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THE BLOCKED ROAD TO PICTORIAL COMMUNICATION

IN 1916 and 1917, when the department of prints of the Metropolitan Museum of Art in New York was being started, there was much talk and argument about what the character of its collection should be. In the course of those discussions I became aware that the backward countries of the world are and have been those that have not learned to take full advantage of the possibilities of pictorial statement and communication, and that many of the most characteristic ideas and abilities of our western civilization have been intimately related to our skills exactly to repeat pictorial statements and communications.

My experience during the following years led me to the belief that the principal function of the printed picture in western Europe and America has been obscured by the persistent habit of regarding prints as of interest and value only in so far as they can be regarded as works of art. Actually the various ways of making

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prints (including photography) are the only methods by which exactly repeatable pictorial statements can be made about anything. The importance of being able exactly to repeat pictorial statements is undoubtedly greater for science, technology, and general information than it is for art.

Historians of art and writers on aesthetic theory have ignored the fact that most of their thought has been based on exactly repeatable pictorial statements about works of art rather than upon first-hand acquaintance with them. Had they paid attention to that fact they might have recognized the extent to which their own thinking and theorizing have been shaped by the limitations imposed on those statements by the graphic techniques. Photography and photographic process, the last of the long succession of such techniques, have been responsible for one of the greatest changes in visual habit and knowledge that has ever taken place, and have led to an almost complete rewriting of the history of art as well as a most thoroughgoing reevaluation of the arts of the past.

Although every history of European civilization makes much of the invention in the mid-fifteenth century of ways to print words from movable types, it is customary in those histories to ignore the slightly earlier discovery of ways to print pictures and diagrams. A book, so far as it contains a text, is a container of exactly repeatable word symbols arranged in an exactly repeatable order. Men have been using such containers for at least five thousand years. Because of this it can be argued that the printing of books was no more than a way of making very old and familiar things more cheaply. It may even be said that for a while type printing was little more than a way to do with a much smaller number of proof readings. Prior to 1501 few books were printed in editions larger than that handwritten one of a thousand copies to which Pliny the Younger referred in the second century of our era. The printing of pictures, however, unlike the printing of words from movable types, brought a completely new thing into existence—it made possible for the first time pictorial statements of a kind that could be exactly repeated during the effective life of the printing surface.

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This exact repetition of pictorial statements has had incalculable effects upon knowledge and thought, upon science and technology, of every kind. It is hardly too much to say that since the invention of writing there has been no more important invention than that of the exactly repeatable pictorial statement.

Our failure to realize this comes in large measure from the change in the meaning and implications of the word 'print' during the last hundred years. For our great grandfathers, and for their fathers back to the Renaissance, prints were no more and no less than the only exactly repeatable pictorial statements they knew. Before the Renaissance there were no exactly repeatable pictorial statements. Until a century ago, prints made in the old techniques filled all the functions that are now filled by our line cuts and half tones, by our photographs and blueprints, by our various colour processes, and by our political cartoons and pictorial advertisements. If we define prints from the functional point of view so indicated, rather than by any restriction of process or aesthetic value, it becomes obvious that without prints we should have very few of our modern sciences, technologies, archaeologies, or ethnologies—for all of these are dependent, first or last, upon information conveyed by exactly repeatable visual or pictorial statements.

This means that, far from being merely minor works of art, prints are among the most important and powerful tools of modern life and thought. Certainly we cannot hope to realize their actual role unless we get away from the snobbery of modern print collecting notions and definitions and begin to think of them as exactly repeatable pictorial statements or communications, without regard to the accident of rarity or what for the moment we may regard as aesthetic merit. We must look at them from the point of view of general ideas and particular functions, and, especially, we must think about the limitations which their techniques have imposed on them as conveyors of information and on us as receivers of that information.

From very ancient times materials suitable for the making of

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prints have been available, and apposite skills and crafts have been familiar, but they were not brought into conjunction for the making of exactly repeatable pictorial statements in Europe until roughly about A.D. 1400. In view of this it is worth while to try to think about the situation as it was before there were any prints.

As it seems to be the usual custom to begin with the ancient Greeks when discussing anything that has to do with culture, I shall follow the precedent. There is no possible doubt about the intelligence, the curiosity, and the mental agility of a few of the old Greeks. Neither can there be any doubt about the greatness of their influence on subsequent European culture, even though for the last five hundred years the world has been in active revolt against Greek ideas and ideals. For a very long time we have been taught that after the Greeks there came long periods in which men were not so intelligent as the Greeks had been, and that it was not until the Renaissance that the so intelligent Greek point of view was to some extent recovered. I believe that this teaching, like its general acceptance, has come about because people have confused their ideas of what constitutes intelligence with their ideas about what they have thought of, in the Arnoldian sense, as culture. Culture and intelligence are quite different things. In actual life, people who exemplify Arnoldian culture are no more intelligent than other people, and they have very rarely been among the great creators, the discoverers of new ideas, or the leaders towards social enlightenment. Most of what we think of as culture is little more than the unquestioning acceptance of standardized values.

Historians until very recent times have been literary men and philologues. As students of the past they have rarely found anything they were not looking for. They have been so full of wonder at what the Greeks said, that they have paid little attention to what the Greeks did not do or know. They have been so full of horror at what the Dark Ages did not say, that they have paid no attention to what they did do and know. Modern research, by men who are aware of low subjects like economics and technology, is rapidly



1. Painted woodcut from Boner's *Der Edelstein*, Bamberg, 1461.
About actual size.



2. Metal cut of St. Martin. Reduced.

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changing our ideas about these matters. In the Dark Ages, to use their traditional name, there was little assured leisure for pursuit of the niceties of literature, art, philosophy, and theoretical science, but many people, nevertheless, addressed their perfectly good minds to social, agricultural, and mechanical problems. Moreover, all through those academically debased centuries, so far from there having been any falling off in mechanical ability, there was an unbroken series of discoveries and inventions that gave the Dark Ages, and after them the Middle Ages, a technology, and, therefore, a logic, that in many most important respects far surpassed anything that had been known to the Greeks or to the Romans of the Western Empire.

As to the notorious degradation of the Dark Ages, it is to be remembered that during them Byzantium was an integral part of Europe and actually its great political centre of gravity. There was no iron curtain between the East and the West. Intercourse between them was constant and unbroken, and for long periods Byzantium was in actual control of large parts of Italy. We forget the meaning of the word Romagna, and of the Byzantine arts of Venice and South Italy. These things should be borne in mind in view of the silent implication that Byzantium, from which later on so much of Greek learning came to the West, never lost that learning. This implication is probably quite an untrue one. Both East and West saw a great decline in letters. The Academy at Athens was closed in A.D. 529. At Byzantium the university was abolished in the first half of the eighth century. Psellos said that in the reign of the Emperor Romanos (1028–34) the learned at Constantinople had not reached further than the portals of Aristotle and only knew by rote a few catch words of Platonism. The Emperor Constantine (1042–54) revived the university on a small scale and made Psellos its first professor of philosophy. Psellos taught Platonism, which he personally preferred to the then reigning variety of Aristotelianism. So far as concerned intellectual activity there was probably much more in the West than in the East, though directed at such different ends that it evaded the

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attention of students trained in the traditional classical lore. Where the East let so much of the inherited culture as it retained become gradually static and dull, the West turned from it and addressed its intelligence to new values and new things.

In spite of all this it was the Dark Ages that transmitted to us practically all we have of Greek and Roman literature, science, and philosophy. If the Dark Ages had not to a certain extent been interested in such things it is probable that we should have very little of the classical literatures. People who laboriously copy out by hand the works of Plato and Archimedes, Lucretius and Cicero, Plotinus and Augustine, cannot be accused of being completely devoid of so-called intellectual interests. We forget that the Greeks themselves had forgotten much of their mathematics before the Dark Ages began, and it is easy to overlook such a thinker as Berengar, in the West, who, about the middle of the eleventh century, challenged much of what we regard as Greek thought by asserting that there is no substance in matter aside from the accidents.

The intelligence, as distinct from the culture, of the Dark and Middle Ages, is shown by the fact that in addition to forging the political foundations of modern Europe and giving it a new faith and morality, those Ages developed a great many of what today are among the most basic processes and devices. The Greeks and Romans had no thought of labour-saving devices and valued machinery principally for its use in war—just as was the case in the Old South of the United States, and for much the same reasons. To see this, all one has to do is to read the tenth book of Vitruvius. The Dark and Middle Ages in their poverty and necessity produced the first great crop of Yankee ingenuity.

The breakdown of the Western Empire and the breakdown of its power plant were intimately related to each other. The Romans not only inherited all the Greek technology but added to it, and they passed all this technology on to the Dark Ages. It consisted principally in the manual dexterity and the brute animal force of human beings, most of them in bondage. In the objects that have come down to us from classical times there is little evidence of any

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actively working and spreading mechanical ingenuity. As shown by Stonehenge, the moving and placement of heavy stones goes back of the beginnings of written history. The Romans did not, however, pass on to the Dark Ages in the West the constantly renewed supply of slaves that constituted the power plant about which the predatory Empire was built. In other words, the Dark Ages found themselves stranded with no power plant and with no tradition or culture of mechanical ingenuity that might provide another power plant of another kind. They had to start from scratch. The real wonder, under all the circumstances, is not that they did so badly but that they did so well.

The great task of the Dark and the Middle Ages was to build for a culture of techniques and technologies. We are apt to forget that it takes much longer to do this than it does to build up a culture of art and philosophy, one reason for this being that the creation of a culture of technologies requires much harder and more accurate thinking. Emotion plays a surprisingly small part in the design and operation of machines and processes, and, curiously, you cannot make a machine work by flogging it. When the Middle Ages had finally produced the roller press, the platen press, and the type-casting mould, they had created the basic tools for modern times.

We have for so long been told about the philosophy, art, and literature, of classical antiquity, and have put them on such a pedestal for worship, that we have failed to observe the patent fact that philosophy, art, and literature can flourish in what are technologically very primitive societies, and that the classical peoples were actually in many ways of the greatest importance not only very ignorant but very unprogressive. Progress and improvement were not classical ideals. The trend of classical thought was to the effect that the past was better than the present and that the story of human existence was one of constant degradation. In spite of all the romantic talk about the joy and serenity of the Greek point of view, Greek thought actually developed into a deeply dyed pessimism that coloured and hampered all classical activities.

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It is, therefore, worth while to give a short list of some of the things the Greeks and Romans did not know, and that the Middle Ages did know. For most of the examples I shall cite I am indebted to Lynn White's remarkable essay on Technology and Invention in the Middle Ages.¹ The classical Greeks and Romans, although horsemen, had no stirrups. Neither did they think to shoe the hooves of their animals with plates of metal nailed to them. Until the ninth or tenth centuries of our era horses were so harnessed that they pushed against straps that ran high about their necks in such a way that if they threw their weight and strength into their work they strangled themselves. Neither did the classical peoples know how to harness draft animals in front of each other so that large teams could be used to pull great weights. Men were the only animals the ancients had that could pull efficiently. They did not even have wheelbarrows. They made little or no use of rotary motion and had no cranks by which to turn rotary and reciprocating motion into each other. They had no windmills. Such water wheels as they had came late and far between. The classical Greeks and Romans, unlike the Middle Ages, had no horse collars, no spectacles, no algebra, no gunpowder, no compass, no cast iron, no paper, no deep ploughs, no spinning wheels, no methods of distillation, no place value number systems—think of trying to extract a square root with either the Greek or the Roman system of numerals!

The engineers who, in the sixth century A.D., brought the great monolith that caps the tomb of Theodoric across the Adriatic and set it in place, were in no way inferior to the Greek and Roman engineers. The twelfth-century cathedrals of France represent a knowledge of engineering, of stresses and strains, and a mechanical ingenuity far beyond anything dreamed of in classical times. The Athenian Parthenon, no matter what its aesthetic qualities, was but child's play as engineering compared to buildings like the cathedrals at Rheims and Amiens.

It is perhaps hard for us, who have been educated in the fag

¹ *Speculum*, vol. XV, p. 141 (April 1940).

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end of the traditional humanistic worship of the classical peoples, to realize that what happened in the ninth and tenth centuries of our era in North-Western Europe was an economic revolution based on animal power and mechanical ingenuity which may be likened to that based on steam power which took place in the late eighteenth and early nineteenth centuries. It shifted the economic and political centre of gravity away from the Mediterranean with its technological ineptitude to the north-west, where it has been ever since. This shift may be said to have had its first official recognition in the two captures of Constantinople in 1203 and 1204. It is customary from the philological point of view to regard these captures as a horrible catastrophe to light and learning, but in fact they actually led to the wiping out of the most influential centre of unprogressive backward-looking traditionalism there was in Europe.

In view of the things the Greeks and Romans did not know, it is possible that the real reason for the so-called darkness of the Dark Ages was the simple fact that they were still in so many ways so very classical.

It is well to remember things of this kind when we are told about the charm of life in Periclean Athens or in the Rome of the Antonines, and how superior it was to that of all the ages that have succeeded them. The inescapable facts are that the Greek and Roman civilizations were based on slavery of the most degrading kind, that slaves did not reproduce themselves, that the supply was only maintained by capture in predatory warfare, and that slavery is incompatible with the creation of a highly developed technology. Although a few of the highly educated Greeks went in for pure mathematics and theoretical science, neither they nor the educated Romans ever lowered themselves to banausic pursuits. They never thought of doing laborious, mechanical things more efficiently or with less human pain and anguish—unless they were captured and sold into slavery, and what they thought then did not matter. As all these things in the end are of great ethical importance, it should also be remembered that the so cultured Greeks left it to the brutal

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Romans to discover the idea of humanity, and that it was not until the second century of our era that the idea of personality was first given expression. If the educated Greeks and Romans had demeaned themselves by going in for civil technology as hard as they did for a number of other things the story might have been different. But they did not, even in matters that would have been greatly to the advantage of the governing groups in society.

Thus, the Romans are famous for the military roads they built all over the Empire, and the Dark and Middle Ages are held up to scorn for having let those roads go to pieces. However, if we think that those roads were not constructed for civil traffic but as part of the machinery of ruthless military domination of subject peoples, it is possible to regard their neglect as a betterment. Those later Ages substituted other kinds of roads for the Roman variety, roads that were not paved with cemented slabs of stone for the quicker movement of the slogging legions, but roads that, if paved at all, were paved with cobbles, which in many ways and from many unmilitary points of view were more efficient. It is significant that the world has never gone back to the Roman methods of road-building, and that as late as the days of my own youth streets in both London and New York were still paved with cobbles.

To take another example: the Greeks were great seamen. The Athenian Empire was a maritime empire. But the Greeks rowed and did not sail. If you cannot beat up into the wind you cannot sail. All the Greeks' sails enabled them to do was to blow down the wind a little faster. They did not dare to venture beyond sight of land. The rudder at the end of the keel and the lateen and fore and aft sails, like the mariner's compass, were acquisitions of the Dark and Middle Ages. Actually, until the Renaissance and even later, the Mediterranean peoples never learned how to do what we call sailing. The Battle of Lepanto, in 1571, was fought by men in row-boats—large row-boats, to be sure—which grappled with each other so that their men could fight it out hand to hand. The test as between the thought based on the ancient row-boat techniques and

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that based on the mediaeval deep-water sailing came seventeen years after Lepanto, when the great Spanish Armada met the little English fleet. This was the crucial battle in the last long-drawn-out attempt of the Mediterranean to recover the hegemony it had lost before the end of the tenth century, and in it it went down to utter and disastrous defeat. Within a little more than a hundred years it was distant England that held Gibraltar and Port Mahon and was the great Mediterranean sea power.

On the intellectual and administrative side of ancient life we meet the same lack of mechanical ingenuity. Few people have been more given to books and reading than the upper classes of Greece and Rome. Books were made by copying by hand. The trade in them flourished at Athens, at Alexandria, and at Rome. Great libraries were formed in the Hellenistic period and in the early centuries of the Roman Empire. Plato says that in his time a copy of Anaxagoras could be bought for a drachma, which, according to the Oxford Dictionary, may be considered as being worth less than twenty-five cents. Pliny, the Younger, in the second century of our era, refers to an edition of a thousand copies of a text. Had the Romans had any mechanical way of multiplying the texts of their laws and their legal and administrative rulings and all the forms needed for taxation and other such things, an infinite amount of time and expense would have been saved. But I cannot recall that I have either read or heard of any attempt by an ancient to produce a book or legal form by mechanical means.

In its way the failure of the ancients to address their minds to problems of the kinds I have indicated is one of the most cogent criticisms that can be made of the kind of thought in which they excelled and of its great limitations. The Greeks were full of all sorts of ideas about all sorts of things, but they rarely checked their thought by experiment and they exhibited little interest in discovering and inventing ways to do things that had been unknown to their ancestors. They refined on ancient processes, and in the Hellenistic period they invented ingenious mechanical toys, but it is difficult to point to any technological or labour-saving

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devices invented by them that were of any momentous social or economic importance. This is shown in several odd ways. For one, the learned writers of accounts of daily life in ancient times have no hesitancy in mixing up details taken from sources that are generations apart, as though they all related to one unchanging state of affairs. For another, modern students have not hesitated to play up as a great and profound virtue the lack of initiative of the Greek craftsmen in looking for new subjects and new manners of work. Thus Percy Gardner, lauding the Greek architects and stone-cutters, in his article on Greek Art in the eleventh edition of the *Encyclopaedia Britannica*, says, 'Instead of trying to invent new schemes, the mason contents himself with improving the regular patterns until they approach perfection.' One can hear the unctious drip from that deadly word 'perfection'—one of the greatest inhibitors of intelligent thought that is known to man. The one epoch-making discovery in architectural construction that was made by the classical peoples seems to have been the arch—but the Romans had to bring it with them to Byzantium. Apparently there were no Greek voussoirs, i.e. stones so cut and shaped as to fit together in an arch or vault.

Learned men have devoted many large and expensive volumes to the gathering together of all the literary evidence there is about classical painting and drawing and to the reproduction of all the specimens of such drawing and painting as have been found. It appears from these books that there are no surviving classical pictorial statements, except such as were made incidentally in the decoration of objects and wall surfaces. For such purposes as those there was no need or call for methods to exactly repeat pictorial statements. From the point of view of art as expression or decoration there is no such need, but from that of general knowledge, science, and technology, there is a vast need for them. The lack of some way of producing such statements was no less than a road block in the way of technological and scientific thought and accomplishment.

Lest it be thought that in saying this I am merely expressing a



3. 'The Duchess'. Wood blocks from Holbein's *Dance of Death*, c. 1520. About actual size, and enlarged head.



4. Woodcut from Osatus's *La vera perfezzione del disegno*, Venice 1561.
Slightly enlarged.

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personal prejudice, I shall call your attention to what was said about it by a very great and unusually intelligent Roman gentleman, whose writings are held in particularly high esteem by all students of classical times. Some passages in the *Natural History* of Pliny the Elder, a book that was written in the first century of our era, tell the story in the most explicit and circumstantial of manners. As pointed out by Pliny, the Greeks were actually aware of the road block from which they suffered, but far from doing anything about it they accommodated themselves to it by falling back into what can only be called a known and accepted incompetence. More than that, I believe, they built a good deal of their philosophy about this incompetence of theirs. In any case, what happened affords a very apposite example of how life works under the double burden of a pessimistic philosophy and a slave economy. There is nothing more basically optimistic than a new and unprecedented contrivance, even though it be a lethal weapon.

Pliny's testimony is peculiarly valuable because he was an intelligent eye-witness about a condition for which, unfortunately, all the physical evidence has vanished. He cannot have been the only man of his time to be aware of the situation and the call that it made for ingenuity. Seemingly his statement has received but slight attention from the students of the past. This is probably due to the fact that those students had their lines of interest laid down for them before the economic revolution that came to England in the late eighteenth and early nineteenth centuries and did not reach Germany until after 1870, at a time when the learned and the gentry knew nothing and cared less about what they regarded as merely mechanical things. The preoccupation of the post-mediaeval schools and universities with classical thought and literature was probably the greatest of all the handicaps to technological and therefore to social advance. It would be interesting to see a chronological list of the establishments of the first professorships of engineering. With rare exceptions the mechanical callings and knowledges were in the past as completely foreign to the thought and life of the students of ancient times as they were

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to the young elegants who attended the Academy or walked and talked with Aristotle. So far as I have been able to observe they still are.

In any event, according to Bohn, what Pliny said was this:

‘In addition to these (Latin writers), there are some Greek writers who have treated of this subject (i.e. botany). . . . Among these, Crateuas, Dionysius, and Metrodorus, adopted a very attractive method of description, though one which has done little more than prove the remarkable difficulties which attended it. It was their plan to delineate the various plants in colours, and then to add in writing a description of the properties which they possessed. Pictures, however, are very apt to mislead, and more particularly where such a number of tints is required for the imitation of nature with any success; in addition to which, the diversity of copyists from the original paintings, and their comparative degrees of skill, add very considerably to the chances of losing the necessary degree of resemblance to the originals . . .’ (Chap. 4, Book 25).

‘Hence it is that other writers have confined themselves to a verbal description of the plants; indeed some of them have not so much as described them even, but have contented themselves for the most part with a bare recital of their names, considering it sufficient if they pointed out their virtues and properties to such as might feel inclined to make further inquiries into the subject’ (Chap. 5, Book 25).

‘The plant known as “paeonia” is the most ancient of them all. It still retains the name of him who was the first to discover it, being known also as the “pentorobus” by some, and the “glycicide” by others; indeed this is one of the great difficulties attendant on forming an accurate knowledge of plants, that the same object had different names in different districts’ (Chap. 10, Book 25).¹

It is to be noted that in his account of the breakdown of Greek botany, Pliny does not fall back upon general ideas of a woolly

¹ Quoted by permission of G. Bell & Sons, Ltd., the present publishers of Bohn’s Library.

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kind. There is no *Zeitgeist* explanation, no historicism, no suggestion that things were not done simply because people in their wisdom and good taste preferred not to do them even though of course they could have done them if they had wanted to. Pliny's reason is as hard and brutal a fact as a bridge that has collapsed while being built. This essay amounts to little more than a summary account of the long slow discovery of ways to erect that bridge.

In view of this I shall rephrase what Pliny said: The Greek botanists realized the necessity of visual statements to give their verbal statements intelligibility. They tried to use pictures for the purpose, but their only ways of making pictures were such that they were utterly unable to repeat their visual statements wholly and exactly. The result was such a distortion at the hands of the successive copyists that the copies became not a help but an obstacle to the clarification and the making precise of their verbal descriptions. And so the Greek botanists gave up trying to use illustrations in their treatises and tried to get along as best they could with words. But, with words alone, they were unable to describe their plants in such a way that they could be recognized—for the same things bore different names in different places and the same names meant different things in different places. So, finally, the Greek botanists gave up even trying to describe their plants in words, and contented themselves by giving all the names they knew for each plant and then told what human ailments it was good for. In other words, there was a complete breakdown of scientific description and analysis once it was confined to words without demonstrative pictures.

What was true of botany as a science of classification and recognition of plants was also true of an infinite number of other subjects of the very greatest importance and interest to men. Common nouns and adjectives, which are the materials with which a verbal description is made, are after all only the names of vaguely described classes of things of the most indefinite kind and without precise concrete meanings, unless they can be exemplified by

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pointing to actual specimens. In the absence of actual specimens the best way (perhaps the only way) of pointing is by exhibiting properly made pictures. We can get some idea of this by trying to think what a descriptive botany or anatomy, or a book on machines or on knots and rigging, or even a sempstress's hand-book, would be like in the absence of dependable illustrations. The only knowledges in which the Greeks made great advances were geometry and astronomy, for the first of which words amply suffice, and for the second of which every clear night provides the necessary invariant image to all the world.

All kinds of reasons have been alleged in explanation of the slow progress of science and technology in ancient times and in the ages that succeeded them, but no reference is ever made to the deterrent effect of the lack of any way of precisely and accurately repeating pictorial statements about things observed and about tools and their uses. The revolutionary techniques that filled this lack first came into general use in the fifteenth century. Although we can take it for granted that the making of printed pictures began some time about 1400, recognition of the social, economic, and scientific, importance of the exact repetition of pictorial statements did not come about until long after printed pictures were in common use. This is shown by the lateness of most of the technical illustrated accounts of the techniques of making things. As examples I may cite the first accounts of the mechanical methods of making exactly repeatable statements themselves. Thus the first competent description of the tools and technique of etching and engraving was the little book that Abraham Bosse published in 1645; the first technical account of the tools and processes used in making types and printing from them was that published by Joseph Moxon in 1683; and the first similar account of wood-cutting, the oldest of all these techniques, was the *Traité* of J. M. Papillon, which bears on its title page the date 1766. It is not impossible that Moxon's *Mechanick Exercises*, which were published serially in the last years of the seventeenth century, had much to do with England's early start in the industrial revolution.

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Anyone who is gifted with the least mechanical ingenuity can understand these books and go and do likewise. But he can do so only because they are filled with pictures of the special tools used and of the methods of using them. Parts of Moxon's account of printing can be regarded as studies in the economy of motion in manipulation. I have not run the matter down, but I should not be surprised if his book were not almost the first in which such things were discussed.

Of many of the technologies and crafts requiring particular manual skills and the use of specialized tools there seem to have been no adequate accounts until the completion of the great and well illustrated *Encyclopaedia* of Diderot and his fellows in the third quarter of the eighteenth century, just before the outbreak of the French Revolution. But the *Encyclopaedia* was a very expensive and very large set of volumes, intended for and limited to the use of the rich. Curiously, the importance of its contribution to a knowledge of the arts and crafts has attracted comparatively little attention as compared to that which has been given to its articles on political matters, although there is good reason to think that they had equally great results.

The last century is still so close to us and we are so busy keeping up with the present one, that it is hard for us to realize the meaning of the fact that the last hundred and fifty years have seen the greatest and most thoroughgoing revolution in technology and science that has ever taken place in so short a time. In western Europe and in America the social, as well as the mechanical, structure of society and life has been completely refashioned. The late Professor Whitehead made the remarkable observation that the greatest invention of the nineteenth century was that of the technique of making inventions. But he did not point out that this remarkable invention was based in very large measure on that century's sudden realization that techniques and technologies can only be effectively described by written or printed words when they are accompanied by adequate demonstrative pictures.

The typical eighteenth-century methods of book illustration

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were engraving and etching. Etchings and engravings have always been expensive to make and to use as book illustrations. The books that were fully illustrated with them were, with few exceptions, intended for the consumption of the rich and the traditionally educated classes. In the eighteenth century the title pages of these books sometimes described them as being 'adorned with elegant sculptures', or other similar words. The words 'adorned' and 'elegant' tell the story of their limitations, mental and financial alike. Lest it be thought that the phrase I have just quoted came from some polite book of verse or essays, I may say that it has stuck in my memory ever since at the age of ten I saw it on the title page of a terrifying early eighteenth-century edition of *Foxe's Martyrs*, in which the illustrators went all out to show just what happened to the Maryian heretics. Under the circumstances I can think of few phrases that throw more light on certain aspects of eighteenth-century life and thought.

Although hundreds of thousands of legible impressions could be printed at low cost from the old knife-made woodcuts, the technique of woodcutting was not only out of fashion in the eighteenth century, but its lines were too coarse and the available paper was too rough for the woodcut to convey more than slight information of detail and none of texture.

At the end of the eighteenth century and the beginning of the nineteenth century a number of very remarkable inventions were made. I shall mention but three of them. First, Bewick, in the 1780's, developed the technique of using an engravers, tool on the end of the wood, so that it became possible to produce from a wood-block very fine lines and delicately gradated tints, provided it were printed on smooth and not too hard paper. Next, in 1798, Robert, in France, invented, and shortly afterwards, in England, Fourdrinier perfected, a paper-making machine, operated by power, either water or steam, which produced paper by a continuous process. It also made possible the production of paper with a wove surface that was smoother than any that had previously been made in Europe. When fitted with calendar rolls the

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machine produced paper that was so smooth it was shiny. Finally, just before 1815, Koenig, a German resident in England, devised for the (*London*) *Times* a printing press that was operated by power and not by the strength of men's backs. In connection with a revival of Ged's earlier invention of stereotyping, these inventions brought about a very complete revolution in the practice of printing and publishing. The historians of printing have devoted their attention to the making of fine and expensive books, and in so doing they have overlooked the great function of books as conveyors of information. The history of the cheap illustrated book and its role in the self-education of the multitude has yet to be written.

It took but a comparatively short time for these three or four inventions to spread through the world. As they became familiar there was such a flood of cheap illustrated informative books as had never before been known. Nothing even approaching it had been seen since the sixteenth century. It took only a few decades for the publishers everywhere to begin turning out books of this kind at very low prices. In a short time the world ceased to talk about the 'art and mystery' of its crafts. In France they said that the Revolutionary law abolishing the guilds opened the careers to the talents, but it was actually these cheap illustrated informative books that opened the crafts to everyone, no matter how poor or unlearned, provided only that he knew how to read and to understand simple pictures. As examples of this I may cite the well-known *Manuels Roret*, the publication of which goes back to 1825, and the English *Penny Cyclopaedia* which began in 1833. It is to be noted that for a long time in the nineteenth century the upper classes and the traditionally educated made few contributions to the rapidly lengthening list of new inventions, and that so many of those inventions were made by what in England until very recent years were condescendingly referred to as 'self-educated men'. The fact was that the classicizing education of the men who were not self educated prevented them from making inventions.

In the Renaissance they had found a solution of the dilemma

INTRODUCTION

of the Greek botanists as described by Pliny. In the nineteenth century informative books usefully illustrated with accurately repeatable pictorial statements became available to the mass of mankind in western Europe and in America. The result was the greatest revolution in practical thought and accomplishment that has ever been known. This revolution was a matter as momentous from the ethical and political points of view as from the mechanical and economic ones. The masses had begun to get the one great tool they most needed to enable them to solve their own problems. Today the news counters in our smallest towns are piled with cheap illustrated magazines at which the self-consciously educated turn up their noses, but in those piles are prominently displayed long series of magazines devoted to mechanical problems and ways of doing things, and it would be well for the cultured if they but thought a little about the meaning of that.

I think it can be truthfully said that in 1800 no man anywhere, no matter how rich or highly placed, lived in such physical comfort or so healthily, or enjoyed such freedom of mind and body, as do the mechanics of today in my little Connecticut town.

If any one thing can be credited with this it is the pervasion of the cheap usefully informative illustrated book.

II

THE ROAD BLOCK BROKEN

THE FIFTEENTH CENTURY

PRINTS began to pervade the life and thought of western Europe in the fifteenth century. It is therefore necessary to take a glance at what we have been told about that century.

Probably the worst way there is to discover the most important thing done in any historic period is to take the word of that period for it. What to the generation of its occurrence is merely a casual happening, an amusing toy, or an impractical intellectual or physical adventure, in time frequently becomes all-important for the world.

In spite of this we are still asked to think of the Renaissance in terms of what some literary people of that time thought were the most important things it did. Thus almost every book dealing with the Renaissance says that the principal events of the fifteenth century were the recoveries of Greek thought and of the classical forms of art. This statement is so customary and is made with such an air of finality that most of us have come to believe it. And, yet, on the very face of the record, it is impossible to believe it. We have forgotten that the literary and artistic men who evolved and