# PART II SPRINGS OF MECHANIZATION

## MOVEMENT

Ever in flux and process, reality cannot be approached directly. Reality is too vast, and direct means fail. Suitable tools are needed, as in the raising of an obelisk.

In technics, as in science and art, we must create the tools with which to dominate reality. These tools may differ. They may be shaped for mechanization, for thought, or for the expression of feeling. But between them are inner bonds, methodological ties. Again and again, we shall recall these ties.

### Movement: The Classical and Medieval Attitude

Our thinking and feeling in all their ramifications are fraught with the concept of movement. We owe, in large measure, our understanding of the world to the Greeks. From them we inherited a magnificent foundation: mathematics and geometry, modes of thought and expression. Yet, we have departed a long way from the Greeks. In many respects we have gained; in the main, we have lost. One of the spheres in which we have gone beyond Greece is in the comprehension of movement. The urge to explore movement — that is, the *changing* in all its forms — determined the channels through which flow our scientific thought and ultimately our emotional expression.

If the Greeks did not find an adequate explanation of movement, if they did not reduce it to exact logical terms, it was not because they were incapable, but because of their fundamental view of the cosmos. They lived in a world of eternal ideas, a world of constants. In that world, they were capable of finding the appropriate formulation for thought and feeling. We inherited their geometry and their logic. Aristotle and all antiquity with him thought of the world as something reposing in itself, as something that had been in existence since the beginning of time.

In opposition came the religious idea that the world was created and set in motion by an act of will. In high Gothic times, this conception of the moved world yielded scientific consequences. The Scholastics rehabilitated Aristotle. As is well known, Aristotelian authority became so powerful in the seventeenth century that it almost succeeded in crushing the new idea of a world based on movement (Galileo). At the same time the Scholastics challenged



Aristotle on an important issue. Thomas Aquinas' questioning how the world was created from nothingness, and what principles and first causes underlay God's action, led to a searching into the question of change and, closely related to this, into the nature of movement.

As the Greek temple symbolizes forces in equilibrium, in which neither verticals nor horizontals dominate, the earth in the classical view formed the forever immovable center of the cosmos.

The soaring verticals of the Gothic cathedrals mark no equilibrium of forces. They seem the symbols of everlasting change, of movement. The stillness and contemplation emanating from these churches escapes no one; but, at the same time, the whole architecture, both within and without, is caught up in an unceasing stream of movement.

Parallel in time, the Scholastics become ever more concerned with explaining the nature of movement. The hypothesis of the earth's daily rotation was increasingly discussed, as Pierre Duhem has pointed out, by the circle of Parisian philosophers from the fourteenth century on. Nicolas Oresme, Bishop of Lisieux (1320?–82), gave ample support to this hypothesis,[1] and — says Duhem, the great French physicist, mathematician, and historian — with greater precision than Copernicus later. Oresme propounds the theory in a penetrating commentary to the first translation into the French, made at Charles V's behest, of Aristotle's Treatise on the Heavens (*Du Ciel et du Monde*). He entitles the relevant chapter: 'Several fine arguments . . . to show that the earth moves in daily movement and the sky not.'[2] Here he proposes that the movement of the heavens can equally well be explained by the circling of the earth around the sun; that the earth revolves, not the sky around the earth. To Pierre Duhem's question whether Oresme inspired Copernicus, it has been objected that Copernicus started from the logical and geometrical contradictions of the Ptolemaic system.[3] This in no way lessens Oresme's achievement.

Nicolas Oresme rises from the brilliant circle of Parisian Scholastics, its last great representative after Jean Buridan (1300–*c*.1358) and Albert of Saxony (1316–90). Ever present in their discussions and cogitations is the giant figure of Aristotle. There was no other guide. On him they test their thought; on

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[1] Pierre Duhem, 1861–1916, has brought this aspect of Nicolas Oresme to light in 'Un précurseur français de Copernic, Nicole Oresme (1377),' *Revue générale des sciences pures et appliquées*, Paris, 1909, vol. 20, pp.866–73.

[2] *Le livre du Ciel et du Monde*, Oresme's French translation of Aristotle, has recently been printed in *Medieval Studies*, vols. III–V, New York, 1941, with a commentary by Albert D. Menut and A. J. Denomy.

[3] Duhem's third volume of his *Etudes sur Léonard de Vinci, Les précurseurs parisiens de Galilée*, Paris, 1913, demonstrates in monumental fashion that the principles of Galilean mechanics were already formulated in this circle.

him it kindles. He affords the one foothold. They grope in scientific night, cautiously feeling their way into the unknown. Now they argue, against ancient authority, that the earth turns; now, that it does not. We must take care not to read into their theological and Aristotelian conceptions our own mathematical conception, one that has been growing in our consciousness ever since Descartes. Amid their groping they think as boldly as the Gothic master builders; they lay aside the fantastic Aristotelian conception of movement, and put a new one in its place — one that still prevails.

### The Fourteenth Century, First to Represent Movement

All that concerns us in this connection is the first *graphical representation of movement.* The treatise in which Nicolas Oresme achieves this, the treatise *On Intensities,*[4] proceeds after the Aristotelian fashion from the general investigation of the qualities and quantities of an object. Oresme seeks insight into the changing intensity of a quality. He determines this by a graphical method. He traces the extension (*extensio*) of the subject or bearer on a base line that corresponds to Descartes' $x$-axis of the seventeenth century; and he marks the intensity of the bearer in different stages by straight lines drawn vertically from the base line ($y$-axis). The ratio of the intensities to one another appears in these vertical lines. The changing quality of the bearer is represented in the geometrical figure delimited by the summits of the vertical lines. Oresme's treatise is accompanied by marginal figures in one of which (fig. 1) the intensities rise side by side like organ pipes.[5] The curve they delimit represents variation in the quality.

Oresme carries over this basic method as he investigates the essence of movement, thus gaining insight into the nature of speed (*velocitas*) and of acceleration. By a graphical method he represents movement, time, speed, and acceleration.[6]

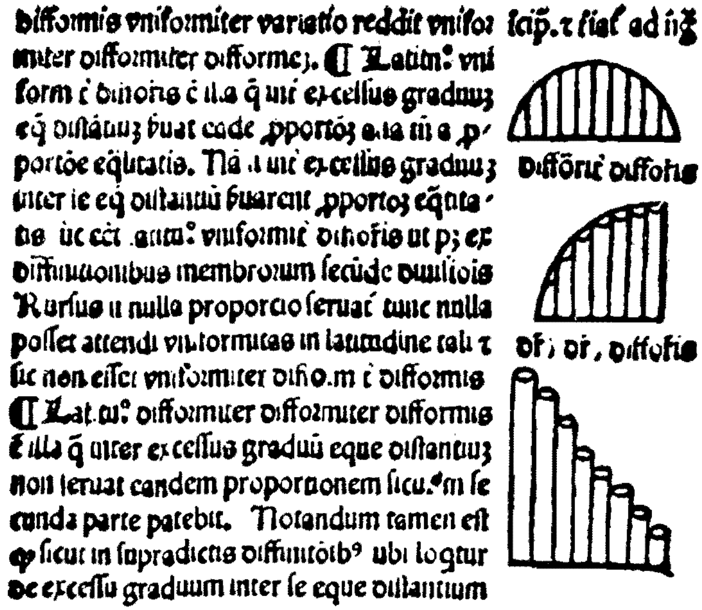
What was new in Oresme's graphical system? Oresme was the first to recognize that movement can be represented only by movement, the changing only by the changing. This is done by repeatedly representing the same subject at various times. To portray a subject freely several times in a single picture was not unusual in medieval art. One has only to think of the late Gothic works in which the same figure (for instance Christ in the stations of the Cross) appears

[4] *Tractatus de uniformitate et difformitate intensium.* MS. Bibliothèque Nationale, Paris. Printed in several editions, toward the end of the fifteenth century.

[5] See also H. Wieleitner, 'Ueber den Funktionsbegriff und die graphische Darstellung bei Oresme,' in *Zeitschrift fuer die Geschichte der mathematischen Wissenschaften*, dritte Folge, vol. 14, Leipzig, 1913.

[6] Summarized in Ernst Borchert's doctoral thesis 'Die Lehre von der Bewegung bei Nikolaus Oresme,' in *Beitraege zur Geschichte und Philosophie des Mittelalters*, Band XXXI, 3, Münster, 1934, p.93.





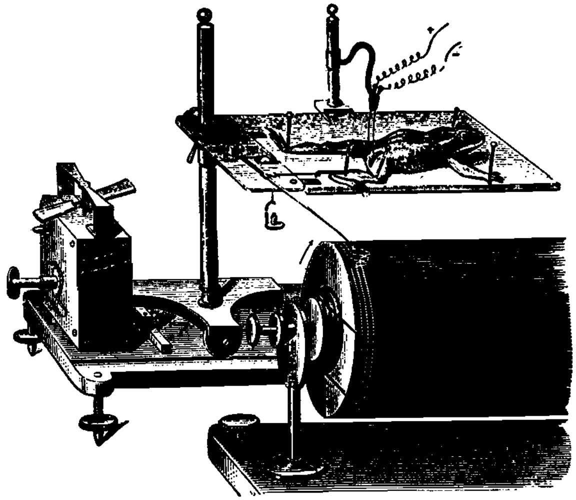
1. NICOLAS ORESME: The First Graphic Representation of Movement, c.1350. *The changing qualities of a body were graphically interpreted for the first time by Nicolas Oresme, bishop of Lisieux. The variation is shown by verticals erected above a horizontal, the later X-axis.* (Tractatus de Latitudine Formarum, *Second edition, Padua,* 1486)

more than once within one frame of reference. When Descartes, in his *Geometria* (1637), represented the laws of conic sections by a system of co-ordinates, the Aristotelian-scholastic conception had disappeared and variables had become basic, not only in graphic representation but in mathematics. By means of variables, Descartes interrelates mathematics and geometry.

### The Nineteenth Century and the Capturing of Movement

#### *Organic Movement in Graphic Form, c.1860*

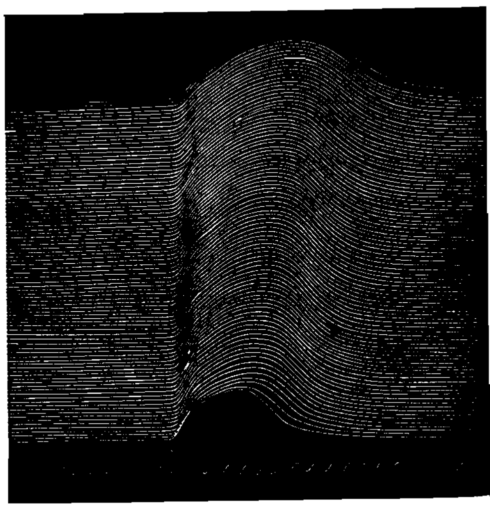
The nineteenth century makes the great leap and literally learns to feel the pulse of nature. Early in his career, the French physiologist, Étienne Jules Marey, 1830–1904, invented the Spygmograph (1860), which inscribed on a smoke-blackened cylinder the form and frequency of the human pulse beat.



**2.** E. J. MAREY: The Myograph, Device for Recording the Movements of a Muscle. Before 1868. *Registering reactions of a frog's leg to repeated electrical stimulation.* (*Marey*, Du mouvement dans les fonctions de la vie, *Paris*, 1868)

In this period scientists such as Wundt and Helmholtz were eager to devise apparatus to gauge motion in muscles and nerves (fig. 2). Marey is one of these great *savants*, key witnesses today for the constituent side of the nineteenth century.

Movement, movement in all its form — in the blood stream, in the stimulated muscle, in the gait of the horse, in aquatic animals and molluscs, in the flights of insects and birds — was the ever-returning burden of Marey's research. From the start of his career, when he devised the recorder for the human pulse beat, down to his last studies in 1900, when he investigated the eddies of moving air streams and registered them on the photographic plate; from his first book on the circulation of the blood 'based on a graphical study of the blood,' down to his last and most popular book, *Le Mouvement* (1894), translated into English



**3.** E. J. MAREY: Record of the Movement of a Muscle. Before 1868. *Responses of the frog's leg to stimulation by an electric current.* (*Marey*, Du mouvement dans les fonctions de la vie, *Paris*, 1868)



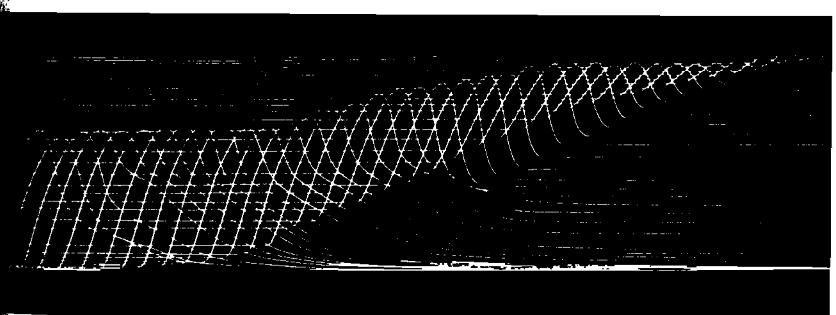
the following year, Marey's thought ever revolves around a central concept of our epoch: Movement.

Marey quite consciously looks back to Descartes,[7] but instead of graphically representing conic sections he translates organic movement into graphic form. In his book *La Méthode graphique dans les sciences expérimentales*, which reflects his mastery of the subject and his universal outlook at its most brilliant, he acknowledges his spiritual ancestors [8] with the respect that only the great can give.

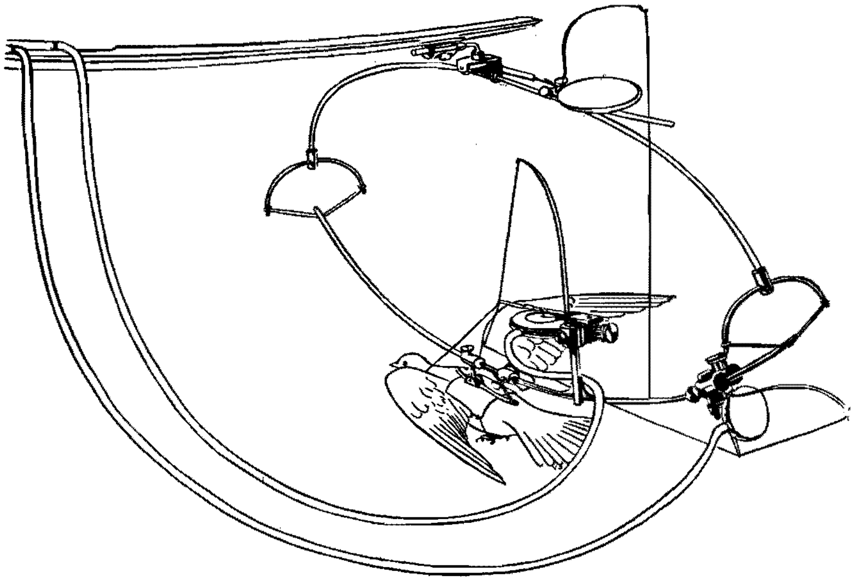
The eighteenth century had witnessed early efforts to extend graphic representation to new domains. The object was to make intelligible a movement of historical dimensions, as Playfair did in 1789 when he charted the fluctuating national debt between 1688 and 1786 in curves that clearly betrayed the effect of wars. Later the phases of the cholera epidemic of 1832 were traced by the same method. The drawing of contour lines on maps was attempted, according to Marey, as far back as the sixteenth century, but only became current in post-Napoleonic times. Marey also mentions an eighteenth-century attempt to represent the successive phases of the horse's gait (fig. 11).

James Watt, inventor of the steam engine, has some claim to be called Marey's direct ancestor. For Watt, Marey reports, 'introduced the first registering device in mechanics, penetrated at first blow one of the most difficult problems: to measure graphically within the cylinder the work developed by steam.' [9] These indicators, diagrammatically registering the movement of the steam,

[7] Marey, *La Méthode graphique dans les sciences expérimentales*, Paris, 1885, p.iv.
[8] Ibid. pp.11–24.
[9] Ibid. p.114.



**4.** E. J. MAREY: Trajectory of Responses in a Frog's Leg. Before 1868. *Coagulation of the muscle and gradual loss of function as the effect of rising temperature.* (*Marey*, Du mouvement dans les fonctions de la vie, *Paris*, 1868)



5. E. J. MAREY: Recording Larger Movements — Flight, 1868. *To trace the more extensive movements of a bird in flight, Marey harnessed a pigeon to the arm of a merry-go-round. The wings, connected to pneumatic drums, record their trajectory on a cylinder.*

form a bridge to Marey's activity. Marey unites the genius of the experimental physiologist with that of the engineer. He is inexhaustible, in the first half of his career, as an inventor of a 'recording apparatus' (fig. 2) whose needles register the movement on smoked cylinders.[10] The forms that develop often have a fascination all of their own (figs. 3,4). These curves, says the savant, might be called the 'language of phenomena themselves.' [11] Early in the 'eighties Marey began to use photography.

[10] When Marey studied the flight of birds he constructed a working model of a monoplane having two propellers (1872) driven by a compressed air motor (today at Musée de l'Aeronautique, Paris). In 1886 he invented daylight-loading film. And with the first movie camera (which contained all essential parts), he made a brief scene of a man climbing off a bicycle in the Champs-Elysées.

[11] Marey, op.cit.





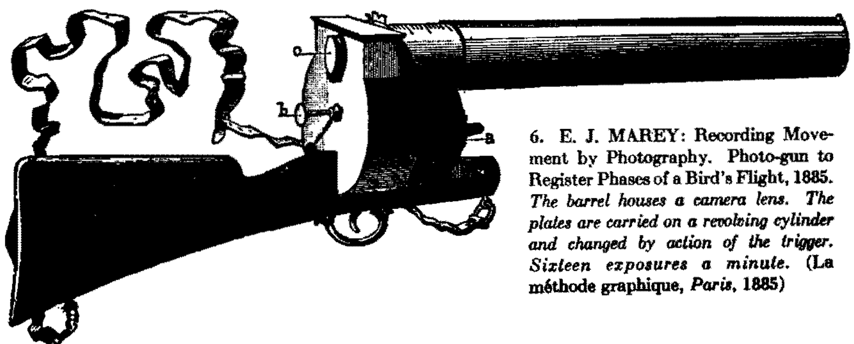
Finally Marey comes to the domain that is of particular concern to us: rendering the true form of a movement as it is described in space. Such movement, Marey stresses again and again, 'escapes the eye.'

He first attempted a graphic portrayal of movement in the late 'sixties. A dove harnessed to a registering device (fig. 5) transmits the curve of its wing beats to smoked cylinders. From these the form of the movement is plotted out point by point.

At the beginning of the 'eighties, Marey began to use photography for the representation of movement. The idea occurred to him in 1873, when an astronomer showed the Académie des Sciences four successive phases of the sun on a single plate. Another hint he found in the 'astronomical revolver' of his colleague Janssen, who — approximately at the same time — caught on its revolving cylinder the passage of the planet Venus across the sun. Marey now tried using this procedure for terrestrial objects. He devised his 'photographic gun' (fig. 6) to follow flying sea gulls. Instead of stars in motion he portrayed birds in flight.[12]

The astonishing photographic studies of motion that Muybridge was performing in California also stimulated Marey to work along these lines, although their methods, as we shall see, differed considerably. Muybridge arranged a series of cameras side by side so that each camera caught an isolated phase of the movement. Marey, as a physiologist, wanted to capture movement on a single plate and from a single point of view, to obtain the undisguised record of continuous motion as he had graphically registered it on his smoked drums.

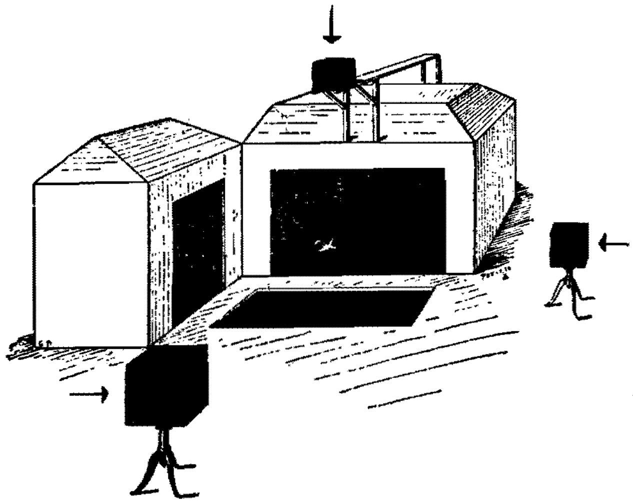
[12] Marey also devised the first movie camera with film reels (1886), and showed Edison his first short 'movie' during the Paris Exhibition of 1889. Like most of the great nineteenth-century scientists, Marey was not interested in the market value of his ideas. The practical solutions came from Edison in the beginning of the 'nineties and from Lumière in 1895.



6. E. J. MAREY: Recording Movement by Photography. Photo-gun to Register Phases of a Bird's Flight, 1885. *The barrel houses a camera lens. The plates are carried on a revolving cylinder and changed by action of the trigger. Sixteen exposures a minute.* (La méthode graphique, *Paris*, 1885)

Marey invited Muybridge to visit him in Paris (1881), and introduced him in his house to a gathering of Europe's most brilliant physicists, astronomers, and physiologists, who welcomed Muybridge's straightforward tackling of the problem.

Muybridge's photography of flying birds did not entirely satisfy Marey, who wished to gain full insight into the three-dimensional character of flight — as Descartes had projected geometrical forms: for the flight of insects and of



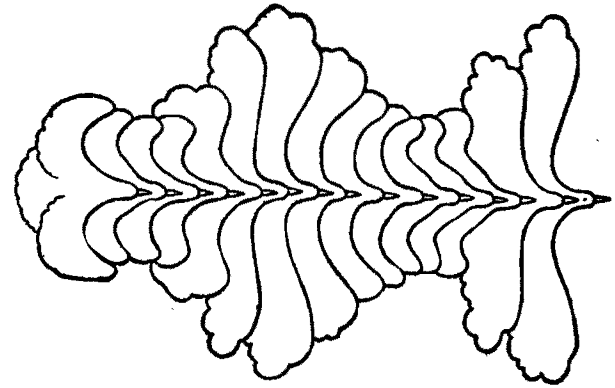
7. E. J. MAREY: Recording a Gull's Flight in Three Projections Photographically. Before 1890. *At Marey's laboratory in the Parc des Princes, Paris, three still cameras placed at perpendicular angles to the line of flight simultaneously record a seagull's passage before black walls and over a black floor.* (Le vol des oiseaux, *Paris*, 1890)

birds is spatial. It evolves freely in three dimensions. Around 1885 Marey pointed three cameras in such a way as to view the bird simultaneously from above, from the side, and from the fore (fig. 7). At his laboratory in the Parc des Princes, Paris, he set up a vast hangar, before whose black walls and ceiling the sea gull flew over a black floor. These simple realities, normally hidden to the human eye, have an impressiveness that needs no further explanation.

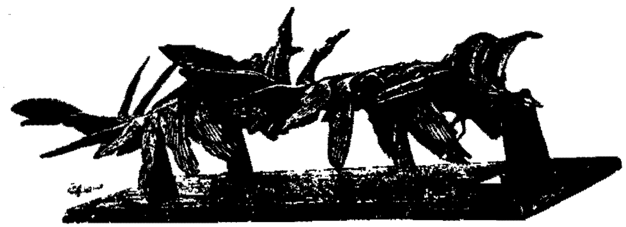
For better knowledge of the bird's flight, Marey later drew diagrams in which he separated the overlapping phases of the photograph (figs. 8–10). He even modeled the sea gull in its successive attitudes (fig. 9) — sculpture that would have delighted Boccioni, creator of the 'Bottle evolving in Space' (1912) and of the 'Marching Man' (1913). In his later research [13] Marey made extensive use of the movie camera, which proved not especially suited to this purpose.

[13] Marey, *La Chronophotographie*, Paris, 1899, pp.37ff., or as he calls it 'images chronophotographiques recueillies sur pellicule mobile.'

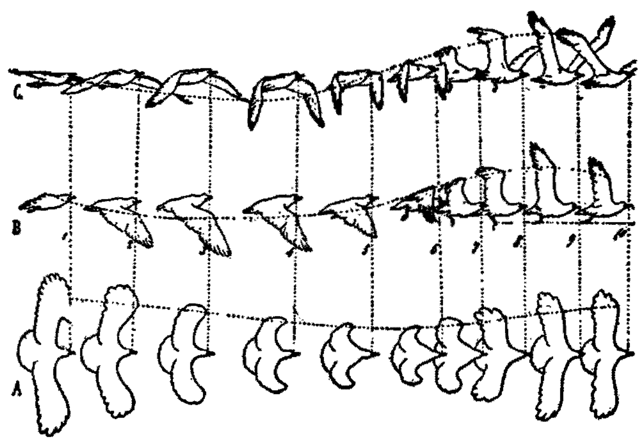




8. E. J. MAREY: Horizontal Projection of the Flying Seagull. Before 1890. (Le vol des oiseaux)



9. E. J. MAREY: Bronze Model of the Flying Seagull. (Le vol des oiseaux)




10. E. J. MAREY: Gull's Flight Recorded in Three Projections by Apparatus Shown in Fig. 7. *The sinuous line represents projection on the vertical plane. The dotted lines connecting the heads mark identical phases. For the sake of clarity the distance between phases is exaggerated on the diagram.* (Le vol des oiseaux)

More significant were Marey's earlier experiments with the portrayal of movement in its own right, movement detached from the performer. It was not Marey who carried this thought to its conclusion. But his trajectories of a bird's wing (*c.*1885) and of a man walking (*c.*1890) deserve a place in the historical record.

To visualize movement as it evolves in space, Marey first tried describing his name in mid-air with a shiny metal ball, and found his signature clearly written on the plate. He attached a strip of white paper to the wing of a crow, which he let fly before a black background (*c.*1885). The trajectory of each wing beat appeared as a luminous path (fig. 18). Around 1890 he placed a brilliant point at the base of the lumbar vertebrae of a man walking away from the camera (fig. 17). In a later lecture (1899) he speaks of these curves as 'a luminous trail, an image without end, at once manifold and individual.'[14] This scientist sees his objects with the sensibility of a Mallarmé. Marey called his procedure 'time photography' (*chronophotographie*); its object is to render visible 'movements that the human eye cannot perceive.'

For lack of technical means these early promises did not reach full maturity. The fulfilment was to come from elsewhere, from the industrial sphere. This occurred around 1912, in 'scientific management.' The object was to record a given motion cycle in utmost detail. Only thus could one accurately observe the work process. For the first time, images of pure motion are obtained with entire precision — images giving a full account of the hand's behavior as it accomplishes its task. We see into a closed domain. Frank B. Gilbreth, the American production engineer, built up this method step by step around 1912 and achieved the visualization of movement. How this investigation proceeded, and what parallels simultaneously arose in painting, the section on Scientific Management and Contemporary Art will attempt to show.

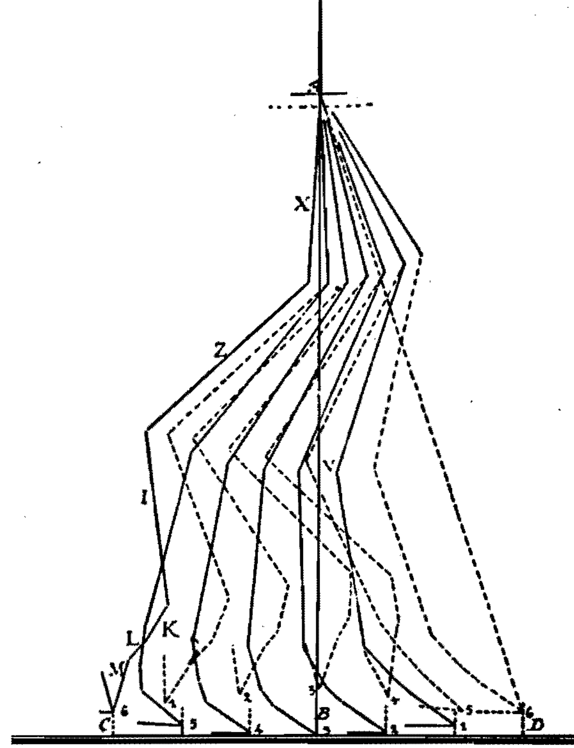
***Movement Investigated***

A line leads from the fourteenth century to the present: Oresme — Descartes — Marey — Gilbreth: The theologian-philosopher — the mathematician-philosopher — the physiologist — the production engineer. Three of these men arose in the country that is outstanding for visualization in all of its domains. The fourth, an American, appeared as soon as efficiency demanded knowledge of 'the one best way to do work.'

Nicolas Oresme, Bishop of Lisieux, was the first investigator to represent in graphic form the ceaselessly changing: movement.

[14] Ibid. p. 11.



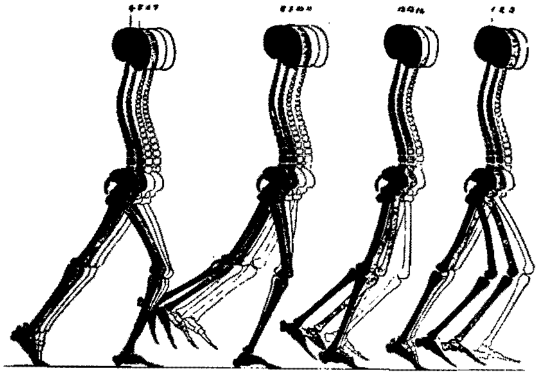



11. GRIFFON AND VINCENT: Graphic Representation of a Horse's Gait, 1779. *One weakness of this method, Marey points out, is that the motion is shown as if centering around a static point.* (*Marey,* La Méthode graphique)

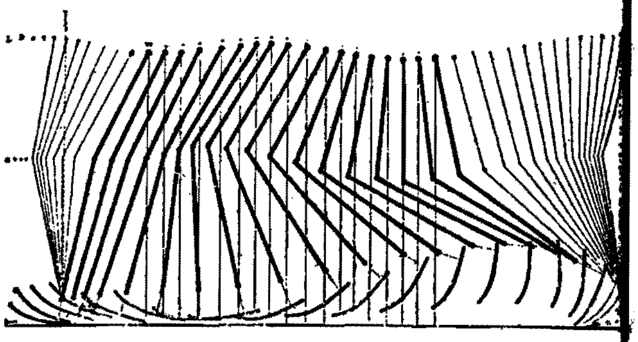
Frank B. Gilbreth (1868–1924) was the first to capture with full precision the complicated trajectory of human movement.

We do not wish to strain the comparison. Nicolas Oresme marks at a decisive point the schism between the ancient and modern world. A task so easy in appearance as the representation of movement demands a faculty of thought and abstraction hard for us to grasp today. The American production engineer, Frank B. Gilbreth, is but one link in the great process of mechanization. But in our connection we do not hesitate to point out a bridge between Nicolas Oresme and Gilbreth. Oresme realized the nature of movement and represented it by graphic methods. Gilbreth, about five and a half centuries later, detached human movement from its bearer or subject, and achieved its precise visualization in space and time (fig. 19). Gilbreth is an innovator in the field of scientific management. His thinking and his methods grow out of the great body of nineteenth-century science.

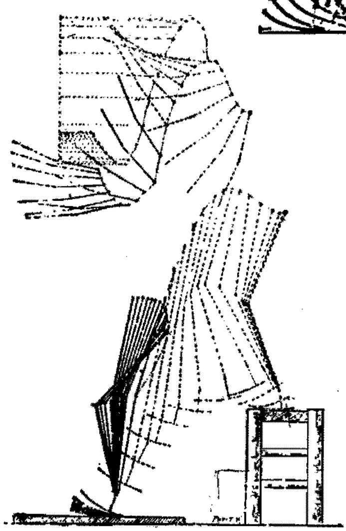
A new realm opens: new forms, new expressive values, transcending the domain of the engineer.



12. Successive Positions in a Human Step. (*From* The Mechanism of Human Locomotion, *by the German anatomists and E. H. Weber*, 1830's. (*Marey*, La méthode graphique)



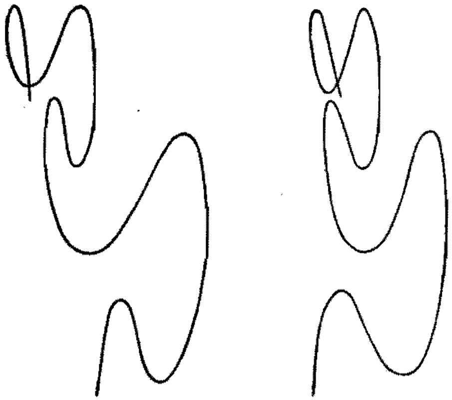
13. E. J. MAREY: Oscillations of the Leg in Running. Before 1885. *The model to be photographed was clothed in black, with a bright metallic strip down the side of the arms, body, and legs.*



14. E. J. MAREY: Jump from a Height with Stiffened Legs. c.1890. *Diagram from a photograph made by the same method as in Fig.* 13.

15. MARCEL DUCHAMP: 'Nude Descending the Staircase,' 1912. (*Arensberg Collection, Hollywood, Cal. Courtesy Museum of Modern Art, N. Y.*)

16. EADWEARD MUYBRIDGE: Athlete Descending a Staircase. c.1880. *Muybridge set up a series of cameras at twelve-inch intervals, releasing their shutters electromagnetically to obtain a sequence of motion phases. Each picture showed an isolated phase.* (The Human Figure in Motion, *6th ed., London, 1925*)

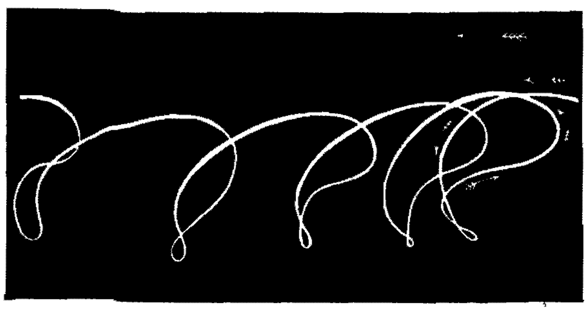


17. E. J. MAREY: Man Walking Away from the Camera. Stereoscopic Trajectory of a Point at the Base of the Lumbar Vertebrae. c.1890. *'A luminous trail, at once manifold and individual.' — Marey.*

Movement, the ceaselessly changing, proves itself ever more strongly the key to our thought. It underlies the concept of function and of variables in higher mathematics. And in physics, the essence of the phenomenal world has been increasingly regarded as motion-process: sound, light, heat, hydrodynamics, aerodynamics; until, in this century, matter too dissolves into motion, and physicists recognize that their atoms consist of a kernel, a nucleus, around which negatively charged electrons circle in orbits with a speed exceeding that of the planets.

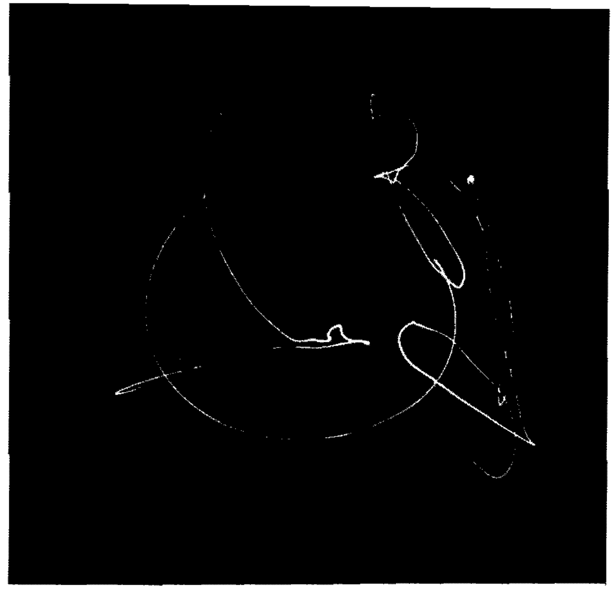
A parallel phenomenon occurs in philosophy and literature. Almost simultaneously with Lumière's cinematograph (1895–6), Henri Bergson was lecturing to the Collège de France on the 'Cinematographic Mechanism of Thought' (1900).[15] And later James Joyce split words open like oysters, showing them in motion.

[15] Cf. Bergson, *Creative Evolution*, Eng. trans., New York, 1937, p.272.

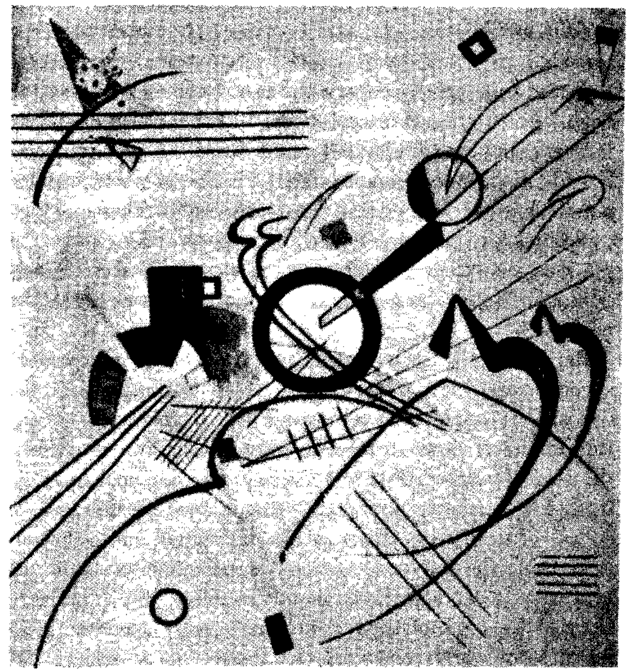


18. E. J. MAREY: Photographic Trajectory of a Crow's Wing. c.1885. *Five wing beats. Marey attached a strip of white paper to the wing of the bird and allowed it to fly before a black background.*





19. FRANK B. GILBRETH: Cyclograph Record of the Path of the Point of a Rapier Used by an Expert Fencer. 1914. *'This picture illustrates the beautiful smooth acceleration and deceleration and complete control of the motion path.' (Photo and caption by courtesy of Lillian M. Gilbreth)*



20. WASSILY KANDINSKY: Pink Square. Oil, 1923. *(Courtesy Buchholz Gallery, New York)*

Perhaps our epoch, unaccustomed to translating thought into emotional experience, can do no more than pose the question: Are the trajectories, as recorded by a production engineer, 'to eliminate needless, ill-directed, and ineffective motions,' in any way connected with the emotional impact of the signs that appear time and again in our contemporary art? Only in our period, so unaccustomed to assimilating processes of thought into the emotional domain, could serious doubt arise.

## THE CREED OF PROGRESS

ONCE more the contrast should be stressed between the ancient and the modern outlook. The ancients perceived the world as eternally existing and self-renewing, whereas we perceive it as created and existing within temporal limits; that is, the world is determined toward a specific goal and purpose. Closely bound up with this belief that the world has a definite purpose is the outlook of rationalism. Rationalism, whether retaining belief in God or not, reaches its ideological peak in thinkers of the latter half of the eighteenth century. Rationalism goes hand in hand with the idea of progress. The eighteenth century all but identified the advance of science with social progress and the perfectibility of man.

In the nineteenth century the creed of progress was raised into a dogma, a dogma given various interpretations in the course of the century.

In the first decades industry increasingly assumes the prestige held by science. For Henri de Saint-Simon industry is the great liberator. It will sweep away nationalism and militarism. An army of workers will girdle the earth. The exploitation of man by man will disappear. The greater part of Saint-Simon's life was spent in the eighteenth century. His conceptions rest on universal grounds. He sees in mechanization not what was made of it, but what it might become.

Beginning with the nineteenth century, the power to see things in their totality becomes obscured. Yet the universalistic outlook did not fail altogether to live on. It would be a rewarding task to follow the survival and dying-out of this tendency down to the filtering of isolation into the various branches: in the state (nationalism); in the economy (monopolism); in mass production; in science (specialistic approach without heed to universal implications); in the sphere of feeling (loneliness of the individual and isolation of art). This much is certain: the universal outlook is still manifested in remnants around mid-century. It can sometimes be felt in public life. The first of the world expositions at the close of the revolutionary years (London, 1851) was to be a manifestation of world peace and of industrial co-operation. The closely connected



idea of free trade reached its short peak under Gladstone in the next decade.

A glimmer of universality is also found in the writings of the great savants, such as Claude Bernard's *Introduction à la physique expérimentale*, 1865.

Herbert Spencer, most influential spokesman for the creed of progress as the second half of the century came to understand it, surely did not intend his evolutionary teachings in the sociological sphere (before Darwin) as license for commercial irresponsibility in the name of *laissez faire*. Evolution is now used interchangeably with progress, and natural selection with the results of free competition. In this roundabout way Herbert Spencer was turned into the philosopher of the ruling taste. He provided the theoretical bulwark. A sociologist has recently observed that over 300,000 copies of Spencer's works were sold in America in the space of four decades.[1]

Eighteenth-century faith in progress as formulated by Condorcet started from science; that of the nineteenth century, from mechanization. Industry, which brought about this mechanization with its unceasing flow of inventions, had something of the miracle that roused the fantasy of the masses. This was especially true in the time of its greatest popularity and expansion, the latter half of the century. The period in which the great international expositions are historically significant — from London, 1851, to Paris, 1889 — roughly delimits that time. These festivals to the ideas of progress, mechanization, and industry fall off as soon as faith in the mechanical miracle becomes dimmed.

Belief in progress is replaced by faith in production. Production for production's sake had existed ever since the Lancashire cotton spinners first showed the world what mechanization on the grand scale was capable of doing. With the waning of faith in progress, floating as a metaphysical banner over the factories, there entered that faith in production as an end in itself. Fanaticism for production as such was heretofore confined to the manufacturing groups. In the time of full mechanization, faith in production penetrated every class and ramification of life, thrusting all other considerations into the background.

## ASPECTS OF MECHANIZATION

MECHANIZATION, as envisaged and realized in our epoch, is the end product of a rationalistic view of the world. Mechanizing production means dissecting work into its component operations — a fact that has not changed since Adam Smith thus outlined the principle of mechanization in a famous passage of his

[1] Thomas Cochran and William Miller, *The Age of Enterprise, A Social History of Industrial America*, New York, 1942, p.125. Cf. the entire chapter, 'A Philosophy for Industrial Progress,' ibid. pp. 119–28.

*Wealth of Nations* in 1776: 'The invention of all those machines by which labor is so much facilitated and abridged seems to have been originally owing to the division of labor.' It need only be added that in manufacturing complex products such as the automobile, this division goes together with a re-assembly.

The rationalistic approach to things came to the fore in the Renaissance. Complex events — the movement of bodies for instance — were dissected into their components and united in a resultant (parallelogram of forces). The nineteenth century and our century expanded to the gigantic this principle of division and re-assembly, until the whole factory became an organism with division and assembly occurring almost automatically.

The second half of the sixteenth century, especially in Italy, saw an increase of technical books. They are practical, and offer great variety of schemes to raise the efficiency of manual labor or to replace it by mechanical power. Archimedes screws, waterwheels, pumping machinery, and gear transmission were developed considerably. In hardly a point, however, did they advance beyond Hellenistic times. On the whole their devices were incomparably more primitive. They are but spelling exercises in mechanization. And even more remarkable to a later period: the mechanizing of production was not attempted. Mechanization could not become a reality in an age of guilds. But social institutions change as soon as the orientation changes. The guilds became obsolete as soon as the rationalistic view became dominant and moved continually toward utilitarian goals. This was the predestined hour for mechanization.

### Invention and the Miraculous

Our present-day point of view tends to identify the inventive impulse with the mechanizing of production — an identity that cannot be taken for granted. The Ancients thought along altogether different lines; they placed their inventive gifts in the service of the miracle. They created magical machinery and automatons. Admittedly, they used their mathematical and physical knowledge for practical purposes too. Hero of Alexandria, whose writings are preserved, and whose name has become a sort of generic name for Hellenistic invention, built and improved oil-presses, fire-fighting pumps; invented lamps with automatically advancing wicks, or water-tube boilers for heating baths. The technical equipment of the later Roman thermae, recent excavations give reason to believe, originated in Egypt in the time of the Ptolemies. We shall return to this point when dealing with the mechanization of the bath.

In a practical direction the sole systematic application of the Ancient's physical knowledge was to warfare. The Alexandrian inventors built cannon working by compressed air, with bronzen barrels bored so accurately that fire spurted



as the charge was released. But completely foreign to their outlook was the idea of placing their great inventive talents in the service of production.

This book's subject compels us to pass over the period which by its experimentation is closer than almost any other to the nineteenth century — Hellenistic Alexandria, of the third and second centuries B.C.[1]

Among the most fertile ideas of Alexander the Great was that of Hellenizing the East, and for this he founded the city of his name on the Nile Delta, much as, earlier, the Greeks had founded Miletus or any of their colony cities. Here, through Greek thinkers and scientists, emerged a civilization oriented toward precise science. Its doctors laid down the bases of brain anatomy, gynaecology, and surgery. And similarly with the foundations of geometry (Euclid) and astronomy (Ptolemy).

Amid this atmosphere, under the Ptolemies, throve the Alexandrian School of inventors, whose writings, schemes, and experiments reflect the calm leisure as well as the complex character of this Hellenistic city: on one hand the precision of Greek thinking, on the other the love of the marvelous that flourished in the Orient.

The Alexandrian inventors were masters in combining the so-called 'simple machines,' such as the screw, the wedge, the wheel and axle, the lever, the pulley, powered by combinations of water, vacuum or air pressure, to carry out complicated movements or manipulations. Thus the temple gates swung open automatically as soon as fire was kindled on the altar and swung to when the flame died. Religious plays, several acts in length, were staged with mechanically moved figures, which, to minimize friction, Hero put on wheels gliding over rails of wood. So far as we know, no sign of an application to practical transportation has been found. Wooden rails are said to have appeared in English mines in the early seventeenth century. Here they eased the hauling of coal wagons. Only about 1770 did the general use of rolling stock on wooden rails astonish continental visitors to English coal mines.[2]

Economic reasons can easily be given to explain the lack of interest in production: the ancients had cheap labor at their disposal in the form of slaves. But this fails to explain why they did not apply their knowledge practically; did not use their rails to speed the vehicles on their highways; used their automatons to dispense consecrated water and did not commercialize them for selling beverages; did not put to everyday use their facility with vacuum, air pressure, and mechanical contrivances.

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[1] The following remarks are based on unpublished studies by the author on The Inventive Impulse.
[2] T. S. Ashton, *Iron and Steel in the Industrial Revolution*, London, 1924, p.63.

The fact was that they possessed an inner orientation, an outlook on life different from ours. Just as we were unable to invent a form of relaxation suited to our way of life, the ancients gave little thought to lending their inventive powers to practical ends.

Inexhaustible are the proposals for birds that move their wings and chirp when water pressure drives air through hidden pipes; for water organs built on the same principle; for series of magic vessels with intermittent flow; for automatons that alternately pour water and wine or deliver a quota of consecrated water when a coin is inserted.

This love of the miraculous was passed on to the Arabs. Conspicuous in Islamic miniatures are the automatons, all based on Alexandrian principles.

The urge to put invention in the service of the miracle survived throughout Islam down to the eighteenth century. What created a sensation in the late eighteenth century was not the new spinning machinery, but the manlike automatons who walked, played instruments, spoke with human voices, wrote, or drew. They were shown before the courts of Europe, and finally toured from fair to fair, well into the nineteenth century. The perfecting of automatons in the eighteenth century is related to the high standard of the crafts and especially to the refinement of the clock-making industry. They are based on a minute decomposition and reintegration of movements, which formed the best of disciplines for the invention of spinning machinery.

## The Miraculous and the Utilitarian

To go one step further: observing the constituent elements of these tools that were decisive for the first period of mechanization, textile machinery, and steam engines, we find them to be the last term of a development extending from Alexandrian times onward. What has changed is the orientation, from the miraculous to the utilitarian. The steam engine, as left by James Watt, combines utilization of the vacuum (condenser) with transmission of movement; and the machines of the textile industry show the same cunning mind for decomposing and recombining movements that created the man-like automatons.

To illustrate in a simple way how the miraculous and the utilitarian co-existed in the eighteenth century, we shall recall one of the great inventors of the Rococo: Jacques de Vaucanson, 1709–82. He is a mechanical genius whose lifetime runs parallel with Louis XV and Buffon. In him the two opposite conceptions dwell side by side. His automatons bear witness to an astonishing capacity for turning machines into performers of complex organic movements. Vaucanson had studied anatomy, music, and mechanics, all of which he intimately fused in his most famous automatons, the flutist, the drummer, and the mechanical duck.



The flutist, which Vaucanson submitted to the Paris Academy of Science for examination in 1738 and which, says Diderot, was seen by all Paris, possessed lips that moved, a moving tongue that served as the air-flow valve, and movable fingers whose leather tips opened and closed the stops of the flute. On the same principle Vaucanson constructed a drummer, who at the same time played a three-holed shepherd's pipe. Even more admired was the mechanical duck. It could waddle and swim. Its wings imitated nature in every detail and they beat the air. It would wag its head, quack, and pick up grain, the passage of which could be observed in swallowing movements. A mechanism inside ground up the grain and caused its exit from the body much as in natural circumstances. 'It was necessary in a little space to construct a chemical laboratory, to decompose the main constituents [of the grain] and cause them to issue forth at will.' It was thus described in the *Encyclopédie* of 1751 [3] by no less a contributor than the mathematician D'Alembert. Vaucanson had exhibited his duck in 1741, according to the *Encyclopédie*, whose report directly reflects the impression made upon the most advanced contemporaries by this marvelous mechanism. D'Alembert, in his description of the flutist,[4] points out that he is reproducing the greater part of Vaucanson's own account,[5] 'which seemed to us worthy of preservation,' and the acute critic Diderot cannot but exclaim with unwonted enthusiasm at the end of D'Alembert's article, 'What finesse in all these details; what delicacy in all the parts of this mechanism. . . .' [6] Indeed, in addition to a love of the marvelous, Vaucanson's automatons and the long line of similar creations by others reflect the extraordinary mechanical subtlety of the eighteenth century.

The philosopher Condorcet, who succeeded Vaucanson in the Académie des Sciences, mentions in his éloge that Frederick the Great had sought to attract him to the Potsdam court in 1740.[7] But in 1741 Cardinal Fleury, the real ruler of France, named Vaucanson 'Inspector of the Silk Manufactures.' It is then that his genius turns to the mechanizing of production. He makes numerous improvements in spinning and weaving, and proves himself a foresighted organizer. About 1740 he constructs a mechanical loom for figured silks. Its heddles are automatically raised and lowered by means of a drum pierced with holes, on the same principle that controlled the air supply and the selection of notes in his flutist. In Alexandria we already find mechanisms being released by

[3] *Encyclopédie ou Dictionnaire raisonné*, vol. I, p.196.

[4] Ibid. under 'Androide,' pp.448–51.

[5] J. de Vaucanson, *Mécanisme d'un fluteur mécanique*, Paris, 1738.

[6] *Encyclopédie*, p.451.

[7] Condorcet, 'Éloge de Vaucanson,' in *Histoire de l'Académie Royale des Sciences, Année* 1782, Paris, 1785.

means of pins or grooves. Vaucanson's looms place him in the long series of inventors who, from the seventeenth century on, attempted to solve the automatic manufacture of fabrics. Vaucanson's loom did not have immediate consequences. In 1804 the inventor Jacquard of Lyons assembled the fragments of Vaucanson's loom in the Paris Conservatoire des Arts et Métiers [8] and thus invented his weaving automaton, the Jacquard loom, which has remained standard to this day, and reproduced mechanically even the most fantastic patterns.

It is Vaucanson's practical activities that are historically the most interesting. In 1756 [9] he set up a silk factory at Aubenas near Lyons, improving or inventing every detail of the building and of the machinery, even to the reels, which most ingeniously joined the threads from the cocoons as they lay in the bath, and the twisting frames that spun them. To the best of our knowledge this is the first industrial plant in the modern sense, built nearly two decades before Richard Arkwright founded the first successful spinning mills in England. Vaucanson had insight into the fact that industry could not be housed in wooden shacks or in random buildings, but required a concentrated plant where every detail was carefully thought out, and whose machines were moved by a single power. His treatise gives full details of the plan.[10] The factories — he later built a second factory — are three stories high, and well planned in every detail. The source of power is a single overshot water wheel. He calls for softened light, which is obtained from windows with oiled paper. Primitive ventilation and vaulting insure to some extent the moist and temperate atmosphere necessary for spinning the silk. Vaucanson set up his spinning machines (*moulins à organsiner*) in large, well-lighted halls. The small models preserved in the Conservatoire des Arts et Métiers, Paris, show a striking elegance of construction and have an imposing number of vertical spindles. The 'flyers' of the turn of the century are anticipated here. What a contrast with the unwieldy four or eight spindle constructions used in the first cotton spinning machines of England!

Yet these efforts came to nothing. Eighteenth-century France was a testing ground in almost every domain. Ideas arose that could become reality only in the nineteenth century, for they were unable to sink roots in Catholic France under the Ancien Régime. Mechanization was among these.

[8] Vaucanson himself began a collection of machine models of various kinds, which became the nucleus of the Conservatoire des Arts et Métiers during the Revolution.

[9] We give the date as 1756, since in his *Mémoires*, 1776, Vaucanson speaks of an experiment made at Aubenas twenty years previously. Cf. J. de Vaucanson, 'Sur le Choix de l'Emplacement et sur la Forme qu'il faut donner au Bâtiment d'une Fabrique d'Organsin,' in *Histoire de l'Académie Royale, Année* 1776, p.168.

[10] Precise illustrations of Vaucanson's installation are given. See especially Planches v et vi.



### The Mechanizing of Production

To carry through the mechanizing of production, another class of inventors, another class of doers, other sociological conditions, and another textile proved necessary.

Silk was a luxury textile for a luxury class. The English experimented with cotton from the start, and constructed all their machines with cotton in mind. Here was the road to mass production. And just as the textile itself was rougher, of a rougher fiber too was the class and the environment that pushed forward its mechanization.

Here the inventors were neither nobles nor savants. No academy published their experiments, and today's knowledge of the beginnings has to be pieced together from fragments. No government set up privileged factories: the mechanizing of production began in the North, in Lancashire, far from the ruling classes and the High Church of England. Lonely spots like Manchester — which did not attain corporate status before the nineteenth century and was without hampering guild restrictions — and a proletarian class of inventors were needed. One of the earliest of Manchester's large manufacturers observed these facts by 1794. 'Towns where manufactures are most flourishing, are seldom bodies corporate, commerce requiring universal encouragement instead of exclusive privileges to the natives and freemen of a particular district. Those who first introduced the cotton manufacture into Lancashire were Protestant refugees, who probably found small encouragement for themselves and their industries amongst the corporate towns of England.' [11]

John Wyatt, who stretched the yarn between pairs of revolving cylinders instead of by hand and set up the first small mill in a Birmingham warehouse in 1741, landed in debtors' prison. James Hargreaves, inventor of the spinning jenny between 1750 and 1757, was a poor weaver. And Richard Arkwright, 1732–92, the first successful cotton spinner, who turned to advantage ideas upon which other men had foundered, was by trade a barber. Not before 1767 did he turn from his normal calling, which consisted in buying up dull hair and by some process making it usable. In 1780 twenty factories were under his control, and at his death he left his son a large fortune. Climbing from below — he was the thirteenth child of a poor family — armed with an unbreaking will to conquer, and possessing a flair for success, he exemplifies in every trait the type of the nineteenth-century entrepreneur. In a hostile environment, without protectors, without government subsidy, but nourished by a relentless

[11] T. Walker, *Review of Some of the Political Events Which Have Occurred in Manchester During the Last Five Years*, London, 1794. Quoted in Witt Bowden, *Industrial Society in England Toward the End of the Eighteenth Century*, New York, 1925, pp.56–7.

utilitarianism that feared no financial risk or danger, the first mechanization of production was accomplished. In the following century the mechanization of cotton spinning became everywhere almost synonymous with industrialization.

### *The Simple and the Complicated Craft*

First experiences are often decisive for the future development. Of mechanization this is certainly true in more than one respect. What distinguishes European from American mechanization can be observed in the eighteenth-century beginnings as it can a century and a half later. Europe began with the mechanizing of the simple craft: spinning, weaving, iron making. America proceeded otherwise from the first. America began with the mechanizing of the complicated craft.

While Richard Arkwright, around 1780, was fighting his way upward to a power without precedent, Oliver Evans, on the banks of a solitary creek not far from Philadelphia, was mechanizing the complicated craft of the miller. This was achieved by continuous line production, in which the human hand was eliminated, from the unloading of the grain to the processed flour.

At that time there was no American industry. Trained workers were scarce. The well-to-do imported from England their fine furniture, glassware, carpets, fabrics; the pioneer farmer of the hinterland made his own utensils and furniture.

The sudden leap from Robinsonian conditions amid the virgin forest into an advanced stage of mechanization is a phenomenon that recurs again and again in this period. The impulse behind it was the necessity to economize labor and the dearth of skilled workers. The way in which, simultaneously with the opening of the prairie to agriculture around 1850, the necessary machinery was created and the complicated craft of the farmer increasingly mechanized forms one of the most interesting chapters of the nineteenth century. But the impulse was there even earlier. Only thus can we understand that by 1836 two mid-western farmers had on the field a harvesting machine (fig. 89) that performed in a continuous production line the entire harvesting task of threshing, cleaning, and bagging the grain. It appeared about a century ahead of its time. These symptoms assert the orientation from which sprang the whole development of the United States. The dimensions of the land, its sparse population, the lack of trained labor and correspondingly high wages, explain well enough why America mechanized the complicated craft from the outset.

Yet an essential reason may lie elsewhere. The settlers brought over their European mode of living, their European experience. But from the organization of the complicated craft and the whole culture in which such institutions had



grown, they were suddenly cut off. They had to start from scratch. Imagination was given scope to shape reality unhindered.

### *The Gothic Roots of the Highly Developed Craft*

Strife and turmoil notwithstanding, the European development had flowed on unbroken until mechanization entered upon the scene. The highly developed craft has its roots in the late Gothic period. Its rise is inseparably bound up with the revival of municipal life. The need for organized living within a community explains why in the thirteenth and fourteenth centuries city life that had dwindled more and more began to function again, and why, on both old and new cultural soil, cities were founded in numbers exceeded only by the nineteenth-century development in America. The modest timber houses of the Gothic towns, each with its similar front, and built on an equal lot, formed the birthplace of the highly developed handicraft.

Only as the Gothic period was nearing its close, after the raising of the urban cathedrals, did the new burgher class set about the creation of an adequate domestic setting — the burgher interior. Down to the nineteenth century this late Gothic interior continued as a core of further development. Parallel with this, the culture of handicrafts underwent continuous refinement down to the time when mechanization finally set in.

Then a remarkable symbiosis occurs. Handicraft lives on side by side, or intermingled with, industrial production, for the Gothic roots did not perish altogether. A token of this was the obligation to pass through the traditional stages from apprentice to journeyman and master. Even the factory mechanic was trained in a similar way. This careful formation in all branches yielded excellently qualified workers, and led to the basic divergences, for better and for worse, between America and the Continent. The butcher, the baker, the joiner, the peasant, have persisted since Gothic times. In a few countries like Switzerland, besides the Gothic nucleus of the city, many usages have remained alive, even to the way of speech. An inner resistance to mechanization keeps it from penetrating over-far into the sphere of intimate living. And when this does occur, it is likely to be after hesitation and in the wake of America.

The complicated handicraft tends however to give to life a certain rigidity and slowness. In America, where it is lacking, its absence is compensated for by the habit of tackling problems directly. The axe, the knife, saw, hammer, shovel, the household utensils and appliances, in short the panoply of instruments whose form had remained static for centuries in Europe, are taken up and shaped anew from the first quarter of the nineteenth century on. America's original contribution, the mechanizing of the complicated craft, sets in vigorously after mid-century, especially in the early 'sixties, with a second wave of advance between 1919 and 1939. We shall briefly discuss the significance of these decades.

## Profile of the Decades

### *The 'Sixties*

In every domain there are times that foreshadow future developments with extraordinary swiftness, even if a tangible outcome, an intense follow-through, is not immediately achieved. The 'sixties in America were such a time. Not in great names or in great inventions. But to the period after 1850 we shall again and again, in this book, trace impulses and trends that have strongly influenced our epoch.

A collective fervor for invention seems to course through this period. In the seventeenth century the inventive urge was possessed by a limited group of scholars — philosophers and savants like Pascal, Descartes, Leibnitz, Huygens, or further back, the universal man of the Leonardo type. The orientation that was later to sway the masses of the people first takes shape in the minds of the few. Until late in the eighteenth century, inventive activity, so far as it found record in the British Patent archives, was no more than a trickle. Toward the mid-nineteenth century it gained its hold over the broad masses, and perhaps nowhere more strongly than in the America of the 'sixties. Invention was in the normal course of things. Everyone invented, whoever owned an enterprise sought ways and means by which to make his goods more speedily, more perfectly, and often of improved beauty. Anonymously and inconspicuously the old tools were transformed into modern instruments. Never did the number of inventions per capita of the population exceed its proportion in America of the 'sixties. But we must beware of assuming an identity between the inventive urge and the degree of industrialization. Such was by no means the case. Taking the key industry of the nineteenth century as an index, Europe and particularly England are seen to have been well in the lead. Around mid-century, according to the *Revue des Deux Mondes*,[12] America had 5.5 million power spindles, France 4 million, and England 18 million. Greater still, even at a later time, was the weaving potential of Europe. In 1867 America had over 123,000 power looms, France 70,000, and England 750,000.[13]

Whoever wishes to know what was going on in the American psyche at this

[12] *Revue des Deux Mondes*, 1855, IV p.1305.
[13] Blennard, *Histoire de l'industrie*, Paris, 1895, vol. III p.60 ff.



time will find evidence not only in American folk-art. The activity of the anonymous inventor is more revealing. But only a fraction of the popular habit of invention is preserved in the Patent Office. If we turn so often to the patent drawings, it is as objective witnesses, although the drawings in themselves often have an artistic directness that distinguishes them from the technical routine of a later time. In them no small portion of folk-art lies concealed.

In the American patent lists of the late 'thirties, few schemes for the improvement of steam engines or of textile manufacture are to be found, whereas ideas for facilitating the complicated handicrafts and initial efforts to mechanize human surroundings are conspicuous. This becomes truly evident in the 'sixties, in agriculture, in breadmaking, in the mass processing of meat, in the household. Mechanization penetrated many areas with success. For others, like the household, the time had not yet come. From this period, however, it was but a step to the time of full mechanization, which realized what the 'sixties had foreshadowed.

### *The Time of Full Mechanization,* 1918–39

We designate the period between the two World Wars as the time of full mechanization. The development is too fluid to be tied within strict limits. Before 1918 full mechanization was already setting in, and it was by no means ending in 1939. Even within these years there are times of widely varying intensity. Yet with good warrant one may call the era between the wars the time of full mechanization.

Our point of view is too close to allow a total reckoning of what happened in these two decades, or of what the consequences may be to us. This much, however, is certain: at one sweep, mechanization penetrates the intimate spheres of life. What the preceding century and a half had initiated, and especially what had been germinating from mid-nineteenth century on, suddenly ripens and meets life with its full impact.

True, changes affected living as soon as mechanization announced itself in the early nineteenth century; yet the influence was limited to fairly narrow areas, to those places such as Manchester, Roubaix, Lille, where the large textile factories began to flourish and, with their slums, undermined the structure of the whole city. The greater body of life was left undisturbed.

Never, as we shall see later, was the standard of English agriculture more enthusiastically praised than around mid-nineteenth century. On the Continent too the farming population, even of the industrialized nations, outnumbered that of all other occupations. In the United States in 1850, about 85 per cent of the population was rural, and only 15 per cent urban. This ratio began slowly to decline around the end of the century. By 1940 less than 1 in 4 of the total population lived on farms.[14]

In the latter half of the nineteenth century, with the widening of the railroad network, the accelerated growth of metropoli, and, in America, the mechanizing of many complicated crafts, the influence of mechanization was already reaching deeper into life.

Now, around 1920, mechanization involves the domestic sphere. For the first time it takes possession of the house and of whatever in the house is susceptible of mechanization: the kitchen, the bath, and their equipment, which capture the fantasy and arouse the acquisitive instinct of the public to an astonishing degree. In the time of full mechanization more appliances grew into household necessities than had been introduced in the whole preceding century. They absorb an unprecedented share of space, cost, and attention. To establish at what moment the various electrical appliances became popularized we addressed a questionnaire to one of the large mail-order houses;[15] it appears that the minor appliances — fans, irons, toasters, wringers — entered the catalogues in 1912; the electric vacuum cleaner in 1917; the electric range in 1930; and the electric refrigerator in 1932.

The mechanization of the kitchen coincides with the mechanizing of nutrition. As the kitchen grows more strongly mechanized, the stronger grows the demand for processed or ready-made foods.

Around 1900 the canning industry — meat packing excepted — was still in a rather chaotic state in regard both to production and to quality. The time of full mechanization brings an enormous increase in the output and varieties of processed foods: from excellent canned soups, spaghetti in sauce, and strained baby food, to canned dog, cat, or turtle food. The time of full mechanization is identical with the time of the tin can.

The phenomenon of submitting food to mass production is likewise seen in the development of chain restaurants. A single enterprise in a single building in New York prepares food for 300,000 people daily. Doughnuts swimming in hot fat are transported on the endless belt, and the march of apple pies goes on continuously through the immense tunnel oven by military rows of twelve.

We shall confine ourselves almost exclusively to mechanization's advance into the private sphere, and to the simpler things, such as the kitchen, the bathroom, and their appliances. But mechanization implanted itself more deeply. It impinged upon the very center of the human psyche, through all the senses.

[14] *Sixteenth Census of the United States*, 1940, 'Agriculture,' vol. III, p.22.

[15] We owe this information to Professor Richard M. Bennett, who was for a time with Montgomery Ward in Chicago.



For the eye and the ear, doors to the emotions, media of mechanical reproduction were invented. The cinema, with its unlimited possibility of reproducing an optical-psychic process, displaces the theater. The eye accommodates itself to two-dimensional representation. The adding of sound and of color aims at an increasing realism. New values are born with the new medium, and a new mode of imagination. Unfortunately, the demand for mass production caused the medium to be used along the path of least resistance, to the debasement of public taste.

For the reproduction of sound through space even greater potentialities were opened. More than any other medium, the radio acceded to power in the time of full mechanization, influencing every aspect of life. Now music is mechanized in its full tonal range. The phonograph, originating in the eighteenth century, was but a forerunner of this mechanization. Its refinement occurred parallel to the introduction of the radio. As sound was added to the moving picture, so sight was added to radio — television.

To close the circle, transportation breaks into intimate living. Transportation was one of the favorite objects of nineteenth-century mechanization. But the locomotive is a neutral vehicle. The automobile is a personal appurtenance which comes to be understood as a movable part of the household: one the American is least willing to give up. With the exaggeration permitted to a moral critic, John Steinbeck remarks, in 1944, that most of the children 'were conceived in Model-T Fords and not a few were born in them. The theory of the Anglo-Saxon home became so warped that it never quite recovered.'[16]

At all events, the highway network was adapted to the automobile in the decades between the World Wars. The automobile is a harbinger of full mechanization. Its mass production began in the second decade, but took decisive effect only at the beginning of full mechanization. First concrete highways, later parkways, made cruising so effortless that one is led to drive for driving's sake, to overcome one's inner restlessness, or to escape from oneself by depressing the gas pedal. This trend can be observed everywhere, but nowhere so strongly as in America. In the land where in the 1840's Henry Thoreau profoundly but unsentimentally described the life of the tramper, based on the close contact of man with nature, the automobile has almost crowded out the pedestrian. Walking, relaxation for its own sake, because the body demands it, or because the brain requires a pause in which to recuperate, is increasingly eliminated by the motor-car.

To investigate the sociological implications of the automobile or the psychic

[16] John Steinbeck, *Cannery Row*, New York, 1944.

effects of the radio and cinema is an inviting task. But such research pertains to fields other than ours and demands the teamwork of many disciplines.

In the time of full mechanization still newer developments set in, whose drift and implications cannot be foreseen. It is no longer replacement of the human hand by the machine, but of intervention into the substance of organic as well as of inorganic nature.

In the inorganic, it is the exploration of the structure of the atom and its use for as yet unknown ends.

One sphere is already taking clearer shape: one that intervenes directly into organic substance. Here the demand for production delves into the springs of life, controls generation and procreation, influences growth, alters structure and species. Death, generation, birth, habitat undergo rationalization, as in the later phases of the assembly line. The host of unknowns that these processes involve makes uneasiness hard to dispel. Organic substance or inorganic, it is experimentation with the very roots of being.

What occurs in art in this period gives the most intimate insight regarding how deeply mechanization penetrated man's inner existence. The revealing selection in Alfred Barr's 'Cubism and Abstract Art' (N. Y., 1936) tells in what different ways the seismographic artist responded to the beginning of full mechanization. At this point we can no more than give a few hints of the many-sidedness of this perception.

Mechanization has penetrated down to the artist's subconsciousness. The dream Giorgio de Chirico reports his most obsessive (1924) intermingles the image of his father with the daemonic strength of the machine: 'I struggle in vain with the man whose eyes are suspicious and very gentle. Each time I grasp him, he frees himself by quietly spreading his arms . . . like those gigantic cranes. . . .' (J. Thrall Soby, *G. de Chirico.*)

The same anxiety and loneliness pervade the melancholic architectures of his early period and his tragic mechanical dolls, portrayed in every detail, yet disquietingly taken to bits.

On the other hand there are Léger's large canvasses, around 1920, building the city's image out of signs, signals, mechanical fragments. There are Russians and Hungarians, themselves far from mechanization, yet inspired by its creative power.

In the hands of Marcel Duchamp and others, machines, these marvels of efficiency, are transformed into irrational objects, laden with irony, while introducing a new aesthetic language. The artists resort to elements such as machines, mechanisms, and ready-made articles as some of the few true products of the period, to liberate themselves from the rotten art of the ruling taste.



# PART III MEANS OF MECHANIZATION