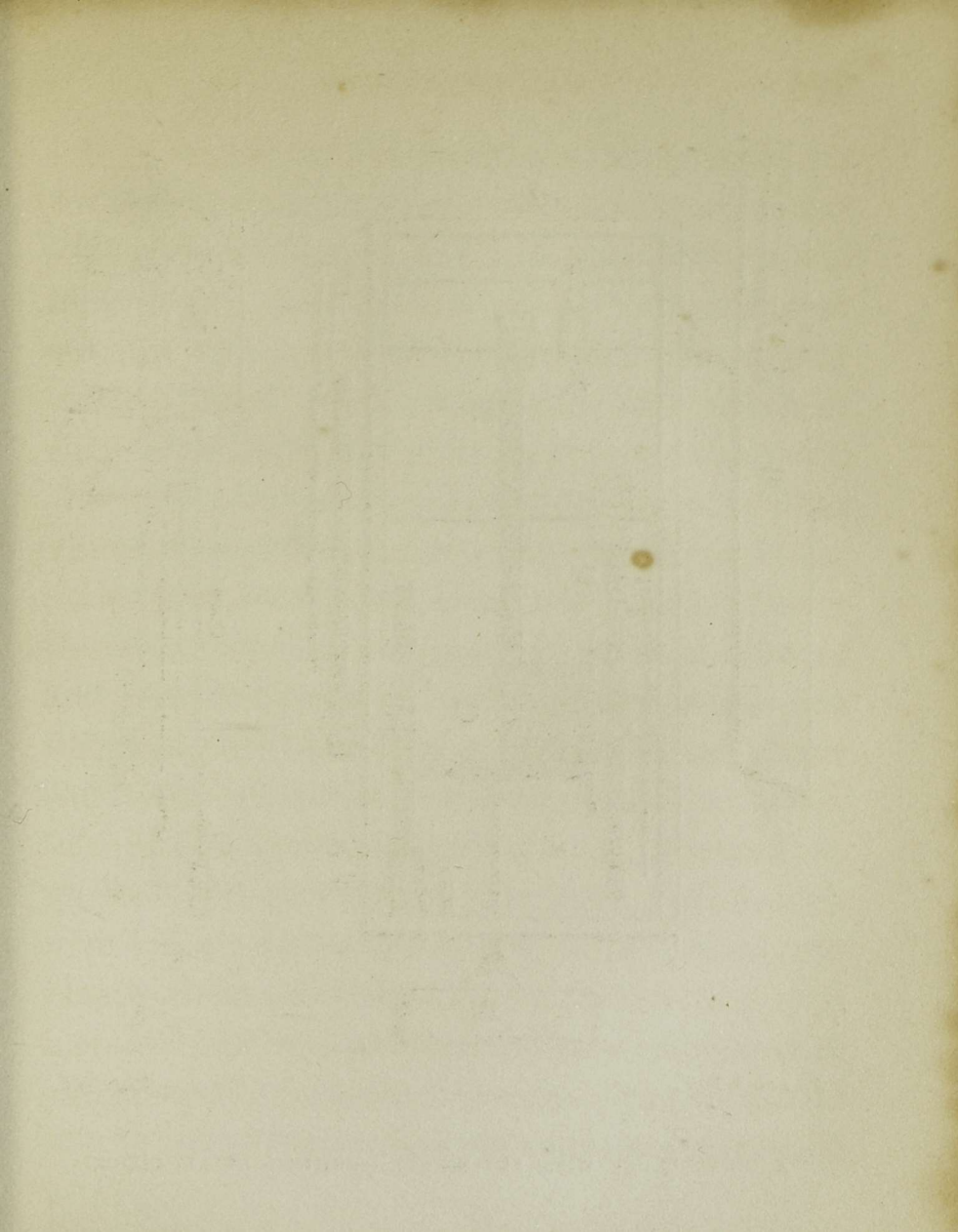


wheel, could, I have no doubt, be made to guide the hands of a dial like those at present used. But we have not opportunity this evening to examine the structure or merits of water-clocks; the drawing (plate 23) is a representation of one of them. We must attend to those made with wheels.

“ Clocks of this kind were at first very rude machines, and their performance must have been far from regular at the best. Who was the real inventor, and when they were first constructed, cannot now be ascertained. It is indeed most likely that clocks, like other human contrivances, were the work of innumerable heads and hands, which improved the mechanism from time to time. It is however believed that such things as *wheel-clocks* existed full twelve hundred years ago in Italy. England had no machines of the kind that we know of until long afterwards. There was an Abbot of St. Albans, in the fourteenth century, who con-

trived a clock much celebrated for its skilful structure, but of its parts and operation we know nothing. It is recorded that clock-makers were first introduced into England in 1368, when Edward III. granted a licence for three artists to come over from Delft, in Holland, and practise their occupation in this country.

“The first clocks were made to run down by means of a fly-wheel, like a roasting-jack; they therefore required very frequent winding up, and must have been subject to great variations in their rate of going (see plate 24). This cut represents a section of the most ancient clock of which we have any precise description; I wish you to observe the striking part of it, regulated, as I have just said, by a fly-wheel, after the manner of a roasting-jack. If you were to open the case and to examine a Dutch clock, you would find this old principle of movement still followed.



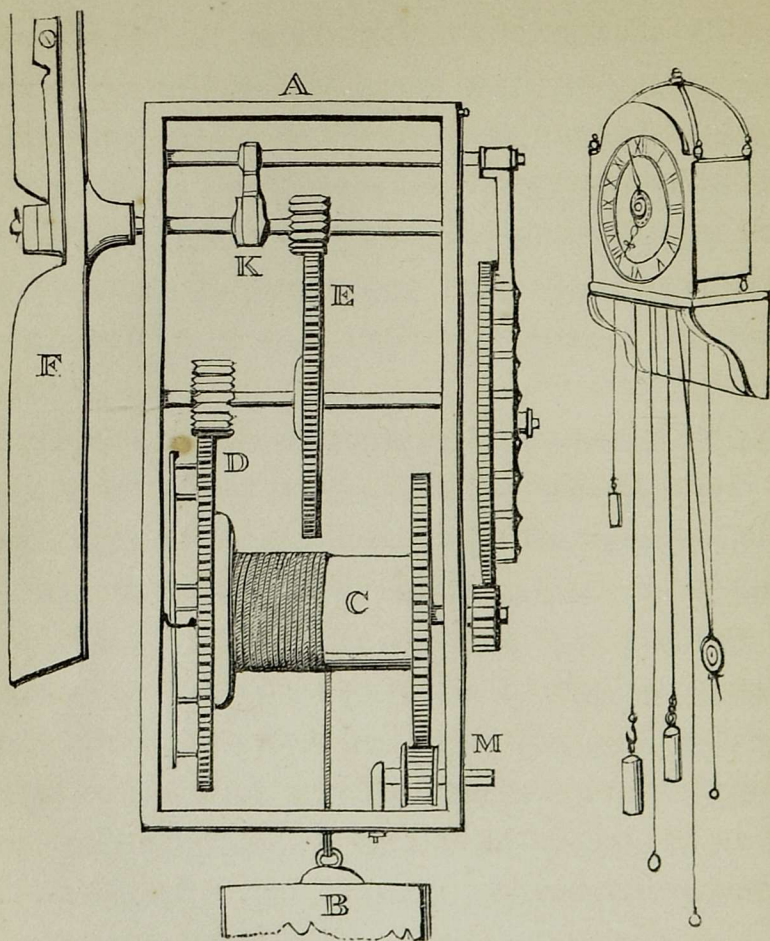


PLATE XXIV.

“ A, section of the frame ; B, the weight, or moving and maintaining power acting upon the rope and cylinder c, which is provided with a peculiarly constructed wheel, which is essential in winding up the weight, called a ratchet, connecting it by a click with the wheel d. The other parts and wheels, e k, continue the movement from the weight to the fly at f. This fly, by means of the resistance which its wings or fanners meet with from the air, regulates the intervals between each blow of the hammer attached to the wheel d. The bell is not shown in the cut. When the weight has drawn from the cylinder the chain or rope fixed to it, a key must be applied at m, which it is obvious would wind up the rope and weight as before. The other parts it is not my intention here to notice.

“ And now we must endeavour to understand the mystery of toothed wheels, by which motion is communicated, with various degrees of

power and velocity, from one part of a machine to another.

“As mills and other engines, as well as clocks and watches, are thus constructed and put in action, it is a very important part of practical mechanics, and not a few entire volumes with numerous plates have been published “*On the Teeth of Wheels.*” I have already explained the principle of the lever, which, being supported on a fulcrum or block, has generally the power applied at one end and the resistance at the other. Thus a small power will lift a great weight *a little height*, and when the lever is depressed by the power as much as possible, it can raise the weight no higher : for you see the end here of the lever represented, on which the man’s hand is placed (see plate 4), is down to the ground. If, therefore, I wish to continue raising the weight, I must employ the power in a different way. If I attach this lever to a circular board, the axle of the board

or wheel becomes the fulcrum; and if the weight be fixed to the rim of another circular board or wheel, I can raise it just as well; but still my lever fails me soon, for the short end slips from under the weight: what is to be done? Each wheel has but *one tooth*, and can therefore act upon the other only a little way round. Well, then, we will suppose another lever working on the same centre, and acting against a pin lower down than the body to be raised. Now we can lift it so much higher. It appears, then, that what we want in order to continue raising the weight is, first, a number of projecting catches fixed in a circle round and near the centre of the great wheel; secondly, a handle, or winch, to turn it by. Then we must have a complete set of pins or catches in the circumference of the smaller wheel, answering to those near the centre of the other; so, by moving the large wheel round by the winch,

the catches, pins, or teeth of the two wheels acting against each other, the second wheel revolves, and the weight upon it is lifted as high as it will go, and by an advantage of power equal to that of a simple lever. A wheel so employed is therefore called a perpetual lever, and such it is. If now the weight, instead of being placed on the circumference of the wheel, be suspended to a cord, and that cord be fastened to a cylinder or roller on the axis of the second wheel, here is the power of another perpetual lever gained—a lever of the second order, whilst it is evident that the large wheel was a lever of the first order.

“There is now an important observation to make connected with our present subject, and which I have adverted to before:—what we gain in power we lose in time. For it will take, perhaps, twelve revolutions of the great wheel to accomplish one of the little wheel;

and, as the circumference of that wheel is, we will say, twelve times as great as that of the cylinder on which the cord is wound, it will take twelve revolutions of this wheel to raise the weight a height equal to the measure of its own circumference. So you see the winch must be moved one hundred and forty-four times as fast as the weight. The hand must carry it twelve feet to raise the weight one inch; but then, if the weight is one hundred and forty-four pounds, the power exerted by the hand is only a little more than equal to one pound. A child, therefore, whose natural strength is sufficient to overcome a resistance of only one pound, can thus by a machine raise one hundred and forty-four pounds, which a strong man would with difficulty lift; and thus, by the addition of wheel to wheel and power to power, we might raise a ton weight by the strength of a single hair, as I think I have said before.

“Now, it is the custom for wise mechanics to consider duly the nature of the work to be performed, before they combine the mechanical powers in any engine. If it be required to lift, or move, a great weight a small distance, then a simple lever will suffice. If the weight must be raised from a considerable depth or to a height, then the wheel or winch and axis with a cord is proper, as in raising a bucket from a well. If the weight or resistance be too great for the winch thus applied, then either blocks of pulleys may be used, such as I have spoken of before, or wheels with teeth, such as I have just described.

“But sometimes the object is, not to raise a weight by means of wheel-work, but to move wheel-work by means of a weight, as in clocks; or to accomplish the same by a spring, as in moveable time-keepers or watches. Here the slowness with which the weight moves, compared with the speed of the remote wheels, is

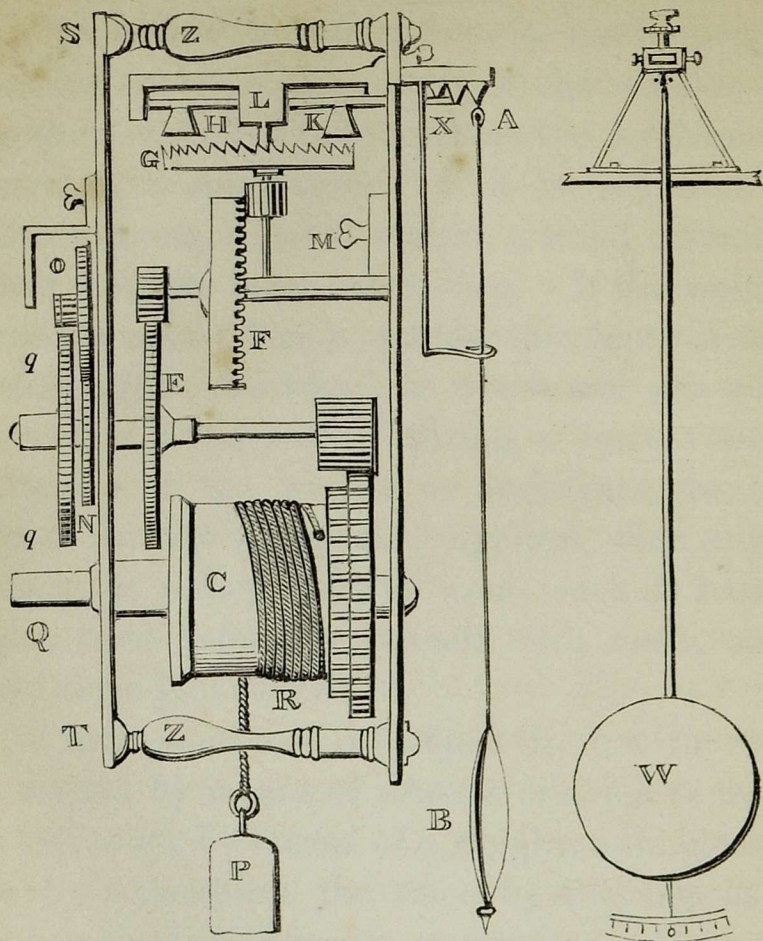


PLATE XXV.

an advantage; for the power continues so much the longer in operation without renewal; so that, by increasing the weight, and adding to the train of wheels, clocks might be made to go for years without winding up."

Mr. Lever now pointed attention to a common thirty-hour brass clock, which was deprived of its face and covers, and elevated on a stand for the purpose; but, foreseeing that its internal mechanism would not be conspicuous enough to be understood by his company generally, he had prepared a large diagram representing the parts, as in our plate, to which we must refer by means of letters as before. (See plate 25.)

"The annexed cut represents the profile of a common thirty-hour clock.

"P is a weight suspended by a rope, that winds about the barrel c, which is fixed upon an axis; the pivots go into holes in plates of brass or iron, in which they turn freely;

these plates are connected by four pillars, *z z* : and the whole together is called the frame. The weight *p*, if not restrained, would necessarily turn the barrel *c* with a uniform accelerated motion, in the same manner as if the weight was falling freely from a height. But the barrel is furnished with a ratchet wheel *r*, the right side of whose teeth strike against the click, fixed with a screw to the wheel close to it, so that the action of the weight is communicated to the latter. This motion it communicates to the wheel *e* by means of the pivot and pinion above it, as likewise to the wheel *f*, which moves the pinion upon the axis of which the crown or balance-wheel *g* is fixed. The pivots of the pinion just below the latter play in holes of the plates *l m*. The motion begun by the weight is transmitted from the wheel *g* to the palettes *k*, and by means of the fork *x*, riveted in the palettes,

communicates motion to the pendulum A B, which is suspended upon the hook A. The pendulum describes on the point A an arc of a circle, alternately going and returning. At every vibration of the pendulum, the teeth of the balance-wheel G act so upon the palettes K, that after one tooth has communicated motion to the palette K, that tooth escapes; then the opposite tooth acts upon the other palette, and escapes in the same manner; and thus each tooth of the wheel escapes the palettes K, after having communicated its motion to them in such a manner that the pendulum continues to move. The wheel E revolves in an hour: upon the pivot of this wheel is a wheel N, with a long socket fastened in the centre, upon the extremity of which socket the minute-hand is fixed. The wheel N acts upon the wheel O, the pinion of which acts upon the wheel Q Q, fixed upon a socket which turns

along with the wheel *N*. The wheel *q q* makes its revolution in twelve hours, and upon its socket the hour-hand is fixed.

“ Thus, it is obvious that the weight *P* turns all the wheels, and at the same time continues the motion of the pendulum; that the quickness of the motion of the wheels is determined by that of the pendulum; and that the wheels point out the parts of time, divided by the uniform motion of the pendulum. When the cord upon which the weight is suspended is entirely run down from off the barrel, it is wound up again by a key, which goes on the square end of the axis at *Q*, by turning it in a contrary direction to that in which the weight descends.

“ It is evident that these wheels, actuated by the weight, would run down in a few minutes, and keep no time, if they were not in some way detained and regulated in their motion. I have mentioned that fly-wheels or

balances, were formerly used. The invention of pendulum clocks is owing to the happy industry of the seventeenth century, and the honour of that discovery is disputed between two experimental philosophers, Galileo and Huygens. The latter, who wrote an excellent volume on the subject, declares that it was first put in practice in the year 1657. Others contend for Galileo; we cannot change sides like a pendulum between them. The first pendulum clock made in England was in the year 1662, during the reign of Charles II., by one Fromantil, a Dutchman.

“By a pendulum, in mechanics, we mean any heavy body so suspended as that it may swing backwards and forwards about some fixed point, by the force of gravity. These alternate motions of the pendulum are called its *oscillations*, or vibrations. The point round which the pendulum moves is called its centre of motion or point of suspension, and the length

is determined by the distance of the bob, or ball, at the end, from that point. I suppose most of my young friends are aware that, the longer the pendulum the slower are its motions. Those little clocks which have pendulums only about six inches in length, tick nearly as fast as watches ; whilst our eight-day and other clocks, whose pendulums are rather more than thirty-nine inches long, tick seconds, or only sixty times in a minute.

“ Now, if a pendulum could keep itself continually going, it would be very easy to connect a dial and index with it to mark the passing time ; but, having to make its way through the air, and to overcome a certain degree of friction or resistance at the point of suspension, it would scarcely preserve its own motion an hour, and requires a maintaining power to assist it. This is furnished by the weight and wheels of the clock ; and that wheel, and the contrivance immediately con-

nected with the pendulum are called the *escapement*, because a portion of the wheel is suffered to escape at every vibration. Here is a drawing of the balance-wheel of a watch: the action of this wheel upon the balance is the same as the escapement in a clock; it obliges the balance to vibrate backwards and forwards like a pendulum (see plate 26), and at each vibration a palette allows a tooth of the balance-wheel to escape, regulating the motion of the wheels produced by the joint action of the main-spring and spiral balance-spring. If you examine the escapement of a clock, you will perceive that the teeth of the wheel are not upright, but lean forward like those of a saw, (as you see in the drawing before us,) and the wheel goes in that direction. Now, it is easy to observe that, as the pendulum swings on one side, it inclines the arched piece attached to it, and thus one tooth of the wheel lodges against one

end. When the pendulum swings the contrary way, that part of the arch or click rises and lets the tooth pass; then another tooth falls on the other side, which in turn is dismissed; and thus, as the pendulum vibrates, one tooth at a time is permitted to escape. In this manner the wheel by slow and regular degrees revolves, and, as the pendulum receives a slight impulse at every stroke of the tooth, it is continued in its accustomed motion. This is the sort of escapement commonly used in the better and larger sort of clocks; but various other means have been adopted for the same purpose.

“As one hand of a clock moves twelve times as fast as the other, the part which carries the minute-hand is made to turn in a tube on which the hour-hand is fitted, and the teeth of the dial wheels are so numbered as to make the two hands proceed in their proper and comparative time exactly. As to the striking

part of a clock, it is not quite so easily explained without an actual and attentive examination of the machine. It is an apparatus in which a great deal of ingenuity and nice arithmetical calculation have been required and exercised. A train of wheels being put together, and short pins fixed to the circumference of one wheel, these, as they pass successively, act on the tail of a hammer, which is thus withdrawn and released, so that the bell is smartly struck. The number of strokes is regulated by the slow motion of a wheel behind, the edge of which is notched at distances of regularly increasing extent, so as to allow progressively one more revolution of a wheel, and one more stroke of a hammer, every hour from one till twelve, after which it commences with one again. There are also many methods of accomplishing the task of thus striking the hour, but none is more simple than this.

“ The wooden clocks, which are common in kitchens and cottages, are made and put together in a wonderfully cheap and expeditious way, and they often act extremely well, particularly when there are no young gentlemen at hand to disturb their allotted functions. Church or turret clocks differ from others only in the size and strength of their parts. They must, in fact, be made capable of moving with great power ; for the hands are long and heavy, and apt to be resisted by the wind ; and as these clocks are required to announce the hour to a whole parish, the hammer is very heavy, and strikes the bell a tremendous blow. I do not therefore think that a wooden clock intended for a room would adequately supply the place of a public dial, though placed in the most conspicuous situation.

“ Clocks which exhibit the time and strike

the hour are in general reckoned sufficient for common use. Many church-clocks, however, strike at the quarters, and some play a tune with great exactness. The Dutch clocks not unfrequently imitate a cuckoo, by inflating a small pair of bellows as they strike; and there are shops in London, where clocks are constantly on sale, which perform the various functions of musicians, dancers, files of soldiers, mowers, horsemen, and the like. But the artists of former days exercised their fancy and ingenuity more than would be thought profitable at present in the complex performances of clock-work. We read, that in the fourteenth century an artist named James Dandi constructed a clock for the city of Padua, which was long considered the wonder of the period. Besides indicating the hours, it represented the motion of the sun, moon, and planets, and pointed out the different festi-

vals of the year. On this account Dandi obtained the name of Horologio, which became that of his posterity.

“But the clocks of the cathedrals of Strasburg and of Lyons are much more celebrated. That of Strasburg was the work of Conrad Dasypodius, a mathematician, who finished it about 1573. This clock had three or four faces, or dial-plates, two of which performed their revolutions in a year, and indicated the days of the year, and all peculiar days as they occurred. On the other plates were shown the eclipses of the sun and moon : in another part the days of the week were represented by the different divinities from whom they took their names ; the divinity of the day appeared in a car rolling over the clouds, and at midnight this retired to give place to the succeeding one. Then there was a globe, borne on the wings of a pelican, around which the sun and moon revolved ; and all the usual

changes and appearances of the heavenly bodies were here exhibited with the most punctual precision. There were, besides, various figures of men and angels, which accomplished their several movements ; one of these struck a bell with a sceptre, and another turned a sand-glass at the expiration of an hour. Different animals also were formed, which emitted sounds similar to their natural voices. Among these was a cock, which, immediately before the hour was struck, stretched forth his neck, clapped his wings, and crowed ! I am sorry to say, however, that the greater part of this surprising piece of mechanism has long since become deranged and motionless. The clock at Lyons is said to have preserved its functions better, and it exhibits and performs nearly as much as the other.

“ A very curious clock, the work of Martinat, a celebrated artist of the seventeenth century, was formerly to be seen in the royal apart-

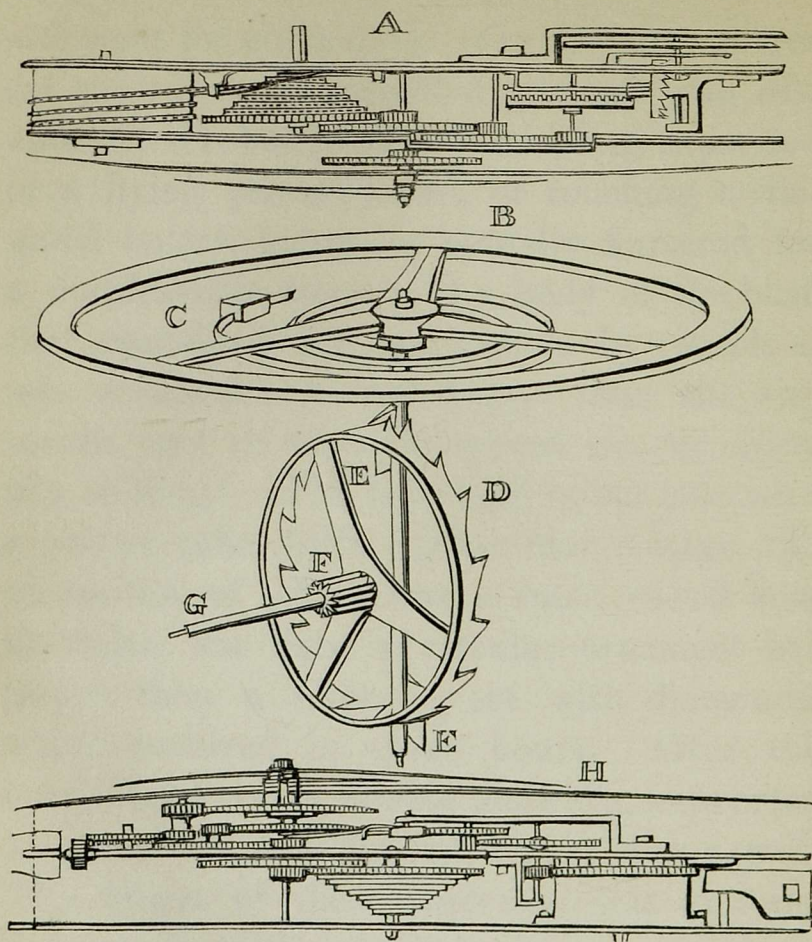
ments at Versailles. Before it struck the hour, two cocks, on the corners of a small edifice, crowed alternately, clapping their wings ; soon afterwards, two side doors opened, at which appeared two figures bearing cymbals, beaten upon by a kind of guards with clubs. When these figures had retired, the centre door was thrown open, and a pedestal supporting an equestrian statue of Louis XIV. issued from it, whilst a group of clouds separating, gave passage to a figure of Fame, which came and hovered over the statue. An air was then performed by bells, after which the two figures re-appeared ; the guards raised their clubs, which they had lowered in the presence of the king, and the hour was then struck in the usual manner.

“ These machines were the work of foreign artists. English skill has been generally and more profitably exerted in the perfection of engines, perhaps less curious and complex,

but far more useful in the sciences and the arts of life. French and other mechanicians will make clocks and watches and self-moving figures, which shall perform at a great expense that which might be nearly as well left undone ; but English artists will construct timepieces of such extraordinary excellence, that navigators may sail round the world and scarcely find the variation of a second. However, we have no need to resign to others all claims to admiration on account of the ingenious devices in clock-making to which we have referred. Two clocks were constructed some years ago by English makers, as a present from the East India Company to the Emperor of China.

“ These clocks were in the form of chariots, in each of which a lady was placed in a fine attitude, leaning her right hand upon a part of the chariot, under which appeared a time-piece of curious workmanship, little larger than a shilling, that struck, and repeated,

and went for eight days. On the lady's finger sat a bird, finely modelled, and set with diamonds and rubies, and with its wings expanded in a flying posture; and, on touching a diamond button below, it actually fluttered for a considerable time. The body of the bird, that contained the mechanism by which it was actuated, was not bigger than the sixteenth part of an inch—about the thickness of a shilling! The lady held in her left hand a golden tube, little thicker than a large pin, on the top of which was a small round box, to which was fixed a circular ornament not larger than a sixpence, set with diamonds, which revolved in three hours. Over the lady's head was a double umbrella, supported by a small fluted pillar not thicker than a quill. The larger of these umbrellas was at some distance from the clock, and seemed to have no connexion with it; but a secret communication existed, and a hammer regularly struck



the hour, and repeated the same at pleasure. The lady had at her feet a golden dog.

“And now,” continued Mr. Lever, “we must pay a little attention to the mechanism of those truly wonderful, though minute, machines called pocket watches. I think that human industry and ingenuity have produced nothing beyond these, considering the extreme fineness of the parts, some of which to the naked eye are even scarcely visible. The same principle of toothed wheels is adopted here as in clocks and the largest engines, but the maintaining power, the escapement, and the regulating motion, are quite different. This,” said Mr. Lever, pointing to a drawing which we have represented, plate 26, “exhibits the internal parts of a common watch, the upper plate being removed.

A, section, inside of a common watch.

B, the balance.

C, the spiral spring.

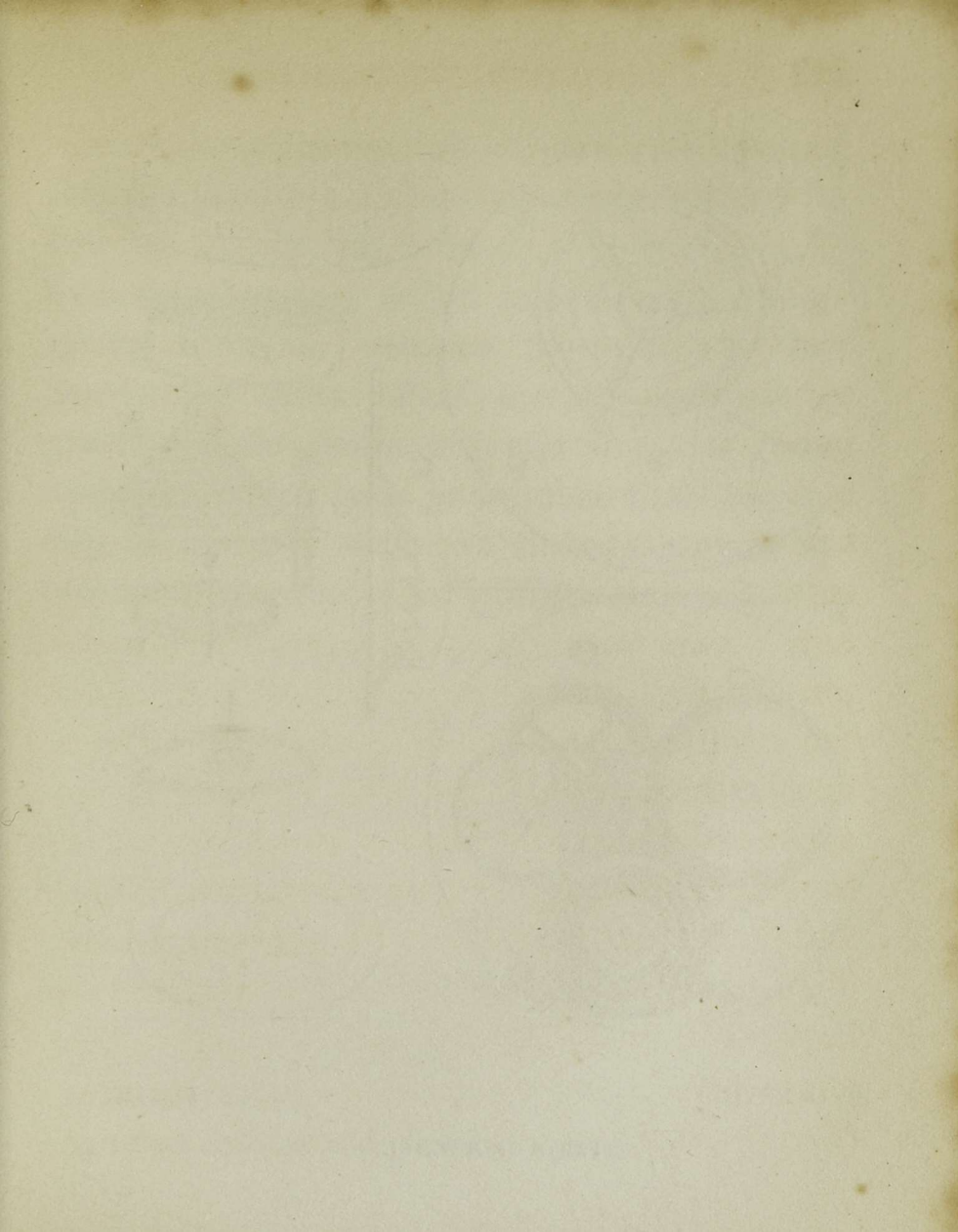
D, the balance-wheel, or escapement.

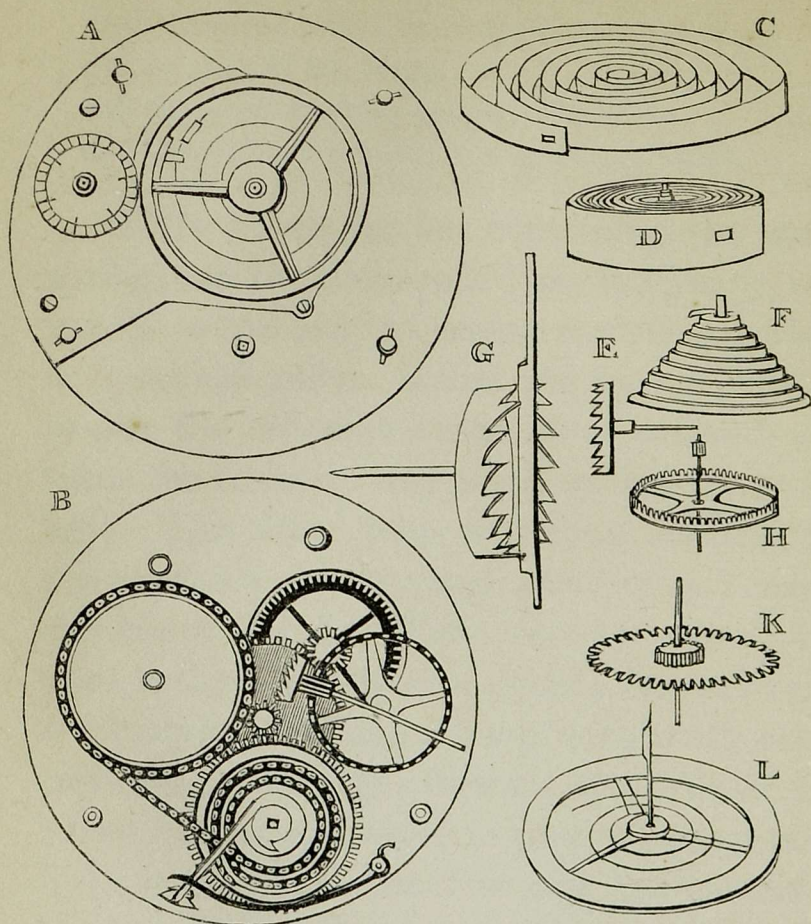
E E, palettes of the verge.

F G, the pivot carrying balance-wheel D.

H, section showing works of a repeating watch.

“ Here we see the box containing the main-spring, and the chain coiled partly upon it, and partly on the next adjoining movement, which is a conical roller, called the fusee; this actuates the wheel whereon it is centred, and turns the contrary way when wound up by the key. This wheel joins and turns another, the pin of which goes through the dial and carries the minute-hand. That second wheel acts upon a third, which acts upon a fourth having a circumference like a hoop with teeth on its top edge; this urges forward the fifth or last wheel, the axis of which is placed horizontally. This small wheel has few and comparatively large teeth, and it moves quickly round, acting on the projecting leaves, or catches, or palettes, of the verge, on which is fixed the balance.





This balance is the bright blue ring of steel that we perceive so conspicuously gliding to and fro, on opening a watch. It is regulated by a spiral spring, called sometimes the hair-spring from its extreme fineness. It has nearly the same effect on the balance as gravity on the pendulum, and was the grand invention which gave to watches their regularity of motion. Some of these parts are represented separately for greater clearness.

PARTS OF A WATCH.

PLATE 27.

- A, the upper plate, balance exposed.
- B, the works, looking down upon them.
- C, main-spring.
- D, barrel for main-spring.
- F, fusee for chain.
- G, the escapement, balance-wheel, and verge.
- H, contra, or fourth wheel.
- K, centre, or second wheel.
- E, balance-wheel.
- L, verge, balance, and pendulum spring.

“The main-spring, you see, is a spiral of many turns, but when contained in its little circular box there is little space between them. The end of this spring, which is fixed to the pin in the centre, detains that part; whilst the other end, attached to the circumference of the box, is carried round, when winding up, by the action of the chain coiled about the outside. Thus the spring becomes more and more bent, and resists more and more, and its effort, of course, is to unbend itself, and this it can only do by pulling the chain which is rolled round the fusee; and this can only obey the impulse by actuating all the other wheels, and thus the watch is kept in action.

“The internal chain of a watch—that connecting line which, like a cord, communicates the power of the main-spring to the other parts, is a most exquisitely delicate specimen of ingenuity and skill. It is formed of a

number of small plates in pairs and singly, alternately riveted together so as to admit of motion sideways, and yet to withstand the incessant pull and the wear of the little engine. There seems enough of apparatus to be contained in the compass of a common watch — yet has the whole been comprised within the size of a shilling, including all the parts needful for announcing the hours and quarters, by striking them at command!

“It is hard to say whether a steam-engine or a watch be worthy of the most admiration; each is beautiful and wonderful in its way: but let us never forget that the mechanism of Nature — the works of the Great Artificer, when considered by even a common understanding, make these efforts of man appear but mean and worthless. Think, oh! think, of the vast bodies which roll around us in the heavens, whose motions are exact to a second of time, and that from age to age. Think of the

power of Nature acting on a smaller scale, when the elements, as we call them, are in tempestuous action ; ten thousand steam-engines could not make their efforts noticed beside the tremendous results of one hour's hurricane, or an earthquake of the southern climes. And talk we of the tiny wonders of a repeating watch, which may be worn in a finger-ring ? Take a drop of water from a pool, place it under a microscope of sufficient power, and you will see that it is a peopled world — animals, a thousand of whom would be invisible to the naked eye, will then be seen using their unnumbered limbs, accomplishing thereby their various wills and motions, and possessing therefore parts as duly and truly contrived as those of an elephant or a man."

LECTURE ON THE STEAM-ENGINE.

THIS lecture was rendered peculiarly attractive by a beautiful *working* model of a steam-engine.

It was with difficulty that the youthful philosophers, who at first gathered round the table, were prevented from employing their untaught hands somewhat prejudicially on this and other delicate apparatus. Mr. Lever, however, having observed that the steam-engine was exhibited to best advantage when the ruler of its own motions, obtained that security for the expensive model for which he was anxious; thus commenced:—

“I am glad to perceive that the subject for this evening’s lecture has been accounted so interesting as to procure me an unusually large assembly; I trust that I shall be able clearly to explain and exemplify the nature

and origin of steam-power as applied to machinery, and the construction of those potent engines of which we all hear so much. We may suppose the first man who caused water to boil to have been as ignorant of the new qualities imparted to the fluid as was Crusoe's man Friday. Perhaps the rolling clouds that passed successively from his cauldron occasioned his first emotions of surprise, and he might not feel assured that pot and all would not take the same airy form, and seek the skies. The rattling ebullition, no doubt, amazed him also; but the effect on his hands, if he presumed to meddle, was unquestionably the most memorable incident in the strange experiment with fire and water. The uses to which the boiling fluid could be applied in the preparation of food did not, I should think, long remain unknown; and so important were these uses to man in all states of society, savage or civilized, that they contented him

apparently for a thousand years or more. The pottage formed a grateful meal, whilst the vapour that canopied the cook was not the subject of a curious thought.

“ And it would perhaps surprise us could we know how few persons out of a hundred, who in the present day observe the rushing streams from the domestic kettle, trouble themselves to inquire what is its nature, what are its powers, and how they may be and are employed for the most important purposes of life. Those of my respected audience who may not as yet have turned their thoughts this way, will give me leave to say, that they do their minds injustice by omitting to furnish and employ them as others do with so much benefit and enjoyment. Let not any facts or subjects be despised as *common*, at least till they are understood and known to be unimportant.

“ Early history does not often leave the

story of ambition and of national affairs, to record the incidents of human thought, or the simple experiments of the first philosophers. We do not really know who first invented the plough, the loom, or the potter's wheel, though we are certain that their use has been understood from a period as ancient as that to which history extends. With respect, therefore, to steam-power, of which even our grandfathers had scarcely any notion, it is not to be expected that ancient authors can inform us. Yet are the moderns deprived of any claim to the original invention here by those who lived nearly two thousand years ago ! Hero, a philosopher of Syracuse, has left us the description of a machine, probably of his own invention, which was undoubtedly a steam-engine, if it was ever executed. It was to consist of globular vessels supported as on pivots. The support is a pipe proceeding from the vessel of water below. Two other

bent pipes are inserted in the globe, having their orifices placed in opposite directions. Now, when the water boils, the steam enters the globe by the lower pipe, and issues at those above. The force of the steam, rushing against the air, causes each pipe to recoil from it, and thus the globe cannot remain at rest, but turns round with considerable velocity. I might perhaps explain this action, by reminding my young friends of those beautiful fireworks which circulate with such rapidity on a central pin. The ignited gas, rushing forth from the catherine-wheel, operates in the same way as the steam in Hero's machine. Both are interesting as philosophical toys, but to neither of them are we indebted for any very useful result; nor do we read of steam being employed as a moving power again until the middle of the sixteenth century, when Hero's invention seems to have been revived, though described as a new thing; 'very well

adapted for turning a spit for the relief of the cook !’ Our present steam-engines are expected to do rather more than this !

“ From such small beginnings, and so slowly, did this grand power arise into notice and renown. It excited little attention in the seventeenth century, when De Caus, a French engineer, described a method of raising water in a pipe by the expansive force of steam, confined in a copper vessel. The first person in modern times who really applied the power of steam to any useful purpose was Branca, an eminent Italian mathematician. He dwelt at Rome, about two hundred years ago, and contrived a machine of a very simple kind, to pound and bruise drugs, by raising heavy stampers ; so simple, that *a certain ingenious youth*, with a little humble assistance from me, has furnished us with a working model ; and I think that those of my young friends who are disposed,

may, at the cost of a few shillings, provide themselves with engines of this kind."

Mr. Lever then produced the apparatus referred to ;—it was a mere copper vessel, having no opening but that formed by a pipe soldered into the top of the kettle. This pipe was bent in a horizontal direction, and was made to point near the edge of a small wheel, having cogs or vanes like those of a water-wheel. A charcoal fire was now urged to brightness beneath the kettle, which was more than half filled with water ; steam presently issued with vigour from the spout, and turned the wheel with great speed and regularity.

"The steam," said Mr. Lever, "operates here only as a stream of air would do, acting against the vanes. Its real power is nearly lost, by being expended to a great extent on the atmosphere before it reaches the wheel,

and its performance would not now pay for the fuel required to make the water boil."

The company having satisfied themselves by the exhibition of this little contrivance, the lecturer proceeded.

"Hitherto we have not met with an English name connected with the subject of steam-power; but we must now mention an individual, whose fame has been extolled by some beyond that of any other inventor of modern times. The Marquis of Worcester lived in the reign of Charles II. He was an ingenious but a vain and self-confident man, whose turn of mind, leading him to mechanical pursuits, produced many schemes, some new and some old; some clever and others very absurd; but for nearly all of which he claimed great praise and honour as the sole inventor. He wrote a work, now frequently referred to, called 'The Century of Inventions,' which has been chiefly celebrated for the account of steam-power

there given. The Marquis says, ‘ I have invented an admirable and forcible way to draw up water by fire—*not* by drawing it or sucking it upwards, which can be done but at a certain distance; but this way hath no bounder, if the vessel be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full of water, stopping and screwing up the broken end, as also the touch-hole, and making a constant fire under it; within twenty-four hours it burst and made a great crack; so that, having a way to make my vessels that they are strengthened by the force within them, and the one to fill the other, I have seen the water run like a constant stream forty feet high!’

This nobleman afterwards wrote a book on this invention. The work he calls ‘ An Exact and True Definition of the most stupendous Water-commanding Engine, invented by

the Right Honourable (and deservedly to be praised and admired) Edward Somerset, Lord Marquis of Worcester.’

“The truth seems to be, that the Marquis had studied the subject of steam-power, and had paid attention to the works of others, so as to perceive, more than any *one* of them had done before, what the force and utility of steam might be ; and, although his endeavours were little regarded during his life and for years after his death, they at length excited attention, and caused others to put in practice some things which he had suggested. We have now mentioned Hero among the ancients, and De Caus, Branca, and the Marquis of Worcester among the moderns, whose names are connected with the history of the steam-engine ; but yet nothing like such a machine as now goes by that name had been constructed.

“And now we will suppose that the invention had made no farther progress than to enable

us to shoot a stream of water forty feet high, or to burst a cannon—which of us, being fully aware of the vast power here obtained, could suggest a plan for causing this power to perform any one of the numerous operations at present accomplished by it? There is steam issuing from the kettle: close up the spout and the lid firmly, and the vessel will explode with dangerous violence; or cause the steam to press on the mass of water, so as to force the fluid through a pipe in the manner of a fountain; the effect is curious but not particularly useful. Grinding corn—sawing timber—propelling ships—printing books, we should not soon accomplish by fire and water, although persuaded that all this is possible.

“ Ingenious men long contented themselves with the mere task of raising water, whilst adjusting the steam or fire engines as they were then called. Indeed, this was a most important object, for the mines of our own country

had in many places been deserted, though abounding in valuable metals, in consequence of the water which occupied their vast recesses. Machinery worked by wind or horses had been used; but the purpose was not thus half accomplished, and the expense was great. Towards the close of the seventeenth century, Captain Savery, a seaman, offered an engine of a new kind to the miners; but they, discouraged by the failure of former schemes, paid little attention to his proposals; and it was some years before this truly eminent engineer obtained the notice he deserved. Nothing worthy of the name of a steam-engine had been made before; and the Captain at length had the satisfaction of exhibiting his contrivance with success before King William, and he afterwards constructed several of these machines for raising water in various situations.

“But Savery’s machine, though of great

merit compared with anything attempted before, was still rude and imperfect; it employed a gigantic power, but at so great a disadvantage, that the pipes were continually bursting; whilst the work performed was, as we should now say, inconsiderable. Newcomen, a blacksmith, and Cawley, a glazier, at Dartmouth, now engaged with great energy and success in the improvement of steam-machinery, and carried the thing far beyond Savery's engine in effective power and usefulness; but these were indebted to an individual in their employ for a most important and little expected improvement. This genius was no other personage than an indolent youth—yes, a lazy boy;—I am happy to observe increased attention in my audience.—This lad, named Humphrey Potter, being appointed to the office of adjusting certain parts as the engine went on, took the liberty of adding a catch to the working beam, which performed his

task for him whilst he played the idler elsewhere ; and the fact was, that the engine thus performed twice as many strokes in a minute as it could accomplish in any other way. Humphrey Potter had not an idle brain, such as those generally have who prefer indolence to useful occupation.

“After Newcomen and Cawley, many artisans and men of science continued to improve the steam-engine, and they rendered it gradually more manageable and efficient ; but the great name connected with this subject we have not yet mentioned. James Watt was born at Greenock, in Scotland, in the year 1736. His father was one of the magistrates of that town. James was apprenticed to a mathematical instrument-maker, and when his time was expired, he went to London to perfect himself in his business there. He, however, soon returned to Scotland, and was appointed instrument-maker to the University

of Glasgow. Here his attention was first directed to steam-engines by Dr. Robison, then a student; but young Watt was obliged to mind his business, which left him little time for steam-contrivances, until it was his lot to repair a model of Newcomen's engine, belonging to the University.

“And now, before we can well understand the nature of Mr. Watt's principal contrivances, we must examine the structure of the steam-engine, as it is usually made in the present day. I must request my young friends to favour me with their whole attention, or our time and trouble will be spent this evening in vain. In order to have a clear notion of this subject then, we must bear in mind this fact, as the foundation of the whole, that water when heated to the boiling-point naturally assumes the form of vapour, and thus passes away, and this vapour occupies a space about two thousand times as

large as the water that produced it. Now, it is this *difference in size between the water and its vapour*, and the *power* by which the change is made from one state to another, that gives motion to the steam-engine. If I could cause this block of wood to expand itself so as to become two thousand times as large as it now is, and if this expansion were accomplished with an irresistible force, I need not be long in placing the substance in such a situation as to actuate machinery in all directions. Then again, if I could find the means of suddenly contracting that expanded substance into its original dimensions, and that too by an irresistible power, I might contrive my apparatus so as to be kept in motion also by that means. It is true that I can to a certain extent cause this piece of wood to do as I have said. By burning it, the greater portion is converted into smoke, which, if at liberty, does expand and form a

large volume, like vapour. But smoke has no power to *make itself room* if confined, nor can it be reduced to the bulk of the wood again by any process with which I am acquainted. No.—Water is the material which, by the application of heat, is caused thus to expand with an almost immeasurable force, and the vapour thus formed will, by the sudden withdrawal of heat, *return to its former condition and bulk, as water*; being unconsumed and unchanged, and not necessarily reduced a single drop. Thus it is that Nature conducts her vast processes, whereby clouds are formed, the earth is watered, rivers flow, and these, with the ocean, form clouds again by evaporation and distillation constantly going on, but without the least waste of the material itself.

“ We have seen how Hero, De Caus, Branca, and others, employed steam as a prime mover: let us endeavour to acquaint ourselves with the manner in which the same power is now

made to produce results so vast and important to mankind. We will now suppose that a small tube or hollow cylinder is fitted with a plug, having a wire attached to it to communicate motion. Now this plug, being made to slide up and down, but yet so tight as to prevent any fluid from passing, is called a *piston*, and the wire a piston-rod. See!—here is a glass cylinder which shows what I mean—it is about six inches long and one inch in diameter. A young friend has, at my request, cut out a piece of cork, and fitted a wire to it, by which, you see, I can move the piston up and down by my hand. But it is plain that, if I can introduce anything within the cylinder and under the piston, which has power to make its own way, it will raise the piston for me; and if, when it is so raised, I can suddenly withdraw that power from beneath, and place it at the top of the piston, that body will immediately descend, and be ready to receive

the power from below as before. Thus, so long as I can continue to apply my power each way alternately, I shall have an alternate movement of the piston-rod at my command—this is called by mechanics a reciprocating motion, and may be applied in various ways to perform the various operations needed.

“I have already stated, that water, by the application of heat assuming the form of steam, supplies us with the vast expansive power we need, and that, by the withdrawal of that heat, it returns to its former bulk. The glass tube will not admit of the introduction of steam; but you can easily conceive that if it could be admitted here, and had no other way of escape, it would force this piston upwards. If then the cylinder and its contents were suddenly cooled, the steam, instead of occupying nearly the whole of the tube, would be condensed, and fill only a two-thousandth part

of the bulk in the form of a few drops of water within, in which case the mere pressure of the air on the top of the piston would force it violently down; and thus old machines, called atmospheric engines, were formerly worked. But now, at the instant the steam is condensed below, fresh steam is admitted above, and thus we have as much power one way as the other."

The audience had by this time nearly all risen from their seats, for it was evident that preparations were making for setting the little steam-engine in actual operation. Frank was seen busily passing to and fro, partly behind the green curtain, and the continued blowing of a roaring fire was heard. At length water hot from a kettle was brought forth, and poured into the reservoir allotted for its reception belonging to the engine. Immediately after this, a large sparkling iron heater was brought from the fire-place, and

thrust into the part which we should call the furnace of the engine. A simmering noise was presently heard, and in the course of two or three minutes steam began to issue: the engine at first slowly, then rapidly, showed proofs of inward power; and at length the rocking lever-beam, the dancing piston-rods, and the swiftly revolving fly-wheel, gave abundant evidence, beneath clouds of vapour hissing from various apertures, that this was indeed an effective steam-engine.

The lecturer had no longer any need to request attention. All eyes were fixed on the beautiful mechanism, which thus satisfactorily displayed its various functions before them. It was not till the heat of the iron was so far gone as to fail in keeping the water boiling, when the machine of course stopped, that Mr. Lever found an interval for the due explanation of the sundry parts and motions. As my young readers have not the machine before

them, it will be necessary to refer them to the engraving, which represents so much of a common steam-engine as may be sufficient for our present purpose. I must refer to and describe the parts by the letters placed against them in plate 28. A is the boiler, with the furnace underneath it. B is a pipe leading from it, and connected with the cylinder c. I must explain that this is what is called a *section* of the thing; that is, it is shown as if cut in half down its whole length, to exhibit its internal apparatus. Here you observe the piston and rod, marked d. Now the pipe B is so contrived that it can admit steam from the boiler into the cylinder, either above or below the piston alternately. Next, observe a vessel surrounded by cold water, and connected by a pipe with the cylinder. s is the tube of a pump on the common principle, having its piston and rod connected with the great beam; this beam moves on a centre, and its motion

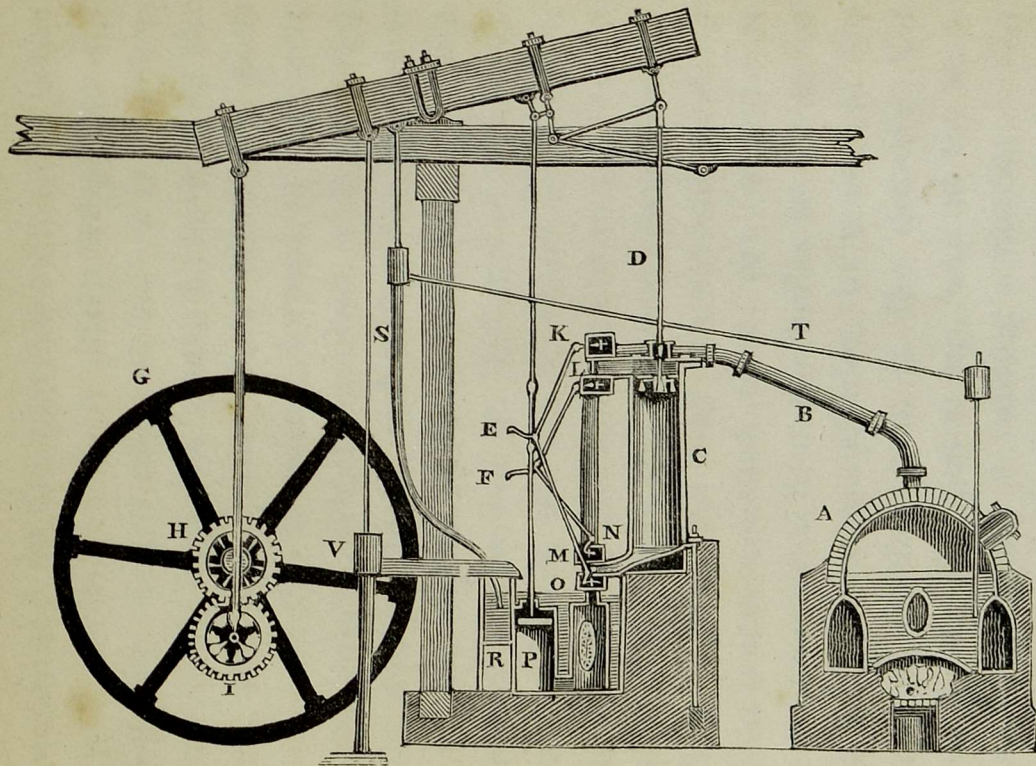


PLATE XXVIII.

SECTION OF WATT'S STEAM-ENGINE.

is occasioned by the piston-rod *D*, as it slides up and down. *V* is a pump supplying the cold water already referred to. *T* is the connecting tube from the pump *S*, to convey the water into the boiler when otherwise done with. *G* is the fly-wheel, formed of cast-iron, of vast weight, which revolves with amazing power and swiftness, and makes the motion of the whole engine uniform and steady. This is moved by the rod at the end of the lever-beam, and acts on the fly-wheel by a crank, such as turners and knife-grinders use with a treadle. *H* marks the sun and planet wheels.

Now I think we may understand how the motion is accomplished, thus: the communication being opened from the boiler to the under part of the steam-cylinder, by means of the bars and catches seen in the drawing, the steam forces the piston up, and at the same time the air-pump *P* causing a vacuum—that is, a space emptied of air or any other fluid—

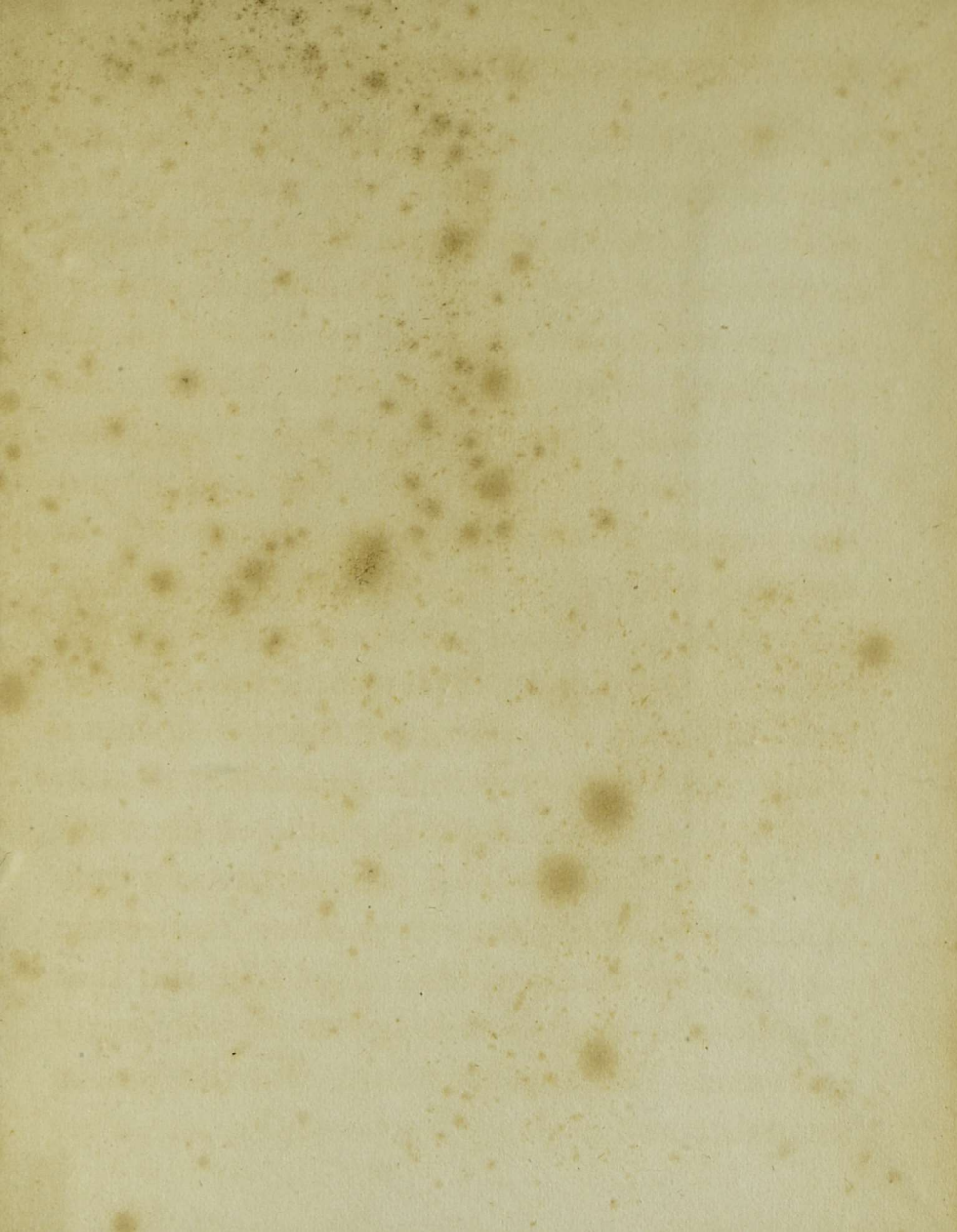
in the condenser connected with it, the steam rushes into the condenser, and now a vacuum is formed beneath the piston, at which moment the steam enters above the piston, and is in like manner drawn off and condensed; and thus alternately the pressure of the steam acting on the under and upper sides of the piston, a *reciprocating* motion is produced in the beam, and this will continue as long as the steam is produced.

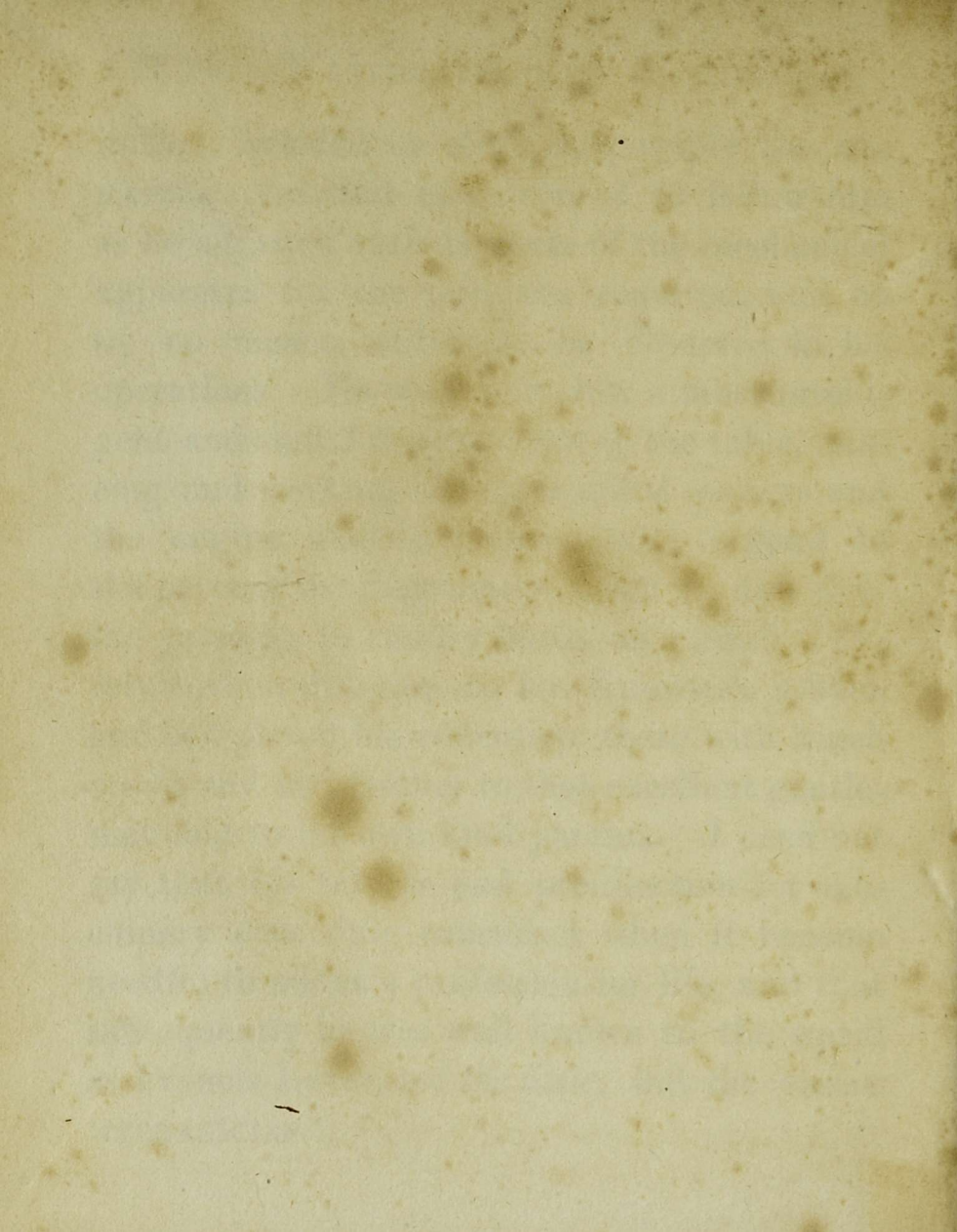
The lecturer had a great advantage in pointing out to his pupils the actual parts as he explained them. We have given the substance of his remarks, which it is hoped will, by a diligent examination of the plate, be understood. “This,” continued Mr. Lever, “is the form nearly which Mr. Watt gave to the steam-engine, and it very little resembles the engine he found in use. A few bushels of coals will now perform the work of two hundred horses in a day, and by the genius of man this vast power

is now made capable of the most tremendous exertions of engine force, or the most delicate operations of the loom and reel. If a lake is to be drained,—a forest to be reduced to beams or boards ;—if artillery is to be bored, or a watch-chain polished ;—if the produce of the field is to be prepared for the housewife's use ;—if produce and manufactures are to be conveyed to distant shores ;—if merchants desire to convey themselves or their goods from Manchester to Liverpool ;—and lastly, if the press is to record and transmit these wonders—the steam-engine is the great and efficient performer.”

Mr. Lever then made his bow to the company before him, and closed these his familiar lectures. We have not had time or space to notice our friend Frank much in narrating them, nor to represent him in the conspicuous situation really occupied by him whilst his father delivered his instructions. The lad,

indeed, avoided as much as possible the numerous eyes that endeavoured to follow him as he adjusted various parts of the mechanical apparatus for the purposes required, and he by no means wished to be observed in his operations. He was, however, a most intelligent and skilful *demonstrator* at the table, placing and working the mechanical powers and the engine models, pointing with a wand to the parts of the diagrams referred to, and finding passages in sundry books as wanted. He returned in due time to Dr. Knowles's school, and completed his education there with much credit and satisfaction to that excellent gentleman and to his own kind parents. I need not say that his talents and predilection for machinery were duly consulted when it became needful to adopt a profession for life, and that subsequently he was well known to the world as Francis Lever, *not the little*, but the GREAT MECHANICIAN !





52 CA. Hum

