SIGFRIED GIEDION

SPACE, TIME AND ARCHITECTU

the growth of a new tra

CAMBRIDGE, MASSACHUSETTS
HARVARD UNIVERSITY PRESS
FIFTH EDITION, REVISED AND ENLARGED
1967

PART VI SPACE–TIME IN ART, ARCHITECTURE AND CONSTRUCTION

The fact that modern painting bewilders the public is not strange: for a full century the public ignored all the developments which led up to it. It would be very surprising if the public had been able to read at sight an artistic language elaborated while its attention was elsewhere, absorbed by the pseudo art of the *salons*.

SHOW KEYNOTE

THE RESEARCH INTO SPACE: CUBISM

In many places, about 1910, a consciousness that the painter's means of expression had lost contact with modern life was beginning to emerge. But it was in Paris, with cubism, that these efforts first attained a visible result. The method of presenting spatial relationships which the cubists developed led up to the form-giving principles of the new space conception.[1]

The half-century previous to the rise of cubism had seen painting flourish almost nowhere outside of France. It was the high culture of painting that grew up in France during this period which formed the fostering soil for our contemporary art. Young people of talent — whether Spanish like Picasso, or Swiss like Le Corbusier — found their inspiration in Paris, in the union of their powers with the artistic tradition of that city. The vitality of French culture served to the advantage of the whole world. Among the general public, however, there was no sympathetic response to this achievement. It was from a form of art which the public despised that nineteenth-century painting drew its positive strength. Cubism, growing up in this soil, absorbed all its vigor.

[1] We shall treat contemporary movements in art here only so far as their methods are directly related to the space conceptions of our period, and in order to understand the common background of art, architecture, and construction. For an understanding of these movements the elaborate catalogues of the Museum of Modern Art, New York, are very useful. See Alfred H. Barr, Jr., *Cubism and Abstract Art* (New York, 1936), and Robert Rosenblaum, *Cubism and Twentieth Century Art* (New York, 1960). For a short survey with emphasis on historical relations, see J. J. Sweeney, *Plastic Redirections of the Twentieth Century* (Chicago, 1935); for the relation of contemporary art to education, industrial design, and daily life, see L. Moholy-Nagy, *The New Vision* (New York, 1938). The close relation of contemporary sculpture to primitive art, on the one hand, and, on the other, to an enlargement of our outlook into nature is stressed in C. Giedion-Welcker, *Contemporary Sculpture* (New York, 1955).

Picasso has been called the inventor of cubism, but cubism is not the invention of any individual. It is rather the expression of a collective and almost unconscious attitude. A painter who participated in the movement says of its beginnings: "There was no invention. Still more, there could not be one. Soon it was twitching in everybody's fingers. There was a presentiment of what should come, and experiments were made. We avoided one another; a discovery was on the point of being made, and each of us distrusted his neighbors. We were standing at the end of a decadent epoch."

From the Renaissance to the first decade of the present century perspective had been one of the most important constituent facts in painting. It had remained a constant element through all changes of style. The four-century-old habit of seeing the outer world in the Renaissance manner — that is, in terms of three dimensions — rooted itself so deeply in the human mind that no other form of perception could be imagined. This in spite of the fact that the art of different previous cultures had been two-dimensional. When earlier periods established perspective as a constituent fact they were always able to find new expressions for it. In the nineteenth century perspective was misused. This led to its dissolution.

The three-dimensional space of the Renaissance is the space of Euclidean geometry. But about 1830 a new sort of geometry was created, one which differed from that of Euclid in employing more than three dimensions. Such geometries have continued to be developed, until now a stage has been reached where mathematicians deal with figures and dimensions that cannot be grasped by the imagination.

These considerations interest us only in so far as they affect the sense of space. Like the scientist, the artist has come to recognize that classic conceptions of space and volumes are limited and one-sided. In particular, it has become plain that the aesthetic qualities of space are not limited to its infinity for sight, as in the gardens of Versailles. The essence of space as it is conceived today is its many-sidedness, the infinite potentiality for relations within it. Exhaustive description of an area from one point of reference is, accordingly, impossible; its character changes with the point from which it is viewed. In order to grasp the true nature of space the observer must project himself through it. The stairways in the upper levels of the Eiffel Tower are among the earliest architectural expression of the continuous interpenetration of outer and inner space.

Space in modern physics is conceived of as relative to a moving point of reference, not as the absolute and static entity of the baroque system of Newton. And in modern art, for the first time since the Renaissance, a new conception of space leads to a self-conscious enlargement of our ways of perceiving space. It was in cubism that this was most fully achieved.

Space-Time

The cubists did not seek to reproduce the appearance of objects from one vantage point; they went round them, tried to lay hold of their internal constitution. They sought to extend the scale of feeling, just as contemporary science extends its descriptions to cover new levels of material phenomena.

Cubism breaks with Renaissance perspective. It views objects relatively: that is, from several points of view, no one of which has exclusive authority. And in so dissecting objects it sees them simultaneously from all sides — from above and below, from inside and outside. It goes around and into its objects. Thus, to the three dimensions of the Renaissance which have held good as constituent facts throughout so many centuries, there is added a fourth one — time. The poet Guillaume Apollinaire was the first to recognize and express this change, around 1911. The same year saw the first cubist exhibition in the Salon des Indépendants. Considering the history of the principles from which they broke, it can well be understood that the paintings should have been thought a menace to the public peace, and have become the subject of remarks in the Chamber of Deputies.

The presentation of objects from several points of view introduces a principle which is intimately bound up with modern life — simultaneity. It is a temporal coincidence that Einstein should have begun his famous work, *Elektrodynamik bewegter Körper*, in 1905 with a careful definition of simultaneity.

The Artistic Means

"Abstract art" is as misleading a term for the different movements which depart from the spatial approach as "cubism" is for the beginnings of the contemporary image. It is not the "abstract," it is not the "cubical," which are significant in their content. What is decisive is the invention of a new approach, of a new spatial representation, and the means by which it is attained.

This new representation of space was accomplished step by step, much as laboratory research gradually arrives at its conclusions through long experimentation; and yet, as always with real art and great science, the results came up out of the subconscious suddenly.

The cubists dissect the object, try to lay hold of its inner composition. They seek to extend the scale of optical vision as contemporary science extends the law of matter. Therefore contemporary spatial approach has to get away from the single point of reference. During the first period (shortly before 1910) this dissection of objects was accomplished, as Alfred Barr expresses it, by breaking up "the surfaces of the natural forms into angular facets." Concentration was entirely upon research into a new representation of space — thus the extreme scarcity of colors in this early period. The pictures are gray-toned or earthen, like the grisaille of the Renaissance or the photographs of the nineteenth century. Fragments of lines hover over the surface, often forming open angles which become the gathering places of darker tones. These angles and lines began to grow, to be extended, and suddenly out of them developed one of the constituent facts of space-time representation — the plane (*fig.* **257**).

The advancing and retreating planes of cubism, interpenetrating, hovering, often transparent, without anything to fix them in realistic position, are in fundamental contrast to the lines of perspective, which converge to a single focal point. The p

Hitherto planes in themselves, without naturalistic features, had lacked emotional content. Now they came to the fore as an artistic means, employed in various and very different ways, at times representing fragments of identifiable objects, at

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

---

[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 bis *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.

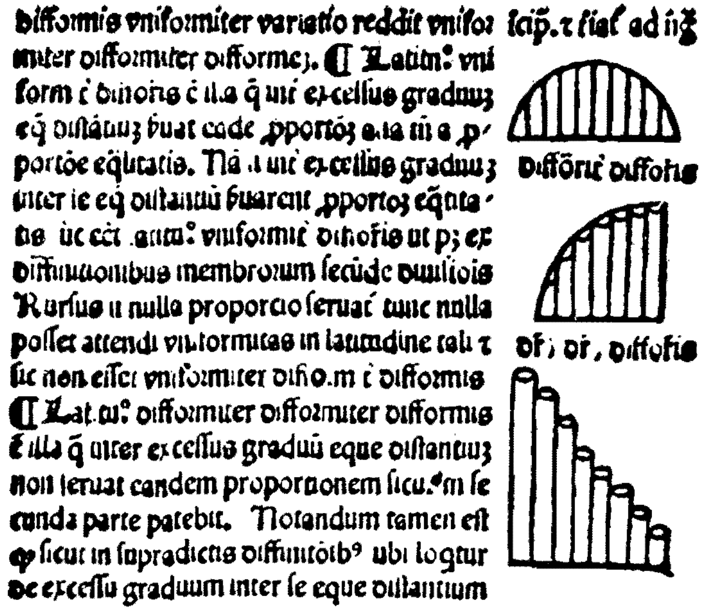
Oresme carries over this basic method as he investigates the essence of movement, thus gaining insight into the nature of speed (*velocitas*) and of acceleration. By a graphical method he represents movement, time, speed, and acceleration.[6]

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.


difformis vniformiter variatio reddit vnifor
miter difformiter difformem. ¶ Latitu° vni
formiter difformis est illa q̄ inter excessus graduum
eq̄ distantiū suat eadē pportiōē a.ia iii a p
portiōe equalitatis. Nā si inter excessus graduum
inter se eq̄ distantium seruaret pportioē equalita
tis tūc esset latitu° vniformiter difformis ut p; ex
diffinitionibus membrorum secunde diuisionis
Rursus si nulla proporcio seruaret tunc nulla
posset attendi vniformitas in latitudine tali z
sic non esset vniformiter diffo. m e difformis
¶ Lat. iii° difformiter difformiter difformis
est illa q̄ inter excessus graduū eque distantium
non seruat eandem proportionem sicut in se
cunda parte patebit. Notandum tamen est
q sicut in supradictis diffinitionibus ubi loquitur
de excessu graduum inter se eque distantium

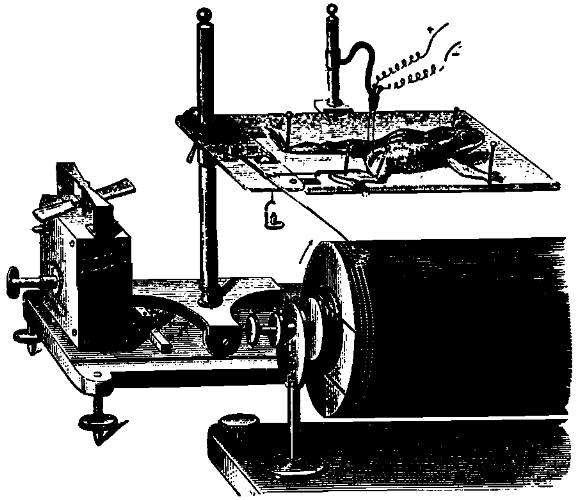
1. NICOLAS ORESME: The First Graphic Representation of Movement, *c.*1350. *The changing qualities of a body were graphically interpreted for the first time by Nicolas Oresme, bishop of Lisieux. The variation is shown by verticals erected above a horizontal, the later X-axis.* (Tractatus de Latitudine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

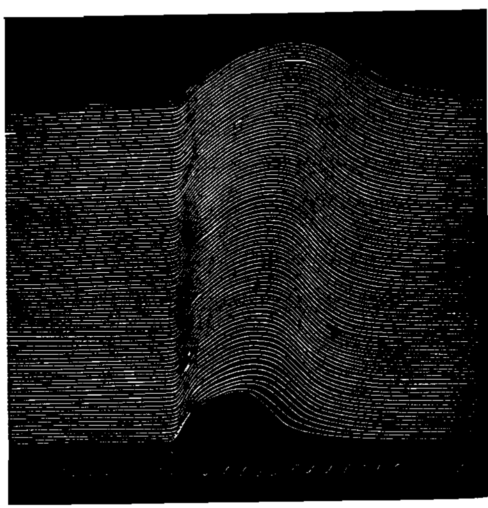
The nineteenth century makes the great leap and literally learns to feel the pulse of nature. Early in his career, the French physiologist, Étienne Jules Marey, 1830–1904, invented the Spygmograph (1860), which inscribed on a smoke-blackened cylinder the form and frequency of the human pulse beat.



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)

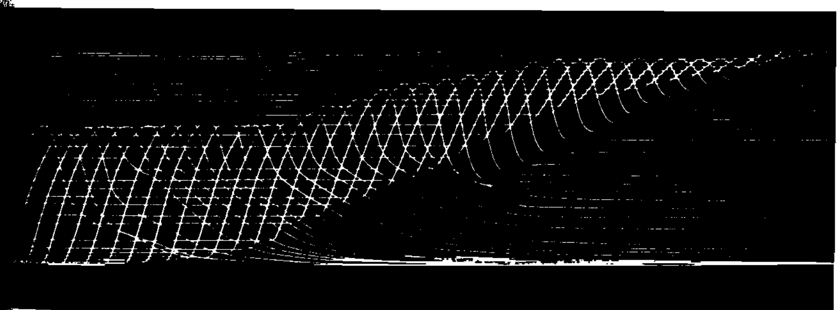
the following year, Marey's thought ever revolves around a central concept of our epoch: Movement.

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.

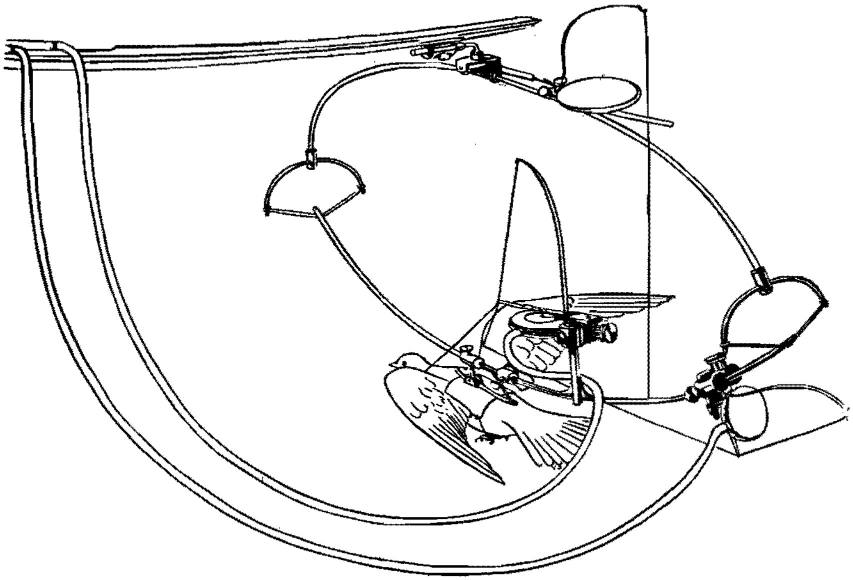
The eighteenth century had witnessed early efforts to extend graphic representation to new domains. The object was to make intelligible a movement of historical dimensions, as Playfair did in 1789 when he charted the fluctuating national debt between 1688 and 1786 in curves that clearly betrayed the 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.

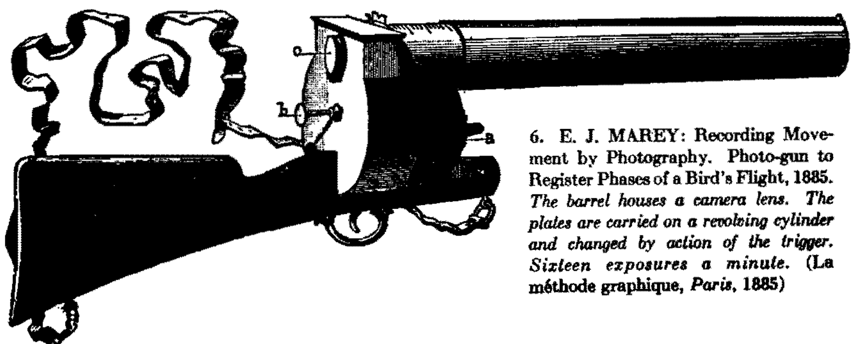
Finally Marey comes to the domain that is of particular concern to us: rendering the true form of a movement as it is described in space. Such movement, Marey stresses again and again, 'escapes the eye.'

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.

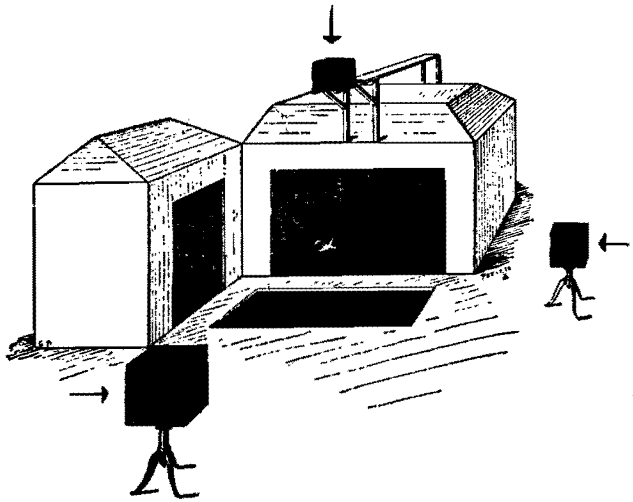
[12] Marey also devised the first movie camera with film reels (1886), and showed Edison his first short 'movie' during the Paris Exhibition of 1889. Like most of the great nineteenth-century scientists, Marey was not interested in the market value of his ideas. The practical solutions came from Edison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

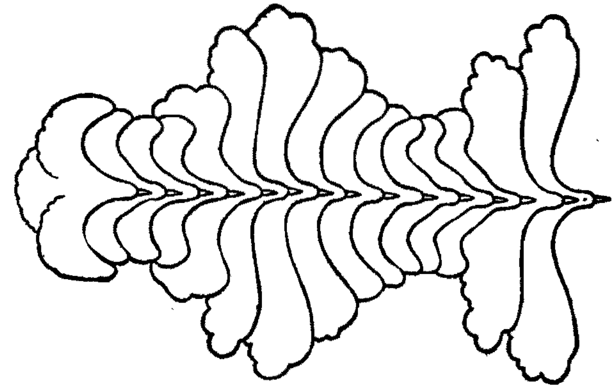
birds is spatial. It evolves freely in three dimensions. Around 1885 Marey pointed three cameras in such a way as to view the bird simultaneously from above, from the side, and from the fore (fig. 7). At his laboratory in the Parc des Princes, Paris, he set up a vast hangar, before whose black walls 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.

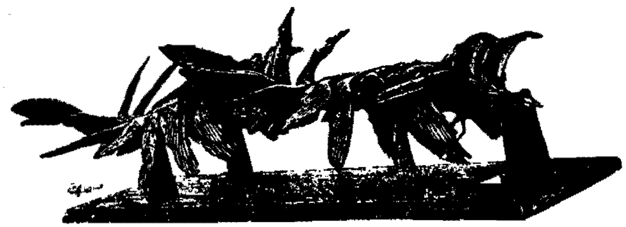
For better knowledge of the bird's flight, Marey later drew diagrams in which he separated the overlapping phases of the photograph (figs. 8–10). He even modeled the sea gull in its successive attitudes (fig. 9) — sculpture that would have delighted Boccioni, creator of the 'Bottle evolving in Space' (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.'

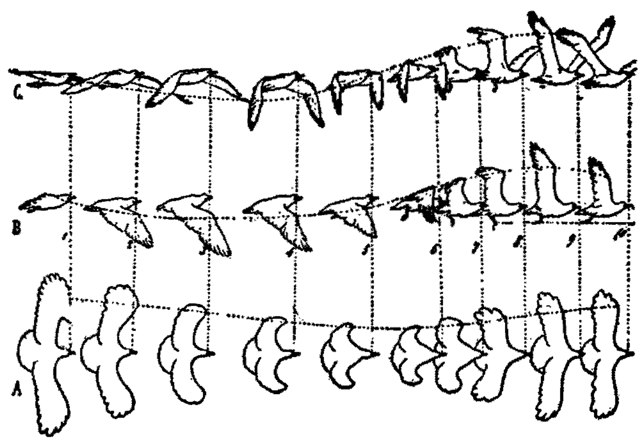
8. E. J. MAREY: Horizontal Projection of the Flying Seagull. Before 1890. (Le vol des oiseaux)





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.'

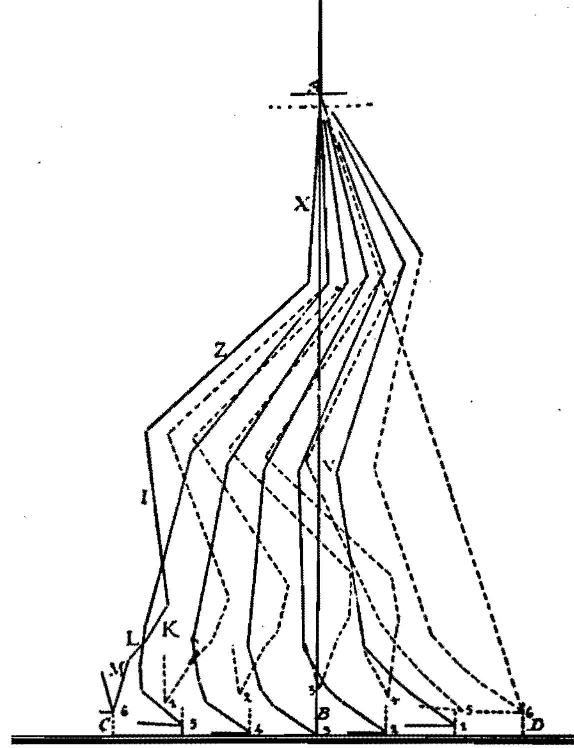
For lack of technical means these early promises did not reach full maturity. The fulfilment was to come from elsewhere, from the industrial sphere. This occurred around 1912, in 'scientific management.' The object was to record a given motion cycle in utmost detail. Only thus could one accurately observe 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.

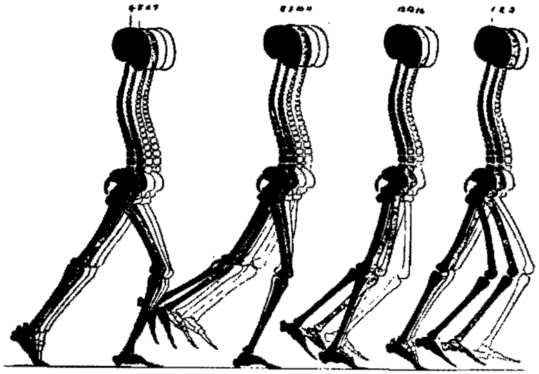


11. GRIFFON AND VINCENT: Graphic Representation of a Horse's Gait, 1779. *One weakness of this method, Marey points out, is that the motion is shown as if centering around a static point.* (Marey, La Méthode graphique)

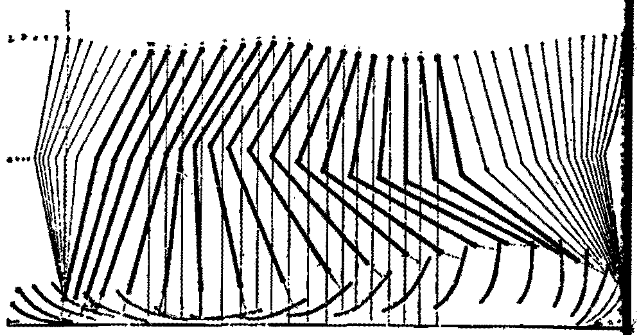
Frank B. Gilbreth (1868–1924) was the first to capture with full precision the complicated trajectory of human movement.

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.

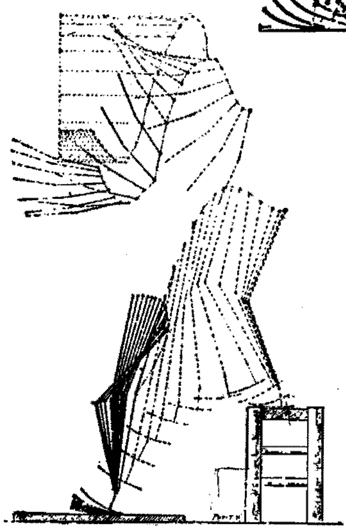
A new realm opens: new forms, new expressive values, transcending the domain of the engineer.



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)



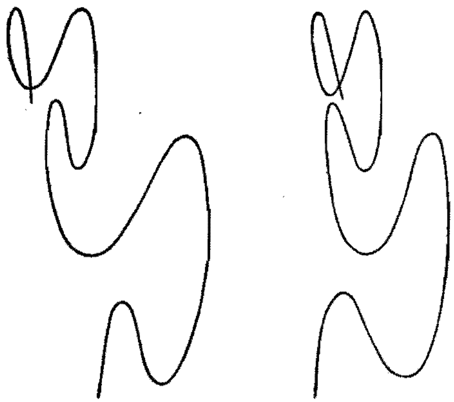
13. E. J. MAREY: Oscillations of the Leg in Running. Before 1885. *The model to be photographed was clothed in black, with a bright metallic strip down the side of the arms, body, and legs.*



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*)

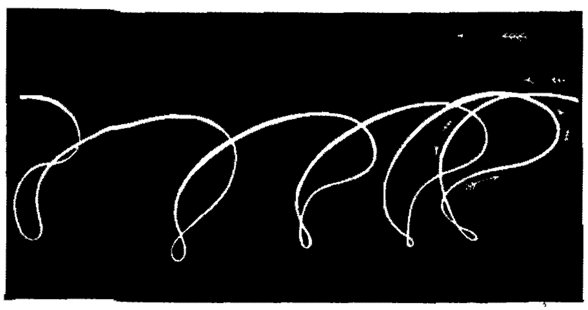


17. E. J. MAREY: Man Walking Away from the Camera. Stereoscopic Trajectory of a Point at the Base of the Lumbar Vertebrae. c.1890. *'A luminous trail, at once manifold and individual.' — Marey.*

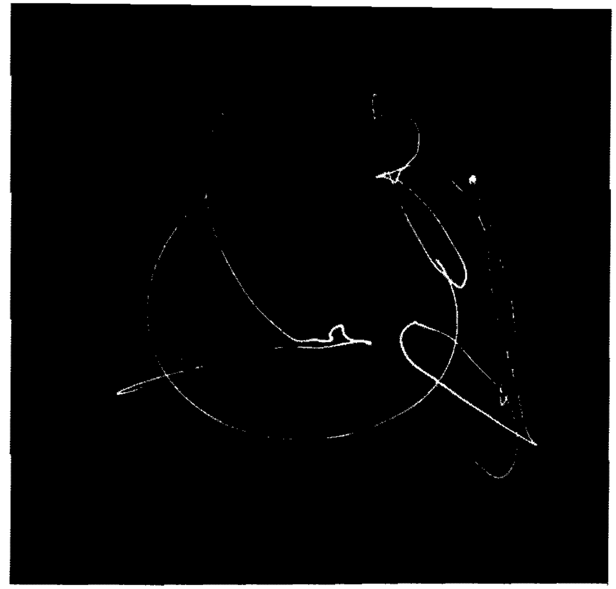
Movement, the ceaselessly changing, proves itself ever more strongly the key to our thought. It underlies the concept of function and of variables in higher mathematics. And in physics, the essence of the phenomenal world has been increasingly regarded as motion-process: sound, light, heat, hydrodynamics, 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.

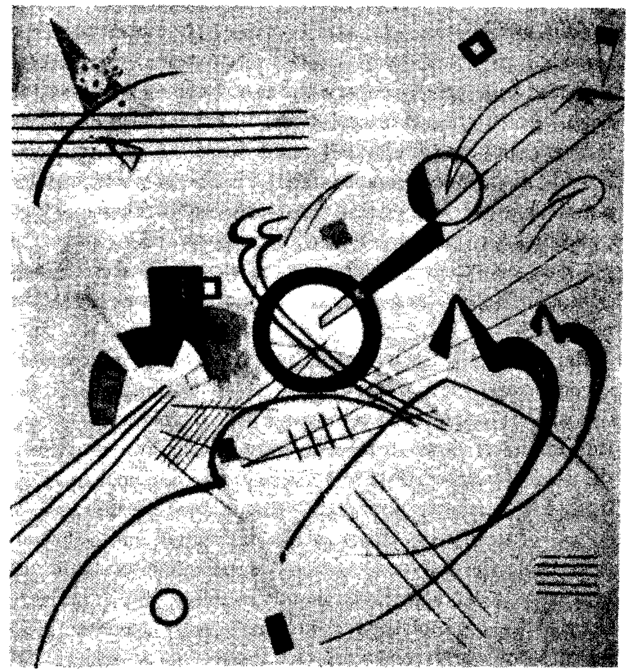
[15] Cf. Bergson, *Creative Evolution*, Eng. trans., New York, 1937, p.272.



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.