Preferred citation: P.E. Wrist. Paper in the age of information. A brief historical perspective of the role of paper in the communication of information. In **Papermaking Raw Materials**, *Trans. of the VIIIth Fund. Res. Symp. Oxford, 1985*, (V. Punton, ed.), pp 927–938, FRC, Manchester, 2018. DOI: 10.15376/frc.1985.3.927.

PAPER IN THE AGE OF INFORMATION

A BRIEF HISTORICAL PERSPECTIVE OF THE ROLE OF PAPER IN THE COMMUNICATION OF INFORMATION

Peter E. Wrist

Pulp and Paper Research Institute of Canada
570 St. John's Boulevard
Pointe Claire, P.Q., Canada H9R 3J9

In today's world paper plays many parts. It announces our arrival and our departures and it records the other significant moments of our lives. It protects our purchases, and brings us produce from far away places. It soothes our sneezes, strains our coffee, adorns our party tables and absorbs our incontinence. Indeed, if you have ever attempted to walk through the streets of New York during a garbage strike, you must have wondered how civilization ever existed before there was an abundant supply of paper. Yet, barely a hundred years ago, paper was a scarce and precious resource. There are those today who foretell a future equally parsimonious in its use. Indeed they ask, "Is there a future for paper in the Age of Information?".

In order to address this question, I would like to spend a few moments recalling some of the major events which have occurred during the history of man's written communication, and touch upon the close relationship which has existed between the four key elements of this important activity. These elements are:

The language(s) used to communicate the message.
The symbol creating and composing device(s).
The image forming material, and
The image receptor.

Man's earliest recorded use of permanent images for purposes of communication is probably found in the cave paintings of Altamira, Spain and of Lascaux, France. They date from the end of the ice age, about twenty thousand years ago. J. Bronowski, in his T.V. series "The Ascent of Man", noted that the caves containing these paintings by early man were remote from the caves he used for daily living. They appear therefore to have served a special purpose. Bronowski noted that a person entering the caves with a lantern is only able to see the portrayed animals one at a time. He therefore speculated that the caves were not intended as art galleries but rather they served the purpose of training centres where the student hunter could view the animals one by one, in postures typical of the hunt; a charging bison, a running deer or a turning boar. In the silence of the cave, he could prepare himself to face these critical moments of loneliness and danger in the hunt and learn to flex his spear arm calmly and without fear. Even seventeen thousand years later wall paintings and writings were used extensively in the tombs of the Egyptian pharaohs to instruct their entourage in the rudiments of agriculture and astronomy for use in their after-lives.

Symbolic writing, as distinct from art or decoration, evolved independently at a number of centres of civilization. The earliest recorded evidence is from Sumeria, and dates back to around 3100 B.C. At first, an individual pictogram was used for each word or idea. The pictorial realism of the early Egyptian characters is readily apparent to the modern eye. Over time the characters become more stylized, reflecting the need to simplify and speed up the writing process, and to convey abstract ideas. In early China, accounts of major events were recorded on the inside surface of the tribal ceremonial cooking pot. Today, these artifacts provide us with both a record of the times and of the evolution of Chinese pictograms since the 14th century B.C. Chinese characters and Japanese Kangi symbols are the major examples of this early form of writing still in common use today.

In the next phase of development, separate characters were used to represent each syllable of a word. Japanese Kana symbols are examples of this phonetic writing still in use today. Finally, symbols representing individual sounds evolved, completing the transition of communication from a writing system based on visual imagery to one based on the spoken word.

Three different alphabets arose about a 1000 B.C., differing primarily in the way they represented the vowel sounds. Of these the Greek system, using a separate symbol for each vowel, proved to be the most flexible, and became the most widely adopted. Thus in place of the several thousand characters required by the Chinese language, most Western languages today use less than thirty. This major reduction in the number of symbols used in writing proved of critical significance in the successful development of printing in later years. I will return to this point again later.

The earliest portable writing materials were pieces of bone, wood and metal. The use of clay tablets used by the Sumerians can be traced back some 4 to 5 thousand years. A major breakthrough came around 2200 B.C. with the invention of papyrus in Egypt. This sheetlike material was made from the papyrus reed. Longitudinal strips were cut from the reeds and placed side by side to form a sheet. A second layer, placed at right angles to the first, was then bonded to it with a natural glue, possibly dissolved from the reed itself. The sheets were consolidated by beating their surface with a wooden hammer before setting them out to dry in the sun. The surface was finally prepared for writing by rubbing it smooth with a piece of ivory or a smooth shell. Scrolls of papyrus were made by gluing individual sheets together. The uniformity of appearance, colour, and ink receptivity was very poor and it was only possible to write on one side of the sheet. The strongest sheets were placed on the outside of the roll as protection for the lower quality grades that were placed on the inside.

Papyrus continued in common use in the Middle East until the 8th or 9th centuries A.D. when paper, spreading slowly westward from China, gradually replaced it because of its superior properties. Papyrus would have proved a very difficult material to use in today's copying machines because of its variability and a tendency to delaminate and curl when heated.

There is also evidence of the independent development and use of a papyrus-like material in Central and Southern America before the arrival of the conquistadores. Inner layers of the bark of a species of fig tree were removed and cut into strips. After beating to make them pliable, the strips were laid side by side and formed into a sheet in a manner similar to papyrus.

Unfortunately most of the manuscripts of this region were destroyed by the Spanish priests accompanying the conquistadores but one of them recorded the process he saw being used to make the sheets.

The second genre of writing substrate - parchment - was invented around 200 B.C in the Greek city of Pergamum in N.W. Asia Minor. Apparently in an act of spite, King Ptolemy V of Egypt placed an embargo on the shipment of papyrus to King Eumenes II, of Pergamum, a studious and culture-loving monarch who maintained one of the finest libraries outside of Alexandria. Necessity proved the mother of invention and Eumenes' researchers quickly developed a process for treating animal skins to make them into an acceptable writing material. Indeed they went further and conceived the idea that skins from unborn animals would make even brighter and more pliable sheets - and so they produced the first vellum, a superior product that was reserved for special manuscripts. Sheepskins were found to be the most suitable for making parchment, which fitted well with the growing use of wool for clothing. The use of parchment spread through Europe and proved to be a very durable and suitable material for the production of manuscripts. It remained the only writing material in use throughout most of Europe until the 14th and 15th centuries. Even after the arrival of paper, parchment continued to be used for hand-written documents and it was capable of reproducing very fine detail in the multi-coloured illuminations used in books. Village records of births, deaths and civil contracts were recorded on parchment in England well into the 18th century, although by then paper was in widespread use for the printing of books. Parchment proved vastly superior to papyrus - its surface could be treated with glues and pigments to improve its smoothness, brightness, and ink receptivity. It was possible to write on both sides and it was thin and strong enough to be folded and bound into books. The quality and speed of writing was increased as a result of the improved surface and the use of quill pens and true inks became practible. This association of parchment with fine hand writing is reflected in the use of the terms Parchment and Vellum in the commercial names of many of todays better grades of writing paper.

The third writing material to appear was paper. Although popularly believed to have been the first invented by Ts'ai Lun

at the Chinese court in 105 A.D., its use in China has been traced to the 2nd century B.C. Claims of still earlier invention in India have been made, but are not generally accepted. Paper differed from both papyrus and parchment in that it was a manmade composite structure formed by the deposition of individual fibres from an aqueous slurry onto a cloth or screen. This fundamental difference in sheet structure proved most important, for it eventually made it possible to engineer sheets with widely differing properties, and so freed the writer from the severe limitations of sheets made from reeds or skins. The Chinese made paper from fibres prepared by macerating the inner bark of the mullberry tree, as well as from cotton rags, hemp and old fishing nets soaked in a mildly alkaline solution of wood ash. The size of individual sheets was only limited by the size and weight of the forming mould that the papermaker could handle. After forming, the fibre mat was couched from the forming screen, pressed between woollen felts and was then hung up to dry in a loft or in the sun. The art of papermaking arrived in Egypt during the 10th century from where it was brought to Spain and Sicily by the Moors in the 12th century. It finally reached Central Europe in the 14th and 15th centuries, and later crossed to the New World with the early colonists. The principal fibres used in Europe were linen and cotton derived from old garments. The manufacturing process changed little until the 19th century, the only operation that was mechanised was the beating of the fibres in a machine that became known as a hollander. From its introduction in the 14th century until the late 19th century, the output of paper was severely constrained by the availability of cotton and linen rags. In fact, in England in 1666 the shortage of rags led to a law banning the use of rags for burial shrouds - a step that was said to have conserved one hundred tons of rags per year for papermaking. In 1855 the shortage of rags in the U.S.A. led entrepreneurs to import mummies from Egypt in order to use their linen shrouds for papermaking. Except for periods of local shortage however, the price of paper remained remarkably stable for over four hundred years, but at a level that kept it out of the reach of the average person.

Although machines for making continuous webs of paper, were developed in France and later in England at the turn of the 18th century the full impact of these inventions were not realized for another fifty years until after the development of

four new processes for making pulp fibres out of wood. The period 1850 - 1884 saw the development of groundwood and then of the chemical processes, soda, sulphite, and finally alkaline sulphide [kraft]. These new pulping methods provided access to an abundant and widely distributed source of raw material, the forest, and it quickly became possible to satisfy the rapidly growing demands of the Industrial Revolution and the social revolution which accompanied it for a cheap writing material. In the years that followed the introduction of paper from wood pulp, the publication of books increased rapidly and the record keeping needs of the expanding commercial enterprises could be satisfied by a product whose cost in real terms has declined steadily to the present day.

The critical importance of the timing of these pulping discoveries to the economic growth flowing from the Industrial Revolution is illustrated by the fact that in 1879, in the period immediately before woodpulp became available in the U.S., the magazine "Scientific American" seriously proposed the use of the fibrous componants of cowdung to alleviate the severe shortage of rags for papermaking at the time. This is only one example of the many desperate suggestions that were made during this period to find suitable alternatives to rags.

Paper quickly proved to be a very versatile communications medium in contrast to papyrus and parchment because it was possible to engineer into it different properties to suit different user needs. Over time, major improvements in the quality and versatility have been made so that paper today can be customized to serve a wide variety of end uses.

The third component of the writing system, the ink or marking fluid has changed least over time. Until the advent of novel copying systems in recent years, there had been little innovation in printing inks for over a thousand years. Three broad categories of inks had evolved - the first oil-based inks were adaptations of paints, and were made by grinding natural pigments with a natural oxidisable oil. Next came water-based inks using carbon black pigment coated with a water soluble adhesive. This ink was very suitable for making the brush strokes of Chinese characters. Finally, the true inks based on an aqueous solution of iron salts and gallic acid were developed for use with the quill pen and the smooth, water resistant surface of parchment. Each ink made different demands on the

surface properties of the receptor, and special surface treatments were developed to match the ink to the surface.

The advent of xerography introduced a completely new marking medium - in one form of xerography the ink is used in a dry powdered form. This ink is required to stick first to a charged image forming surface and then transfer to the paper sheet on which it is fused by heating. Once again, paper was quickly modified to meet these new requirements and at modest cost.

In recent times, the image forming materials have become increasingly complex. For example, in carbonless paper two colourless colour forming chemicals are coated onto the paper, one protected from the other by encapsulation within impermeable microcapsules until the capsule walls are ruptured by the pressure of the writing instrument. Another system uses colourless coatings which create a coloured image when activated by the heat of a stylus or laser beam. In ink-jet printing the inks must be conductive to electricity, remain fluid in the printing head and set rapidly on the sheet.

The fourth component of the system is the image forming tool. The earliest tools were sharpened sticks or scribes. The invention of the animal hair brush around 150 B.C. greatly increased the speed and fluidity of writing Chinese characters. The use of printing from precarved masters goes back to the Sumerians who used carvings on the surface of small stone or metal cylinders to imprint the scribe's signature into the surface of the clay tablets. The earliest known copying of a written message onto paper occurred around 175 A.D. in the form of rubbings made from masters cut into metal or wood, followed three hundred years later by printing from small carved wooden seals similar to those used today by the Japanese. The first recorded printing of text onto paper occurred in 770 A .D. It was a million copy run of a Buddhist prayer and it is thought to have been printed from a metal block. Several copies of this first edition are still in existence today.

It is against this background of painfully slow progress that we must evaluate the importance of the development of the Gutenberg printing press in Germany in 1450. The invention was one of those rare convergences of several technologies resulting in a dramatic impact on society. Movable type had been invented in China four hundred years earlier, but with

thousands of individual pieces of type to manipulate, it did not make printing any easier, and failed to catch on. Movable metal type was invented in Korea in 1390 but once again, the complexity of the language prevented its adoption. Indeed the movable type printing press did not completely replace the wooden printing block in China or Japan until the early 20th century. Gutenberg's success was the result of several factors. He was skilled and knowledgable in metallurgy and engraving, both important in making the metal type. His German language required only twenty six characters and greatly simplified the type inventory. The papermaking process had arrived in Germany some fifty years earlier and it contributed a pressing machine that could be readily adapted for pressing the type against the paper, and finally, the newly arrived paper made from rags provided the ideal printing surface - soft, absorbent, and conformable to the irregular surface of the type of the press. Parchment was totally unsuitable to receive either the ink or the type. The combination of paper and press was so successful that they spread together throughout Europe in less than fifty years. Indeed the conformability of rag paper to movable type was so important to the success of the process that the spread of printing and papermaking went hand in hand until the 19th century.

The impact of the Gutenberg press on the spread of the written word can be appreciated from the fact that fifty years before the invention took place, an Italian nobleman hired forty five scribes to handcopy his library of two hundred volumes - it took them two years. After Gutenberg, a single printer could have carried out the same task in about one month - a thousandfold increase in productivity. Even so, it was not until the late 19th century that its full potential as a communications media for the masses was realized when wood pulp finally removed the constraint of an inelastic rag supply.

Until the present century the ability to copy written material, as distinct from printing, was very limited. Pressing wet tissue against an inked original was a very unsatisfactory method and carbonpaper copies could only be made simultanously with the original. Ozalid and multilithography could be used to make a number of copies if the originals were prepared on special paper masters. Photography was slow and expensive. The unfulfilled need for a process to copy an ordinary original was so great that the thermofacsimile process

of the 1950's was highly successful for a time inspite of its atrocious quality and dark, brittle paper.

The discovery of xerography by Carlson in 1938 has changed all that. In its earliest form, xerography was conceived as a way to copy an original piece of writing or printed material, using an intermediate optically produced master on a photo-conductive surface. In fact before the first commercially successful copier became available in 1960 the process was being used in office print shops to copy original material into offset printing plates. The distinction between copying and printing quickly became very blurred, and with the advent of the newer generations of copiers, the quality of a copy became comparable with that of conventional office printing presses. The distinction between the two becomes even more diffuse with the advent of the so called "Intelligent Copiers" which allow the output of a computer to be combined with the optical image of a printed piece into a printed image without any intermediary step. The metal type of the Gutenberg press has been replaced by electronic pulses and solid state printing heads.

The convergence of computers, the new electronic printing processes such as laser xerography or ink-jet and modern tele-communications by satellite and optical fibre are bringing about a new revolution in written communication whose impact will be as sweeping in the 20th century as that of the Gutenberg press in 1450. Once again there is a simplification of alphabet - the two characters of the binary code have replaced the twenty six letters of the alphabet. This innova-tion permits the rapid electronic manipulation and movement of text, data, and graphics in any combination. Document compos-ing can be carried out electronically, merging material from many different sources. Storage, retrieval and transmission of information can be carried out instantaneously over great distances and printed out in many remote places simultaneously. Perhaps the biggest change that the new technologies provide is the ability to think of a page of information not as an ordered sequence of words or drawings but rather as a single image which can be broken down into an array of cells or pixels - each of which can be characterised by its coordinates and its average optical density. In a sense, each pixel is analogous to an individual cell of a half tone print. This represent-tion of a completely composed page in binary form makes

possible a new form of printing - binary, or matrix printing - and thereby opens up a whole new range of contact and non-contact printing methods. As larger computer memories, and faster transmission rates are developed, the size of the pixels into which a sheet may be divided will be reduced to such a level that the resolution and print quality achievable will equal that of the highest resolution printing processes. Half-tone qualities will be achievable by varying the dot pattern within the printed pixels. With only a modest further improvement it will be possible to print high quality images in colour. This new method of printing for the first time makes it possible to print Egyptian pictograms and Chinese characters as easily as Roman letters. Instead of having to handle thousands of different types, the individual characters are built up electronically on demand by the computer.

At this stage of development it is too early to say which of the new imaging techniques will emerge as the eventual leader - laser xerography - ink-jet - thermal transfer - or perhaps a newer technology such as encapsulated photochemically active coatings.

Each of these new marking systems will require their own papers for optimum print quality. There will be many opportunities for developing innovative papers in the "Age of Information".

The convergence of these many technologies today is producing a revolution in man's ability to communicate that will exceed the impact of the Gutenberg press of 500 years ago. It is likely to result in at least another thousand-fold increase in the rate of information transfer. While it will certainly be technically feasible with the new technology to develop information communication systems which do not require the use of paper, it is unlikely that this will occur. The major cost reduction and productivity opportunities which are possible with the new technologies lie not in saving the cost of paper but rather in reducing the cost of collecting, analysing, composing, transmitting, storing, retrieving and distributing the information. Whenever the systems interface with a human being, the binary language of the computer must be converted and presented in oral or written form. It is at this human-machine interface that paper's advantages are most important. A printed record is easy to handle, has good

optical contrast, is very portable, is unlikely to create reader eye fatigue or create reader error, and it can be used in many places where even a flat video screen would not be convenient. Even the advent of electronic filing, rather than reducing the use of paper, has had the exact opposite result since a paper copy is usually generated when the file is created and a second one created each time the information is retrieved. Electronic mail is also frequently printed out by the sender and again by the receiver so that each can analyse the information away from the system.

The extent to which these new systems are increasing the consumption of paper is already evident in the growth of form-bond grades. During the past 25 years the amount of computer paper required to support a billion constant dollars of GNP has quadrupled; in other words, the growth of computer paper has grown at a rate of 6% higher than that of the GNP itself. In the last decade these grades of paper have increased their share of the GNP while that of most other grades such as packaging, tissue and newsprint have stayed constant or slightly declined.

What conclusions can we draw from this historic perspective of human communication? Perhaps the most important is that communication is a system. It involves a choice of characters to represent language; a device, either mechanical or electronic, to manipulate the characters; an image forming system and a receptor sheet. Characters have evolved from the early pictorial imagery of Egypt and China to binary symbolism; the image manipulating device from the scribe or brush to the computer and laser printer; the marking material from ink to electrophoretic powder and the receptor from bones to paper. As we think of the future of paper in the context of communications we must think of it in terms of the paper properties required by these new methods. Some of them have been discussed at earlier symposia, although usually without particular reference to this use. The relative importance of different paper properties is likely to change in the future. Dimensional stability may well become more important than tensile strength, and stiffness than burst. Surface texture and uniformity will probably be more critical than internal bond strength or structure. As paper becomes a more highly engineered structure, the properties of fillers, adhesives, pigments and coatings will become as, or more important than

the fibres themselves or the way they were processed. Rather than creating a diminishing role for fundamental paper research in the future, the Age of Information is more likely to expand the needs and opportunities. It will require us to broaden our research horizons beyond the study of cellulose fibres alone and to explore the whole field of image formation on paper and its interaction with all of the components of the sheet.

Thank you for inviting me to address this distinguished audience and my best wishes to you all for a successful symposium.