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FREDERIC L. HOLMES
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ALEKSANDR NIKOLAEVICH LEBEDEV–FRITZ ZWICKY

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Editorial Board

LEBEDEV, ALEKSANDR NIKOLAEVICH (*b.* Moscow, Russia, 21 May 1881; *d.* Moscow, 3 June 1[illegible]), *biochemistry*.

After graduating from a classical gymnasium in Moscow, Lebedev entered the Faculty of Natural Sciences at Moscow University in 1897. Upon receiving his bachelor's degree in 1901, he became an assistant in the chemical laboratory of N. D. Zelinsky at the university. There he became interested in catalysis and the occurrence of catalytic phenomena in living forms.

Already possessing an exceptional chemical background, Lebedev decided to expand his biological and agronomical education while continuing his work at Zelinsky's laboratory by enrolling in the Petrov-Rasumov (today the Timiriazev) Agricultural Institute, from which he received a master's degree in agronomy (1904).

Lebedev was sent abroad in the year 1905–1906 to train for the professorship. He worked with Georg Bredig in Heidelberg, where he conducted his first research on the influence of a high-frequency current on hydrogen peroxide. In 1907 he went to Berlin, where he worked in the laboratory of Eduard Buchner at the University of Berlin. For a few months in 1910 he worked with Emil Fischer at his Institute of Organic Chemistry, also at the University of Berlin.

In Buchner's laboratory Lebedev began his lengthy research on the chemical nature of alcohol fermentation. At that time the discussions resulting from contradictions in the opinions of Louis Pasteur, Marcellin Berthelot, and Moritz Traube had not been forgotten, and the conception that the chemical metabolic processes in the cell could be represented as a chain of connected biocatalytic reactions was being increasingly affirmed. Lebedev studied the kinetics of alcoholic fermentation, then began to search for intermediate products of the conversions of sugar in the process of alcohol fermentation. He was seeking to determine a general scheme of these processes, something that Adolf von Baeyer and Eduard Vohl had already attempted to do, but unsuccessfully and only speculatively. Lebedev's intense work in the laboratory led to a hemorrhage in his eye and an exacerbation of existing tuberculosis. He discontinued his work in the laboratory and went to Palermo, Sicily, where he began to summarize the data he had collected.

In 1911 Lebedev continued his research on fermentation at the Pasteur Institute's biochemical section, headed by Gabriel Bertrand. Here he developed a method for obtaining the enzyme of fermentation, zymase, from dry yeast. (More precisely, zymase is an enzyme complex inducing extracellular fermentation of sugars.) This method of maceration became the classical one, displacing Buchner's method. Lebedev read a paper on this work before the Paris Chemical Society, which awarded him its prize for it.

Upon his return to Russia, Lebedev was given a teaching position at the Don Polytechnical Institute in Novocherkassk. While there, he published his most important articles on the chemical nature of fermentation, and he summarized his research in *Khimicheskie issledovaniia nad vnekletochnym spirtovhym brozheniem* (Chemical research on extracellular alcohol fermentation, 1913), which he presented to Moscow University for the doctorate in chemistry. This work received the University Award, and in 1914 Lebedev elected professor of the highest order at the Don Polytechnical Institute.

In 1911 Lebedev showed that dihydroxyacetone is fermented by yeast juice; and in 1912, with N. Griaznov, he established that for fermentation to occur, the enzyme reductase was required, the activity of which was induced by a thermostable coenzyme. This coenzyme could be separated from zymase by means of dialysis, and the addition of the dialysate or a small quantity of boiled yeast juice restored the initial activity of zymase that was lost during dialysis. Lebedev obtained osazones of intermediate products of fermentation, and he identified them as hexose-phosphorus ethers.

In 1909 Lebedev proposed the first scheme of alcohol fermentation, with the main role in this process being played by trioses: glyceraldehyde and dihydroxyacetone. In 1912 Lebedev clarified this scheme, including in it triose phosphates as indispensable intermediate products of the anaerobic decomposition of carbohydrates. This scheme was confirmed by Otto Meyerhof and Gustav Embden.

In 1921 Lebedev moved to Moscow as professor of agronomy at Moscow University (where he worked until his death). At the same time he became a member of the Scientific Research Institute of the university. From 1930 he headed the biochemical laboratory of the Central Scientific Research Food Institute, and from 1935 he headed the biochemistry laboratory of the All-Union Institute of Experimental Medicine in Moscow.

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A. N. SHAMIN

LEFSCHETZ, SOLOMON (*b.* Moscow, Russia, 3 September 1884; *d.* Princeton, New Jersey, 5 October 1972), *mathematics.*

Lefschetz was the son of Alexander Lefschetz, an importer, and his wife, Vera, who were Turkish citizens. Shortly after his birth the family moved to Paris, where he grew up with five brothers and one sister. French was his native tongue, but he learned Russian and other languages in later years. From 1902 to 1905 Lefschetz studied at the École Centrale, Paris, graduating as *ingenieur des arts et manufactures*. In November 1905 he emigrated to the United States and found a job at the Baldwin Locomotive Works near Philadelphia. In early 1907 he joined the engineering staff of the Westinghouse Electric and Manufacturing Company in Pittsburgh. In November of that year he lost his hands and forearms in a tragic accident.

Lefschetz soon realized that his true bent was mathematics, not engineering. Among his professors at the École Centrale had been Émile Picard and Paul Appell, authors of famous treatises on analysis and analytic mechanics that he now read. In 1910, while teaching apprentices at Westinghouse, Lefschetz determined to make his career in mathematics. He enrolled as a graduate student at Clark University, Worcester, Massachusetts, and obtained the Ph.D. in just one year with a dissertation on a problem in algebraic geometry proposed by W. E. Story. On 17 June 1912 Lefschetz became an American citizen, and on 3 July 1913 he married Alice Berg Hayes, a fellow student at Clark who had received a master's degree in mathematics. She helped him to overcome his handicap, encouraging him in his work and moderating his combative ebullience. They had no children.

From 1911 to 1913 Lefschetz was an instructor at the University of Nebraska, Lincoln, where he taught a heavy load of beginning courses but found ample time to pursue his own work in algebraic geometry. In 1913 he moved to a slightly better position at the University of Kansas in Lawrence. As his work became known in America and Europe, he rose through the ranks to become full professor in 1923. In 1919 he was awarded the Prix Bordin by the Académie des Sciences of Paris and in 1923 the Bôcher Memorial Prize of the American Mathematical Society.

In 1924 Lefschetz accepted a post at Princeton University, where he spent the rest of his life. He had prized the opportunity for solitary research at Nebraska and Kansas, but he welcomed the new world that opened up to him at Princeton. He acquired distinguished geometers as colleagues—James W. Alexander, Luther P. Eisenhart, Oswald Veblen—and met stimulating visitors from abroad, such as Pavel Aleksandrov, Heinz Hopf, M. H. A. Newman, and Hermann Weyl. His first (1926) of some thirty doctoral students was the topologist-to-be Paul A. Smith, who had followed him to Princeton from Kansas.

From his Ph.D. to his appointment to the faculty of Princeton, Lefschetz worked mainly in algebraic geometry, his most important results being presented in his 1921 paper "On Certain Numerical Invariants of Algebraic Varieties with Application to Abelian Varieties" and in his 1924 monograph *L'analysis situs et la géométrie algébrique*. The study of the properties of families of algebraic curves and surfaces began in the nineteenth century as part of the theory of algebraic functions of complex variables. For Lefschetz, too, curves and surfaces—and, more generally, algebraic varieties—were significant representations of the corresponding functions. He was able to solve some of the problems encountered by his predecessors and to enlarge the scope of the subject by the use of new methods. As he put it, "It was my lot to plant the harpoon of algebraic topology into the body of the whale of algebraic geometry."

In the 1850's G. F. B. Riemann founded the modern theory of complex algebraic curves by considering, for each curve, an associated surface now called the Riemann surface. The theory was further developed by Guido Castelnuovo, Federigo Enriques, Francesco Severi, and especially Émile Picard. (Lefschetz, while at the École Central, had taken Picard's demanding course.) Riemann and these later mathematicians recognized that it is the topological properties of the Riemann surface (the connectedness properties of the surface as a whole rather than its metrical and local properties) that are significant, yet at the time there was no theory of such properties. In the 1890's Henri Poincaré established such a theory (under the name "analysis situs"), and Lefschetz used Poincaré's results to extend the work of Riemann and his successors.

Riemann had used a series of cuts to turn the

Riemann surface into an open 2-cell (and the correspondence between the function and the 2-cell then gave the desired results); Lefschetz used a series of cuts to turn a nonsingular algebraic variety of complex dimension d into an open $2d$-cell. This allowed him to answer many questions (for example, he showed that not all orientable manifolds of even dimension are the carrier manifolds of algebraic varieties) and to extend the theory of integrals of the second kind to double and triple integrals on an algebraic variety of any dimension.

Lefschetz took up Poincaré's study of curves on a surface, which he generalized to the study of subvarieties of an algebraic variety. He found necessary and sufficient conditions for an integral $(2d-2)$-dimensional homology class of variety V of complex dimension d to contain the cycle of a divisor on V. This result and others allowed Lefschetz to make important contributions to the theory of correspondences between curves and to the theory of Abelian varieties. (A much more detailed review by W. V. D. Hodge of Lefschetz's work and influence in algebraic geometry appears in the volume *Algebraic Geometry and Topology.)*

According to Hodge, "Our greatest debt to Lefschetz lies in the fact that he showed us that a study of topology was essential for all algebraic geometers." Lefschetz' work in algebraic geometry also gave great impetus to the study of topology, since its value to other areas of mathematics had been demonstrated. In 1923 Lefschetz turned to the development of Poincaré's topology, calling it algebraic topology to distinguish it from the abstract topology of sets of points.

Almost all of Lefschetz' topology resulted from his desire to prove certain fixed-point theorems. Around 1910 L. E. J. Brouwer proved a basic fixed-point theorem: Every continuous transformation of an n-simplex into itself has at least one fixed point. In a series of papers Lefschetz obtained a much more general result: For any continuous transformation f of a topological space X into itself, there is a number $L(f)$, often called the Lefschetz number, such that if $L(f) \neq 0$, then the transformation f has a fixed point. $L(f)$ is defined as follows: f induces a transformation f_p of the pth homology group H_p of the space X into itself; consider H_p as a vector space over the rational numbers and let $\mathrm{Tr}(f_p)$ be the trace of f_p; then $L(f) = \Sigma\,(-1)^p\,\mathrm{Tr}(f_p)$. For $L(f)$ to be well defined, certain restrictions must be placed on X; Lefschetz succeeded in progressively weakening these restrictions.

Lefschetz used the following simple example to explain his fixed-point theorem. Let f be a continuous transformation of the interval $0 \leq x \leq 1$ into itself. The curve consisting of the points $(x,f(x))$ represents f. (See Figure 1.) The diagonal $0 \leq x = y \leq 1$ represents the identity transformation i, that is, the transformation that sends each point of the interval to itself. The points of intersection (called the coincidences) of f and i are the fixed points of f. We want a number that is the same for all continuous transformations of the interval $0 \leq x \leq 1$. The number of coincidences is not constant; f and g, for example, differ in this respect. But if, for a particular transformation, we count the number of crossings from *above* to below (marked a in the figure) and the number of crossings from *below* to above (marked b in the figure), and if we subtract the latter from the former, we get a number (here, 1) that is the same for all continuous transformations of an interval into itself. That is, for this space (the interval $0 \leq x \leq 1$), the Lefschetz number $L(f)$ is 1. Since $L(f)$ is not zero, any continuous transformation of $0 \leq x \leq 1$ into itself has a fixed point. (It is intuitively clear that any continuous curve passing from the left side of the square to the right side must intersect the diagonal.)

In 1923 Lefschetz proved this fixed-point theorem for compact orientable manifolds. Since an n-cell is not a manifold, this result did not include the Brouwer fixed-point theorem. By introducing the concept of relative homology groups, Lefschetz in 1927 extended his theorem to manifolds with boundary; his theorem then included Brouwer's. He continued to seek generalizations of the theorem; in 1927 he proved it for any finite complex, and in 1936 for any locally connected space. Lefschetz studied fixed points as part of a more general study of coincidences. If f and g are transformations of space X into space Y, the points x of X such that $f(x) = g(x)$ are called the coincidences of f and g. One can prove that under certain conditions two transformations must have coincidences—for example, in Figure 1, if f and g are continuous and f is above g at 0 and below g at 1, then the number of times f crosses g from above to below (marked α) minus the number of times f crosses g from below to above (marked β) is necessarily 1.

In the course of this work Lefschetz invented many of the basic tools of algebraic topology. He made extensive use of product spaces; he developed intersection theory, including the theory of the intersection ring of a manifold; and he made essential contributions to various kinds of homology theory, notably relative homology, singular homology, and cohomology.

A by-product of Lefschetz' work on fixed points

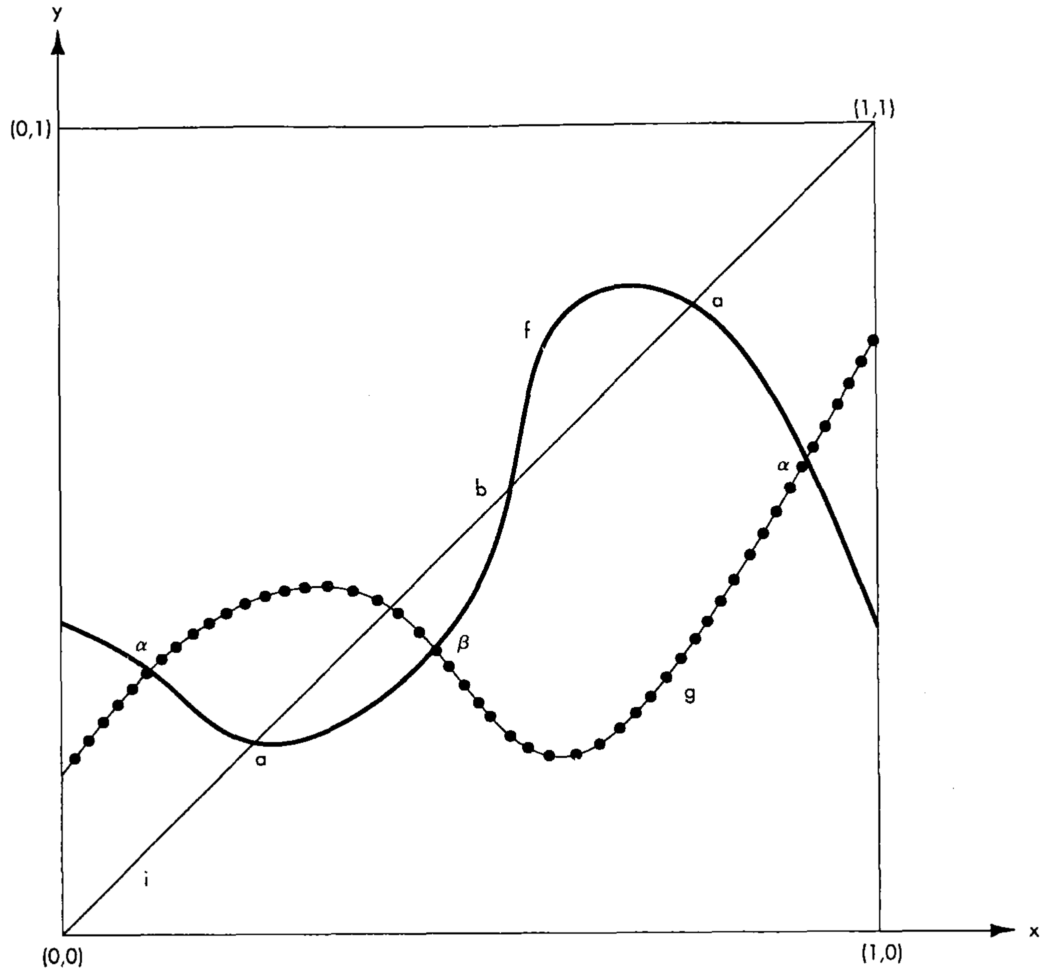

FIGURE 1.

was his duality theorem, which provided a bridge between the classical duality theorems of Poincaré and of Alexander. The Lefschetz duality theorem states that the p-dimensional Betti number of an orientable n-dimensional manifold M with regular boundary L equals the $(n-p)$-dimensional Betti number of M modulo L (that is, without L). Figure 2 shows an oriented 2-manifold M with regular boundary L in three parts, one exterior and two interior. The absolute 1-cycles c_1 and c_2 generate the 1-dimensional Betti group of M with boundary L, and the relative 1-cycles d_1 and d_2 generate the relative 1-dimensional Betti group of M modulo L. Thus the 1-dimensional Betti numbers of M and M modulo L are both 2. Cuts along d_1 and d_2 turn the 2-manifold into a 2-cell. (A full exposition of Lefschetz' fixed-point theorem and his duality theorem is in his *Introduction to Topology*, 1949.)

During his years as professor at Princeton (1924–1953), Lefschetz was the center of an active group of topologists. His *Topology* (1930) and his *Algebraic Topology* (1942) presented comprehensive accounts of the field and were extremely influential. Indeed, these books firmly established the use of the terms "topology" (rather than "analysis situs") and "algebraic topology" (rather than "combinatorial topology"). (A thorough review by Norman Steenrod of Lefschetz' work and influence in algebraic topology appears in *Algebraic Geometry and Topology*, 1957.)

Lefschetz was an editor of *Annals of Mathematics* from 1928 to 1958, and it was primarily his efforts—insisting on the highest standards, soliciting manuscripts, and securing rapid publication of the most important papers—that made the *Annals* one of the world's foremost mathematical journals. As Steenrod put it, "The importance to American mathematicians of a first-class journal is that it sets high standards for them to aim at. In this somewhat indirect manner, Lefschetz profoundly affected the development of mathematics in the United States."

There was another way in which Lefschetz contributed to the beginning of the publication of advanced mathematics in the United States. As late as the 1930's the American Mathematical Society, whose Colloquium Publications included books by

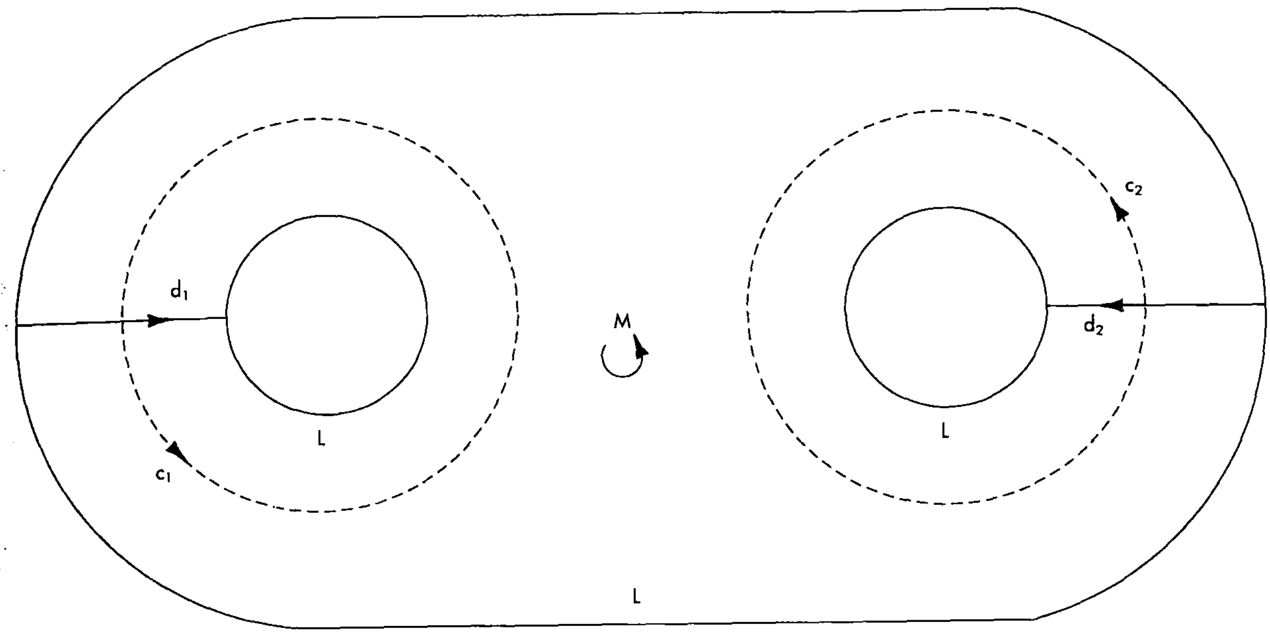

FIGURE 2.

Lefschetz in 1930 and 1942, was almost the only U.S. publisher of advanced mathematics books. However, two important series of advanced mathematics monographs and textbooks began in 1938 and 1940: the Princeton Mathematical Series and the Annals of Mathematics Studies, both initiated by A. W. Tucker, student and colleague of Lefschetz. Lefschetz wrote two important books for the former series (1949, 1953) and wrote or edited six books for the latter.

In 1943 Lefschetz was asked to consult for the U.S. Navy at the David Taylor Model Basin near Washington, D.C. Working with Nicholas Minorsky, he studied guidance systems and the stability of ships, and became acquainted with the work of Soviet mathematicians on nonlinear mechanics and control theory. Lefschetz recognized that the geometric theory of differential equations, which had begun with the work of Poincaré and A. M. Liapunov, could be fruitfully applied, and his background in algebraic geometry and topology proved useful. From 1943 to the end of his life, Lefschetz gave most of his attention to differential equations, doing research and encouraging others.

Lefschetz was almost sixty years old when he turned to differential equations, yet he did important original work. He studied the solutions of analytic differential equations near singular points and gave a complete characterization, for a two-dimensional system, of the solution curves passing through an isolated critical point in the neighborhood of the critical point. Much of his work focused on nonlinear differential equations and on dissipative (as distinct from conservative) dynamic systems. This work contributed to the theory of nonlinear controls and to the study of structural stability of systems. The Russian topologist L. S. Pontriagin, who was a good friend of Lefschetz' both before and after the war, also turned to control theory as a result of his wartime work. (Lawrence Markus' "Solomon Lefschetz: An Appreciation in Memoriam" contains a more detailed account of Lefschetz' work and influence on differential equations.)

In 1946 the newly established Office of Naval Research provided the funding for a differential equations project, directed by Lefschetz, at Princeton. This soon became a leading center for the study of ordinary differential equations, and the project continued at Princeton for five years after Lefschetz' retirement in 1953. In 1957 he established a mathematics center under the auspices of the Research Institute for Advanced Study (RIAS), a branch of the Glen L. Martin Company of Baltimore (now Martin-Marietta). In 1964 Lefschetz and many of the other mathematicians in his group at RIAS moved to Brown University to form the Center for Dynamical Systems (later named the Lefschetz Center for Dynamical Systems). J. P. LaSalle, who had spent the year 1946–1947 with the differential equations project at Princeton and who was Lefschetz' second in command at RIAS, became director at the Brown center. Lefschetz helped to found the *Journal of Differential Equations* and served as an editor for some fifteen years. He continued his work at Brown until 1970.

Lefschetz translated two Russian books on differential equations into English, and he edited several volumes on nonlinear oscillations. He gave constant encouragement to his younger colleagues, in some cases cajoling them into proving important theorems. His work in differential equations showed the usefulness of geometric and topological methods and helped to raise the intellectual stature of applied mathematics.

Throughout his life Lefschetz loved to travel. In the 1920's and 1930's he made many trips to Europe, especially to France, Italy, and the Soviet Union. During World War II, European travel was impractical, so Lefschetz was visiting professor at the National University of Mexico (1944). Although he did not know Spanish when he arrived there, several weeks later he was giving his lectures in that language. He returned for several months in the academic year 1945–1946, and in the following two decades made many trips to Mexico City, spending most winters there from 1953 to 1966. He helped to build a lively school of mathematics at the National University of Mexico, and in recognition of his efforts the Mexican government in 1964 awarded him the Order of the Aztec Eagle, rarely presented to a foreigner.

Lefschetz was Henry Burchard Fine (research) professor of mathematics at Princeton (1933–1953), succeeding Oswald Veblen, the first holder of the chair (1926–1932). He was chairman of the department of mathematics at Princeton from 1945 until his retirement in 1953. Lefschetz served as president of the American Mathematical Society (1935–1936). The Accademia Nazionale dei Lincei of Rome awarded him the Antonio Feltrinelli International Prize, one of the world's highest mathematical honors, in 1956. In 1964 he was awarded the National Medal of Science by President Johnson "for indomitable leadership in developing mathematics and training mathematicians, for fundamental publications in algebraic geometry and topology, and for stimulating needed research in nonlinear control processes." He was granted honorary degrees by Paris, Prague, Mexico, Clark, Brown, and Princeton. He was a member of the American Philosophical Society and of the National Academy of Sciences, and a foreign member of the Royal Society of London, of the Académie des Sciences of Paris, of the Academia Real de Ciencias of Madrid, and of the Reale Instituto Lombardo of Milan.

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ALBERT W. TUCKER
FREDERIK NEBEKER

LEHMAN, JEAN-PIERRE (*b*. Caen, France, 10 August 1914; *d*. Paris, France, 26 February 1981), *vertebrate paleontology*.

Jean-Pierre was the second child of Madeleine Auvray and Gaston Lehman, a civil engineer descended from old Parisian stock. He studied at the Lycée Carnot, and later at the Sorbonne, then the seat of the Faculty of Sciences, escaping for only a year to Grenoble, where chemistry instruction (then required for a *licence* in natural sciences) was of a higher standard. In Grenoble he met Ingegärd Eneström, a Swedish doctor's daughter, who was finishing her higher education in French. They married and lived in Paris most of their lives, with an annual trip to Sweden; they had one son and two daughters. Although educated as a Catholic, Lehman professed a serene atheism. He was an officer of the Légion d'honneur and of the Palmes académiques and was elected in 1979 to the Académie des sciences.

Lehman taught at the Lycée de Nice from 1940 to 1945, then at the Laboratoire de géologie de la faculté des sciences de Paris from 1950 to 1955, and finally at the École normale supérieure de Saint-Cloud and the Muséum national d'histoire naturelle, as the holder of the chair in paleontology, from 1956 to 1981. He attracted a large number of students and founded a school of paleoanatomy that soon became officially recognized as the Institut de paléontologie, now one of the world's most important centers of paleontology. He also organized international colloquia (1961, 1966, 1973), gave conferences in many foreign countries, and served as secretary, then vice president, of the Société géologique de France. His tireless efforts in promoting the cause of paleontology led him to become editor of the journal *Les annales de paléontologie*, then to found the *Cahiers de paléontologie*, where several of his disciples have published anatomical monographs. He was also a member of the scientific committee of the Fondation Singer Polignac, which published, thanks to his influence, several paleontological works.

Lehman contributed to the *Traité de zoologie* of P. P. Grassé (vol. XIII, fasc. 3) and the *Traité de paléontologie* of Jean Piveteau (vols. III, IV, and V). He translated many paleontological works from Swedish, German, and English. Not content to publish in his specialized field of research alone, he addressed the major problems of paleontology and evolution in four thoughtful books and many papers. Finally, he oversaw the renovation of the Galerie de paléontologie, established the Galerie de paléobotanique, and organized public paleontological exhibitions in the Parc de Vincennes and in the museum.

The driving power behind all these activities was Lehman's tenacity and enthusiasm for research. His *Diplôme d'études supérieures* (1937), a prelude to the *Agrégation* degree (1939), influenced his whole career: it concerned the fishes of the Upper Devonian of Scania and was prepared at the Museum of Natural History of Stockholm. He later dedicated all his scientific activity to the study of lower vertebrates and to work directly or indirectly carried out with the Swedish team; Erik A. Stensiö had made Stockholm the heart of such research. Lehman began with a study of Agnatha (jawless vertebrates), and the knowledge he acquired on this group allowed him later to discuss the problem of the origin of vertebrates. But very rapidly the fish of North Africa and Madagascar became a main focus of his research, with the material coming essentially from his own excavations (in 1950, 1952, 1954, 1961, 1964, 1966, 1969, 1974, and 1979). His 1969 expedition to Spitzbergen, for which he obtained much financial and material support, produced twenty-three tons of fossils that are still under study. The Arthrodires from the Upper Devonian of Morocco were known previously only by isolated plates. Lehman's new material brought not only the knowledge of new taxa of giant size, but also that of the endocranium, the thoracic shield, and the head-thorax link.

On the other hand, the presence in Africa of species of an otherwise American genus allowed him to draw paleogeographic conclusions. The Actinopterygians from Madagascar (Paleonisciformes, Parasemionotiformes) were the subject of his doctoral thesis. Before his studies, reconstructions of the endocranium were rare; he made some with such great precision that they are now "better known than those of many genera of extant Teleostomes." He also followed the evolution of the dermal cephalic skeleton, showing that bone fusions or dissociations are frequent in Actinopterygians. He confirmed moreover the morphogenetic role of the pit lines and established the precocity of bone regression in these fishes. Finally he showed that the Actinopterygian *Cheirolepis* was not an intermediate form between Crossopterygians and Actinopterygians and that "Chondrichthyens" and "Holosteens" were not valid systematic units. Lehman was still studying Actinopterygian fishes when he died.

For the Crossopterygians and Dipnoans, Lehman used the same methodology: the search for fossils, careful anatomical study, establishment of bone homologies (for example, between the squamosal of Crossopterygians and the propercular of Actinopterygians), and phyletic considerations (for example, the heterogeneity of the Crossopterygians, the origin of Urodeles).

The Triassic stegocephalians constitute the second center of his research. Those from Madagascar had rarely been studied. After finding well-preserved skulls of néorachitomes, bentosuchids, rhinosuchoids, and Trematosauria, he described them, followed growth series, and recognized new taxa, including the most ancient members of the Brachypodoids. The presence of freshwater Bentosuchids in marine formations led him to reconstruct local paleoecology and to recognize continental relations between Madagascar and the Northern Hemisphere in the Eotriassic, as well as a separation between Madagascar and Africa as early as that epoch. Concerning the Moroccan stegocephalians, they were virtually unknown until the work of Lehman. They appear to be quite varied, but their study mainly demonstrated the insufficient systematic value of the vertebral criterion in Stegocephalia; the existence of two separate lineages, batracomorphs and reptiliomorphs; the evolution of the otic notch in this group; and the state of specialization of Embolomers. It also clarified the composition of the Ichthyostegalia.

These numerous and various analyses were underlined by Lehman's constant preoccupation "to consider each fossil as a vestige of a once living animal" and "to revive these ancient groups whose comparison with extant forms gives less evident results than do Tertiary vertebrates." Lehman was one of the first paleontologists to examine lower vertebrates from a functional as well as an anatomical point of view, relying heavily on comparative anatomy.

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D. Sigogneau-Russell

LEIPUNSKII, ALEKSANDR IL'ICH (*b.* Dragli, Grodnenskaia guberniia, Russia [now Poland], 7 December 1903; *d.* Obninsk, Kaluzhskaia oblast, U.S.S.R., 14 August 1972), *physics*.

Leipunskii's father, Il'ia Isaakovich Leipunskii, was a construction and road technician; his mother, Sophia Naumovna, was a housewife.

Leipunskii started working in 1918; before he entered the Petrograd Polytechnical Institute (1921) he had served as an unskilled laborer and as a foreman's assistant at a chemical factory in Rybinsk (now Andropov). He graduated from the Faculty of Physics and Mechanics at the Petrograd Polytechnical Institute (PTI) in 1926. When he was still a student, he started work at the PTI in the laboratory of N. N. Semenov (1924–1928). After a year of preparation, Leipunskii moved to the Ukrainian PTI in Kharkov, where he worked from 1929 to 1941 (with two interruptions when he was at the Cavendish Laboratory, Cambridge [1934–1935], and in Leningrad as head of a department at the Radium Institute). At the Ukrainian PTI, Leipunskii advanced from senior physicist to director. From 1941 to 1952 he was head of the department of physics, deputy director, and director of the Institute of Physics of the Ukrainian Academy of Sciences (Kiev). In 1952 he moved to the Institute of Energy Physics in Obninsk and from 1959 to 1972 was its scientific head.

At the Leningrad PTI, Leipunskii was involved with chemical physics and electronic chemistry. The main results are concerned with the experimental investigation of nonelastic collisions when the excited atoms (molecules) transfer their energy to slow electrons by the radiation-free mechanism; this reaction is inverse to that of excitation of atoms by electrons due to elastic collisions. With G. D. Latishev, Leipunskii conducted a classical experiment that demonstrated the existence of such processes for excited atoms of mercury. He also investigated dissociation and recombination of halogen molecules and the formation of the negative ions.

After moving to Kharkov, Leipunskii shifted his attention to nuclear physics and worked on the design of linear (and in the late 1930's cyclic) accelerators. With his colleagues he carried out an experiment on splitting the nuclei of lithium by artificially accelerated protons (this experiment, the first of its kind in the Soviet Union, was a modification of a classical experiment by J. D. Cockroft and E. T. S. Walton). In a series of experiments on absorption of neutrons within a wide temperature range (20–463 K), Leipunskii was the first to discover the resonance effects on light nuclei during neutron scattering.

While at the Cavendish Laboratory in Cambridge (1934–1935), directed by Rutherford, Leipunskii carried out important research on β-decay and on the physics of the neutrino. He developed the experimental technique for demonstrating the existence of the neutrino that was based on the investigation of energy distribution of recoil nuclei of the C 11 isotope released in the course of β-decay associated with the "flight" of a neutrino. This experiment (realized in part) may be thought of as a prototype of the research carried out in 1938 at A. I. Alikhanov's laboratory at the Leningrad PTI and of the decisive result achieved by James Allen in 1942 in his investigation of an energy spectrum of recoil nuclei arising from the decay of Be 7.

Leipunskii devoted the last twenty-five years of his life to the development of reactor engineering. In 1947, during his study of nuclear processes involving fast neutrons, Leipunskii developed the idea of breeding the nuclear fuel in fast-neutron reactors following the formation of plutonium from U 238. In 1949 he started working on the practical realization of this idea. At the Institute of Energy Physics in Obninsk, he developed the procedure of designing breeder fast-neutron reactors, having solved many problems associated not only with the nuclear processes but also with some purely engineering problems, particularly the choice of a heat-transfer fluid, for which he suggested using liquid metals (sodium).

As a result of these efforts, the first fast-neutron reactor in the Soviet Union started operating in 1955. By the end of the 1950's, the possibility of breeding the nuclear fuel and the reliability of the reactors' design had been demonstrated by experiments on their laboratory prototypes, built by Leipunskii's group. In 1959 the 5,000-kw fast-neutron reactor went into operation, and work had started on design and construction of an industrial power station with fast-neutron reactors, its electrical power being equal to 350,000 kw. The station and reactor, located at Shevchenko, on the coast of the Caspian Sea, would solve three problems at once: production of nuclear fuel, production of electric energy, and distillation of water (the last saving power). The importance of this plant increased with time because the fast-neutron breeders solved the problem of supply of a nuclear fuel.

Leipunskii's achievements are not limited to those already mentioned. He was chief editor of the journal *Physikalische Zeitschrift der Sowjetunion,* which was published in the Soviet Union from 1932 to 1937 and received international recognition. He also was among the founders of the Moscow Institute of Engineering Physics, where he taught and served as head of a department.

In 1924 Leipunskii was elected a full member of the Ukrainian Academy of Sciences. In 1960 he and his colleagues O. D. Kasachkovskii, I. I. Bondarenko, and L. N. Usachev were awarded the Lenin Prize for their work on fast-neutron reactor physics. In 1963 Leipunskii was awarded the title of Hero of Socialist Labor.

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V. J. FRENKEL

LEMAÎTRE, GEORGES (*b.* Charleroi, Belgium, 17 July 1894; *d.* Louvain, Belgium, 20 June 1966), *astrophysics, cosmology.*

Georges Lemaître was the oldest son of Joseph Lemaître, a factory owner, and Marguerite Lannoy, the daughter of a brewer. His parents were devout Catholics and in 1904 sent him to a Jesuit school in Louvain, where he received education in religion, humanities, and classical languages. Attracted by the exact sciences, he enrolled at the Catholic University of Louvain in 1911, where he studied engineering. Lemaître served as a soldier in the Belgian army during World War I and received several military honors. After the war he returned to the University of Louvain, where he changed from engineering to mathematics and physics. He received his doctorate in 1920. In 1927 he was appointed professor at the university, a position he kept until his retirement in 1964.

Parallel with his scientific career, Lemaître had an ecclestiastical career in the Catholic church. After theological studies he was ordained as an abbé in 1923 and later he obtained the rank of monseigneur. From 1960 until his death he served as president of the Pontifical Academy of Sciences in Rome. Lemaître published several theological works. He believed that religion and science should not be mixed, although they would ultimately lead to the same truth. Lemaître believed that God would hide nothing from the human mind, not even the physical nature of the very early universe. This epistemic optimism, derived from his Christian belief, may have helped him in formulating the first scientific creation cosmology.

Lemaître's scientific career began in 1923, when he received a traveling fellowship. He went to Cambridge and studied under Eddington, under whose influence he specialized in the theory of general relativity. In 1924 and 1925 he continued his postgraduate studies in the United States, at Harvard and MIT. During his stay in the United States, he attended the American Astronomical Society conference in Washington, at which Hubble's discovery of the Cepheid variables in the Andromeda nebula was announced. He became increasingly occupied with cosmology and, while at MIT in 1925, suggested a modification of de Sitter's cosmological theory. Lemaître's model was nonstatic and included a red shift caused by the Doppler effect. After his return to Louvain, he developed his theory further, and in 1927 he published a new cosmological theory that combined the advantages of the earlier theories of Einstein and de Sitter. Lemaître showed that the field equations of general relativity allowed an expanding universe and derived a velocity-distance relation. Although Lemaître's universe was expanding, in 1927 Lemaître's theory did not involve a creation or a definite age. The basic equation of Lemaître's theory was nearly the same as the one found by Alexander A. Friedmann in 1922, but Lemaître had been unaware of Friedmann's work.

Lemaître's paper went unnoticed until 1930, when he called Eddington's attention to it. Eddington strongly endorsed Lemaître's work and had it translated into English. In 1931 Lemaître moved from obscurity to fame. He suggested that the world might have originated from just one quantum of enormous energy and later the same year he developed this scenario into the hypothesis of the primeval atom. According to Lemaître's "fireworks theory of evolution" the world started as a super-radioactive disintegration of the primeval atom. During the 1930's he published several expositions of this idea, the first example of a big bang cosmology. He believed that it could be put to observational tests and that the cosmic rays were remnants of the original super-radioactive disintegration.

In order to decide whether the cosmic radiation is of cosmogonic origin, Lemaître engaged in the 1930's in an extensive examination of the orbits of charged particles in the geomagnetic field. This work, done in collaboration with Manuel Sandoval Vallarta, was seriously criticized by Fredrik Störmer, the dean of the field. The idea of the primeval atom also had consequences regarding the formation of galaxies and clusters of galaxies. Lemaître studied these consequences in several papers and believed that they were supported by astronomical observations.

Lemaître's work was primarily in cosmology and astrophysics, but he also worked in other fields. He was an able mathematician who liked to deal with classical mathematical problems such as the three-body problem, and he was very interested in the computational problems of astronomy.

Lemaître favored a simple and direct approach to the study of the universe and emphasized physical ideas rather than mathematics. He did not believe that cosmology could be made a deductive science and disliked tendencies of mysticism or apriorism. During the 1930's Eddington, Edward Milne, and others developed cosmological theories which were based upon a priori principles and rational thought. Lemaître was opposed to these rationalist cosmologies and also to the later steady state theory, which he criticized for being founded on philosophical rather than scientific reasoning.

Lemaître received many awards and honors. In 1934 he received the Osborne Mendel Medal (U.S.A.) and the Prix Franqui (Belgium) and in 1953 the first Eddington Medal (England).

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HELGE KRAGH

LEVERETT, FRANK (*b.* Denmark, Iowa, 10 March 1859; *d.* Ann Arbor, Michigan, 15 November 1943), *glacial geology*.

Leverett was the eldest child of Ebenezer Turner Leverett and Rowena Houston Leverett, descendants of English emigrants who settled in the Massachusetts Bay Colony in the mid seventeenth century. He was educated in Denmark, Iowa, first in the public schools and later at the Denmark Academy. Upon completion of these studies in 1878, at age nineteen, he took a teaching position in the public schools in Denmark. From 1880 to 1883 he served as instructor in natural sciences at the Denmark Academy. This appointment proved to be a turning point in Leverett's career, for during these years he became interested in geology, frequently leading his students to fossiliferous localities in nearby Pennsylvanian strata. During this time he also fulfilled college language requirements in Latin and Greek that would permit him to continue his education.

Though he never again engaged in full-time teaching, Leverett maintained close ties with the academic community through his position as staff lecturer at the University of Michigan. He spent the academic year 1883–1884 at Colorado College, Colorado

Springs, where he further developed his interest in geology, particularly mineralogy. In September 1884 he entered Iowa State College of Agriculture and Mechanic Arts at Ames and received the B.S. in 1885. During this relatively brief stay at Iowa State the pattern of his professional career began to unfold. He wrote, for example, a senior thesis on an artesian well near Des Moines; and his first scientific paper, "Drainage Changes in Eastern Iowa," was published in 1885 in *Aurora*, the college monthly. Water wells and drainage changes induced by continental glaciation were subjects that held his interest throughout his professional career.

On 22 December 1887 Leverett married Frances E. Gibson, who died in 1892. He married Dorothy Christina Park on 18 December 1895. There were no children from either marriage.

Leverett was elected to the American Philosophical Society in 1924 and to the National Academy of Sciences in 1939. He was a fellow of the Geological Society of America and the American Association for the Advancement of Science, serving as vice president of the latter in 1928. He was president of the Michigan Academy of Science, Arts, and Letters in 1910. Leverett was a member of the academies of science of Iowa, Wisconsin, and Washington, D.C., and the Geological Society of Washington; a corresponding member of the National Geographic Society; and a member of the American Geophysical Union, Phi Kappa Phi, and Sigma Xi. He was awarded an honorary D.Sc. by the University of Michigan in 1930.

Leverett's professional career began in 1886, when he was hired as a field assistant by Thomas C. Chamberlin, who was in charge of the Division of Glacial Geology of the U.S. Geological Survey. Leverett remained a field assistant until 1890, at which time he was appointed an assistant geologist with the survey. In 1901 he advanced to geologist, and in 1928 to senior geologist, the position he held at the time of his retirement in 1929. From 1909 until 1929 he was staff lecturer in glacial geology at the University of Michigan.

Leverett was first and foremost a field geologist. Although he traveled extensively in Canada and Europe as well as in the United States, his published work deals almost exclusively with the glacial geology of the north-central United States. Working at a time and in areas where few topographic base maps existed, Leverett mapped glacial deposits and landforms with a precision and attention to detail previously unknown. Most of his fieldwork was done on foot and alone. He estimated that in the course of his work he had walked the equivalent of four times around the globe. His detailed mapping extends from the eastern Dakotas to Pennsylvania and is meticulously documented in more than 300 field notebooks on file with the U.S. Geological Survey. It has been estimated that these contain more than 45,000 pages of notes.

Leverett described his field technique in some detail, stating, according to Rieck and Winters (1981), that an "effective field party" should include people who, collectively, possess the following skills: the ability to recognize, map, photograph, and sketch all classes of glacial features; sufficient familiarity with the region to "work out the directions of ice movement and to discriminate superposed drift sheets of different constitution and age"; the ability to survey and make topographic maps; and familiarity "with plant communities and their relations to various soils," including buried soils. Leverett thought that a party of four was necessary to encompass all these specialties. That he worked alone is an indication of the breadth of his knowledge and understanding.

Leverett's published work is monumental; at the time of his death he ranked first among the members of the U.S. Geological Survey in terms of the number of reports published—some 170 titles. Though, by virtue of his training and temperament, he was ideally suited to engage in the detailed but broad-ranging studies that these reports represent, the early influence of Chamberlin is nevertheless clearly evident. In 1884 Chamberlin had published his report on the terminal moraine of the second glacial epoch and recognized the overall continuity of these deposits from the Dakotas to the Atlantic. This work provided a broad outline; Leverett contributed detailed descriptions and interpretations, tasks for which Chamberlin offered encouragement and counsel, but that he had neither the time nor the inclination to undertake himself. Leverett's work documented multiple glaciation, implying climatic change. Aside from his detailed maps, Leverett's greatest contribution to glacial geology was the historical framework and the evidence of multiple glaciation that emerged from his work.

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RICHARD C. ANDERSON

LEVINSON, NORMAN (*b.* Boston, Massachusetts, 11 August 1912; *d.* Boston, 10 October 1975), *mathematics.*

Levinson entered the Massachusetts Institute of Technology in 1929, having graduated from Revere High School earlier that year. In June 1934 he received the B.S. and M.S. degrees in electrical engineering. At that time he had completed practically every graduate course offered by the department of mathematics and had obtained results that H. B. Phillips, head of the department, described as "sufficient for a doctor's thesis of unusual excellence." Among these courses was Fourier series and integrals, given in the fall of 1933–1934 by Norbert Wiener. Wiener had given Levinson a copy of the unpublished manuscript "Fourier Transforms in the Complex Domain," by R. E. A. C. Paley and Wiener, for revision. When Levinson found a gap in a proof and was able to prove a lemma that corrected it, Wiener typed the proof, affixed Levinson's name to the paper, and submitted it to a journal for him.

This incident began a friendship that lasted the rest of their lives. Wiener and Phillips arranged an MIT Redfield traveling fellowship for Levinson for the year 1934–1935, which Levinson spent at Cambridge University, where he studied under the distinguished mathematical analyst G. H. Hardy. In June 1935 he received the doctorate in mathematics from MIT. Levinson was then awarded a National Research Council fellowship for the years 1935–1937, which he spent at the Institute for Advanced Study and Princeton University under the supervision of John von Neumann. Upon being offered an instructorship in mathematics at MIT, Levinson was released from his fellowship, went to MIT in February 1937, and remained there for the rest of his life, except for periods on leave. In February 1938 he married Zipporah Wallman.

Levinson's early work centers on results related to the Paley-Wiener book (published in 1934). Levinson sharpened many results and obtained significant new ones. In 1940 the American Mathematical Society published his work in this area as *Gap and Density Theorems*. After its appearance Levinson decided to shift his field to nonlinear differential equations. He soon obtained substantial mathematical results, and his outstanding contributions to differential equations were recognized by the American Mathematical Society in 1954 when it awarded him the Bôcher Prize. In addition, Levinson's work touched many areas of mathematical analysis and its applications. In the period 1946–1947 he wrote two papers that simplified and explained Wiener's work on stationary time series, which had a significant impact on random signal theory in general and on geophysical signal processing in particular. His work contributed to some of the improved petroleum prospecting methods that made possible the discovery of virtually all the offshore oil fields found since 1960, as well as most of the onshore discoveries.

Levinson did work in probability, quantum mechanics, complex programming, and analytic number theory. In 1967 he became the fortieth mathematician to be elected to the National Academy of Sciences, and in 1971 he was appointed Institute professor at MIT. Also in 1971 he was awarded the Chauvenet Prize of the Mathematical Association of America. The paper for which he received this prize was in analytical number theory and served as a precursor to the papers he wrote on the Riemann hypothesis. Levinson greatly advanced this theory and was on the threshold of perhaps his greatest achievement in mathematics at the time of his death.

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