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Technics and Civilization

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A Harvest Book
Harcourt Brace & Company
San Diego New York London

CHAPTER I. CULTURAL PREPARATION

1: Machines, Utilities, and "The Machine"

During the last century the automatic or semi-automatic machine has come to occupy a large place in our daily routine; and we have tended to attribute to the physical instrument itself the whole complex of habits and methods that created it and accompanied it. Almost every discussion of technology from Marx onward has tended to overemphasize the part played by the more mobile and active parts of our industrial equipment, and has slighted other equally critical elements in our technical heritage.

What is a machine? Apart from the simple machines of classic mechanics, the inclined plane, the pulley, and so forth, the subject remains a confused one. Many of the writers who have discussed the machine age have treated the machine as if it were a very recent phenomenon, and as if the technology of handicraft had employed only tools to transform the environment. These preconceptions are baseless. For the last three thousand years, at least, machines have been an essential part of our older technical heritage. Reuleaux's definition of a machine has remained a classic: "A machine is a combination of resistant bodies so arranged that by their means the mechanical forces of nature can be compelled to do work accompanied by certain determinant motions"; but it does not take us very far. Its place is due to his importance as the first great morphologist of machines, for it leaves out the large class of machines operated by man-power.

Machines have developed out of a complex of non-organic agents for converting energy, for performing work, for enlarging the mechanical or sensory capacities of the human body, or for reducing to a mensurable order and regularity the processes of life. The automaton is the last step in a process that began with the use of one part or another of the human body as a tool. In back of the development of tools and machines lies the attempt to modify the environment in such a way as to fortify and sustain the human organism: the effort is either to extend the powers of the otherwise unarmed organism, or to manufacture outside of the body a set of conditions more favorable toward maintaining its equilibrium and ensuring its survival. Instead of a physiological adaptation to the cold, like the growth of hair or the habit of hibernation, there is an environmental adaptation, such as that made possible by the use of clothes and the erection of shelters.

The essential distinction between a machine and a tool lies in the degree of independence in the operation from the skill and motive power of the operator: the tool lends itself to manipulation, the machine to automatic action. The degree of complexity is unimportant: for, using the tool, the human hand and eye perform complicated actions which are the equivalent, in function, of a well developed machine; while, on the other hand, there are highly effective machines, like the drop hammer, which do very simple tasks, with the aid of a relatively simple mechanism. The difference between tools and machines lies primarily in the degree of automatism they have reached: the skilled tool-user becomes more accurate and more automatic, in short, more mechanical, as his originally voluntary motions settle down into reflexes, and on the other hand, even in the most completely automatic machine, there must intervene somewhere, at the beginning and the end of the process, first in the original design, and finally in the ability to overcome defects and to make repairs, the conscious participation of a human agent.

Moreover, between the tool and the machine there stands another class of objects, the machine-tool: here, in the lathe or the drill, one has the accuracy of the finest machine coupled with the skilled attendance of the workman. When one adds to this mechanical complex an external source of power, the line of division becomes even more difficult to establish. In general, the machine emphasizes specialization of function, whereas the tool indicates flexibility: a planing machine performs only one operation, whereas a knife can be used to smooth wood, to carve it, to split it, or to pry open a lock, or to drive in a screw. The automatic machine, then, is a very specialized kind of adaptation; it involves the notion of an external source of power, a more or less complicated inter-relation of parts, and a limited kind of activity. From the beginning the machine was a sort of minor organism, designed to perform a single set of functions.

Along with these dynamic elements in technology there is another set, more static in character, but equally important in function. While the growth of machines is the most patent technical fact of the last thousand years, the machine, in the form of the fire-drill or the potter's wheel, has been in existence since at least neolithic times. During the earlier period, some of the most effective adaptations of the environment came, not from the invention of machines, but from the equally admirable invention of utensils, apparatus, and utilities. The basket and the pot stand for the first, the dye vat and the brick-kiln stand for the second, and reservoirs and aqueducts and roads and buildings belong to the third class. The modern period has finally given us the power utility, like the railroad track or the electric transmission line, which functions only through the operation of power machinery. While tools and machines transform the environment by changing the shape and location of objects, utensils and apparatus have been used to effect equally necessary chemical transformations. Tanning, brewing, distilling, dyeing have been as important in man's technical development as smithing or weaving. But most of these processes remained in their traditional state till the middle of the nineteenth century, and it is only since then that they have been influenced in any large degree by the same set of scientific forces and human interests that were developing the modern power-machine.

In the series of objects from utensils to utilities there is the same relation between the workman and the process that one notes in the series between tools and automatic machines: differences in the degree of specialization, the degree of impersonality. But since people's attention is directed most easily to the noisier and more active parts of the environment, the rôle of the utility and the apparatus has been neglected in most discussions of the machine, or, what is almost as bad, these technical instruments have all been clumsily grouped as machines. The point to remember is that both have played an enormous part in the development of the modern environment; and at no stage in history can the two means of adaptation be split apart. Every technological complex includes both: not least our modern one.

When I use the word machines hereafter I shall refer to specific objects like the printing press or the power loom. When I use the term "the machine" I shall employ it as a shorthand reference to the entire technological complex. This will embrace the knowledge and skills and arts derived from industry or implicated in the new technics, and will include various forms of tool, instrument, apparatus and utility as well as machines proper.

2: The Monastery and the Clock

Where did the machine first take form in modern civilization? There was plainly more than one point of origin. Our mechanical civilization represents the convergence of numerous habits, ideas, and modes of living, as well as technical instruments; and some of these were, in the beginning, directly opposed to the civilization they helped to create. But the first manifestation of the new order took place in the general picture of the world: during the first seven centuries of the machine's existence the categories of time and space underwent an extraordinary change, and no aspect of life was left untouched by this transformation. The application of quantitative methods of thought to the study of nature had its first manifestation in the regular measurement of time; and the new mechanical conception of time arose in part out of the routine of the monastery. Alfred Whitehead has emphasized the importance of the scholastic belief in a universe ordered by God as one of the foundations of modern physics: but behind that belief was the presence of order in the institutions of the Church itself.

The technics of the ancient world were still carried on from Constantinople and Baghdad to Sicily and Cordova: hence the early lead taken by Salerno in the scientific and medical advances of the Middle Age. It was, however, in the monasteries of the West that the desire for order and power, other than that expressed in the military domination of weaker men, first manifested itself after the long uncertainty and bloody confusion that attended the breakdown of the Roman Empire. Within the walls of the monastery was sanctuary: under the rule of the order surprise and doubt and caprice and irregularity were put at bay. Opposed to the erratic fluctuations and pulsations of the worldly life was the iron discipline of the rule. Benedict added a seventh period to the devotions of the day, and in the seventh century, by a bull of Pope Sabinianus, it was decreed that the bells of the monastery be rung seven times in the twenty-four hours. These punctuation marks in the day were known as the canonical hours, and some means of keeping count of them and ensuring their regular repetition became necessary.

According to a now discredited legend, the first modern mechanical clock, worked by falling weights, was invented by the monk named Gerbert who afterwards became Pope Sylvester II near the close of the tenth century. This clock was probably only a water clock, one of those bequests of the ancient world either left over directly from the days of the Romans, like the water-wheel itself, or coming back again into the West through the Arabs. But the legend, as so often happens, is accurate in its implications if not in its facts. The monastery was the seat of a regular life, and an instrument for striking the hours at intervals or for reminding the bell-ringer that it was time to strike the bells, was an almost inevitable product of this life. If the mechanical clock did not appear until the cities of the thirteenth century demanded an orderly routine, the habit of order itself and the earnest regulation of time-sequences had become almost second nature in the monastery. Coulton agrees with Sombart in looking upon the Benedictines, the great working order, as perhaps the original founders of modern capitalism: their rule certainly took the curse off work and their vigorous engineering enterprises may even have robbed warfare of some of its glamor. So one is not straining the facts when one suggests that the monasteries—at one time there were 40,000 under the Benedictine rule—helped to give human enterprise the regular collective beat and rhythm of the machine; for the clock is not merely a means of keeping track of the hours, but of synchronizing the actions of men.

Was it by reason of the collective Christian desire to provide for the welfare of souls in eternity by regular prayers and devotions that time-keeping and the habits of temporal order took hold of men's minds: habits that capitalist civilization presently turned to good account? One must perhaps accept the irony of this paradox. At all events, by the thirteenth century there are definite records of mechanical clocks, and by 1370 a well-designed "modern" clock had been built by Heinrich von Wyck at Paris. Meanwhile, bell towers had come into existence, and the new clocks, if they did not have, till the fourteenth century, a dial and a hand that translated the movement of time into a movement through space, at all events struck the hours. The clouds that could paralyze the sundial, the freezing that could stop the water clock on a winter night, were no longer obstacles to time-keeping: summer or winter, day or night, one was aware of the measured clank of the clock. The instrument presently spread outside the monastery; and the regular striking of the bells brought a new regularity into the life of the workman and the merchant. The bells of the clock tower almost defined urban existence. Time-keeping passed into time-serving and time-accounting and time-rationing. As this took place, Eternity ceased gradually to serve as the measure and focus of human actions.

The clock, not the steam-engine, is the key-machine of the modern industrial age. For every phase of its development the clock is both the outstanding fact and the typical symbol of the machine: even today no other machine is so ubiquitous. Here, at the very beginning of modern technics, appeared prophetically the accurate automatic machine which, only after centuries of further effort, was also to prove the final consummation of this technics in every department of industrial activity. There had been power-machines, such as the water-mill, before the clock; and there had also been various kinds of automata, to awaken the wonder of the populace in the temple, or to please the idle fancy of some Moslem caliph: machines one finds illustrated in Hero and Al-Jazari. But here was a new kind of

power-machine, in which the source of power and the transmission were of such a nature as to ensure the even flow of energy throughout the works and to make possible regular production and a standardized product. In its relationship to determinable quantities of energy, to standardization, to automatic action, and finally to its own special product, accurate timing, the clock has been the foremost machine in modern technics: and at each period it has remained in the lead: it marks a perfection toward which other machines aspire. The clock, moreover, served as a model for many other kinds of mechanical works, and the analysis of motion that accompanied the perfection of the clock, with the various types of gearing and transmission that were elaborated, contributed to the success of quite different kinds of machine. Smiths could have hammered thousands of suits of armor or thousands of iron cannon, wheelwrights could have shaped thousands of great water-wheels or crude gears, without inventing any of the special types of movement developed in clockwork, and without any of the accuracy of measurement and fineness of articulation that finally produced the accurate eighteenth century chronometer.

The clock, moreover, is a piece of power-machinery whose "product" is seconds and minutes: by its essential nature it dissociated time from human events and helped create the belief in an independent world of mathematically measurable sequences: the special world of science. There is relatively little foundation for this belief in common human experience: throughout the year the days are of uneven duration, and not merely does the relation between day and night steadily change, but a slight journey from East to West alters astronomical time by a certain number of minutes. In terms of the human organism itself, mechanical time is even more foreign: while human life has regularities of its own, the beat of the pulse, the breathing of the lungs, these change from hour to hour with mood and action, and in the longer span of days, time is measured not by the calendar but by the events that occupy it. The shepherd measures from the time the ewes lambed; the farmer measures back to the day of sowing or forward to the harvest: if growth has its own duration and regularities, behind it are not simply matter and motion but the facts of development: in short, history. And while mechanical time is strung out in a succession of mathematically isolated instants, organic time—what Bergson calls duration—is cumulative in its effects. Though mechanical time can, in a sense, be speeded up or run backward, like the hands of a clock or the images of a moving picture, organic time moves in only one direction—through the cycle of birth, growth, development, decay, and death—and the past that is already dead remains present in the future that has still to be born.

Around 1345, according to Thorndike, the division of hours into sixty minutes and of minutes into sixty seconds became common: it was this abstract framework of divided time that became more and more the point of reference for both action and thought, and in the effort to arrive at accuracy in this department, the astronomical exploration of the sky focussed attention further upon the regular, implacable movements of the heavenly bodies through space. Early in the sixteenth century a young Nuremberg mechanic, Peter Henlein, is supposed to have created "many-wheeled watches out of small bits of iron" and by the end of the century the small domestic clock had been introduced in England and Holland. As with the motor car and the airplane, the richer classes first took over the new mechanism and popularized it: partly because they alone could afford it, partly because the new bourgeoisie were the first to discover that, as Franklin later put it, "time is money." To become "as regular as clockwork" was the bourgeois ideal, and to own a watch was for long a definite symbol of success. The increasing tempo of civilization led to a demand for greater power: and in turn power quickened the tempo.

Now, the orderly punctual life that first took shape in the monasteries is not native to mankind, although by now Western peoples are so thoroughly regimented by the clock that it is "second nature" and they look upon its observance as a fact of nature. Many Eastern civilizations have flourished on a loose basis in time: the Hindus have in fact been so indifferent to time that they lack even an authentic chronology of the years. Only yesterday, in the midst of the industrializations of Soviet Russia, did a society come into existence to further the carrying of watches there and to propagandize the benefits of punctuality. The popularization of time-keeping, which followed the production of the cheap standardized watch, first in Geneva, then in America around the middle of the last century, was essential to a well-articulated system of transportation and production.

To keep time was once a peculiar attribute of music: it gave industrial value to the workshop song or the tattoo or the chantey of the sailors tugging at a rope. But the effect of the mechanical clock is more pervasive and strict: it presides over the day from the hour of rising to the hour of rest. When one thinks of the day as an abstract span of time, one does not go to bed with the chickens on a winter's night: one invents wicks, chimneys, lamps, gaslights, electric lamps, so as to use all the hours belonging to the day. When one thinks of time, not as a sequence of experiences, but as a collection of hours, minutes, and seconds, the habits of adding time and saving time come into existence. Time took on the character of an enclosed space: it could be divided, it could be filled up, it could even be expanded by the invention of labor-saving instruments.

Abstract time became the new medium of existence. Organic functions themselves were regulated by it: one ate, not upon feeling hungry, but when prompted by the clock: one slept, not when one was tired, but when the clock sanctioned it. A generalized time-consciousness accompanied the wider use of clocks: dissociating time from organic sequences, it became easier for the men of the Renascence to indulge the fantasy of reviving the classic past or of reliving the splendors of antique Roman civilization: the cult of history, appearing first in daily ritual, finally abstracted itself as a special discipline. In the seventeenth century journalism and periodic literature made their appearance: even in dress, following the lead of Venice as fashion-center, people altered styles every year rather than every generation.

The gain in mechanical efficiency through co-ordination and through the closer articulation of the day's events cannot be overestimated: while this increase cannot be measured in mere horsepower, one has only to imagine its absence today to foresee the speedy disruption and eventual collapse of our entire society. The modern industrial régime could do without coal and iron and steam easier than it could do without the clock.

3: Space, Distance, Movement

"A child and an adult, an Australian primitive and a European, a man of the Middle Ages and a contemporary, are distinguished not only by a difference in degree, but by a difference in kind by their methods of pictorial representation."

Dagobert Frey, whose words I have just quoted, has made a penetrating study of the difference in spatial conceptions between the early Middle Ages and the Renascence: he has re-enforced by a wealth of specific detail, the generalization that no two cultures live conceptually in the same kind of time and space. Space and time, like language itself, are works of art, and like language they help condition and direct practical action. Long before Kant announced that time and space were categories of the mind, long before the mathematicians discovered that there were conceivable and rational forms of space other than the form described by Euclid, mankind at large had acted on this premise. Like the Englishman in France who thought that bread was the right name for *le pain* each culture believes that every other kind of space and time is an approximation to or a perversion of the real space and time in which *it* lives.

During the Middle Ages spatial relations tended to be organized as symbols and values. The highest object in the city was the church spire which pointed toward heaven and dominated all the lesser buildings, as the church dominated their hopes and fears. Space was divided arbitrarily to represent the seven virtues or the twelve apostles or the ten commandments or the trinity. Without constant symbolic reference to the fables and myths of Christianity the rationale of medieval space would collapse. Even the most rational minds were not exempt: Roger Bacon was a careful student of optics, but after he had described the seven coverings of the eye he added that by such means God had willed to express in our bodies an image of the seven gifts of the spirit.

Size signified importance: to represent human beings of entirely different sizes on the same plane of vision and at the same distance

from the observer was entirely possible for the medieval artist. This same habit applies not only to the representation of real objects but to the organization of terrestrial experience by means of the map. In medieval cartography the water and the land masses of the earth, even when approximately known, may be represented in an arbitrary figure like a tree, with no regard for the actual relations as experienced by a traveller, and with no interest in anything except the allegorical correspondence.

One further characteristic of medieval space must be noted: space and time form two relatively independent systems. First: the medieval artist introduced other times within his own spatial world, as when he projected the events of Christ's life within a contemporary Italian city, without the slightest feeling that the passage of time has made a difference, just as in Chaucer the classical legend of Troilus and Cressida is related as if it were a contemporary story. When a medieval chronicler mentions the King, as the author of The Wandering Scholars remarks, it is sometimes a little difficult to find out whether he is talking about Caesar or Alexander the Great or his own monarch: each is equally near to him. Indeed, the word anachronism is meaningless when applied to medieval art: it is only when one related events to a co-ordinated frame of time and space that being out of time or being untrue to time became disconcerting. Similarly, in Botticelli's The Three Miracles of St. Zenobius, three different times are presented upon a single stage.

Because of this separation of time and space, things could appear and disappear suddenly, unaccountably: the dropping of a ship below the horizon no more needed an explanation than the dropping of a demon down the chimney. There was no mystery about the past from which they had emerged, no speculation as to the future toward which they were bound: objects swam into vision and sank out of it with something of the same mystery in which the coming and going of adults affects the experience of young children, whose first graphic efforts so much resemble in their organization the world of the medieval artist. In this symbolic world of space and time everything was either a mystery or a miracle. The connecting link between events was the cosmic and religious order: the true order of space was Heaven, even as the true order of time was Eternity.

Between the fourteenth and the seventeenth century a revolutionary change in the conception of space took place in Western Europe. Space as a hierarchy of values was replaced by space as a system of magnitudes. One of the indications of this new orientation was the closer study of the relations of objects in space and the discovery of the laws of perspective and the systematic organization of pictures within the new frame fixed by the foreground, the horizon and the vanishing point. Perspective turned the symbolic relation of objects into a visual relation: the visual in turn became a quantitative relation. In the new picture of the world, size meant not human or divine importance, but distance. Bodies did not exist separately as absolute magnitudes: they were co-ordinated with other bodies within the same frame of vision and must be in scale. To achieve this scale, there must be an accurate representation of the object itself, a point for point correspondence between the picture and the image: hence a fresh interest in external nature and in questions of fact. The division of the canvas into squares and the accurate observation of the world through this abstract checkerboard marked the new technique of the painter, from Paolo Ucello onward.

The new interest in perspective brought depth into the picture and distance into the mind. In the older pictures, one's eye jumped from one part to another, picking up symbolic crumbs as taste and fancy dictated: in the new pictures, one's eye followed the lines of linear perspective along streets, buildings, tessellated pavements whose parallel lines the painter purposely introduced in order to make the eye itself travel. Even the objects in the foreground were sometimes grotesquely placed and foreshortened in order to create the same illusion. Movement became a new source of value: movement for its own sake. The measured space of the picture re-enforced the measured time of the clock.

Within this new ideal network of space and time all events now took place; and the most satisfactory event within this system was uniform motion in a straight line, for such motion lent itself to accurate representation within the system of spatial and temporal

co-ordinates. One further consequence of this spatial order must be noted: to place a thing and to time it became essential to one's understanding of it. In Renascence space, the existence of objects must be accounted for: their passage through time and space is a clue to their appearance at any particular moment in any particular place. The unknown is therefore no less determinate than the known: given the roundness of the globe, the position of the Indies could be assumed and the time-distance calculated. The very existence of such an order was an incentive to explore it and to fill up the parts that were unknown.

What the painters demonstrated in their application of perspective, the cartographers established in the same century in their new maps. The Hereford Map of 1314 might have been done by a child: it was practically worthless for navigation. That of Ucello's contemporary, Andrea Banco, 1436, was conceived on rational lines, and represented a gain in conception as well as in practical accuracy. By laying down the invisible lines of latitude and longitude, the cartographers paved the way for later explorers, like Columbus: as with the later scientific method, the abstract system gave rational expectations, even if on the basis of inaccurate knowledge. No longer was it necessary for the navigator to hug the shore line: he could launch out into the unknown, set his course toward an arbitrary point, and return approximately to the place of departure. Both Eden and Heaven were outside the new space; and though they lingered on as the ostensible subjects of painting, the real subjects were Time and Space and Nature and Man.

Presently, on the basis laid down by the painter and the cartographer, an interest in space as such, in movement as such, in locomotion as such, arose. In back of this interest were of course more concrete alterations: roads had become more secure, vessels were being built more soundly, above all, new inventions—the magnetic needle, the astrolabe, the rudder—had made it possible to chart and to hold a more accurate course at sea. The gold of the Indies and the fabled fountains of youth and the happy isles of endless sensual delight doubtless beckoned too: but the presence of these tangible goals does not lessen the importance of the new schemata. The categories of time and space, once practically dissociated, had become united: and the abstractions of measured time and measured space undermined the earlier conceptions of infinity and eternity, since measurement must begin with an arbitrary here and now even if space and time be empty. The itch to *use* space and time had broken out: and once they were co-ordinated with movement, they could be contracted or expanded: the conquest of space and time had begun. (It is interesting, however, to note that the very concept of acceleration, which is part of our daily mechanical experience, was not formulated till the seventeenth century.)

The signs of this conquest are many: they came forth in rapid succession. In military arts the cross-bow and the ballista were revived and extended, and on their heels came more powerful weapons for annihilating distance—the cannon and later the musket. Leonardo conceived an airplane and built one. Fantastic projects for flight were canvassed. In 1420 Fontana described a velocipede: in 1589 Gilles de Bom of Antwerp apparently built a man-propelled wagon: restless preludes to the vast efforts and initiatives of the nineteenth century. As with so many elements in our culture, the original impulse was imparted to this movement by the Arabs: as early as 880 Abû l-Qâsim had attempted flight, and in 1065 Oliver of Malmesbury had killed himself in an attempt to soar from a high place: but from the fifteenth century on the desire to conquer the air became a recurrent preoccupation of inventive minds; and it was close enough to popular thought to make the report of a flight from Portugal to Vienna serve as a news hoax in 1709.

The new attitude toward time and space infected the workshop and the counting house, the army and the city. The tempo became faster: the magnitudes became greater: conceptually, modern culture launched itself into space and gave itself over to movement. What Max Weber called the "romanticism of numbers" grew naturally out of this interest. In time-keeping, in trading, in fighting men counted numbers; and finally, as the habit grew, only numbers counted.

4: The Influence of Capitalism

The romanticism of numbers had still another aspect, important for the development of scientific habits of thought. This was the rise of capitalism, and the change from a barter economy, facilitated by small supplies of variable local coinage, to a money economy with an international credit structure and a constant reference to the abstract symbols of wealth: gold, drafts, bills of exchange, eventually merely numbers.

From the standpoint of technique, this structure had its origin in the towns of Northern Italy, particularly Florence and Venice, in the fourteenth century; two hundred years later there was in existence in Antwerp an international bourse, devoted to aiding speculation in shipments from foreign ports and in money itself. By the middle of the sixteenth century book-keeping by double entry, bills of exchange, letters of credit, and speculation in "futures" were all developed in essentially their modern form. Whereas the procedures of science were not refined and codified until after Galileo and Newton, finance had emerged in its present-day dress at the very beginning of the machine age: Jacob Fugger and J. Pierpont Morgan could understand each other's methods and point of view and temperament far better than Paracelsus and Einstein.

The development of capitalism brought the new habits of abstraction and calculation into the lives of city people: only the country folk, still existing on their more primitive local basis, were partly immune. Capitalism turned people from tangibles to intangibles: its symbol, as Sombart observes, is the account book: "its life-value lies in its profit and loss account." The "economy of acquisition," which had hitherto been practiced by rare and fabulous creatures like Midas and Croesus, became once more the everyday mode: it tended to replace the direct "economy of needs" and to substitute money-values for life-values. The whole process of business took on more and more an abstract form; it was concerned with non-commodities, imaginary futures, hypothetical gains.

Karl Marx well summed up this new process of transmutation: "Since money does not disclose what has been transformed into it,