A descriptive and historical account of hydraulic and other machines for raising water

Ewbank, Thomas

London, 1842

Eisenbibliothek Schlatt

Persistent Link: https://doi.org/10.3931/e-rara-143483

Chapter I.

BOOK III.

MACHINES FOR RAISING WATER BY COMPRESSURE INDEPENDENTLY OF ATMOSPHERIC INFLUENCE.

CHAPTER I.

DEFINITION of machines described in this Book—Forcing Pumps—Analogy between them and bellows—History of the bellows that of the pump—Forcing pumps are water bellows—The Bellows of antediluvian origin—Tubal Cain—Anacharsis—Vulcan in his forge—Egyptian, Hindoo, and Peruvian blowing tubes—Primitive bellows of goldsmiths in Barbary—Similar instruments employed to eject liquids—Devices to obtain a continuous blast—Double bellows of the Foulah blacksmiths, without valves—Simple Asiatic bellows—Domestic bellows of modern Egypt—Double bellows of the ancient Egyptians—Bellows blowers in the middle ages—Lantern bellows common over all the East—Specimens from Agricola—Used by negroes in the interior of Africa—Modern Egyptian blacksmiths' bellows—Vulcan's bellows—Various kinds of Roman bellows—Bellows of Grecian blacksmiths referred to in a prediction of the Delphic oracle—Application of lantern bellows as forcing pumps—Sucking and forcing bellows pumps—Modern domestic bellows of ancient origin—Used to raise water—Common blacksmiths' bellows employed as forcing pumps—Ventilation of mines.

MACHINES of the third class described in this Book, are such as act by compressure: the water is first admitted into close vessels and then forcibly expelled through apertures made for that purpose. This is effected in some by compressing the vessels themselves, as in bellows pumps—in others by a solid body impinging on the surface of the liquid, as in fire engines—sometimes a column of water is used for the same purpose, at others the expansive force of compressed air. Of the last two, Heron's fountain, air engines, and soda fountains, are examples. Strictly considered, these machines have nothing to do with the pressure of the atmosphere, (the active principle of those of the second class,) but in practice it is very generally employed. When the working cylinder of a forcing pump is immersed in the water it is intended to raise, or when the latter flows into it by gravity, it is a forcing pump simply; but when the cylinder is elevated *above* the water that supplies it, and consequently is then charged by atmospheric pressure, the machine is a compound one, embracing the peculiar properties of both sucking and forcing pumps. The latter therefore differ from the former in raising water above their cylinders; and to elevations that are only limited by the strength of their materials and the power employed to work them. They have been considered by some writers as the oldest of all pumps. We shall consider their varieties in the order in which we suppose they were developed.

An intimate connection has ever subsisted between the forcing pump and the bellows; they are not only identical in principle, but every form adopted in one has been applied to the other. The bellows, from the simple sack or skin employed by the negroes of Africa to the complex and efficient instrument of China, and the enormous blowing machines of

our foundries, has been used to raise water: and every modification of the pump, not even excepting the screw, has been applied as a bellows.[a] A singular proof of the analogy between them and of their connection in ancient times, is, that in one of the earliest accounts we have of the *cylindrical* pump, (viz. by Vitruvius) it was used as a bellows "to supply wind to hydraulic organs." And that rotary pumps are as numerous as rotary bellows, is known to every mechanic. Thus, while pumps have been used as bellows, bellows have been employed as pumps; and every device to obtain a continuous current of air in the one, has been adopted to induce an unbroken stream of water in the other.

The history of the bellows is also that of the pump; and if we mistake not it affords the only legitimate source now open in which the origin of the latter can be sought for with any prospect of success. Under this impression we shall examine the bellows of various people, and in doing so the reader will find an auxiliary, but very important branch of the subject, illustrated at the same time, viz. that which relates to VALVES, for the bellows was probably the first instrument of which they formed a part. No other machine equally ancient can be pointed out in which they were required. In fine, the forcing pump is obviously derived from the bellows, or rather it is an application of that instrument to blow water instead of air—an application probably coeval with its invention.

The origin of the arts is generally considered as a subject of mere conjecture. Antiquarians and historians despair of discovering any thing of importance relating to the early history of any of the simple machines. In the present case, however, there can be no doubt that the *first* bellows was the *mouth*; and it was the first pump too, both atmospheric and forcing. The representation of it when employed as a bellows was a favorite subject with ancient statuaries and painters. Pliny gives several examples, and among others, Stipax the Cyprian, who cast an elegant figure of a boy "roasting and frying meat at the fire, puffing and blowing thereat with his mouth full of wind, to make it burn." Aristoclides, was also celebrated for a painting of a boy, "blowing hard at the coals; the whole interior of the room appeared to be illuminated with the fire thus urged by the boy's breath, and also what a mouth the boy makes." Holland's Translation.

That the bellows is of antediluvian origin, there can be little doubt, for neither Tubal Cain nor any of his pupils could have reduced and wrought *iron* without it. The tongs, anvil and hammer of Vulcan, (or Tubal Cain) have come down to our times, and although the particular form of his bellows be not ascertained, that instrument is, we believe, as certainly continued in use at the present day, as the tools just named. Nor is there any thing incredible in such belief, for if even the common opinion, that the whole globe was enveloped in the deluge, be true, Noah and his sons, aware that the destinies of their posterity, so far as regarded the arts of civilization, must in a great measure depend upon them, would naturally secure the means of transmitting to them the knowledge of those machines that related to metallurgy, as among the most essential of all. Of these, the bellows was quite as important as any other; without it, other tools would have been of little avail. Now if we refer to oriental machinery, (among which the bellows of the son of Lamech is to be found if at all,) we shall find, in accordance with its characteristic unchangeableness, that the instrument now used over all Hindostan and Asia in general, and by the modern blacksmiths of Cairo and Rosetta, is identical with

[a] Hachette's Traité élémentaire des Machines, p. 142.

that with which the smiths of Memphis, and Thebes, and Heliopolis, urged their fires, between three and four thousand years ago, and is similar to those found figured in the forges of Vulcan on ancient medals and sculptures. Numerous were the forms in which the bellows was anciently made, but the general features of the one to which we allude, (the lantern bellows) have remained as unchangeable as those of blacksmiths themselves.

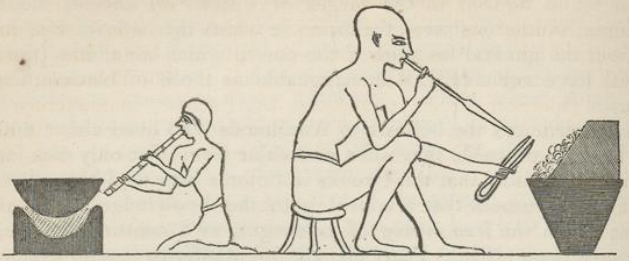
Strabo attributed the bellows to Anacharsis who lived about 600 years B. C. but it is probable that some particular form of it only was intended, for it is not credible that the Greeks in Solon's time could have been ignorant of an instrument that is coeval with the knowledge of metals; and without which the *iron money* of Lycurgus, two centuries before, could never have been made. Pliny (B. vii, 56) attributes it with greater propriety to the Cyclops, who are supposed to have flourished before the deluge. The prophet Jeremiah, who lived long before Anacharsis, speaks of it in connection with metallurgical operations. "The bellows are burned, the lead is consumed of the fire, the founder melteth in vain." Isaiah, who lived still earlier, viz. in the 8th century B. C. alludes to the blacksmith's bellows—"the smith that bloweth the coals in the fire." And Job, nine or ten centuries before the Scythian philosopher flourished, speaks of "a fire not blown." The prophet Ezekiel also speaks of the blast furnace as common—"they gather silver, and brass, and iron, and lead, and tin, into the midst of the furnace, to *blow the fire* upon it to melt it." xxii, 20. Homer, as might be supposed, could not fully describe the labors of Vulcan, without referring to this instrument. His account of the great mechanic at work, is equally descriptive of a smith and his forge of the present day.

> Obscure in smoke, his forges flaming round,
> While bathed in sweat from fire to fire he flew;
> And puffing loud, the roaring bellows blew.
> * * * * * *
> Just as the god directs, now loud, now low,
> They raise a tempest, or they gently blow.
>
> *Iliad*, xviii, 435, 545. *Pope.*

The first approach made to artificial bellows was the application of a reed or other natural tube, through which to direct a stream of air from the mouth—a device that has never passed into desuetude. Such was the origin of the modern blow-pipe, an instrument originally designed to increase the intensity of ordinary fires, but which subsequently became (as the arts were developed) indispensible to primitive workers in metal. How long blowing tubes preceded the invention of other devices for the same purpose is uncertain; but from the fact that oriental jewelers and goldsmiths still fuse metal in pots by them, it may be inferred they were the only instruments in use for ages, before the bellows proper was known: a circumstance to which their universal employment over all Asia at the present time may be attributed, and the skilful management of them by mechanics there. As the only contrivance for urging fires in primitive times, men would naturally become expert in using them, and, as in all the arts of the East, their dexterity in this respect would be inherited by their children, and be retained in connection with their use, with that tenacity that has scarcely ever been known to give up an ancient tool or the ancient mode of using it: hence the paucity of their implements; a file, a hammer, a pair of tongs, and a blowing tube, being in general all that the budget of an African or Asiatic jeweler contains.

As we have given figures of sucking tubes to illustrate the origin of

the atmospheric pump, we here insert some of blowing tubes, as showing the incipient state of the forcing pump.



No. 98. Egyptian using a reed. 1600 B. C. No. 99. Ancient Egyptian Goldsmith.

No. 98, represents an Egyptian blowing a fire with a reed. It is from the paintings at Beni Hassan, and extends back through a period of 3,500 years. According to Mr. Wilkinson, the figure is that of a goldsmith, "blowing the fire for melting the gold," but from the comparative large size of the vessel, it would seem rather to be a cauldron in which the articles were *pickled*. No. 99, is the figure of a goldsmith either soldering or fusing metal with the blow-pipe, from the sculptures at Thebes. The portable furnace has raised cheeks to confine and reflect the heat. The pipe is of metal with the end enlarged and pointed.[a]

No. 100. Goldsmith of Hindostan

Sonnerat, has given (in the volume of illustrations to his voyages,) a plate representing modern goldsmiths of Hindostan, from which the annexed figure (No. 100) is copied. It will serve to show, when compared with the preceding cuts, what little changes have taken place in some mechanical manipulations in the East, from very remote times. A similar figure is in Shoberl's Hindostan. The same mode of fusing their metals was practiced by the ancient gold and silver smiths of Mexico and Peru. Instead of bellows, says Garcilasso, the latter had blow-pipes "made of copper, about a yard long, the ends of which were narrow, that the breath might pass more forcibly by means of the contraction, and as the fire was to be more or less; so accordingly they used eight, ten, or twelve of these pipes at once, as the quantity of metal did require." (Commentaries on Peru, p. 52.)

The next step was to apply a leathern bag or sack, formed of the skin of some animal, to one end of the tube (shown in No. 80) as a substitute for the mouth and lungs. The bag was inflated by the act of opening it, or by blowing into it, and its contents expelled by pressure. To such Homer seems to allude in his account of Eolus assisting Ulysses:

> The adverse winds in leathern bags he braced,
> Compressed their force, and locked each struggling blast. *Odys.* 10.

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[a] Ancient bronze tongs or forceps, similar to those in the cut, have been found in Egypt, which retain their spring perfectly. Crucibles similar to those used at the present day have also been discovered. Wilkinson's Manners and Customs of the Ancient Egyptians. vol. iii, 224.

And Ovid:

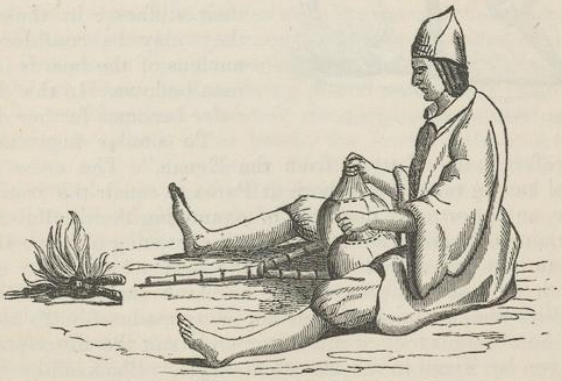
> A largess to Ulysses he consigned,
> And in a steer's tough hide enclosed a wind. *Met.* xiv.

The goldsmiths' bellows of Barbary consists of a goat's skin, having a reed inserted into it: 'he holds the reed with one hand and presses the bag with the other.' (Ed. Encyc. vol. iii, 258.) The Damaras, a tribe of negroes in Southern Africa mentioned by Barrow, manufacture copper rings, &c. from the ore. The bellows they use, he observes, "is made of the skin of a gemsbok, (a species of deer) converted into a sack, with the horn of the same animal fixed to one end for a pipe."

Simple instruments of this description have always been applied to eject liquids. Small ones were commonly used by ancient physicians in administering enemas; a purpose for which they are still used. Large ones were recommended by Apollodorus the architect, a contemporary of Pliny and Trajan, as a substitute for fire engines, when the latter were not at hand. When the upper part of a house was on fire, and no machine for throwing water to be procured, hollow reeds, he observed, might be fastened to leathern bags filled with water, and the liquid projected on the flames by compressing them.

As the current of wind from a single sack or bag, necessarily ceased as soon as it was collapsed, some mode of rendering the blast *continuous* was desirable; and in the working of *iron* indispensible. The most obvious plan to accomplish this was to make use of *two* bags, and to work them so that one might be inhaling the air, while the other was expelling it—that is, as one was distended, the other might be compressed. This device we shall find was very early adopted, and by all the nations of antiquity.

But by far the most important improvement on the primitive bellows or bag, was the admission of air by a *separate opening*—a contrivance that led to the invention of the VALVE, one of the most essential elements of hydraulic as well as pneumatic machinery. The first approach to the ordinary valve, was a device that is still common in the bellows of some African tribes. A bag formed of the skin of a goat, has a reed attached to it to convey the blast to the fire; and the part which covered the neck of the animal is left open for the admission of air. This part is *gathered up* in the hand when the bag is compressed, and opened when it is distended.



No. 101. Bellows of the Foulah Blacksmiths.

An improvement upon this primeval device is exhibited in the bellows of the Foulah blacksmiths, on the western coasts of Africa. It consists

of two calabashes connected together by two hollow bamboos or reeds, inserted into their sides, and united at an angle to another which leads to the fire, as represented in the figure. A large opening is made on the top of each, and a cylindrical bag or tube made of soft goats' skins stitched or otherwise secured round the edges. The workman seats himself on the ground, and placing the machine between his legs, he grasps the ends of the bags, and by alternately raising each with the mouth *open*, and pushing it into the calabash when *closed*, the air in the latter is forced into the fire, and a uniform blast maintained. The action is very similar to that of gathering in the hands the lower edges of two hat linings, and constantly drawing one out and thrusting the other in.

The negroes of the Gold Coast are represented to have other kinds of bellows. The principal tools of their smiths, are "a hard stone for an anvil, a pair of tongs and a small pair of bellows, with three or more pipes, which blow very strong—an invention of their own." We have not been able to find any description of these. See Grand Gazetteer, Art. Guinea; and Histoire Générale, tom. v, 214.

Another species equally simple but more efficient, is common in Asia, Africa, and also in Wallachia, Greece and other parts of Europe. The contrivance for admitting the air is an improvement upon the last, but the orifice is still opened and closed by the fingers of the blower. Instead of the mouth of each bag being drawn up in the hand, it is stretched out in the form of a long slit; to the lips of which two strips of wood are sewed. The inner side of each strip is made straight and smooth, so that when brought together, they form a close joint. They are grasped in the middle by the workman, who alternately opens them when he raises the mouth to admit the air, and closes them when he expels it.

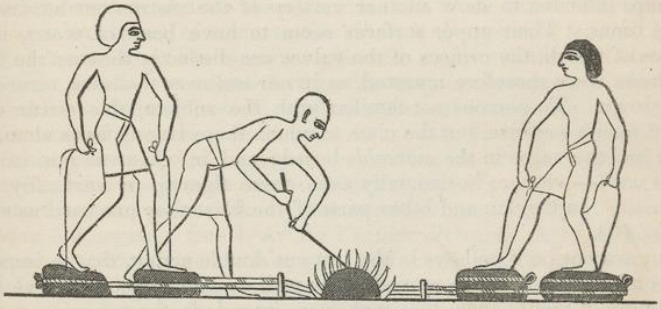
No. 102. Primitive Bellows of Asia.

No. 102 represents the assistant of a Hindoo blacksmith, urging his fire with a pair of these instruments, (copied from the volume of plates to Sonnerat's Voyages.) From an inspection of the figure, it will be perceived that the strips facilitate the act of compressing each bag, by their extending quite over it, as well as by their stiffness: in these respects they may be considered as the nucleus of the boards in the common bellows. In this device, the *valve* becomes further developed.

To similar instruments, Mr. Emerson refers in his 'Letters from the Egean.' The crew of a Hydriot vessel having taken her ashore at Paros to repair the iron clasp of her rudder, an opportunity occurred of examining their bellows. Mr. E. describes them as "a very antique device," consisting of "two sheepskins, united by an iron pipe introduced into the fire, which were alternately dilated with air and compressed, by an Arab slave who knelt above them." With the exception of their not being made of bull's hide but of sheepskin, he observes they would completely suit the description of the bellows given by Virgil in the Fourth Georgic. Blacksmiths in Ceylon use the same kind, but made of bullocks' hides, and furnished with nozzles of bamboo. The blower seats himself on the ground between the two bags, and works them with his hands, pulling up one and pushing

down the other. (See a figure in Davis' history of that island, and also in the Register of Arts, vol. i, 300.) The *domestic* bellows of Egypt is made in the same way, and probably has always been so: to it, Job most likely alluded, (chap. xx, 26.) "The ordinary hand bellows now used for small fires in Egypt, (says Mr. Wilkinson) are a sort of bag made of the skin of a kid, with an opening at one end like the mouth of a common carpet bag, where the skin is sewed upon two pieces of wood; and these being pulled apart by the hands and closed again, the bag is pressed down and the air thus forced through the pipe at the other end."

The next improvement seems to have been that by which the slit was superseded by a flap or clack, so as to be *self-acting*, as in the ordinary European or American bellows—in other words a *valve*, that opened by the pressure of the atmosphere when the bag was raised, and which was closed by its own weight or by the elasticity of the confined air. Among the interesting discoveries which recent examinations of Egyptian monuments have brought to light, figures of such bellows have been found sculptured in a tomb at Thebes, which bears the name of Thothmes III, one of the Pharaohs who was contemporary with Moses. No. 103 represents four employed at one fire, each pair being worked by the hands and feet of a laborer, and in a manner singularly ingenious and effective; proving that the Egyptians of those times well knew how to combine muscular energy with the weight of the body to produce a maximum effect.



No. 103. Egyptian Bellows and Bellows Blowers. 1500 B. C.

The bags were secured to frames or to the ground, and appear to have had rings of cane within them to keep the leather extended in a horizontal direction. A separate pipe proceeded from each to the fire. The valves or clacks are not shown because being placed underneath they were out of sight. In working them a laborer stood upon two, one under each foot, and taking two cords in his hands, the lower ends of which were secured to the top of the bags; he alternately rested his weight upon each to expel the air, and inflated them when exhausted by pulling the cords; thus the whole weight of his body was uninterruptedly employed in closing one bellows, while the muscular force of his arms was incessantly engaged in opening another. We question if a more simple and efficient application of human effort can be produced.

Such bellows were used in Egyptian kitchens, and were indeed necessary when the massive cauldrons and huge joints of meat boiled in them, are considered.[a] The same practice continued through the middle ages, in Europe, when 'bellows blowers' formed part of the establishment of

[a] Wilkinson's Manners and Customs of the Ancient Egyptians. vol. ii, 384. Vol. iii, 339.

royal kitchens, and whose duty it was "to see that soup when on the fire was neither burnt nor smoked."[a] Among the relics that formerly belonged to Guy, the famous Earl of Warwick, is a cauldron or kitchen boiler, made of bell-metal, which contains 120 gallons, but whose capacity does not equal that of more ancient ones.[b] To the old custom of employing persons exclusively at the bellows, as in the preceding cut, Virgil alludes in the following line:

One stirs the fire and one the bellows blows. *En.* viii.

Every modern bellows maker would be convinced from an inspection of the last figures, that valves were employed, since the instruments could not possibly have acted without them; but all doubts respecting an acquaintance with the valve in those remote ages when the sculptures were executed, is removed by two other bellows portrayed in the same tomb, and shown in the next cut. These differ from the preceding and were

No. 104. Egyptian Bellows in use before the Exodus.

perhaps intended to show another variety of the instrument as made in those times. Their upper surfaces seem to have been of wood, in the centre of which, the orifices of the valves are distinctly shown; the valves or clacks were therefore inverted, as in our ordinary bellows turned upside down. To persons not familiar with the subject, this circumstance might excite surprise, but the class to which these belong have almost *always* had the valve in the *moveable* board; and in whatever position they were used—whether horizontally as in these figures, or vertically as in the next. In Ceylon and other parts of the East they are used as shown in No. 104.

But are not both bellows in the last cut double-acting, that is, impelling air from them both when moved up as well as when pushed down? From the figures it would seem that such were intended; for *two pipes* are represented as proceeding from *each*, while one only is connected to those in No. 103; and one instrument was deemed sufficient to occupy one laborer—to this there possibly may be an allusion in the knots on the ends of the cords, which, in the hieroglyphical language of Egypt may signify the greater liability of slipping through the hands, in consequence of the superior force required to work them. Indeed *four* different bellows are represented. In No. 103, two are made of single bags, and two of double ones, as appears by the bands around them: and in No. 104, one is round like the lantern bellows, and the other oblong, both kinds of which are common at this day in the East; and both, as already remarked, seem to be double acting like those of our smiths.

This variety was probably designedly introduced into the sculptures to aid in conveying to posterity a knowledge of the state of the arts at that time in Egypt. The circumstance is an interesting one, and should lead to a more thorough examination of those wonderful, those eternal records of the arts and sciences of past ages, than has ever been given them; not only every group but every figure among the millions imprinted on these

[a] Fosbroke's Encyc. Antiq. [b] Moule's English Counties. Lon. 1831.

imperishable pages, deserves not merely to be scrutinized, but accurately copied. Many of them are fraught with information of the highest interest to the arts; and whether the mass of hieroglyphical records be ever understood or not, there is no difficulty in comprehending the most interesting of these.

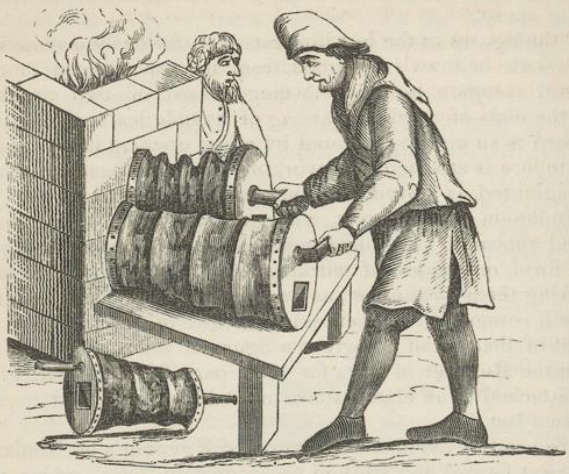
One of the figures in the last illustration is obviously a modification of the old *lantern* bellows (so named from its resemblance to the paper lantern, still common in Egypt:) they consist of two circular boards united to the ends of a cylindrical bag of flexible leather. In the centre of one board is an opening covered by a flap opening inwards, and to the other the tuyere is attached. In working them, the board, through which the air is admitted, is moved, and the other kept stationary. They are quite common in Asia, Egypt, and generally throughout the oriental world; and appear to have undergone no change whatever, either in their materials, form, or modes of working them, since the remotest times: even working them by the feet, as practiced by Egyptians under the Pharaohs, is still common at the native iron-forges of Ceylon. Dr. Davy in his account of that island has given a figure of them, a copy of which is inserted in the Register of Arts for 1828, page 267: the cords for raising them are attached to an elastic stick, instead of being held in the hands as in the two last cuts.

They are used by modern blacksmiths of Egypt in a horizontal position, (as in the next figure) and worked by an upright lever, which the assistant pushes from and draws towards him. M. P. S. Girard has given a figure and description of them in the *Grande Description*, tom. ii, E. M. p. 618, planche 21. He observes that the coppersmiths of Cairo and Alexandria use the same; and further that they are common in the interior of Africa: "leur forme est probablement tres ancienne. Il rèsulte en effet de quelques reseignemens que m'ont donnés des marchands venus avec les caravanes de Dârfour, que des soufflets de la même forme sont employè par les peuples de *l'interieur de l'Afrique.*"

Lantern bellows were formerly common in Europe. They were employed in old organs. See L'Art du Facteur d'Orgues, Arts et Mètieres, p. 667, plates 132 and 135. Sometimes the blowers had their feet fixed upon the upper boards, and holding by a horizontal bar they inflated one bellows by raising one foot, and compressed the other by pushing down the other foot. (Encyc. Antiq.) The scabilla of the Romans were small bellows of the same kind, one of which was attached to one foot for the purpose of beating time, and with castanets were used to animate dancers. Several are figured by Montfaucon. The ancients varied the form of the bellows almost infinitely in adapting them to various purposes. Some were attached to altars to aid in the combustion of victims: one for this purpose is represented on one of the Hamilton vases. Lantern bellows were also common in European *blast* furnaces. No. 105 shows their application to this purpose, copied from the De Re Metallica of Agricola. Similar bellows, except the boards being of an oblong form like the one in 103, are common in Hindostan, and worked by hand as in the next figure, but without any frame to support them; the blower kneels and works them in nearly a vertical position. See a figure in Shoberl's Hindostan, vol. v, p. 9.

The bellows of Vulcan were probably of the same kind. Those represented in tom. i, p. 24, of Montfaucon's Antiquities, appear, from that portion of them which is seen projecting from the back of the forge, to be identical with those in No. 105, and worked in precisely the same way. In plate xx, on Painting, of D'Agincourt's History of the Fine

Arts, which contains some illustrations of the Eneid, executed in the 4th and 5th centuries, Vulcan's forge is represented and the bellows blower behind it, apparently with the same kind of instrument as here shown.



No. 105. Lantern Bellows from Agricola

That Vulcan's bellows were not permanent fixtures as those of our smiths are, but were similar to those figured above, appears from their having been laid aside when not in use, in common with other implements of the forge; a practice usual at the present time in various parts of the east: and we may add that like modern blacksmiths of Asia, he *sat* at work. Thus, when his wife Charis informed him of the arrival of Thetis at their dwelling, he replied:—

> Haste, then, and hospitably spread the board
> For her regale, while with my best despatch
> I *lay my bellows* and my tools *aside*.
> He spake, and vast in bulk and hot with toil,
> *Rose* limping from his anvil-stock,
> Upborne with pain on legs tortuous and weak:
> First, from the forge dislodg'd he *thrust apart*
> *His bellows*, and his tools collecting all,
> Bestowed them careful in a silver chest.

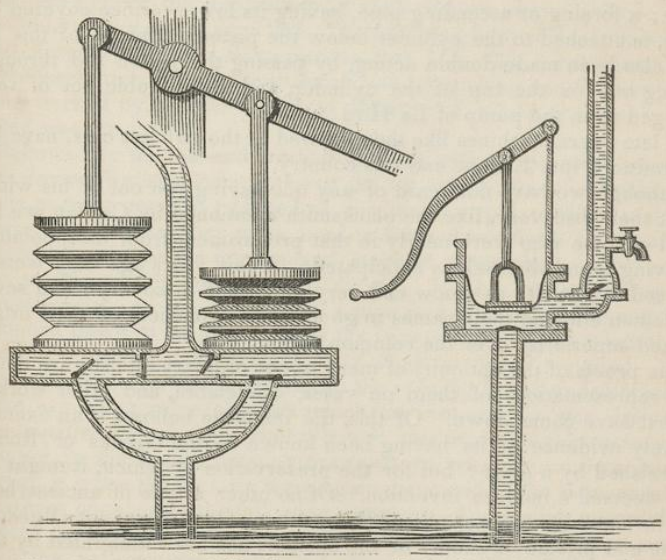
And when he subsequently returned to make the armor which Thetis required for her son, he

> . . . . . to his bellows quick repaired,
> Which *turning to the fire*, he bade them move.—*Il.* XVIII.—*Cowper.*

A singular circumstance is related by Herodotus, which shows that the same mode of obtaining a continuous blast, viz. by two bellows, (and in all probability by the same kind as those above figured) was employed by blacksmiths in ancient Greece. The Lacedemonians having been repeatedly defeated by the Tegeans, sent an embassy to the Delphic oracle, to ascertain the means by which they could overcome them. The Pythian assured them of success if they recovered the body of Orestes, the son of Agamemnon, which had been buried several centuries somewhere in Arcadia, the land of their enemies. Being unable to discover the tomb they sent a second time to inquire concerning the place of his interment, when they received the following answer·

A plain within th' Arcadian land I know,
Where *double winds* with *forced* exertion blow,
Where form to form with mutual strength replies,
And ill by other ills supported lies;
That earth contains the great Atrides' son;
Take him and conquer: Tegea then is won.

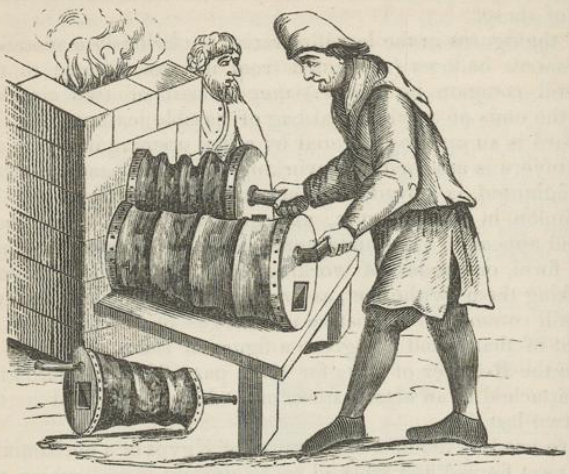
On the receipt of this, search was again made for the body without intermission, and at last it was discovered in a singular manner. At the time a commercial intercourse existed between the two countries, a Spartan cavalry officer, named LICHAS, being in Tegea, happened to visit a smith at his forge, and observing with particular curiosity the process of working the iron, the smith desisted from his labor and addressed him thus: "Stranger of Sparta, you seem to admire the art which you contemplate; but how much more would your wonder be excited, if you knew all that I am able to communicate! Near this place, as I was sinking a *well*, I found a coffin seven cubits long. I never believed that men were formerly of larger dimensions than at present, but when I opened it, I discovered a body equal in length to the coffin—I correctly measured it, and placed it where I found it." Lichas, after hearing this relation, was induced to believe that this might be the body of Orestes, concerning which the oracle had spoken. He was further persuaded, when he recollected that the *bellows* of the smith might intimate the *two winds;* the anvil and the hammer might express one form opposing another; the iron also, which was beaten, might signify ill succeeding ill, rightly conceiving that the use of iron operated to the injury of mankind. The result proved the sagacity of the Spartan: the body was recovered, and finally the Tegeans, says Herodotus, were conquered. Clio, 67, 68.



No. 106. Double Lantern Bellows Pump. No. 107. Single Forcing Pump.

The application of lantern bellows as forcing pumps is, without doubt, of great antiquity: their adaptation to raise water was too obvious not to have been early perceived, and hence we infer that they were at least occasionally employed for that purpose by most of the nations of old. Such pumps are mentioned in old works on hydraulics; but as they have never

Arts, which contains some illustrations of the Eneid, executed in the 4th and 5th centuries, Vulcan's forge is represented and the bellows blower behind it, apparently with the same kind of instrument as here shown.



No. 105. Lantern Bellows from Agricola

That Vulcan's bellows were not permanent fixtures as those of our smiths are, but were similar to those figured above, appears from their having been laid aside when not in use, in common with other implements of the forge; a practice usual at the present time in various parts of the east: and we may add that like modern blacksmiths of Asia, he *sat* at work. Thus, when his wife Charis informed him of the arrival of Thetis at their dwelling, he replied:—

> Haste, then, and hospitably spread the board
> For her regale, while with my best despatch
> I *lay my bellows* and my tools *aside*.
> He spake, and vast in bulk and hot with toil,
> *Rose* limping from his anvil-stock,
> Upborne with pain on legs tortuous and weak:
> First, from the forge dislodg'd he *thrust apart*
> *His bellows*, and his tools collecting all,
> Bestowed them careful in a silver chest.

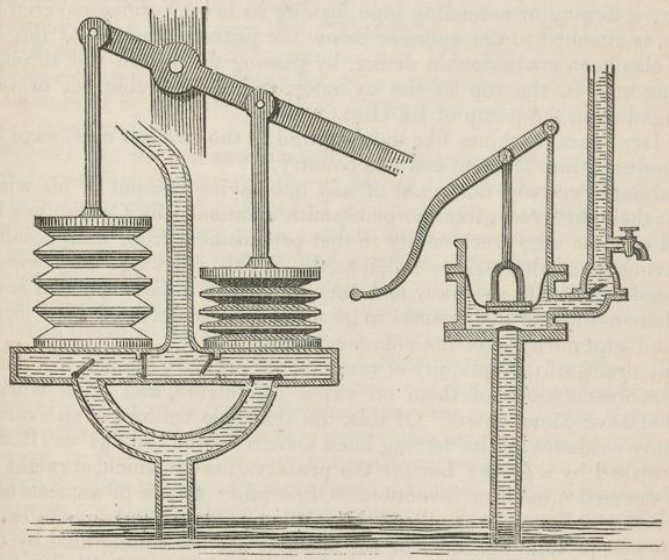
And when he subsequently returned to make the armor which Thetis required for her son, he

> . . . . . to his bellows quick repaired,
> Which *turning to the fire*, he bade them move.—*Il.* XVIII.—*Cowper.*

A singular circumstance is related by Herodotus, which shows that the same mode of obtaining a continuous blast, viz. by two bellows, (and in all probability by the same kind as those above figured) was employed by blacksmiths in ancient Greece. The Lacedemonians having been repeatedly defeated by the Tegeans, sent an embassy to the Delphic oracle, to ascertain the means by which they could overcome them. The Pythian assured them of success if they recovered the body of Orestes, the son of Agamemnon, which had been buried several centuries somewhere in Arcadia, the land of their enemies. Being unable to discover the tomb they sent a second time to inquire concerning the place of his interment, when they received the following answer·

A plain within th' Arcadian land I know,
Where *double winds* with *forced* exertion blow,
Where form to form with mutual strength replies,
And ill by other ills supported lies;
That earth contains the great Atrides' son;
Take him and conquer: Tegea then is won.

On the receipt of this, search was again made for the body without intermission, and at last it was discovered in a singular manner. At the time a commercial intercourse existed between the two countries, a Spartan cavalry officer, named LICHAS, being in Tegea, happened to visit a smith at his forge, and observing with particular curiosity the process of working the iron, the smith desisted from his labor and addressed him thus: "Stranger of Sparta, you seem to admire the art which you contemplate; but how much more would your wonder be excited, if you knew all that I am able to communicate! Near this place, as I was sinking a *well*, I found a coffin seven cubits long. I never believed that men were formerly of larger dimensions than at present, but when I opened it, I discovered a body equal in length to the coffin—I correctly measured it, and placed it where I found it." Lichas, after hearing this relation, was induced to believe that this might be the body of Orestes, concerning which the oracle had spoken. He was further persuaded, when he recollected that the *bellows* of the smith might intimate the *two winds;* the anvil and the hammer might express one form opposing another; the iron also, which was beaten, might signify ill succeeding ill, rightly conceiving that the use of iron operated to the injury of mankind. The result proved the sagacity of the Spartan: the body was recovered, and finally the Tegeans, says Herodotus, were conquered. Clio, 67, 68.



No. 106. Double Lantern Bellows Pump. No. 107. Single Forcing Pump.

The application of lantern bellows as forcing pumps is, without doubt, of great antiquity: their adaptation to raise water was too obvious not to have been early perceived, and hence we infer that they were at least occasionally employed for that purpose by most of the nations of old. Such pumps are mentioned in old works on hydraulics; but as they have never

come into general use, even in modern times, a particular account of them previous to the art of printing, is not to be expected. A writer in the *Grande Description of Egypt*, describing the smith's bellows of that country, observes :—" Ces sortes de soufflets ètoient employés verticalement dans le seizieme siècle tant pour animer le feu des forges que *pour èlever l' eau*, soit en rarefiant l'air soit en le comprimant; ils sont décrits dans l'ouvrage de Ramelli, imprimé en 1558."

No. 106 represents a double lantern bellows-pump, as used in the 16th century. The mode of its operation is too obvious to require detailed description. As one bellows is distended by working the lever, the atmosphere drives water up the suction-pipe into its cavity; and the other at the same time being compressed, expels its contents through the ascending or forcing pipe : the valves at the lower part of the latter, and those over the orifices of the two branches of the suction-pipe opening and closing, as shown in the figure. There is a pump similar to this, but geared in a different manner, in Hachette's Traite elèmentaire des machines. Papin, in a way to raise water, which he proposed enigmatically in the Philosophical Transactions in 1685, used the lantern bellows as a forcing-pump. In a solution by another writer, it is said :—" A vessel made like the body of a pair of bellows, or those puffs heretofore used by barbers being filled with water, a piece of clockwork put under it, may produce the jets." Phil. Trans. Abridg., vol. i. 539. A similar application of the bellows was described in Besson's Theatre, in 1579, the moveable board being impelled by a spring.

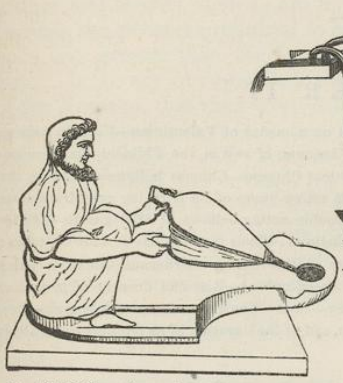
No. 107 is another example of bellows forcing-pumps. It consists of the frictionless piston of Gosset and Deville, (No. 83,) but without a valve; a forcing or ascending pipe, having its lower orifice covered by a valve, is attached to the cylinder below the piston. Pumps of this kind have also been made double acting, by passing the piston rod through a stuffing box on the top of the cylinder, and by a double set of valves arranged as in the pump of La Hire.

Of late years machines like those figured in the two last cuts, have been reintroduced into Europe and this country.

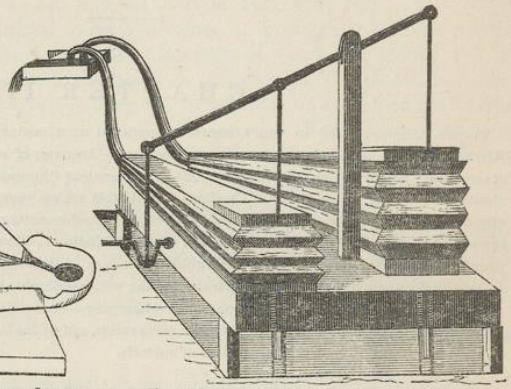
Although we have not heard of any one having run out of his wits for joy at their discovery, like the blacksmith mentioned by Cardan, we have heard of some who were nearly in that predicament from disappointment in having found themselves anticipated. A few years ago they were announced in this city as a new and very important discovery; and several gentlemen allowed their names to go abroad as vouchers of their originality and superiority over the common pump.

The proofs of the antiquity of many of our ordinary utensils are derived from representations of them on vases, candelabra, and other works of art that have come down. Of this, the domestic bellows is an example; the only evidence of its having been known to the Greeks or Romans, is furnished by a *lamp;* but for the preservation of which, it might have been deemed a modern invention. Of no other article of ancient household furniture are more specimens extant than of lamps, and not a little of the public and private economy of the ancients has been illustrated by them. Among those in private collections and public museums, are some that were once suspended in temples, others that illuminated theatres and baths—that decorated the banqueting-rooms of wealthy patricians, as well as such as glimmered in the dwellings of plebeians; the former are of bronze, elaborately wrought and enriched, the latter mostly of earthenware. The fertility of conception displayed in these utensils is wonderful. All nature seems to have been ransacked for devices, and in modifying

them, the imaginations of the designers ran perfectly wild; while many are in their forms and decorations exquisitely chaste, others are bizarre and some are obscene. There is one of bronze on which an individual is represented blowing the flame with his mouth, as in the act of kindling a fire; and in another the artist has introduced, as an appropriate embellishment, a person performing the same operation with a pair of bellows, of precisely the same form as those in our kitchens. No. 108 is a figure of this lamp, from the 5th volume of Montfaucon's Antiquities.



No. 108. Bellows figured on a Roman Lamp.



No. 109. Bellows Forcing Pumps from Kircher.

An example of the application of such bellows as atmospheric pumps has already been given, page 207. The adjoining figure (No. 109) is copied from Kircher's Mundus Subterraneus, tom. i., p. 230, Amsterdam, 1665: it represents two large bellows employed as sucking and forcing pumps, being worked by a water wheel, to the axis of which the crank represented was attached.

Bellows like the last and worked in a similar manner, were among ancient devices for ventilating mines: the various modes of adapting them to the purpose may be adduced as another example of their analogy to pumps. Sometimes they were used to force down fresh air in sufficient quantities to render the impure and stagnant atmosphere below respirable; at others they drew the foul air up. In the first case, they were placed near the mouth of the shaft, a pipe was attached to the nozzle and continued down to the place where the miners worked, and when the bellows were put in motion, currents of fresh air were supplied. In the latter case, the pipe was connected to the opening in the under board, i. e. to the aspirating valve, through which the impure air was drawn, and then expelled out of the nozzle; but in this case an expiring valve was required in the nozzle, opening outwards to prevent air from entering through it when the bellows were again distended. The same result was sometimes obtained in the following manner: An opening was made and covered by a valve in the upper board instead of the lower one, and when the bellows were distended, the impure air rushed up the pipe which was attached to the nozzle, and was expelled through the opening covered by the flap when the bellows were closed. Several figures representing these and other applications of bellows are given by Agricola.

Goguet observes that draft furnaces were probably invented early, *but bellows were not.* We should suppose the reverse was the fact; for the advantages of an artificial blast must have been obvious from the first

sight, were left unnoticed by that intelligent sailor. The bellows of *Madagascar*, says Sonnerat, "is composed of the hollow trunks of two trees tied together. In the bottom there are two iron funnels, and in the inside of each trunk a sucker furnished with raffia, which supplies the place of tow. The apprentice, whose business it is to use this machine, alternately sinks one of the suckers while he raises the other."[b] Similar implements are also used in smelting iron as well as in forging it. In the first volume of Ellis's "History of Madagascar," Lon. 1838, there is a representation of two men reducing iron ore by means of four piston bellows. No. 111 is a copy.

No. 111. Piston Bellows of Madagascar.

The furnace is described as a mere hole dug in the ground, lined with rude stonework and plastered with clay. It was filled with alternate layers of charcoal and ore, and covered by a conical roof of clay, a small opening being left at the apex. The bellows were formed of the trunks of trees, and stood five feet above the ground, in which they were firmly imbedded. The lower ends were closed "air tight," and a short bamboo tube conveyed the wind from each to the fire, as represented. "A rude sort of piston is fitted to each of the cylinders, and the apparatus for raising the wind is complete." As no mention is made of valves nor of the openings through which air entered the cylinders, it is probable that the pistons were perforated for that purpose, and the passages covered by flaps or valves opening downwards, a device which the artificers of Madagascar are acquainted with. See No. 114. These bellows are of various sizes, though generally from 4 to 6 inches in diameter. Sometimes only one is used, but it is then made of larger dimensions, and the blower *stands* and works it with both his hands. To do it conveniently, he raises himself on a bank of earth. The bellows are not always perpendicular, but are inclined as figured in the back ground of the cut.

[b] Sonnerat's Voyages, iii. 36.

The blacksmiths of *Java* use the same kind. Raffles, in his History of the Island, (2 vol. 193,) after quoting Dampier's description of the bellows of Mindanao, observes his account "exactly corresponds" with that of Java. "The blacksmiths' bellows of *Sumatra*," says Mr. Marsden, "are thus constructed: two bamboos of about four inches diameter and five feet in length, stand perpendicularly near the fire, open at the upper end and stopped below. About an inch or two from the bottom a small joint of bamboo is inserted into each, which serve as nozzles, pointing to and meeting at the fire. To produce a stream of air, bunches of feathers, or other soft substance, are worked up and down in the upright tubes like the piston of a pump. These, when pushed downwards, force the air through the small horizontal tubes; and by raising and sinking each alternately, a continual current of air is kept up."[c] The *Bashee* Islanders use the same kind of bellows.[d] The smiths of *Bali* have them also: "their instruments are few and simple, their forge small, and worked by a pair of upright bellows, such as we find described in Raffles' Java."[e] They are not confined to southern Asia and the Ethiopian Archipelago, but are used in continental Africa. "The bellows of the negro artificers on the *Gambia*, are a thick reed or a hollow piece of wood, in which is put a stick wound about with feathers, [a piston,] which by moving of the stick, makes the wind."[f]

Without entering into the controversy respecting the origin of wooden bellows, it may be inferred from the preceding extracts, that such have been in use from remote times; and that the cylindrical forcing-pump, so far as regards the principle of its construction, is equally ancient: of this, the instrument now to be described, affords another indication. It is the bellows of the most numerous and most singular of all existing people—a people, the wisdom of whose government has preserved them as a nation, through periods of time unexampled in the history of the world, and which still preserves them amidst the prostration by European cupidity of nearly all the nations around them; a people, too, who notwithstanding all that our vanity may suggest to depreciate, have furnished evidence of an excellence in some of the arts that never has been surpassed. The *Chinese*, like the ancient Egyptians, whom they greatly resemble, have been the instructors of Europeans in several of the useful arts; but the pupils, like the Greeks of old, have often refused to acknowledge the source whence many inventions possessed by them were derived, but have claimed them as their own: of the truth of this remark, we need only mention *printing*, the *mariner's compass*, and *gunpowder*.

In the bellows of the Chinese, we perceive the characteristic ingenuity and originality of that people's inventions. A description and figure of their bellows were published in London, 1757, by Mr. Chambers, in a work entitled "Designs of Chinese Buildings, Furniture, Dresses, Machines and Utensils, from drawings made in China." The following account from the fourth volume of the "Chinese Repository," a very interesting work published at Canton in China, is substantially the same. "The bellows used by them is very aptly called '*Fung Seäng*, 'wind box,' and is contained in an oblong box about two feet long, ten inches high, and six inches wide. These dimensions, however, vary according to the whim of the maker, and they occur from *eight inches*, to four feet or more in length, and so of the width and height. The annexed profile view will give some idea of the principle upon which it is constructed."

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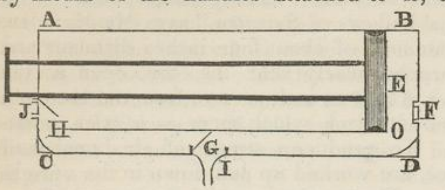
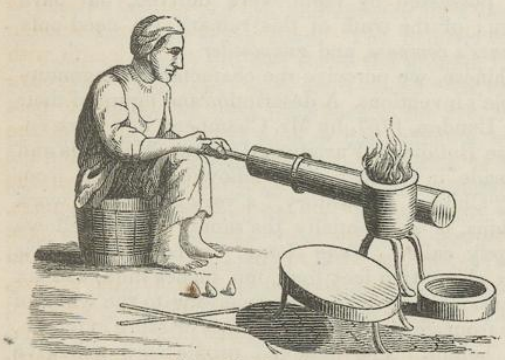
[c] History of Sumatra, p. 181. [d] Dampier's Voyages, i. 429. [e] Chinese Repository, iv. 455. [f] Ogilvy's Africa, Lon. 1670, p. 356.

"A, B, C, D, is a box divided into two chambers at the line O H. In the upper one is the piston E, which is moved backwards and forwards by means of the handles attached to it; and is made to fit closely by means of leather or paper. The lid of the box slides upon the top, and is sufficiently thick to allow the workman to labor upon it. At F J are two small holes each covered with a valve; and just below them, at O H in the division of the two chambers, are larger holes, for the entrance of the wind into the lower chamber. This part of the bellows is made of a thick plank, hollowed into an ovoid form, and is about an inch thick. The clapper G is fastened to the back side of the box, and plays horizontally against the two stops placed near the mouth I. It is made as high as the chamber, and when forced against the stop, it entirely closes the passage of air beyond. When the piston is forced inwards, as represented in the cut, the valve at F is closed, and that at J is opened; and thus the upper chamber is constantly filled with air. The wind driven into the lower chamber by the piston urges the clapper G against the stop, and is consequently forced out at the mouth. The stream of air is uninterrupted, but not equable, though in the large ones the inequality is hardly perceived. An iron tube is sometimes attached to the mouth which leads to the furnace, and in other cases the mouth itself is made of iron." The Chinese generally use them in an inclined or horizontal position, frequently making use of the upper side as a work bench. In the figure (and the one given by Chambers) two rods are connected to the piston to prevent it from springing when used: this appears to be the practice with regard to those of large dimensions. In small ones a single rod is sometimes used, and the chamber is cylindrical. In the collection of M. Bertin, (a French minister and secretary of state in the former part of the last century,) which contained "about 400 original drawings, made at Pekin, of the arts and manufactures of China" a portable and *single-acting* bellows is represented as in the next figure.[a]



No. 112. Section of a Chinese Bellows.



No. 113. Chinese Single Bellows, and Tinker.

"This instrument is made like a box in which is a piston, so constructed that when it is drawn out behind, the vacuum which it occasions in the box makes the air rush in with great impetuosity through a lateral opening, to which a sucker [a valve] is affixed: and when the piston returns in an inverse direction, the sucker [valve] closes itself, and the air is forced out by the opposite extremity." Navarette preferred the

[a] China, its Customs, Arts, &c., translated from the French. Lon. 1824; vol. i. 17.

Chinese bellows to the European one, he said it was more commodious and efficient.[b] It is employed to some extent in Java, having been introduced from China.[c]

Since the preceding remarks were written, we have examined two bellows from China, in the splendid "Chinese Collection" in Philadelphia. One of them belonged to a traveling blacksmith. It is formed of a cylindrical joint of bamboo, 2½ feet in length, and between five and six inches diameter. The piston rod is a wire ¼ or ⅜ of an inch thick, with a small gimlet handle. Air is admitted through a cluster of five or six small holes in each end, which are covered in the inside by paper flaps: these are the induction valves, marked J F in No. 112. Along one side of the bellows a strip of wood 2½ inches wide and 1¼ thick, is secured by what appears to be eight small thumb screws, and the junction made tight by cement or wax; this projecting piece resembles those on the sides of high pressure steam-engine cylinders, and is intended for a somewhat similar purpose, its interior being hollowed into a passage for the wind when expelled by the piston from either end of the cylinder. A short metallic tube conveys the wind from the middle of this piece to the furnace as in No. 112. The ends of the bellows are secured from splitting by two thin and narrow iron hoops, and at one place a small clamp is driven across a crack, as is sometimes practiced in mending wooden bowls. The instrument resembles the one in the last figure, but is double acting: the figure of the artist accompanying it is seated on the ground and works it with one hand while he attends the fire with the other.

The other bellows consists of a long box like the one figured at No. 112. From the circumstance of its not being confined in a glass case, and permission to examine its interior having been politely accorded, we had an opportunity of ascertaining some particulars that are not mentioned in any published account of these instruments that has fallen in our way. It is twenty-two inches long, seven deep, and five wide, made of thin boards of a species of fir and extremely light: the sides and ends are dovetailed together; and the bottom appeared to be intended to slide over the sides, having strips projecting from it and no pins or nails visible; this arrangement enables a person to examine the interior, and to replace or repair the valves, &c. with great facility. The boards of which the machine is made are of a uniform thickness (about ⅜ of an inch) except the top, which is 1¼ inches. The reason for this extra thickness was perceived as soon as it was removed, (it was secured to the sides and ends by long wooden pins,) for a deep and wide groove is made through its whole length with the exception of ¼ of an inch at each end, and at the middle of the groove a passage is cut at right angles to it through one side for the air to pass into the tuyere. Upon the removal of this thick cover, the inside of the box was not exposed, for another thin one was found inserted within the sides, and flush with their edges. This was a board slipped between the sides and resting upon the upper edge of the piston, having two openings, one at each end, which coincided with the groove in the outer cover, (the inner cover is represented by the line H O in No. 112;) hence the wind is driven by the piston alternately through each opening into the groove, and by the action of the valve in the middle of the latter, is compelled to pass into the tuyere. This valve is represented at G in No. 112, and from an inspection of that cut, it will be apparent that some contrivance of the kind is absolutely necessary, in order to prevent the wind when forced from one end of the bellows, from passing along the groove

[b] Histoire Gènèrale, Tom. viii. 106. [c] Raffles' Java, ii. 193.

into the other end: it consists of a narrow piece of hard wood of the same depth as the groove, and of a length that rather exceeds the width of the groove. A hole is drilled through one end and a pin driven through it into the solid part of the cover, so that it turns freely on this pin, and closes and opens a passage for the escape of the wind into the tuyere. It is driven by the wind at every stroke of the piston against the opposite cheek of the groove, and thus prevents the wind from passing into the other end of the cylinder, as shown at G in No. 112. It is surprising how easily this valve plays although its upper and lower edges rub against the surfaces of the two covers—a trifling movement of the piston drives it against the cheek, and occasions a snapping sound somewhat like that from the contact of metal.

When the inner cover was raised out of its place, the piston and induction valves were exposed to view, and the simplicity and efficiency of these parts were in keeping with the rest: the two valves are mere flaps of paper, glued at their *lower* edges to the under side of the openings, and hence they stand nearly perpendicular, instead of being suspended from above; the slightest impulse of air closed them. The piston is half an inch thick, but is reduced at the edges to a quarter of one; it appears to be formed of two thin pieces which, united, are equal in thickness to that mentioned; and between them are inserted two small sheets of moderately stiff paper, which project an inch over every side. The part that projects is folded at the corners and turned over the edges of the piston; one sheet being turned one way, and the other the contrary, so that when the piston is moved, the air presses the paper against the sides of the bellows and renders the piston perfectly tight, on the same principle as the double cupped leathers of fire-engines and other forcing-pumps; and at the same time without any perceptible increase of friction. The two piston rods are half inch square, and work through holes in one end of the box without any stuffing-box. The whole machine is of wood, except the paper for the piston and valves. Although the instrument appears to be a rectangular box, it is not exactly so, the bottom being a little wider than the top.

It would be superfluous to point out the application of piston bellows to raise water, since they are perfect models of our atmospheric and forcing-pumps. Why, then, it may be asked are not the Chinese found in the possession of the latter? In reply to this question, it may be observed: 1. That from our imperfect knowledge of the people, it is not certain that such machines have not been, and are not used to a limited extent in the interior of that great empire. 2. That custom, and probably experience, have induced them, in common with other nations of the Oriental world, to give the preference to more simple devices—to their chain pump, bamboo wheel, &c., a preference which we know is in some instances based on solid grounds: for example, the chain pump as used by them, raises more water with the same amount of labor, than any atmospheric or forcing-pump, if placed under the same circumstances. And as for the noria or bamboo wheel, which driven by a current, raises water night and day, and from 20 to 50 feet, we are told that it answers the purpose "as completely as the most complicated European machine could do; and I will answer for it [says Van Braam] that it does not occasion an expense of ten dollars." 3. A circumstance connected with one of their ancient as well as modern scenic representations, shows that when the *forcing* or spouting of water is required, their artists are at no loss for devices to effect it; and that, too, under very unusual circumstances. One of the pantomimes performed at Pekin is the "*Marriage of the Sea with the Land.*" The

latter divinity made a display of his wealth and productions, such as dragons, elephants, tigers, eagles, ostriches, chestnut and pine trees, &c. The *Ocean*, on the other hand, collected whales, dolphins, porpoises and other sea monsters, together with ships, rocks, shells, &c., "all these objects were represented by performers concealed under cloths, and who played their parts admirably. The two assemblages of productions, terrestrial and marine, made the tour of the stage, and then opened right and left to leave room for an immense whale, which placed itself directly before the emperor, and *spouted out several hogsheads of water*, which inundated the spectators who were in the pit."[a] As both the water and forcing apparatus were contained within the moving figure, we can only imagine the jets to have been produced by means of piston or bellows forcing-pumps, or something analogous to them—or by air condensed in one or more vessels containing water, like soda fountains. 4. If Chinese lads never discovered a source of amusement in the application of their bellows (some of which are only *eight inches* long) as squirts or pumps, they must differ essentially from lads of other nations—a position that few judges of human nature would admit. Boys are the same in all ages, and the mischievous youngsters of the Celestial Empire have doubtless often derived as much pleasure from annoying one another with water ejected from these implements, as those of Europe and this country do with similar devices. Such an application of them was sure to be found out by boys, if by no one else. Whether the bellows-pump originated in this manner or not, may be uncertain, but several useful discoveries have been brought to light in much the same way: it was a youth who changed the whole character of the steam-engine, by giving it that feature upon which its general utility depends—his ingenuity, stimulated by a love of play, rendered it self-acting.

The antiquity of the Chinese bellows is a subject of much interest. It may have been the instrument which Anacharsis introduced into Greece, it having, perhaps, been employed by his countrymen, the ancient Scythians, as well as by their descendants, the modern Tartars. If it has been in use, as supposed, from times anterior to Grecian and Roman eras, the origin of the pump in the second century B. C. can hardly be sustained; for when the induction valves of one of these bellows are placed in water, (as we suppose has occasionally been done ever since its invention,) it is then the "water forcer" of Ctesibius; and if pipes be connected to F and J, (No. 112,) and their orifices placed in a liquid, the apparatus becomes the double acting pump of La Hire. But what may be surprising to some persons, its construction is identical with that of the steam-engine; for let it be furnished with a crank and fly wheel to regulate the movements of its piston, and with apparatus to open and close its valves, then admit steam through its nozzle, and it becomes the double acting engine of Boulton and Watt. Again, connect its induction orifices to a receiver, and it becomes an exhausting air-pump; apply its nozzle to the same vessel, and it is a condensing one. The most perfect blowing machine, and the *chef d'œuvre* of modern modifications of the pump, are also its fac-similes.

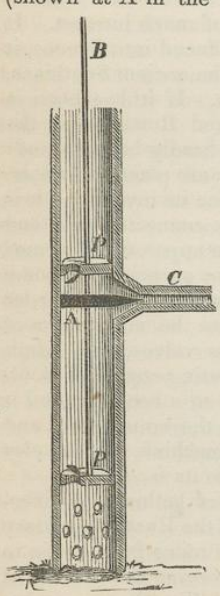
It would seem that the Chinese have other kinds of bellows, or different modes of working these. Bell, in his account of the Russian embassy in 1720, says that he was lodged in a village twelve miles from Pekin in a cook's house, which gave him an opportunity of observing the customs of the people even on trifling occasions: "My landlord," he observes, "being in his shop, I paid him a visit, where I found six kettles placed in a

[a] China, its Costumes, &c., iii. 34.

row on furnaces, having a separate opening under each of them for receiving the fuel, which consisted of a few small sticks and straw. On *his pulling a thong*, he blew a pair of bellows which made all his kettles boil in a very short time."[c] Like other Asiatics, the Chinese have probably a variety of these instruments. The van, or winnowing machine, which we have received from them, is a *rotary* bellows. See page 70 of this volume.

Various rotary bellows are described by Agricola, as employed in the ventilation of mines, and worked by men with cranks, and in one instance by a horse treading on the periphery of a wheel.[d] Rotary blowing machines have been represented as of more recent origin, but they are in all probability of great antiquity. The Spaniards introduced them into Peru as early as 1545, to reduce the silver ores, but they were soon abandoned.[e] For rotary pumps, see a subsequent chapter of this book.

We are indebted for some interesting information respecting the arts of various islanders of the Indian ocean to Mr. William Clark of Philadelphia, who, besides spending several years in whaling voyages, resided two years in Southern Africa. The vessel to which he was attached having on one occasion touched on the coast of Madagascar, some native smiths were found using bellows that excited particular attention; some were cylindrical, being formed of bored logs, others were square trunks, five or six inches in diameter, and about five feet long; but the internal construction of both was the same. The ship's carpenter was permitted to open one. It was composed of four planks that had been split from trees, the insides shaved smooth and straight, and the whole put together with wooden pins instead of nails or screws. It was divided into two parts by a partition or disk, which was permanently secured in its place, (shown at A in the annexed cut,) where, like a piston, it occupied the entire space across. On one side of the trunk, and opposite the edge of A, an opening was made for the insertion of the tube C that conveyed the wind to the fire, the edge of A at this place being feathered, and a small projecting piece added to it, in order to direct the current of air from either side of the partition into C. An opening was made in the centre of A, through which a smooth piston rod B, played; two pistons or boards, P P, accurately fitted to work in the trunk, were attached on opposite sides of the partition to B; these pistons were perforated, and the openings covered by flaps or valves like those of a common pump box, but the upper one was secured to the *under* side of the piston as shown in the figure. The trunk rested on four short pieces of wood pegged to it. In some, holes were made at the lower part for the admission of air. These bellows were therefore double acting, and consequently one of them was equal in its effects to two of those represented at No. 111, which drive the air out only on the descent of the piston, whereas these forced it into the fire both on ascending and descending. Thus, when the blower raised the rod B, the flap on the lower piston closed, and the air in that division of



No. 114. Double Acting Bellows of Madagascar.

[c] Bell's Travels, i. 312. [d] De Re Metallica, pp. 162, 163, 164, 169. [e] Garcilasso's Commentaries, p. 347.

the trunk was expelled through C; at the same time the flap of the upper piston was opened by its own weight and the air passing through it, and on the descent of B all the air in the upper part of the trunk was forced into the fire in like manner; hence an uninterrupted, though not an equable blast of wind was kept up. The whole apparatus was of wood except the flaps, which were pieces of green hide rendered pliable by working them in the hands; and they were prevented from opening too far by narrow slips of the same material pegged over them. There was no packing to the pistons, but they were moved with great rapidity.

These bellows are different from those described by Dampier, Sonnerat and Ellis, as used in the same island; but they serve to corroborate a remark that has been made by several travelers, viz: that the negroes of Africa are in possession of a great variety of those instruments. The one above described is a fine specimen of their ingenuity, for there can be little doubt that it is original with them—it evidently is not derived from the double acting bellows of China, nor can it have been procured from Europe, since nothing of the kind has, we believe, ever been used there. It is the only bellows that we have met with having valves in the pistons.

It need hardly be observed that double *pumps* have been made on the same principle. There is one figured by Belidor in the second volume of his Architecture Hydraulique, which differs from the above figure only in having two short piston rods connected together by a frame on the outside of the cylinder, instead of one long one working through the disk.

No stronger proofs could possibly be adduced of the analogy between pumps and bellows, than what the figures in this and the preceding chapter afford.

While engaged on this part of the subject we were induced to refer again to the accounts of the old Mexicans and Peruvians, in hopes of finding some indications of the pump in the instruments employed to urge air into their furnaces; but, strange as it will appear to modern mechanics, they are said to have been wholly ignorant of the bellows. This, if true, is a very singular fact; and, considering the extent to which they practiced the arts of metallurgy, one that is unexampled in the history of the world. It appears, moreover, irreconcilable with the opinion of their oriental origin; for it is difficult to conceive how emigrants or descendants of emigrants from Asia, could have been ignorant of this simple instrument which has been used in one form or another on that continent from the earliest times, and which is still employed by the rudest tribes there, and also in all those parts whence the early Peruvians are supposed to have come. The bellows is common almost as the hammer, from the peninsular of Malacca to that of Kampschatka, and from the Phillippine islands to those of Japan. In Africa, too, it is used in great variety and by people whose progress in the arts is far behind that of the ancient smiths of America.

How little is known respecting the mechanical implements of Mexican and Peruvian workmen and of their processes, and yet but three centuries have elapsed since the latter were in full operation! We are not aware that a single tool has been preserved, much less their modes of manufacture; nor is this much to be wondered at when the spirit that animated the conquerors is considered—it was the acquisition of gold, not the tools for or manner of working it, that they had in view; and had it not been for the prodigious amount of bullion which they found worked into various figures and utensils, we should scarcely have ever heard of the latter; and yet the workmanship on some of them, exceeded the value of the metal. That there are errors in the accounts of early writers on the arts and apparatus of old American mechanics is unquestionable, and among them

may be mentioned that which confined the materials of their cutting instruments to obsidian and other stones; whereas it is now certain that they had chisels, &c. of bronze or alloys of copper and tin; and probably of a similar composition to those of Egyptian workmen. As for bellows, it was no easy task (supposing it had been undertaken by the old historians of Mexico and Peru) to determine positively that they were *unknown* throughout those extensive countries. To ascertain what tools were and were not used, required something more than a superficial knowledge of the people. Before a stranger could speak decidedly on the subject of bellows, it was necessary that he should become familiar with their modes of working the metals, by frequently visiting them in their workshops and dwellings; and, from an intimate knowledge of their language, making inquiries respecting the tools and details of the processes adopted by artisans of distant tribes; for bellows might be used to a limited extent in one country, and (from variety in the ores, articles manufactured or customs of workmen) not at all in another. But there does not appear to have been any efforts made to collect information of this kind by the conquerors—its value was not appreciated by them or by their immediate successors, and hence the opportunity was neglected and could never be recalled; for other historians agree with Clavigero, that the wonderful arts of the Mexican and Peruvian founders were soon *lost*, "by the debasement of the Indians and the indolent neglect of the Spaniards." Even Garcilasso, although a native Indian, by his mother's side, does not seem to have possessed any particular knowledge on the subject of working the metals: he derived his information from Acosta, to whose work he refers his readers.

But what are the proofs that bellows were unknown to the subjects of Manco Capec and Motezuma? The principal one is derived from their fusing metals without them: they kept their furnaces in blast, it is alledged, by the breath of a number of men who blew on the fires through tubes of bamboo. That this was often practiced there is no doubt, and that it was the general custom is admitted; but it does not therefore follow that they had no contrivances for producing artificial blasts: this will appear from the practice of oriental gold and silver smiths, both of ancient and modern times. The fusion of gold and silver with blowing tubes is a device of remote antiquity, and like all ancient customs relating to the useful arts, it is still practiced by the Hindoos, Malays, Ceylonese, Persians and other Asiatics; and also by Egyptians and numerous African tribes. The goldsmiths of Sumatra, Mr. Marsden observes, "in general *use no bellows*, but blow the fire with their mouths through a joint of bamboo; and if the quantity of metal to be melted is considerable, three or four persons sit round the furnace, which is an old broken *kwali*, or iron pot, and blow together: at Padang alone, where the manufacture is more considerable, they have adopted the Chinese bellows."[a] We have already described the single and also a double acting bellows of these people; besides which they have that of China, and yet it seems that all the working goldsmiths of the country, except those of a single town, still melt their metal as the Mexicans and the Peruvians did: hence the mere fact of the old smiths of these continents using blowpipes to fuse metal, is no more a proof of their ignorance of bellows, than the like practice is of modern Asiatics being also ignorant of them.

Nothing is easier than to err respecting a knowledge of bellows in former times, by inferences drawn from the use of blowpipes. In the oldest

[a] History of Sumatra, 179.

monuments of Egypt (those of Beni Hassan) the latter are represented in the remote age of Osirtasen, 1700 B. C. which to a superficial observer might lead to the supposition that the former were then unknown; but a close examination of the sculptures shows the fallacy of such a conclusion, since blowing tubes are also figured long after the reign of Thothmes in whose time bellows were certainly common.[a] Again, on the last day of the feast of Tabernacles, the Jews were allowed by rabbinical precepts to light one fire from another, but not to strike new fire from stone or metal, nor to quench it, although to save their goods, "nor to blow it with bellowes, but with a *reede*."[b] Now a stranger, having an imperfect knowledge of Jewish customs, upon witnessing fires thus blown would, in some parts of the world, be very apt to conclude that they had no bellows. And again, if we had not a proof that our domestic bellows was known to the Romans, we might have inferred from Pliny's account of statuaries and painters representing individuals blowing fires with their *mouths*, that artificial instruments for the purpose were then unknown.

Enough may be gathered from early writers on America to account for bellows not being employed in those operations in which they would seem to have been most required, viz: in smelting of metals. According to Acosta, some ores could not be reduced by bellows, but only by air furnaces. Garcilasso, in the last chapter of the eighth book of his Commentaries, makes the same remark. In smelting the silver ore of Potosi, he says the Indians used neither bellows nor blowing tubes, but a natural wind, which, in their opinion, was the best; they therefore fused the ore in small furnaces placed on the hills in the night time, whenever the wind was sufficient for the purpose; and it was a pleasant sight, he observes, "to behold eight, ten, or twelve thousand of those fires at the same time, ranged in order upon the sides of the mountains." The Spaniards suspecting that the metal, when thus diffused among a great number of hands, might be more readily purloined, and that much of it was wasted in so many fires, introduced blast furnaces, the fires in which were urged "by large bellows," but these not succeeding, (the blast being too strong,) they had recourse to rotary bellows, ("engines with wheels, carried about with sails like a windmill which fanned and blowed the fire,") but these also failed to accomplish the purpose, "so that the Spaniards despairing of the success of *their* inventions, *made use of those which the Indians had framed and contrived.*" No stronger reason could be adduced why the bellows was not previously used in the reduction of ores.

At a subsequent fusion of the metal in their dwellings, the workmen (says Garcilasso) instead of bellows, continued to use blowing tubes, "though our [Spanish] invention of bellows is much more easie and forcible to raise the fire." Supposing they were ignorant of bellows before the arrival of the Spaniards, here is a proof that after they became acquainted with these instruments, they still preferred their tubes, as the gold and silver smiths of Asia generally do at this day; and hence the use of such tubes does not show, as has been stated, "that they were unacquainted with the use of bellows."

If there was nothing else to adduce in favor of the old Peruvians being acquainted with bellows, or with the principle of their construction and application, than the balsas or blown floats which their fishermen and those of Chili used instead of boats, we should deem them sufficient. These were large bags made of skins of the sea wolf and filled with air. They

[a] Wilkinson's Manners and Customs of the Ancient Egyptians, iii. 339. [b] Purchas' Pilgrimage, 223.

were "so well sewed, that a considerable weight could not force any of it out." They carried from twelve to fourteen hundred pounds, and if any air escaped, there were two leathern pipes through which the fishermen "blow into the bags when there is occasion." Frezier's Voyage to the South Seas, page 121. These were real bellows, only applied to another purpose. Had they not been found less efficient or less economical than blowing tubes, they would doubtless have been used as substitutes for the latter in the fusion and reduction of ores. It may here be noticed as a singular fact, and one which may possibly have reference to bellows, that *Quetzalcoatl*, the Mexican God of the air or wind, was also the Vulcan of all the nations of Anahuac.

Both Mexicans and Peruvians were accustomed from their youth to use blowing tubes, for the primitive air gun, through which to shoot arrows and other missiles by the breath, was universally used, and the practice is still kept up by their descendants. Motezuma, in his first interview with Cortez, shrewdly compared the Spanish guns, as tubes of unknown metal, to the *sarbacans* of his countrymen. From the expertness acquired by the constant employment of these instruments in killing game, it was natural enough to use them instead of bellows to increase the heat of their furnaces, and custom rendered them very efficient.

We have prolonged our remarks on this subject because it has been concluded that remains of furnaces, found far below the surface in various parts of this continent and in regions abounding with iron, could never have been employed in reducing that metal; for in those remote ages in which such furnaces were in action, the bellows, it is said, was *unknown;* a position that we think untenable, and quite irreconcilable with the advanced state of metallurgy in those times.

Before leaving the subject of bellows and bellows pumps, we may remark that numerous illustrations of the latter may be found in the natural world. To an industrious investigator, the animal kingdom would furnish an *endless variety*, for every organized being is composed of tubes and of liquids urged through them. The contrivances by which the latter is accomplished may be considered among the prominent features in the mechanism of animals; and although modified to infinitude, one general principle pervades the whole; this is the *distension and contraction* of flexible vessels or reservoirs in which fluids are accumulated and driven through the system. On the regular function of these organs the necessary motions of life chiefly depend; by them urine is expelled from the bladder, blood from the heart, breath from the lungs, &c.; they are natural bellows pumps, while other devices of the Divine Mechanician resemble syringes or piston pumps.

The whale spouts water with a bellows pump, and in streams compared with which the jet from one of our fire-engines is child's play. His blowing apparatus consists of two large membranous sacs; elastic and capable of being collapsed with great force. They are connected with two bony canals or tubes whose orifices are closed by a valve in the form of two semicircles, similar to those known to pump makers as butterfly valves. When the animal spouts, he forcibly compresses the bags, already filled with water, and sends forth volumes of it to the height of 40 or 50 feet. The roaring noise that accompanies this ejection of the liquid is heard at a considerable distance, and is one of the means by which whalers, in foggy weather, are directed to their prey. The proboscis of the elephant is sometimes used as a hose pipe, through which he plays a stream in every direction by the pump in his chest. Numerous insects that live in water move their bodies by the reaction of that liquid on streams they eject from

their bodies: oysters and some other shell fish move in this manner. Myriads of marine animals also ascend and descend in their native element by means of forcing pumps: when about to dive, they admit water into certain receptacles, and in such quantities as to render their bodies specifically heavier than the fluid they float in; and when they wish to ascend, they pump out the water which carried them down.

That expert gunner, the jaculator fish, shoots his prey with pellets or globules of water as from a piston pump. When an insect hovers near or rests on some aquatic plant within five or six feet of him, he shoots from his tubular snout a drop of water, and with so "sure an aim as generally to lay it dead." The habit of ejecting saliva, which some persons acquire, is by making a pump of the mouth and a piston of the tongue. Other animals practice the same; thus the llama of Chili and Peru, when irritated, "ejects its saliva to a considerable distance"—Frezier says ten paces, or thirty feet. The spurting snake of Southern Africa, it is said, ejects its poison into the eyes of those who attack it with unerring aim. The tongue of the lamprey moves backwards and forwards like a piston, and produces that *suction* which distinguishes this animal and others of the same family. The sting of some insects, that of the bee, for example, is a very complex apparatus, consisting of a lancet with its sheath, to penetrate the bodies of their enemies; first acting as a trocar and canular, and then as a pump to force poison into the wound—"an awl to bore a hole, [says Paley,] and a syringe to inject the fluid."

It perhaps may be supposed from the *form* of common pumps, that there is little resemblance between them and these natural machines, but it should be remembered that this form is purely arbitrary, (they are, as we have already seen, sometimes made of flexible materials, and alternately dilated and collapsed like the chests of animals.) The general custom of making them of hollow cylinders and of inflexible materials, arose from experience having proved that when thus made, they are more durable and less liable to derangement than any others that have yet been devised.

The circulation of the blood in man and other animals is effected by apparatus strikingly analogous to sucking and forcing bellows pumps. The heart is one of these—the arteries are its forcing, the veins its suction pipes, and both pump and pipes are furnished with the most perfect valves. By contraction, this wonderful machine forces the blood through the former to the uttermost parts of the system; and by distension, draws it back through the latter.[a] They vary in dimensions as in construction. Some are adapted to the bodies of animals so minute as to be imperceptible to unaided vision, and from these to others of every size up to the huge leviathan of the deep. The aorta of the whale, says Paley, "is larger in the bore than the main pipe of the water-works at London bridge; and the water roaring in its passage through that pipe, is inferior in impetus and velocity to the blood rushing from the whale's heart."

Every human being may be considered as, nay is, a living pump. His body is wholly made up of it, of the tubes belonging to it, and the liquid moved by it—with such additions as are required to communicate the necessary motion and protect it from injury. Health, life itself, every thing, depends upon keeping it in order. If one of its forcing pipes, (an artery,) be severed, we bleed to death; are any of its sucking tubes (the veins)

[a] In the 6th vol. of Machines approved by the French Academy, is the description of a bellows pump, made in imitation of the heart, by M. Bedaut, who named the working part of it "*La Cœur*," the heart—of which it was a rude resemblance.

choked, the parts around them become diseased, like sterile land for want of nourishment; does the pump itself stop working, we instantly die. The regularity and irregularity of its motions are indicated by the pulse, which has always been adopted as the unerring criterion of health and disease, or as an engineer would say, the number of its strokes per minute, is the proof of its state whether in good or bad working order. The pulse not only indicates incidental disorders in this hydraulic machine, but is a criterion of its age, as well as of its constant condition: the movements are strong and uniform in youth, feeble and uncertain in sickness and age, and as the machine wears out and the period of its labor approaches, its strokes at last cease and its vibrations are then silent for ever.

What mechanic can contemplate this surprising machine without being electrified with astonishment that it should last so long as it does in some people! Formed of materials so easily injured, and connected with tubes of the most delicate texture, whose ramifications are too complex to be traced, their numbers too great to be counted, and many of them too minute to be perceived, and the orifices of all furnished with elaborate valves; that such complicated machinery should continue incessantly in motion, sixty, eighty, and a hundred years, not only without our aid, but in spite of obstructions that are daily thrown in its way, is as inexplicable and mysterious as the power that impels it.

Few classes of men are more interested in studying natural history, and particularly the structure, habits, and movements of animals, than mechanics; and none can reap a richer reward for the time and labor expended upon it. It presents to the studious inquirer sources of mechanical combinations and movements so varied, so perfect, so novel, and such as are adapted to every possible contingency, as to excite emotions of surprise that they should have been so long neglected. There is no doubt that several modern discoveries in pneumatics, hydraulics, hydrostatics, optics, mechanics, and even of chemistry, might have been anticipated by the study of this department of science. Of this truth examples might be adduced from every art, and from every branch of engineering: the flexible water-mains (composed of iron tubes united by a species of ball and socket joint) by which Watt conveyed fresh water under the river Clyde were suggested by the mechanism of a *lobster's tail*—the process of tunneling by which Brunel has formed a passage under the Thames occurred to him by witnessing the operations of the *Teredo*, a testaceous *worm* covered with a cylindrical shell, which eats its way through the hardest wood—and Smeaton, in seeking the form best adapted to impart stability to the light-house on the Eddystone rocks, imitated the contour of the bole of a *tree*. The fishermen's boats of Europe, adapted to endure the roughest weather, are the very model of those formed for her progeny by the female *gnat*; "elevated and narrow at each end, and broad and depressed at the middle"—the beaver when building a dam—but it is vain to quote examples with which volumes might be filled.