Computing and Cultures: The History of Information Technology Before the Digital Age

Early Information Systems

Humans use both tools and information. Our species name is *homo sapiens* – the people who know things. But we have also been called *homo faber* – the people who make things. Both of these are true. From the origins of human culture, people the world over used tools not just for hunting, fishing, and farming, but also for recording information.

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Early African Civilizations

1. **Ishango Bone**: Discovered in the Congo, this bone tool is believed to be one of the earliest forms of counting or tallying, dating back to around 20,000 years ago.
2. **Yoruba Counting**: The Yoruba people of Nigeria used a base-20 counting system, which influenced their complex mathematical and divination practices.

Pre-Columbian Americas

1. **Maya Numerals**: The Maya civilization developed a vigesimal (base-20) numeral system and were one of the earliest to use the concept of zero.
2. **Quipu (Inca)**: The Inca used a system of knotted strings called quipu for record-keeping and calculations. Different knots and string positions represented numbers and information.

Polynesia

1. **Lapita Pottery**: The Lapita culture used patterns and counts on pottery for record-keeping and navigation.
2. **Navigational Calculations**: Polynesians used complex methods for navigation across the Pacific, relying on star positions, wave patterns, and other environmental cues.

Native North America

1. **Wampum**: Some Native American tribes used wampum (beads made from shells) for counting, record-keeping, and trade.
2. **Tally Sticks**: Native tribes used tally sticks to keep track of quantities and transactions.

Ancient China

1. **Counting Rods**: Chinese mathematicians used counting rods placed on a counting board to perform calculations, using a decimal place value system.
2. **Abacus (Suanpan)**: The Chinese abacus, or suanpan, allowed for more advanced arithmetic operations, including multiplication and division.

Ancient India

1. **Hindu-Arabic Numerals**: The numerals 0-9 originated in India and were later transmitted to the Islamic world and Europe. Indian mathematicians also developed sophisticated methods for arithmetic and algebra.
2. **Vedic Mathematics**: This ancient Indian system involved mental calculation techniques and sutras (aphorisms) for rapid calculations.

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The use of recorded information to track crop yields, trade agreements, tax payments, and standard weights and measures allowed early civilizations to expand in size and complexity. The first recorded civilization arose in Sumer in the lower Tigris and Euphrates valley. Sumer kept records on clay tablets with wedge shaped markings called cuneiform. Egypt also featured a very early civilization, known for its colorful hieroglyphic writing as well as for its famous pyramids. As civilizations like these expanded into their frontier areas, they encountered one another. Sometimes this led to peaceful trade. At other times, civilizations attacked and conquered one another. Sumer was replaced by Akkad, which itself was supplanted by Babylon. The Persian Empire conquered both Babylon and Egypt. The Greek speaking Macedonians under Alexander the Great overran Persia and all of its many provinces. Rome then overtook Macedon. Century after century, peoples clashed with one another, exchanging not just blows but also new technologies and innovative ideas. Through both trade and conquest, innovations such as iron tools, the wheel, the chariot, and written language took hold across the ancient world. The writing we still use today is based on one of these ancient innovations. Cuneiform used marks to represent syllables. Hieroglyphics represented whole ideas, syllables, or sounds. The Phoenicians, a coastal people situated between Egypt and the cuneiform civilizations of Mesopotamia, were the first use an alphabetic writing system in which each mark represented a single sound. This sort of sound-based alphabet is adaptable to many world languages. Peoples near the Phoenicians, like the Hebrews and the Greeks, picked up on the Phoenician idea and created alphabets for their own languages, keeping some of the Phoenician letters but changing others or adding new ones to represent their own distinctive sound systems. The Roman Latin alphabet, the one we still mostly use for modern English today, was based largely on the Greek. Can you imagine modern information technology without an alphabet? Our modern systems owe more to the ancients than many of us realize!

The Middle Ages

After the fall of Rome, Western Europe was a backward frontier region on the edge of a great chain of civilizations spanning from East to West across the middle latitudes of Asia, Africa, and the European peninsula. Chinese civilization flourished under the Song Dynasty. India established a great culture, spawning numerous dynasties, religions, and philosophical systems. In the Islamic world, the Baghdad Califate led the world in scientific research and preserved the best of ancient Greek and Roman philosophy. Meanwhile, in Europe itself, the legacy of ancient knowledge barely hung on as cloistered monks copied ancient texts by hand onto vellum pages made of calf skin. Europe at this time focused more on fighting than on learning, and in a history of information technology, Europe is barely worth a mention for hundreds of years after the fall of Rome. Yet by the middle of the 15th century, Europe stood poised to effectively conquer the entire world. What happened? How did a cold, wet, remote, backwater region like Europe rise to global power?

One key to Europe's rise was European willingness to learn and borrow ideas from everyone else. Sourcing technologies across long distance global trade routes, Europe borrowed paper, printing, the magnetic compass, and gunpowder from China. From the neighboring Islamic civilization, European relearned ancient Greek and Roman ideas, as well as Islamic advances in fields like astronomy and medicine. By way of Islam, Europe also obtained a number system more flexible than Roman numerals based on letters of the alphabet. Islamic numerals also incorporated a critical Indian innovation – the number zero – which is vital to the study of algebra, a branch of mathematics whose name derives from the original Arabic.

But if all these technologies and innovations were available all over the ancient world, why did Europe in particular gather all the best solutions and roll them into a movement we now call the Scientific Revolution? An important factor that set Europe apart from other ancient and learned parts of the world was that no single emperor was ever able to conquer Europe. From the 10th to the 20th centuries, European nations were frequently at war with one another. To gain advantages in these endless wars, each nation in turn was always looking for better weapons, more accurate ways to aim cannons, different trade routes, and new sources for timber, spices, silk, gold, silver, or other materials needed to pay soldiers and to prop up royal power. China, by contrast, had entered a great age of discovery in the early 15th century sending hundreds of massive junks as far as the coast of Africa. But the Ming emperor, who then ruled China, put a sudden stop to these voyages. The all-powerful emperor thought these great ocean trips were a waste of money and preferred to focus attention on matters closer to home. Just few years later, sailors like Christopher Columbus and Vasco da Gama launched the age of European discovery. Unlike in China, in Europe there was no all-powerful emperor. If one monarch refused to finance an explorer's fleet, there were other monarchs who could be approached. Columbus asked one monarch after another to fund his voyages, until finally the Spanish monarchs agreed to it, mostly to prevent Columbus from sailing for anyone else. With respect to religion also, Europe was a land of competition. After the Protestant Reformation in 1517 if a church in one nation banned a scientific idea or discovery, a monarch in another country with a different religion could adopt the idea and try it out. Given multiple monarchs and multiple religions, all battling for power but with none of them able to control the whole civilization, Europe transformed from a technical backwater to a hotbed of discovery. Gutenberg's movable type printing press was a key innovation. This led to affordable printing and a mass market for books. Early scientists were spread all over the European continent, but they kept in touch with one another through a physical network of written correspondence called by historians the Republic of Letters. Thinkers like Copernicus, Kepler, Galileo, and Newton informed one another, and created both the science and the mathematics needed for the advent of modern computing.

Early Modern Computing

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During the early scientific revolution, several leading computing ideas and developments laid the groundwork for modern computing. These ideas were largely driven by the needs of scientists and mathematicians to perform more complex calculations and manage data more efficiently. Here are some of the key concepts and inventions:

1. Logarithms

- **John Napier (1614)**: Introduced logarithms, a mathematical tool that transformed multiplication and division into simpler addition and subtraction operations. This innovation greatly facilitated complex calculations, especially in astronomy and navigation.

2. Slide Rule

- **William Oughtred (1622)**: Invented the slide rule, a mechanical device based on logarithmic scales. The slide rule became an essential tool for engineers and scientists for rapid calculations before the advent of electronic calculators.

3. Mechanical Calculators

- **Wilhelm Schickard (1623)**: Designed the first known mechanical calculator, called the "Calculating Clock," which could perform basic arithmetic operations.
- **Blaise Pascal (1642)**: Developed the Pascaline, a mechanical adding machine that could perform addition and subtraction.
- **Gottfried Wilhelm Leibniz (1673)**: Invented the Stepped Reckoner, a more advanced mechanical calculator that could perform addition, subtraction, multiplication, and division. Leibniz also developed the binary number system, which is fundamental to modern digital computing.

4. Binary System

- **Gottfried Wilhelm Leibniz (1679)**: Published his work on the binary numeral system, which represents numbers using only two symbols, 0 and 1. This system is the foundation of modern computer science and digital electronics.

5. Mathematical Tables

- **Henry Briggs (1624)**: Worked with John Napier to create logarithmic tables, which provided precomputed values of logarithms and were widely used for complex calculations.
- **Edmund Gunter (1620)**: Developed Gunter's scale, a precursor to the slide rule, which used logarithmic scales to aid in calculations.

6. Analytical Geometry

- **René Descartes (1637)**: Introduced Cartesian coordinates and analytical geometry in his work "La Géométrie." This mathematical framework allowed geometric problems to be expressed in algebraic terms and vice versa, leading to the development of calculus.

7. Calculus

- **Isaac Newton and Gottfried Wilhelm Leibniz (late 17th century)**: Independently developed the foundations of calculus, a branch of mathematics dealing with continuous change. Calculus became a crucial tool for scientific and engineering calculations.

8. Differential and Integral Calculators

- **Leonhard Euler (18th century)**: Made significant contributions to the development of calculus, introducing many of the notations and methods still in use today.

9. Astronomical and Navigational Tools

- **Johannes Kepler (1609, 1619)**: Formulated the laws of planetary motion, which required extensive numerical computation and led to the development of more sophisticated mathematical techniques.
- **John Flamsteed and Edmond Halley (late 17th century)**: Improved astronomical tables and navigation techniques, necessitating accurate and efficient computation.

10. Punch Card Technology

- **Basile Bouchon (1725)**: Developed an early form of punch card technology for controlling looms, which later influenced data storage and processing techniques in computing.

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While most of the world remained culturally conservative, focusing on existing technologies and traditions, Europeans achieved one scientific breakthrough after another. With the invention of the steam engine and the industrial factory system of production, European power stood head and shoulders above the rest of the world. Entering the 20th century, Europeans in general felt a sense of superiority and entitlement, based on their many advances. Other nations copied as best as they could. Japan, for example, traded in many of its ancient traditions for Western dress and Western production methods, even trying to copy Europe by setting up its own colonial empire. The United States, a European offshoot, embraced the culture of competition and innovation and became the seat of many crucial technical inventions such as the telegraph and the telephone. It seemed as if Western culture was destined to rule the world for the remainder of time. But by the middle of the 20th century, Europe lay in ruins. Global power lay more in the hands of the United States, Russia, and China. How could Europe, the home of the Scientific Revolution, fall from dominance so suddenly?

In one of history's greatest ironies, the very thing that promoted European dominance – competition fueled by warfare – proved to be Europe's ultimate undoing. The application of science, technology, and industrial production to mass warfare led to the vastly destructive First World War, followed all too soon by the even more destructive Second World War. Science and technology put a punctuation mark to an entire era of human history with the dropping of the first atomic bomb. The Manhattan project was formed, under the suggestion of Albert Einstein among others, to create a weapon so terrible that the Allies must surely win the war. On seeing results of the first atomic test, Manhattan project director J. Robert Oppenheimer was moved to quote the Bhagavad Gita: "I am become death, the destroyer of worlds".

The massive destruction and death struggles of the World War II era form the grim backdrop for the invention of digital computing. The first digital computers were weapons systems. They existed to improve the effectiveness of artillery fire or to break the enemy's codes. Governments and militaries the world over still use computing for such combat purposes. But just as iron has far more uses than only swords, information systems have far more purposes than establishing dominance over a threatening enemy. Now as digital computing faces its second century, the world must ask itself if war or peace will be the leading theme for history in the future that lies before us. But to understand that future better, and to explore the many ways our future might possibly turn out, we must first understand the many inventions and innovations that created our current digital society. The following chapters will tell that story, exploring the basis of, the applications for, and the key connections between each of the most vital digital technologies.