

Lynn Petra Alexander Sagan Margulis (1938–2011)

Lynn Petra Alexander Sagan Margulis studied cells and mitochondria in the US during the second half of the twentieth century. She developed a theory for the origin of eukaryotic cells. In that theory, she proposed that two kinds of structures found in eukaryotic cells, mitochondria in animals and plastids in plants, were once free-living bacteria that lived harmoniously and in close proximity to larger cells, a scenario called symbiosis. Margulis proposed that the larger cells eventually engulfed the free-living bacteria, resulting in cells living inside other cells, a situation called endosymbiosis. Margulis' theory is known as the serial endosymbiosis theory (SET). Her work contributed to explanations of the evolution and development of life, as eukaryotic cells comprise most multicellular organisms, including their embryos.

Margulis was born in Chicago, Illinois, on 5 March 1938, the oldest of four daughters born to Leona Wise Alexander and Morris Alexander, an attorney. Margulis applied for college at the age of fourteen, and she enrolled in the University of Chicago in Chicago, Illinois, by the age of sixteen. While there, she began to study genetics. She graduated from University of Chicago with a bachelor degree in liberal arts in 1957.

While at the University of Chicago, Margulis met her first husband, Carl Edward Sagan, a graduate student in physics who became an astronomer and popularizer of science. She married Sagan when she was nineteen years old. They moved to Madison, Wisconsin, where she studied with Walter Plaut and Hans Ris at the University of Wisconsin. She completed her master's degree in zoology and genetics in 1960. Margulis and Sagan moved to California when Sagan took a post-doctoral position at University of California in Berkeley, California. In the same year she began her PhD in genetics at University of California at Berkeley with zoologist Max Alfert. When Sagan joined Harvard University's astronomy department in 1963, Sagan and Margulis moved to Boston, Massachusetts. Margulis and Sagan divorced in 1964.

Margulis took a lectureship at Brandeis University in Waltham, Massachusetts, and she moved there with her two sons, Dorion Sagan and Jeremy Sagan. While at Brandeis, Margulis finished her dissertation and obtained her PhD from University of California at Berkeley in 1965. She then began teaching in the biology department at Boston University, in Boston, Massachusetts, where she remained for twenty-two years.

In 1967, while working at Boston University, Margulis published the article "On the Origin of Mitosing Cells." In the article, Margulis proposed her theory of symbiosis, which argued that eukaryotic cells, which have enclosed nuclei, evolved from free-living bacteria, which do not have enclosed nuclei, living closely together. She proposed that primitive eukaryotic cells engulfed an aerobic bacterium that later became the mitochondria. She later proposed her serial endosymbiosis theory (SET), which stated that some cells engulfed photosynthesizing cyanobacteria, which then became the plastids of algae and plants.

By 1970, Margulis was an associate professor at Boston University, and she expanded her theory of endosymbiosis in *Origin of Eukaryotic Cells*. She published two revised versions of this book as *Symbiosis in Cell Evolution* in 1981 and 1992. Meanwhile, during the 1980s, genetic analysis of the DNA of sub-cellular organelles confirmed her theory that mitochondria and plastids, chloroplasts in plants, were once free-living bacteria.

Margulis married chemist Thomas N. Margulis in 1967. While they were married they had a son Zachary, and a daughter Jennifer. They divorced in 1980. She later said that she quit her job as wife twice, saying that it is not humanly possible to be a good wife, a good mother, and a first class

scientist.

Margulis later advocated for a variant of the Gaia hypothesis, postulated in the 1960s by James Ephraim Lovelock in the UK. The hypothesis likens the earth to a living, self-regulating organism. Margulis worked with Lovelock in the early 1970s on a US National Space and Aeronautics Association (NASA) sponsored search for life on Mars, in which Lovelock looked for ways that life might have modified Mars's atmosphere. Lovelock and Margulis predicted that NASA's Viking space probe would find no life on Mars, which it didn't. Later, in 1993's "Gaia in Science," Margulis stated that Gaia was best hypothesized not as an organism, as in Lovelock's Gaia theory, but as an ecosystem. In her 1998 book *Symbiotic Planet: A New Look at Evolution* she focused on two specific theories and their relationship to each other: serial endosymbiosis theory (SET) and the Gaia hypothesis.

Margulis left Boston University in 1988 and joined the faculty at the University of Massachusetts at Amherst, Massachusetts as Distinguished Professor of Botany. In 1997 she moved to the Department of Geosciences. She was distinguished professor of geosciences at Amherst until her death in 2011.

In addition to Margulis' scholarly publications, she wrote books for popular audiences. Some she wrote with her eldest son Dorion Sagan including *Microcosmos: Four Billion Years of Microbial Evolution* in 1986, and *Acquiring Genomes: A theory of the Origins of Species* in 2002.

Margulis served on many US and international science committees, including some for NASA, American Association for the Advancement of Science (AAAS), American Academy of Arts and Sciences, World Academy of Arts and Sciences, and the National Science Resource Center. She was elected President of the Scientific Research Society Sigma Xi for 2005 to 2006. She was one of three US members on the Russian Academy of Natural Sciences. Margulis also consulted for NASA on biological and geological research.

Margulis received many awards. She was elected to the US National Academy of Sciences in 1983 and received the US National Medal of Science in 1999 presented at the White House by US President Bill Clinton in March 2000. In 1999 she received the William Procter Prize for Scientific Achievement from Sigma Xi. This organization treats this prize as its highest honor, awarded to scientists who made outstanding contributions to research and who communicate the significance of their work to others. Her other awards include a NASA Public Service Award for Astrobiology in 2010, the Darwin-Wallace Medal of the Linnaean Society of London in 2009, the Miescher-Ishida Prize in 1986, and a Guggenheim Fellowship in 1978.

Margulis died at her home five days after suffering a stroke on 22 November 2011.

Sources

1. Carmichael, Mary. "Scientist's Death Halts Unique Research at UMass." *The Boston Globe*, April 24, 2012, Metro edition. <http://www.bostonglobe.com/metro/2012/04/23/umass-shuts-down-lab-deceased-scientist-lynn-margulis/1lrhxwazGtJ6jpECzRCbqO/story.html> (Accessed March 22, 2014).
2. Di Properzio, James. "Full Speed Ahead." *University of Chicago Magazine* 96 (2004). <http://magazine.uchicago.edu/0402/features/speed.shtml> (Accessed March 22, 2014).
3. Guerrero, Ricardo. "Lynn Margulis (1938–2011): In Search of the Truth." *International Microbiology* 14 (2011): 183–6.
4. Lake, James A. "Lynn Margulis (1938–2011): Biologist Who Revolutionized Our View of Early Cell Evolution." *Nature* 480 (2011): 458.
5. Lovelock, James E. "Gaia as seen through the atmosphere." *Atmospheric Environment* (1967): 5798–580.
6. Lovelock, James E., and Lynn Margulis. "Atmospheric homeostasis by and for the biosphere: the Gaia hypothesis." *Tellus* 26 (1974): 2–10.
7. Mann, Charles. "Lynn Margulis: Science's Unruly Earth Mother" *Science* 252 (1991): 378–81.
8. Margulis, Lynn. *Origin of Eukaryotic Cells; Evidence and Research Implications for a Theory of the Origin and Evolution of Microbial, Plant, and Animal Cells on the Precambrian Earth.*

- New Haven: Yale University Press, 1970.
9. Margulis, Lynn. "Endosymbiotic Theory." In *Symbiosis in Cell Evolution-life and its Environment on the Early Earth* (1981): 1-14.
 10. Margulis, Lynn. *Symbiosis in Cell Evolution: Microbial Communities in the Archean and Proterozoic Eons*. 2nd ed. New York: Freeman, 1993.
 11. Margulis, Lynn. "Gaia in Science." *Science* 259 (1993): 745.
 12. Margulis, Lynn. *What is Life?* New York: Simon & Schuster, 1995.
 13. Margulis, Lynn. *Symbiotic Planet: A New Look at Evolution*. New York, NY: Basic Books, 1998.
 14. Margulis, Lynn. "The Phylogenetic Tree Topples." *American Scientist* 94 (2006): 1. <https://www.americanscientist.org/issues/pub/2006/3/the-phylogenetic-tree-topples> (Accessed March 22, 2014).
 15. Margulis, Lynn, and John D. Rummel. "Life in NASA and the Rest of the Universe: New Scientific Opportunities." *BioScience* 51 (2001): 317.
 16. Margulis, Lynn, and Dorion Sagan. *Microcosmos: Four Billion Years of Evolution from our Microbial Ancestors*. New York: Summit Books, 1986.
 17. Margulis, Lynn, and Dorion Sagan. *Acquiring Genomes: A Theory of the Origins of Species*. 1st ed. New York: Basic Books, 2002.
 18. Margulis, Lynn, and Karlene V. Schwartz. *Five Kingdoms: An Illustrated Guide to the Phyla of Life on Earth*. 3rd ed. New York: W.H. Freeman, 1998.
 19. McDermott, Jeanne. "A Biologist Whose Heresy Redraws Earth's Tree of Life." *Smithsonian* 20 (1989): 72-81.
 20. Rose, Steven. "Lynn Margulis Obituary" *The Guardian*, 11 December 2011. <http://www.guardian.co.uk/science/2011/dec/11/lynn-margulis-obituary?INTCMP=SRCH>. (Accessed November 7, 2012)
 21. Sagan, Lynn. "On the Origin of Mitosing Cells." *Journal of Theoretical Biology* 14 (1967): 225-74.
 22. Schwartz, Robert M., and Margaret O. Dayhoff. "Origins of Prokaryotes, Eukaryotes, Mitochondria, and Chloroplasts." *Science* 199 (1978) 395-403.
 23. Tao, Amy. "Lynn Margulis." *Encyclopedia Britannica Online*. <http://www.britannica.com/EBchecked/topic/364780/Lynn-Margulis>. <http://www.britannica.com/EBchecked/topic/364780/Lynn-Margulis> (Accessed November 13, 2012).
 24. Weber, Bruce. "Lynn Margulis, Evolution Theorist, Dies at 73." *New York Times* November, 24, 2011 section B15, New York edition. <http://www.nytimes.com/2011/11/25/science/lynn-margulis-trailblazing-theorist-on-evolution-dies-at-73.html> (Accessed March 22, 2014).