TECHNOLOGY and MANUFACTURING

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Hunting and Gathering Humans are tool using animals, not uniquely among species but with distinctive abilities to innovate. The long human experience before agriculture showed a very slow but steady improvement in tool use (and related capacities, such as boat building). From early stone age reliance on simply picking up objects in nature for use as tools – stones, shells, pieces of wood – the later stone ages (Mesolithic, Neolithic) developed increasing capacity to make tools deliberately. Tools for hunting, and fishing, were particularly important. Many societies invented similar objects independently. An arrow, for example, has been found in South Africa dating from over 60,000 years ago, but stone-tipped shafts, and later bows, were invented in other places as well. Knowledge of some tools, however, spread from contact, particularly in Afro-Eurasia. Improved Neolithic tools, including implements to work the ground, were fundamental to the emergence of agriculture, but agriculture in turn would encourage further technological change.

Impact of Agriculture Agriculture created a certain amount of food surplus, that could free up some people, at least part-time, to work on other kinds of production, including manufacturing. Agricultural societies also had new technological needs. Food storage, for example, was crucial, and improvements in basket-making and pottery were fundamental. A potter's wheel was invented around 6000 BCE in the Middle East, a basic contribution to storage devices; and related artistic work, in adorning pots, pitchers, and vases, reflected this important category. Invention of metal use was even more important, affecting agriculture, manufacturing, and military activity alike. Work with copper came first, then bronze which created firmer implements – around 4000 BCE. Iron was introduced, possibly first in central Asia, around 1500 BCE, creating more effective tools both for farming and for war. Knowledge or independent discovery of these technologies was uneven. Japan bypassed a bronze age, but ultimately learned about iron. The Americas lacked metal technologies (other than precious metals, for adornment) altogether until the arrival of Europeans. Native Americans also lacked the wheel – another key invention in west Asia around 4000 BCE; Americans used wheels for children's toys but no more. Elaborate American agriculture continued to depend on essentially Neolithic technologies, and this was also true in Pacific Oceania.

Artisans New technologies like the potter's wheel and, particularly, metals called for new skills and some specialization in manufacturing. Villages for example required a blacksmith to produce horseshoes (though leather coverings were long used instead) and metal implements. References to these producers are common in early civilizations, often linking them to the gods. All complex societies also developed larger clusters of artisans in cities, making a variety of objects, mainly for local sale and often with a great deal of artistry combined. The importance of skilled artisans extended throughout the remainder of the Agricultural Age, relying on fairly simple tools and, mainly, human power for their production. Millers, however, did use animals or water power to process grains – the one main exception to the reliance on human energy in manufacturing. One other aspect of artisanal production warrants attention: many artisans, because of the value of their skills, and many artisanal organizations tended to resist further technological change. Artisans in many regions – Japan, the Middle East, Europe – formed guilds which oversaw the quality of production, protecting consumers from shoddy goods, but which also guarded against too much innovation.

Agriculture Early agriculturalists used small sticks to dig holes for planting. It was many centuries before wooden ploughs were introduced. China, which became the world's leader in innovation by the classical period, developed the first iron plough, around 500 BCE. Knowledge spread only gradually - technology diffusion was a slow process given the limited contacts in much of the Agricultural Age; Europeans learned of iron ploughs only about 600 CE, where they proved vital in handling the heavy soils of the north. Horse collars, introduced in China late in the classical period, allowed more use of animals in agriculture, and here too knowledge gradually extended to other regions. The scythe was invented around 500 BCE, more effective than the sickle. Romans used the scythe, but this did not persist in Europe and the scythe was reintroduced there only around 1200. China introduced the wheelbarrow, and again other regions gradually picked up the idea. Agricultural inventions deriving from metal use obviously occurred gradually, with major developments usually arising first in Asia and then diffusing slowly.

Other Innovations Classical India generated the most advanced steel industry, adding alloys to iron; though steel gained only limited use until the 19th century. China pioneered in the invention of paper, during the classical

period – vital to the country's considerable bureaucracy. Arabs learned of paper from warfare in western China; two prisoners, brought back to Baghdad, set up the first paper production in the 8th century CE. Europeans copied only later, with a first factory in Sicily in the late 11th century. Printing was first introduced in China in the 11th century, using ceramic blocks; Korea added metal plates a bit later, and Europeans learned of this technology by the 15th century, introducing important improvements at this point, particularly through use of movable type. Other technologies were discussed – for example, the idea of the steam engine surfaced in Hellenistic Egypt and was later considered by both Arab and European scholars. But there were no basic changes in energy sources until the 18th century.

Other Manufacturing Besides artisanal production, some societies also introduced systems of domestic manufacturing, for production of goods for wider sale. This system used home-based production and simple tools, with workers sometimes combining manufacturing with agriculture. Silk production in China initially relied on home-based production, mainly by women, from its introduction around 1000 BCE. Silk thread was then collected by merchants, who took it to larger production centers for weaving. Domestic production, in textiles, shoemaking, and tool making, spread in Europe during the early modern period and also anchored the production of cotton thread in India. Larger production units were rare. In China and later Byzantium, silk weaving took place in larger shops. Shipbuilding was a large operation as well, in many parts of Asia and Europe during the Agricultural Age. In Venice the city-sponsored arsenal employed 16,000 workers at its height. The construction of Chinese junks, in the 15th century, also organized largescale work forces. But these were exceptions during the Agricultural Age as a whole.

Early Modern Changes The acceleration of trade in the early modern period encouraged further manufacturing and, ultimately, technological change. Many scholars talk of an "industrious revolution" in Europe in the 17th and 18th centuries, centered particularly around the spread of domestic manufacturing, outside the boundaries of artisanal guilds. Japan saw manufacturing growth as well, despite being cut off from most global trade. Technological adjustments were part of this process; Chinese inventors for example developed several improvements in manufacturing technologies by the 18th century. By this point, however, technological leadership began to pass to Western Europe, for the first time. Europeans were spurred by opportunities for wider sales both at home and globally, as Europe's trade expanded. Many businessmen wanted to compete more directly with Asian production. By the late 17th century for example, a number of Europeans experimented with new devices to print cotton cloth, to allow competition with skilled, but low cost, workers in India. European culture, stimulated by the Scientific Revolution, also became more open to the idea of technological change and material improvements. Finally, in Britain specifically, a decline in the availability of wood spurred attention to coal mining as an alternative fuel, and the first working steam engine, early in the 18th century, was designed to pump water from deeper mines. Use of coal instead of charcoal for iron smelting was a related change, though techniques here had been introduced in Asia as well. Historians continue to debate why European technology began to diverge from global patterns – the "great divergence" – but several factors seem to be involved.

The Industrial Revolution The essence of the industrial revolution was dramatic technological change, particularly in manufacturing and transportation. Initial changes focused on the development of a practical steam engine by the 1770s, first used widely in textiles and later employed in other industries and in shipping and railways. Use of fossil fuels for energy massively expanded production potential. Equipment to make more manufacturing operations automatic, so that systems would require less labor involvement, was the second basic change. New looms moved thread more automatically – the famous "flying shuttle" initially developed for domestic workers in the 1730s. Combining this technology with steam or water power, and putting production operations into factories where labor could be supervised more intensively, began to expand production very rapidly in key industries. Manufacturing began to outstrip agriculture as the fundamental source of wealth, though technological changes in agriculture, including use of new equipment for harvesting, were vital for the industrialization process as well, releasing labor from the farms and allowing a much smaller percentage of the population to produce basic food supplies. The old principle of the Agricultural Age – eight farmers needed for every ten people total – began to be transcended. Gradually, also, industrial technology and the innovations in transportation displaced widespread use of animals, though a full conversion, even in the leading industrial centers, would await the 20th century.

Geography Britain led in the new industrial technologies, but key inventions also occurred in France, the new United States and elsewhere. Europeans and Americans began to copy British inventions by the 1820s, though Britain tried until the 1840s to keep them secret. Full-scale industrialization began by this point in much of Western Europe, with Germany quickly in the lead, and in the United States. Pilot factories and limited rail systems spread

by the 1850s to Russia, Latin America and elsewhere, but full-scale adoption of the new technologies remained a Western monopoly until later in the 19th century. Then, both Japan and Russia began the process of conversion. Later industrializations had the advantage of being able to copy more advanced machinery – for the industrial revolution sponsored recurrent technological change, at a far more rapid pace than before – but they also faced great competition and often depended on outsiders for some initial technological advice.

The Contemporary Period Three related developments mark the past century in technology and manufacturing in world history. First, massive technology change continued. Even before 1900 oil began replace coal as basic fossil fuel source, and this created new types of engines for transportation, construction work and the like. Increasingly automated processes, aided ultimately by the computer, steadily increased labor efficiencies. Second, basic industrial technologies spread more widely around the world. Key governments sponsored local industries, for example in textile and automobile production, displacing imports in a process known, in fact, as import substitution. Local and foreign businessmen set up factories as well. By 2000 most of the world's population, and not just a largely Western minority, became directly involved with the industrial economy and industrial technology. Third, feeding from this, a number of societies began importing industrial goods from newer centers, such as China, and turning instead to the development of services and other high-technology areas. Japan, the United States, and Britain, most obviously, became centers for banking, insurance, financial services and also commercial entertainment, with a declining manufacturing sector.

Sources

1. "The Origins of Stone Tool Technology in Africa: A Historical Perspective." By Ignacio de la Torre. From *Philosophical Transactions: Biological Sciences*. Volume 366, Number 1567 (April, 2011). http://www.jstor.org/stable/41148932

2. "Technology and Evolution: A Root and Branch View of Asian Iron from First-Millennium BC Sri Lanka to Japanese Steel." By G. Juleff. From *World Archaeology*. Volume 41, Number 4 (December, 2009)

3. "The Industrial Revolution and the Industrious Revolution." By Jan De Vries. From *The Journal of Economic History*. Volume 54, Number 2 (June, 1994). http://www.jstor.org/stable/2123912
   And "Coal and the Industrial Revolution, 1700-1869." By Gregory Clarks and David Jacks. From *European Review of Economic History*. Volume 11, Number 1 (April, 2007). http://www.jstor.org/stable/41378456
   And "From the Editor: The Industrial Revolution: A Teaching Challenge." By Peter N. Stearns. From *OAH Magazine of History*. Volume 15, Number 1 (Fall, 2000). http://www.jstor.org/stable/25163393

4. "Contradictions of Capitalist Industrialization in East Asia: A Critique of 'Flying Geese' Theories of Development." By Martin Hart-Landsberg and Paul Burkett. From *Economic Geography*. Volume 74, Number 2 (April, 1998). http://www.jstor.org/stable/144277

5. "Nimble Fingers: From 19th Century New England Mills to 20th Century Global Assembly Lines." By Lyn Reese. From *OAH Magazine of History*. Volume 3, Number 3(1988). http://www.jstor.org/stable/25162623

6. "Protectionism and the Internationalization of Capital: U.S. Sponsorship of Import Substitution Industrialization in the Philippines, Turkey and Argentina." By Sylvia Maxfield and James H. Nolt. From *International Studies Quarterly*. Volume 34, Number 1 (March, 1990). http://www.jstor.org/stable/2600405

7. "Recent Trends in the History of Technology." By John M. Staudenmaier. From *The American Historical Review*. Volume 95, Number 3 (June, 1990). http://www.jstor.org/stable/2164278

Primary Sources

"Power, Politics, & Protest: Luddites." From *National Archives*. Read 5 primary source documents on right side of page. http://www.nationalarchives.gov.uk/education/politics/g3/

"Rise of Industrial America, 1876-1900: Work in the Late 19th Century." From *Library of Congress*. Read documents on right side of page.
http://www.loc.gov/teachers/classroommaterials/presentationsandactivities/presentations/timeline/riseind/work/

Suggested Reading:

Technology: A World History. By Daniel R. Headrick (Oxford University Press, 2009).

Debating the Industrial Revolution. By Peter N. Stearns (Bloomsbury Academic, 2015).

Creating Modern Capitalism: How Entrepreneurs, Companies, and Countries Triumphed in Three Industrial Revolutions. Edited by Thomas K. McCraw (Harvard University Press, 1998).

The Great Divergence: China, Europe, and the Making of the Modern World Economy. By Kenneth Pomeranz (Princeton University Press, 2001).

Discussion

1. What impact did the development of stone tools have on early human development? How do new findings shift arguments about early mankind?

2. Describe the process of iron technology diffusion in Asia. What impact did it have on this world region?

3. What is the industrious revolution? What role did it have on the Industrial Revolution? What other factors impacted the start of industrialization in Europe?

4. How did the industrialization process differ across world regions? What is the "flying geese" model of East Asia?

5. Were there parallels to the "industrious revolution" in other societies?

6. How was Western Europe affected by Asia's long leadership in manufacturing technology?

7. What are the key issues in figuring out why Western technology began to diverge from that of Asia?

8. What have been the main paths to industrialization during the past century?

9. Overall, what are some of the key current trends and issues in the world history of technology?