From:

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The Culture of
Time and Space
1880 - 1918

6

THE NATURE OF SPACE

In an autobiographical sketch Einstein recalled two incidents from his childhood that filled him with wonder about the physical world. When he was five years old his father showed him a compass. The way the needle always pointed in one direction suggested that there was "something deeply hidden" in nature. Then at twelve he discovered a book on Euclidean geometry with propositions which seemed to be about a universal and homogeneous space.[1] These early memories embodied two opposing views about the nature of space. The traditional view was that there was one and only one space that was continuous and uniform with properties described by Euclid's axioms and postulates. Newton defined this "absolute space" as at rest, "always similar and immutable," but the action of the compass suggested that space might be mutable, with orientations that varied according to its contents. The quivering needle pointed to the north pole and to a revolution in physics.

New ideas about the nature of space in this period challenged the popular notion that it was homogeneous and argued for its heterogeneity. Biologists explored the space perceptions of different animals, and sociologists, the spatial organizations of different cultures. Artists dismantled the uniform perspectival space that had governed painting since the Renaissance and reconstructed objects as seen from several perspectives. Novelists used multiple perspectives with the versatility of the new cinema. Nietzsche and José Ortega y Gasset developed a philosophy of "perspectivism" which implied that there are as many different spaces as there are points of view. The most serious challenge to conventional space came from physical science itself, with the development in the early nineteenth century of non-Euclidean geometries.

Geometry is the branch of mathematics most directly concerned with the nature of space and with the properties of points, lines, planes, and objects in it. Euclid stated without proof certain axioms and postulates that seemed self-evident and from them derived other theorems by deductive logic. His geometry was of two and three dimensions, and for over two millennia it was considered to be the only true geometry of real space. Kant assumed that its propositions were necessarily true and about the world, hence synthetic judgments *a priori.* At the beginning of the nineteenth century it lay at the heart of classical physics and Kantian epistemology. But in the course of that century other geometries challenged the idea that Euclid's was the only valid one. Crucial to it was the Fifth Postulate: that through a point in a plane it is possible to draw only one straight line parallel to a given straight line in the same plane. The non-Euclidean geometries replaced the postulate with others and modified the rest accordingly. Around 1830 the Russian mathematician Nicholai Lobatchewsky announced a two-dimensional geometry in which an infinite number of lines could be drawn through any point parallel to another line in the same plane. In his geometry the sum of the angles of a triangle is less than 180 degrees. In 1854 the German

mathematician Bernhard Riemann devised another two-dimensional geometry in which all triangles had angle sums greater than 180 degrees. Riemann's space was elliptical; that of Lobatchewsky was hyperbolic. These alternative surface spaces contrasted with the flat planar surface of Euclid's two-dimensional geometry in which the angle sum of a triangle is exactly 180 degrees. By the end of the century other mathematicians had developed geometries for all kinds of spaces—a doughnut, the inside of a tunnel, even a space like a venetian blind.[2]

The parallel postulate was a weak point in Euclid. As early as 1621 Sir Henry Savile identified it as a blemish in the system, and to many mathematicians thereafter it did not seem sufficiently self-evident to warrant acceptance without proof. It is therefore ironic that Lawrence Beesley, in his account of the sinking of the *Titanic,* referred to the law of parallels as if it were a symbol of order in the natural world. From a lifeboat he described the beauty of the ship at night, marred by the "awful angle" made by the level of the sea with the rows of porthole lights. "There was nothing else to indicate she was injured; nothing but this apparent violation of simple geometrical law—that parallel lines should 'never meet if produced ever so far both ways.'"[3]

If the spaces of non-Euclidean geometry were not bewildering enough, there were other new spaces that could not be accounted for by any geometry. In 1901 Henri Poincaré identified visual, tactile, and motor spaces, each defined by different parts of the sensory apparatus. While geometrical space is three-dimensional, homogeneous, and infinite, visual space is two-dimensional, heterogeneous, and limited to the visual field. Objects in geometrical space can be moved without deformation, but objects in visual space seem to expand and contract in size when moved different distances from the viewer. Motor space varies according to whatever muscle is registering it and hence has "as many dimensions as we have muscles."[4] In a similar manner Mach defined visual, auditory, and tactile spaces that varied according to the sensitivity and reaction times of different parts of the sensory system. These spaces constituted the physiological foundation for the "natural" development of geometrical space. Symmetry has a bodily source, and the positive and negative coordinates of Cartesian geometry derive from the right and left orientation of our body. Our notion of surface comes from the experience of our own skin. "The space of the skin," Mach wrote, "is the analog of a two-dimensional, finite, unbounded and closed Riemannian space." Terms for basic units of measurement such as "foot" and "pace" reveal anatomical origins, and thus "notions of space are rooted in our physiological organism."[5]

Speculation that there are two- and three-dimensional spaces other than the one described by Euclid and that our experience of space is subjective and a function of our unique physiology was disturbing to the popular mind. Perhaps the most famous critic of these notions was V. I. Lenin, who, in *Materialism and Empirio-Criticism* of 1908, cried "enough" to the proliferation of spaces, to the "Kantian" notion that space is a form of understanding and not an objective reality, and to "reactionary" philosophies such as those of Mach and Poincaré. Like a man trying to hold down a tent in a wind, Lenin raced about defending the objective, material world in absolute space and time that he believed to be the foundation of Marxism and which, he feared, was threatened by recent developments in mathematics and physics. It is an embarrassing performance by a man straining in a field beyond his expertise, but it gives a sense of the concrete implications and political overtones of this seemingly abstract thought.

Lenin began the chapter on "Space and Time" with a statement of the materialist position: there is an objective reality in which matter moves in space and time independently of the human mind. This is in contrast with the Kantian view that time and space are not objective realities but forms of understanding. He conceded that human conceptions of space and time are "relative," but this relativity moves toward the "absolute truth" of objective reality. Mach's statement that space and time are "systems of series of sensations" was "palpable idealist nonsense." He labeled "absurd" Mach's speculation that physicists might seek an explanation for electricity in a space which is not three-dimensional, and he reaffirmed the orthodox position: "Science does not doubt that the substance it is investigating exists in three-dimensional space." He tossed off Poincaré's famous anticipation of the relativity of time and space and then criticized that "scrupulous foe of materialism" Karl Pearson, who had written that time and space are "modes under which we perceive things apart." The kind of thinking that denies the objective reality of time and space is "rotten" and "hypocritical."[6]

Lenin engaged in this polemic because he believed that the reputation and political effectiveness of the Bolshevik party were at stake. When an article appeared in *Die Neue Zeit* (1907) about certain Bolsheviks who had embraced a Machist philosophy and compromised

orthodox Marxism, Lenin decided to attack publicly to define the Bolshevik position and show that Machism was simply an aberration of certain individuals in his party, one manifestation of a general disease of doubting material reality that was infecting modern society as a whole and that could break out in any political party.[7] In the concluding paragraphs Lenin singled out the prominent Bolshevik philosopher A. Bogdanov, who had argued for the social relativity of all categories of experience in *Empirio-monism* (1904–1906). Bogdanov had written that time, like space, is "a form of social coordination of the experiences of different people." Such relativistic idealism undermined materialism and the belief that there is one and only one real framework of time and space in which the events of all cultures take place. According to Bogdanov, Lenin charged, "various forms of space and time adapt themselves to man's experience and his perceptive faculty."[8] This formulation contradicted Lenin's materialism in two respects. The reference to a plurality of spaces challenged the universality of a single space, and the suggestion that these various forms of space and time "adapt" to man's experience identified Bogdanov with the genetic epistemology of both Mach and Poincaré.

While Lenin was combating the social relativism of Bogdanov, a far more important theory of relativity was being developed by Einstein. Efforts by physicists to fit the negative findings of the Michelson-Morley experiment into the body of classical physics were like those of a squirrel trying to bury a nut in a tile floor. Lorentz hypothesized a dilation of time for the beam of light traveling in the direction of the "ether current" just enough to reconcile the experiment with absolute time. George Fitzgerald suggested a similar compromise to hold on to absolute space. He hypothesized that the arms of the apparatus in the experiment actually contracted in length in the direction of the ether flow just enough to compensate for the longer time that the light should take to travel with and against the current as compared with the beam of light that traversed the same distance across and back. Einstein scrapped the Fitzgerald contraction together with the Lorentz dilation and proposed relativity instead. In the special theory of 1905 space was redefined as a quasi-perspectival distortion. The contraction was not a real change in the molecular construction of the apparatus but a distortion created by the act of observing from a moving reference system. This perspectival effect differed from ordinary perspective because it was not due to optics and would occur no matter how far the object observed in motion was from the observer. The relative velocity of the object and viewer was the crucial factor, not the distance between them. With Einstein's explanation no absolute meaning could be given to the concept of the actual length of the apparatus or of the space it occupies. Length is not in anything; it is a consequence of the act of measuring. Thus absolute space has no meaning. In 1916 Einstein explained: "We entirely shun the vague word 'space,' of which, we must honestly acknowledge, we cannot form the slightest conception and we replace it by 'motion relative to a practically rigid body of reference.'"[9] With the general theory of relativity the number of spaces increased beyond calculation to equal the number of moving reference systems of all the gravitational fields generated by all of the matter in the universe. In 1920 Einstein summed up boldly: "there is an infinite number of spaces, which are in motion with respect to each other."[10] Fortunately Lenin was too busy making a revolution to take notice.

While physical scientists were trying to come to terms with the heterogeneity of abstract space, natural scientists began to investigate the relation between the structure of living organisms and their spatial orientation. In 1901 the Russian physiologist Elie de Cyon published an article on the "natural" foundation of Euclidean geometry based on results of experiments that he had been conducting for over twenty years on the physiological origins of experiencing space.[11] His hypothesis was that the sense of space is rooted in the semicircular canals of the ear. Animals with two canals experience only two dimensions and those with one canal are oriented in one. Humans experience three dimensions because they have three canals set in perpendicular planes, and three-dimensional Euclidean space corresponds to the physiological space determined by the orientation of these canals. From these experiments Cyon concluded that the sense of space is not inherent and that Kant's theory that it is an *a priori* category of the mind was wrong. Only the semicircular canals are inherent, and our sense of space derives from them and remains dependent upon them. The boldness of these claims, particularly the attack on Kant, triggered a good deal of scholarly criticism,[12] but Cyon was undaunted and continued to extend his theory. In 1908 he argued that the sense of time also was dependent upon the semicircular canals.[13] The following year his results were incorporated into a classic of theoretical biology, Jacob von Uexküll's *Umwelt und Innenwelt der Tiere*.

Uexküll asks the biologist to set aside everything that he takes for

anted in his own world—nature, earth, heavens, objects in ace—and focus on only that part of the environment that a partic-r organism can actually experience. Although all animals live in same environment, they have their own surrounding world (*Umwelt*). Each species responds to the outer world in its own way, and that response creates its special inner world (*Innenwelt*). The lower animals react to stimuli directly, and only higher animals with some organ of sight develop a proper sense of space. Their brains recognize the surrounding world not merely by direct contact but are also able to mirror objects and spatial relations in the environment. This mirror world or counterworld (*Gegenwelt*) differs with each type of nervous and muscular system. Thus the inner worlds, surrounding worlds, and counterworlds vary with the "building plans" of each animal and constitute different senses of space.

Uexküll modified and extended Cyon's theory to the entire animal kingdom and concluded that the sense of space of all animals, however rudimentary, varied with their unique physiology. Each had special dimensions, even the space sense of one-celled animals. The amoeba's space was a limited one, but he reconstructed it in great detail and characterized it as a "most lively work of art." His appreciation of the creative force generated by the needs and structural patterns of animals led him to a critique of Darwin's theory of natural selection. "It is not true, as people are accustomed to think, that nature compels the animal to adapt, but on the contrary, the animal forms its nature according to its special needs."[14] Among the throng of worlds and living spaces, he speculated, there may also be higher worlds of greater dimensions that we are unable to see, as the amoeba is unable to see the stars in our sky.

This reminder that there are complete worlds with distinctive spatial orientations scattered all along the phylogenetic scale challenged the egocentrism of man. Another challenge came from social scientists. Adventurers and scholars had long sailed about the earth and dug into its crust to find out about other societies, but they always reconstructed them in the uniform space of the modern Western world, never imagining that space itself might vary from one society to another as much as did kinship patterns and puberty rites. Durkheim's arguments for the social relativity of space and its heterogeneity were part of his general theory of the social origin of basic categories of experience.[15] In *Primitive Classification* he challenged the theory, attributed to Sir James Frazer, that social relations are based on logical relations inherent in human understanding. He argued the opposite—that logical categories derive from social categories, space being one of them. To illustrate he described the Zuñi Indians who divided space into seven regions—north, south, east, west, zenith, nadir, and center—which derived from social experience and in which all objects belonged. The wind and air belonged to the north, water and spring to the west, fire and summer to the south, earth and frost to the east. Different birds and plants belonged to specific regions as did the energies of life. The north was the region of the pelican and crane, the evergreen oak, force and destruction. He concluded that their space was "nothing else than the site of the tribe, only indefinitely extended beyond its real limits."[16] Space is heterogeneous in two senses: it varies from society to society, and within societies such as the Zùñi it has different properties in different regions.

In *The Elementary Forms of the Religious Life* Durkheim elaborated on the heterogeneous nature of space, again as part of a general theory of the social origins of the categories of thought. If space were absolutely homogeneous, he argued, it would be useless to coordinate the varied data of sensuous experience. To identify things in space it must be possible to place them differently—to put them above and below, right and left—and so in every society space is heterogeneous. But there is a collective sense of these unique spaces, shared by all member of a society, hence they must have a social origin; and there is evidence that these spatial classifications are structurally similar to social forms: "There are societies in Australia and North America where space is conceived in the form of an immense circle, because the camp has a circular form; and this spatial circle is divided up exactly like the tribal circle, and is in its image. There are as many regions distinguished as there are clans in the tribe, and it is the place occupied by the clans inside the encampment which has determined the orientation of these regions."[17] Durkheim believed that there was a multitude of such spaces about the surface of the globe, differing from each other like patterns of Oriental rugs.[18] In Germany another social scientist unearthed a plurality of spaces buried in time.

Spengler believed that different cultures had a unique sense of space (as well as time) manifested in a symbolism that embraced every aspect of life. This sense of space or extension is the "prime symbol" of a culture, inherent in political institutions, religious myths, ethical ideals, principles of science, and the forms of painting, music, and sculpture. But it is never conceptualized directly, and it is

necessary to interpret many aspects of a culture to grasp its particular notion of extension. The infinitely extended space of the modern "Faustian" era is but one of several in which the great cultures of history have been staged.

The Egyptians conceived of space as a narrow path down which the individual soul moves to arrive at the end before ancestral judges. Their most distinctive constructions are not buildings but paths enclosed by masonry. Reliefs and paintings are done in rows and lead the beholder in a definite direction. In Chinese culture space is also a path that wanders through the world; but the individual is led to his ancestral tomb by nature, by "devious ways through doors, over bridges, round hills and walls," not by rows of stones like the Egyptians. Greek space was dominated by a sense of nearness and limit. The universe was a cosmos, a "well-ordered aggregate of near and completely viewable things" covered by the corporeal vault of heaven. Its government was a clearly circumscribed city-state; its temples, finite structures formed about a center, enclosed by a colonnade. Classical art had "closed" figures with sharply bounded surfaces, and the predominance of the body brought the eye from the distant to the "near and still." Its statues, like its buildings, were clearly delimited, with no suggestion of the infinite or unbounded, and it produced a geometry of regular, closed figures that were the ideal forms of the earth and heaven.[19]

Spengler's account of space in the modern era expands with an exuberance that parallels his thesis—that the prime symbol of the Faustian soul of the modern age is limitless space. Faust's restless striving, the soaring of Gothic cathedrals, and the proliferation of geometric spaces reflect this sense of infinity. Modern music such as Wagner's *Tristan* liberates the soul from material heaviness and sets it free to move towards the infinite. He concludes with a cannonade of evidence for the modern era's sense of the limitlessness of space: "the expansion of the Copernican world picture into that aspect of stellar space that we possess today; the development of Columbus's discovery into a worldwide command of the earth's surface by the West; the perspective of oil painting and of tragedy-scene; . . . the passion of our civilization for swift transit, the conquest of the air, the exploration of the Polar regions and the climbing of almost impossible mountain peaks."[20]

The proliferation of geometrical and physical spaces had a great effect on mathematics and physics but did not generally influence thinking in other areas. The exploration of the experience of space of the amoeba, the Zuñis, and the ancient Egyptians was important to some natural and social scientists but made little stir outside their respective disciplines. However, the multiplication of points of view in painting had an impact far beyond the world of art. It created a new way of seeing and rendering objects in space and challenged the traditional notion of its homogeneity.

The depiction of space in painting reflects the values and fundamental conceptual categories of a culture. In the Middle Ages the importance of persons and things in heaven and earth determined their size and position in space. With the introduction of perspective, objects were rendered to scale according to their actual size and were located in space to reproduce the relations of the visible world.[21] In 1435 the Florentine painter Leon Battista Alberti formulated the rules of perspective that were to govern painting for four hundred and fifty years. He intended to help painters create a unified pictorial space in which God's order, the harmony of nature, and human virtues would be visible. Samuel Edgerton has observed that this formulation of perspective was a "visual metaphor" for the entire Florentine world at that time: its politics were just coming under the authority of the Medici oligarchy; there was a growing rationality in banking and commerce that relied on mathematical orderliness and utilized the system of double-entry bookkeeping; the Tuscan hills were terrassed with neat rows of olive trees and parallel strings of grape vines, all controlled by a centralized land management; proportion and orderliness were valued in every area of culture and were expected to regulate decorum and dress.[22] Although there were occasional variations or intentional violations of the rules of perspective, they governed the rendering of space in art until the twentieth century. Then, under the impact of the Impressionists, Cézanne, and the Cubists that perspectival world broke up as if an earthquake had struck the precisely reticulated sidewalks of a Renaissance street scene.

When the Impressionists left their studios and went outside to paint, they discovered a new variety of points of view as well as shades of color and light. They broke Alberti's rule that the canvas should be placed precisely one meter from the ground, directly facing the subject, and positioned it up and down and at odd angles to create new compositions. They moved in and out of the scene, and the frame ceased to be the proscenium of a cubed section of space that it had traditionally been. Daubigny carried to an extreme their

rejection of the fixed point of view when he painted from a houseboat as it rocked at anchor or actually sailed along the Seine. With these new points of view the Impressionists abandoned the scenographic conception of space.[23]

However varied the scope and angle of Impressionist space, it was essentially one space as seen from one point of view. Cézanne was the first to introduce a truly heterogeneous space in a single canvas with multiple perspectives of the same subject. In *Still Life* (1883–1887) a large vase is reconstructed from two points of view with the elliptical opening more rounded than a strict adherence to scientific perspective would allow and gaping fuller than the opening of the other vase standing next to it on the same flat surface in the same plane. In *Still Life with a Basket of Apples* (1890–1894) the corners of the table are seen from different vantage points and grafted together to create balance with the other shapes. His *Portrait of Gustave Geoffroy* (1895) combines a frontal view of the seated subject with an aerial view of the table before him on which open books are lying with almost no perspectival foreshortening. This optically impossible mixture of points of view enabled Cézanne to show all that he wanted of the man and his work and at the same time conform to the requirements of composition. Cézanne was enamored of the shape of Mont Sainte-Victoire and painted it hundreds of times. By using different perspectives for different parts of the landscape he gradually pulled it out of the distant background toward the foreground until in the later paintings it loomed large as a symbol of his lifelong fascination with form and space. His landscapes broke ground for modern art as he gouged out quarries and cleared trees to make the terrain of Aix-en-Provence conform to his artistic needs.

Cézanne's primary commitment was to the composition of forms on the flat surface of the canvas; conventions for accurately rendering volume and depth were secondary.[24] While most painters had tried to create an illusion of three-dimensional space, Cézanne accentuated the flatness of the picture surface and frequently violated the rules of perspective in deference to it. He never entirely abandoned the techniques for showing depth but compromised them when necessary. And so he broke up consistent linear perspective with multiple perspectives, he violated aerial perspective in landscapes by painting objects in the distance as bright or brighter than those in the foreground, and he occasionally chipped off a piece of pottery when overlapping would interfere with his overall design. He sought to reconcile the properties of volumes in three-dimensional space with the two-dimensionality of the picture plane, and his paintings vibrate from the tension. He also wanted to fuse perceptions and conceptions—the way we see things from a single point of view and the way we know them to be from a composite of several views. Experience tells us that the opening of a vase is circular, but when viewed from the side we see it as an ellipse. Cézanne combined the two perceptions visually with multiple perspectives.

These daring innovations were possible only for someone with a sharp sense of space. Cézanne's unique sensitivity to the effect of slight shifts in point of view is revealed in a letter to his son of September 8, 1906: "Here on the edge of the river, the motifs are plentiful, the same subject seen from a different angle gives a subject for study of the highest interest and so varied that I think I could be occupied for months without changing my place, simply bending more to the right or left."[25] Subtle differences in form and perspective that most painters would not notice occupied Cézanne—fascinated him—for months. He wrestled with them until, as Merleau-Ponty believed, he created "the impression of an emerging order, of an object in the art of appearing, organizing itself before our eyes."[26] He "realized" objects in space as they take form, as the eye darts about the visual field and hovers around things until they are identified in space and integrated into our world of experience. For Cézanne an object in space was a multitude of creations of the seeing eye that varied dramatically with the most minute shifts in point of view.

One of the great fallacies of historical reconstruction is the characterization of events as transitional. The work of Cézanne is one of the most fully realized corpuses in the history of art, and it is particularly misleading to view it as a transition to modern art. Nevertheless the important innovations he made in the rendering of space—the reduction of pictorial depth and the use of multiple perspective—were carried further by the Cubists in the early twentieth century and have therefore come to be viewed as transitional. The Cubists repeatedly expressed their debt to Cézanne and used his techniques to create even more radical treatments of space. Their use of multiple perspective also shows a strong similarity to the cinema, which broke up the homogeneity of visual space.

Rouge, 1973), 9, 10, 58–59; Rudi Blesh and Harriet Janes, *They All Played Ragtime* (London, 1958), 3–23.

53. Hiram Kelly Moderwell, "Ragtime," *New Republic* (October 16, 1915): 286, cited by Edward A. Berlin, *Ragtime: A Musical and Cultural History* (Berkeley, 1980), 51; Walter Lippmann, *Drift and Mastery: An Attempt to Diagnose the Current Unrest* (New York, 1914), 211.

54. William Morrison Patterson, *The Rhythm of Prose* (New York, 1916), 50–51; R. W. S. Mendl, *The Appeal of Jazz* (London, 1927), 46; William W. Austin, *Music in the 20th Century* (New York, 1966).

55. Igor Stravinsky, *An Autobiography* (New York, 1936), 47.

56. George M. Beard, *American Nervousness: Its Causes and Consequences* (New York, 1881), 116.

57. Sir James Crichton-Browne, "La Vieillesse," *Revue scientifique*, 49, (1892): 168–178.

58. Max Nordau, *Degeneration* (New York, 1968), 37–42.

59. John H. Girdner, *Newyorkitis* (New York, 1901), 119.

60. Gabriel Hanotaux, *L'Energie française* (Paris, 1902), 355.

61. Willy Hellpach, *Nervosität und Kultur* (Berlin, 1902), 12.

62. For a survey of the *psychische Spannung* of the age in medical and imaginative literature see Andreas Steiner, *Das nervöse Zeitalter: der Begriff der Nervosität bei Laien und Ärzten in Deutschland und Österreich um 1900* (Zurich, 1964).

63. Henry Adams, *The Education*, 499.

64. William Dean Howells, *Through the Eye of the Needle* (New York, 1907), 10–11.

65. In 1913 there were 4,200 total traffic deaths in the United States. United States Bureau of the Census, *Historical Statistics of the United States Colonial Times to 1970* (Washington, D.C., 1975), 720.

66. Robert Musil, *The Man Without Qualities* (1930; rpt. New York, 1966), 6, 7, 30.

67. Stefan Zweig, *The World of Yesterday* (Lincoln, Nebraska, 1964), 25–26.

68. Charles Féré, "Civilisation et névropathie," *Revue philosophique*, 41 (1896): 400–413.

69. Octave Uzanne, *La Locomotive à travers le temps, les moeurs et l'espace* (Paris, 1912), vi–vii, 244–247, 304. Émile Magne surveys a number of sources which, after Zola's *La Bête humaine* in 1885, affirmed the new aesthetic of the machine: "Le Machinisme dans la littérature contemporaine," *Mercure de France*, LXXXIII (January 16, 1910): 202–217.

6. The Nature of Space

1. Albert Einstein, "Autobiographical Notes," in *Albert Einstein: Philosopher-Scientist*, ed. Paul Arthur Schilpp (Evanston, 1949), 9–11.

2. Max Jammer, *Concepts of Space: The History of Theories of Space in Physics* (Cambridge, Massachusetts, 1969), 144–146; A. d'Abro, *The Evolution of Scientific Thought from Newton to Einstein* (New York, 1927), 35–48.

3. Lawrence Beesley, *The Loss of the SS. Titanic* (New York, 1912), 105.

4. Henri Poincaré, *Science and Hypothesis* (1901; rpt. New York, 1952), 50–58. See also his article, "On the Foundations of Geometry," *The Monist*, 9 (1898): 42.

5. Ernst Mach, *Space and Geometry in Light of Physiological, Psychological, and Physical Inquiry* (1901; rpt. Chicago, 1906), 9, 94.

6. V. I. Lenin, *Materialism and Empirio-Criticism: Critical Comments on a Reactionary Philosophy* (1908; rpt. New York, 1927), 176–189.

7. On the political context of this issue see "Lenin and the Partyness of Philosophy," in David Joravsky, *Soviet Marxism and Natural Science 1917–1932* (London, 1961), 24–44.

8. Cited by Lenin, *Materialism*, 189.

9. Albert Einstein, *Relativity* (New York, 1961), 9.

10. Ibid., 139.

11. E. de Cyon, "Les Bases naturelles de la géométrie d'Euclide," *Revue philosophique*, 52 (July-December 1901): 1–30.

12. Louis Couturat, "Sur les bases naturelles de la géométrie d'Euclide," in ibid., 540–542.

13. E. von Cyon, *Das Ohrlabyrinth als Organ der mathematischen Sinne für Raum und Zeit* (Berlin, 1908), chap. 7.

14. Jacob von Uexküll, *Umwelt und Innenwelt der Tiere* (Berlin, 1909), 195. He extended these findings in *Bausteine zu einer biologischen Weltanschauung* (Munich, 1913).

15. The other categories discussed included cause, class, substance, number, and force. There is an analysis of these arguments in Steven Lukes, *Émile Durkheim: His Life and Work* (New York, 1973), 436–445.

16. Émile Durkheim and Marcel Mauss, *Primitive Classification* (New York, 1970), 43–44, 82, 86.

17. Émile Durkheim, *The Elementary Forms of the Religious Life* (New York, 1965), 22, 32, 489–492.

18. In *Consciousness and Society: The Reconstruction of European Social Thought 1890–1930* (New York, 1958), H. Stuart Hughes interpreted this generation as having discovered "the subjective character of social thought," the necessary mediation of consciousness in the study of man and society. According to Hughes, Durkheim was one of many who "found themselves inserting between the external data and the final intellectual product an intermediate stage of reflection on their own awareness of these data"; see pp. 16, 17. For a discussion of the polarization of space between the right and left hand in the religious practices of different societies see Robert Hertz, "La Prééminence de la main droite: étude sur la polarité religieuse," *Revue philosophique* (December 1909): 553–580. The Marxist historian Henri Lefebvre has analyzed the social "production of space" (especially unique capitalistic and socialistic forms), and he has identified a breakdown of the older uniform

space around 1910, when "Euclidean and perspectival space disappeared as referents along with the other common places (the city, history, paternity, the tonal system in music, the moral tradition, etc.)." See *La Production de l'espace* (Paris, 1974), 34 *ff.*

19. Oswald Spengler, *The Decline of the West* (New York, 1926), I, 174–178; 188–190; H. Stuart Hughes, *Oswald Spengler* (New York, 1952), 78–79.

20. Spengler, *Decline,* 337.

21. A pioneer study of the cultural impact of the introduction of perspective is Erwin Panofsky's "Die Perspektive als 'symbolische Form'," *Vorträge der Bibliothek Warburg* (1924–25).

22. Samuel Y. Edgerton Jr., *The Renaissance Rediscovery of Linear Perspective* (New York, 1975), 30–40.

23. L. Keith Cohen, "The Novel and the Movies: Dynamics of Artistic Exchange in the Early Twentieth Century" (Ph.D diss., Princeton University, 1974), 49–50.

24. For a general discussion of Cézanne's role in the breakdown of scientific perspective see Fritz Novotny, *Cézanne und das Ende der wissenschaftlichen Perspektive* (1938; rpt. Vienna, 1970), 184 and *passim.*

25. John Rewald, ed., *Paul Cézanne Letters* (Oxford, 1946), 262.

26. Maurice Merleau-Ponty, *Sense and Non-Sense* (1948; rpt. Evanston, 1964), 14.

27. Georges Matoré, *L'Espace humain: l'expression de l'espace dans la vie, la pensée et l'art contemporains* (Paris, 1962), 236–242; Standish Lawder, *The Cubist Cinema* (New York, 1975), 12.

28. Charles B. Brewer, "The Widening Field of the Moving-Picture," *The Century Magazine,* 86 (1913): 73–74.

29. Roger Allard, "At the Paris Salon d'Automne" (1910), in *Cubism,* ed. Edward Fry (New York, 1966), 62.

30. Jean Metzinger, "Cubism and Tradition" (1911), in ibid., 66.

31. Guillaume Apollinaire, *Cubist Painters* (1913; rpt. New York, 1944), 13.

32. E. Jouffret, *Traité élémentaire de géometrie à quatre dimensions* (Paris, 1903), 153. This connection was made by Linda Dalrymple Henderson in an article on possible influences of physics and geometry on the Cubists: "A New Facet of Cubism: 'The Fourth Dimension' and 'Non-Euclidean Geometry' Reinterpreted," *The Art Quarterly* (Winter 1971): 411–433. She refutes the facile connections between Cubism and science made by Paul M. Laporte and others and shows that although the Cubists could not have known about Einstein's relativity or Minkowski's space-time theory, they might have learned about the fourth dimension and non-Euclidean geometry from their friend, the insurance actuary Maurice Princet. Although Picasso denied having discussed the fourth dimension with Princet, she speculates that it is possible that he or the other Cubists picked up a suggestion of it from him indirectly.

33. See Judith Wechsler, ed., *Cézanne in Perspective* (Englewood Cliffs, New Jersey, 1975), 7.

34. Albert Gleizes and Jean Metzinger, "Cubism," in *Modern Artists on Art,* ed. Robert L. Herbert (New York, 1964), 7–8.

35. Pablo Picasso, "Statements to Marius de Zayas" (1923), in Fry, *Cubism,* 168.

36. Novotony, *Cézanne,* 141–143, 188.

37. Siegfried Giedion, *Space, Time, and Architecture* 5th ed. (1941; rpt. Cambridge, Mass., 1967), 435.

38. Pierre Francastel, *Peinture et société: naissance et destruction d'un espace plastique de la Renaissance au cubisme* (Lyon, 1951), 247.

39. Max Kozloff, *Cubism/Futurism* (New York, 1973), 70.

40. Wylie Sypher, *Rococo to Cubism in Art and Literature* (New York, 1960), 263–277.

41. Marcel Proust, *Swann's Way* (1914; rpt. New York, 1928), 258–261. On the Cubist nature of the steeples of Martinville see Matoré, *L'Espace humain,* 206. On multiple perspective in Proust and Einstein see Camille Vettard, "Proust et Einstein," *La Nouvelle revue française* (August 1922): 246–252.

42. Cited in Georges Poulet, *Studies in Human Time* (Baltimore, 1956), 319.

43. Proust, *Swann's Way,* 611.

44. Joyce, *Ulysses,* 698–699, 736.

45. Edmund Wilson, *Axel's Castle* (New York, 1931), 221. R. M. Kain wrote of *Ulysses:* "In its cubistic arrangement of contrasting planes and perspectives it is a perfect art form for the modern era"; see *Fabulous Voyager* (New York, 1959), 240. For another aspect of multiple viewpoint in Joyce and its possible connection with cinema see Paul Deane, "Motion Picture Technique in James Joyce's 'The Dead,' " *James Joyce Quarterly* (Spring 1969): 231–236.

46. Friedrich Nietzsche, *Thus Spoke Zarathustra* (New York, 1954), 237.

47. Friedrich Nietzsche, *On the Genealogy of Morals* (New York, 1967), 119.

48. José Ortega y Gasset, "Adám en el Paraíso," in his *Obras Completas* (1910; rpt. Madrid, 1946), I, 471. See Julian Marías, *José Ortega y Gasset,* n.p. (1970), 325–378.

49. José Ortega y Gasset, *Meditations on Quixote* (1914; rpt. New York, 1963), 44.

50. José Ortega y Gasset, "Verdad y perspectiva," *El Espectador,* 1 (1916), 10 *ff.*

51. José Ortega y Gasset, *The Modern Theme* (New York, 1961), 143.

52. Gasset, "Verdad y perspectiva," 116.

53. José Ortega y Gasset, "Doctrine of Point of View," *The Modern Theme,* 94.

54. J. J. Thomson, "Cathode Rays" (1897), in *The World of the Atom,* ed. Henry A. Boorse and Lloyd Motz (New York, 1966), 426.