a final classical theory yielding an adequate quantum theory be as different, conceptually, from present classical electron theories as Dirac's is?

In any event, one of the significant results of recent investigation in quantum field theory, and even in classical field theory, as just indicated, is the recognition of the complexity behind the ultimately simple. And so a new chapter in physics opens, with overtones suggesting that the simplicity of this fundamental intellectual discipline may reside principally in the aesthetic character of its mathematical elegance.


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# Ralph Stayner Lillie: 1875-1952


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THE SCIENTIFIC LIFE of Ralph Stayner Lillie neatly spanned the first half of this century, his first paper appearing in 1901 and his last, just fifty years (and some 125 publications) later. In this period he and a handful of other leaders effectively created the subdiscipline of general physiology. For Lillie had an integrating or generalizing mind; he had little concern for the particular—although his experiments revealed many important facts—and he probed unceasingly for the deeper import and broader impact of the phenomena that engaged his attention. Not the effect of some ion on some function, but the nature of ion action on the colloids and membranes of protoplasm interested him; not fertilization or contraction or conduction, but the whole problem of irritability and response. Few acres of the field of general physiology were not plowed by his sharp understanding and seeded by his generalizing insight.

A complete bibliography of Lillie's papers was prepared for me by Deborah Harlow, librarian of the Marine Biological Laboratory at Woods Hole, and from this alone emerge many interesting lights on his work and his period. In his first decade of publication (1901–10) six papers appeared in such journals as *Biological Bulletin* and *Journal of Experimental Zoology,* and 14 appeared in the *American Journal of Physiology*—the latter including articles on *Arenicola* larvae, the swimming plate of Ctenophora, and the eggs of *Asterias* and *Arbacia.* Two decades later (1921–30) only four of 27 papers reached the *American Journal of Physiology* (and these by 1923), the others being distributed in such new publications as *Journal of General Physiology* and *Journal of Cellular and Comparative Physiology,* the second a journal he helped found and edit. The dozen papers of Lillie's last decade were mostly in philosophical journals—he published in 24 different periodicals over his professional life span—but this represented a shift in emphasis, whereas the earlier change reflected the altered interest of physiology and the growth of its cellular and general offspring.

Only nine of Lillie's papers had a joint author, and five of them were students. In part this reflected the times, for multiple authorship was the exception earlier in the century; in part it may have represented an inclination to have students publish separately; but largely it must have resulted from his personal qualities of mind and manner. Omnivorous in his reading, eager always to discuss (despite some hearing difficulty) or to correspond about an interesting problem, generous in instructing students, at which he was most successful outside the classroom, Lillie was still a solitary worker. His thoughts and labors were his own, and his main influence on others, including the oncoming generation, was exerted by way of the written word, despite the long, busy, and happy summers he spent throughout his adult life in the teeming scientific community of Woods Hole.

The first paper Lillie published established the basic themes of his scientific work. "On the Differences of the Effects of Various Salt-Solutions on Ciliary and on Muscular Movements in *Arenicola* Larvae" touched upon ion action and antagonism, colloids and membranes, irritability and response. The dramatic actions of the common ions of protoplasm never exhausted his interest, and one of his last experimental reports dealt with "The Influence of Neutral Salts on the Photodynamic Stimulation of Muscle." He related ions to the dispersion state of colloidal particles and so to osmotic pressure and membrane permeability, to fertilization and mitosis, to stimulation and anesthesia, to contraction and conduction, to the action of drugs and radiations.

Lillie was perhaps most widely known for his contributions to neurophysiology, especially his provoca-

tive passive iron wire model of nerve fiber conduction (one of many models he studied in relation to other phenomena—e. g., growth). Yet his first paper dealing with nerve (as also his first explicitly philosophical article) did not appear until 1914, "The Conditions Determining the Rate of Conduction in Irritable Tissues and Especially in Nerve;" and his classic on the iron wire, "The Recovery of Transmissivity in Passive Iron Wires as a Model of Recovery Processes in Irritable Living Systems," was not published until 1920. This model, with its eddy currents and membrane of functionally variable resistance, mimicked surprisingly well the physical and physiological attributes of a nerve fiber, predicting saltatory conduction, establishing a relation between surface area and threshold and between resistance and conduction velocity, and giving powerful support to the membrane theory of propagation. This approach was summarized in 1922 in *Physiological Reviews,* "Transmission of Physiological Influence in Protoplasmic Systems, Especially Nerve;" in a lecture on "The Physical Nature of Nervous Action" published in 1929 in the *American Journal of Psychiatry*; and in his definitive volume on *Protoplasmic Action and Nervous Action,* published (2nd ed.) in 1932 by the University of Chicago Press.

No scientist with such a holistic view of his subject could fail to develop philosophical interests, and in the biological domain these would necessarily touch on problems of directive influences on the formation, organization, and behavior of living organisms. Lillie became steadily more engrossed with these problems, and after 1941 all his publications were in the field of philosophy. Unlike many scientists who make casual forays into a foreign territory, he established a thorough competence in this field, published largely in the professional journals of the discipline, and was accepted by the philosophers as one of themselves.

A series of papers in the *Journal of Philosophy,* and later in the *Philosophy of Science,* dealt with such subjects as "The Problem of Vital Organization" (1934), "Biological Causation" (1940), "The Problem of Synthesis in Biology" (1942), and "Vital Organization and the Psychic Factor" (1944). Lillie was regarded by many as turning to vitalism in his later writings, and surely he was far from the hard determinism of most of his colleagues; but he eschewed mysticism in his thinking and sought insistently for factors that contribute to stability, on the one hand, and to innovation, on the other. The latter he termed "psychic," and thereby he may have invited some misunderstanding. A summary of his views was published in 1945 by the University of Chicago Press as *General Biology and Philosophy of Organisms.*

Ralph Lillie was born in Toronto on August 8, 1875, and received his bachelor's degree from the University of Toronto in 1896—and an honorary D.Sc. in 1936. Although he came to the United States for his graduate training (Ph.D. in zoology from the University of Chicago in 1901) and subsequent career, he remained a Canadian citizen. He taught at Nebraska, Harvard, Johns Hopkins, and Pennsylvania before settling at Clark University for seven years as chairman of the Department of Biology. There followed a four-year period at the Nela Research Laboratory before he returned to the University of Chicago in 1924 (where his elder brother, Frank, was established in the Department of Zoology) as professor of physiology for a quarter-century, including a decade as professor emeritus.

Lillie's life centered, physically, about two loci, Chicago and Woods Hole. In early spring a restlessness would seize him, and it became irresistible as the starfish eggs came into season. His year-long course in general physiology was finally telescoped into fall and winter quarters so that the vernal flight was not delayed; and the autumnal return was postponed to the limits of conscience. At Woods Hole, manipulating echinoderm eggs in finger bowls in his third-floor laboratory, or playing a piano duet with Leonor Michaelis, or entertaining with his wife, Helen, his enduring close companion, in his hospitable frame house, or carrying his green bag of papers to and fro, Ralph Lillie seemed most fully himself. It was fitting to hold there a memorial service for him.

The external marks of success were upon Lillie—a trusteeship in the Marine Biological Laboratory, election to the American Philosophical Society, memberships, lectureships, editorships. But his real success was in his character, his thoughts, his appreciation, in the affection given him by his intimates, and the respect given him by his peers. I would generalize what I wrote of him at the University of Chicago:

Ralph Stayner Lillie left us on March 19, 1952, with the same quietness in which he lived so many years among us. Gentle, reticent, deeply thoughtful, he was less widely known on the campus than a number of his colleagues. But those who did come to know him—and these included leaders in science and philosophy and statesmanship throughout the world—prized him as a really creative thinker. In him were blended the experimenter and the artist, and he possessed in generous measure that vein of philosophy seen in all great scientists.

Lillie's analysis of the nature of organism, of evolutionary process, of nervous action, was profound and productive. In his own articles and books and in the publications of his many students and followers are insights and investigations that have enriched all of biology. His penetrative discourse opened vistas of thought to those of us who enjoyed hours with him beyond the classroom level.

If ever the true scholar—wise, humble, kindly, broadly informed and interested, dedicated to the human values of living—graced our quadrangles, Ralph Lillie was such a one.