As I said in the last lecture, from the perspective of science as we know it today, science without text, science without writing, without inscription, without capturing the thinking of scientists—and their data, of course, and their reasoning process—in text is simply inconceivable. No writing, no science. This was already true in the 17th century when the scientific revolution took place. When modern science emerged it was already inconceivable that the people who we now recognize as the founders of modern science, it was inconceivable to them that they not write what they were claiming to have gotten knowledge of. So it was inconceivable to Descartes that he could simply tell the people around him his new methodology for gaining knowledge of nature.

Galileo used print technology brilliantly in order to disseminate his defense of the Copernican theory that the earth moves. Just telling that to a group of disciples who sat around him was not even an option already in the 17th century. How did that come to be? Already in the preceding 200 years of the Renaissance period, humanist scholars had made it the norm that all scholarship, all claims to knowledge, not just knowledge of nature, that all claims to knowledge are captured in print. Europe was effectively print drunk as soon as Gutenberg's moveable metal type print technology became available in the middle of the 15th century. Why was Western European society so ready to respond to the new print technology when it was introduced? I believe because of the legacy of the university tradition, which already had captured the Greek notion that learning is captured in books.

Now the Greek philosophers, starting from around 500 B.C.E. at least, wrote books, and those surviving books from the ancient Greek philosophers were the core texts that were studied at the medieval university. When the medieval university was invented, it was invented as a place where people went to study texts to acquire the knowledge of antiquity, to acquire what wisdom human beings had acquired through the study of texts, and that included theological texts as well. It meant studying commentaries on the Bible, for example. So learning, like legal learning, and medical learning, were associated in the university with the study of texts. Actually studying medicine clinically, which was another strand from the ancient Greeks, was to a considerable extent separate from that, as we will talk about later.

So the tacit, the automatic assumption that science entails writing is a legacy that comes from the ancient Greeks, and so the invention of the idea of writing and how it got to ancient Greece, and why the Greeks responded to it in the way that they did, is an important part of the rise of modern science. Note for now, and, again, something that we will be talking about in repeated lectures in the future, the connection between writing and knowledge as opposed to the connection between writing and doing.

In the last lecture I closed with a description of the accumulation of know-how in the preliterate period of human history from about 10,000 B.C.E. down to approximately, let's say, 3500 or 3000 B.C.E., when a writing system became available, and then spread; that know-how is not keyed to writing: knowledge is. I said then that this distinction, that the philosophical idea of knowledge that became a central part of the scientific tradition, that that idea of knowledge is tied from the beginning to writing. I said that this distinction between knowledge and know-how is reflected in the distinction between science and engineering and, by the way, the superior status that our society gives to science vis-à-vis engineering.

That understanding is rewarded and appreciated, so to speak, culturally more than just doing, that we think of engineering and technology as merely applied science. That means we're subordinating knowhow to knowledge. But even as we will see in the 19th century, modern engineering education, the foundations of techno-science as I described it in the last lecture, is associated with coupling science to engineering and technology—technological innovation—and the key to that turned out to be scientizing engineering. That means introducing science, math, and laboratory courses as the key to engineering education, as opposed to machine shop—to doing. This was a battle in the 19th century that we will be talking about in a subsequent lecture.

So the idea of writing continually comes up, so to speak, as the common denominator here. And that's why I think we need to think about the invention of writing and its transmission to ancient Greece, because that's what became the legacy that applied writing and knowledge in a way that became a tool. More than a tool, a core commitment of science.

Four quick points before we go any further. First of all, writing is a necessary condition for modern science, I believe, but it is not a sufficient condition. The fact that a culture acquires writing, and uses writing intensively, does not guarantee that it is going to generate the idea of knowledge that we find generated by the ancient Greek philosophers, or that modern science is going to arise in that society.

For example, China and Islam, and somewhat later India, all were very print-intensive societies. Especially China and Islam were print-intensive societies. The number of books that were written and printed in China—the Chinese used block printing and then moveable type printing; block printing was used probably 1,000 years before in the West, and moveable type was used hundreds of years before in the West. There were huge numbers of texts, and massive texts, that were printed in China, but the idea of modern science did not arise there. Islamic science and technology, especially from about the 9th century until the 13th century, was far superior to what we might call the science and technology in Western Europe, but the idea of modern science did not arise in Islam. So having writing is a precondition of doing science, but having writing is not a guarantee that science is going to emerge.

Second point: Not having a written language, not being literate, which sometimes has pejorative connotations when we talk about that today, clearly does not mean that a society or a culture is not sophisticated. That's why I spent so much time talking about the extraordinary sophistication of prehistoric, preliterate human beings. How much know-how they had accumulated, what they could do, how they were already transforming the world around them, transforming plants and animals, and through irrigation and construction technologies literally transforming the landscape around them. Within the limits of their knowledge and capabilities, of course—their know-how—they were quite sophisticated. It is a mistake to think that a society that is not literate is therefore not sophisticated and lacks sophisticated know-how.

Third point: What we mean by science is a particular approach to the study of nature, and one of the key foci of this course is to emphasize what makes it particular. But it is not the

only approach to the study of nature. For example, in Islam—especially, as I said, in the period from the 9th to the 12th, 13th, 14th centuries—in China, and in India, there was serious and systematic study of nature. But it did not morph into modern science as study in Western Europe morphed into modern science in the 17th century.

Fourth point: The reason why writing is necessary for science, why it is a necessary condition for science, is because what we mean by scientific knowledge is an abstraction. Unlike know-how, which can be embodied in things and processes and evaluated without needing writing, you can look at—I think I used the illustration of somebody making a bronze pot or making a bronze weapon or making a steel blade for a sword—and you can see either it's good or it's not good, the person either knows how to do it or they don't know how to do it, or how well they know how to do it, etc. So the know-how can be literally embodied, can exist in it, and that's what makes it easier to transmit and to disseminate without writing. But what we mean by science, and we see this, we begin to see this in the 17th century, but it was already evident in ancient Greece, refers to a reality that we do not experience, and that we cannot experience. In principle we cannot experience quarks. We do not experience the microwave background radiation that is, for some, a sign that the big bang theory of the origin of the universe is, roughly speaking, correct. We do not experience cells. We do not experience the base sequence in our DNA guiding the cell metabolism and the metabolic processes of our body. Writing is what embodies scientific knowledge.

Okay, with that as a kind of a background, let's take a look at the invention of writing, which as a historical fact could change if new artifacts are discovered, of course, but it seems as though writing was invented by the Sumerians in the mid-4th millennium B.C.E. The Sumerians were a non-Semitic people speaking a non-Semitic language who moved into, possibly from central Asia, moved into the 18 ©2007 The Teaching Company southeastern sector of what we were all trained to call the Fertile Crescent and to consider the birthplace of civilization. Although the writing was preceded by seals and tokens, which have a symbolic character of course, and we would expect that—because for thousands of years before writing appeared, human beings were living in fairly large social complexes with trade and commerce and government and religion, so there had to be some kind of systematic record keeping—but it is with the Sumerians that we get the first writing system that we know about. And we take this for granted.

Writing was an invention. Writing was invented. Writing is a symbol system. It's a system. The whole thing hangs together, you can't just have one letter. Well, actually at the beginning, the Sumerian language system, and as far as we can tell all the earliest language systems, were logographic. That means that the sign stood for some idea. Sometimes this is called ideographic or pictographic. There are differences among these, but we don't need to concern ourselves with them. The first writing system that we know of, in Sumer, was the signs stood for ideas, stood for what we might call a concept or an idea, and it evolved eventually into an alphabetic language. There is no need for an ideographic language to evolve into an alphabetic language; we see that in Chinese, for example.

The Chinese language probably evolved about 1,500 years after the Sumerian language, ostensibly independently, but there was enough contact between, let's say, 3500 B.C.E. and

1500 B.C.E. between the Middle East and Central and Eastern Asia that it is not impossible that the rise of writing in China was not independent. But it is generally considered to, in fact, have been independent. So the earliest Chinese written inscriptions are from the middle of the 2nd millennium B.C.E., although it is suggested that the signs in that language already existed in maybe 2000 B.C.E., but that is somewhat speculative.

Egypt, by contrast, is very close to Sumer, only a couple of hundred miles away, and there was considerable contact between the Egyptians and the Akkadian Babylonians who conquered the Sumerians in the early 3rd millennium B.C.E., the late 2000s B.C.E., The rise of Egyptian hieroglyphics probably was a reflection of the dissemination of the Sumerian writing system.

The Sumerians inscribed their writing system on clay tablets, so that's called cuneiform. It has nothing to do with the language. The language was logographic as a type of language. That means that each symbol stood for an idea, and typically initially had a pictorial character. But that became clumsy when you wanted to write a long book so that fairly quickly, in both hieroglyphics and in Sumerian cuneiform, the symbols became stylized, and no longer had a strictly pictorial character. You had to learn what the relationship was between the sign and the idea it represented or, in time, the sign and the syllable, how you pronounced it, or the sign and, so to speak, the alphabetic letter that let you string words together in the way that an alphabetic language allows.

Note something very interesting about writing. Once you develop a writing system, it's got to be taught. You have to learn it. There's no natural connection. The pictures start out with this natural connection, but that turns out to be very cumbersome, and in fact, even at the pictographic stage we see that in ancient Egypt and in Babylon there were schools for teaching writing. People had to learn it, and of course once it becomes syllabic or alphabetic, then the signs are completely arbitrary, and there's no way that you can learn to read the language without being taught, so there's a kind of school that arises in a society that adopts language.

So cuneiform script, in which the symbols were ideographic or logographic, was introduced by the Sumerians. Regardless of whether the pictures made sense or not in Sumerian, what happened next is quite interesting. The Sumerians were conquered by the Akkadians, who were a Semitic people who sort of migrated east from the land that in the Bible is called Canaan, and they conquered the Sumerians, and established the first Babylonian Empire. They took the Sumerian writing system, which was invented for a non-Semitic language, and they used it in their Semitic language.

Akkadian is a Semitic language. It is a totally different type of language from a totally different family of languages. It's not like the relationship between French and English or even between French and Spanish. ©2007 The Teaching Company 19 The fact that the Akkadians adopted and adapted the Sumerian script meant that they really did have to take those signs as arbitrary. You really had to learn what those signs stood for because it was a totally different kind of language. That happened sort of seamlessly in the late 2000s B.C.E., and somewhere between 1500 and 2000 B.C.E., that language, which was originally

logographic, in which fairly complicated picture-like symbols were used, became alphabetic. And that seems to have happened in the land of Canaan, which in fact is referred to as Ugarit, and there is a text that has been discovered from, roughly speaking, 1200–1500 B.C.E. written in an alphabetic script.

What's particularly important for us is that Ugaritic, an alphabetic language, perhaps the first alphabetic language that the world has known, was adopted by the Phoenicians—the Phoenicians lived in what is nowadays Lebanon—and by the ancient Hebrews, and later by the Arabs. So Phoenician, Hebrew, and Arabic all have very close common roots, and the alphabets in those languages have striking similarities among them, all being Semitic languages. The Phoenicians are of particular interest because they were the master merchants of the Mediterranean for centuries, starting somewhere around maybe 1200–1100 B.C.E. As they traded through the Mediterranean, they disseminated their alphabetic language to nonliterate people, I guess because it was good for business. It made it easier to do business with people who could communicate with you in writing, and keep records that you could use and rely on.

And in particular, somewhere around the 9th century, in the 800s B.C.E., they taught the Greeks their alphabet. So alpha, beta, gamma, delta in Greek; alef, bet, gimel, dalet in Hebrew, which is the same as the Phoenician, that's not an accident. Now isn't that a cute coincidence? The letters of the Greek alphabet are similar to the Phoenician and Hebrew Ugaritic Canaanitic alphabetic language. No, it's not a coincidence at all. They were taught that.

It is likely that an earlier phase of Greek society, back around 1200 B.C.E., had a written language, a rather clumsy one, derived from Cretan. You may have read about Linear A and Linear B as two ancient languages. Linear B was deciphered after many years, and seems to have been associated with the Minoan civilization dominated by Crete that was destroyed apparently by earthquakes somewhere around 1400 B.C.E. And the ancient Greeks, the Mycenaean Greeks, the ones that fought the Trojan War, perhaps had some written culture, although there's almost no evidence and certainly nothing like a text. But the Hellenic Greeks, the Greeks that we, so to speak, know of from about 800 B.C.E. on, they were taught writing by the Phoenicians, who also taught it to the Etruscans because they traded with the Etruscans in Italy. The Etruscans taught it to the Latins, whom we know as Romans. So the Phoenicians acted as a conduit for the first alphabetic language, which evolved directly out of the Akkadian assimilation of the Sumerian invention of writing.

Now, the Greeks responded to writing with incredible enthusiasm and creativity. The Greek reception of writing led to almost an immediate explosion of cultural productivity, of poetry, of drama, of philosophy, of mathematics, of medicine. The Greeks started pouring out by 500 B.C.E., obviously not the average citizen, but there was a subset of Greek society for whom the production and reading of books were the norm. We can see this very clearly, for example, in Plato's Dialogues written in the middle of the 4th century B.C.E., where it's just taken for granted that an intelligent person, an educated person, reads the books by the philosophers of the preceding hundred or so years. Many of those books failed to survive, but some did, and so we have some idea of what those were.

So since it was in ancient Greece that the idea of knowledge was formulated, became embedded, became the cornerstone of scientific knowledge as we understand it. And since the Greeks responded to writing by making writing books the norm for those who know, there is a kind of a direct line of descent from the invention of writing in Sumer through the morphing of that cuneiform writing into an alphabetic language being taught by the Phoenicians to the Greeks, transmitted through the medieval university to Western Europe as well as other places—Islam, for example.

So it's a kind of interesting way of looking at modern science that a core feature, without which science simply can't be done, has an ancestry that goes back to the invention of writing by the ancient Sumerians. The Teaching Company It has nothing to do with the invention of writing in ancient China, if in fact that was independent, or in the Americas, where in the 1st millennium B.C.E. writing, pictographic writing, and a kind of writing in which the symbols have a phonetic character, apparently, was developed by the Olmec, the Zapotec, and the Mayans; most notably by the Mayans. We only relatively recently deciphered the Mayan inscriptions.

But it's kind of unwieldy to inscribe text on stone as opposed to writing them on papyrus or on parchment and copying and distributing them. We know as a matter of fact that in ancient Greece there was a trade in books already in the 4th century B.C.E.; that people made their living as copyists, for example, copying texts for people. Socrates repeatedly refers to how many drachmas it cost for someone to copy a book if they wanted one, etc.

So we need to recognize, however, some very important things about writing that are often taken for granted. First of all, that it is an invention, and as such, it is the incarnation of an idea. For thousands of years people got along without writing. Why do they all of a sudden need writing? Who did it and why? What was the necessity that was the mother of that invention? We say necessity is the mother of invention. Well, maybe it's true, maybe it's not, but let's suppose we take it for true, what necessity? Was it the social? That the intensifying socialization of life made government and trade, made controlling a population and engaging in life as the population increased and you had all kinds of activities going on, was that the necessity? Well, we don't really know.

There are many different stories in antiquity. People recognizing the power of writing and the glory of writing, sometimes they attributed writing to a gift from the gods. Sometimes to ancient legendary heroes or legendary wise people. In China it was attributed to Ts'ang Chieh, who was a minister of the legendary emperor Huang Di, the "Yellow Emperor." There's no evidence that either of these two characters actually existed, but subsequently in China, looking back to their glorious origins, attributing to their greatest emperor of old and to his wisest minister, the invention of writing. The Greeks sometimes attributed it to a god, Prometheus. Aeschylus in his plays attributes writing to Prometheus because, he says, well, it was an aid to memory. Euripides, on the other hand, disagrees with that, and thinks that the legendary Greek hero Palanites invented writing as a way of long distance communication so you could send letters to people and tell them news and gossip and what you wanted them to do. Aristotle, writing in the 4th century B.C.E. somewhere around

330–340, writes that writing is in the service of money making; that it is particularly useful for keeping records for the household so that you know exactly how much is coming in and how much is going out, and what you're spending your money on. There are many tales of the origin of writing, but we don't know who invented it, and we don't know what the motivation for it was. So, one, it's an invention and it involves an idea. It's a system and, as we will talk about, it's a symbol system. That's very important because symbols need to be interpreted and to be understood.

I want to emphasize now something that is of fundamental importance about technology and knowledge, and that is that—I already referred to this—there is no guarantee that because a technology is introduced into a society that it will be exploited, or the form in which it will be exploited. Writing is a technology; writing is an invention. It's a technological innovation. It also has intellectual implications. We wonder what the connection is between writing and thought. Is writing merely a way of capturing speech, or do you get a kind of a positive feedback loop between writing and thought so that when you write things down you start thinking differently because you can then read what you have written, you disseminate what you write, people respond to what you write, that prompts other people to think in different ways?

So that's another interesting thing about writing. It becomes more valuable the more widely it is disseminated. And we'll see this happening sometimes with technologies. The telephone system: every new telephone makes every other telephone more valuable. You don't get a law of diminishing returns. On the contrary, the value of the Internet goes up as more and more people use it, and just as we saw with the Internet, the more people there are, the more new kinds of goods and services that are invented by people to take advantage of the universality of the Internet. The same thing is true of writing; but it's not automatic.

"A new invention," as Lynn White said, "opens doors." We'll come back to that quotation in a later lecture. It does not force any society to enter through that door. And as a matter of fact, as much as you may think, well, writing is a gimme; once you have writing, you automatically accept it. As a matter of fact, that was not the case. Socrates did not write anything; Plato wrote about his teacher Socrates. Socrates, in fact, in the dialogue called the Phaedrus, gives a sustained argument against writing, and I want to read part of that, because what Socrates says seems to me very powerful. He attributes the invention of writing to Egypt. He assigns it to Egypt and to the Egyptian god Thoth, who gives it to the king. I'm reading from the text of Plato's Phaedrus now:

> Here, O king, is a branch of learning that will make the people of Egypt wiser and improve their memories. My discovery provides a recipe for memory and wisdom. But the king answered and said "O man full of arts, the god-man Thoth, to one it is given to create the things of art and to another to judge what measure of harm and of profit they have for those that shall employ them."

A very prescient and insightful thing for the king to say. The people who make new inventions, who invent new technologies, are not the people who understand what the social impact of those technologies are going to be.

And so it is that you by reason of your tender regard for the writing that is your offspring have declared the very opposite of its true effect. If men learn this, it will implant forgetfulness in their souls. They will cease to exercise memory because they rely on that which is written, calling things to remembrance no longer from within themselves, but by means of external marks. What you have discovered is a recipe not for memory, but for reminder. And it is no true wisdom that you offer your disciples, but only the semblance of wisdom, for by telling them of many things without teaching them you will make them seem to know much while for the most part they know nothing. And as men filled not with wisdom but with the conceit of wisdom they will be a burden to their fellows.

Socrates goes on and compares a written text to a painting:

The painter's products stand before us as though they were alive. But if you question them, they maintain a most majestic silence. It is the same with written words. They seem to talk to you as though they were intelligent, but if you ask them anything about what they say from a desire to be instructed they go on telling you just the same thing forever.

The written text is dead. It is almost guaranteed to be misinterpreted, and therefore, it's really not the gift that it looks like. Okay for record keeping, for remembering that so-and-so owes you $50 and it's due next Monday, but a text is not a substitute for direct face-to-face learning and the transmission of knowledge, which Socrates believed was the only way that one person could communicate knowledge to another.