



Pre-Paper

Before paper was invented, people around the world used many different materials as writing surfaces. Local environments influenced the kinds of materials used: clay tablets, tree bark, or materials such as papyrus and parchment.

Papyrus was developed in Egypt as early as 3,000 BCE. It was made by slicing the papyrus plant lengthwise, and then laying the strips side-by-side. A second layer of strips was placed on top, perpendicular to the first layer. The two layers were then pounded together into a laminate.

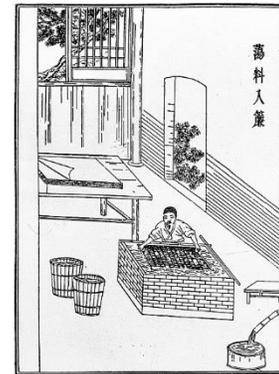
Parchment, named for the Greek city of Pergamum, was invented in the second century BCE. Parchment use was widespread in Europe for centuries, and the United Kingdom continued to use parchment to record new laws into the twenty-first century. To make parchment, the skin of the sheep or cow was scraped, stretched, and lime rubbed into the skin to stabilize it as it dried. The skin would then be cut into smaller pieces for documents. Animal skins were also used to make pages and covers for books.

In south-east Asia, palm leaves were used as a writing surface as long ago as the fifth century BCE. The leaves were cut into a long, rectangular shape. A sharp tool was used to scratch text onto the leaf, and rubbing soot into the marks revealed the writing. Books were made from palm leaves by cutting two holes in each leaf and holding them together with either metal prongs or twine. Lacquered and elaborately painted palm leaves were made into covers to protect the book contents.

Tapa, used widely in tropical civilizations, is a pre-paper cloth like material. There is evidence of tapa being made as early as 4000 BCE in Southeast Asia, in Peru by 2100 BCE, and it is first mentioned by the Chinese in 600 BCE. Tapa is made by beating, but not breaking down, the bark of the mulberry tree into thin sheets. A 2-inch strip of bark can be beaten into a 10 inch sheet. The bark of other trees such as the fig and breadfruit can also be used to make tapa cloth. Tapa is used for many purposes beyond writing, including clothing, bedding, and other household purposes. Tapa degrades easily in its native environment and only fragments remain from its earliest use.

What makes paper different than these materials? Paper is made with pulped plant fiber which is diluted with water, and formed into a sheet using a screen. The plant fibers are linked, or bonded, through the papermaking process through hydrogen bonding.

Early Papermaking



Early Chinese Papermaking

The earliest known paper has been traced back to 200 BCE in China. Archaeologists found a paper prayer embedded into the adobe brick of a home, presumably a blessing. In 105 CE, Ts'ai Lun, who worked for the Chinese emperor, announced and recorded the process of papermaking. Most early paper was used either for religious purposes, by the government, or the very wealthy for business transactions.

The first papers were made from recycled fishing nets, bamboo, mulberry bark, or hemp. Papermakers followed several steps to make paper. First, the papermaker harvested the fibers. Large pits lined with stones or wooden vats were used to soak, or ret, the fibers for up to three months. The papermaker then pounded the fibers into pulp, likely using wooden tools or rocks. The papermaker poured a scoop of pulp on top of a mold and spread it out evenly by hand. Water drained through the screen, leaving the pulp behind. The molds with the wet paper were placed in the sunshine to dry. The dry paper was peeled off the mold, and the process repeated. An average papermaker probably owned 25 to 30 molds. The paper molds were a rectangular frame shaped from bamboo, and the interior portion was a loosely woven screen.



One of Empress Shotoku's Pagodas

Around 600 CE, papermaking expanded to Korea. Though the basic process remained the same, Koreans made several major advances: an animal-powered grinding or pulping mill process; the invention of the *laid paper mold* (a bamboo frame with a screen cover and two deckle strips); and moving the wet paper to wooden boards to dry, allowing the molds to be reused more quickly. The early Koreans were also responsible for two inventions we still use today: the envelope and toilet paper.

Papermaking began in Japan circa 610 CE, brought to Japan by Korean Buddhist Monks. In 770 CE, the Empress Shotoku ordered the first mass printing on paper, known as the Hyakumanto Dharani. One million copies of a series of prayers were printed, commemorating the end of a rebellion. Woodblocks were probably used by the Priests to print the prayers.

The first Japanese paper used similar techniques to the Korean papermaking style, however Japanese papermakers adjusted the process to meet their needs. Some of the paper they made was so thin and smooth, it was almost transparent and felt like silk. This was a far cry from the rough first papers from 800 years previously that probably contained bits of unbeaten bark.

Papermaking Travels

Papermaking practices traveled to the West on a journey very similar to the Silk Road, a trade route from Central Asia to Samarkand in Uzbekistan. In the 8th century CE, Samarkand was experiencing a golden age of science, mathematics, and literature. The inexpensive production of paper allowed that knowledge to be recorded and spread. Samarkand was known for high-quality paper from which copies of the Quran were made. From there, papermaking spread to Baghdad, where the first water-powered paper mill was established in 794 CE. Papermaking and other innovations continued to spread through the Islamic world, to Damascus in Syria, then Cairo in Egypt, and finally to Europe.

The Umayyad Caliphate of Baghdad invaded Morocco in 670 CE, and by 714 CE, the Islamic Caliphate controlled the south of Spain as well, an area that became known as al-Andalus and remained under their control for the next 800 years. The Muslims brought with them knowledge of mathematics, astronomy, medicine, engineering, agriculture, literature, and papermaking, building al-Andalus into a major center of learning. Papermills were established in Xativa where, Andalusians converted Roman olive grinding mills into paper mills. Wire paper molds were used here for the first time, creating a smoother paper surface. In 1151, the water-powered stamping mill was introduced in Spain for pulping the fibers, instead of beating fibers by hand or using a grinding stone. A *stamper* consisted of a long and narrow trough, with heavy wooden hammers powered by a waterwheel to move up and down. As the wheel turned, the hammers would beat the rags in the trough until they turned to pulp.

By 1264 CE, Fabriano, Italy, was home to many well-established paper mills. The Europeans used cotton and linen as their papermaking fiber of choice, collected mostly from recycled clothing. Rag pickers bought old clothing to sell to mills. At the mills, workers sorted the clothing by color, grade, and condition. After buttons and hooks were removed, the rags washed to remove dirt. A rag knife cut the rags into strips. Wet strips were rolled into balls and coated with lime and fermented for a few weeks.

This was not the most effective way to prepare fiber for papermaking: about 1/3rd of the rags rotted and were unusable. The other 2/3rds were ready to beat into pulp. Sometimes the papermakers added lime to the rags to speed up fermentation, but this resulted in weaker paper.



Early European Papermaking

Fabriano papermakers also perfected the paper mold, now made from wood and metal. The mold was in two parts. The bottom portion consisted of a wooden rectangular frame with wooden strips running parallel to the short sides at regular intervals. On top of the wood was a screen woven from brass or copper, similar to the fine mesh of a screen door. The top portion of the paper mold was called a *deckle*. It was a wooden frame and fit around the edges and top of the mold. The term *deckle edge* comes from this kind of papermold. The papermaker put the pieces together and dip them into a wooden vat filled with approximately 90% water and 10% pulp. The papermaker would bring up a mold filled with pulp and water and then shook the mold from side to side to evenly spread the pulp while water drained out.



Stamping Mill



The papermaker removed the deckle from the mold and *couch*, or press, the sheet onto a felt blanket, releasing the wet paper onto the wool. The papermaker could then reuse the mold immediately. Another sheet of felt would be placed directly on top of the wet paper to build a stack approximately 2 1/2 feet high. The stack, or *post*, would be taken to the press, where pressure was applied to gradually remove the water from the paper. A 2-foot high post of paper would become 6 inches high. The paper was taken to the drying loft, the second story of the mill, and dried. If the paper were for stationery or fine printing it was *sized* with a gelatin mixture to provide water resistance and then re-hung in the drying loft. The sized paper was then hand polished by rubbing stones on the paper (called calendaring) and cut, wrapped, and stacked for the market.

Fabriano is also credited with the creation of watermarks and sizing of paper with gelatin (to provide water resistance with writing and printing materials).

Papermaking Comes to Mexico and the United States

The First Makers

Although the Spanish were printing books in Mexico beginning around 1539, the first paper mill wasn't established until in 1575 in the village of Culhuacán just south of Mexico City. Previously, all paper was imported due to the colonial regulations. The Spanish eventually recognized the impracticality of importing paper, and Hernán Sánchez de Muñón and Juan Cornejo were granted a 20-year exclusive contract to make paper.

Papermaking plays an important economic and social role in the history of the United States, from the Rittenhouse Mill in 1690 to today's modern technology. Printers, like those in Mexico, were the first to voice the need for papermaking in the Colonies, as supplies from Europe had limited availability.

William Rittenhouse and his family, papermakers from Germany via the Netherlands, were influenced by William Penn and the promise of religious freedom to immigrate to North America. In 1690, they established the first papermill in the British colonies in Germantown, Pennsylvania, an area north of Philadelphia. This first papermill was built of logs, over Wissahickan Creek, the location chosen because the water was clean and free of heavy mineral deposits.

Rittenhouse and his family made paper in the European method of papermaking. The three men working at the Rittenhouse Mill made about 4 reams of newspaper in a day. Their annual production would have been 1,200 to 1,500 reams of paper.



Rittenhouse Mill Model

Papermaking and its Impact on the Revolutionary War

Between 1639 and 1728, thirty-seven printers operated in the British colonies. They printed over 3,067 books, pamphlets, and broadsides. Six newspapers were in circulation, too. Even though the British could not export enough paper to meet the Colonial demand, concern existed that building new paper mills in the colonies would out-compete existing the mills.

In 1765, England passed the Stamp Act, which imposed a tax on every sheet of paper used for writing or printing, including newspapers. The purpose of the act was to raise funds to pay down the debts of the English government.

Collecting the tax was hard and brought in less revenue than it cost to enforce. Newspaper publishers were displeased with the new tax, and added their voices and influence to the groups wanting to gain independence from England, helping to fan the flames of the Revolutionary War.

The British further tightened their hold in the Colonies by issuing the Townsend tariff schedules of 1767, placing import duties on glass, paper, paperboard, lead, painter's colors and tea. Several of the Colonies reacted by legislating non-importation acts, which included a prohibition of paper. The need for paper became greater and greater, even as Colonists built more paper mills.

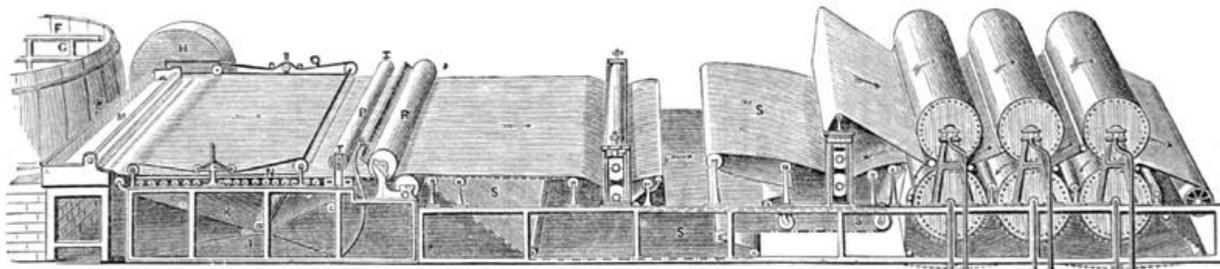
When the Revolutionary War started, people desperate for paper would use anything they could get their hands on, including recycled wallpaper, packing paper, backs of already used paper, and pages from books. On July 19, 1776, the Continental Congress approved a resolution, allowing papermakers to continue making cartridge paper (used to contain pre-measured charges of powder and shot), and on August 9th the Committee of Safety also followed suit.

After the Revolutionary War, papermills proliferated across the former colonies. According to Jacques Pierre Brissot de Warville, a French publisher and journalist, in 1794 he knew of 48 papermills in Pennsylvania and 15 in Delaware. Historian John Maxson estimates that there were approximately 100 to 125 mills in the United States by the end of the eighteenth century.



Benjamin Franklin's Watermark

The Machine Begins



The first paper machine in the United States was built in 1817 at the Gilpin Paper Mill in Brandywine Creek, Delaware. The machine changed the speed and output of papermaking forever. Thomas Gilpin, a papermaker and co-owner of the mill with his brother Joshua, studied with papermakers and paper machine inventors in Europe. He modified the Dickinson Cylinder machine design slightly and procured a US patent for the Gilpin machine. The Gilpin brothers are credited with the invention of the first American paper machine. Papermakers considered the paper machine a tool, as was the paper mold, and

many of the hand papermakers adapted to the new style of production. By the mid to late 1800s the mills which had not changed to the machine could not compete economically in the marketplace, and hand papermaking slowly died.

Growing Pains

The Civil War (1861-1865) caused the next paper shortage in the United States. The majority of papermills were in the Northern states. The South's economy was mostly agricultural, and they imported paper from Europe and the Northern states. When the Civil War started, the South was cut off from paper suppliers. Papermills became targets for both sides in order to handicap communication and production of paper for ammunition cartridges. Marietta, Georgia was home to the largest paper mill in the South, which ran 24 hours a day to make paper before the mill was destroyed in 1864. Rags available for papermaking were in short supply in the North and South, since they were needed for use as bandages. This led to experiments to find alternative fibers to make paper.

The most successful experiments for alternate fibers were taking place in Europe with wood. A wood grinding machine was invented in Germany by Friedrich Gottlieb Keller in 1844, and twenty-two years later the first grinder was imported to the United States. The wood pulp was sold to the Smith Paper Company in Lee Massachusetts for 8 cents a pound.

In 1869, Alfred Denison Remington of the Remington Paper Company of Watertown, New York, made groundwood pulp newsprint. He sent two railroad cars full of the groundwood paper to the New York Times, who promptly rejected the paper as inferior. Remington was the first in the United States to use the sulfur process to produce pulp from wood fibers. Around the same time, William Russell built two groundwood pulp mills in New Hampshire and Vermont. He, too, had a hard time trying to sell the newsprint. Russell's salesmen filled the Boston Herald's paper order of 500 reams of wood newsprint without telling the newspaper publisher. The paper worked so well with their printing processes that they refused to use the rag paper afterwards.

As papermaking became a growing industry in America, research and education became more important. Wood quickly became the most popular papermaking fiber, triggering a new look at forestry practices. In 1895, Dr. Carl Alvin Schenck founded the first forestry school in the United States at the Biltmore Estates in North Carolina, home of the Vanderbilt family. In 1898, Schenck issued his first course catalog to train students in private forest management. The Technical Association for the Pulp and Paper Industry (TAPPI) was founded in 1915 to carry out research into the chemistry and other aspects of papermaking. In 1929, the Institute for Paper Chemistry was founded in Appleton, Wisconsin, as a graduate school to produce researchers and leadership in the paper industry. The Institute of Paper Chemistry is now the Renewable Bioproducts Institute, an Interdisciplinary Research Institute at Georgia Tech, and continues to contribute research to the pulp and paper industry.

Recommendations for Further Reading

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