THE

REV. ROBERT WILLIS, M.A. F.R.S. &c.

ON

MACHINES AND TOOLS FOR WORKING IN METAL, WOOD, AND OTHER MATERIALS.

The portion of the Exhibition which it is proposed to consider this evening, must be considered under a very different aspect from those which have formed the subject of the previous Lectures. Considering the entire collection as made up of Natural Materials, Artificial Products, and the Processes by which the first are converted into the second, it is easy to show that the two first of these groups were exceedingly well and completely represented, and generally interesting and intelligible; but that the last, under which our present subject is included, was, on the contrary, imperfectly represented, and so little understood, as to lose much of its interest.

The consideration of natural or raw materials, belonging as it does to the natural sciences, has been long familiarised to all, as furnishing the most instructive, delightful, and interesting subjects of study and amusement, either in the animal, vegetable, or mineral kingdoms, according to the taste or habits of each observer; and the practical
view of the subject which is especially directed to the useful purposes to which these natural materials may be applied, has been also long since illustrated by collections like that of the Museum of Economic Geology and others, which paved the way for the magnificent and complete collection in the Great Exhibition, in which all nations combined to display with gratitude and pride the natural treasures, of which they are the several depositories, as stimulants to industry and commerce.

The products include the great mass of objects that constitute our food and clothing, contribute to our daily necessities, comforts, and luxuries, and minister to our employments, or to the enjoyments we derive from the fine arts; and thus every person is in one way or other interested in them, and may understand them. The completeness of this part of the collection was also greatly promoted by the commercial advantages that promised to accrue to the exhibitor, as well as to the spectator, by the universal display and choice of all the useful and ornamental results of industry, for the first time offered in one vast bazaar by the whole world of manufacturers to the whole world of customers.

How different is the case with the processes and the machines concerned therewith! In many cases noisy, offensive, and dirty, or requiring conditions of heat or damp, which made it impossible to carry them on in the presence of spectators; and if not labouring under these disadvantages, at least requiring long explanations and experiments to make them intelligible; it is plain that no attempt at a complete collection could be made, if, indeed,
such a result were desirable. Enough of manufacturing machines were really shown to give to the general spectator an idea of their beauty of form and workmanship, and of the precision of their action, according to the style and manner of machine-making which characterise the present age; and such processes were selected for daily practice as were intelligible, at least by their results, if the steps that led to them remained mysterious to the lookers-on. Sheets of white paper, entering at one end of a machine and duly delivered at the other in the complete form of a printed newspaper; envelope folding; weaving and spinning, and the like, served to show the general character of machine-craft, as contrasted with the slow production of such articles by the handicraft methods with which most of the spectators were familiar.

These practical obstacles applied, perhaps, the most forcibly to the class which is appropriated to the present evening, namely, machines for working in wood and metal, which require a solid foundation, are necessarily accompanied in use by noise, chips, and other annoyances, and are expensive to maintain in action, and not, generally speaking, intelligible or interesting to ordinary spectators, at least without systematic explanations, which could not be afforded under the circumstances.

I trust that I have now said enough to show that, without in any respect disparaging the Exhibition, or casting any shade upon that most admirable and unique incident of human history, which we have been so accustomed to look upon with unmixed admiration and delight, we must admit that, from the very nature of the case, this one de-
partment was very incompletely represented with respect to the machinery of our own country, and, of course, still more so with respect to other countries. Any attempt, therefore, to estimate from the Exhibition Catalogue the extent to which machinery is used in the manufactures of this or any other country, considered separately, or its relative employment by different countries, would lead to the most fallacious and unjust conclusions.

But one part of my duty this evening, which forms a principal point of the instructions under which I, in common with my colleagues upon this occasion, have the honour of acting, is "to state freely and without reserve my opinion upon the probable immediate effect of the Exhibition on the particular subject of the lecture."

For the reasons above stated, it is much more difficult to foresee and trace the effects that may be expected in the department at present under review than in the other branches of the collection. But there are two very desirable objects which I shall proceed to develop, and which, if we take advantage of the interest excited on the subject of manufacturing science and art by the Great Exhibition, we may possibly succeed in bringing to bear.

The first object is to effect a more intimate union and greater confidence between scientific and practical men, by teaching them reciprocally their wants and requirements, their methods and powers, so that the peculiar properties and advantages of each may be made to assist in the perfection of the other.

The second object is to promote a more universal knowledge amongst mechanics and artisans of the methods
and tools employed in other trades than their own, as well as of those employed in other countries in their own and other trades.

With respect to the first object, it is no secret that there has always existed an unfortunate boundary wall or separation between practical and scientific men, a mutual distrust or misunderstanding of their relative values, which has deprived them of many great benefits that they might have mutually derived from each other's pursuits. It is true that in many branches of science, as in chemistry, geology, and botany, this barrier has to a great extent been broken through; the practical man has found the benefit of scientific generalisations, and the theorist has been compelled to seek the facts upon which his theories are to be based in the mines and manufactories; thus compelling the two classes to work together and learn to understand each other. Still there remains too much of the ancient contempt for "theory," and of an overweening and conceited value for "facts" and "practice."

In no department of science is this carried to a greater extent than between the mathematical and practical mechanics; and yet the mental process by which the parts of a complex machine are contrived and arranged in the brain of the inventor requires the geometrical faculty, as it is called, to a very high extent: that is to say, the power of conceiving mentally the relations of the parts of complex figures in space. So that, in truth, a man gifted by Nature as a mechanist is also qualified as a geometrician; and the untaught inventor, struggling to give form and reality to his conceptions of a new machine, is,
parts which by chance were made unnecessarily strong and heavy, will probably retain their original errors.

The representations of machines and engines in the collections published in the sixteenth and seventeenth centuries, furnish abundant illustration of these remarks. In all that belongs to the mere motion of these contrivances, the greatest possible ingenuity and fertility of invention is displayed. But in all that concerns construction, framing and adaptation of form and dimensions to resistances, strains, and the nature of the work, a total absence of principle and experience is manifested; so that it is apparent that these machines would act very well in the form of models, but that, if actually set to work, the most of them would knock themselves to pieces in a very short time.

A profound knowledge of theoretical mechanics is not necessary for all persons concerned about machines, any more than an elaborate acquaintance with the entire subject of astronomy is needed by every sailor. Yet sailors have no horror of mathematics, and know very well how to make use of the parts that are prepared for them. And all men who are engaged in the contrivance of machinery, whether in reducing to practice their own inventions, or those of others, should be competently instructed in the elements of the subject, as well as in the history of machinery; and the artisans themselves would find their labour greatly facilitated by a knowledge of geometry and mechanics to a limited extent, proportioned to their requirements.

We may hope that one of the permanent results of
the Exhibition may be, that men's minds being more forcibly led to the consideration of the subject, a system of professional education for practical men may be organised, so as to enable every one to obtain just so much as may be necessary for him in his own position.

The preparation of such a system of education is difficult, and requires great care to avoid the error of teaching much that is unnecessary, and that, in fact, cannot be comprehended, unless by a student who intends to devote much more time, and to enter much more profoundly into those branches of study, than is contemplated for the purposes we are now considering. But we know that difficulties of this kind have been already encountered, and, as it appears, successfully overcome in France, after failures had taught experience.

I have already said, at the outset of these remarks, that not only do practical men require theoretical knowledge, but that, also, theoretical men require practical knowledge, a better acquaintance with the difficulties that practice requires them to lend a hand in developing, explaining, and overcoming. To form a system of education, strictly limited to the requirements of practical men, we must know what these requirements are, and must in imagination place ourselves in the position of these men, to understand the difficulties arising from their occupations, which theory may dispel. We must, in short, select the examples and illustrations of our applied mathematics from the familiar cases of actual machine-work, and endeavour to solve them with the least possible
amount of geometry. It may be worth while to consider a little how this may be attempted.

Every machine is constructed to perform a certain specific operation, and accordingly contains parts especially applied to the work in question; which working parts are connected by the mechanism in such a manner, that each shall move according to the law required by the nature of the work. One, perhaps, constantly revolving slowly; another, rapidly; and a third, back-and-forwards, and so on. But the connecting mechanism by which these different motions are tied together may be varied in many ways, and each is common to all machines that happen to require similar co-existent motions in their working parts.

The nature and principles of trains of mechanism, by which dissimilar motions may be thus produced, the one from the other, can be taught without any reference to the work or purpose of machinery, and is, indeed, best so taught. But to illustrate and fix the teacher’s meaning, it is well to show examples of the application of each motion to some real machine.

Now it must always be recollected, that the merit of a piece of mechanism may be exceedingly great, if considered as an example of pure mechanism; that is, of the ingenuity or profound knowledge displayed in the conversion of one motion into another, although the purpose of the machine to which it happens to be applied may be very trivial. But this is not the way in which the world would judge of machinery; and yet combinations of pure mechanism, that form the essential parts of the most
useful and valuable machines in the manufacturing series, were originally invented for purposes of the most trivial and useless character.

The "differential box" of the bobbin-and-fly frame was first contrived for an equation clock; that is, to enable the hand of a clock to move round the dial in such a way as to point to the true time as shown on a sun-dial. The "slide rest," as we shall presently see, was contrived towards the end of the last century, to enable the amateur turners of the court of France to ornament their snuff-boxes with more precise patterns of guilloche-work. The motions of a mouse-trap may be found in a steam-engine.

Now, in showing the practical application of any given combination of pure mechanism, one machine will do as well as another; but it is better to select one whose purpose and functions are likely to be readily appreciated by the student, that his attention may not be too much distracted from the mechanism. Thus, if I were teaching a mathematical student the differential motion, I should select the equation clock as the example, because its purpose depends upon an astronomical principle which forms part of his proper studies. But if I were teaching a mechanist, I should rather take the bobbin-and-fly frame for my example.

In forming a system of instruction for practical men, therefore, we may, by a more practical selection of examples, be enabled to teach the principles of mechanics, without greatly altering our present methods. It is true that our theoretical writers are rapidly introducing examples of the actual machinery of our own time into their
systems, still these books are necessarily rather intended

to teach machinery to mathematicians, than to teach

mathematics to mechanists.

It may be remarked that, at least in one branch of

mechanics, the "strength of materials," the value of

theoretical and experimental science has been fully recog-
nised by practical engineers, and the Britannia bridge may
be quoted as a triumphant example of the advantages that
arise when theory and practice go hand in hand.

We will now proceed to the immediate subject of our

Lecture, namely, the machines for working in metal, wood,
and other materials.

The object of such machines is to work rough material

into shape, which may be done in three different ways:

(1.) By abrading or cutting off the superfluous portions in

the form of chips or large pieces; (2.) If it possess duc-
tility, we knead it, or press it into form in various ways,
as by hammering, rolling, drawing, &c.; (3.) If it be
fusible, we melt it, and pour it into a mould. I forbear to
include the producing a given form by joining together
pieces, because each piece must be shaped in one or other
of the above ways. The most interesting series of machines
is that which belongs to the first group; and to this I
must, for the present, confine my attention. It may be
interesting to sketch the history of their introduction.
Machines of this kind are either general, like the lathe or
the planing-machines, which are used for a great variety of
purposes, or are especially adapted to the production of a
single object of manufacture; in which case they are often
contrived in a series, as the block-machinery, the machines
for making cedar pencils, and the like, and the introduction of such especial machines is of great importance, and has certainly not yet reached its limits. As the machines of this latter kind are commonly modifications of one or other of the first, the history of the two must be considered together.

The origin of the turning-lathe is lost in the shades of antiquity; and the saw-mill, with a complete self-action, turned by a water-wheel, is represented in a MS. of the thirteenth century at Paris, and is, probably, of much earlier contrivance. The lathe was, in process of time, adapted to the production of oval figures, twisted and swash-work, as it is called, and, lastly, of rose-engine work. The swash, or raking mouldings, were employed in the balusters of staircases and other ornaments at the period of the “Renaissance” in architecture, about the end of the sixteenth century, and, therefore, the swash-lathe assumes somewhat of the character of a manufacturing machine. But the simple lathe was much employed in screen and stall-work during the middle ages. The first real treatise on turning is Moxon’s (1680), which gives us a valuable picture of the state of the art at that period, and he has preserved to us the name of the engine-manufacturer of that day, Mr. Thomas Oldfield, at the sign of the Flower-de-luce, near the Savoy in the Strand, as an excellent maker of oval-engines, swash-engines, and all other engines, which shows that such machines were in demand. A few drawings of such machines occur in earlier works, beginning with Besson, in 1569. From the treatise of Plumier, published at Lyons in 1701, we learn
that turning had long been a favourite pursuit in France with amateurs of all ranks, who spared no expense in the perfection and contrivance of elaborate machinery for the production of complex figures. This taste continued at least up to the French Revolution, and contributed in a very high degree to the advancement of the class of machinery that forms the subject of our present evening. In our own country the literature of the subject is so defective that it is very difficult to discover what progress we were making during the seventeenth and eighteenth centuries. A few scattered hints only can be collected, whereas in France the great "Encyclopédie" and other works, abundantly illustrated, give the most precise and accurate knowledge of the state of this and other mechanical arts.

Smeaton has recorded that, in 1741, Hindley the clockmaker of York showed him a screw-cutting lathe, with change-wheels, by which he could, from the one screw of the lathe, cut screws of every necessary degree of fineness, and either right or left-handed. It seems to be implied that this was a novelty, and that Hindley had invented it; and it was soon imitated by Ramsden, and is now universal. At all events, such a machine is not alluded to in the French works already mentioned, and serves to show the advance we were then making in the practical improvement of the lathe.

But the clockmakers, to which body Hindley belonged, were the first who employed special machines for their manufactures. Their wheel-cutting engine has been ascribed to Dr. Hooke, about 1655, and its use rapidly
spread over the Continent. The gradual improvement of this machine, and the successive forms which it assumed as the art of construction was matured, forms a very instructive lesson. But herein our own countrymen have largely contributed to its perfection. Henry Sully, an English clockmaker, who removed to Paris about 1718, carried with him, amongst other excellent tools, a cutting-engine, which excited great admiration there. The form of the present French engine is, however, derived from Hulot's machine (about 1763). But our English engines, in which the dividing-plate is superseded by a train of change-wheels, so contrived as to require an entire turn of a latch-handle for each shift, and thus secure against error, is derived from Hindley's engine, which he showed to Smeaton in 1741, and which finally passed into the hands of Mr. Reid of Edinburgh.

The fusee-engine, which is another special clockmaker's machine, must have greatly contributed to the perfection of machines for working in metal.

But the next great step towards the perfection of machine tools was the slide-rest. The slow and gradual way in which this invaluable device acquired the distinct and individual form in which it now exists, is a very curious example of the history of machinery, the development of which, at length, would occupy too much space on the present occasion, even if it could be made intelligible without drawings. Suffice to say, that although as early as 1648 Maignan published at Rome* engravings of two

curious lathes for turning the surfaces of metallic mirrors for optical purposes, in which the tool is clamped to frames, so disposed that when put in motion it is compelled to move so as to form true hyperbolical, spherical, or plane surfaces, according to the adjustment, and that although the fusee-engines, screw-cutting lathes, and other contrivances already alluded to, employed tools guided by mechanism, yet the real slide-rest does not make its appearance until 1772, when in the plates of the French "Encyclopédie,"* we find complete drawings and details of an excellent slide-rest, as nearly as possible identical with that usually supplied by Messrs. Holtzappfel and other makers of lathes for amateurs. It must have been contrived a little while before this publication; but the meagre descriptions that accompany the plates leave us completely in the dark with respect to its history. Brah- mah's slide-rest of 1794† is so different and so inferior in convenience, that the two could not have had a common origin; and we must suppose that the French slide-rest was unknown to that ingenious mechanist, although it is scarcely possible that copies of the "Encyclopédie" should not have found their way into our libraries.

But the improvements of the steam-engine, its application to giving motion to the wheels of mills and other machines, the increasing employment of iron, and other advances in the construction of mechanism, which were now developing themselves, gave men courage to devise and carry out large and extensive schemes for the applica-

* Tom. x. pls. 37, 38, 84, 85, 86.
† Weale's edition of "Buchanan's Mill-work."
tion of machinery to manufactures. In our especial de-
partment we may record, as an early example, Bramah,
who, in 1784, obtained the patent for his admirable lock,
and immediately set about the construction of a series of
original machine tools, for shaping with the required pre-
cision the barrels, keys, and other parts of the contrivance,
which, indeed, would have utterly failed unless they had
been formed with the accuracy that machinery alone can
give. In Bramah’s workshop was educated the celebrated
Henry Maudslay, who, as I am informed, worked with him
from 1789 to 1796, and was employed in making the prin-
cipal tools for the locks.

Foremost among the ingenious persons who carried on
this great movement must be recorded Brigadier-general
Sir Samuel Bentham.* From his own account it appears,
that in 1791 steam-engines in this country were exten-
sively employed for pumping mines, and for giving motion
to machinery for working cotton, and to rolling-mills, and
some other works in metal; but that in regard to working
in wood, steam-engines had not been applied, for no
machinery, other than turning-lathes, had been introduced,
excepting that some circular and reciprocating saws and
working tools had been applied to the purpose of block-
making by the contractors who then supplied blocks to
the navy; even saw-mills for slitting timber, though in
extensive use abroad, were not to be found in this country.

General Bentham had at this time made great progress

pp. 221, 293, 307; also Memoir, by Mrs. Bentham, in Weale’s “Quar-
terly Papers on Engineering,” vol. vi.
in contriving machinery for shaping wood, as is sufficiently shown by his remarkable specifications of 1791 and 1798; and he informs us that, rejecting the common classification of works according to the trades or handicrafts for which they are used, he classed the several operations that have place in the working of materials of every description according to the nature of the operations themselves, and, in regard to wood particularly, contrived machines for performing most of those operations whereby the need of skill and dexterity in the workman was dispensed with, and the machines were also capable of being worked by a steam-engine or other power. Besides the general operations of planing, rebating, mortising, sawing in curved, winding, and transverse directions, he completed, by way of example, machines for preparing all the parts of a sash-window and of a carriage-wheel, and actually showed these and other machines in a working state in 1794 in London.

This led to his appointment as Inspector-general of Naval Works, for the purpose of introducing these and various other machines into the royal dockyards, which he immediately set about effecting. From this time (1797) the introduction of machinery for the preparation of blocks and other works in wood at Portsmouth, Plymouth, and other Government establishments, takes its origin. In 1802 the General received a most powerful and efficient auxiliary in the person of Mr. Brunel, who in that year presented his plans for the block-making machinery. His services being immediately secured, and Mr. Henry Maudslay engaged for the construction of the mechanism,
the admirable series of machine-tools were finished and set to work in 1807, by which every part of the block and its sheaves are prepared.

The completeness and ingenuity of this system, the beauty of its action, and the novelty of the forms and construction of the whole of the mechanism, excited so much admiration, that the whole of the machinery in Portsmouth dockyard has usually been popularly ascribed to Mr. Brunel alone. It must not be forgotten, however, that much machinery for the performance of isolated operations had been previously employed, as well by Mr. Taylor of Southampton, the contractor for the blocks of the navy previously to 1807, as by General Bentham himself in the dockyards.

At this distance of time it would be impossible to discover the exact shares of merit and invention that belong to Brunel, Bentham, and Maudslay, in this great work. To the first we may, however, assign the merit of completing and organising a system of machine-tools, so connected in series, that each in turn should take up the work from a previous one and carry it on another step towards completion, so that the attendant should merely carry away the work delivered from one machine and place it in the next, finally receiving it complete from the last.

Some of the individual machines in the series had, it is true, been previously contrived and employed. Thus, the self-acting mortising-machine is distinctly described in Bentham’s specification of 1793, so completely as to entitle him to the full credit of the invention of mortising-machines, whether by the process of boring a hole first
and then elongating it by a chisel travelling up and down vertically, or by the process of causing the hole to be elongated by the rotation of the boring-bit during the travelling of the work. The same specification describes boring-machines, some of which are similar in their arrangements to those of the block series; also the tubular gouge, which is employed in the shaping-machine, and the formation of recesses, by a revolving and travelling tool for the inlaying of the coaks.

One of the most useful machine-tools that made its appearance at the end of the eighteenth century was the circular saw. This had been applied to cutting metal on a small scale, as in the cutting-engine, ever since the time of Dr. Hooke; if, indeed, these early examples were not more like circular files than saws. Where or by whom the woodcutter’s saw was put into the form of a revolving disk has not been recorded. It found its way into this country about 1790, some say from Holland, and was employed at Southampton and elsewhere in wood-mills. Bentham greatly contributed to the practical arrangements necessary to give it a convenient form. He describes and claims the bench now universally used, with the slit, parallel guide, and sliding bevil-guide, and other contrivances.* Brunel introduced a variety of ingenious and novel arrangements, as well as the mode of making large circular saws of many pieces.† Mr. Smart also contrived a series of sawing-machines for making canteens, cutting tenons, &c.

After the completion of the block machinery, it becomes

very difficult to trace the subsequent improvements. The art of machine-making for working in metal was gradually advancing, but is not recorded in patents, and very little described in books. The slide-rest principle was extended, large self-acting lathes constructed, and boring-machines of great precision and improving structure were called into existence by the necessity for extreme accuracy in the cylinders of steam-engines. The best engravings of the machines of this period are in "Bees' Cyclopædia," and in the volumes of the "Transactions" of the Society of Arts.

No greater proof of the obscurity which hangs over the history of machine-tool making, in the first half of this century, can be given, than the unknown origin of the planing-machine for metal. The machine which Nicholas Focq contrived in 1751, which has been called a planing-machine, has no title to the name, or any resemblance to the modern engine. It is nothing but a heavy scraping-tool, which is dragged along the bar upon which it is to operate, and rests upon it, pressed into hard contact with it by strong springs. It will, therefore, smooth the surface, and remove small irregularities, as a carpenter's plane does with a board, but it will not produce a correct plane surface, or even make successive cuts. It is a mere plane, and not a plane-creating engine. Neither could the machines patented by Bentham in 1791, and Bramah in 1802, for planing wood, although real planing-engines, have suggested the engine in question, for their properties and arrangements are wholly different. The engineers' planing-machine made its way into the engineering world
silently and unnoticed; and some years afterwards, when its utility became recognised and men began to inquire into its history, various claimants to the honour of its invention were put forward. We can only learn that, somewhere about 1820 or 1821, a machine of this kind was made by several engineers. Messrs. Fox of Derby, and Roberts of Manchester, appear amongst the number, and the forms which they gave to the engine have remained permanent. Mr. Clement has also been mentioned, as well as others. It is clear that the inventors were not at all aware of the immense importance of their work, but experience has proved the utility of this machine to be so great, that it may be pronounced the greatest boon to constructive mechanism since the invention of the lathe. Nevertheless, no drawing or description of the planing-engine is to be found in any English book until 1833, when the Society of Arts published beautiful engravings of Mr. Clement's machine; the complexity of this, and the unfortunate arrangement of the bed, which he mounted on wheels, has prevented it from being adopted. The French and other Continental mechanical journals, much earlier began to give engravings and descriptions of the English planing-machine. In 1829 the "Industriel" has one of the simplest, and the Bulletin of the "Société d'Encouragement," the collections of Le Blanc, Armengaud, and others, contain engravings, not only of the planing-machines, but of the other machine-tools of all our best English makers, generally accompanied by admirable descriptions and minute details, that may well serve as models to our own writers on such subjects, and at the
same time show how much good service is rendered by the superior mathematical and theoretical education of French engineers. Be it remembered, too, that, not content with describing and analysing our machine-tools, which they do in a most liberal and admiring spirit, they also employ their generalising powers in the endeavour to construct improved forms, and with such great promise of success, that, unless we also begin to apply science to this subject, we run considerable risk of falling behind our ingenious neighbours.

The mortising-engine of the block machinery was applied by Mr. Roberts, of Manchester, to the formation of the key-ways of cast-iron wheels, and also to the paring, or planing by short strokes, of the sides of small curvilinear pieces of metal; such as cams, short levers, and other pieces that do not admit of being finished in the lathe. Thus, under the name of slotting and paring-machine, a new and generally useful machine-tool sprang up; and subsequently another, derived from it, has been produced, and apparently with equal success, under the title of a shaping-machine. It is, in fact, a planing-machine, in which the tool is attached to the end of a horizontal bar, which is moved to and fro, so as to plane, with short transverse strokes, a piece of work fixed on a complex adjusting-bed, or on a revolving mandril, so as to receive the action of the tool.

[All these and other varieties of machine-tools were, in the oral delivery of this Lecture, illustrated by models, without which, or diagrams, it would be impossible to state, in an intelligible form, the explanations of the
general principles which these machines possess in common, which must be therefore omitted in this place.]

The existence of such principles, leads us to the hope that machines much more comprehensive, and yet simpler in form, will be devised for the same purposes, by means of which the construction of machinery in general will attain to greater perfection; and machine-tools be introduced into workshops of a smaller character than at present, in the same manner as the lathe.

In America, a variety of contrivances are employed in workshops to facilitate and give precision to ordinary operations: as, for example, the foot-mortising machine for wood. The earliest contrivance of this useful tool (the offspring of Bentham's mortising-engine), appears to be in a Pennsylvanian patent by John M'Clintic, in 1827,* since which the machine has got into general use in America, and has consequently been the subject of numerous patents for minor arrangements. One of these, by Page, was engraved in the "Mechanics' Magazine" (1836, vol. xxvi. p. 385), and thus introduced to English workmen; and in the last year Mr. Furness, of Liverpool, has patented some improvements in England, and endeavoured to introduce the machine. It formed a very interesting object in the Exhibition, together with other American contrivances for boring, tenoning, and such-like operations, which the peculiar conditions of that country have called into existence, by creating a market for them.

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amongstthemechanistsofdifferentbranchesandcountries.
A very interesting part of the Great Exhibition was the collection of strange-looking tools from France, Germany, and elsewhere, differing in their forms and handles and mode of operation from those employed for the same purposes by our own workmen. Without doubt some of them might afford useful hints; for example, the universal employment of the narrow frame-saw on the Continent for work that we perform with broad-bladed saws, stiffened with brass or iron backs, might lead our workmen to consider whether, after all, our practice is not carried too far in this respect.

But the facilities for working in metal, and its general introduction into all kinds of frame-work, where wood was exclusively employed, as well as the substitution of cast-iron for brass, has made it imperative upon persons of all trades, which are affected by these changes, to learn the management of these new materials, if they desire to profit by the advantages consequent upon their employment. Thus, the philosophical instrument makers formerly employed brass for their metal work, and constructed their machines, even the largest astronomical instruments, in a great number of pieces screwed together. We have now learnt that stability is best ensured by employing fewer pieces, and that cast-iron is, on all grounds, a better material than brass. But the tools and methods of working in cast-iron are wholly different, and therefore the philosophical instrument makers must turn engineers, and employ planing-machines and the like. The making of large clocks, and various other articles of common use,
must undergo the same change. It is useless to say that these men can go to an engineer's shop to get jobs done for them as required. Such a method can only lead to a partial and imperfect employment of the new resources and advantages which are to be developed. For instead of a full and complete adoption of these novelties, the use of them will be necessarily evaded in every case where they can be dispensed with, unless the master-workman can employ them freely as his own.

In machinery we have to deal with every kind of material, and to avail ourselves of the peculiar properties of all, in their appropriate places; and thus a skilful engineer should be familiar with every kind of mechanical manipulation and material, from a sheet of card paper to an iron bar, and ought to know as well how to hem a pocket-handkerchief as to rivet a boiler. It is of no use for him to employ workmen of any trade in carrying out new combinations unless he himself know how to instruct them. A musician who is about to compose a symphony need not be able to play on the violin like Paganini, or on the piano like Thalberg, but he must be well acquainted with the powers and manipulations of these and every other instrument before he can write passages that will bring out their effects and be adapted to performance. And, in the same way, a man who intends to devise and carry out a new machine must be conversant with the peculiar properties and mode of manipulating every kind of material, that thus he may select and avail himself of them to the best advantage.
LECTURES
ON THE RESULTS
OF THE
GREAT EXHIBITION OF 1851,
DELIVERED BEFORE THE
Society of Arts, Manufactures, and Commerce,
THE SUGGESTION OF H.R.H. PRINCE ALBERT,
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