Printing

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Printing is a process for reproducing text and images using a master form or template. The earliest examples include Cylinder seals and other objects such as the Cyrus Cylinder and the Cylinders of Nabonidus. The earliest known form of woodblock printing came from China dating to before 220 A.D.[1] Later developments in printing include the movable type, first developed by Bi Sheng in China.[2] Johannes Gutenberg introduced mechanical movable type printing to Europe in the 15th century. His printing press played a key role in the development of the Renaissance, Reformation, the Age of Enlightenment, and the scientific revolution and laid the material basis for the modern knowledge-based economy and the spread of learning to the masses.[3]

Modern large-scale printing is typically done using a printing press, while small-scale printing is done free-form with a digital printer. Though paper is the most common material, it is also frequently done on metals, plastics, cloth and composite materials. On paper it is often carried out as a large-scale industrial process and is an essential part of publishing and transaction printing.

From top to bottom, left to right: cylinder seal of a scene, block used for woodblock printing, Korean movable type, printing press, lithograph press, offset press used for modern lithographic printing, linotype machine for hot metal typesetting, digital printer, 3D printer in action.

Contents

History

Woodblock printing

Woodblock printing is a technique for printing text, images or patterns that was used widely throughout East Asia. It originated in China in antiquity as a method of printing on textiles and later on paper. As a method of printing on cloth, the earliest surviving examples from China date to before 220 A.D.

In East Asia

The intricate frontispiece of the Diamond Sutra from Tang Dynasty China, 868 A.D. (British Library)

The earliest surviving woodblock printed fragments are from China. They are of silk printed with flowers in three colours from the Han Dynasty (before 220 A.D.). They are the earliest example of woodblock printing on paper appeared in the mid-seventh century in China.

By the ninth century, printing on paper had taken off, and the first extant complete printed book containing its date is the Diamond Sutra (British Library) of 868.[4] By the tenth century, 400,000 copies of some sutras and pictures were printed, and the Confucian classics were in print. A skilled printer could print up to 2,000 double-page sheets per day.[5]

Printing spread early to Korea and Japan, which also used Chinese logograms, but the technique was also used in Turpan and Vietnam using a number of other scripts. This technique then spread to Persia and Russia.[6] This technique was transmitted to Europe via the Islamic world, and by around 1400 was being used on paper for old master prints and playing cards.[7] However, Arabs never used this to print the Quran because of the limits imposed by Islamic doctrine.[6]

In the Middle East

Block printing, called *tarsh* in Arabic developed in Arabic Egypt during the ninth-tenth centuries, mostly for prayers and amulets. There is some evidence to suggest that these print blocks made from non-wood materials, possibly tin, lead, or clay. The techniques employed are uncertain, however, and they appear to have had very little influence outside of the Muslim world. Though Europe adopted woodblock printing from the Muslim world, initially for fabric, the technique of metal block printing remained unknown in Europe. Block printing later went out of use in Islamic Central Asia after movable type printing was introduced from China.[8]

In Europe

Block printing first came to Europe as a method for printing on cloth, where it was common by 1300. Images printed on cloth for religious purposes could be quite large and elaborate. When paper became relatively easily available, around 1400, the medium transferred very quickly to small woodcut religious images and playing cards printed on paper. These prints produced in very large numbers from about 1425 onward.

Around the mid-fifteenth-century, *block-books*, woodcut books with both text and images, usually carved in the same block, emerged as a cheaper alternative to manuscripts and books printed with movable type. These were all short heavily

illustrated works, the bestsellers of the day, repeated in many different block-book versions: the Ars moriendi and the Biblia pauperum were the most common. There is still some controversy among scholars as to whether their introduction preceded or, the majority view, followed the introduction of movable type, with the range of estimated dates being between about 1440 and 1460.[9]

Movable-type printing

Copperplate of 1215–1216 5000 cash paper money with ten bronze movable types

Movable type is the system of printing and typography using movable pieces of metal type, made by casting from matrices struck by letterpunches. Movable type allowed for much more flexible processes than hand copying or block printing.

Around 1040, the first known movable type system was created in China by Bi Sheng out of porcelain.[2] Sheng used clay type, which broke easily, but Wang Zhen by 1298 had carved a more durable type from wood. He also developed a complex system of revolving tables and number-association with written Chinese characters that made typesetting and printing more efficient. Still, the main method in use there remained woodblock printing (xylography), which "proved to be cheaper and more efficient for printing Chinese, with its thousands of characters".[10]

The earliest known woodcut, 1423, Buxheim, with hand-colouring

Jikji, "Selected Teachings of Buddhist Sages and Son Masters" from Korea, the earliest known book printed with movable metal type, 1377. Bibliothèque Nationale de France, Paris

Copper movable type printing originated in China at the beginning of the 12th century. It was used in large-scale printing of paper money issued by the Northern Song dynasty. Movable type spread to Korea during the Goryeo Dynasty.

Around 1230, Koreans invented a metal type movable printing using bronze. The Jikji, published in 1377, is the earliest known metal printed book. Type-casting was used, adapted from the method of casting coins. The character was cut in beech wood, which was then pressed into a soft clay to form a mould, and bronze poured into the mould, and finally the type was polished.[11] The Korean form of metal movable type was described by the French scholar Henri-Jean Martin as "extremely similar to Gutenberg's".[12] Cast metal movable type was spread to Europe between the late 14th century and the early 15th century.[6][13][14][15][16]

Around 1450, Johannes Gutenberg introduced what is regarded as the first modern movable type system in Europe (see printing press), along with innovations in casting the type based on a matrix and hand mould; adaptations to the screw-press; the use of a linseed-oil base for ink; and the creation of a softer and more absorbent paper.[17] Gutenberg was the first to create his type pieces from an alloy of lead, tin, antimony, Copper and Bismuth – the same components still used today.[18]

The printing press

Johannes Gutenberg started work on his printing press around 1436, in partnership with Andreas Dritzehen – whom he had previously instructed in gem-cutting – and Andreas Heilmann, the owner of a paper mill.[13]

Compared to woodblock printing, movable type page setting and printing using a press was faster and more durable. Also, the metal type pieces were sturdier and the lettering more uniform, leading to typography and fonts. The high quality and relatively low price of the Gutenberg Bible (1455) established the superiority of movable type for Western languages. The printing press rapidly spread across Europe, leading up to the Renaissance, and later all around the world.

Gutenberg's innovations in movable type printing have been called the most important invention of the second millennium.[19]

A case of cast metal type pieces and typeset matter in a composing stick

Rotary printing press

The **rotary printing press** was invented by Richard March Hoe in 1843. It uses impressions curved around a cylinder to print on long continuous rolls of paper or other substrates. Rotary drum printing was later significantly improved by William Bullock.

Conventional printing technology

All printing process are concerned with two kinds of areas on the final output:

Page-setting room - c. 1920

1. Image Area (printing areas)
2. Non-image Area (non-printing areas)

After the information has been prepared for production (the prepress step), each printing process has definitive means of separating the image from the non-image areas.

Conventional printing has four types of process:

1. Planographics, in which the printing and non-printing areas are on the same plane surface and the difference between them is maintained chemically or by physical properties, the examples are: offset lithography, collotype, and screenless printing.
2. Relief, in which the printing areas are on a plane surface and the non printing areas are below the surface, examples: flexography and letterpress.
3. Intaglio, in which the non-printing areas are on a plane surface and the printing area are etched or engraved below the surface, examples: steel die engraving, gravure
4. Porous, in which the printing areas are on fine mesh screens through which ink can penetrate, and the non-printing areas are a stencil over the screen to block the flow of ink in those areas, examples: screen printing, stencil duplicator.

Letterpress

Letterpress printing is a technique of relief printing. A worker composes and locks movable type into the bed of a press, inks it, and presses paper against it to transfer the ink from the type which creates an impression on the paper.

Letterpress printing was the normal form of printing text from its invention by Johannes Gutenberg in the mid-15th century and remained in wide use for books and other uses until the second half of the 20th century, when offset printing was developed. More recently, letterpress printing has seen a revival in an artisanal form.
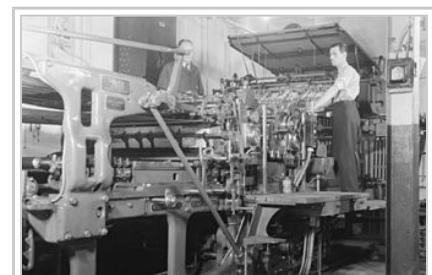

Miehle press printing Le Samedi journal. Montreal, 1939.

Offset

Offset printing is a widely used printing technique. Offset printing is where the inked image is transferred (or "offset") from a plate to a rubber blanket. An offset transfer moves the image to the printing surface. When used in combination with the lithographic process, a process based on the repulsion of oil and water; the offset technique employs a flat (planographic) image carrier. So, the image to be printed obtains ink from ink rollers, while the non-printing area attracts a film of water, keeping the non-printing areas ink-free.

Currently, most books and newspapers are printed using the technique of offset lithography.

Gravure

Gravure printing is an intaglio printing technique, where the image being printed is made up of small depressions in the surface of the printing plate. The cells are filled with ink, and the excess is scraped off the surface with a doctor blade. Then a rubber-covered roller presses paper onto the surface of the plate and into contact with the ink in the cells. The printing cylinders are usually made from copper plated steel, which is subsequently chromed, and may be produced by diamond engraving; etching, or laser ablation.

Gravure printing is used for long, high-quality print runs such as magazines, mail-order catalogues, packaging and printing onto fabric and wallpaper. It is also used for printing postage stamps and decorative plastic laminates, such as kitchen worktops.

Other printing techniques

The other significant printing techniques include:

- Flexography, used for packaging, labels, newspapers
- Dye-sublimation printer
- Inkjet, used typically to print a small number of books or packaging, and also to print a variety of materials: from high quality papers simulating offset printing, to floor tiles. Inkjet is also used to apply mailing addresses to direct mail pieces
- Laser printing (toner printing) mainly used in offices and for transactional printing (bills, bank documents). Laser printing is commonly used by direct mail companies to create variable data letters or coupons.
- Pad printing, popular for its unusual ability to print on complex three-dimensional surfaces
- Relief print, mainly used for catalogues
- Screen-printing for a variety of applications ranging from T-shirts to floor tiles, and on uneven surfaces
- Intaglio, used mainly for high value documents such as currencies.
- Thermal printing, popular in the 1990s for fax printing. Used today for printing labels such as airline baggage tags and individual price labels in supermarket deli counters.

Impact of German movable type printing press

Quantitative aspects

It is estimated that following the innovation of Gutenberg's printing press, the European book output rose from a few million to around one billion copies within a span of less than four centuries.[20]

Religious impact

Samuel Hartlib, who was exiled in Britain and enthusiastic about social and cultural reforms, wrote in 1641 that "the art of printing will so spread knowledge that the common people, knowing their own rights and liberties, will not be governed by way of oppression".[21] Both churchmen and governments were concerned that print allowed readers, eventually including those from all classes of society, to study religious texts and politically sensitive issues by themselves, instead of having their thinking mediated by the religious and political authorities.

In the Muslim world, printing, especially in Arabic scripts, was strongly opposed throughout the early modern period, though sometimes printing in Hebrew or Armenian script was permitted. Thus the first movable type printing in the Ottoman Empire was in Hebrew in 1493.[22] According to an imperial ambassador to Istanbul in the middle of the sixteenth century, it was a sin for the Turks to print religious books. In 1515, Sultan Selim I issued a decree under which the practice of printing would be punishable by death. At the end of the sixteenth century, Sultan Murad III permitted the sale of non-religious printed books in Arabic characters, yet the majority were imported from Italy. Ibrahim Muteferrika established the first press for printing in Arabic in the Ottoman Empire, against opposition from the calligraphers and parts of the Ulama. It operated until 1742, producing altogether seventeen works, all of which were concerned with non-religious, utilitarian matters. Printing did not become common in the Islamic world until the 19th century.[23]

European output of books printed by movable type from ca. 1450 to 1800[20]

Jews were banned from German printing guilds; as a result Hebrew printing sprang up in Italy, beginning in 1470 in Rome, then spreading to other cities including Bari, Pisa, Livorno, and Mantua. Local rulers had the authority to grant or revoke licenses to publish Hebrew books,[24] and many of those printed during this period carry the words 'con licenza de superiori' (indicating their printing having been licensed by the censor) on their title pages.

It was thought that the introduction of the printing medium 'would strengthen religion and enhance the power of monarchs.'[25] The majority of books were of a religious nature, with the church and crown regulating the content. The consequences of printing 'wrong' material were extreme. Meyrowitz[25] used the example of William Carter who in 1584 printed a pro-Catholic pamphlet in Protestant-dominated England. The consequence of his action was hanging.

The widespread distribution of the Bible 'had a revolutionary impact, because it decreased the power of the Catholic Church as the prime possessor and interpretor of God's word.'[25]

Replica of the Gutenberg press at the International Printing Museum in Carson, California
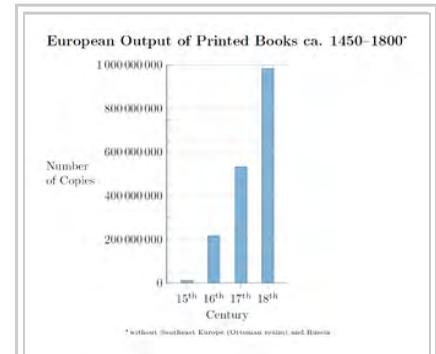
Social impact

Print gave a broader range of readers access to knowledge and enabled later generations to build directly on the intellectual achievements of earlier ones without the changes arising within verbal traditions. Print, according to Acton in his lecture *On the Study of History* (1895), gave "assurance that the work of the Renaissance would last, that what was written would be accessible to all, that such an occultation of knowledge and ideas as had depressed the Middle Ages would never recur, that not an idea would be lost".[21]

Print was instrumental in changing the nature of reading within society.

Elizabeth Eisenstein identifies two long-term effects of the invention of printing. She claims that print created a sustained and uniform reference for knowledge as well as allowing for comparison between incompatible views.[26]

Asa Briggs and Peter Burke identify five kinds of reading that developed in relation to the introduction of print:

1. Critical reading: due to the fact that texts finally became accessible to the general population, critical reading emerged because people were given the option to form their own opinions on texts
2. Dangerous Reading: reading was seen as a dangerous pursuit because it was considered rebellious and unsociable especially in the case of women, because reading could stir up dangerous emotions such as love and that if women could read, they could read love notes
3. Creative reading: printing allowed people to read texts and interpret them creatively, often in very different ways

than the author intended
4. Extensive Reading: print allowed for a wide range of texts to become available, thus, previous methods of intensive reading of texts from start to finish, began to change and with texts being readily available, people began reading on particular topics or chapters, allowing for much more extensive reading on a wider range of topics
5. Private reading: became linked to the rise of individualism because before print, reading was often a group event, where one person would read to a group of people and with print, literacy rose as did availability of texts, thus reading became a solitary pursuit

The invention of printing also changed the occupational structure of European cities. Printers emerged as a new group of artisans for whom literacy was essential, although the much more labour-intensive occupation of the scribe naturally declined. Proof-correcting arose as a new occupation, while a rise in the amount of booksellers and librarians naturally followed the explosion in the numbers of books.

Bookprinting in the 16th century

Comparison of printing methods

<div align="center">Comparison of printing methods[27]</div>

printing process	transfer method	pressure applied	drop size	dynamic viscosity	thickness of ink on substrate	notes	cost-effective run length
Offset printing	rollers	1 MPa		40–100 Pa·s	0.5–1.5 µm	high print quality	>5,000 (A3 trim size, sheet-fed)[28] >30,000 (A3 trim size, web-fed)[28]
Rotogravure	rollers	3 MPa		50-200 mPa·s	0.8–8 µm	thick ink layers possible, excellent image reproduction, edges of letters and lines are jagged[29]	>500,000[29]
Flexography	rollers	0.3 MPa		50–500 mPa·s	0.8–2.5 µm	high quality (now HD)	
Letterpress printing	platen	10 MPa		50–150 Pa·s	0.5–1.5 µm	slow drying	
Screen-printing	pressing ink through holes in screen				<12 µm	versatile method, low quality	
Electrophotography	electrostatics				5–10 µm	thick ink	
Inkjet printer	thermal		5–30 picolitres (pl)	1–5 Pa·s	<0.5 µm	special paper required to reduce bleeding	<350 (A3 trim size)[28]
Inkjet printer	piezoelectric		4–30 pl	5–20 mPa s	<0.5 µm	special paper required to reduce bleeding	<350 (A3 trim size)[28]
Inkjet printer	continuous		5–100 pl	1–5 mPa·s	<0.5 µm	special paper required to reduce bleeding	<350 (A3 trim size)[28]
Transfer-print	thermal transfer film or water release decal					mass-production method of applying an image to a curved or uneven surface	

Digital printing

By 2005, Digital printing accounts for approximately 9% of the 45 trillion pages printed annually around the world.[30]

Printing at home, an office, or an engineering environment is subdivided into:

- small format (up to ledger size paper sheets), as used in business offices and libraries
- wide format (up to 3' or 914mm wide rolls of paper), as used in drafting and design establishments.

Some of the more common printing technologies are:

- blueprint – and related chemical technologies
- daisy wheel – where pre-formed characters are applied individually
- dot-matrix – which produces arbitrary patterns of dots with an array of printing studs
- line printing – where formed characters are applied to the paper by lines
- heat transfer – such as early fax machines or modern receipt printers that apply heat to special paper, which turns black to form the printed image
- inkjet – including bubble-jet, where ink is sprayed onto the paper to create the desired image
- electrophotography – where toner is attracted to a charged image and then developed
- laser – a type of xerography where the charged image is written pixel by pixel using a laser
- solid ink printer – where cubes of ink are melted to make ink or liquid toner

Vendors typically stress the total cost to operate the equipment, involving complex calculations that include all cost factors involved in the operation as well as the capital equipment costs, amortization, etc. For the most part, toner systems are more economical than inkjet in the long run, even though inkjets are less expensive in the initial purchase price.

Professional digital printing (using toner) primarily uses an electrical charge to transfer toner or liquid ink to the substrate onto which it is printed. Digital print quality has steadily improved from early color and black and white copiers to sophisticated colour digital presses such as the Xerox iGen3, the Kodak Nexpress, the HP Indigo Digital Press series, and the InfoPrint 5000. The iGen3 and Nexpress use toner particles and the Indigo uses liquid ink. The InfoPrint 5000 is a full-color, continuous forms inkjet drop-on-demand printing system. All handle variable data, and rival offset in quality. Digital offset presses are also called direct imaging presses, although these presses can receive computer files and automatically turn them into print-ready plates, they cannot insert variable data.

Small press and fanzines generally use digital printing. Prior to the introduction of cheap photocopying the use of machines such as the spirit duplicator, hectograph, and mimeograph was common.

3D printing

3D printing is a form of manufacturing technology where objects are created using three-dimensional files and 3D printers. Objects are created by laying down or building up layers of material. As of 2012, some companies such as Sculpteo or Shapeways are proposing online solutions for 3D printing.

Gang run printing

Gang run printing is a method in which multiple printing projects are placed on a common paper sheet in an effort to reduce printing costs and paper waste. Gang runs are generally used with sheet-fed printing presses and CMYK process color jobs, which require four separate plates that are hung on the plate cylinder of the press. Printers use the term "gang run" or "gang" to describe the practice of placing many print projects on the same oversized sheet. Basically, instead of running one postcard that is 4 x 6 as an individual job the printer would place 15 different postcards on 20 x 18 sheet therefore using the same amount of press time the printer will get 15 jobs done in the roughly the same amount of time as one job.

Printed electronics

Printed electronics is the manufacturing of electronic devices using standard printing processes. Printed electronics technology can be produced on cheap materials such as paper or flexible film, which makes it an extremely cost-effective

method of production. Since early 2010, the printable electronics industry has been gaining momentum and several large companies, including Bemis Company and Illinois Tool Works have made investments in printed electronics and industry associations including OE-A and FlexTech Alliance are contributing heavily to the advancement of the printed electronics industry.[31][32]

Printing terminologies

Printing terminologies are the specific terms used in printing industry. Following is the list of printing terminologies.[33]

- Airshaft
- Anilox
- Ben-Day dots
- Bleed (printing)
- Broadsheet
- California Job Case
- Camera-ready
- Card stock
- Catchword
- CcMmYK color model
- CMYK color model
- Colophon (publishing)
- Color bleeding (printing)
- Composing stick
- Computer to film
- Computer to plate
- Continuous tone
- Contone (printing)
- Die (philately)
- Dot gain
- Dots per centimeter
- Dots per inch
- Double truck
- Dry transfer
- Dultgen
- Duotone
- Duplex printing
- Edition (printmaking)
- Error diffusion
- Flong
- Foil stamping
- Folio (printing)
- For position only
- Frisket

- Galley proof
- Gang run printing
- Grey component replacement
- Halftone
- Hand mould
- Hellbox
- Hexachrome
- Hot stamping
- Imposition
- Inkometer
- Iris printer
- Iron-on
- Job Definition Format
- Key plate
- Keyline
- Kodak Proofing Software
- Mezzotint
- Nanotransfer printing
- Non-photo blue
- Overprinting
- Pagination
- Paste up
- Pre-flight (printing)
- Prepress
- Prepress proofing
- Press check (printing)
- Registration black
- Rich black
- Set-off (printing)
- Spot color
- Stochastic screening
- Transfer-print
- Trap (printing)
- Under color removal

See also

- Color printing
- Cloud printing
- Converters (industry)
- Electrotyping

- Flexography
- Foil stamping
- Hot metal typesetting
- In-mould decoration

- In-mould labelling
- Intaglio (printmaking)
- Jang Young Sil
- Letterpress printing
- Movable type
- Offset printing
- Pad printing
- Print on demand
- Printmaking

- Printed T-shirt
- Security printing
- Typography
- Wang Zhen
- Waterless printing
- Laurens Janszoon Coster
- Printing press check
- Jikji
- Printed electronics

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    A somewhat later one, showing 18th century developments is

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External links

- 🌐 "Printing". *Encyclopædia Britannica*. **22** (11th ed.). 1911.
- Prints & People: A Social History of Printed Pictures (http://libmma.contentdm.oclc.org/cdm/compoundobject/collection /p15324coll10/id/94303/rec/1), an exhibition catalog from The Metropolitan Museum of Art (fully available online as PDF)
- Centre for the History of the Book (http://www.hss.ed.ac.uk/chb)
- Children of the Code – Online Video: The DNA of Science, The Alphabet and Printing (http://www.childrenofthecode.org/Tour/c5/davinci.htm)
- Planet Typography – history of printing (http://www.planet-typography.com /directory/histoire.html) – selection of international sites dedicated to the

Look up *printing* in Wiktionary, the free dictionary.

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history of printing

- Printing Industries of the Americas (http://www.gain.net) – national trade association for printers and companies in the graphic arts
- Printwiki (http://printwiki.org/)
- The development of book and printing (http://www.gutenberg-museum.de/index.php?id=19&language=e). English website of the Gutenberg-Museum Mainz (Germany)
- BPSnet British Printing Society (http://www.bpsnet.org.uk)
- Taiwan Culture Portal: Ri Xing Type Foundry一 preserving the true character of Chinese type (http://www.culture.tw/index.php?option=com_content&task=view&id=1964&Itemid=157)
- A collection of printing materials from the 19th Century (http://digitalcollections.library.ubc.ca/cdm/landingpage /collection/mathison) – Documents printed by R. Mathison Jr., The Job Printer, in Vancouver, B.C. - UBC Library Digital Collections
- International Printing Museum, Carson, CA, Web site (http://www.printmuseum.org/)
- Museum of Printing, Andover, MA, Web site (http://www.museumofprinting.org/)

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