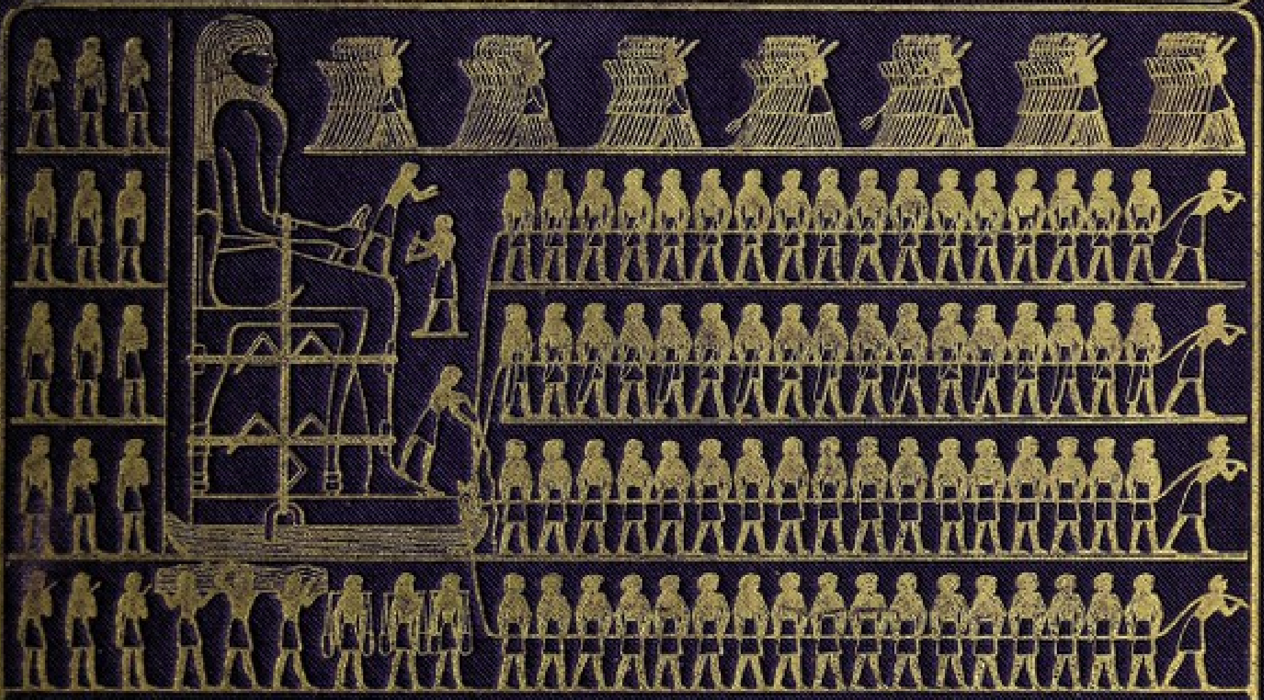
ENGINEERING OF ANTIQUITY



ENGINEERING OF ANTIQUITY

Fig. 34.—The Flour-Mill of Pompeii, with its Bakery.

Frontispiece.

ENGINEERING OF ANTIQUITY

AND TECHNICAL PROGRESS IN ARTS AND CRAFTS

BY

GEORGE FREDERICK ZIMMER, A.M.Inst.C.E.

WITH FIFTY-SIX ILLUSTRATIONS

MOST OF WHICH HAVE BEEN REPRODUCED BY THE AUTHOR, WITH THE KIND PERMISSION OF THE AUTHORITIES, FROM THE RECORDS AT THE BRITISH MUSEUM

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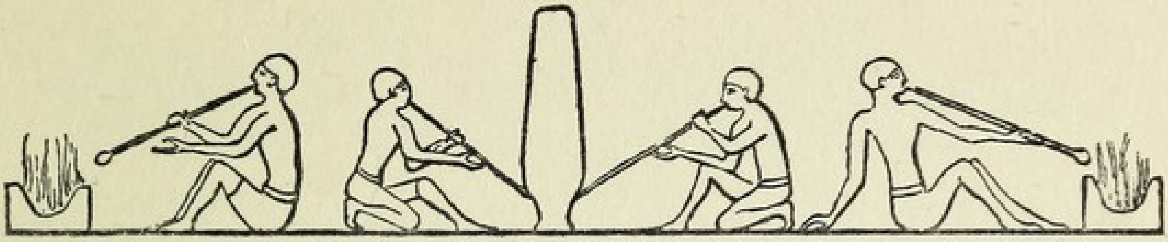
PREFACE

It was my first intention to condense my notes on the Engineering of Antiquity into the compass of an article for a technical magazine to which I am a frequent contributor; but as this proved next to impossible, I thought it better that the results of my researches should be published by themselves in the form of a small book. Only the most important data have been dealt with. There is a vast amount of additional matter which might have been included, both in picture and word, which I shall be pleased indeed to add to these pages if it is manifested that sufficient interest is taken in the subject.

Being an engineer by profession and an archæologist by inclination, it is but natural that I should be interested in that part of antiquity which concerns engineering, and I venture to hope that the perusal of the following pages may be as pleasing to engineers and those interested in the work of the ancients as the research involved has been to me. The collected records have unfolded to myself a vast field of enjoyment, and if only a small percentage of those interested in technical and educational growth and development consider the following pages worth reading, I shall feel amply rewarded for the labour bestowed upon them.

G. F. ZIMMER.

82, Mark Lane, E.C



Egyptians making Glass.

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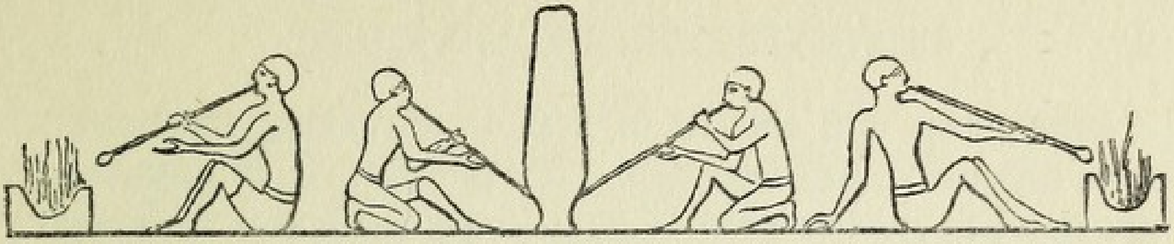


EGYPTIANS MAKING GLASS.

ENGINEERING OF ANTIQUITY

INTRODUCTION

It must be acknowledged that there is an increasing desire of modern thought to look back and appreciate the cultural work of nations and generations which have long passed away, but the ever-progressing strides in technical knowledge have left the engineer but little leisure to inquire into the interesting history of his profession, so that the memory of the earliest pioneers is not always honoured with the credit which is due to them.

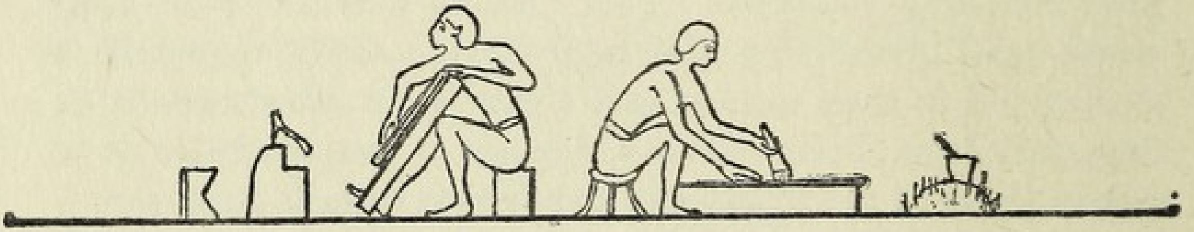
When Franklin defined man as a tool-making individual, he uttered a truism indeed, for invention is man's attribute; the bee still makes its comb the same as ever, and is no greater mathematician now than in the days of Euclid; the beaver builds his house and the chaffinch its beautiful nest as they did in the days of Solomon. Animals are endowed by an Omnipotent Creator with instinct which is fully developed on their reaching maturity. This instinct teaches them their wants, and gives them the sagacity to satisfy them; it is stereotyped in their nature, and there is no advancement or departure from Divine laws which are so unchangeable as to reduce those of the Medes and Persians to utter insignificance. It is very different with man; he enters this world perhaps more helpless than any other creature, but he is endowed by the same Creator with intellect and wisdom to enable him to fight his own battle of life, and to provide for himself food, raiment, and home, as he desires, and as climatic circumstances dictate.

Intelligence and culture in man is advancing constantly from generation to generation. It is the attribute of invention which distinguishes natural man (the *genus homo*) from the brute.

Tools, implements, and weapons were the first necessities of primitive man in his struggle for existence. Wood, bones, and rough stones were the first materials he used; then followed polished stones; later, according to some authorities, bronze; and lastly iron, marking, as they did, different eras. It is, however, by no means certain that iron was not used before bronze in some regions, according to the locality or geographical distribution, and the advancement of the culture and opportunity of its people. Taylor says:

> "Just as certain plants and animals are peculiar to certain districts, so it is with such implements as the Australian boomerang, Polynesian stick and groove for fire-making, the tiny bow and arrow used for a lancet or phleme by tribes about the Isthmus of Panama; and in like manner with many an art, myth, or custom, found isolated in a peculiar field."

Let us here depart from this thread of thought to look a little more closely into the history and antiquity of iron as compared with bronze.



EGYPTIAN CARPENTERS USING GLUE.

EGYPTIAN GOLD AND SILVER SMITHS.

THE ANTIQUITY OF IRON

THE Chinese are reputed to have had iron since the time of the Emperor Fo-Hi, who is supposed to have reigned in the time of Tubal-Cain of the Bible. The aborigines of Tibet, the Miao-Tze, had swords and hatchets of iron at that time, and the Emperor Yu received tributes from them in supplies of iron, *circa* 2000 B.C. The first records of iron in the Bible are found in Genesis iv. 22, where Tubal-Cain was mentioned as an instructor of every artificer in brass and iron. (Tubal means "smith.") Tubal-Cain lived in the eighth generation after Adam; according to Jewish time calculation, in the year 1057 after the creation of the world, or, say, 3,000 years before Christ. Homer distinctly mentions the use of iron ("Iliad," xxiii. 261), and his "black *hyanus*" is believed to be steel; the same applies to the *adamas* of Hesiod, who also mentions the iron of the deity Dactyli of Crete. Iron (*barzel*) was in general use by the Jews before the Babylonian Captivity—indeed, it was known to them as early as the days of Job—and Moses speaks of an iron furnace. According to Chinese annals, the invention or introduction of iron is timed at 2940 B.C. This evidence does not, however, give us the earliest age when in remote antiquity the cultus of man was advanced by this most important advance—the introduction of iron. Egyptian records must therefore come to the rescue, and prove to us that during the reign of the Kings early in the Fourth Dynasty (*circa* 3700 B.C.) iron was used, and this date is earlier than those of Tubal-Cain and the first Emperor of China.

Herodotus mentions that iron tools were used by the builders of the Pyramids, and in the monuments of Thebes, and even in the tombs near Memphis, which date back more than 4,000 years. Butchers are represented sharpening their knives on steels suspended from their aprons ; the blue colour with which they were painted can only represent iron or steel. Again, in the tomb of Rameses III. the distinction between bronze and iron weapons is clearly shown, as the one is painted red and the other blue, so there can be no doubt that both metals were used at the same period.

The introduction of metals which helped the civilization of man in such a marvellous manner was in the following sequence: Gold was probably known first, much before iron, though the only good it did was to foster vanity and greed, as it could not be used for anything but personal adornment. Now we must ask ourselves the question, Which was the first metal of real use in the cultural progress of man? Copper, bronze, and iron were used in some parts of the ancient world almost at the rudiments of civilization. There is an old theory which is nearly universally accepted, and that is, that copper and bronze are older than iron. The ethnologist's theory is also that, after the Stone Age, bronze came first, because in ancient graves bronze weapons and utensils were found and not iron ones; but this is obviously no sound reasoning, as iron corrodes so much more easily, especially in the nitrous soil of Egypt, that it cannot be preserved for thousands of years in a buried condition except by some lucky coincidence. On the other hand, iron implements are said to have indeed been preserved in such condition from a time before bronze was known.

Let us now investigate the metallurgical aspect. Bronze is, of course, an alloy—a mixture of copper and tin—and there is no likelihood that ores containing both these metals in a suitable proportion should have been found by the ancients so as to melt them into bronze. It is far more likely that both copper and tin were procured in their pure metallic state long before they were mixed into bronze. Copper ores are, moreover, much rarer and much more difficult to manipulate than iron ores, as the former require a temperature of 1100° to melt, whilst the latter will yield iron in a suitable form for further treatment by forging at 700°, so that there are no technical difficulties which are likely to have retarded the introduction of iron, and it may be that both iron and copper were known to antiquity before the dawn of history.

The matter stands absolutely differently with regard to bronze: tin is indispensable in its production. Now tin is rare, and in antiquity it was, of course, rarer still, for it is only found in a few places more or less inaccessible to the Egyptians, Assyrians, and Phœnicians, except by import from India, Spain, and England; probably first from India, where tin is mentioned in old Sanskrit records as *Kastira.* The Phœnician shippers imported tin from Cornwall and Devonshire and kept its source a secret from the jealous Roman shippers.

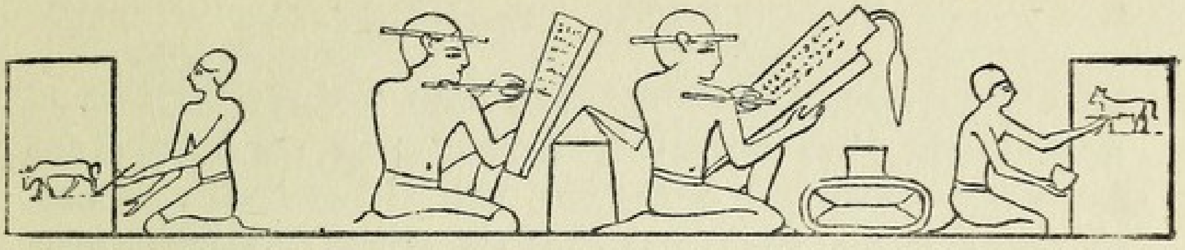
The following is quoted from Sir J. Gardener Wilkinson, the famous Egyptologist:—

> "Ezekiel, indeed, expressly says that the Tyrians received tin, as well as other metals, from Tarshish, which, whether it was situated, as some suppose, in Arabia or on the Indian coast, traded in the production of the latter country; and the lamentation of the prophet on the fall of Tyre, though written as late as the year 588 B.C., relates to a commercial intercourse with that place, which had been established and continued to exist from a much earlier period.
>
> "It is probable that the Phœnicians supplied the Egyptians with this article (tin), even before it was brought from Spain and Britain. The commercial intercourse between the two nations dated at a most remote epoch (Herod. I., i.). . . . That the production of India already came to Egypt at the early period of Joseph's arrival in that country is evident from the spices which the Ishmaelites (Gen. xxxvii. 25) were carrying to sell there; . . . and that some of the objects found at Thebes of the time of the third Thothmes and succeeding Pharos argue that the intercourse was constantly kept up.
>
> "The first mention of tin, though not the earliest proof of its use, is in connection with the spoils taken by the Israelites from the people of Midian in the year 1452 B.C., where they are commanded by Moses to purify 'the gold and the silver, the brass, the iron, the tin and the lead, by passing it through the fire' (Num. xxxi. 22)."

Bronze was not made in India originally, but it was imported according to old records, from the West. There are reasons for believing that bronze was originally made by the Semitic inhabitants of Western Asia, probably also by the aborigines of the Lower Euphrates territory, but it is sure that the introduction to a large extent was effected by the Phœnicians, who used it very extensively.

The theory that bronze was automatically used by different races as soon as their cultus had arrived at the required step is absolutely false. This might have been so with iron and copper, but the manufacturing of bronze required metallurgical knowledge and experience, and it is therefore almost unquestionable that the Phœnicians manufactured it largely, and exported it throughout the inhabited coasts of the Mediterranean, and even beyond.

These enterprising merchants instructed the natives, to whom they sold bronze metal as such, in the art of melting and casting this metal into implements and weapons, so that it soon became more popular, at least for a time, than iron. Bronze was composed of from 5 to 25 per cent. of tin, according to the purpose for which it was used; the more tin, the harder was the bronze up to 30 per cent., at which it was too brittle for use. The alloy generally sold by the Phœnicians consisted of 90 parts copper and 10 of tin, and the bronze weapons, etc., found as the remainders of different nations, when analyzed, justify the assumption that if not the weapons, then at least the bronze from which they were made was of Phœnician origin.



Egyptian Scribes and Artists.

TOOLS AND IMPLEMENTS

During a period when primitive man was hunter and fisherman, his utensils included club, spear, knife, axe, bow and arrow; when his civilization had advanced to agriculture, he added such implements of husbandry as the plough, spade, and sickle; with his further cultural developments he introduced different crafts, and invented the saw, shears, gimlet, tongs, plane, potter's-wheel, the blower or bellows, the lathe, and the loom. Without engineering or technical developments, man would never have risen socially above the brute, and his culture or civilization has been brought about in the first stages by the tools of his own creation, which provided means to improve his social condition by enabling him to make such implements and household accessories as added comforts in all directions of his narrow sphere.

The progress of culture and civilization in the present day is a most complicated process; it entails never ceasing warfare with resisting interests and forces. But in the time of antiquity this was not so, as all strove to provide themselves with the best implements, both for domestic use and for purposes of the chase and warfare, to improve their standard of life.

Aristotle mentions in his mechanical problems the following accessories as existing: The lever and balance-weight, the beam-scale, the tongs, the key or wedge, the crank and axle, the roller, wheel and pulley, the pulley-block, the potter's-wheel, the catapult, and the tooth-wheel. He does not mention the screw in any of its forms, but this was probably known in the time of Archimedes (born 287 B.C.), and it is probable that, although the screw is attributed to him, he was only entitled to the credit of introducing it from Egypt, where the screw must have been known in some form before the birth of Archimedes. The reason why Aristotle does not mention the screw may be sought in the fact that it was associated with mechanical work, which was despised by the ancient Greeks, as also were all kinds of labour, which were looked upon as dishonourable vocations; so much so that Plato and Aristotle advocated that all those pursuing industries should be deprived of the right of citizenship, as the pursuit of crafts, industries, and barter, was in their opinion not only dishonourable, but also a hindrance to virtue.

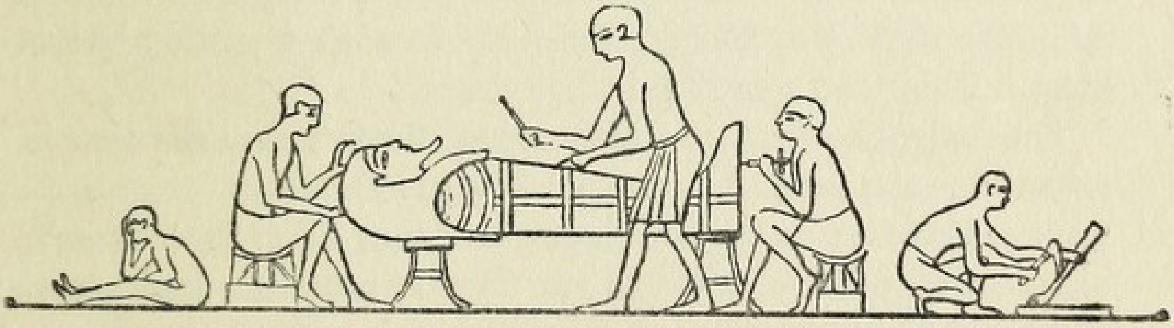
Some of the oldest evidence showing distinctly and extensively the unmistakable marks left by the tools of prehistoric man refers to Egypt and Babylonia; in the quarries of Syene may be seen to this day the chisel-marks, the rows of holes which were bored prior to splitting off stone blocks, including those enormous monoliths used in the construction of the Egyptian and Babylonian monuments. According to Belzoni, the procedure was as follows: Grooves of 2 inches wide were cut by means of chisels and drills; the stone blocks were afterwards broken off along these marks by the use of some kind of implement. This no doubt refers to the insertion of wooden wedges, which, when saturated with water, would expand and sever the rock. Lancret has observed an obelisk in course of preparation, and from the work, as far as it went, found that the splitting-surface of the rock was most cunningly utilized by the Egyptians so as to save as much cutting of the stone as possible. One can hardly wonder at that, when one takes into consideration the primitive tools which had to be used.

The Egyptians used both metal and stone tools in the execution of their magnificent sculptural work, but it is probable that the Babylonians used both iron and bronze tools for their work at an earlier date; at least, some of the discoveries at the Palace of King Sargon in Nineveh seem to point to the fact. Sir Henry Layard found in Nimrod portions of a large iron saw with small even teeth (now in the British Museum), evidently used for cutting stone, and the Romans are known to have used saws up to 12 feet long for cutting their stone-work.

THE HOMESTEADS

The homesteads of remote antiquity were caves, piled-up stone slabs, tents, and log cabins; the home of man improved gradually step by step, and it is a fact that the most superb palaces and structures of national character represent on a larger scale the modest abode of the poor man of the same period.

As man advanced from an imperfect to a higher civilization, he was not content with the building of ordinary human dwellings, but erected some of the most stately monuments, which, apart from their architectural merits, involved technical ingenuity which will excite the admiration of engineers for all time.



Egyptian Carpenters.

CONVEYING LOADS

We can only form a hazy idea of the means of transport used for the enormous stone blocks required by the ancient Egyptians and Assyrians for their monuments. They used probably a kind of wooden sledge, composed of two runners connected by transverse timbers morticed into the runners. These sledges were employed to convey colossal stone figures, sometimes in their half-finished state, from the quarries to their destination. Herodotus reports that King Cheops,* when building his pyramid, employed workmen to bring the stones from the quarries in the Arabian mountains to the banks of the River Nile, and after their arrival there they were conveyed on the river on rafts; then he employed others who had to pull the sledges with their loads to the required destination. The men were employed in shifts of 100,000 for three months a shift, and it took ten years alone to prepare the road upon which the stones had to be dragged. The length of the road was five stadia, or about three-quarters of a mile, the width was 60 feet, and it led through a cutting 48 feet deep. This road was of polished stone.

The Assyrians conveyed their monoliths in a similar manner, as may be seen from the bas-reliefs of the Palace of Kouyunjik. This palace was built under the Assyrian King Sennacherib, who destroyed Babylon in 694 B.C. These bas-reliefs depict some of the building operations, amongst which are those showing the transport of these stones, partly by water and partly by land; for the former they employed rafts composed of timber, and made more buoyant by the inflated skins of animals. Fig. 1 shows one of these monoliths in transit, having holes through which

* Cheops, Fourth Dynasty, *circa* 3733 B.C.

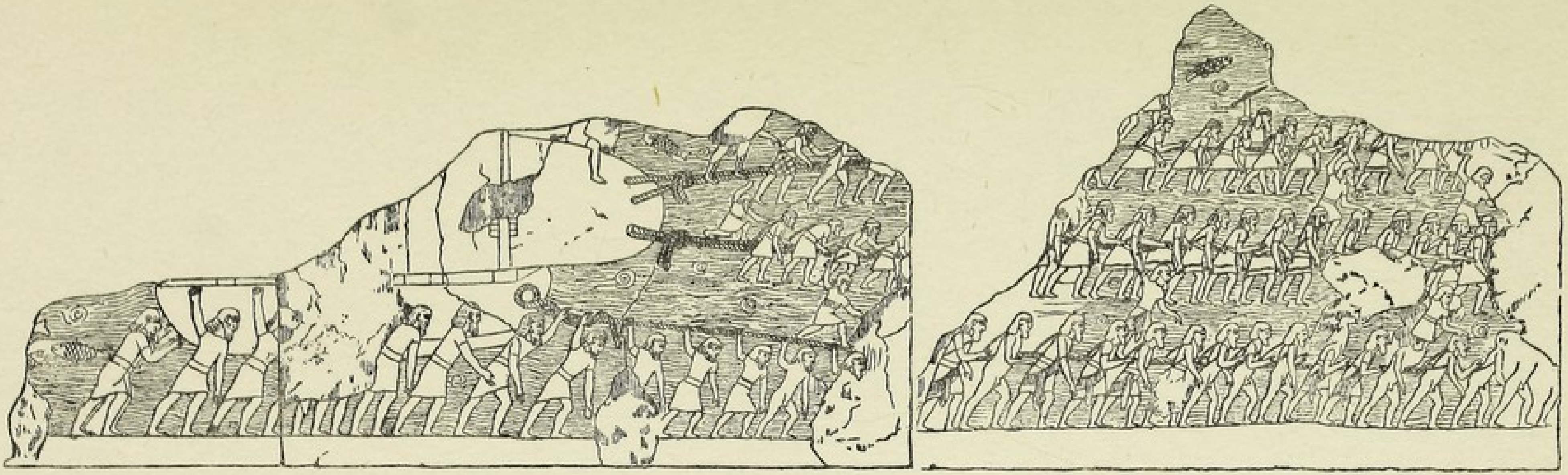


Fig. 1.—The Transport of an Obelisk.

From a series of bas-reliefs in the Palace of Kouyunjik of King Sennacherib, now at the British Museum.

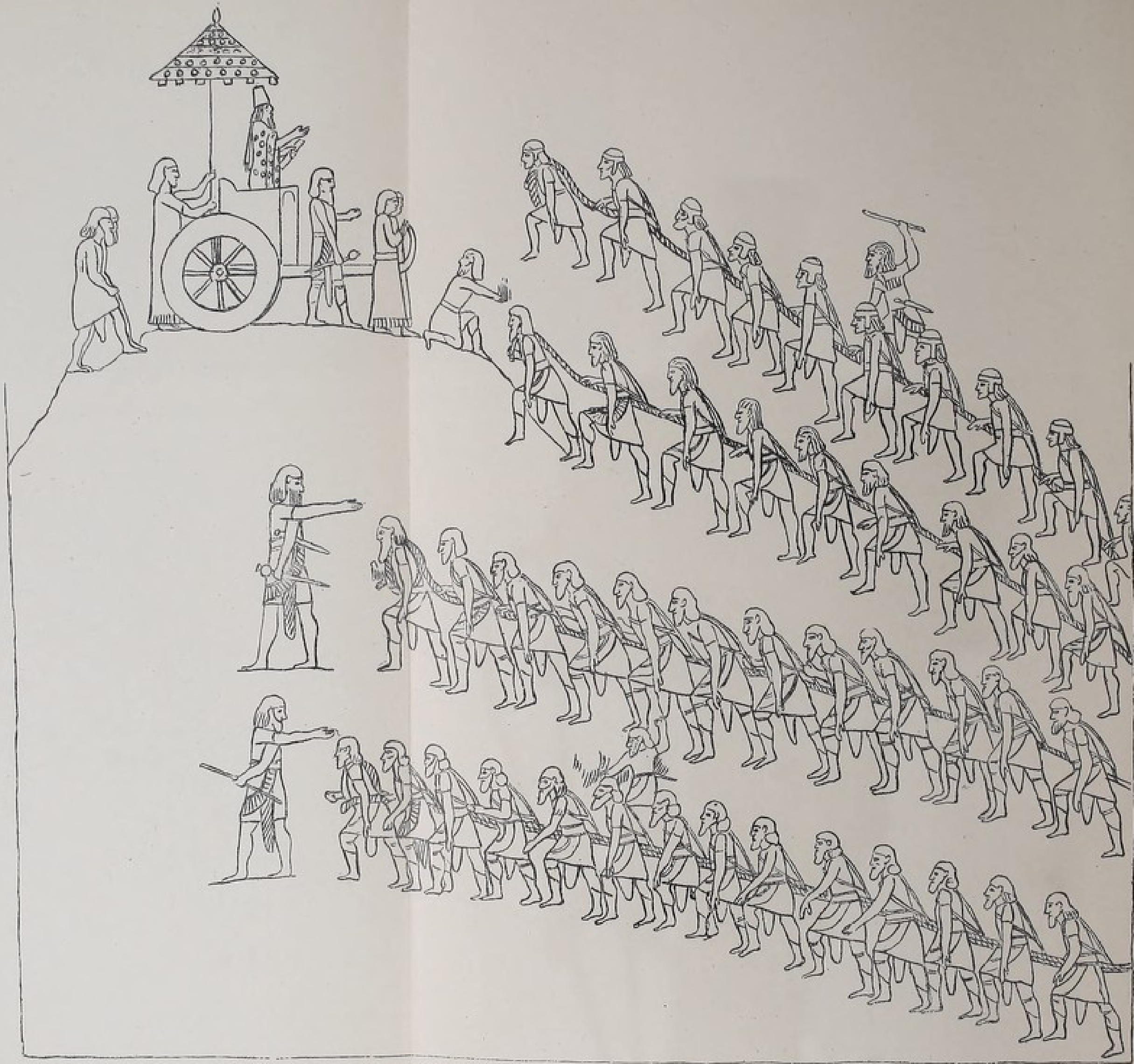


Fig. 2.—The Transport of an Unfinished Colossal Assyrian Bull under King Sennacherib's own Direction.

From a bas-relief of Sennacherib's Palace, Kouyunjik, now at the British Museum.

two ropes are passed; a third rope is attached to the front of the raft; gangs of men are pulling on all three ropes, partly in the water and partly on land. The task-masters are armed with swords or sticks to urge on the miserable slaves. The conductor of the operation sits on the stone colossus and gives his orders; the continuation of this bas-relief (not given here) shows thirty-six more men on each rope. The original bas-reliefs from which these illustrations were taken are in the British Museum.

Fig. 2 shows the stone figure of an unfinished bull on a sledge, which is pulled similarly by slaves in short, jerky pulls, whilst others lift behind with levers and wedges; on the top of the stone are four persons who command and conduct the proceedings, the King himself, in his chariot, watching the performance. One of the conductors beats time by clapping his hands; the second figure holds a megaphone to his mouth, calling out the commander's instructions; the third figure is evidently the chief commander. A fourth person with a staff in his hand, in a kneeling position, is behind the others to instruct those with the levers and wedges. Not shown here, but on the continuation of the bas-relief, are depicted men with ropes and timbers, trees, and the river; on the latter can be seen boats, rafts, and also a man floating on an inflated skin.

Fig. 3 is a representation of a further bas-relief which exhibits a similar proceeding; workmen or slaves are shown carrying saws, hatchets, shovels, ropes and timbers. In this representation the proceedings are conducted by three superintendents standing on the colossal bull—one with a megaphone in his hand; the King is seated in a richly ornamented chariot, attended by two eunuchs (one on either side), and surrounded by his bodyguard; this is on the next bas-relief (not shown here).

An adjacent bas-relief is shown in Fig. 4 of a human elevator constructing an artificial mound for the King's palace.

These illustrations of the means adopted for the transport of immense weight no doubt depicts the process employed, but it is hardly to be supposed that the number of men shown pulling on the ropes was the actual number employed; it is more likely that the number of men was far greater. The conveyance and erection of these monoliths, representing the Assyrian Winged Bull, took place approximately 700 B.C., and it is an extraordinary fact that Sir Henry Layard, when removing some of these same monoliths 2,250 years later, used exactly the same means of transport, with the only exception that, instead of a sledge and rollers, he used a four-wheeled waggon; this was no doubt a vast improvement, and even with this it took 300 men to move them.

Fig. 5 shows the transport of a sandstone statue of Dhuthotep, as represented by an Egyptian fresco in one of the Berscheh tombs;* the statue is secured to one of the sledge-like conveyances already mentioned, and is slowly pulled along by four double rows of men, altogether 172. Curiously the four rows of men are shown above each other, as the Egyptian artists were not well acquainted with perspective. At the top of the picture are soldiers and citizens with palm-boughs who have come to greet the arrival of the statue; the leader of the proceedings stands upon the knees of the statue, and beats time so that all pull together with short jerky pulls. Upon the feet of the figure stands a man who pours water or oil upon the path by way of lubrication; above the figure stands another who holds an incense-box; low down on the left are represented men with boards to put under the sledge, and others with water or oil to replenish the supply of the man on the feet of the statue; behind are depicted four rows of officials and three task-masters. The hieroglyphics accompanying this drawing inform us that the statue is 13 ells, or 19 to 50 feet high. It will be interesting to read the description in hieroglyphics which accompanies this fresco, a literal translation of which is given by G. Maspero in the Transactions of the Society of Biblical Archæology, as follows:

> "In the tomb of Thothotpou the statue was a very large one, and required a great amount of skill. Bringing a

* Time of Osirtasen II., of the Seventeenth Dynasty in the sixteenth century B.C.

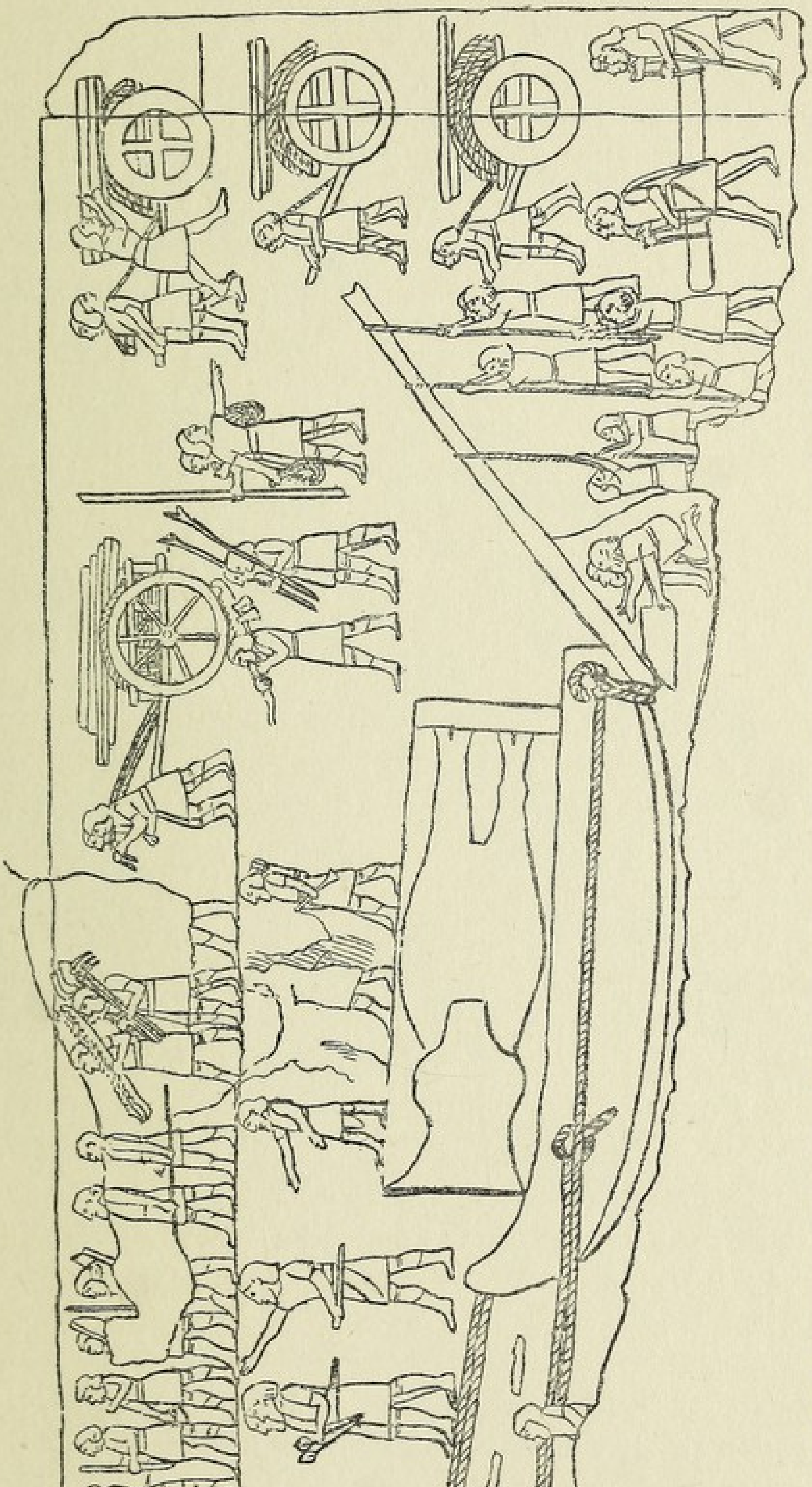


Fig. 3.—An Unfinished Colossal Assyrian Bull being conveyed to the Palace of Kouyunjik by Slaves.

From a bas-relief of Sennacherib's Palace, now in the British Museum.

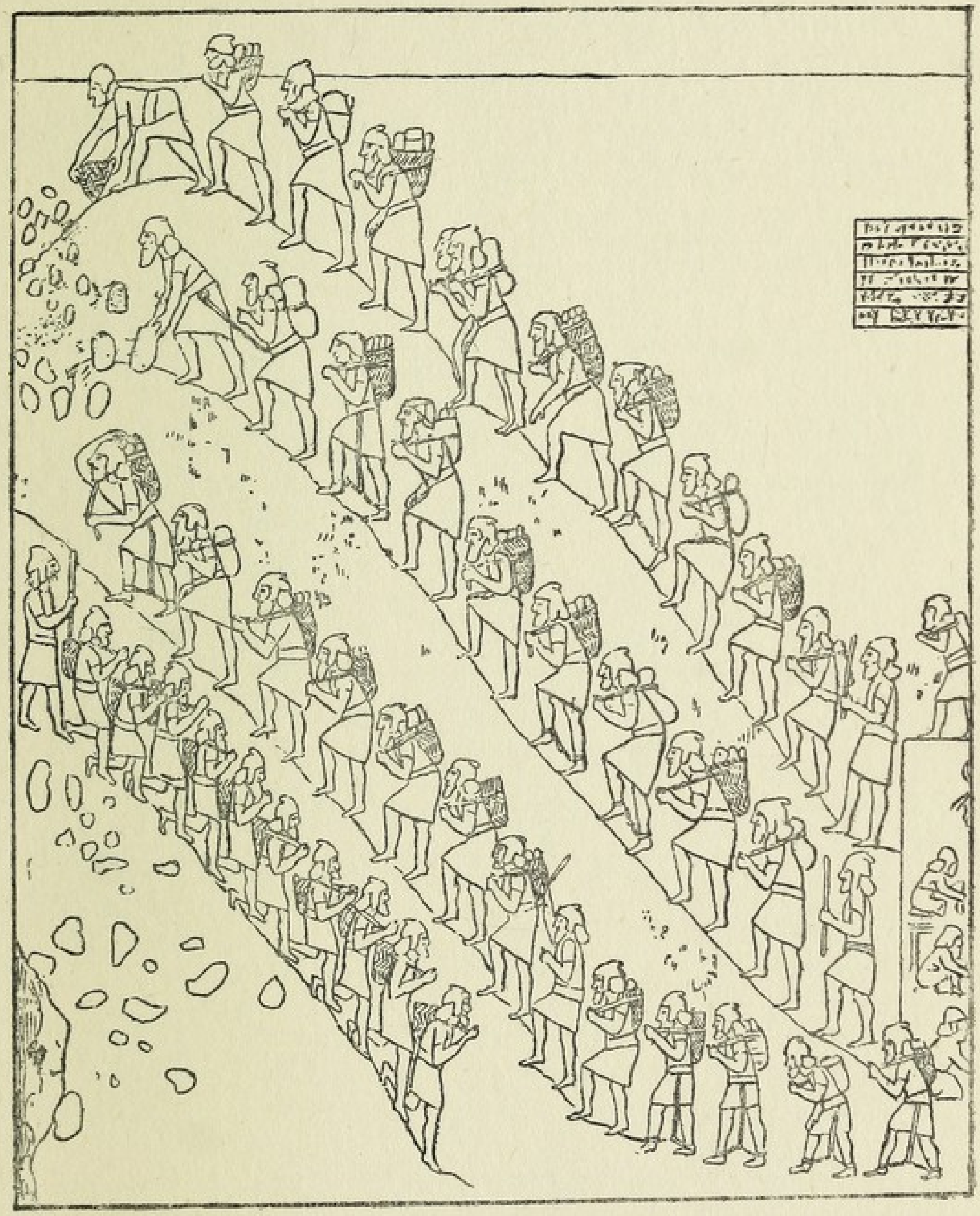


FIG. 4.—THE CONSTRUCTION OF AN ARTIFICIAL MOUND BY CAPTIVES FROM THE CITY OF BALADA, UPON WHICH THE PALACE OF KING SENNACHERIB WAS BUILT.

From a bas-relief of this palace, now at the British Museum.

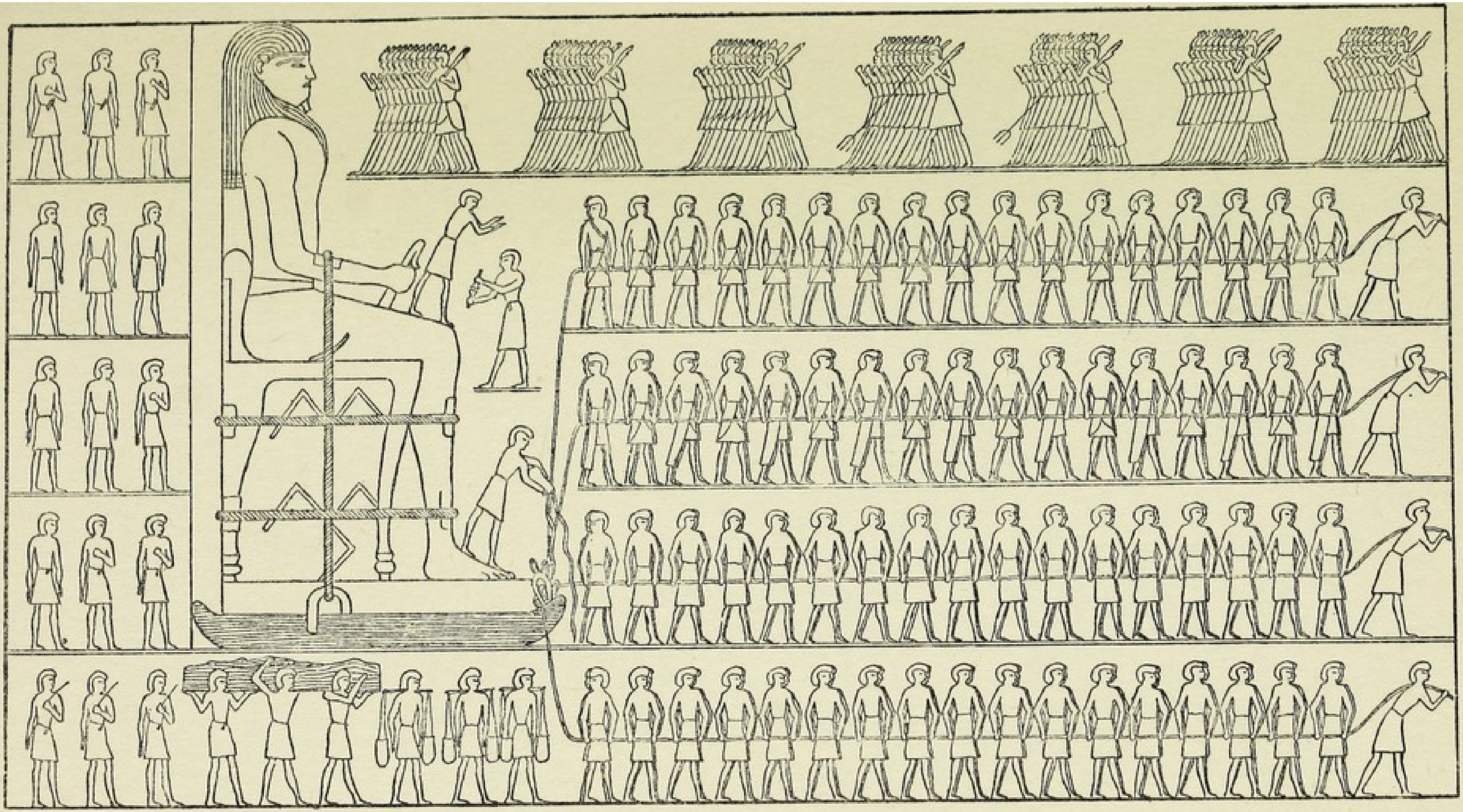


Fig. 5.—The Transport of the Statue of Dhuthotep.

From a fresco in the Bercheh Rock Tomb, Twelfth Dynasty; after Lepsius. The original fresco is 8 feet 11 inches long.

statue of thirteen cubits in stone of Hâït-noub: 'Lo, an unintelligible thing it is, the road it went over, more than anything; lo, an unintelligible thing it is how men could drag such huge masses of stone on it; an unintelligible thing it is to have such a block of compact stone. I caused generations of goodly youths to go and make a road for this statue, with the various classes of stone-cutters and polishers, and task-masters, with them, skilled in selecting men of strong arm. I went to bring it and my heart expanded with joy, and the townspeople in a body rejoiced so much that it was better than anything to see it; the old men here lent a shoulder to the statue, as well as the youths of strong arm, and those whose heart was weak, their hearts grew strong, and every one of them displayed the power of a thousand men! Lo, this statue, a large square block, a marvel it was, greater than anything! Barges were ready, full of requisites; the hips of warriors and generations of goodly youths were dragging away the hips of the statue, their mouths praising the favour which I was receiving from the king; my children proceeded in full attire behind me, and my vassals shouted praises. When I reached the locality of my tomb, the gods in a body rejoiced so much, that it was better than anything to see it; the princes made before, the Sabi-Khamer made in olden times in the interior of this town, and which I placed on pedestals on the brink of the river, they were not envious of what I made or what was done for me, for, thus indeed did I insure eternity to me since were put, in this my tomb, its eternal works.

"'The people of the city came out in a body with boughs to greet the statue of their prince.' (The legend above this is much broken; what remains reads as follows:) 'The Hermopolitan nome was in feast, and its heart expanded with joy; its old men who were inactive, and its young men who were not inactive . . . went equally to give the prince joy of his monuments.' The upper row of those pulling consisted of 'the generations of the western Hermopolitan nome, coming in peace!' say that 'the working men of the town are in feast, and their heart expands when they see their monuments; whereas the reward of the prince is done in their middle, his house and the house of his fathers are at rest.' In the second row are 'the generations of the young men and soldiers of the Hermopolitan nome, coming in peace. Their words: "It is good of a generation to work for its lord, the splendid reward he has won by the favours of every king; let us go and serve his children after him, for our heart is delighted by the lasting and perpetual favours of the king." ' Next to them we see ' the classes of the townpeople of the Hermopolitan nome, coming in peace!' " Oh beloved by Thoth, Thothotpou, friend of the king, beloved of thy townpeople, praised by the gods of thy town! The lords of the temples are in feast; their hearts expand when they see the favours received from the king!' The fourth row was composed by ' the generations of the eastern Hermopolitan nome, coming in peace. They say: " Thereas comes my lord to the town of Terôti, Hor rejoices in it, and his fathers are in feast; their hearts expand, rejoicing about his beautiful monuments." ' A man standing on the knees of the colossus claps his hands and beats the time for the workmen: the burden of his song was in honour of the prince. ' Saith the time-beater of the soldiers . . . Thothotpou, friend of the king.' The name of the man offering incense is Amoni-Onkhou, and he enjoys a long title. The statue is followed by twelve men, the names of which are destroyed except in the instance of ' the majordomo Nouhri.' They were probably sons of the prince and officials of the prince's household."

The monarch of Coptos, says Breasted, was able to send an expedition of his own to the Hammamat quarries which brought back two stone blocks 17 feet long. A second expedition returned with a block 25 feet 6 inches long, drawn by nearly 200 men along the desert road over fifty miles to the Nile. The people of the Nomarch of the Hare nome dragged from the quarries of Hatnub ten miles to the river a huge block of alabaster weighing over 60 tons, and large enough for a statue of the Nomarch some 22 feet high.

Henu, Chief Treasurer of Mentuhotep V.,* was despatched to the quarries near the Red Sea by the Hammamat road with a following of 3,000 men. Such was the efficiency of his organization that each man received daily two jars of water and twenty small biscuit-like loaves. A simple calculation will show what enormous quantities the commissariat had to provide during the march and the stay at the quarries of

* The last Pharaoh of the Eleventh Dynasty, *circa* 2000 B.C.

Hammamat. Everything was done to make the desert road safe and possible, so Henu dug fifteen wells and cisterns along the route. On his arrival at the Red Sea, Henu built a ship which he despatched to Punt, while he himself returned by way of Hammamat, where he secured and brought back with him fine blocks for the statues in the royal temples, undoubtedly by the means already described and illustrated.

The mighty twin-colossi erected in honour of Amenhotep III. at Thebes are each hewn out of single blocks of granite, and were brought hundreds of miles down the Nile from Assuan. These sitting statues are about 47 feet high, and weigh about 847 tons. Another example is the statue of Rameses II. (the Great), lying now in the Temple of Thebes, called Ramesum after him. It was hewn from a single block of granite 60 feet high, and, according to Sir J. G. Wilkinson, weighs over 887 tons. It is believed that this monolith also came from the quarries at Assuan.

Flinders Petrie discovered the remains of an even larger colossus at Tanis which stands 125 feet high, with the pedestal, and is estimated to have weighed 1,200 tons. The Olympian Jove was 60 feet high, and the statue of Apollo measured, according to Pausanias, 45 feet, whilst the Colossus of Rhodes was 105 feet high.

The 127 columns forming part of the Temple of Diana of Ephesus were 60 feet high and 7 feet in diameter, cut from single blocks of marble. The architects Chersiphron and his son Metagenes, we learn, conveyed these monoliths, after lagging them with wood, a distance of eight miles from the quarries to the site of the temple, by rolling them with the help of oxen.

The Syrians moved and erected enormous stones at Baalbeck, probably heavier than those of the Egyptians, measuring 60 feet by 9 feet by 12 feet thick.

Nearer home we have the monoliths of Stonehenge and those of Carnac in Brittany, probably conveyed and erected 3,500 years ago by a people with but the crudest appliances, so that here, also, combined brute force must have been the motive power.

With reference to the distance to which these monoliths had to be conveyed, mention might be made that the granite quarries of Syene were 130 miles from Thebes and 650 miles from Memphis, and that it is 800 miles to the Delta.

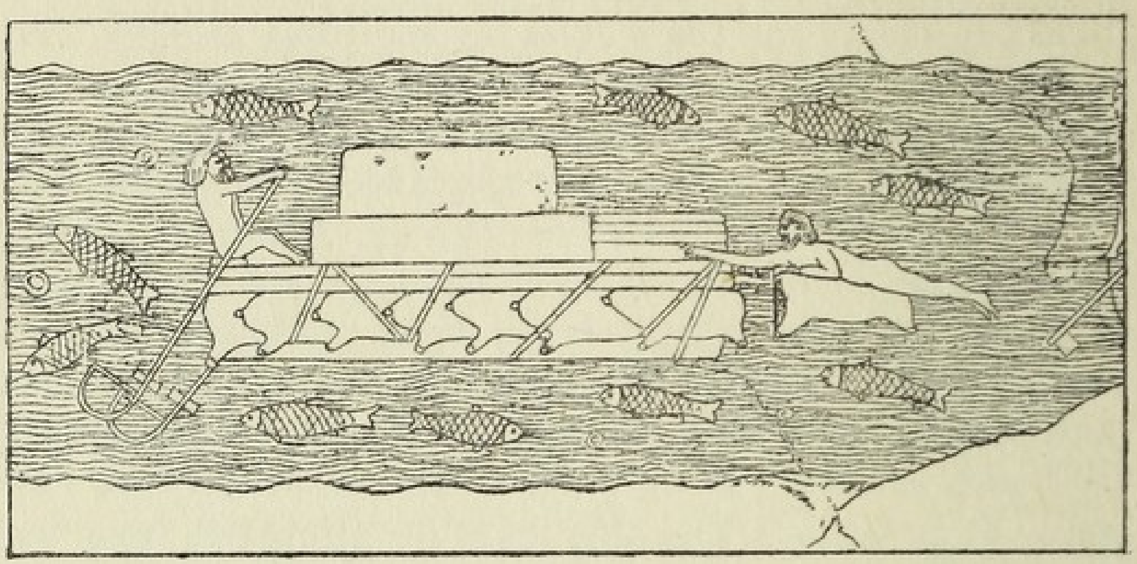


Fig. 6.—The Transport of Building Materials by Water as practised by the Ancient Assyrians.

From a bas-relief at Nineveh; after Victor Place. The raft is composed of timber and inflated skins.

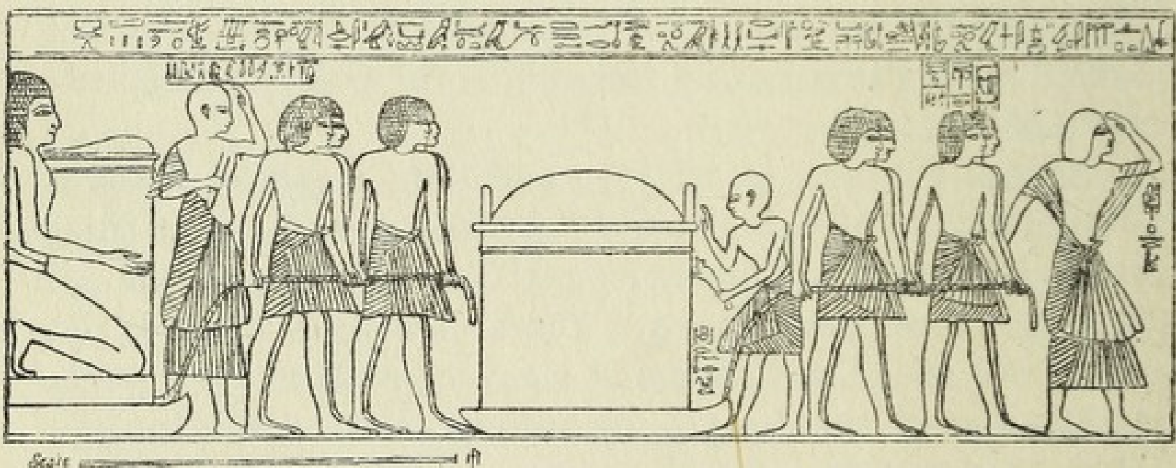


Fig. 7.—Represents Transport of Smaller Building Material by Means of Sledges.

The illustration is taken from the fresco in Grave No. 27 in the district of Sagâra. New Empire, Nineteenth-Twentieth Dynasty. After Lepsius.

Fig. 6 shows the means of transport of building material by water, as practised by the ancient Assyrians; while Figs. 7 to 14 depict the transport of smaller figures and stones by the Egyptians.

When dragging heavy loads along the ground, the friction was so enormous that extreme energy was required to move them, even if only by jerky pulls, a few inches at a time, so that the inertia of a moving mass never came into play. The Egyptians laid down planks, or polished the road, to reduce friction, and even then they had to pour water or oil on the path to prevent the wooden runners from taking fire. The Assyrians, on the other hand, who moved their great

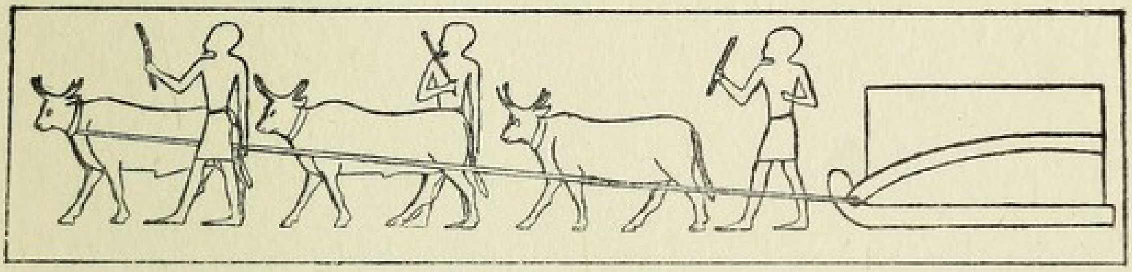
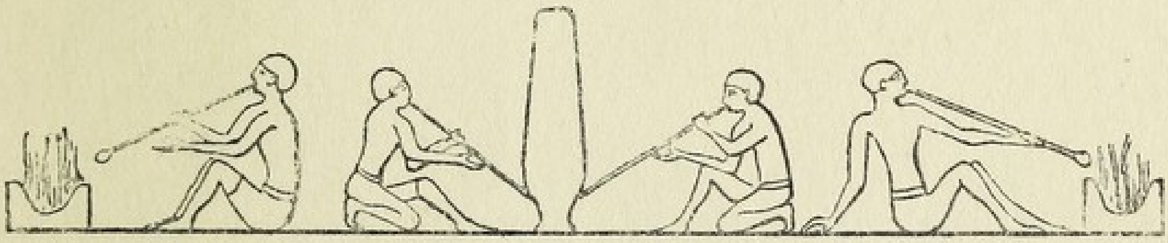


Fig. 8.—Represents Transport of Stone Blocks by Oxen.

The original is carved in the face of the rock at Maâsara, from the alabaster quarries of El Bosra. New Empire, Seventeenth Dynasty. After Lepsius.

monuments at about the same time, used rollers between the load and its path in order to reduce friction, which was indeed a great step forward in mechanics. This can be seen from Fig. 2, in which a man appears on the bas-relief in the act of placing a roller in such a position; none of the Assyrian representations show water poured on the path, whilst all the Egyptian ones do.



Egyptians making Glass.

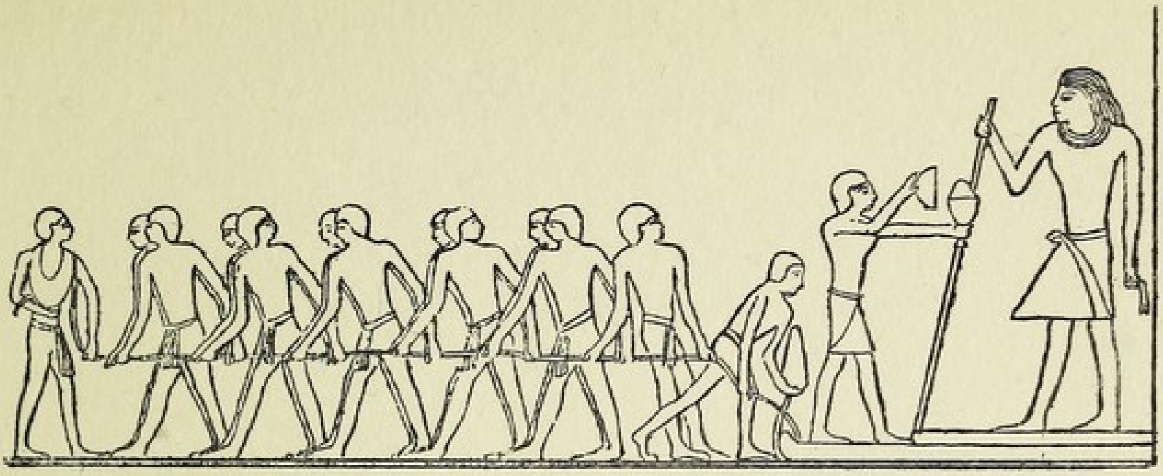


Fig. 9.

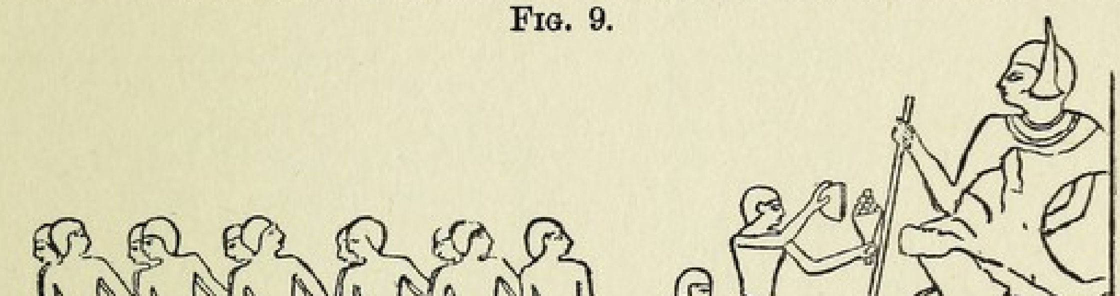


Fig. 10.

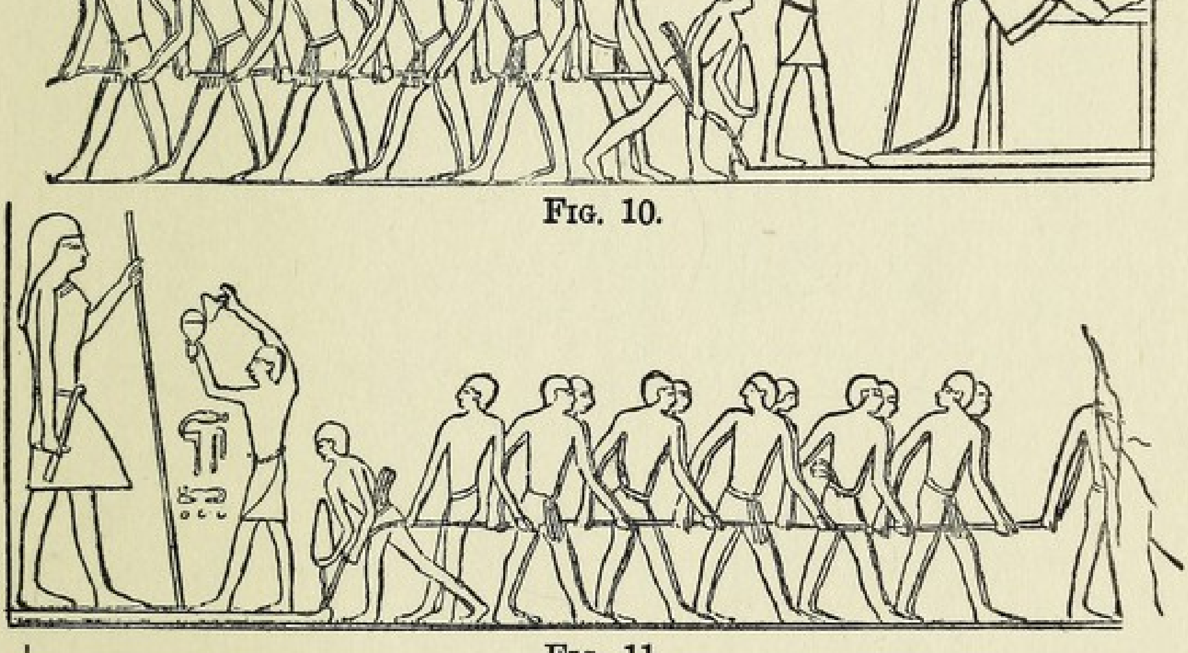


Fig. 11.

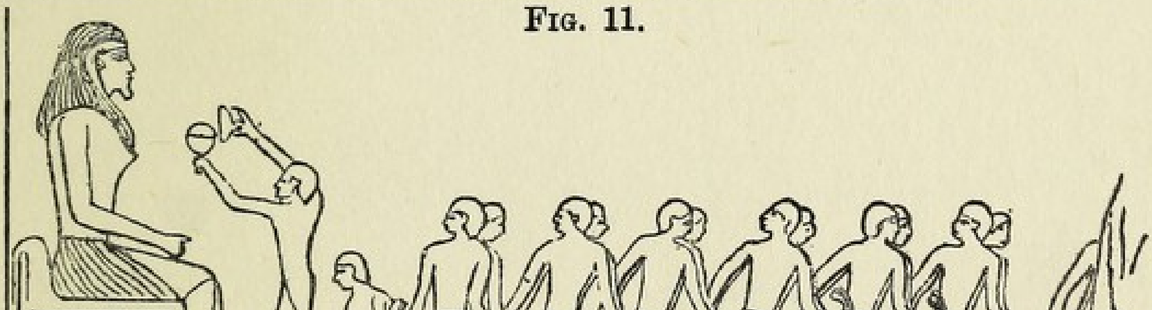


Fig. 12.

Figs. 9 to 12.—Four Similar Illustrations representing the Transport of Various Statues of Divinities in Wood and Stone on Sledges.

All four are from frescoes in Tomb 16 of the Pyramid of Sagâra. Ancient Empire, Fifth Dynasty; after Lepsius.

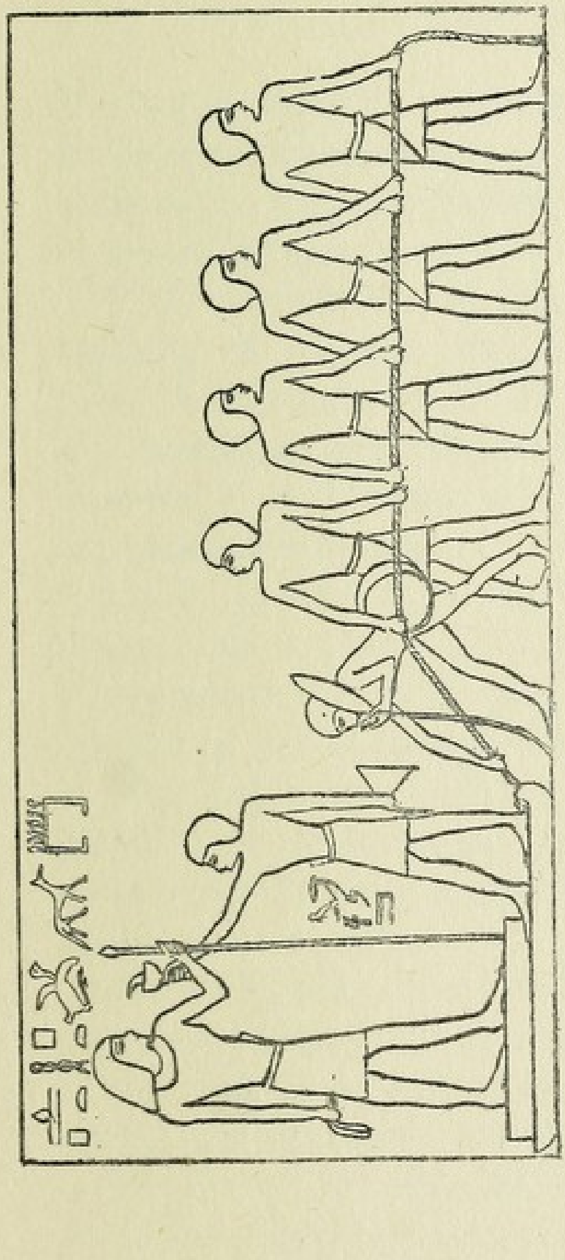


Fig. 13.—Similar to Figs. 9 to 12, and from Tomb 31 of the Pyramid of Sagâra.

Ancient Empire, Fourth Dynasty. After Lepsius.

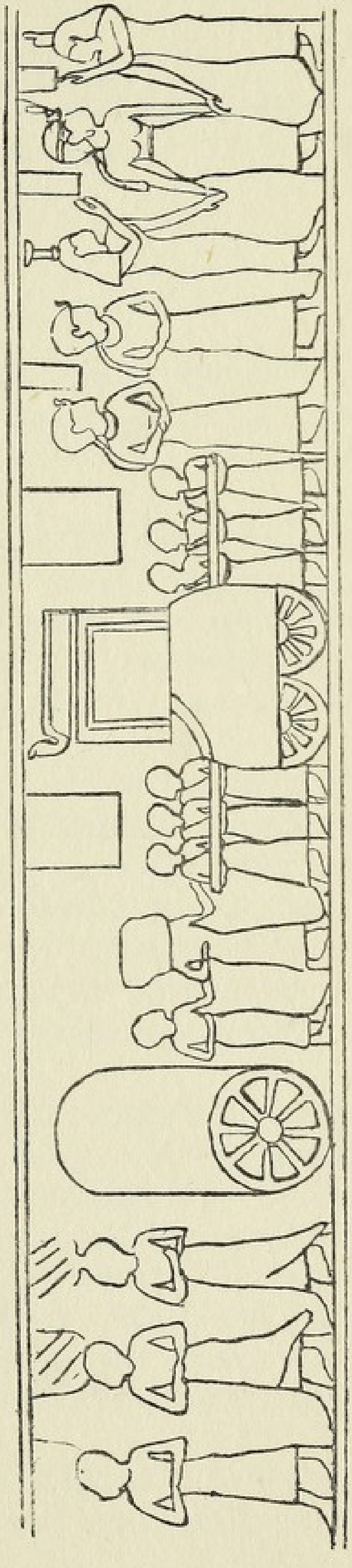
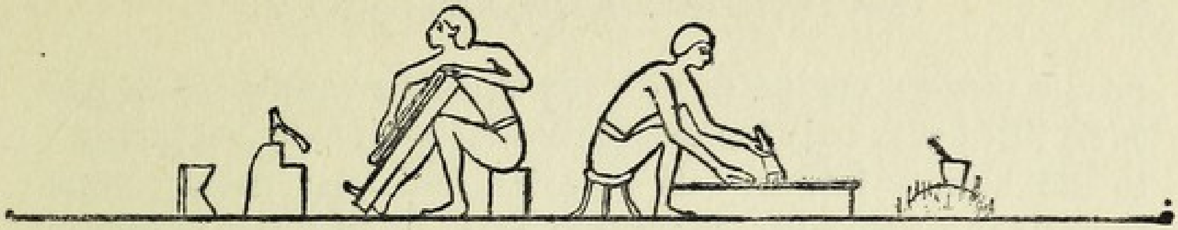


Fig. 14.—Shows Ethiopian Method of conveying Smaller Loads by Vehicles with Two and Four Wheels.

The illustration is from Begerauieh. After Lepsius.



Egyptian Carpenters using Glue.

LIFTING LOADS

Having dealt with methods of moving heavy objects in a horizontal direction, let us now see how the people of antiquity coped with the greater difficulty of moving their loads in a vertical direction.

With the advent of monumental architecture and the building of palaces, where stones of greater weight than three or four men could lift had to be handled, to accomplish this technical ingenuity had to be brought into requisition, in order to find means to apply human efforts in conjunction with mechanical method.

Let it be said from the beginning that the operation of lifting does not lend itself so readily to pictorial effect from a spectacular point of view as hauling, especially when the instinct of perspective is wanting in the artist; and this may in some way account for the fact that the pictorial records, so plentiful in other directions, are wanting of this particular operation. It must therefore be more or less conjectural how this work was done.

It may be accepted as likely that the lowering, if such took place, of these stone blocks at the quarry, and the raising of them at their destination, were accomplished by similar means, but of course with the order of proceeding reversed.

The Great Pyramid, the most gigantic human work in the world, required an enormous amount of lifting, and must have been erected at a period at which the builders had reached a degree of efficiency in mechanical science which some are inclined to under-estimate.

In this wonderful work—the caprice of King Cheops—huge blocks, many of them 30 feet long and over, which would puzzle modern engineers with the most up-to-date plant, had to be lifted with only the most primitive mechanical appliances to aid human labour. It took 100,000 men twenty years to build this pyramid. It covers a space of 13 acres, measures at the base 768 feet, and is 452 feet high. It appears to be a solid mass of masonry, and, if so indeed, contains 85,000,000 cubic feet of stone. The outside consisted of blocks none of which were, it is said, less than 30 feet long.

The general principle adopted in antiquity for moving heavy loads was the application of physical force, consisting of the combined efforts of large numbers of people; but we are uncertain in what way this force was applied for lifting loads, or what was the connecting link between the force and the loads. Opinions are divided between levers, rocking-cradles, and inclined planes. The first two means would appear the most likely for such work as the Pyramids, whilst in work of lesser magnitude the use of the latter is more probable.

In recent years closer investigations have been made by Choisy, the results of which were published in "L'Art de Bâtir chez les Egyptiens," and which were based upon observations made upon remainders and marks left which served him as a clue towards arriving at his theory of the method employed. The conclusion is that these heavy stones were lifted by the simultaneous application of a great number of weighted levers.

Fig. 15 shows how the operation was accomplished; it is taken from Choisy, who says that, however heavy a block may be, nothing is easier than to raise it by means of a series of levers placed under the stone along its whole length, and weighted by counterweights as shown in "M." Assuming for argument's sake that the proportion of the lever is 5 to 1, a simple calculation will show that with a small weight placed on the long end of the lever, barely as long as an ordinary plank, one can raise the largest block. When the stone block is balancing upon the lever as shown in position "N," earth is rammed under the lower surface as shown in "N^1"; then the points of the support of the lever are likewise raised with earth, as in "M^1," and this cycle of operations is repeated again and again till the block arrives at its required height, where it can be made to slide off gently into position by moving some of the earth at one side.

Fig. 16 shows how, by raising a stone and letting it slide

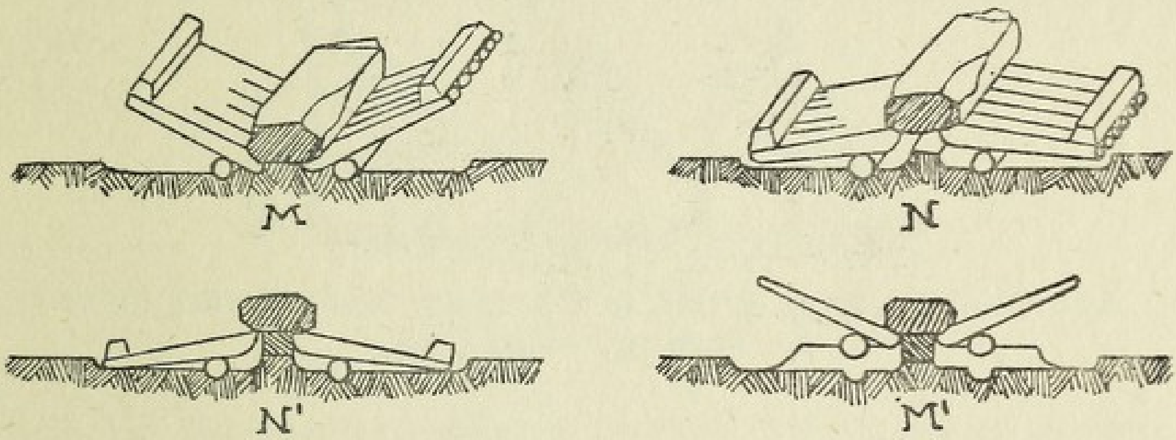


Fig. 15.—Diagrams showing the Cycle of Four Stages in which, according to Choisy, the Egyptians lifted Monoliths.

gradually down an incline, it may be brought into position step by step without cables or blocks. The stone block is raised in the first instance as previously described and illus-

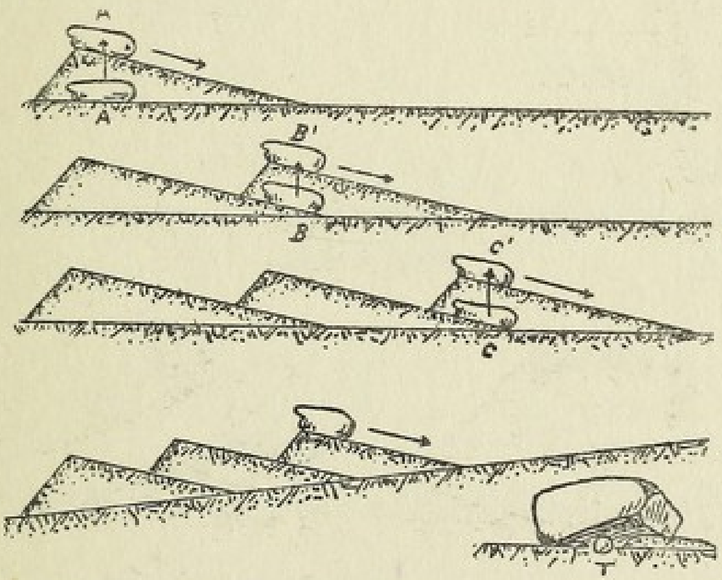


Fig. 16.— Diagrams showing the Forward Movement of a Stone Block by alternately lifting and then letting it slide down an Incline. After Choisy.

trated in Fig. 15. It is then allowed to slide down in the direction in which it is to be moved, and this is repeated, as the illustration (Fig. 16) shows, either on a level or inclined path, until the stone arrives at its destination. If a change in the direction is necessary, a small stone (T) can be used as a pivot for the turning.

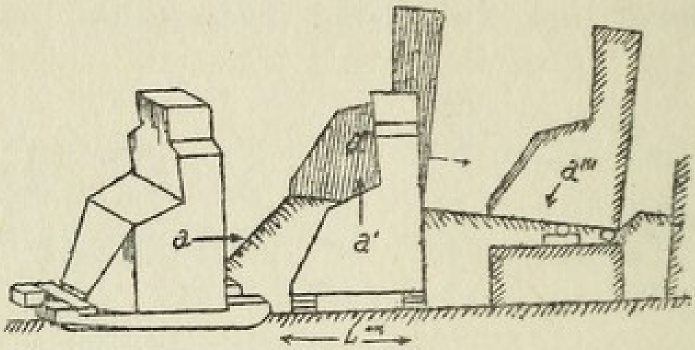


FIG. 17.—METHOD OF MOVING AN UNFINISHED STONE FIGURE ON TO ITS PEDESTAL. After Choisy.

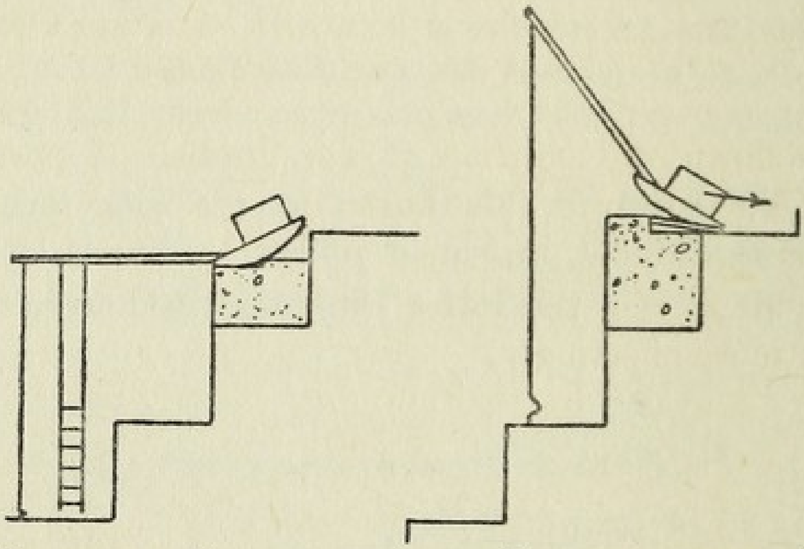


FIG. 18.—RAISING A BLOCK DURING THE BUILDING OF THE PYRAMIDS. After Choisy.

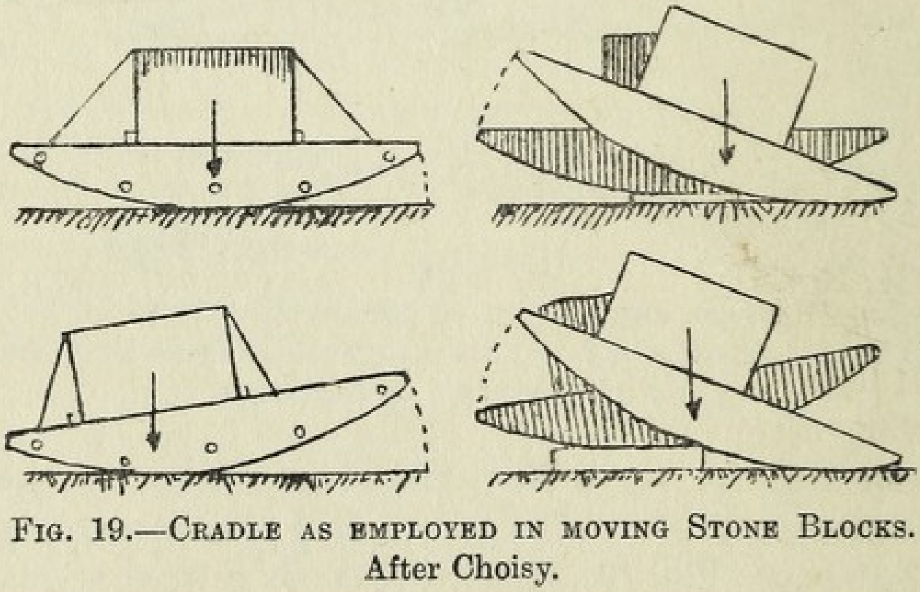


FIG. 19.—CRADLE AS EMPLOYED IN MOVING STONE BLOCKS. After Choisy.

Fig. 17 shows how a stone figure is moved on the same principle, whilst Fig. 18, taken from the same author, shows a stone block on rocker-like timber supports or cradles, which were gradually rocked from side to side and packed up with earth on to a higher level each time, and eventually allowed

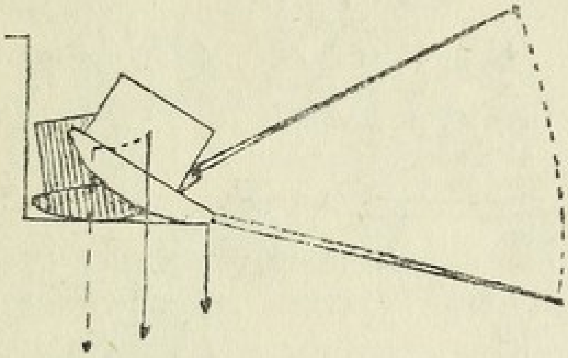


Fig. 20.—The Application of Lever to the Cradle for placing Stone Blocks. After Choisy.

to slide down into position off the cradle. A portion of the pyramid is shown in this illustration; a long lever was used to rock the cradle, and men pulled by means of ropes and rope ladders. On the latter the men stood to add their full weight more effectually.

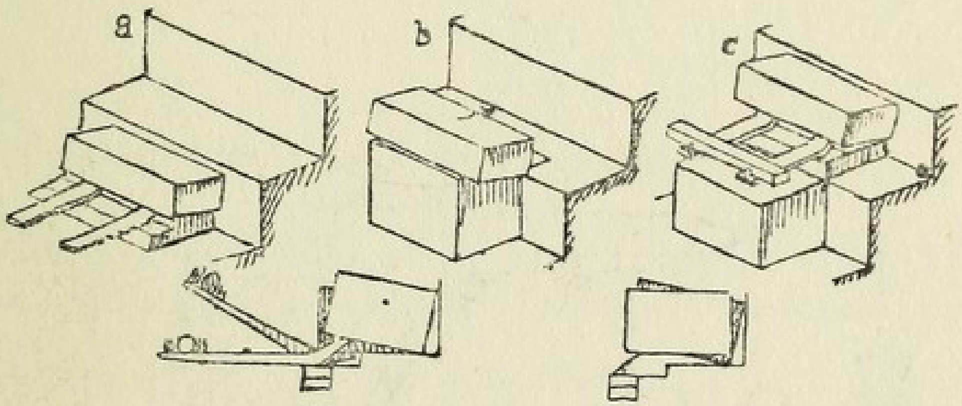


Fig. 21.—The Setting of Stone Blocks on Pyramids. After Choisy.

Fig. 19 shows the cradle with its movements drawn a larger scale, whilst Fig. 20 shows the application of the long lever to land a stone into position. Fig. 21 also shows the final moving of stone blocks into position on a pyramid. Fig. 22 gives an imaginary illustration of the Egyptians pulling a lever.*

* *Technische Monatshefte.*

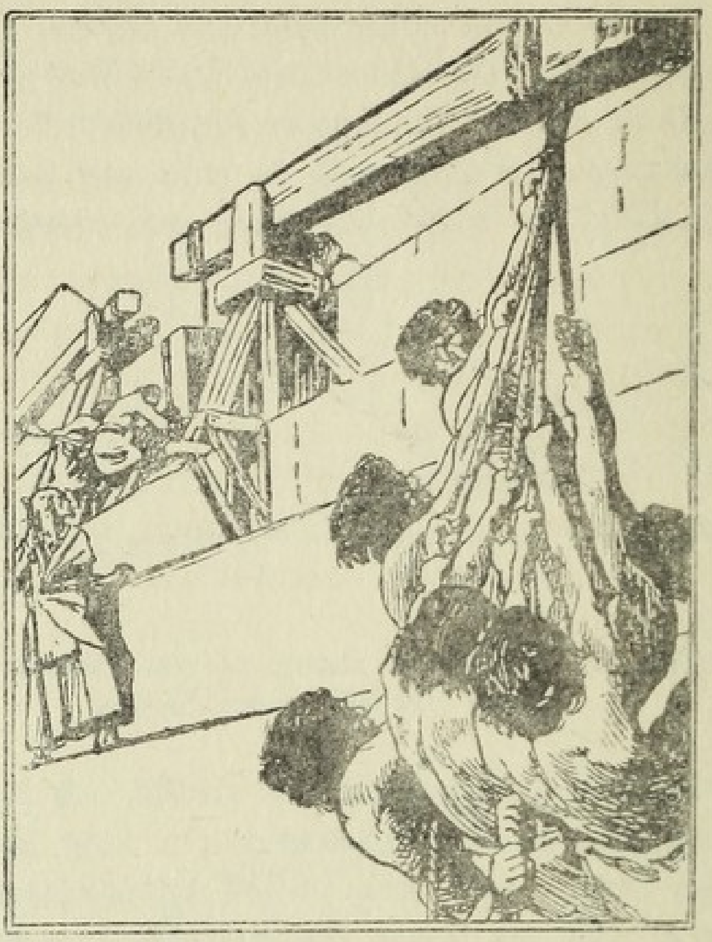


FIG. 22.—THE EGYPTIANS AT WORK ON A PYRAMID.

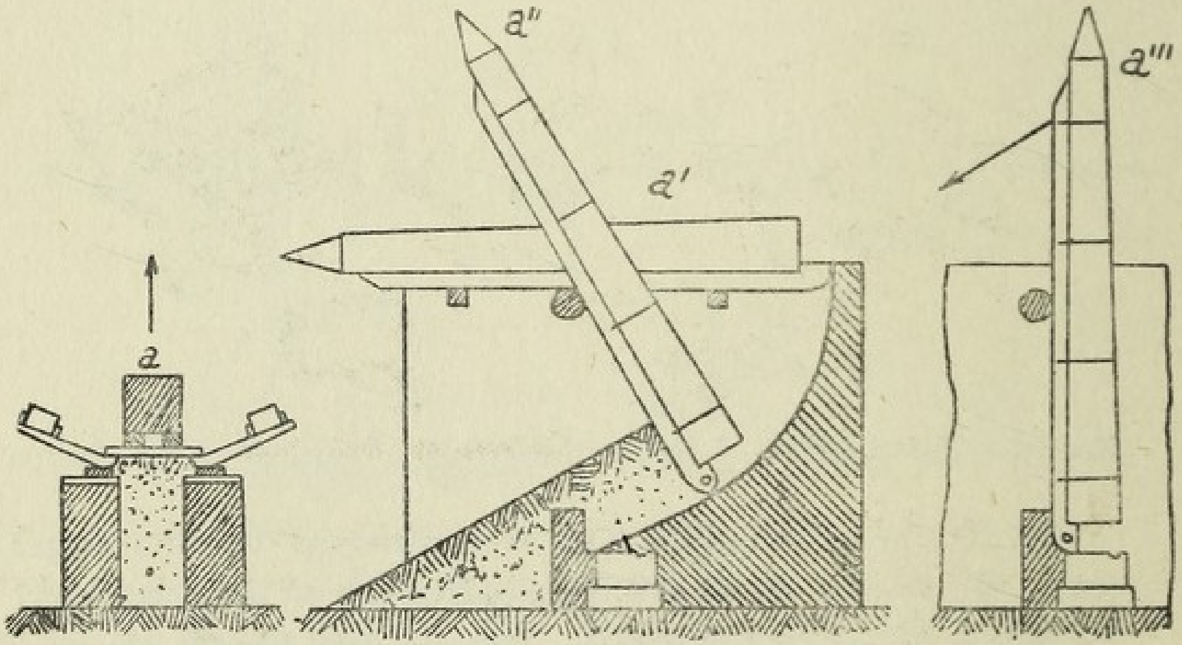
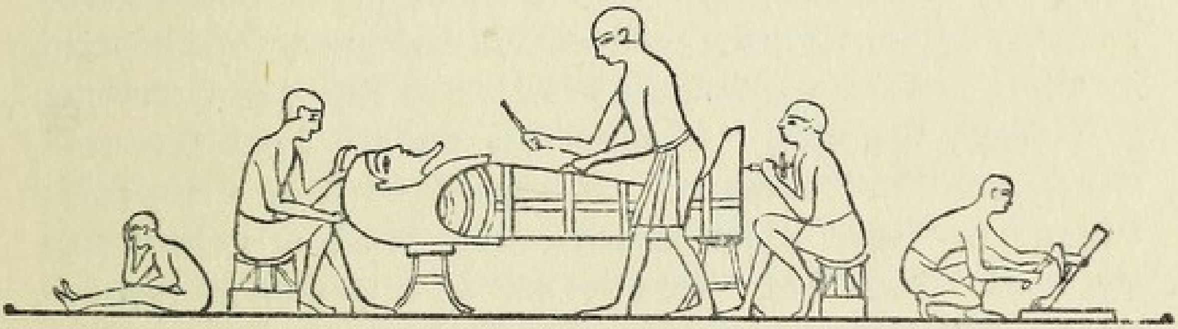


FIG. 23.—THE SETTING UP OF AN OBELISK BY THE EGYPTIANS.
After Choisy.

The huge obelisks, according to Choisy, were raised in a similar manner, as shown by Fig. 23. After securing the monolith to a stout timber support, it was first raised in a horizontal position by the successive use of a great number of weighted levers, and no doubt the additional efforts of many men, and supported by temporary walls on either side. When these walls reached a height equal to about half that of the obelisk, a heavy timber support was fixed crosswise at approximately its centre of gravity; the lower end was then allowed to descend by the gradual removal of the supporting earth on that side, with the additional aid of men and ropes. Fig. 23 shows this very clearly. When the obelisk stood upright, earth in sacks, or loose, was heaped upon the pedestal which was ready to receive it, after which it was gradually lowered, by removing first the timber supports, and then the earth, until it was in position on the pedestal.



EGYPTIAN CARPENTERS.

Egyptian Gold and Silver Smiths.

THE ORIGIN OF MACHINERY

The observation that the use of rollers under heavy loads made the task of moving them much easier, and saved energy and time, led the way to the invention of the waggon; but notwithstanding this drag—sledges were used for heavy loads.

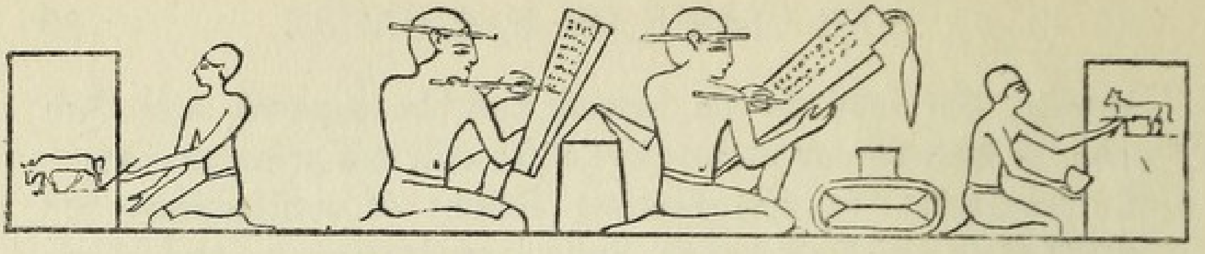
Rollers were no doubt the first step, also, in the invention of machines, and the word "machine," or an equivalent for it, was used by all the nations of antiquity. Professor Holzar, who may be accepted as an authority, says the word is neither of Greek nor Roman origin; neither does he attribute it to any of the Eastern nations of culture, but in his opinion it is an extremely ancient expression and a legacy of prehistoric times, probably hailing from the earliest Indo-Europeans, and brought by them, in their wanderings, to Asia and Europe. According to Holzar, the word "machine" is derived from the word "mankana" or "varkana," or respectively from the syllable "man" or "var," which means exertion-work, or to turn, and the word "kana" or "kara"—that is, a cylindrical piece of wood. This seems to confirm the theory that what was first called a machine was nothing more than a roller upon which to move a load, or at any rate that the roller should be looked upon as the initial element of the earliest efforts in mechanical engineering.

The invention and introduction of the waggon may rightly be considered as that of one of the first machines, if one likes to call it so, and there can be but little doubt that the application of the roller to the moving of loads gradually led to it. It is worthy of note that, during engineering operations, heavy loads are moved, even to this day, by rollers being placed between the load to be moved and the ground, and that vehicles with two or more wheels are still the principal means of locomotion in the present height of civilization—two institutions which thus owe their introduction to prehistoric antiquity.

Waggons with two and four wheels were used by the ancient Egyptians and Assyrians. The Greek heroes fought at the time of Homer in two-wheeled chariots, the army of Cyrus was followed by many four-wheeled waggons, the Persians had four-wheeled waggons drawn by four horses.

The earliest wheels were solid wooden discs, and such a wheel (22 inches in diameter and 6 inches wide), of Egyptian origin, is to be seen in the British Museum. The wheels shown in most of the Assyrian bas-reliefs have four, six, or eight spokes. All the early wheels revolved on their axles, except some of the Roman ones, which were fixed to the spindle and revolved with the same.

The use of the roller implies rotation, and the practical application of a quickly revolving roller or stick pointed at one end was probably one of the first means of producing fire, and was, with slight modifications, in use in far-back prehistoric times, and, curiously, is of almost universal distribution. In order to get quicker action, these fire-producing sticks were rotated by a bow and string, the latter being twisted round the stick. This practically led to the introduction of the drill, and there can be little doubt but that many of the holes in the old bone and stone weapons and implements were bored with these.



Egyptian Scribes and Artists.

THE ROPE

Before entering into the industries of antiquity as far as technical progress is concerned, let us investigate a little more closely the subject of the rope, which played a most important part; it will therefore not be uninteresting to look back on its history.

Vegetable fibre, such as flax and that of the date-palm, was often used for rope-making, by twisting it into strands.

It is more than likely that thongs of leather and raw hide were twisted into ropes. The papyrus, besides being used to furnish writing-paper for the ancients, formed also a most desirable raw material for rope-making.

So far as is known, the ancients, though they made extensive use of fibre ropes, were apparently not much acquainted with wire ropes; there is, however, unmistakable evidence that even wire ropes were made by them. It is certain that the Assyrians practised the art of beating metal into wire, and a fine specimen of bronze rope was found in the city of Pompeii, which is now preserved in the Museo Burbonico at Naples. There is no information as to the purpose to which this rope was applied, but its discovery in buried Pompeii is significant in view of the very modern date that has been claimed for the introduction of the wire rope.

Sir Henry Layard, whose discoveries at Nineveh laid bare the daily life of the Assyrians, unearthed in the palace at Nimrod a bas-relief depicting the siege of a castle. One of the principal figures in the carving is a warrior, who is depicted cutting a rope to which the beseiged had attached a bucket, with which they were attempting to draw up water from a source outside the castle wall (see Fig. 24). The rope, it will be seen, runs over a pulley-block. This bas-relief is about 3,000 years old, and undoubtedly illustrates a primitive form of rope haulage. Pulley-blocks which are used in connection with ropes are also of considerable age; they were known to the ancient Egyptians, and it is believed that the ancient Chinese used blocks with multiple pulleys. In the

Fig. 24.—One of the Earliest Pictorial Records of using the Rope and Block.
From an Assyrian bas-relief.

museum at Leyden a sheave and pulley-block of Egyptian origin may be seen, to which great antiquity is assigned. This sheave is of fir wood, and the block of tamarisk. The ropes found with these relics of an almost prehistoric past have also been preserved, and consist of strands twisted together out of the fibres of the date-palm.

THE INDUSTRIES OF ANTIQUITY, WITH SPECIAL REFERENCE TO TECHNICAL PROGRESS

The developments of technical knowledge unfold before our eyes a wealth of interesting pictures which are well worth collecting, so that it may not be out of place to give here a brief account of some of the results of these developments.

Agriculture.

Egypt being essentially an agricultural country in which the most favourable circumstances and conditions obtained, the harvests of wheat and barley were enormous, from the almost inexhaustible fertility of the soil of its valley; thus, it was in the fields and pastures that the Egyptian masses toiled to produce their annual wealth.

Agriculture was also carried on by the Babylonians and Assyrians with the greatest success. Herodotus tells us that corn yielded regularly two hundredfold, and in the best seasons three hundredfold; he further says that the blades of wheat and barley had a width of four fingers, and that he was afraid to state the height to which sesame and millet grew for fear of being taxed with exaggeration. These two countries, aided by a most elaborate system of irrigation, were the most fertile known.

There can be no doubt that those of the ancients who arrived at the highest degree of primitive culture laid the foundation of their successes by the invention and adoption of water-lifting or irrigation works for agricultural purposes. This is particularly applicable to the Egyptians, Assyrians, and the inhabitants of the Euphrates and Tigris districts, and history tells us, unmistakably, that the destruction or neglect of these irrigation works was followed by the downfall of the nations concerned.

A vast and elaborate system of irrigation, by dykes, reservoirs and canals, which was greatly improved by the Kings of the Twelfth Dynasty,* was employed for distributing the Nile waters at flood-time, and made Egypt the prosperous country it was and is. It is impossible to here mention the general details of this wonderful system, neither is it intended to enter into the subject of the conveying of water from place to place for long distances, or to enlarge on such magnificent water-works as those of ancient Rome, but rather to confine ourselves to the mechanical means employed by antiquity for raising water from one level to another, as when employed for irrigation purposes.

The Raising of Water.

When the Nile sinks below the level of the fields and when it becomes necessary to use artificial means to raise and carry the life-saving waters to the growing crops in the outlying fields during the low Nile—for one hundred days from the first of April—then mechanical means are employed.

Machines of antiquity for the purpose of raising water may be divided into two great classes, ignoring for the present minor or less important systems. There are, first, appliances which work intermittently, and which are manipulated by human or animal labour; and, second, appliances which work continuously, and are driven by water-power or animal labour.

The first or intermittent system is no doubt the most ancient, and probably the oldest form of water-lifter was the shadoof, which was used in Egypt and Assyria, and is still in use to this day. The shadoof is indeed a very simple appliance. It exists as a unit, and also in series, according to the height to which the water has to be lifted; so if a treble shadoof is spoken of, it means three units, each of which lifts the water to a higher level.

* 2466 to 2266 B.C.

Fig. 25 represents a double shadoof from a bas-relief that was found at the palace of Sennacherib at Nineveh, now at the British Museum. The shadoof is similar to the well-sweep of our grandfathers, and is worked as follows: Close to the river or creek from which the water is to be raised is formed a water-tight basin on a higher level, separated from the river by a wall or dam, and into this the water is lifted by means of a large bucket, generally of leather, and suspended by a rope or pole from a balanced beam. The balance weight is sometimes of stone, and sometimes merely a lump of dry clay. A man works the apparatus as seen in the illustration; he slowly fills the basin, but, as he cannot lift higher than a few feet, the operation generally has to be repeated several times, and successive shadoofs fill basin above basin until the

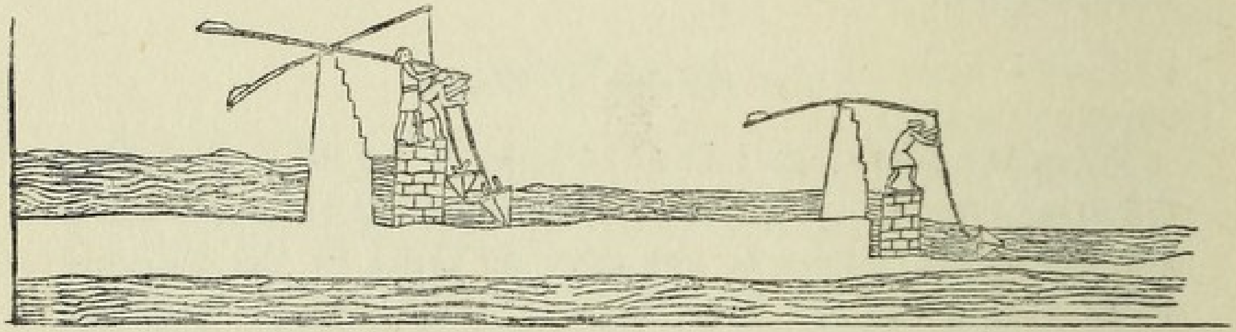


Fig. 25.—A Double Shadoof as used by the Assyrians.
From a bas-relief from King Sennacherib's Palace, now at the British Museum.

top of the river-bank is reached, from which the water will run by gravity through channels into the fields. The Egyptian shadoof is exactly the same as the Assyrian, and it is on record that in the former country it was necessary to raise 1,600 to 2,000 tons of water per acre per hundred days by these means for one crop. The raising of the water at low Nile is to a height of from 18 inches to 10 feet in the lower delta, from 18 inches to 25 feet in Cairo, and from 18 inches to 30 feet in Upper Egypt. The maximum height of lifting for one shadoof is 2 to 3 yards, so that when the river is low multiple shadoofs become necessary.

The ancient inhabitants of India had a very similar appliance named the "picota," which almost explains itself (see Fig. 26); but it was a little more advanced, as it apparently lifted the water to the full height required in one operation. One man stands in the river and sees that the bucket is properly filled, whilst one or two more men lift the beam with pole and bucket by their own weight. The position of the pole and bucket on the beam is adjustable, so as to coincide with the weight of the manipulators. A similar intermittent device, also named "picota" is shown in Fig. 27. Here, instead of human labour, oxen are used; the bucket is made of animal skin with an outlet, and is raised by ropes passing over pulleys. A further method used also in India, particularly in Bengal, was the "jantu." This consisted of an open wooden trough, one end of which was closed. This trough was provided with a swivel or hinge near the open end, and was worked like a one-sided seesaw—that is, the closed end was dipped into the river to a depth at which it filled itself; the end was then raised, when the water ran out of the other (the open) end of the trough at a higher level. The jantu was often made double-acting; it was then closed at both ends, with a common delivery in the middle, so that it was like a complete seesaw, and the ends were raised and lowered alternatively.

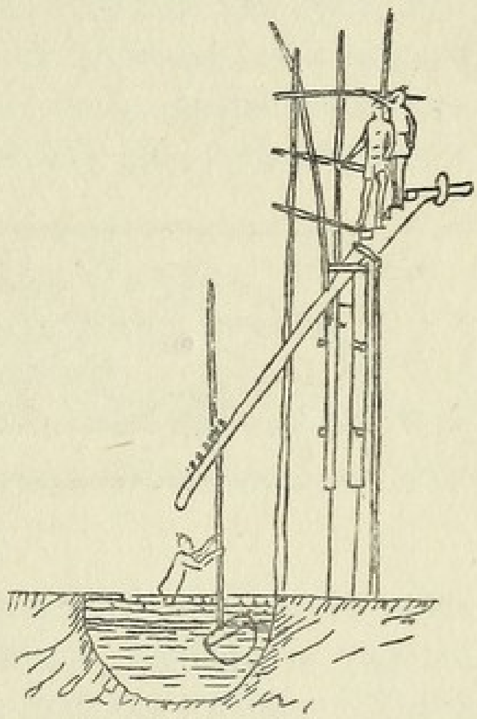


Fig. 26.—The Indian Method of lifting Water by Means of the Picota.

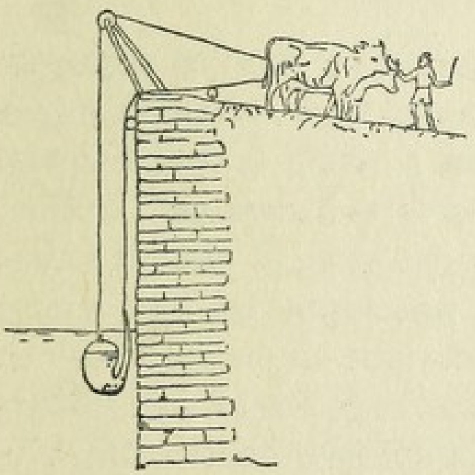


Fig. 27. — The Use of an Indian Picota as worked by Oxen.

The second type of water-lifting machine, which worked continuously and was generally power-driven, was closely connected with the water-wheel. We are often in the habit of calling a water-wheel a mill-wheel, but there can be no doubt that the first water-wheels were used for the purpose of lifting water; and such a water-wheel for irrigation purposes, of great antiquity, was and still is employed in China, where it has been in use for several thousands of years. The wheel is an undershot wheel—that is to say, it is driven by the water which passes under the wheel; it is worked in a stream or

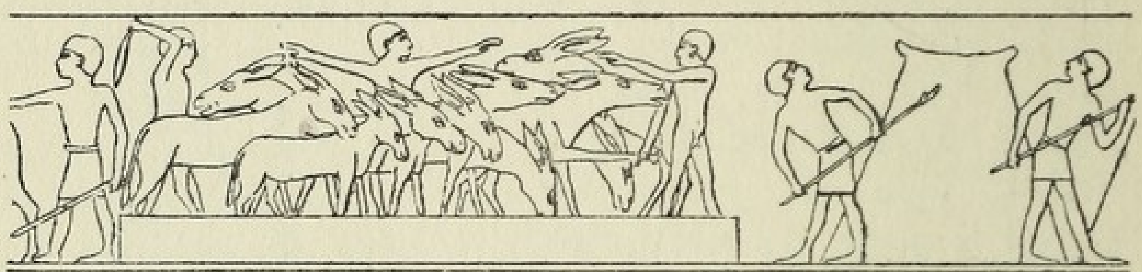
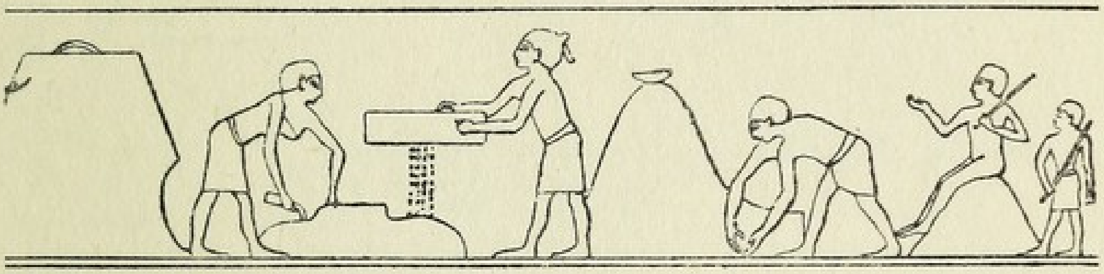


Fig. 28.—Thrashing, Sifting, and

river, so has only to dip into the water; the construction is entirely of bamboo; on the circumference of the wheel are fixed, in oblique position, a great number of cups, or rather pieces of bamboo, of large diameter, and closed at the lower end: these fill with water as they pass through the stream, and empty themselves into a trough when in the highest position; the water is thus lifted nearly as high as the diameter of the wheel, and the trough leads the water in a constant stream to the desired point.

In Egypt it was found that human labour was too expensive to employ with the shadoof for lifting up high banks, so animal gears were used which manipulated a chain of earthenware pots, attached to endless ropes; they were known as "sakkie." The action was as follows: An upright piece of timber served the purpose of the main shaft, and was supported by bearings at both ends; a pole was tied to it at right angles, to which an animal was harnessed to go round and round as in the ordinary horse-gear; to the lower end of this upright shaft a roughly-made wooden wheel was fixed; this geared into a similar wheel at right angles, which was fixed to a horizontal wooden beam or shaft supported by two bearings. To this horizontal shaft was fixed either a kind of sprocket wheel which supported and revolved the endless chain of rope and pitchers which dipped into the water and filled at the bottom, emptying themselves at the top, or a wooden wheel with a hollow rim divided into compartments open on one side; these latter wheels were 4 to 5 yards in diameter, and reached below the surface of the water, where the compartments filled, and emptied in a trough when at the top. The latter system was used where the water-level was not more than 10 feet below the ground, and the



CLEANING GRAIN. After Lepsius.

former when it was more. Appliances similar to the above were used in many other countries of antiquity, but they are all so much alike that a detailed description of further examples appears unnecessary. Two of the names given to these machines are the *tympanon* and the *noria*. The Archimedean screw (so called) has also been used in connection with water-wheels, especially in the Spanish mining districts.

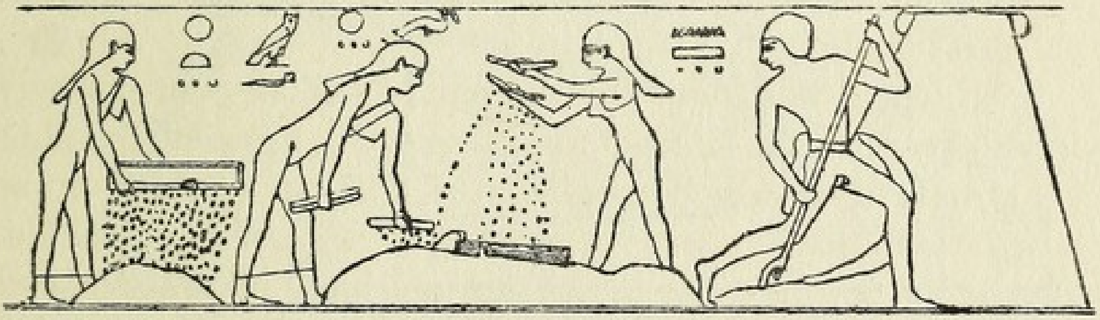


FIG. 29.—WOMEN SIFTING AND WINNOWING GRAIN. After Lepsius.

The invention of the motor-driven water-lifting machine marks an important epoch in the progress of the civilization of primitive man, as it was the first successful attempt to harness the resources of Nature for his service.

It will be interesting to see from Fig. 28 the primitive agricultural operations of the Egyptians. On the left are shown mules in a low enclosure treading out the corn; then we see two men filling wheat into two receptacles; next is a man with a hand sieve, and a woman filling it; on the left is

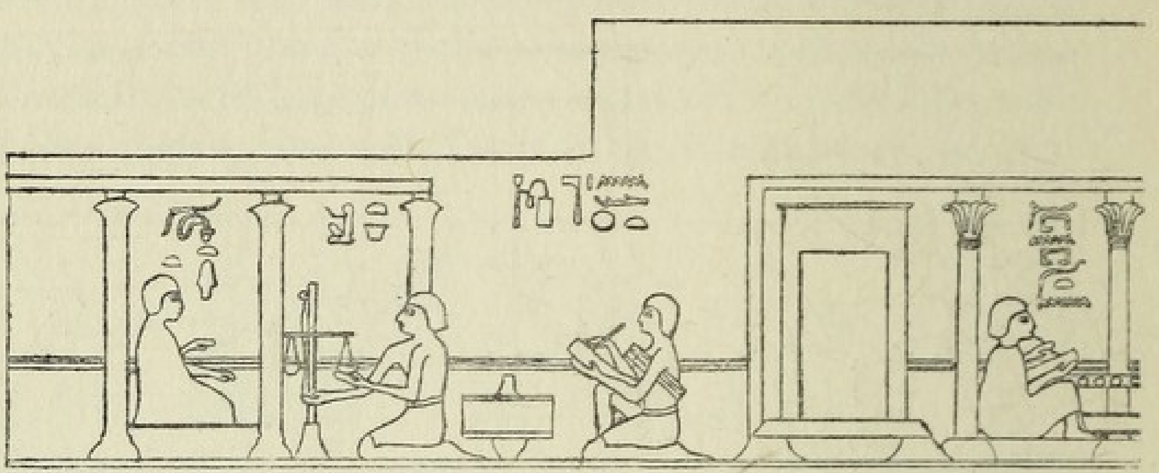


FIG. 30.—WAREHOUSING OF

The illustration is from a fresco in the tomb at Benihasan, Twelfth Dynasty; intends the weighing of gold and silver, whilst the secretary writes down the officials. On the right we see the sacks filled with grain and carried into the of the quantity deposited in the store.

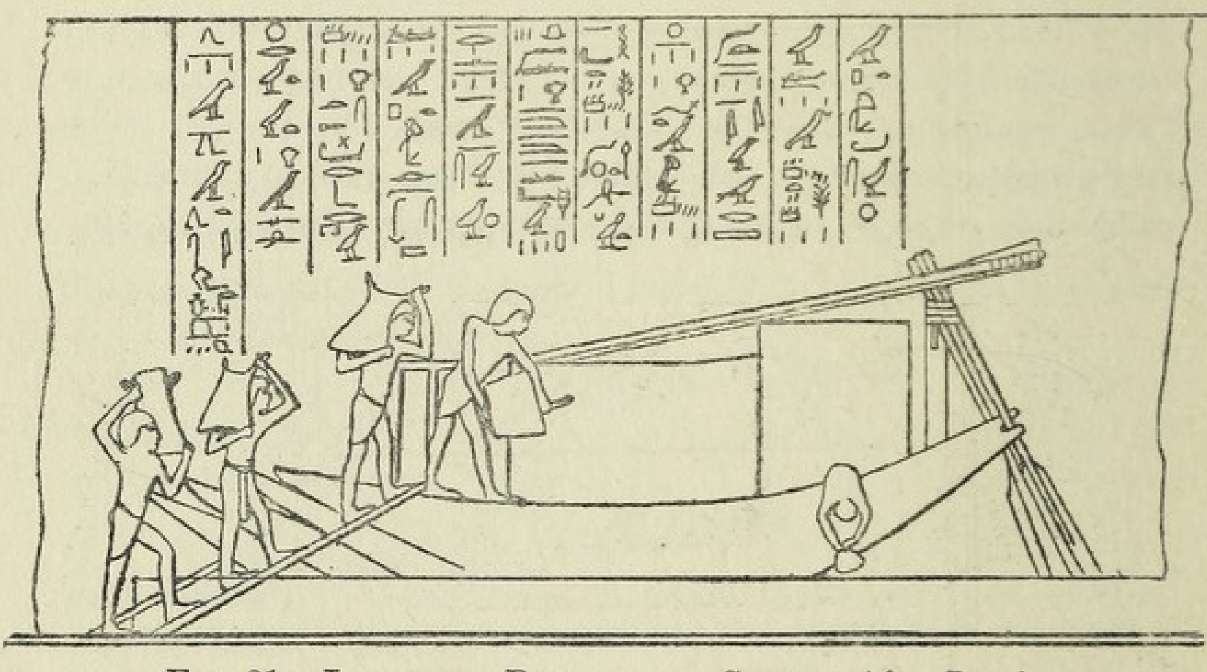
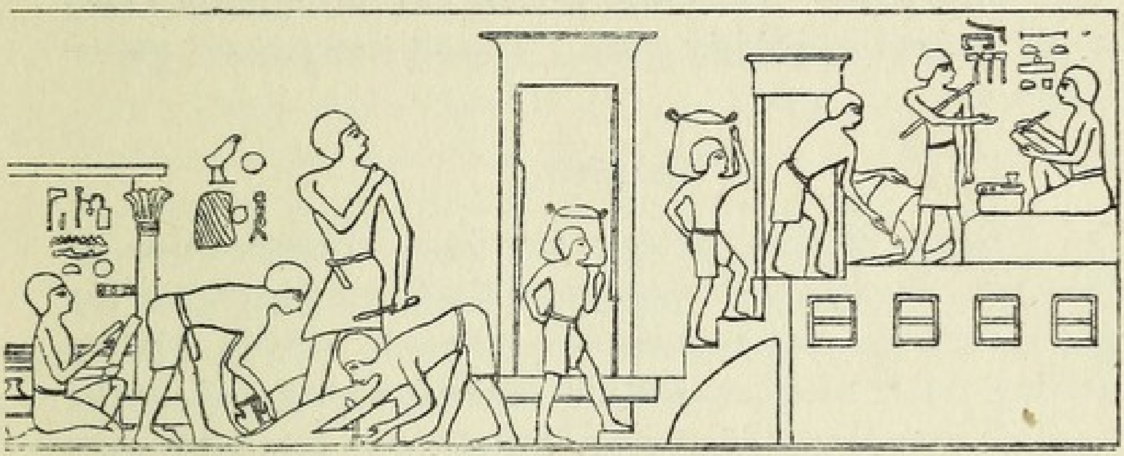


FIG. 31.—LOADING A BARGE WITH GRAIN. After Lepsius.

shown how the sifted wheat is disposed of under the supervision of two officials. Fig. 29 shows three women sifting and winnowing the grain, and a man filling it into a bin.

The reproduction of an ancient fresco is seen in Fig. 30; it represents the officers of the Nomarch Khnumhotep at Benihasan, with the scribes and functionaries of the government. On the left is the Treasury, where the gold and silver rendered in exchange for grain is weighed and the amount booked; in the middle is the steward of the estate, who records the amount of corn bought; at the right the sacks are filled and deposited



GRAIN BY THE EGYPTIANS.

after Lepsius. On the left is the Treasury, with the Treasurer, who super-
amount. In the middle is the office of the Agricultural Department, with two
granary, under the supervision of an official and a clerk, who enters a record

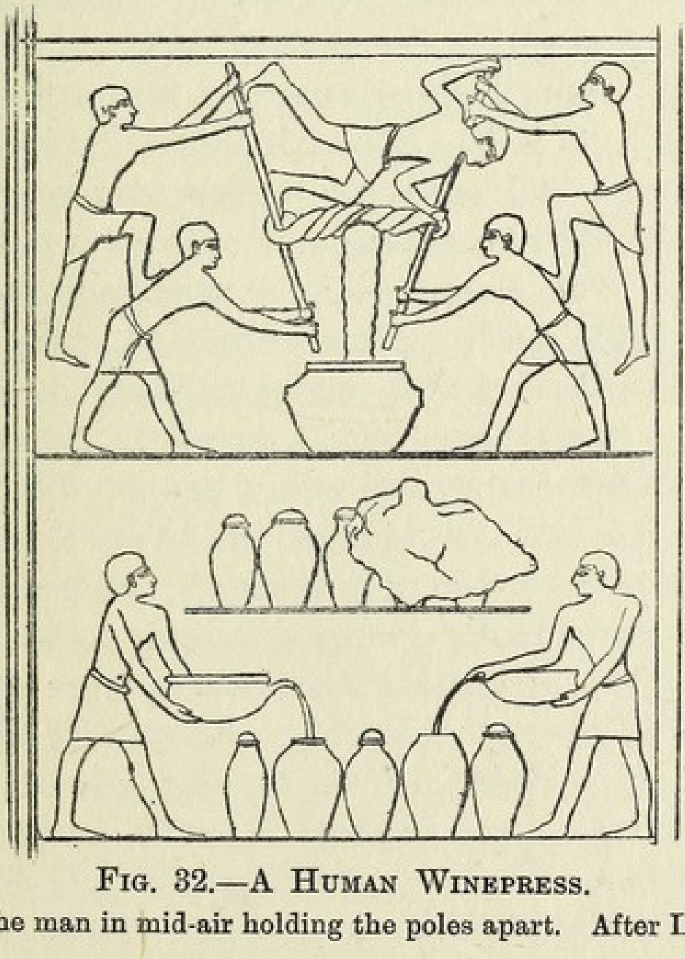


FIG. 32.—A HUMAN WINEPRESS.

Note the man in mid-air holding the poles apart. After Lepsius.

in the granary: a book is kept denoting the quantity so stored. Fig. 31 shows the loading of a barge with grain. Fig. 32

depicts the quaint way in which the products of the vineyard were treated. After the grapes had been crushed by treading, they were filled into a sack or cloth, which was then twisted by men with poles. The lower picture shows the wine being filled into vessels of pottery ware. The oil was pressed out in a similar way.

Milling.

The history of flour-milling has been reconstructed by archæology. Though the remnants of the Stone Age, when the savage ground his corn between two stones by simply rubbing or beating them together, are necessarily scanty, yet, being diffused all over the globe, they afford more or less conclusive evidence of the dawn of culture of mankind. It is a remarkable fact that almost all the primitive implements of the Stone Age are to be matched by appliances in actual use among the least advanced races of mankind to-day. The ancestor of the millstone was probably a rounded stone about the size of a man's fist, with which grain or nuts were pounded and crushed into coarse meal or pulp. These implements were generally of hard sandstone, and were used against another stone, which by dint of continual hammering and rubbing was worn into a saucer shape. The second stone was sometimes the upper surface of a large rock, and numbers of rocks with such indentations have been found, where probably in olden times several women would have stood round to grind, or rather pound, their meal. Crushing-stones are of different shape, ranging from the ball-like implements to an elongated stone resembling more the pestle of a mortar; mullers of the latter type are not infrequently found among prehistoric remains in America. The globular corn-crushers were evidently in use in Homer's time, and several specimens were discovered on the shores of Asia Minor on the reputed site of the city of Troy, and also among the ruins of Mycenæ, on the other side of the Ægean Sea. From the writings of Virgil, we may conclude that both the primitive mortar and the quern were in use simultaneously in the classical age of Rome; it is possible to trace the development of the saddle-stone from the primitive pounder or muller. The saddle-stone is the connecting link between the pounder and the quern, which was itself the direct ancestor of the millstone used sometimes to this day in the manufacture of flour.

Fig. 33 shows two women of the classical period pounding corn; this is taken from an antique Greek vase. The saddle-stone was the first grinding implement in the true sense of the word; it consisted of a round stone with a more or less concave face, on which wheat or other grain was spread, and on this hollow surface was rubbed and ground into a coarse meal. Saddle-stones have been discovered in the sand caves of Italy; among the sites of the old lake-dwellings in Switzerland; in the dolmens of France; in the pit dwellings of the British Isles; and among the remains of primitive folk all the world over, with other relics of the Stone and Bronze Ages.

FIG. 33. — TWO WOMEN POUNDING OR GRINDING CORN.

From an antique Greek vase; after Blümner.

The Romans of the classical period seem to have distinguished the saddle-stone from the quern, as we find allusions to the *mola trusatilis*, which may be translated "thrusting mill." This would fairly describe a backward and forward motion; and *mola versatilis* evidently referred to the revolving millstone or quern. According to Richard Bennet, who names Italy as the birthplace of the quern, the first complete milling machine is in all probability not older than the second century B.C. Whoever was the originator of the quern revolutionized flour-milling. The rotary motion of the millstone became the essential principle of the trituration of the grain, and exists to-day. Varro and Pliny attribute the *mola versatilis*, or quern, to the Volsinian or Etruscan people of ancient civilization, whose subjection by the Romans dated from *circa* 280 B.C. We cannot help referring to the words of Scripture in Exod. xi. 4, where we read: "All the firstborn in the land of

Egypt shall die, from the firstborn of Pharaoh that sitteth upon the throne, even unto the firstborn of the maidservant that is behind the mill." The law of Moses, with admirable wisdom and exemplary kindness, decreed that "no man shall take the nether or the upper millstone to pledge; for he taketh a man's life to pledge."

The mill common among the Hebrews differed little from that which is in use to this day throughout Western Asia and Northern Africa; it consisted of two circular stones, each about 2 feet in diameter and 6 inches thick. The lower was called the nether millstone, and the upper the runner or rider. The former was usually fixed to the floor, and had a slight elevation in the centre; that is, it was slightly convex on its grinding surface. The upper stone had a concavity in its under-surface, fitting or receiving the convexity of the lower stone. There was a hole in the upper stone through which the corn was introduced, a handful at a time. The upper stone had an upright stick fixed in it eccentrically as a handle, by which it was made to turn upon the lower stone; by this action the corn was ground, and came out as a coarse meal all round the circumference. Again we find references in the words of Scripture, which speak of "two women . . . grinding at the mill." The date of this passage is about A.D. 30. It is hardly possible that the mill our Saviour refers to can have been a saddle-stone at which two females were simultaneously working, as in the Wycliffe version of the Bible, dating from the fourteenth century, this passage is translated: "Tweine wymmen schulen ben gryndynge in a querne; oone schal be taken, and the tother lefte." The earlier references just given from the Old Testament undoubtedly refer to the querns also, so that this type of mill must be of much older origin than 200 years B.C.; this disposes of the theory that the quern was of Italian origin of the second century B.C.

A typical Roman mill of the age of Augustus may be seen among the ruins at Pompeii (Fig. 34, frontispiece), which depicts what is believed to have been a public *pistrinium*, or mill with a bakery. The mill consists of four pairs of mill stones. The circular base of these mills is 5 feet in diameter and 1 foot in height; the *meta*, the conical half of which is concealed from view, is about 2 feet high, the dimensions of the *catillus*, or movable parts, being the same. These mills, instead of fitting together in a convex and concave form, have quite conical surfaces at an angle of about 45 degrees. The movable or runner stones were evidently rotated by slave labour, as there is not sufficient room for the perambulation of a horse, or even a donkey. The upper stones have lugs at the sides through which poles were pushed, so that several slaves could work together. Slave labour was chiefly used for driving mills till the introduction of Christianity, and long after millstones had been harnessed to water-power, but was finally abolished by the Emperor Constantine; criminals, however, were employed at this work up to a much later period.

The Romans are credited by some authorities with being the first people to apply water-power to drive their millstones, which they connected with the water-wheel by a horizontal spindle, through the intervention of bevel gearing of three or four to one. The oldest records, however, concerning mills driven by water-power are found in the writings of Strabo the geographer; according to his reports, there was during the reign of Mithridates the Great, King of Pontus—*circa* 100 B.C.—a mill so driven, near his residence.

Roman millers utilized the numerous town water-supplies to drive their mills; but when the Gothic King, Vitiges, besieged Rome, A.D. 536, he destroyed fourteen of these water-supplies, and thereby silenced many of the mills, particularly as the people could not fall back on horses or steers for driving-power, there being none in the city. In this dilemma Belisar invented the floating mills on the Tiber. These mills were erected on rafts which were anchored in the river, and provided with undershot water-wheels which were revolved by the passing stream.

Shipbuilding.

An industry of great importance in the earliest times was shipbuilding, the origin of which is lost in the mists of antiquity. On a pre-dynastic Egyptian vase appears, amongst

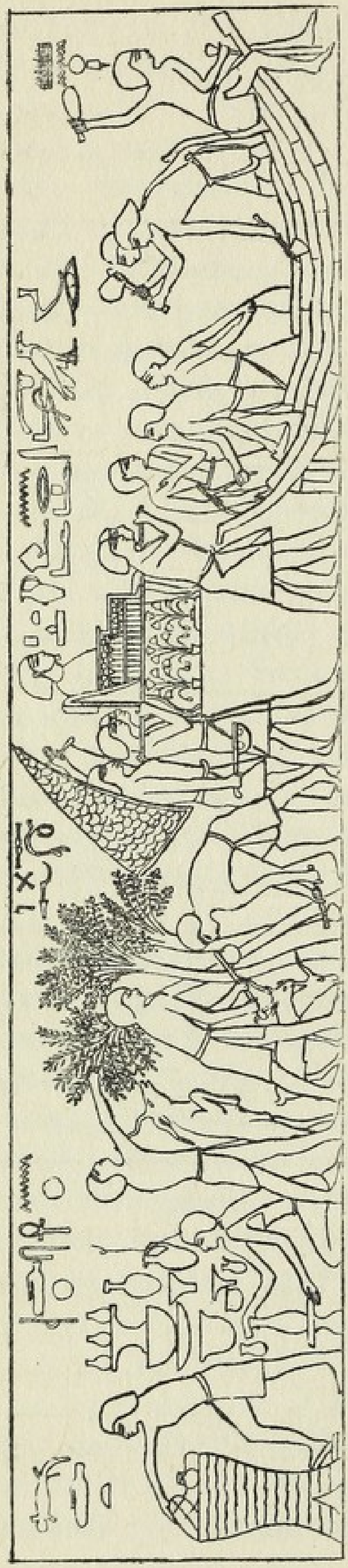


Fig. 35.—Shipbuilding and Pottery by the Ancient Egyptians.
From a fresco in a tomb at Benihasan, Twelfth Dynasty. After Lepsius.

its ornamentation, representations of long ships with rows of oars, thus proving that ships were in use even before the First Dynasty. An ebony tablet of the time of Menes—First Dynasty, 3400 B.C.—at Abydos, shows representations of ships, apparently consisting of wooden frames covered with skins. The first known Assyrian ships were tub-shaped, and made of skins stretched over timber frames. The fullest records of this industry are, however, given by the indelible testimony of Egypt.

In a land void of natural forests timber was scarce; the chief trees available were the date-palm, sycamore, tamarisk, and acacia, none of which furnished suitable timber for shipbuilding, although their woods must of necessity have been used in the earliest stages, as other and more suitable timber would have had to be conveyed to Egypt from abroad by means of ships. Fig. 35 shows one of the earliest pictorial records of the way in which ships were built by the Egyptians. On the left of the picture are men felling trees, which appear to be date-palms, and their timber may have been used for at least some part of the ship; on the right are the boat-builders at work, and some person of note, carried by four slaves, is seen inspecting their progress. This reproduction* is taken from a tomb of Beni-hasan of the Twelfth Dynasty. Fig. 36 shows on a still more extensive scale the shipbuilding operations of ancient

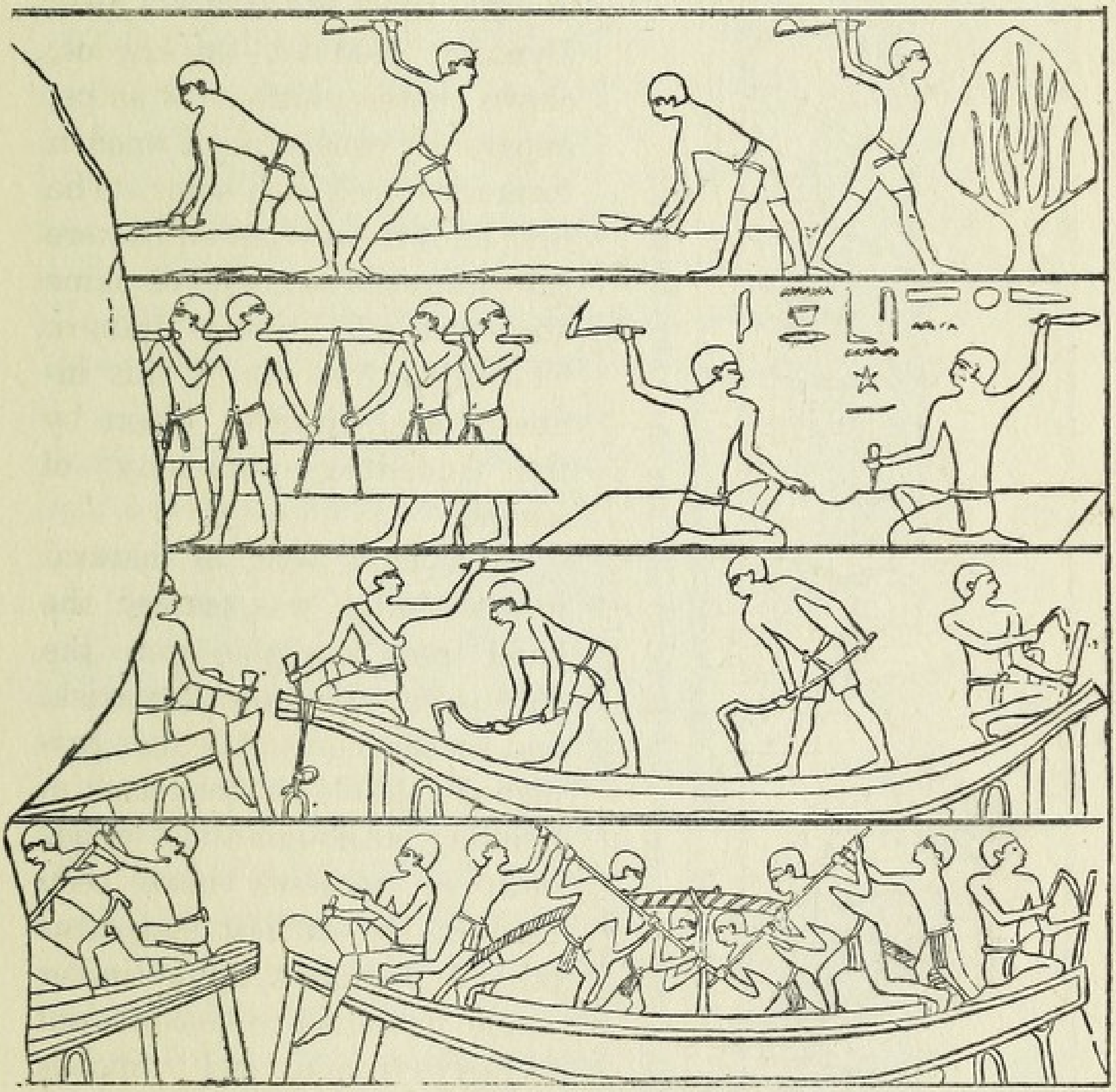


FIG. 36.—SHIPBUILDING BY THE EGYPTIANS.
From a fresco in a tomb at Sauiet el Meitin, Sixth Dynasty. After Lepsius.

Egypt. The two top rows show the felling of trees and the rough preparation of the timber, whilst the two lower rows represent the builders at work on the ships themselves. The timber chiefly imported for shipbuilding was cedar, brought in large quantities from Syria by the Egyptians

* Lepsius, "Denkmäler."

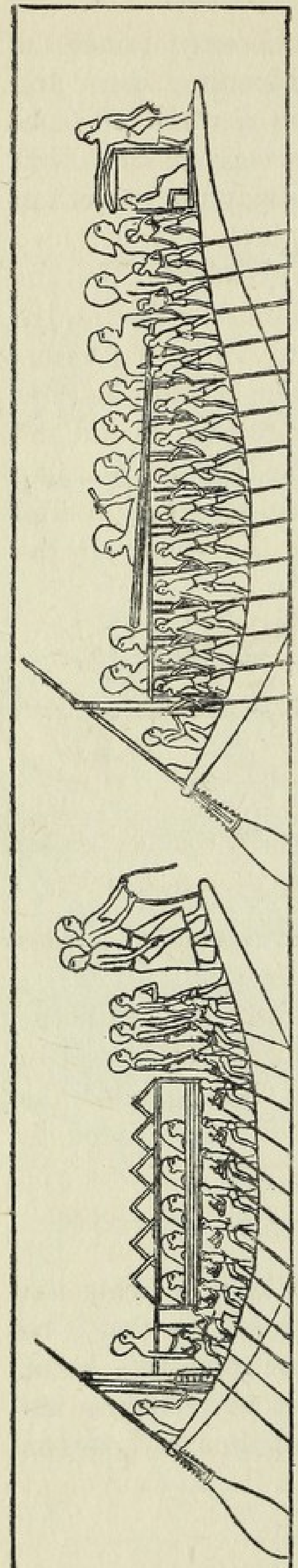


Fig. 37.—Two Egyptian Pleasure-Boats.
From a fresco in a tomb at Benihasan, Twelfth Dynasty. After Lepsius.

for this purpose. Shipbuilding was practised largely in every town, and the vessels built included all manner of craft—from the heavy cargo-boat for grain, to the elaborately ornamented *dahabiyeh*, the pleasure-boat of the nobles, with large sails and manned by oarsmen. Sea-going vessels were built chiefly on the shores of the Red Sea. We read that, when opening up commerce with the Phœnicians, a fleet of forty vessels was sent to procure cedar wood from the slopes of Lebanon. Sahure, the successor of Userkof, established the first known naval power in history, and, according to Breasted, despatched a fleet against the Phœnicians. A bas-relief discovered quite recently in his pyramid temple at Abusir shows some of the ships with Phœnician captives among the Egyptian sailors; this is the earliest surviving pictorial record of sea-going ships—*circa* 2750 B.C.—and the oldest known representation of the Semitic Assyrians.

Fig. 37 shows two Egyptian pleasure-boats. Another fleet, says Breasted, was sent by Sahure to still more remote waters, on a voyage to Punt, as the Egyptians called the Somali coast at the south end of the Red Sea, and along the south side of the Gulf of Aden. From this region, which, like the whole East, he termed God's Land, were obtained the fragrant gums and resins so much desired for the incense and ointments indispensable in the life of the Oriental. Voyages to this country may have been made as early as the First Dynasty, for at that time the Pharaohs already used myrrh in considerable quantities, although this may have been obtained in trading with the intermediate tribes. We read, also, that the enterprising young monarch Mernere commissioned Uni, his Chief Treasurer, to establish a regular connection by the waterway of the Nile with the granite quarries at the head of the First Cataract, to procure the material for the sarcophagus and the royal pyramids; and this was accomplished by one warship and seven boats, which were laden with great blocks of granite. Sailing-ships were much improved in the Sixth Dynasty, by the

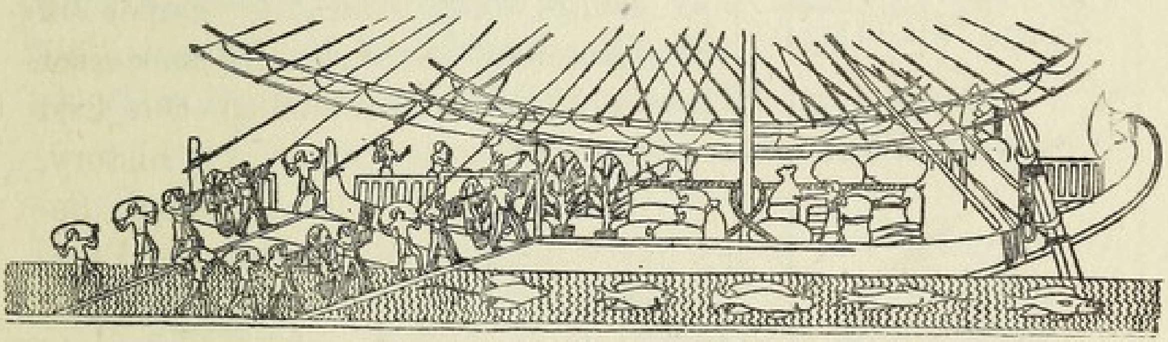


FIG. 38.—LOADING TWO OF QUEEN HAT-SHOPSET'S SHIPS AT PUNT.

introduction of the ancient steering oar on a kind of rudder post, and the attachment of a tiller.

During the reign of Rameses III. the intercourse with the outside world by water was greatly extended, and several of the temples had their own fleets. Rameses exploited the copper-mines of Attica, in the peninsula of Sinai, and brought back great quantities of this metal. He also reopened the line of communication with Punt, which had been neglected.

Navigation under this King was carried on, perhaps, on a larger scale than even under the Pharaohs of the Eighteenth Dynasty. Rameses tells of a sacred barge, "Userhet," he built for the deity Ammon at Thebes, which was 130 cubits, or nearly 224 feet, in length, built in the King's own yard, of enormous cedar blocks, and overlaid with fine gold to the waterline. In the temple built by Rameses III. to Ammon at

Thebes may be seen on some of the bas-reliefs the representation of the first naval battle on salt water of which we have any record.

Fig. 39. — A Greek Ship's Carpenter of the Classical Period. After Blümner.

Fig 38 represents the loading of two of the ships for the return journey from Punt to Egypt; the illustration is from the original bas-relief in the Der-el-Bahari temple at Thebes, and records Queen Hat-shopset's expedition to the land of Punt, South Arabia. The ships are clearly visible, with parts of their huge sails. The cargo consisted chiefly of spices, gums and myrrh-trees. The expedition, which consisted of five vessels, all of which safely returned, was under the direction of the Queen's Chief Treasurer, Nehsi, and took place in the ninth year of her reign—*circa* 1700 B.C.

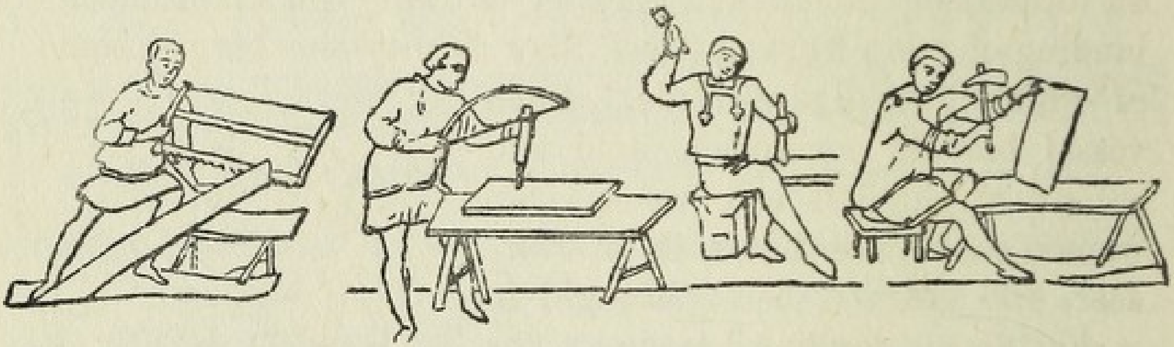


Fig. 40.—Carpenters at Work.

From an antique cut-glass vessel of Greek origin, now in the Vatican.

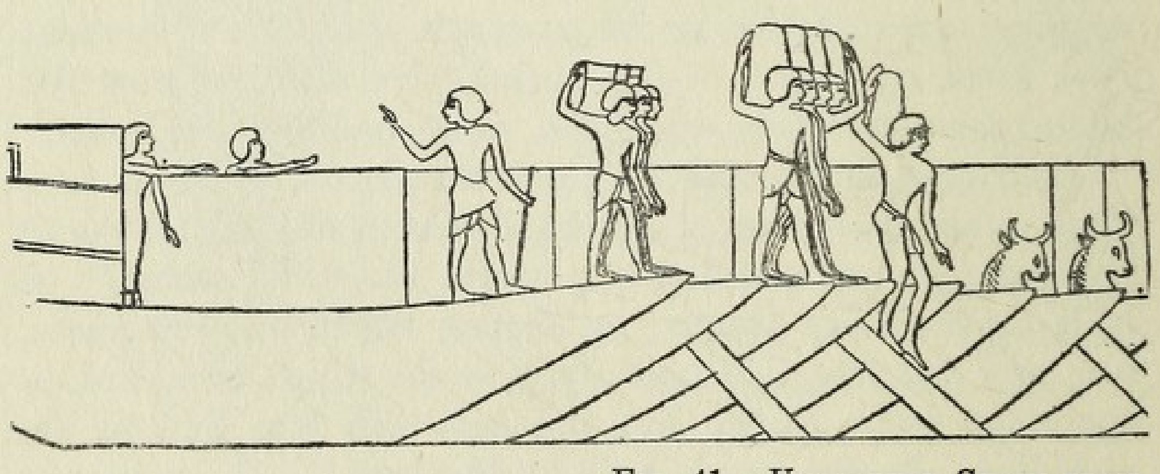
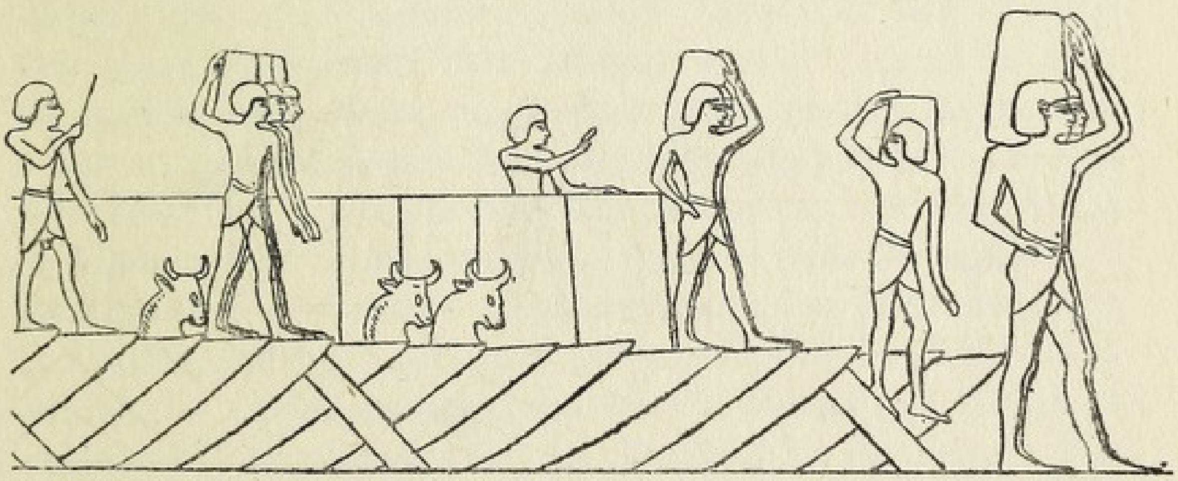


Fig. 41.—Unloading Grain from

Some workmen employed in shipbuilding are seen in the next two illustrations. Fig. 39 is taken from part of a Greek bas-relief, and shows a Greek carpenter at work with chisel and mallet on a ship's bow. Fig. 40 is taken from the bottom of a glass vessel found in the Catacombs, and now in the Vatican; it represents different kinds of carpenter's work—a man using a saw, another drilling, a third using a chisel, and the fourth an axe.

The Nile was at this period alive with boats, barges, and craft of all kinds, bearing the products of the Egyptian industries and agriculture to the treasury of the Pharaohs or to the markets for disposal by barter. No money was available; it was simply a matter of exchange: a pot for a fish, a bundle of onions for a pan, or a box for a jar of ointment. In large transactions gold and copper in ring form, and of fixed weights, circulated in lieu of money.

As the Egyptian grain trade was so closely connected with the shipment of grain, it might not be out of place to give here an interesting illustration (Fig. 41) showing the simultaneous landing of grain from not less than twenty-one barges, some of which have figure-heads. Each vessel has its covered-in hold and cabin; at the left side we see two women in conversation with an overseer, and grain is being brought in sacks down landing-boards. The pretty little group shows a native



Egyptian Barges. After Lepsius.

man and woman bargaining with two Egyptians for grain. The original of this fresco is in the Abd-el-Qurna Tomb, New Kingdom, Eighteenth Dynasty (after Lepsius). Carpenters and other artisans at work may be seen in Figs. 42 to 44.

Pottery.

Next of importance among the industries of antiquity may be mentioned the potter's art, which spread rapidly through all countries; it was undoubtedly one of the very first advances in the civilization of mankind. The almost universal existence of clay, the ease with which it could be moulded with the fingers only, even before such tools as the potter's wheel were invented, and the tenacity with which it retained the form given to it, encouraged the progress of the art.

The clay was kneaded with men's hands or feet, and after it was worked into a homogeneous mass it was formed into convenient portions with the hands, and placed on the potter's wheel, which was of very simple form, and generally turned by hand. It is believed that the potter's wheel was an Egyptian invention, in spite of Pliny's assertion that it was of Athenian origin, as the Egyptian frescoes prove that it was in use prior to the arrival of Joseph in Egypt, and therefore before the foundation of Athens.

The Assyrians and their neighbours made very beautiful pottery ware, and in the Nimrod Mount were found vases of classical form—jars, amphoræ with pointed base, bowls and cups, as well as lamps. Pottery was one of the staple industries of Egypt; faience vessels, with their pretty green and blue glazed pottery, were made, as we see in parts of Figs. 35 and 45. The quantity of these small vessels used by so vast a population was enormous, and our museums are filled with specimens of early pottery showing distinctly the stage of culture arrived at by their makers. In addition to the household requirements and smaller ware, the Egyptian potter had to furnish big vessels of a coarser finish, for storing oils, wines, and all manner of foodstuff, for private and public establishments.

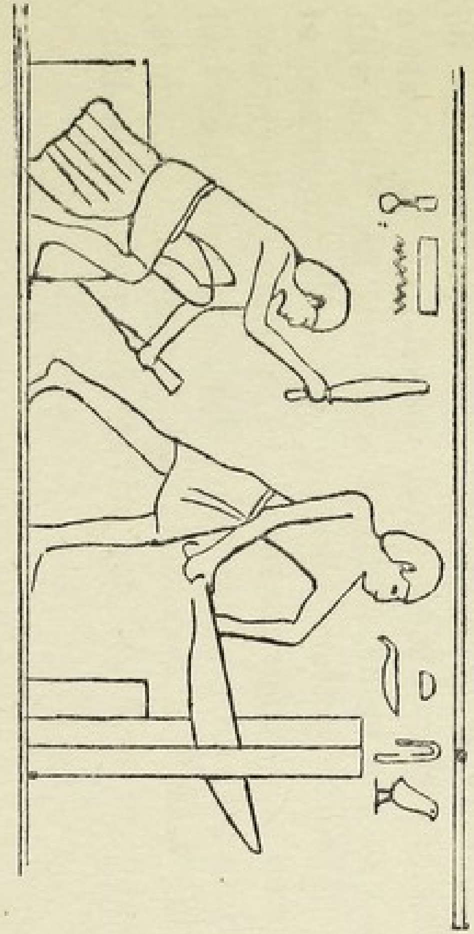


Fig. 43.—Egyptian Carpenters at Work.

From a fresco at Giseh, Fifth Dynasty. After Lepsius.

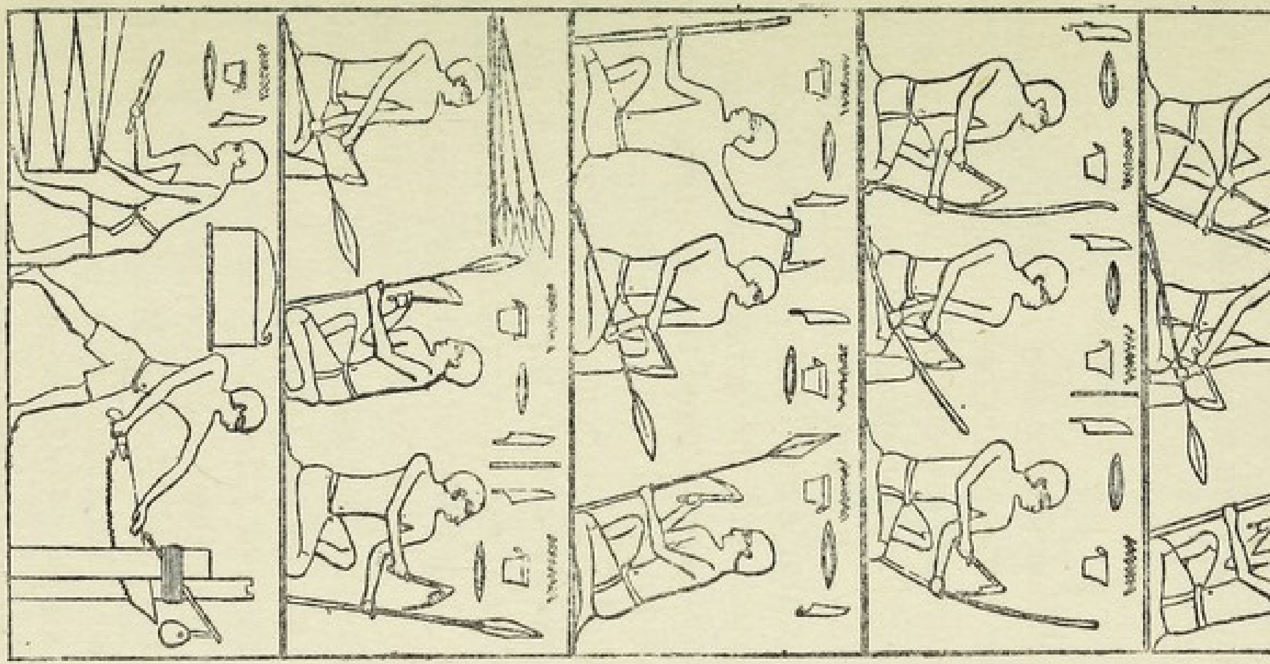


Fig. 42. — Carpenters making Implements and Weapons.

From a tomb at Sauiet el Meitin, Dynasty. After Lepsius

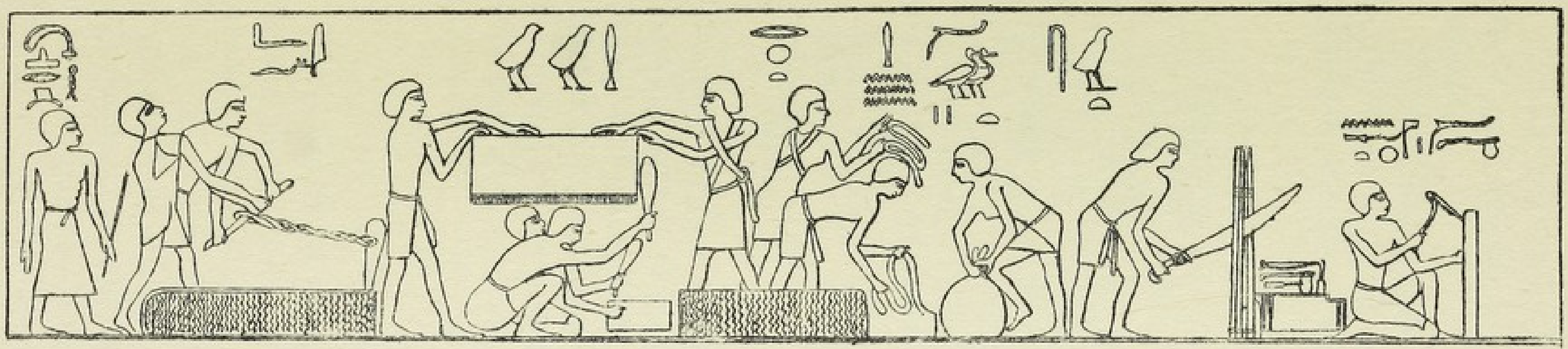


FIG. 44.—EGYPTIAN CARPENTERS AND OTHER ARTISANS AT WORK.

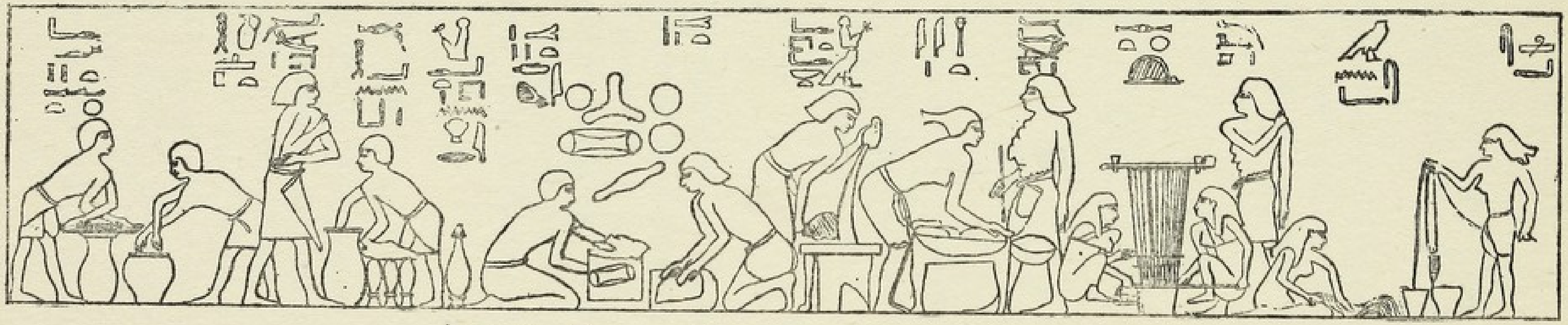


FIG. 45.—EGYPTIAN POTTERS AND TEXTILE WORKERS.

Coptos and its neighbourhood were particularly noted for their productions, as the clay found there was peculiarly suitable.

The next illustration (Fig. 46) is of great age, and represents a potter at work; it is from a Greek tazza at the British Museum, and shows a man sitting in front of a potter's wheel

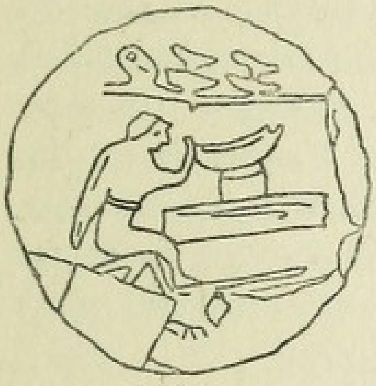


Fig. 46.—An Archaic Illustration of a Greek Potter at his Wheel.

From a tazza in the British Museum.

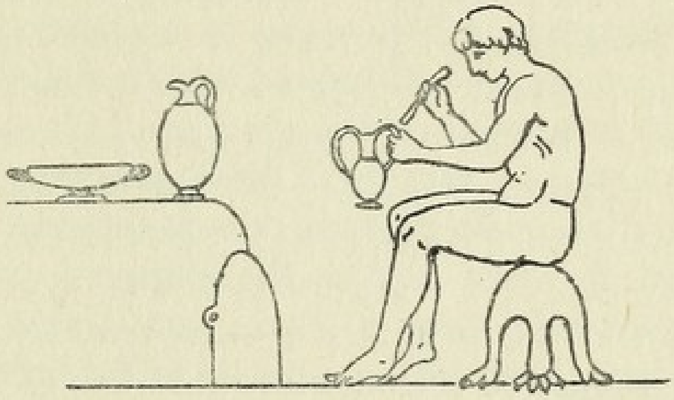


Fig. 47.—A Greek Potter of the Classical Period.

From a cameo.

forming a shallow vase or bowl, while on a shelf on the wall are what appear to be either implements or finished productions. A representation of a later date is shown in Fig. 47, which depicts a Greek youth engaged in pottery work. In front of him is a low oven, upon which two Greek vases are standing, evidently to dry. The illustration is from a cameo, after Blümner.

Masonry and Sculpture.

The products of the prolific potter had to yield slowly to those of the artificer in stone for more elaborate work for the houses of the nobles. Crude statuettes in wood, ivory, and stone, represented the beginning of the plastic art, which was to achieve such triumphs in the early dynastic ages of Egypt.

The stones available to the ancient Egyptians were granite from the quarries at the First Cataract, and sandstone, which was quarried at Silsileh. The harder and more ornamental stones came chiefly from Hammamat, between Coptos and the Red Sea; alabaster, from Hatnub, near Amarna; and limestone, from Ayan or Troia, opposite Memphis, and from many other places. Sir J. G. Wilkinson informs us that those condemned to hard labour in the quarries, as a punishment, were required to assist in moving a certain number of stones, according to the extent of their offence, ere they were liberated; which seems to be proved by this expression, "I have dragged 110 stones for the building of Isis at Philæ," in an inscription at the quarries of Gertassy in Nubia. In order to keep an account of their progress, they frequently cut the initials of their name, or some private mark, with the number, on the rock whence the stone was taken, as soon as it was removed; thus, C. XXXII., P.D. XXXIII., and numerous other signs, occur at the quarries of Fateereh.

Artistic craftsmen produced from the scarcer stones, such as alabaster, diorite, and porphyry, magnificent vessels—cups, bowls, jars, vases, etc.

The Egyptians were very skilful in the art of masonry and sculpture; they drilled holes through the hardest stone, like diorite, with hollow copper drills, and granite was sawn with long copper saws, sharp sand or emery-powder being used in connection with these copper tools. Iron tools were also employed, although not extensively at first, but there are no records available as to how the earliest supplies were obtained.

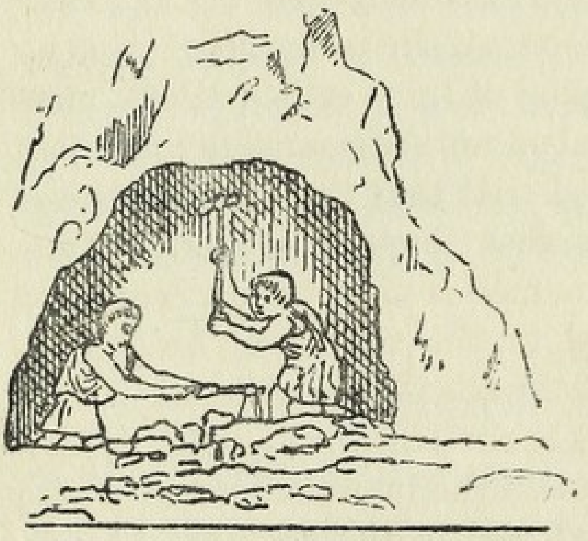


FIG. 48.—TWO MEN QUARRYING.
From the Greek or Roman period. After Blümner.

In addition to the stones already mentioned, the ancients used, particularly for inlaid work, malachite, lapis-lazuli, and turquoise. The only illustration in connection with quarry work available, and that only in a small way, is from a miniature of a

Virgil Codex in the Vatican, and Fig. 48 is a representation of a portion of this miniature. It shows Greeks or Romans at work in a quarry. The men are represented as standing in a cave or drift.

Brickmaking.

In spite of the fact that good stone was available for building purposes, the Egyptians employed enormous quantities of sun-dried bricks, manufactured and used not only for the dwellings of the poor, but also for the homes of the rich, as well as for city walls, forts, storehouses, etc. As is well known from Holy Scripture, the Israelites were forced into this service of brickmaking, and Fig. 49 gives a representation of this operation; even the typical characteristics of the faces are clearly visible. The Egyptian bricks were a great deal larger than ours of to-day; sometimes they had an admixture of straw, and they varied in size from 12 inches by 6 inches to 18 inches by 9 inches. Of course they were not fired in a kiln, but merely sun-dried. In spite of their perishable nature, some very fine specimens are still preserved at the British Museum.

The Babylonians and Assyrians also employed bricks extensively, both sun-dried and kiln-burnt, the latter being used for outside work exposed to the action of the weather. Botta mentions that the bricks of Khorsabad were of coarse temper, that the burning was but slight, and that they therefore possessed little firmness. Layard states that some of the bricks from Nimrod appear to have been enamelled with a thick coating of colouring matter, and exposed to the action of fire. Blue and white glazed tiles lined the walls of the chamber in the Pyramid of Sakkára, dating back to the Third or Fourth Dynasty. This gives us the first attempts in the manufacture of glazed bricks and tiles, so extensively used in the present era. In the classical age burnt bricks and tiles were largely employed, and they can be seen in any Roman wall extant. Even concrete was reinforced with burnt tiles in the classical age.

The Metal Industry.

Wonderful discoveries have been made in archæology which have established beyond a doubt the triumph of the intellect displayed by the ancients, especially by the Assyrians, Babylonians, Chaldeans, Edomites, Egyptians, and Persians.

Some processes of metallurgy were undoubtedly known before the Flood, and the metallic riches of their mountains were exploited by all the above-mentioned people, who extracted gold, silver and copper, iron, antimony and lead. The metal tools used by them must have been furthermore hardened, or the clear cut of the sepulchral work in hard

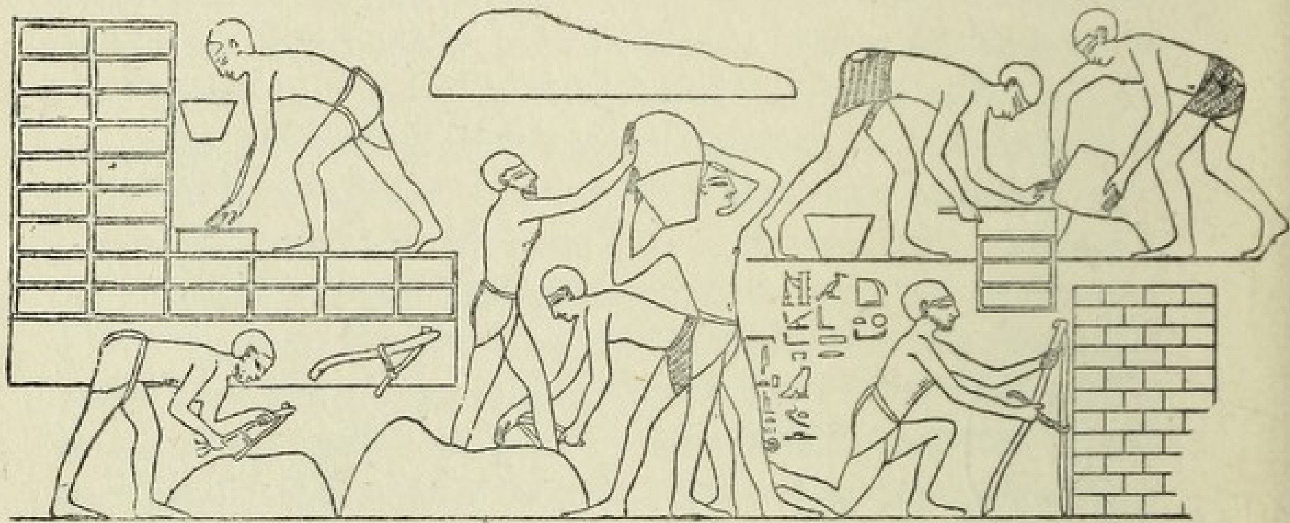
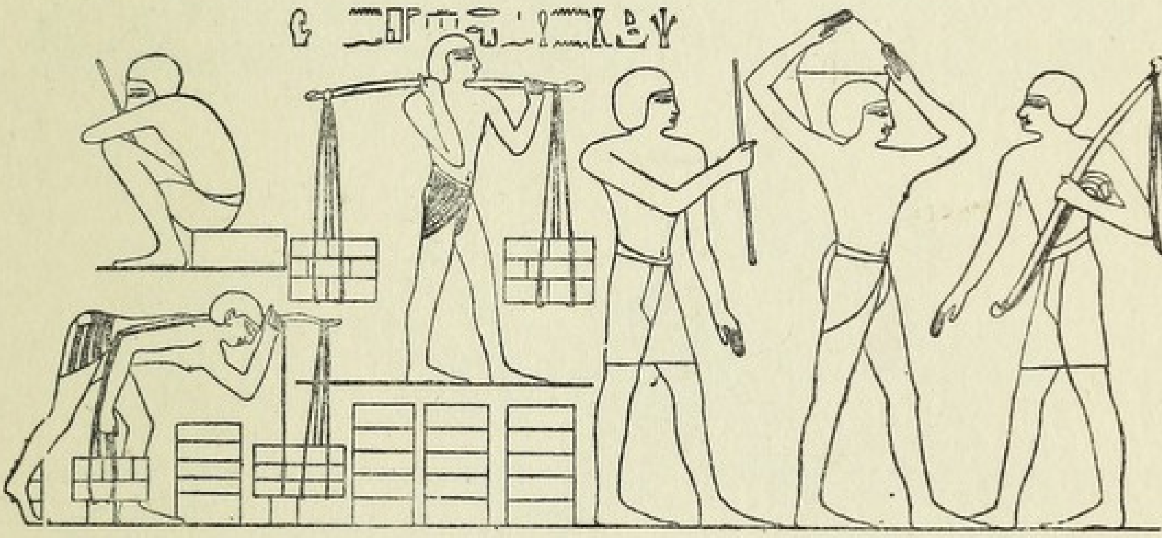


Fig. 49.—Children of Israel
From a fresco in a tomb of Abd el Qurna

stone would have been impossible. Copper tools were tempered by hammering, and later on by the judicious admixture of tin, as we have already seen; they also hardened their copper tools by the use of carbonate of zinc, which was found in the resources of Nature, and the application of which formed a hard brass incrustation on the copper. Iron, and later steel, tools were undoubtedly used; indeed, it would have been strange if a process of steel-making had not been discovered, if we take into consideration the fact that wood and charcoal were the only fuels available for smelting furnaces, and that steel is produced by the addition of carbon to iron. Copper was largely used, first pure, and later mixed with tin, as bronze, which latter alloy was probably the most popular metal for the implements and utensils of both peace and war.

We have already dealt rather fully with the subject of iron and its antiquity, but we might here mention that the Assyrians used this metal in the earliest stages of their civilization, and this is proved by the discoveries of Layard in the ruins of Nimrod, where he found all kinds of weapons and accoutrements made of this metal, including helmets and scales of coats of mail.

Sir J. G. Wilkinson tells us that iron and copper mines which were worked in older times are found in the Egyptian desert.



MAKING BRICKS IN EGYPT.
at Thebes, Eighteenth Dynasty. After Lepsius.

Gold was plentiful, as is evident from many ancient records, such as those of the building of Solomon's Temple, for which the gold was accumulated by David (1 Chron. xxii. 14), probably from India, Arabia, and Africa. Herodotus mentions a statue of solid gold in Babylon 12 cubits high, and also a second statue, table, and throne, which weighed together 800 talents, or over 40 tons. From Deodorus we learn that the quantity of gold taken by Xerxes from the Temple of Belus at Babylon amounted to more than 7,350 Attica talents, or £21,000,000.

The smiths were very expert in early times in the manufacture of tools, implements, and weapons, as well as fittings for other handicrafts. They used chiefly iron and copper, but not infrequently bronze and precious metals. Some of the articles made were nails, spokes, and hinges, besides tools for the many other artisans and the fittings they required in their particular work. Ornamental work was skilfully executed, such as the manufacture of copper, gold and silver vessels for the homes of the aristocracy, as well as beautifully ornamented weapons. Silver was scarce in Egypt, but was used, being probably imported from Silesia in Asia Minor. Gold was more plentiful than silver, and less valued; it was mined in the granite mountains on the coast of the Red Sea, where it was found in the pure state in quartz veins. Jewellery was much used for the ornaments of the Pharaohs and nobles, but, unfortunately, we have only a record of their manufacture,

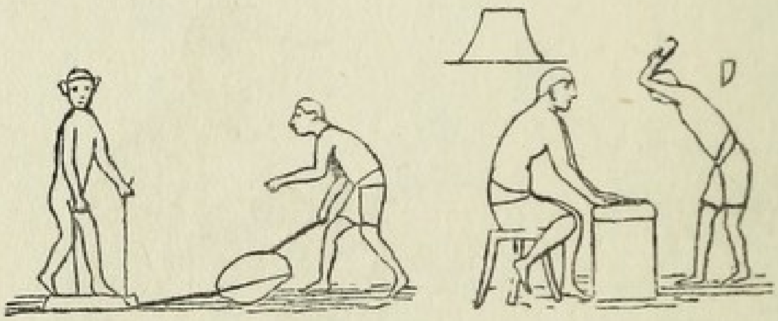


Fig. 50.—Ancient Egyptian Representation of Ethiopian Smiths.

there being comparatively few actual specimens of the art left.

According to Dr. Ludwig Beck's researches, iron was first used by the Ethiopians. On an Egyptian bas-relief now at Florence is represented the heating or melting and hammering of iron (Fig. 50). The hieroglyphical symbol behind the man who is beating the metal is said to signify iron; it must be admitted that the same symbol also represents brass, and even wood; but as in Ethiopia iron was much more abundant than in Egypt, and as Herodotus states that copper was a rare metal there, it might be reasonable to accept Dr. Beck's views. The first figure in the illustration is evidently a negro slave, judging by his round head and outstanding ears. He manipulates a kind of bellows with his feet, and, by two strings—with his hands, in a similar way to that shown in other

Egyptian frescoes. The other figures are Ethiopians. After the iron ore in the furnace had formed a spongy metallic mass, it was beaten out on the anvil of wood and stone. In place of a hammer a stone is used, manipulated by both hands.*

One of the most important items in the iron industry, as well as in the smelting of other metals, is the fan or blower, at any rate in so far as technical progress is concerned, so we propose to go more fully into the history of these mechanical devices.

The Blowers used for Smelting, etc.

The earliest method for producing a fierce fire for manufacturing purposes was the fan, generally in the form of a

FIG. 51.—ONE OF THE EARLIEST TYPES OF BLOWER FOR FURNACES. From "Stahl und Eisen."

palm-leaf or bird's wing. More advanced blowers were on different principles and of different types; there were skin blowers, pumps, bellows, and combinations of these.

An old form of a primitive mechanical blower was the skin or bag blower. It consisted generally of two bags made of the skins of animals, usually sheep or goats; the neck end of these skins was connected with two tubes, whilst the lower end was open and fitted with wooden slats, similar to the

* The illustration is taken from Beck, "Geschichte des Eisens."

fittings of a travelling-bag (see Fig. 51). These bags or skins were opened alternately, extended to their full length, then closed and compressed so as to expel the enclosed air intermittently out of the two tubes, thus creating a constant blast. It is believed that these skin blowers had their origin in Central Africa, whence their adoption spread to Egypt, also farther north to Europe, and thence to Asia. Primitive races are still using this method, chiefly throughout Africa. There was an expert smith in the Somali village at the White City, Shepherd's Bush, who used one of these blowers, and the writer has seen the same primitive appliances, within recent years, in

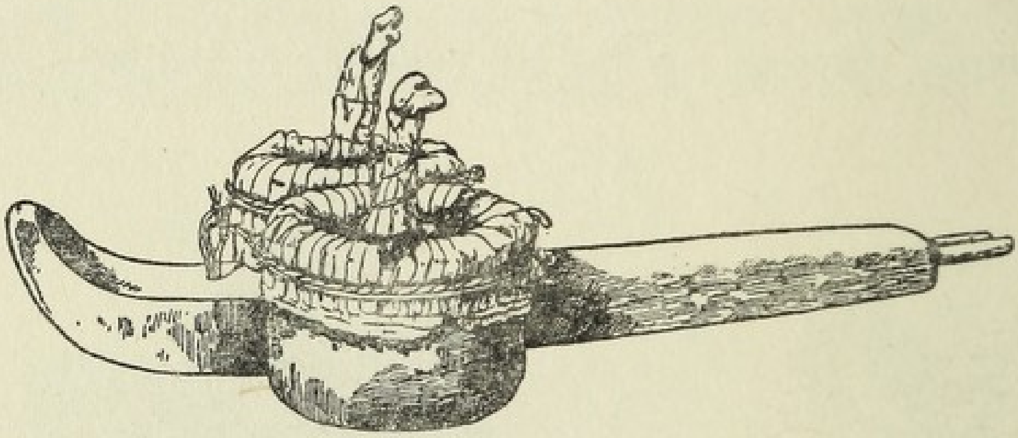


FIG. 52.—BLOWER IN USE AT CAMEROONS.

From "Stahl und Eisen."

regular use by the much more civilized Roumanian gipsies. A similar blower, but more after the pump type, is shown in Fig. 52; it is also of African origin, and about as popular as the first-mentioned. The illustration is taken from a blower used by the Bakwiris in the Cameroons. It consists of a wooden body having two cylinder-like excavations into which two discs fit loosely; these are bound round with skin, or in this case with banana-leaves, and the two handles are formed of the thigh-bones of goats. Two metal tubes pass into the wooden tubes, and terminate in a clay nozzle. The pistons are worked alternately by hand. Similar blowers were used at a very early age by the ancient Egyptians, but, according to the pictorial records which are preserved to this day, they were more frequently operated by the feet of attendants or slaves, as shown in Fig. 53,* which was taken from the Temple of Karnac, Eighteenth Dynasty. The blowers were probably the oldest mechanical devices for the purpose, and were used as early as the time of Thothmes III. They consisted of two leather bags, fitted into simple frames from which long pipes were carried to the fire; the pipes were first simple reeds

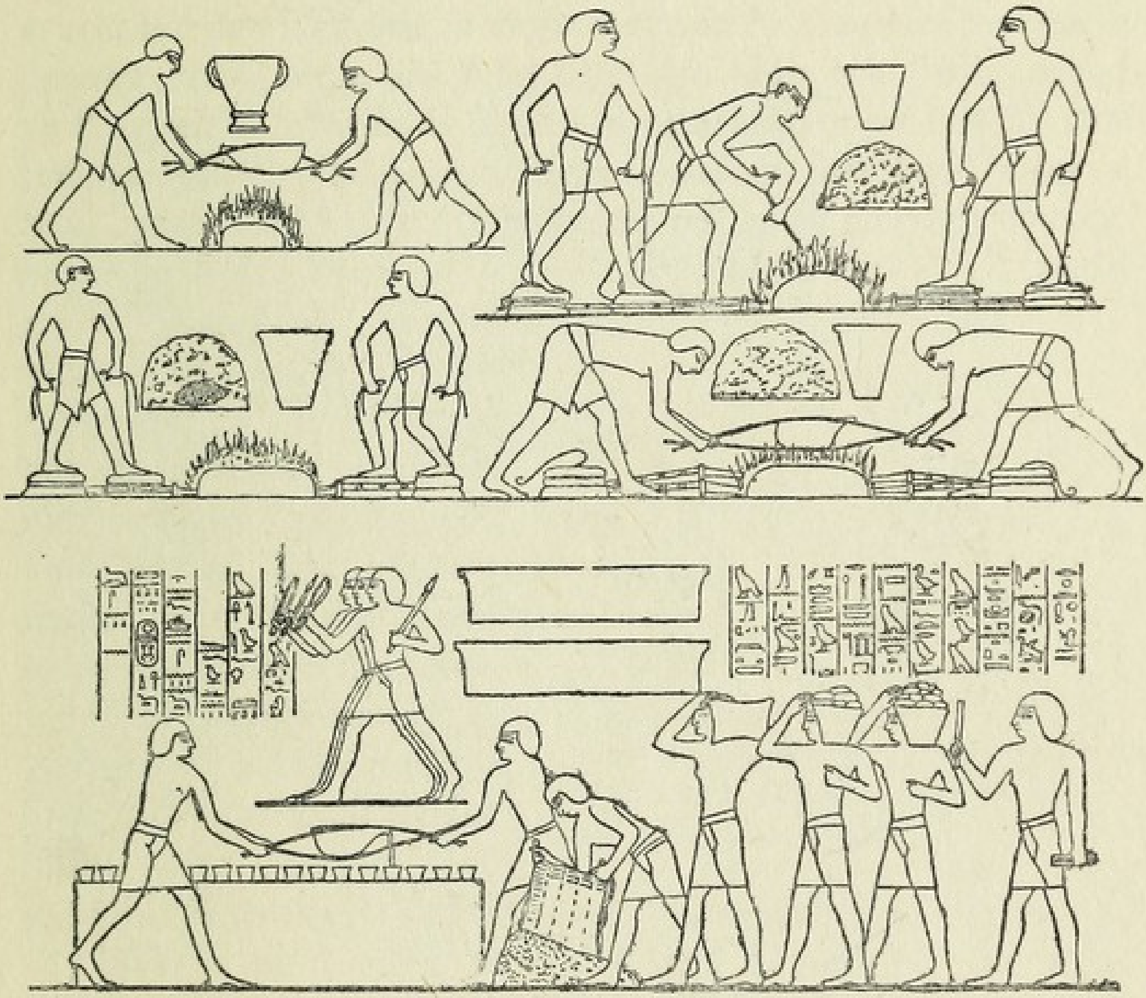


FIG. 53.—ANCIENT EGYPTIAN BLOWER IN CONNECTION WITH THE METAL INDUSTRY. After Prisse d'Avennes.

with metal nozzles, but later metal tubes were substituted. The illustration shows the complete progress of the Egyptian metal industry from the delivery of the ore to the casting of the metal in moulds. Some of the negro smiths used a pair of bowl-shaped vessels, exactly like a pair of pudding basins, tied over with a loose skin, to the middle of which a stick was attached; these bowls were placed side by side in an oblique

* See also Fig. 50.

position, and the sticks were manipulated in and out alternately by a native who squatted in front. The exit for the wind passed through a pipe or a pair of pipes which blew into a continuation pipe a little distance off, so that the suction air could pass in through this space (from Ratzel, "History of Mankind").

The blower used by the native smiths at Djur in Africa consisted of a pair of clay pipes formed somewhat in the shape of two cornucopias. The two outlets at the thin end led into a larger pipe; the wide openings of these pipes were covered with loose baggy skins with a hole in the centre; this acted as a valve, and the operator, when manipulating the bellows, opened the hole when he extended the skins for suction, and closed it when compressing. In the application of these blowers, particularly when worked by the feet, a simple method was employed to save the extension of the bellows by hand: two springy bent sticks were used, the ends of which were connected to the skins of the two bellows and kept them extended by strings, so that the manipulator had only to press them down.

Fig. 54.—A Blacksmith of the Greek or Roman Period. From a vase.

A very good representation of an ancient Greek smith and his tools may be seen in Fig. 54; it is taken from a vase. In the middle of the picture is seen a furnace; the smith is sitting on a low stool in the act of taking a red-hot piece of iron from the furnace with his tongs; the anvil is just in front of him, and with his left hand he is shielding his face from the heat of the fire; a portion of the bellows is visible on the left just behind the furnace. Opposite the smith stands his assistant, with a sledge-hammer ready to strike (after Blümner).

The pump as used for a blower by the Ifugaos, a wild tribe of the Philippine Islands, is shown in Fig. 55. In the illustration a blacksmith is seen at work with his assistant, who works the bellows, which consist of two cylinders with a piston in each

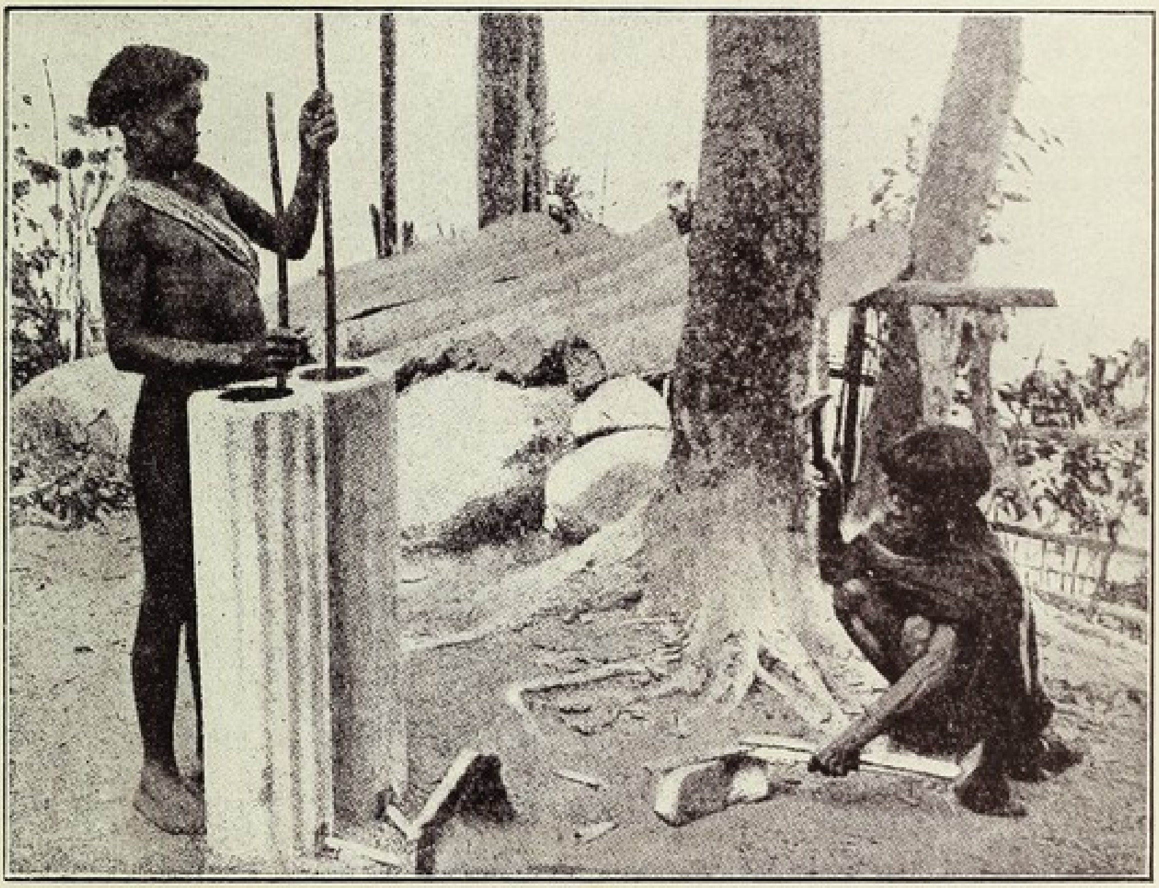


Fig. 55.—A Philippine Blacksmith.

To face p. 74.

attached to a central rod; these rods and pistons are alternately worked up and down as shown in the illustration. According to the Philippine *Journal of Science,* these smiths are very expert in working and tempering iron; their principal manufactures are axes, bolos, and campilanes, as well as knives for rice harvesting and other purposes; but all the weapons become dull very soon owing to their being iron instead of steel. The common bellows are the most modern, and may really be called a modification of the first skin bellows.

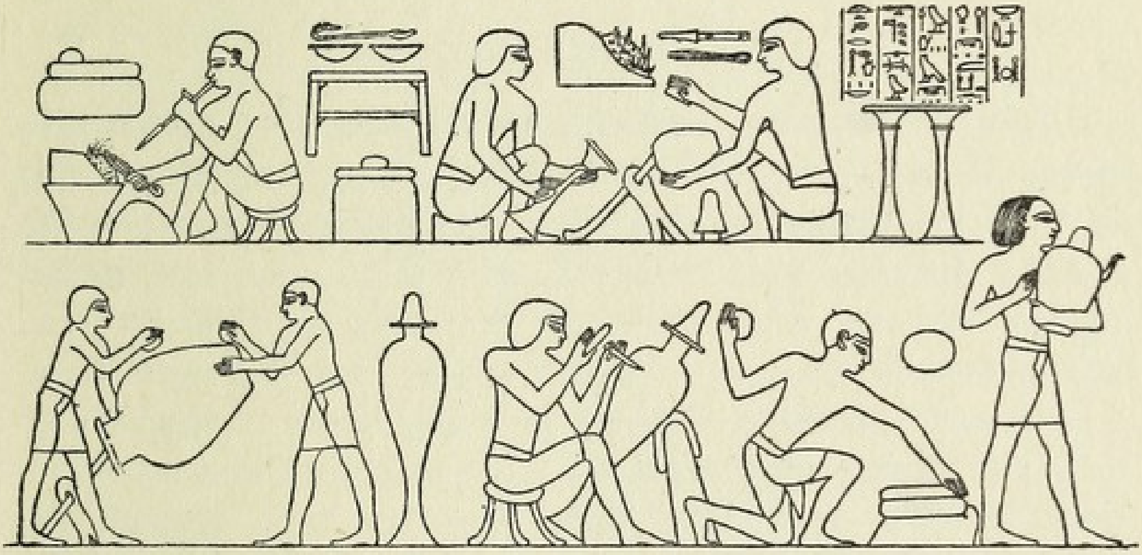


Fig. 56.—Egyptian Artisans manufacturing Gold and Silver Vessels.

From a fresco at Thebes, Eighteenth Dynasty. After Prisse d'Avennes.

Before concluding this section mention must be made of Fig. 56, which is most interesting, and represents the manufacture of gold and silver vessels in all its details, even to the ornamentation of the vessels by chasing.

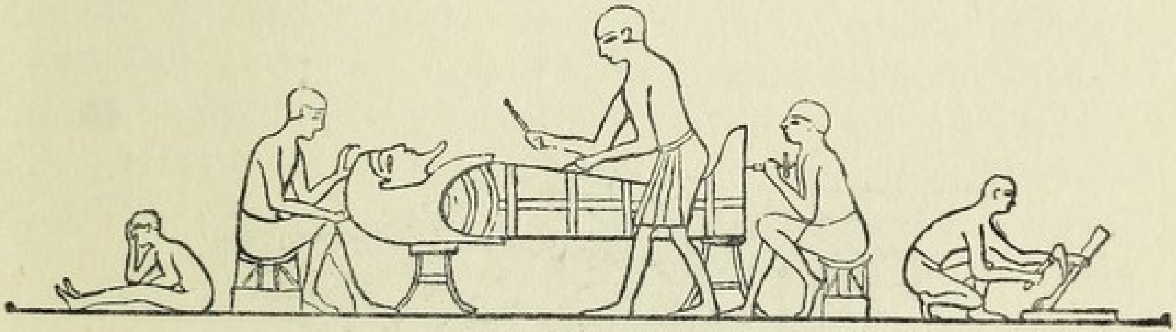
The Tanning Industry.

This was more or less understood among primitive nations, and was done by the Egyptians; they produced soft skins dyed in all manner of colours. The demand for leather was so great that the home supply was inadequate, and skins had to be imported from neighbouring countries. Conquered tribes of Asia and Africa had to pay tribute in hides, etc. The materials used for the tanning process were the pods and bark of a species of acacia (*nilotica*) and the bark of the sumac, or *Rhus oxyacanthoides*. Leather was used for footwear as well as for the coverings of stools, beds, and cushions, also for canopies and baldachins. Leather was largely made by the Assyrians for harness work, and was richly decorated; the Persians employed leather for garments as well as for the royal standard. Skin vessels were in great demand by all nations of antiquity for holding liquids. Leather finally served as writing material before the introduction of parchment.

The Textile Industry.

Linen, cotton, wool, and silk, were subjected to textile processes in antiquity. Flax was cultivated largely in the days of the Pharaohs, and other vegetable fibres from the marshy districts were collected, as well as spun and woven by the women. Flax especially was very skilfully treated; the coarser varieties were of good quality, but the royal linen was of such exquisite fineness that the limbs of the wearer were visible through the fabric. This is shown in some of the frescoes, where persons of importance are seen dressed, but the outline of their figures is discernible through the garments. There was also a large industry in the coarser textures. Existing specimens of all grades of the ancient Egyptian textile industry are to be seen at the British Museum. Pliny gives a very full account of the treatment of flax by the early Greco-Romans; according to this, the process was very much the same as that employed to-day. The flax was tied in bundles, exposed to the sun for a few days, then immersed in water for a few weeks and again dried in the sun, when it was ready for the further processes of carding and spinning. Fig. 45 shows, amongst other industrial pictures, two Egyptian women weaving, dyeing operations, and the preparation of raw materials.

Cotton goods were probably first woven in India, and the Assyrians are believed to have imported cotton from there; at any rate, they were familiar with cotton as an article of clothing. No species of the cotton plant was indigenous in Mesopotamia, or even near its borders. Mention is made of the cultivation of cotton, on one of the islands of the Persian Gulf, by Theophrastus, and it was probably imported there from India, its undoubted place of origin. Herodotus mentions the "tree-wool" from India as excelling in beauty and quality that of the sheep. The Egyptians must have known cotton, although linen appears to have been used almost exclusively, because Rosellini has found some cotton seeds in a tomb at Thebes. The Assyrians were expert weavers, as were the Egyptians, and produced principally linen and woollen fabrics. Silk was first woven in China, and was imported from there by the overland route to Western Asia and thence to Assyria, Greece, and Rome. The robes of the nobles of these countries were in all probability of silk. Pliny states that silken garments which were brought into Greece were unravelled by the women and rewoven into other forms.



Egyptian Carpenters.

SKILLED ARTISANS AND CRAFTSMEN

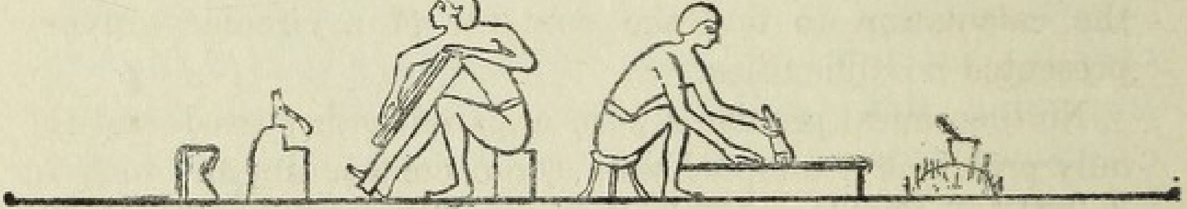
Great importance was attached by the ancient kings and rulers to having command over those skilled in arts and crafts, so much so that conquerors took all those of the conquered who were skilled in mechanical arts to their own country. Instances of this policy are found in Holy Writ, where we learn that the Philistines in the days of Saul carried away all the Hebrew smiths and their tools to their own country; likewise Nebuchadnezzar carried out the same tactics after the capture of Jerusalem.

CIVIL ENGINEERING

Canals were constructed in great numbers by the engineers of antiquity, some for conveying water through aqueducts, others sufficiently wide and deep for navigation purposes; some, to mention an example, were constructed at a very early age across the Plain of Mesopotamia, which unites the Rivers Euphrates and Tigris at a number of points, and opened a large sphere for navigation.

Perhaps the most important was the ancient Suez Canal, or, rather, the canal which connected the Red Sea and the Nile, the scheme of Necho, the son of Psanmetichus, 630 b.c., and constructed by Darius, son of Hystasps, after the conquest of Egypt by the Persians. The canal had its most northern terminus at Bubastis, on the Nile, and, after running in a south-westerly direction, turned to the south, and followed the course taken by the present Suez Canal, whilst its southern terminus was at Patymos, north of Suez, on the Red Sea. Several existing watercourses and the Temsah Lakes were used for this new waterway. Herodotus gives information concerning this wonderful work from his own personal experience, as he saw the canal in full activity fifty years after the death of Darius. Strabo, who visited Egypt shortly before the Christian era, reports having seen the canal covered with vessels. This canal of the Pharaohs was at some points up to 160 feet wide, and varied in depth up to 25 feet—enormous dimensions for the small ships of that period.

The aqueducts and smaller canals for town water-supplies and irrigation are too numerous to mention in detail, and their closer description would almost fill a volume, for nearly all nations of antiquity used them more or less. In conjunction with these aqueducts, dams were constructed across rivers, composed of enormous stone blocks held together by iron clamps, and the workmanship was as accurate as that employed in the building of the Pyramids. These dams were built particularly by the Egyptians and Assyrians, for the special purpose of retaining the higher water-level in the upper regions of their rivers. As an instance, a dam opposite Nimrod may be cited, which has withstood the fast-running Tigris for ages, and is still a witness to the skill of the Assyrian engineers. There are larger and better examples of Egyptian dams to be found in connection with their huge irrigation schemes, many of which in those regions were in existence at the time of Alexander's conquests in Asia. The construction of embankments, forts, city walls, and bridges, also form interesting subjects; the stones of the bridges were likewise connected by copper, iron, or bronze clamps or dogs fixed into position by liquid lead. The military machines, such as battering-rams and catapults—the designs of which may be seen from frescoes and bas-reliefs—proved the capability of the Assyrians as military engineers.



Egyptian Carpenters using Glue.

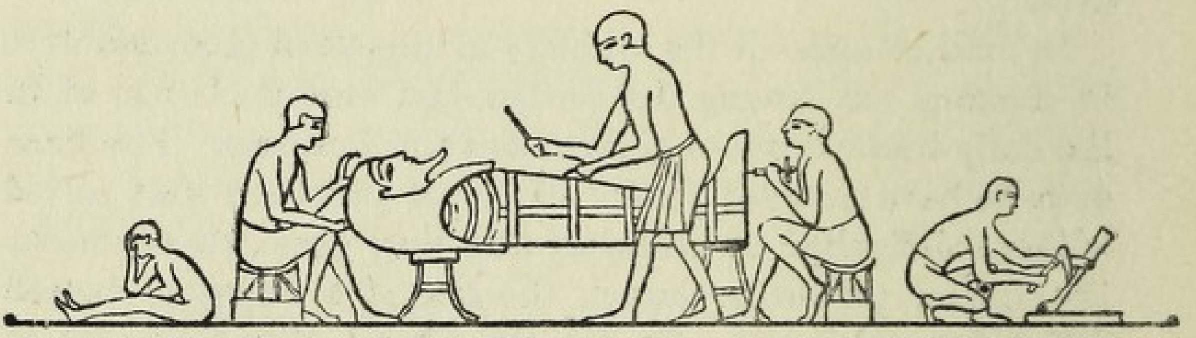
Egyptian Gold and Silver Smiths.

SCIENCE AND MATHEMATICS

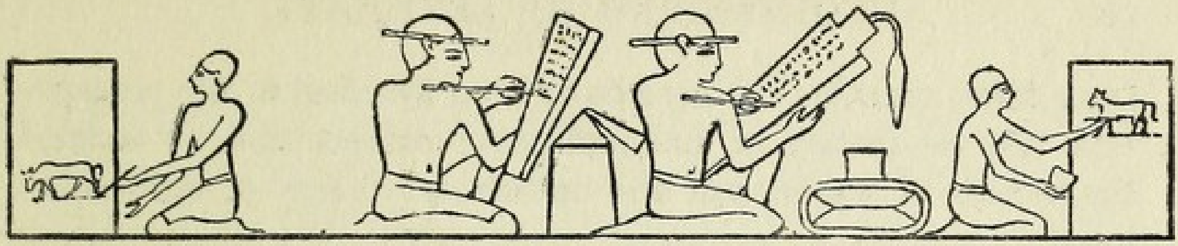
It would be most unfair were we not to accord to the Ancients, especially the Assyrians, Babylonians, Chaldeans and Egyptians, their acquaintance with science. They knew astronomy and even foretold eclipses; they introduced the sundial and the division of the day into twelve hours; in addition to what has already been mentioned, they manufactured glass, were acquainted with practical chemistry, and produced beautiful dyes.

In mathematics all the ordinary arithmetical processes were in common use among the scribes, and were made use of in the daily transactions of government and business. Fractions seem to have troubled them; algebraic problems were solved without difficulty; in geometry also they were able to master the simpler problems, though the area of a trapezoid caused difficulties and errors. On the other hand, they were able to determine the area of a circle with sufficient accuracy for their purposes. To determine the contents of a heap of grain, it was reckoned roughly as the contents of a hemisphere, and the calculation to find the contents of a circular granary presented no difficulties.

No theoretical problems were apparently discussed, and the only problems attempted were those continually met with in daily life. The laying out the ground plans of pyramids, etc., was accomplished with great accuracy, and a highly developed knowledge of mathematics was thus at the disposal of those employed in technical enterprise. We can see from all this that before the dawn of recorded history man had reached a state in which the greater number of the greatest arts had been to a degree attained. He had a language; he knew how to clothe, feed, and house himself; he was acquainted with the use of fire; he could make his own implements of war and peace; he had domestic animals, a knowledge of agriculture, and an established system of government. He also knew how to embellish his surroundings by painting and sculpture, and he had acquired the art of writing his own language.



Egyptian Carpenters.



Egyptian Scribes and Artists.

CONCLUSION

We cannot close these remarks without referring to the most remarkable knowledge of applied mechanics and engineering generally of Leonardo da Vinci, who, though he lived in more modern times (1492-1519), is best known as the master of the Florentine school of painters; but this was only one manifestation of his vast skill and knowledge, as he comprehended every branch of art, science and industry, and stands unique as a universal genius. The vast collection of his sketch-books is filled with machine designs and details reaching into all branches of mechanics, and he has there outlined the progress of future ages.

Buffet says:* "Leonardo anticipated Copernicus in forming a just conception of planetary motions. Before Newton he apprehended the principles of gravitation. He was familiar with the laws of motion; he was aware that the earth revolved; he attributed the tides to solar attraction. Like Galileo, he discovered the earth-shine on the dark of the moon; he also discovered the burnt-out condition of that satellite. He noted that the apparent size of the stars increases towards the horizon, and he distinguished their scintillation as a phenomenon independent of themselves. He speaks of 'constructing glasses to see the moon larger,' a single lens though this may be. It is said that he invented the barometer, afterwards realized by Torricelli, and directed his studies toward the thermometer, for which Galileo has received honours. He likewise conceived a compass with movable centre, and a most improved form of the balance.

"Centuries before Cuvier he reconstructed extinct animals

* *American Machinist.*

from fossil remains There have been ascribed to his perception the realization of the molecular composition of water, the motion of waves, and the undulatory theory of light and heat.

"He studied combustion and called smoke 'fire without air,' thence inferring that fire feeds on air. He investigated the possibilities of steam power, and designed a steam cannon. Steam pumps also seem to have been in his mind. Moreover, there is one of his sketches which, though obscure, has been thought by some to indicate a steamboat.

"Mathematics he followed far, and made many geometrical discoveries. He studied the formation of the regular polyhedrons; he was the first in Italy to employ plus and minus signs. One of his myriad mechanical investigations was concerning the power of a lever moved on an inclined plane.

"In hydraulics alone he did enough to furnish fame for several men. Until he arose, so far as we know, that branch of physics had been neglected from antiquity. His canal irrigation and harbour engineering gave him plenty of opportunities for applying it. Thus, he had occasion to solve such problems as, the quantity of water required to fill a certain canal, and the length of time it should run. In recondite diagrams he depicted the contours of different jets issuing horizontally from orifices. The mill pipe, he found, is not filled by parallel threads of water, but by periodic eddies or currents, the vertical axes of which shift their position.

"Many were his inventions relating to this favourite element, water. Pumps of complicated design occupy large spaces in his books. He designed novel buoys, diving apparatus, and the first life-preserver. Among the earliest canal locks were his. His drawings display dredges of different types and gigantic machines which were to be advanced along the canal bed for systematic digging on both sides.

"Liquids were not the only fluids that he studied, but his researches extended to the gaseous realm. Thus, he treated the resistance, or pressure, of the air as dependent on its weight. He measured its density and, as already mentioned, he devised the most important meteorological instruments.

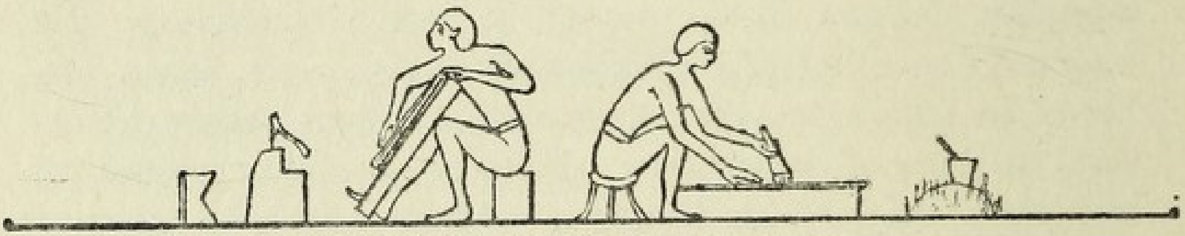
His elaborate work on the study and imitation of wings should be classed rather with mechanics than with pneumatics, for he displayed great ingenuity in the design of flying-machines, ornithopters, and helicopters. He also knew the use of the parachute.

"Leonardo's industrial machine-designing gives us greatest cause to marvel. Mechanical details that never would have been ascribed to the beginning of the sixteenth century, and complete apparatus of infinite variety and purpose, luxuriate in his huge notebooks. Cams, levers, gears, worms, ratchets, sprockets, and chains, abound in almost every pattern, ancient or modern. We find rolling-mills, draw-benches, power-hammers, cranes, shears, threading-machines, file-cutting machines, rope-making appliances, and metal or wood-working tools, such as lathes, planers, boring-mills, boring-jigs, self-centering chucks, bending-machines, and broaches. A stone-cutting saw of his invention is still used in the Carrera marble quarries. He was far advanced in the use of automatic machinery for needle-grinding, gold-beating, and other purposes. He planned many patterns of radius grinders for use in the manufacture of concave deflectors.

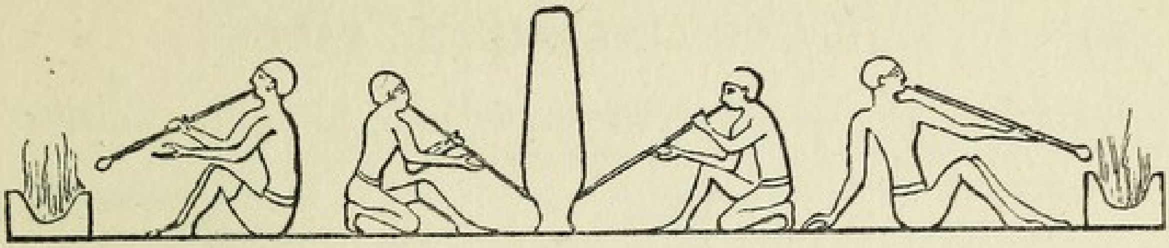
"During the Medicean age, Florentine fabrics were celebrated; it was therefore natural that some of Leonardo's most recondite designs should appear in textile machinery. He designed a complicated multiple cloth-cutter, a gig, looms, etc. Yet in da Vinci's time the constructive arts were largely subservient to those of destruction. Military engines engrossed an inordinate share of his attention. Those which he designed follow a line of contact between ancient and modern warfare. On the other hand are catapults, ballistas, huge crossbows bent with windlasses, and instruments for scaling and battering down fortress walls. On the other hand there are breech-loading cannon, divers types of artillery carriages, various forms of multiple-barrelled guns. He designed machines for drawing and rolling iron staves used in artillery manufacture, and he shows a thorough knowledge of foundry practice. He also studied the composition of explosives. Whether he invented any instruments of torture is not disclosed by a superficial examination of his books, but if he did he found a ready market for them in Italy in his day."

If all the writings of antiquity giving records of all the national developments before the dawn of history had been preserved to us, we should have had an abundance of material for this subject, but unfortunately the ancient writers used perishable materials ; a papyrus, or even a parchment roll, did not remain intelligible for more than a few generations under the ordinary circumstances then existing, and unless copies had been taken from time to time the record it contained must unavoidably have been lost (there are comparatively few exceptions to this). We have to rely, therefore, for the most part, on the story told by the bas-reliefs and frescoes left from antiquity.

Abundant evidence has, however, been given in the foregoing to prove beyond a doubt that many of our present-day methods, if only in principle, are thousands of years old.



EGYPTIAN CARPENTERS USING GLUE.



EGYPTIANS MAKING GLASS.

TABLE GIVING THE APPROXIMATE DATES OF SOME OF THE INDUSTRIES OF, AND METHODS EMPLOYED IN, ANTIQUITY

THE table is based on the actual articles since found, or the pictorial records left by the ancients. They do not necessarily refer to the earliest use, but often only to the time when they were first depicted. Thus, for instance, brick arches are known to have been built 3,570 years ago, whereas the first records of brick-making date back only about 3,000 years. Likewise with the manufacture of glass. We know that glass bottles were made, by specimens found, 5,600 years ago, whilst the manufacture of glass was not illustrated at a date prior to 1500 B.C.

	B.C.	
Iron dates back to 188 years before the Trojan War, or	1370	—*i.e.*, 3,280 years ago.
According to other authorities	1450	—*i.e.*, 3,360 ,,
According to the monuments at Thebes and Memphis	...	4,000 ,,
Bronze was known and used in, or soon after, the Sixth Dynasty	3266-3133	*i.e.*, 5,110 ,,
Gold was fashioned into ornaments as early as the Fourth Dynasty, or	...	5,500 ,,
Gold wire is found on ornaments bearing the name of Osirtasen I.	1740	—*i.e.*, 3,650 ,,
Fine gold wire for embroidery was used before the Exodus (Exod. xxxix. 3) ...	1491	—*i.e.*, 3,400 ,,
Ear-rings and bracelets of silver and gold were in use in the time of Abraham (Gen. xxiv. 47, 53)	...	say 3,800 ,,
Homer mentions silver cups made by the Sidonians ("Iliad," xxiii. 741, and "Odyssey," iv. 618, etc.).		

Bracelets, rings, armlets, necklaces, and ear-rings, are known to have been manufactured in the time of Osirtasen I. ...	... *i.e.*, 3,650	years ago.
Also in time of Thothmes III.	... *i.e.*, 3,500	„
Shipbuilding: The first records are pre-dynastic, say...	B.C. 3500—*i e.*, 5,400	„
Clinker-built ships were known in the Twelfth Dynasty	2466-2266 *i.e.*, 4,280	„
Phœnician sailors were sent by Neco on a voyage of discovery to ascertain the form of the African continent, and they doubled the Cape of Good Hope about 2,100 years before Vasco da Gama, or	... 3,300	„
Phœnician merchants sent their ships to our coast in search of tin	450-400 *i.e.*, 2,350	„
Columns supported Egyptian temples since the Sixth Dynasty	3266-3133 *i.e.*, 5,110	„
Bricks (sun-dried) are shown in the course of manufacture	... 3,000	„
Brick arches were built in the reign of Amenhotep	1660—*i.e.*, 3,570	„
Vaulted granaries at Benihasan date from the Twelfth Dynasty	2466-2266 *i.e.*, 4,280	„
Glazed tiles lined the walls of the chamber of the Pyramid of Sakkara, bearing the name of a King of the Third or Fourth Dynasty, or nearly	... 5,680	„
Glass bottles may be traced as far back as the Fourth Dynasty, or	... 5,600	„
Glass manufacture is represented in the time of Osirtasen I.	1740—*i.e.*, 3,650	„
Stained glass, ground glass, and cut glass were known	... 3,000	„
The lapidary's wheel was known before the Exodus	1491—*i.e.*, 3,400	„
Cutting and engraving precious stones was an art learned by the Israelites in Egypt (Exod. xxviii. 17-31 and xxxiv. 6) ...	1491—*i.e.*, 3,400	„
Porcelain was introduced into Egypt from China	200—*i.e.*, 2,100	„
The potter's wheel was known in Egypt before the arrival of Joseph	1740—*i.e.*, 3,560	„
The bellows and the siphon date back at least to the time of Thothmes III.	1600—*i.e.*, 3,500	„

	B.C.	
Carriages with spoked wheels commenced to be built in the Eighteenth Dynasty, or ...	1700-1500	*i.e.*, 3,500 years ago.
The weaver's loom is illustrated in the Egyptian records	...	2,000 ,,
Spinning, dyeing, and weaving, were known before the Exodus (Exod. xxxv. 25) ...	1491—*i.e.*,	3,400 ,,
Linen was purchased by Solomon from the Egyptians, say, 1000 B.C.; it must therefore have been manufactured	...	2,900 ,,
Mordants in the textile industries, and the use of metallic oxides, are described by Pliny, and were probably used nearly ...	...	2,000 ,,
Ropes were twisted of fibre and leathern thongs in the time of Thothmes III. ...	1600—*i.e.*,	3,500 ,,
The "circular cut" for making the longest leathern thongs from a single piece of leather was known	...	3,300 ,,
The same process was used by Dido to make a thong to measure out the plot of land on which to build Carthage.		
The roller under a load probably dates from the reign of Sennacherib	...	2,550 ,,
The pulley-block was used both in Egypt and Assyria probably	...	3,000 ,,
Papyrus as a writing material was in general use in Egypt in the time of Cheops, the builder of the Great Pyramid	3733—*i.e.*,	5,600 ,,
Parchment was likewise used for the records of the temples in the Eighteenth Dynasty	1700-1500	*i.e.*, 3,500 ,,
Glue was in general use by the Egyptian carpenters	...	3,300 ,,
Timekeepers to check workmen were employed in the Eighteenth Dynasty ...	1700-1500	*i.e.*, 3,500 ,,
A calendar with a year of 365 days was in vogue in Egypt as early as	1322—*i.e.*,	3,235 ,,

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