

[Frank Rattray Lillie \(1870-1947\)](#) ^[1]

By: Wellner, Karen Keywords: [Biography](#) ^[2] [Laboratories](#) ^[3] [Cell lineage](#) ^[4]

Frank R. Lillie was born in Toronto, Canada, on 27 June 1870. His mother was Emily Ann Rattray and his father was George Waddell Little, an accountant and co-owner of a wholesale drug company. While in high school Lillie took up interests in entomology and paleontology but went to the University of Toronto with the aim of studying ministry. He slowly became disillusioned with this career choice and decided to major in the natural sciences. It was during his senior year that he developed his lifelong interest in [embryology](#) ^[5]. Graduating with a BA in 1891 Lillie then moved to the [Marine Biological Laboratory](#) ^[6] (MBL) at [Woods Hole](#) ^[7], Massachusetts, to work and study with [Charles Otis Whitman](#) ^[8], the founding director of the MBL. Lillie collected and studied [cell lineage](#) ^[9] side-by-side with some of the most prominent embryologists of the time: Edmund B. Wilson, Edwin G. Conklin, and [Aaron L. Treadwell](#) ^[10]. Along with his [cell lineage](#) ^[9] studies, Whitman guided Lillie to work on the question of how blastomeres contributed to the formation of organs in fresh water clams.

In 1892 Lillie followed Whitman to the [University of Chicago](#) ^[11] zoology department where Whitman had accepted a chair appointment. In 1894 Lillie graduated with a PhD in zoology. His dissertation was a descriptive study of [cell lineage](#) ^[9] in freshwater mussels. From 1894 through 1899 Lillie worked as an instructor at the [University of Michigan](#) ^[12]. In 1895 he married Frances Crane, sister of Chicago businessman Charles R. Crane. His brother-in-law would soon play a large role in introducing Lillie to the social elite in Chicago and helping to expand the MBL campus. During his marriage Lillie and his wife had five daughters, one son, and three adopted sons. Lillie briefly taught biology in upstate New York at Vassar College before returning to the [University of Chicago](#) ^[11] as an assistant professor of [embryology](#) ^[5]. In 1902 he was made an associate professor followed by a full professor in 1906. In 1908 Lillie published his classic book on [chicken](#) ^[13] [embryology](#) ^[5], *Development of the Chick: An Introduction to Embryology* ^[14]. Along with writing the text, Lillie prepared a large series of serial sections of the [chick](#) ^[15] embryo at various stages to serve as illustrations. With revisions, the text and laboratory manual continue to be used to the present time, serving as one of the best accounts available on bird development.

In 1910 Lillie was made chair of the Department of Zoology. During this time he united the [embryology](#) ^[5] program with the rest of the zoology department. With the combining of the departments, the budgets were also combined and Lillie was able to use his influence to obtain more money for embryological research. In 1931 Lillie was appointed dean of the Division of Biological Sciences at Chicago. After many years of distinguished teaching and research he was made the Andrew MacLeish Distinguished Service Professor of Embryology and the dean of biological sciences. In 1935 he was given emeritus professor status.

Although rarely written about, Lillie was a member of Chicago's [Eugenics Education Society](#) ^[16], a committee member of the Second International Eugenics Congress, and served on the advisory council for the Eugenics Committee of the United States. In the early 1920s Lillie envisioned an Institute of Genetic Biology that would gather data to examine population problems, public health, and social control, but this never came to fruition.

Lillie is probably best known for his leadership at the [Marine Biological Laboratory](#) ^[6] at [Woods Hole](#) ^[7]. He organized the MBL's first course in [embryology](#) ^[5] in 1893 and became course director the following year. At that time the MBL consisted of one small building, a few skiffs, and a dock. In 1902 funding for the laboratory was so great that the corporation and board of the MBL considered transferring the laboratory to the [Carnegie Institution of Washington](#) ^[17] to make the MBL Carnegie's permanent marine research laboratory. Lillie and Whitman opposed the transfer and convinced the board to reverse its offer to Carnegie. To this day the MBL remains a laboratory relatively free from layers of outside control.

From 1900 to 1942 Lillie worked tirelessly to improve the laboratories and accommodations for the myriad of scientists who descended on [Woods Hole](#) ^[7] during the summer months. Lillie called upon his brother-in-law to help finance the expansion of the MBL and Crane served as president of the corporation from 1904 through 1924. The Crane laboratory at MBL was named after the man who financed its building. Lillie was instrumental in making the marine laboratory into one of the leading research laboratories in the world. Not only did he serve as president of the corporation from 1925 to 1942 but he also served as Managing Editor of the MBL's scientific publication *The Biological Bulletin* ^[18] for twenty-five years.

Lillie was an outstanding administrator and teacher but the depth of his research in [embryology](#) ^[5] and development is also remarkable. His early research primarily dealt with [egg](#) ^[19] cleavage and early development in invertebrates. Although his early [cell lineage](#) ^[9] work was mainly descriptive and comparative, it helped lay the foundation for experimental studies by [Wilhelm Roux](#) ^[20] in 1888 and [Hans Driesch](#) ^[21] in 1891. Lillie heavily influenced his former student and noted embryologist Ernest E. Just to continue working with *Nereis* to show the relationship of [egg](#) ^[19] cleavage planes to the entry point of [sperm](#) ^[22].

In 1903 and 1904 Lillie published several papers on his studies of the [chick](#) ^[15] embryo. Included in the papers was discussion

about the formation of the [amnion](#)^[23] and his experiments with cauterizing parts of the embryo to see how further development of parts of the embryo were affected. Lillie had always shown interest in the [chick](#)^[15] embryo. He was convinced that [chick](#)^[15] embryos were the best choice for almost any type of experimental work of embryological problems.

From 1910 to 1921 Lillie's research centered on [fertilization](#)^[24] in the [annelid](#)^[25] *Nereis limbata* and sea urchins *Arbacia*^[26] *punctulata* and *Strongylocentrotus*^[27] *franciscanus* and *S. purpuratus*. Lillie proposed that there were specific substances (fertilizin and antifertilizin) secreted by [egg](#)^[19] and [sperm](#)^[22]. Part of Lillie's "fertilizin theory" likened the interaction between gametes to that of the lock-and-key fashion of antibodies and antigens. This was notable in that Lillie applied the then current immunological concepts and terminology to that of [fertilization](#)^[24].

Lillie's investigation of the factors influencing the development of freemartins (sterile genetic female calves born as a twin to fertile male calves) helped Lillie answer the question of how sexually indifferent embryos at the beginning of development later turn into males or females. Beginning in 1914 Lillie worked with stockmen in the Swift and Company stockyard to obtain fifty-five pairs of *in utero* fetal twins from freshly slaughtered pregnant cows. In 1917 Lillie published his study in the *Journal of Experimental Zoology*^[28] with the finding that [freemartin](#)^[29] bovine twins are non-identical and that they share the same [placenta](#)^[30], allowing for blood to be freely exchanged between the twin fetuses. A male's [testes](#)^[31] form early in development and "masculinizing" substances ([hormones](#)^[32]) are released and circulate through the fused umbilical arteries. Lillie concluded that the [freemartin](#)^[29] was a genetic female calf that had certain male sexual characteristics due to the action of a fetal male sex [hormone](#)^[33]. This work led to the concept that once a gene directs a gonad to differentiate into [testes](#)^[31] or an [ovary](#)^[34], accessory reproductive structures in genetic males develop in the male direction due to the presence of male [hormones](#)^[32]. Genetic females develop rudimentary reproductive structures because they are not inhibited from developing due to a lack of male [sex hormones](#)^[35]. Lillie's research with freemartins introduced the notion of the nature and action of [sex hormones](#)^[35] to embryologists when little was known about [hormones](#)^[32]. Soon, others at the [University of Chicago](#)^[11] attempted to produce freemartins in [birds](#)^[36] ([Benjamin Willier](#)^[37]) and mammals ([Carl R. Moore](#)^[38]). Castration experiments in fetal mammals *in utero* and research in the isolation and purification of [sex hormones](#)^[35] was undertaken in other laboratories at the [University of Chicago](#)^[11]. The subsequent work stemming from Lillie's [freemartin](#)^[29] investigation helped form the field of [reproductive biology](#)^[39].

Even after retiring from the [University of Chicago](#)^[11] in 1935, Lillie continued with his [sex hormone](#)^[33] studies by investigating the physiology and development of bird feathers. He used the Brown Leghorn fowl, a bird that displays a notable [sexual dimorphism](#)^[40] in feather color and patterns. He collaborated with [Mary Juhn](#)^[41] and His Wang to discover that embryonic feather papillae all start out with the same background color. Further feather coloration and patterns develop in an orderly fashion in response to both female [sex hormones](#)^[35] and thyroxin. Part of his research involved using castrated males into which injections of estrogens and thyroxin were given to induce "female" feather colorings in the birds' regenerating feathers.

From 1935 to 1939 Lillie was president of the [National Academy of Sciences](#)^[42] and in 1935 to 1936 was chairman of the [National Research Council](#)^[43]. To date he is the only person ever to have held both leadership positions in the two organizations at the same time. Lillie was also appointed chairman of the [National Academy of Sciences](#)^[42] Oceanographic Committee to study the financing and construction of an Institute of Oceanography. In 1930 he helped secure a three million dollar grant from the [Rockefeller Foundation](#)^[44] to help locate and build the Oceanographic Institute next door to the MBL. Lillie served as president of the [Woods Hole Oceanographic Institute](#)^[45] from 1930 to 1939.

Lillie died of a stroke on 5 November 1947 in Billings Hospital at the [University of Chicago](#)^[11], the campus at which his professional life had so intimately been connected. Thus ended the career of one of the world's foremost embryologists and science administrators—a career that science historian Philip J. Pauly identified as having helped make biology the first science in which Americans became internationally recognized.

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Publisher

Arizona State University. School of Life Sciences. Center for Biology and Society. Embryo Project Encyclopedia.

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Last Modified

Wednesday, July 4, 2018 - 04:40

DC Date Accessioned

Thursday, May 10, 2012 - 13:10

DC Date Available

Thursday, May 10, 2012 - 13:10

DC Date Created

2009-07-22

DC Date Created Standard

Wednesday, July 22, 2009 - 07:00

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