Iron first came from space

PEOPLE WERE USING THE METAL WELL BEFORE THEY LEARNED TO PRODUCE IT, SAYS

S ANANTHANARAYAN

Early human history is divided into the Stone Age, Bronze Age and Iron Age – depending on what material tools and weapons were made of. But archAeological evidence shows that iron as a material, although scarce, was known even in the Stone Age. In the *Journal of Archaeological Sciences*, Professor Thilo Rehren of University College, London, at Qatar, and colleagues describe their studies on iron beads strung in Egyptian necklaces all of 5,000 years ago. These beads were strung along with gold and precious stones, which shows that iron was considered rare and valuable, too. The source of iron, before smelting the metal became possible, around 1200 BCE, is the remains of iron-rich meteorites that separate the metal from the ore during their formation or in their descent to earth.

On earth's surface, iron cannot remain iron for long. All the iron is thus in the form of the oxides, and found in rocks and minerals of iron ore. Something that is true of other metals too. Copper, for example, is found very occasionally as the metal, but mostly in combination with sulphur, or carbon or as the oxide. Tin is also mostly found as the oxide. In the case of these ores, the metal can be extracted by driving out the oxygen, or sulphur, using reducing agents like carbon, at relatively lower temperatures. The oxides of iron, on the other hand, need high temperatures to be reduced.

This is the reason that copper was the first metal to be extracted in reasonable quantities and, alloyed with the addition of tin, it formed the basis for the Bronze Age. The use of metal tools marks the end of the Stone Age and the use of bronze is placed at around 3000 BCE. Copper ore could be easily reduced in earthenware furnaces and the use of bronze became widespread. Bronze could be readily shaped and sharpened and artisans and craftsmen discovered new trades with the new tools that no longer needed to be fashioned from stone.

Egyptian artifacts at the Petrie museum, UCL.

And then came the Iron Age. Extraction of iron takes higher temperatures and materials for smelting. The Iron Age had, hence, to wait till the technology was available. A period of scarcity of tin and copper, which is easily deformed, is thought to have accelerated the advent of iron. Once iron production started, the efficiency and economy of the process and the superior qualities of the metal greatly changed the industrial landscape. The start of the Iron Age is placed at around 1200 BCE, but there is now evidence of iron production having started as early as 1800 or 2000 BCE.

Iron before its time

The remarkable thing is that in small quantities, iron is still found in artifacts that predate the Iron or even the Bronze Age. These samples of iron are thought of as originating in meteorites, where the ores are reduced by high temperatures attained without the help of human-made furnaces. Ancient people, hence, found scraps of iron when meteorites reached earth and discovered that the material could be deformed or shaped when worked on. The material, always in small quantities, was then used for ornamental purposes.

Thilo Rehren

The ULC-Qatar team considered the case of iron beads that were found in an ancient Egyptian necklace that is now in the Petrie museum at the UCL. The nine beads appear in the 5,000-year-old necklace along with gold and gemstones, which indicates that iron was rare and valuable. The beads are made from iron first beaten into sheets and then rolled into tubes, which indicates proficiency in metalworking.

"The shape of the beads was obtained by smithing and rolling, most likely involving multiple cycles of hammering, and not by the traditional stone-working techniques such as carving or drilling, which were used for the other beads found in the same tomb," says Professor Thilo Rehren. The nickel-rich iron that is found in meteorites is harder than copper, which was used in the Bronze Age. Fourth millennium BC metalworkers, who worked with meteorite iron, hence already knew techniques that helped bring in the Iron Age after smelting of iron became possible.

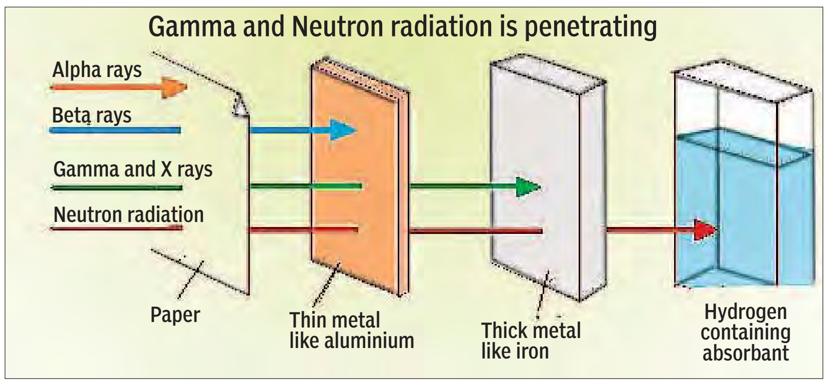
The UCL team worked on the iron beads to show that they did, indeed, consist of meteorite iron. By the time the beads were discovered, in 1911, in excavations at a cemetery site at the village of el-Gerzeh in lower Egypt, they were already completely corroded. Any attempt to analyse the material of the beads in the ordinary way would thus have destroyed the ancient find. The UCL scientists hence used a method of non-invasive scanning that is also used to scan cargo that is carried, for instance, in goods containers, to peer "without touching" into the delicate remains of ancient craftsmanship.

Neutron and gamma ray scan

In neutron and gamma ray scanning, samples are bombarded with high energy radiation to observe both transmitted and scattered radiation with the use of detectors. In the case of cargo scanning, the objective is to detect possible explosives, often hidden behind dense materials to prevent detection. Neutron and gamma ray beams are electrically neutral and manage easy passage through materials. The picture created by the transmitted and also the scattered particles enables the contents to be discovered, without any damage or the possibility of setting off explosions. The same method can equally analyse the internals of the scraps of artifact iron, without physical damage to the corroded filaments.

The analyses revealed that the samples were rich in nickel, cobalt, phosphorus and germanium — elements that are found in normal iron only in traces. "The really exciting outcome of this research is that we were for the first time able to demonstrate conclusively that there are typical trace elements such as cobalt and germanium present in these beads, at levels that only occur in meteoritic iron," says Professor Rehren.

"We are also excited to be able to see the internal structure of the beads, revealing how they were rolled and hammered into form. This is very different technology from the usual stone bead drilling, and shows quite an advanced understanding of how the metal smiths worked this rather difficult material."



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IN-DEPTH INTERACTIONS

TAPAN KUMAR MAITRA EXPLAINS THE PROCESS BY WHICH A HISTONE OCTAMER FORMS THE NUCLEOSOME CORE

The first insights into the underlying molecular organisation of the nucleosome emerged from the work of Roger Kornberg and his associates, who developed techniques for assembling nucleosomes from purified mixtures of DNA and protein. They found that chromatin fibres composed of nucleosomes could be generated by mixing together DNA and all five histones. However, when they attempted to use individually purified histones, they discovered that nucleosomes could be assembled only when the histones had been purified by gentle techniques that left histone H2A bound to histone H2B, and histone H3 bound to histone H4. When these H3-H4 and H2A-H2B complexes were mixed with DNA, chromatin fibres exhibiting a normal nucleosomal structure were reconstituted. Kornberg, therefore, concluded that histone H3-H4 and H2A-H2B complexes were an integral part of the nucleosome.

To investigate the nature of these histone interactions in more depth, Kornberg and his colleague, Jean Thomas, treated isolated chromatin with a chemical reagent that formed covalent cross-links between protein molecules that were located next to each other. After treatment with this reagent, the chemically cross-linked proteins were isolated and analysed by polyacrylamide gel electrophoresis. Protein complexes the size of eight histone molecules were prominent in such gels, suggesting that the nucleosomal particle contained an octamer of eight histones.

Given the knowledge that histones H3-H4 and histones H2A-H2B each form tight complexes, and that these four histones are present in roughly equivalent amounts in chromatin, Kornberg and Thomas proposed that histone octamers were created by joining together two H2A-H2B dimers and two H3-H4 dimers, and that the DNA double helix was then wrapped around the resulting octamer.

One issue not addressed by the preceding model concerns the significance of histone H1, which is not part of the octamer. If individual nucleosomes are isolated by briefly digesting chromatin with micrococcal nuclease, histone H1 is still present (along with the four other histone and 200 bp of DNA). When digestion is carried out for longer periods, the DNA fragment is further degraded until it reaches a length of about 146 bp; during the final stages of the digestion process, histone H1 is released.

The remaining particle, consisting of a histone octamer associated with 146 bp of DNA, is referred to as a core particle.

The DNA that is degraded during digestion from 200 to 146 bp in length is referred to as linker DNA because it joins one nucleosome to the next.

Since histone H1 is released upon degradation of the linker DNA, histone H1 molecules are thought to be associated with the linker region. The length of the linker DNA varies somewhat among organisms, but the DNA associated with the core particle always measures close to 146 bp, which is enough to wrap around the core particle roughly 1.7 times.

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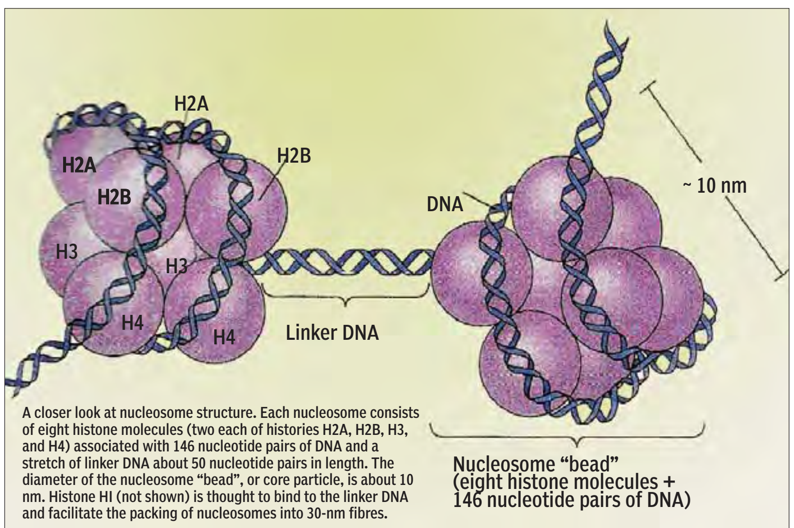


A closer look at nucleosome structure. Each nucleosome consists of eight histone molecules (two each of histories H2A, H2B, H3, and H4) associated with 146 nucleotide pairs of DNA and a stretch of linker DNA about 50 nucleotide pairs in length. The diameter of the nucleosome "bead", or core particle, is about 10 nm. Histone HI (not shown) is thought to bind to the linker DNA and facilitate the packing of nucleosomes into 30-nm fibres.

Fuel source of the future

THE URGENCY FOR COMMERCIALISING THE USE OF HYDROGEN AS AN ALTERNATIVE IS GAINING STRENGTH, WRITES **SWAYAMDIPTA BAG**

The dream of using hydrogen as a clean fuel source is closer to reality, according to new research at the University of Colorado in Boulder, USA. As per a recent report in the journal *Science*, researchers have developed a unique system that would use sunlight as an energy source to split water into hydrogen and oxygen. "The method," it said, "would use a vast array of mirrors that would concentrate sunlight onto a single point atop a central tower. The temperatures there could rise to as high as 1,350° Celsius." That energy would then be sent to a reactor vessel containing metal oxide (made up of a combination of iron, cobalt, aluminum and oxygen), which, when heated, would release oxygen atoms.

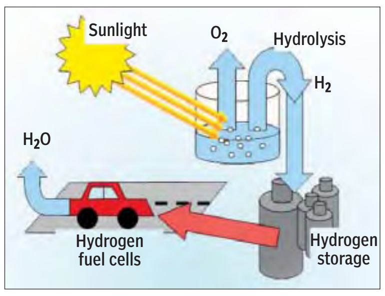
"That, in turn, would cause the material to seek out new oxygen atoms. When steam produced from the boiling water in the reactor vessel is added, the oxygen molecules would adhere to the metal oxide, freeing hydrogen molecules to be collected as gas." The most positive side of the system is that there is no swing in the temperature. However, the commercialisation of such a solar-thermal reactor will take some time.

The use of hydrogen as a clean fuel source is no new concept. The National Aeronautics and Space Administration has used liquid hydrogen successfully since the 1970s to propel its space shuttle and other rockets into orbit. In this method, hydrogen fuel cells power the shuttle's electrical systems, producing pure water (a clean byproduct), which the crew drinks. However, the urge for commercialisation of hydrogen power as an alternative source of fossil fuel is gaining strength in recent days. According to the British Broadcasting System, petroleum could last for only 50 years, natural gas 70 years and coal 250 years. But the greater rate of the use of fossil fuels invites largescale pollution globally. In spite of the enormous pollution of fossil fuels, all sources of non-conventional energy, like solar, tidal, sea wave, geothermal, wind, biogas, waste garbage recycling, bio-fuel (other than hydrogen) and ocean thermal energy conversion have failed to emerge as true alternatives of fossil fuels.

Of course, there are a good number of technical and economic obstacles behind such a grave situation and yet there is appropriate potentiality only in the use of hydrogen, which is the simplest element. A hydrogen atom consists of only one proton and one electron and it's also the most plentiful element in the universe. Despite its simplicity and abundance, hydrogen doesn't occur naturally as a gas on earth – it's always combined with other elements. For instance, water is a combination of hydrogen and oxygen, and hydrogen is also found in many organic compounds like hydrocarbons.

Hydrogen contains relatively high amount of energy and, once manufactured, it is an energy carrier. These energy can be delivered to fuel cells to generate electricity and heat, or be burned to run a combustion engine. As per safety standards are concerned, hydrogen fuel in automotive vehicles is as safe as gasoline.

Hydrogen can be produced in many ways. The use of a biological vector (bacteria or algae) as a means to split water and, therefore, produce hydrogen gas, would allow solar energy input.



In electrolysis, an electrical current could be used to separate water into its components of oxygen and hydrogen. Currently, most hydrogen is made from natural gas through the process of reforming. In this process, it could be separated from hydrocarbons through the application of heat. According to recent research report published in the journal *Nature Materials*, "tiny (nano-sized) particles of haematite (crystalline iron oxide, or rust) have been shown to split water into hydrogen and oxygen in the presence of solar energy. The result could bring the generation of cheap hydrogen from sunlight and water a step closer to reality, ultimately building globally benchmarked knowledge infrastructure for India.

An enthusiastic team of Virginia Tech researchers has discovered a new way to extract large quantities of hydrogen from any plant, and a report says this new environmentally friendly method of producing hydrogen utilises renewable natural resources, releases almost no greenhouse gases and does not require costly or heavy metals. It is true that previous methods to produce hydrogen have been expensive enough and create hazardous greenhouse gases, however, "to liberate the hydrogen, Virginia Tech scientists separated a number of enzymes from their native micro-organisms to create a customised enzyme cocktail that does not occur in nature". These enzymes, when combined with xylose (which comprises as much as 30 per cent of plant cell walls and is often called wood sugar) and a polyphosphate, it could liberate three times as much hydrogen as ordinary micro-organisms can achieve.

Whatever the process, we urgently need an abundant source of clean energy like hydrogen.

THE WRITER IS A LIFE FELLOW, THE GEOGRAPHICAL SOCIETY OF INDIA

PLUS POINTS

Two Mars moons

A spectacular new video from the National Aeronautics and Space Administration's Mars rover *Curiosity* "captured" the Red Planet's two tiny moons eclipsing each other in an otherworldly skywatching first. It snapped 41 images of the moons in the night sky on 1 August with rover scientists then stitching them together to make the final 30-second video. It is the first time a view of the two Martian satellites — called Phobos and Deimos — eclipsing each other has been captured from the vantage point of the planet's surface, Nasa officials said.

The new *Curiosity* video had plenty of scientific value in addition to its gee-whiz appeal, officials said. For example, researchers were studying the images to refine their knowledge of the orbits of Phobos and Deimos, both of which appear to be captured asteroids. "The ultimate goal is to improve orbit knowledge enough that we can improve the measurement of the tides Phobos raises on the Martian solid surface, giving knowledge of the Martian interior," Mark Lemmon of Texas A&M University said in a statement. "We may also get data good enough to detect density variations within Phobos and to determine if Deimos' orbit is systematically changing."

Lemmon is a co-investigator for *Curiosity's* Mastcam instrument, which took the pictures using its telephoto lens. Phobos' orbit was taking it closer to the surface of Mars very slowly, researchers said, while Deimos may gradually be getting farther and farther away from the planet. Phobos is just 14 miles wide on average, while Deimos is even smaller. But *Curiosity* was able to spot both of them because they orbit quite close to the Red Planet's surface — 3,700 miles in Phobos' case and 12,470 miles for Deimos.

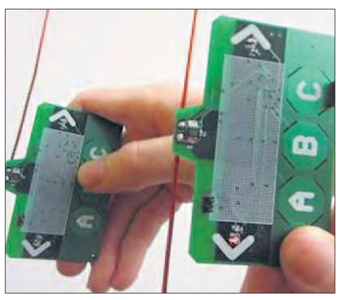
MIKE WALL

Power from air

Engineers from the university of Washington have created a new system of wireless communication devices that interact with one another without batteries or wired power. Called "ambient backscatter", the system works by absorbing the many types of transmissions – from radio waves, Wi-Fi, mobile networks and the like – that are all around us in the air. Prototype devices talk to each other by using antenna to intercept and reflect these signals back and forth.

"We can repurpose wireless signals that are already around us into both a source of power and a communication medium," said lead researcher Shyam Gollakota, an assistant professor of computer science and engineering. "It's hopefully going to have applications in a number of areas, including wearable computing, smart homes and self-sustaining sensor networks."

The new technology could greatly speed the development of the Internet of Things – the concept of imbuing our built environment with Internet connectivity — as current technology is hamstrung by the need to supply each device with its own power source.



The researchers give the example of building such communicating sensors into a bridge, monitoring the integrity of the concrete and steel. If an irregularity is detected, a signal is sent. This technology could be cheaply integrated into a range of structures, without the worry that the power supply would run out.

Other applications could be more prosaic but equally useful — tags for your keys and wallet to help you find them if they're lost; or sensors built in to credit cards to enable easy wireless payments.

JAMES VINCENT/THE INDEPENDENT