Pontryagin, Lev Semionovich | Encyclopedia.com

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(*b*. Moscow, Russia, 3 September 1908; *d*. Moscow, Russia, 3 May 1988)

topology, algebra, theory of differential equations, game theory.

Pontryagin was born into an ordinary family; his father, Semen Akimovich Pontryagin, was a ledger clerk, his mother Tatyana Andreevna (maiden name Petrova) a dressmaker. Because his family's income was very small, he could not enter a gymnasium but only an ordinary municipal school. When he was fourteen years old, a stove explosion left him blind. His mother became his eyes and provided everything for his future education: She helped him to do lessons, read his books out loud (including the mathematical books in Russian and also in German), and later she inserted the formulas in his papers, which he typed himself. He had already become interested in mathematics at school, and in 1925 he entered the Mathematics and Physics Faculty of Moscow University. Among his professors were such scientists as Dmitri F. Egorov, Nikolai N. Luzin, Dmitri D. Men'shov, Aleksandr Y. Khinchin, and Pavel S. Aleksandrov. As early as his second year at the university Pontryagin began to participate in Aleksandrov's topological seminar, study combinatorial topology, and obtain his first important results on the Alexander duality theorem. He graduated from Moscow University in 1929 and was awarded a scholarship, with Aleksandrov acting as his supervisor. Beginning in 1930 he worked in Moscow University, becoming a professor there in 1935. In 1934 the Steklov Institute moved from Leningrad to Moscow, and soon Pontryagin was invited to work there; he became head of the Department of Topology and Geometry at the institute in 1935. He combined this work with his responsibilities as a professor of the Mechanics and Mathematics Faculty of the Moscow University.

Topology The first series of Pontryagin's topological works was completed by his demonstration of a duality law that connected the homology groups of bounded polyhedrons in Euclidean space and the homology groups of the complement of the space. Pontryagin's duality law was the beginning of a new direction in topological research—the theory of topological duality. Using it, Pontryagin elaborated the general theory of characters for commutative topological groups—the first distinguished achievement in topological algebra, a new branch of mathematics. Pontryagin went on to demonstrate that there are only three examples of locally compact connected division rings—the field of real numbers, the field of complex numbers, and the ring of quaternions. He found results that reveal the structure of compact and locally compact topological groups and resolved Hilbert's fifth problem for commutative locally bicompact groups in 1934. He published these findings in 1938 in his classic book, *Nepreryvnye gruppy*, which was immediately translated into English as *Topological Groups*.

In 1934 Elie Cartan proposed the problem of calculating the homology groups of the classical compact Lie groups in his lecture in Moscow University. Pontryagin played a very important role in solving this problem in 1935.

In the 1930s Pontryagin published work on the theory of dimension. He studied homotopy theory and the theory of fiber bundles. He introduced the notion of framed manifolds, which gave rise to the development of cobordism theory. He took the first steps in the theory of cohomology operations. His most famous achievement was the discovery of characteristic classes (Pontryagin characteristic classes). These studies prepared the way for the subsequent rise of algebraic topology.

Theory Oscillation; Theory of Automatic Control In the early 1930s Pontryagin became acquainted with the physicist Alexander A. Andronov. At this time Pontryagin was beginning his studies in the theory of oscillation and the theory of automatic control. The first results of these studies were the works of Pontryagin and Andronov on dynamical systems ("O statisticheskom rassmotrenii dinamicheskikh system, 1933) and on structurally stable systems ("Systèmes grossiers," 1937). In these works Pontryagin showed a lively interest in questions about natural science and technology and demonstrated how to derive very productive mathematical problems from them.

But the sharpest turn in the direction of his research occurred in 1952. In the autumn of that year he organized a seminar at the Steklov Institute on mathematical questions in the theories of oscillation and automatic control. He drew Vladimir G. Boltyanskii, Revaz V. Gamkrelidze, and Evgenii F. Mishchenko into his work in these areas, and they became his active collaborators. One of the main directions of the work of this seminar became the elaboration of the theory of equations with a small parameter in the higher derivatives. The numerically rich results they obtained allowed them to obtain new outcomes in different physical phenomena.

Theory of Optimal Processes Another direction of the seminar's activity was the theory of optimal control, which is the development of the classical calculus of variations. Results obtained by Pontryagin and his disciples Boltyanskii, Gamkrelidze, and Mishchenko, in this direction received recognition and found extensive technical applications. Pontryagin found a necessary optimality condition—the famous Pontryagin's maximum principle. He and his collaborators explored the existence

and uniqueness of the optimal control in the linear case, the sliding modes in the nonlinear case, and other situations. Their results made up the contents of their famous book, *Matematicheskaia teoriia optimalnykh protsessov*(1961; *The Mathematical Theory of Optimal Processes*, 1962), which was awarded the Lenin Prize in 1962. In the years following, Pontryagin actively developed the theory of differential games.

Pontryagin combined research activity and pedagogical work. In 1954 he began to lecture in the Mechanics and Mathematics Faculty of Moscow University on ordinary differential equations. A considerable proportion of these lectures was devoted to important technical applications: the Vyshnegradskii theory of the Watt regulator, the Andronov theory of the valve generator, and so on. These lectures formed the basis of his well-known textbook, *Obyknovennye differentcial'nye uravneniya* (1961; *Ordinary Differential Equations*, 1962). In 1975 he received the State Prize for this book. In his final years, Pontryagin taught in the Computer Science and Cybernetics Faculty of Moscow University (from 1970 as the head of the department of the optimal control). An excellent teacher, he trained an entire galaxy of pupils, among whom are such famous scientists as Vladimir A. Rokhlin, E. F. Mishchenko, Vladimir G. Boltyanskii, R. V. Gamkrelidze, Mikhail M. Postnikov, and Dmitrii V. Anosov.

Pontryagin combined his strenuous research and pedagogical work with intensive activity within Soviet and international mathematics institutions. He was on the boards of various mathematical journals at home and abroad. For example, from 1958 to 1975 he was a board member of the mathematical series of the *Izvestiya Akademii Nauk SSSR* (*Proceedings of the Academy of Sciences of the USSR*). From 1969 to 1983, Pontryagin was the vice president of the Bureau of the National Committee of Soviet Mathematicians. In 1970–1974 he was the vice president and in 1974–1978 a member of the executive committee of the International Mathematical Union. In 1975–1987 he was the editor-in-chief of the *Matematicheskii Sbornik* (*Sbornik: Mathematics*). From 1982 to 1988 he was the president of the Commission on Mathematical Education in the Schools of the Komissiya po Shkol'nomu Matematicheskomu Obrazovaniyu Otdeleniya Matematiki Akademii Nauk SSSR (Mathematical class of the Academy of Sciences of the USSR). In the 1980s, he actively participated in the successful campaign against the Soviet government's plan to redirect the northern European and Siberian rivers, which could have had dangerous ecological consequences as well as damaging the economy and culture of the country.

Overcoming Disability The most striking thing about all of Pontryagin's achievements is that they were done by a man who was blind. He had to make complicated calculations mentally and store enormous amounts of information in his memory. In addition to his work in mathematics, he participated in sports—in particular, skiing, which he did with the help of a person in front of him who made the ski track for those behind him to use. To some, Pontryagin resembled the heroes of the Renaissance. He liked Benvenuto Cellini's memoir, and in imitation of Cellini, Pontryagin wrote his own memoir, *Zhizneopisanie L'va Semionovicha Pontryagina, matematika, sostavlennoe im samim* (1998; Biography of Lev Semionovich Pontryagin, mathematician, composed by himself).

Honors and Awards Pontryagin's scientific achievements brought him recognition at home and abroad. He was elected a corresponding member of the Akademii Nauk SSSR (Academy of Sciences of the USSR) in 1939 and became a full member in 1958. He received many other Soviet honors for his activities, including Hero of Socialist Labor (1969), the Order of Lenin on three occasions (1967, 1969, 1978), the Order of the October Revolution (1975), and the Order of the Labor Red Banner (1945). He also received the Stalin Prize (1941), the Lenin Prize (1962), and State Prize of the USSR (1975). For his series of works on the differentiable manifolds, the Academy of Sciences of the USSR gave him the N. I. Lobachevskii Prize in 1966. He lectured in the United States (1964, 1972), Great Britain (1969), and France (1973). He never retired; up to his death he was the member of Steklov Institute and the director of his department in the university.

BIBLIOGRAPHY

Pontryagin's autobiography, Zhizneopisanie L'va Semionovicha Pontryagina, matematika, sostavlennoe im samim *(Moscow: IChP "Prima V," 1998), includes a bibliography of his works. The Archive of Russian Academy of Sciences has a significant quantity of unpublished documents related to Pontryagin.*

WORKS BY PONTRYAGIN

With Alexander Andronov and Alexander Vitt. "O statisticheskom rassmotrenii dinamicheskikh sistem." *Zhurnal eksperimental'noi i teoreticheskoi fiziki* 3, no. 3 (1933): 165–180.

"Systèmes grossiers." *Doklady Academii Nauk SSSR* 14, no. 5 (1937): 247–251.

Foundations of Combinatorial Topology. Translated by Frederick Bagemihl and Horace Komm. Rochester, NY: Graylock Press, 1952.

"Smooth Manifolds and Their Applications in Homotopy Theory." *American Mathematical Society Translations*, series 2, 11 (1959): 1–114.

Ordinary Differential Equations. Translated by Leonas Kacinskas and Walter B. Counts. Reading, MA: Addison-Wesley, 1962.

With Vladimir G. Boltyanskii, Revaz V. Gamkrelidze, and Evgenii F. Mishchenko. *The Mathematical Theory of Optimal Processes*. Translated by D. E. Brown. New York: Pergamon Press, 1964.

Topological Groups. 2nd ed. Translated by Arlen Brown. New York: Gordon and Breach, 1966.

Selected Works. Translated by P. S. V. Naidu. 4 vols. New York: Gordon and Breach, 1986.

Izbrannye nauchnye trudy. 3 vols. Moscow: Nauka, 1988. The Soviet edition of Pontryagin's *Selected Works*.

Zhizneopisanie L'va Semionovicha Pontryagina, matematika, sostavlennoe im samim. Moscow: IChP "Prima V," 1998. Pontryagin's memoir.

OTHER SOURCES

Aleksandrov, Pavel S., and Evgenii F. Mishchenko. "Lev Semionovich Pontryagin: K 50-letiyu so dnya rozhdeniya" (Lev Semionovich Pontryagin: For his 50th anniversary). *Uspekhi matematicheskikh* 14, no. 3 (1959): 195–199.

———, Vladimir G. Boltyanskii, Revaz V. Gamkrelidz, et al. "Lev Semionovich Pontryagin: K 60-letiyu so dnya rozhdeniya" (Lev Semionovich Pontryagin: For his 60th anniversary). *Uspekhi matematicheskikh nauk* 23, no. 6 (1968): 187–196.

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