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Presidential Address

The History of Ancient Technology

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I propose today to give a rapid and rather superficial survey of the technical achievements in the ancient world, covering approximately the period from 3500 B.C. to 1000 B.C., with special reference to chemistry.

The history of technology has, it is true, been studied, and we possess excellent monographs on parts of it, such as the history of iron, of sugar, of alum (by our first President, Professor Charles Singer), and of dyes, not to mention the story of mechanical inventions, but it has not been sufficiently appreciated and used by the general historians, or even by historians of science.

Dr. Sarton in his *Introduction to the History of Science*, although devoting ample space to theologians, poets, lawyers and chronologists, begins his story with Homer, and in a later period, when he comes to deal with technology, he hurriedly leaves the subject to discourse on trade guilds. I know only one book dealing with the general history of early science, that on *Greek Science* by Professor Benjamin Farrington, which shows a proper appreciation of the technology of the ancient world.

The Greeks were not interested in experimental science and their contributions were in other fields. Book learning and abstract thought were the occupations of their masters and scholars, and so they long continued to be in teaching which followed Greek traditions. Apart from mathematics, which has also been said not to be a science, the Greek contributions to science are less impressive than might be supposed. It is only in descriptive or speculative sciences which are even today in a rather primitive stage of development, such as zoology, that the Greeks seem to us so modern, and even there they played the part of observers—as good observers, sometimes, as an intelligent peasant would be.

Whenever a Greek philosopher showed any interest in science as we now understand it, or even in mathematics, he was almost invariably supposed, in later tradition at least, to have derived his knowledge from the Egyptians or the Chaldaeans, just as, in still later times, he was regarded as having obtained it from the Devil.

Ancient applied Chemistry included, among other things, the extraction of metals from their ores, the formation of alloys, the production of glazed pottery and other glazed articles, and of glass and coloured pastes, the preparation of pigments, inks and dyes, and of salts, the extraction of vegetable oils, the compounding of ointments and perfumes, the production of intoxicating drinks and the preparation of drugs.

The ancient peoples were often very highly skilled in the technical arts, and not at all primitive in this respect. In some cases a high standard of work was reached by mere patience, as when a block of hard stone such as granite or porphyry was shaped into a thin-walled vase by the use of stone grinders and abrasives without the assistance of the wheel. All the processes were executed in a way which leaves nothing to be supplied in order to make them rank with the best achievements of the modern craftsman, and the culture of the Bronze Age was, in fact, on a high level. The manual worker was not very highly esteemed, and his hard life is graphically described in some Egyptian papyri, which show that he usually wished to become a scribe or clerk, in which capacity he had the opportunity of rising to a higher level of comfort and appreciation. We still have our trade-union leaders and shop stewards.

The outstanding achievements in applied Chemistry in the earliest period were made in some special areas, notably in Egypt and in Mesopotamia. Although iron was known there before 3000 B.C., and was in extensive use from about 1700 B.C., almost the whole period we shall consider was in the Bronze Age, since the beginning of an Iron Age is properly associated with the use on the large scale of iron weapons. The date 1000 B.C. marks the beginning of an intrusion of an iron-using race or races into Mediterranean sites, called by the Greeks the Dorian invasion as far as their particular experience was concerned, and it marked a definite break in the continuity of craftsmanship, and a lowering of standards in many directions. The Classical Period of Greece and Rome, which lies in the Iron Age, is in some respects a period of decadence in the technical arts.

In considering the range of materials involved we may well begin with the metals. The earliest discovery of metals is still in many ways mysterious and has been supposed to go back to 5000 B.C. at least in Egypt. The old authors preserve fragments of legends in which the great inventors are gods and kings. In ancient Egypt the god Ptah was the inventor of metallurgy. In an inscription of Rameses II (1250 B.C.) the god says to the king: "I have wrought thy body of gold, thy bones of copper, thy vessels of iron", and this is the first *definite* reference to iron in a text, although the metal was known long before. King Sennacherib the Assyrian in 700 B.C. says that he made clay moulds at the command of his god, and cast in them great bronze statues of bulls and lions weighing over 10,000 talents, "as if making half shekel pieces".

Gods and kings could pride themselves on the technical achievements of their lands, whilst the actual inventors remain for all time in nameless obscurity. Even in the classical period, the military leaders crowd the ample pages of the historians, whilst the names of the engineers who made their victories possible are in most cases unknown, or have been rescued from oblivion by scraps of papyri found in dust-bins. The names of the common soldiers who first scaled the walls are recorded, but the names of inventors of powerful military equipment are suppressed by the historians, who, like the whole of antiquity, despised the technologists. Archimedes, we are told, regarded his inventions as mere trifles as compared with his abstract mathematics, and the history of Greek invention after his time is mostly of toys or automatic machines designed for polite amusement. The technologist came to his own in very much later times, when it was realised that he could make a fortune from his work, and with it enter the circles of polite society. Let us, however, return to our subject.

The earliest known metal was probably gold, which was encountered in alluvial washings and could not escape attention, although mining from the rock was very soon in use. Copper has, however, been found in some of the oldest Egyptian graves without gold. The earliest specimens of gold are unrefined and contain varying amounts of silver, and usually some copper. When the silver reached 20 per cent. or more, the resulting pale-yellow natural alloy, now called electrum, which is harder than gold, was given a special name in Egypt, and this name, *asem,* is perhaps the oldest name of a metal to be recorded. It occurs on an ebony tablet of King Menes, the first king of the first dynasty (about 3400 B.C.). Asem is also mentioned in the inscription on the obelisk of Thothmes III now standing on the Thames Embankment and incorrectly called "Cleopatra's needle", which may at one time have been plated with the metal. This king once received about 4 tons of electrum as tribute from Asia and Nubia.

Gold was used in great profusion in Egypt during the XVIII dynasty, since a gold coffin in Tutankhamen's tomb was over 6 ft. long and weighed 110·4 kgm., and in the Amarna letters (1375 B.C.) the King of the Mitanni in the Euphrates region writes to Pharoah begging him to "send me so much gold that it cannot be measured, for in my brother's land gold is as common as dust". He also mentions that: "thou sentest my father a great deal of gold . . . . but the tablet thou sentest me was as if it were alloyed with copper". The King of Babylon wrote to Ikhnaton (1375–1350 B.C.) saying that his gold was not as good as his father's; from 20 minas of this gold put in the furnace only 5 minas of fine gold remained. These letters show that some kind of refining process was used in Asia Minor about 1400 B.C., long before its use in Lydia in 550 B.C., the traditional date for the introduction of the process of refining gold. Since Pharoah had sent the base metal in the hope that it would pass as gold, we may suppose that the methods of refining and testing gold were not well known in Egypt in his time. Almost pure gold first occurs in Egypt about 525 B.C. It is probable that the process of purification was that described about 116 B.C. by Agatharchides. He also gives a graphic picture of the conditions of slave labour in the mines, and there is no doubt, from incidental allusions in old Egyptian texts, that these conditions were equally severe in the older period, when gold was got from mines in the so-called *Arabian Desert*, between the Nile and the Red Sea. Gold also came from the Sudan in the form of rings. The use of crude vitriols, known at an early period in Egypt, in refining gold seems possible. The powder used in fairly recent times for the purification of gold, and called the "royal cement", consisted of brick dust, calcined green vitriol and common salt.

Silver was of little importance in Egypt, but it occurs in fairly large amounts in early Sumerian remains at Ur. The silver at Ur is in the form of useful objects such as tumblers, as well as ornamental, so that the metal was probably in fairly extensive use. Most of this early silver came from Asia Minor, and the Hittites were particularly important in the development of the metallurgy of silver. There are interesting finds of artistic silver on the Phoenician coast at Byblos, going back to 2000 B.C. A silver coinage was early in use in Phoenicia and Palestine.

The extraction of copper was very early in Egypt, the metal occurring in the Predynastic period, when it was smelted from carbonate ore which is easily reduced in charcoal fires. The wrinkled slag on the surface of molten copper is mentioned in the Edwin Smith papyrus, the oldest parts of which go back to 3000 B.C. There is a $3\frac{1}{2}$ lb. copper axe head of the middle Predynastic period, about 4000 B.C. In the II dynasty the art of working copper had reached a high stage of perfection, as the actual articles show. Equally remarkable are the highly artistic works in copper from early Sumerian sites, going back to before 3000 B.C. In both regions the copper was obtained in a very pure condition and very good castings were made, as well as hammered work.

We do not know enough about the actual processes used by the metallurgists, but are better informed of the working of metal, as there are good representations of metal workshops in Egypt, e.g. one of the Old Kingdom (2980–2475 B.C.) showing the weighing of precious metals and malachite, a furnace with men blowing the fire with a mouth-blowpipe (probably a reed tipped with clay), the cutting and hammering of metal and the putting together of necklaces and costly ornaments. Blowpipes were used to a much later period, down to the XVIII dynasty where they are also shown. Bellows were in use in Egypt at least as early as 1580 B.C. They were dish bellows, still used in Africa, being wooden or clay dishes covered with leather, the skins being pressed down by stepping on them and raised by pulling strings. There are no valves, the air entering through leaky places. The blowing tubes were probably reeds tipped with clay. The metal was melted in clay crucibles, actual specimens of which are known, and was poured through funnels, probably also of clay, into the moulds. Quite large castings were made, and a quantity of metal was poured simultaneously from a number of crucibles, a process which is difficult even today if good castings are to be made.

Really good castings were first possible with the alloy bronze, containing copper and tin, which has a lower melting point than pure copper. Bronze occurs in small amounts in Egyptian remains of the Old Kingdom but became abundant in the Middle Kingdom (XII dynasty). It seems very probable that the metals copper and tin were used separately and melted together to form the bronze, since they are shown brought to the furnaces in blocks of different shapes. The copper was in large hide-shaped blocks, which were traded in the Aegean in the Cretan period, actual specimens being known. The source of the tin for the early bronzes is a matter of speculation. In some Egyptian representations blocks of a material called dḥty are shown carried by Cretans. The tin may have come from Khorassan in Persia, where Strabo says it was found, or from the Syrian coast near Byblos. Tin itself occurs in Egypt from the XII dynasty (2000–1788 B.C.) and was perhaps known earlier.

It is customary to distinguish between a Copper Age and a Bronze Age, following in this order, but if the objects are correctly dated, very good normal tin bronze occurs in Sumerian remains at Ur about 3500 B.C., and is followed, not preceded, by a Copper period, when the objects are of nearly pure copper. On other Sumerian sites copper is the earliest common metal.

The Sumerian and Egyptian metal workers had different techniques. This is especially noteworthy in the axes. The heads of the early Sumerian axes are cast in the more fusible bronze, and are socketted, whilst the Egyptians used flat hammered axes of the less fusible copper, not socketted but bound to the haft by thongs, and such copper axes were also used by the Sumerians about 3000 B.C.

There is no brass (copper-zinc alloy) in early Egypt and Mesopotamia, but some of about 1400–1000 B.C. was found in Palestine, containing up to 23 per cent. of zinc. In the Roman period the brass industry of Cyprus was important. The brass furnace was built into a house of two storeys, the roof being open to the air. In the wall was a charging door and the apertures for the bellows, which were in a separate house. The fuel was put in first and kindled, then the zinc ore broken into small pieces, and more fuel. The zinc oxide driven off was collected in the upper storey like fleeces of wool. The same type of furnace was used for making brass in Rammelsberg in the 17th century A.D., and there small quantities of metallic zinc were collected from the cooler walls of the furnace. Strabo mentions a metal he calls mock-silver (*pseudargyros*), and this was probably zinc obtained in this way, without distillation. Finds of objects of metallic zinc of about Strabo's time have been reported.

Isolated finds of iron, both meteoric (containing nickel) and terrestrial (free from nickel) occur both in Egypt and Mesopotamia in the earliest period. In Egypt the metal came into sparing use about 2000 B.C. There was a well-developed iron industry among the later Assyrians, and the remains of the palace of Ashurnazirpal at Nimrud (885–860 B.C.) included large masses of iron. This king also obtained large amounts of iron as tribute from Hittite kings. The working of iron probably originated neither in Egypt nor in the Euphrates Valley. Old legends point to the Chalybes, tribes related to the Hittites and living in the region between the Caspian and Black Seas, as the first workers in iron, which they traded with the Egyptians and Babylonians. They seem also to have been the inventors of steel, about 1400 B.C.

Remains of an iron foundry of about 1200 B.C. and a steel dagger of about 1350 B.C. were found in Palestine, and Rameses II, about 1250 B.C. obtained iron from the Pontos region. In a text Rameses asks the Hittite king for iron, and receives the reply : " As for pure iron (i.e. steel) about which you have written, there is no iron in my warehouse at Kizwatna now and to make it would be inconvenient, but I have given written orders that it shall be made. As soon as it is ready I will send some ; at the moment I send only a dagger."

The ancient pigments were mostly natural, an exception being the Egyptian blue. This colour, the use of which goes back to the Predynastic period, is mentioned by some ancient writers, but its preparation is first given by Vitruvius from an Alexandrian source. In quite recent times Egyptian blue has been shown to contain a definite crystalline compound, CaO, CuO, $4SiO_2$. This is formed by heating fine sand, calcium carbonate, copper carbonate and a little alkali carbonate as a flux for several hours in the temperature range 830–900° C. Below and above this limited range it is not formed, and it is somewhat of a mystery as to how the Egyptian technologists were able to control the temperature so accurately.

Glass itself was known very early in Egypt and Mesopotamia. There are finds of glass in both localities before 3500 B.C. in the form of beads, and a large piece of blue glass of about 2400 B.C. was found in Mesopotamia. The Egyptians were very skilled in the making of glass, the remains of a factory of about 1400 B.C., with a profusion of glass objects, being found at Amarna.

Blue glass was mostly coloured with copper, although specimens of the 14th century B.C. containing cobalt occur both in Egypt and Mesopotamia, the latter also containing lead. Most of the earlier historians of technology denied the use of cobalt in ancient glass. Blue glass imitating lapis lazuli and called *uqnu* was a speciality in Babylonia, and Assyrian tablets of about 650 B.C. give recipes for many imitation gems. A similar tablet of the 17th century B.C., written in a very difficult style, also describes its preparation. Colourless glass was made in Egypt from about 1400 B.C. Blowing glass seems to have been unknown until it was invented in Sidon about the beginning of the Christian era. Both Seneca and Pliny speak of blown glass as something new in their time. The Egyptian representations of the XII dynasty at Beni Hasan, formerly considered to depict glass blowing, are now thought to refer to metal work, although the tips of the blowpipes certainly suggest masses of glass taken up for blowing. The forms of ancient glass are very skilfully produced and some coloured pieces are very beautiful, although they are often opaque. The rather mysterious *vasa murrina* of the Romans were probably of coloured glass.

On the side of organic chemistry, perhaps the use of dyes is the most interesting. Dyeing was very old in Egypt, where red, yellow and green clothing is shown in the oldest pictures. Ancient Egyptian dyes definitely established by analysis are indigo and safflower (*Carthamus*). The use of indigo, perhaps obtained from a kind of woad, is especially interesting since the Romans, who then obtained it from India, were unable to get it into solution, and used it only as a pigment. Pliny puts it among the minerals. The Egyptians seem to have known the use of mordants, since Pliny mentions that they first impregnated the fabric with chemicals which did not give it any colour, but when it was put into a cauldron of boiling dye it was drawn out showing various colours although there was only one colour in the cauldron. Alum was well known in Ancient Egypt. Parti-coloured fabrics, some printed, were found in Egypt at Ikhmim from about Pliny's time, and the process probably went back to an earlier period. The use of the so-called Phoenician purple, a dibromoindigo obtained from molluscs, may have begun in Crete, where large heaps of the murex shells have been found. In later times dyeing in purple was carried out on the large scale in Tyre and Sidon. The process is rather fully described by Pliny and has been successfully imitated in modern times. There were two kinds of mollusc used, the *buccinum* (with trumpet-shaped shells) and the *pelagium*. The juices were combined, mixed with a little salt and boiled in a lead cauldron. The liquor was tested by putting in a piece of washed wool (the " swatch " of the modern dye laboratory) and the boiling was continued until this came out in the required shade, which was a very dark red or crimson rather than what we now call purple. The main quantity of wool was then put in, left for five hours, taken out, and immersed in a new bath, producing the so-called " double-dyed " purple, which was very expensive. Pliny says 1 lb. of double-dyed wool cost £31 5s. 0d. It had a rather unpleasant fishy smell, but the suggestion of d'Arcy Thompson that this was due to the bromine is a better tribute to his Greek than his chemistry.

In Mesopotamia we have the beginnings of the petroleum industry. Bitumen occurs in some of the oldest Sumerian remains and was obtained from Hit, on a river of the same name flowing into the Euphrates about a hundred miles north of Babylon. It was extensively used by the Babylonians for cement, for asphalt drains, floors, etc. These uses have only recently been resumed. The petroleum wells at Kerkut were well known in antiquity, although they awaited exploitation until our own time. The Babylonians also obtained naphtha (Babylonian *naptu*) or crude petroleum, used for lamps. There are two kinds, a black and a white. Strabo says the naphtha of Susiana (which he calls a kind of sulphur) when brought near a fire was ignited and could only be extinguished by a large quantity of water, or by mud, vinegar, alum and glue—an ancient anticipation of the " foamite " process. Pliny speaks of a white naphtha, which Dioskourides called " filtered asphalt ". It is difficult to see what it could be except refined petroleum, although distillation is said to have been unknown in the early period (the old names for filtration and distillation are the same). Perhaps it was refined by filtration through kaolin or some kind of absorbent clay.

It is still believed by many people that chemical processes and industries were in a very primitive state in the early civilisations. This is incorrect, and the brief sketch of some of the achievements of the Bronze Age which I have just given may serve to present a more correct picture of the reality. The subject of early technology is full of interest to the general historian as well as the historian of science, and there is plenty of accessible material available to him if he cares to use it.