

**IN
MEMORY
OF
LYNN
MARGULIS**
(1938-2011)



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Puffer's Pond, in North Amherst (Massachusetts), was one of Lynn's favorite places.

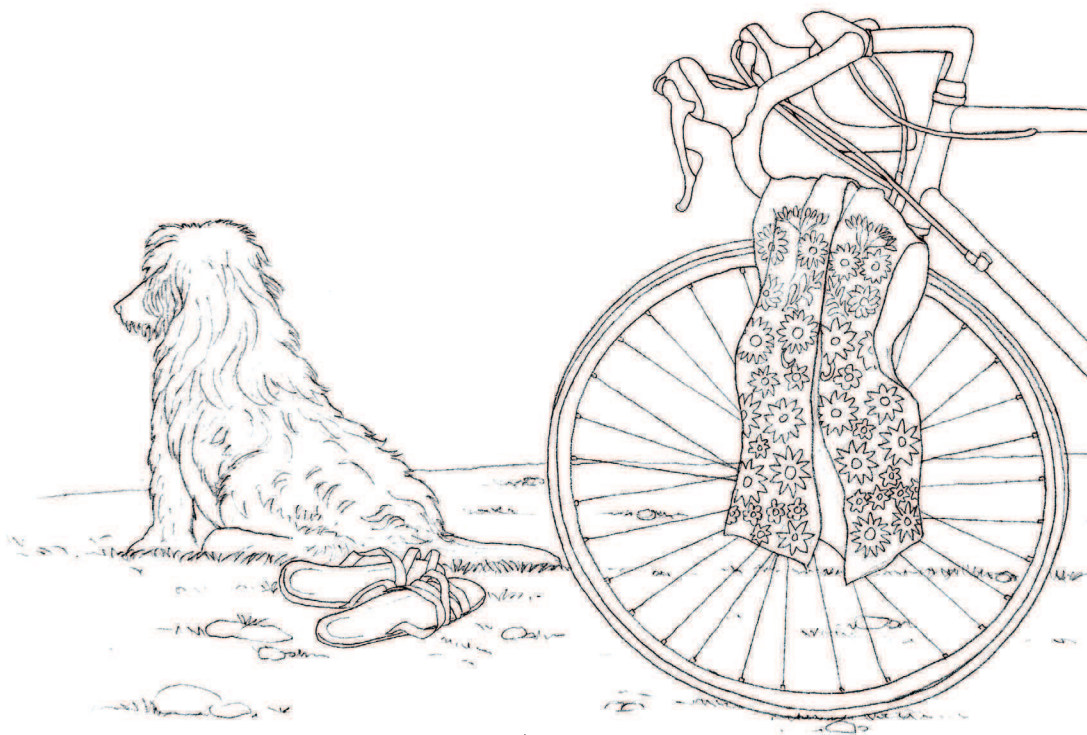
A PORTRAIT BY COLLEAGUES AND FRIENDS

ONCE UPON A TIME
LYNN MARGULIS

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ONCE UPON A TIME LYNN MARGULIS

SHORT CONTRIBUTIONS COMPILED BY CARMEN CHICA



SEPTIMUS
E|D|I|T|O|R|I|A|L

The cover composition tries to evoke Lynn Margulis, absent, in an environment close to her. Puffer's Pond, where she used to swim during most of the year, even in cold temperatures. Her dog, who used to accompany her. The bike, her favorite transport and in the background, the extraordinary hues of autumn in New England. On the back cover, the same environment with a beaver that could often be seen around.

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THINKING ABOUT LYNN

Moselio Schaechter

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*Las honestas palabras nos dan un claro indicio de la honestidad
del que las pronuncia o las escribe.*

Honest words give us a clear indication of the honesty of
the one who pronounces or writes them.

MIGUEL DE CERVANTES (1547-1616)

Lynn Margulis changed the way we think about evolution, our cells, ourselves. To her we owe the now universal acceptance of the symbiotic origin of the eukaryotic cell. Seldom even among the scientific notables do we find an insight of such weightiness. Notice that I call her achievement an insight, not a discovery or an invention. It was not the result of direct experimentation, rather a realization that emerged from her deep thinking and erudition, an understanding that she then put forward vehemently. And therein lies the tale.

How did this come about? If you seek historical details and specifics, I would refer you to Jan Sapp's chapter in the book on Lynn edited by Dorion Sagan. Here I will sketch a brief picture of the unique endosymbiosis that brought about this achievement, a symbiosis between Lynn's excellence as a geneticist/cytologist and her fervent personality. Lynn trained under a distinguished cytologist at the University of Wisconsin, Hans Ris, whose career was anchored in both the 19th century era of hugely detailed protist cytology and

the modern biological revolution. In such an atmosphere, and Lynn being Lynn, she became steeped in cytological learnedness, both of the old and the new. She gravitated to the elaborate and beautiful world of protist biology and became an expert in its intricacies.

From early on, she was aware of the proposal of Ris and others that organelles such as mitochondria and plastids were of bacterial origin. However, in their advocacy they did not fully use the tools that conveyed the implications of this process for evolution, one could say its evolutionary immanence. The notion that the eukaryotic cell, replete with its organelles, arose through symbioses required such a huge mental leap that most people were refractory to its acceptance. Somehow, people needed a proverbial hit over the head, and Lynn delivered just that with her classic 1967 paper in the *Journal of Theoretical Biology*. Its message took some time to penetrate, but penetrate it did, and with a vengeance.

Lynn did not stop here. She reached further and saw symbiosis — previously treated as an interesting eccentricity of Nature pertinent to lichens, the roots of legumes, or the rumens of cows— as the main force in evolution. At the time, this was blasphemy against the neo-Darwinian dogma that evolution proceeded by the stepwise selection of single mutations. In Lynn's powerful vision, symbiosis provided that alternative. Nowadays, a testament to her impact, it is common place to consider evolution as modular, with important changes in a lineage arising (probably most of them early in evolution) by the acquisition of packets of genes. Such a packet has on occasion arrived, as she envisioned, in the form of the entire genome of a symbiont; more frequently, via other mechanisms that deliver smaller clusters of genes. Genes travel via viruses, through sex, or simply as naked DNA. However, so imbued was she with the symbiogenesis idea that

she had little time for those other ways to transfer genes *en masse*. This passionate espousal of her view was also reflected in the ire with which she savaged Neo-Darwinism and its adherents.



Photo by Lluís Pou at his home in L'Astort, near Barcelona, Sept 12, 1992.
From left to right Carl Rustenholz, Lorraine Olendzenski, Lynn Margulis,
Ricardo Guerrero, Moselio Schaechter, Carmen Chica.

Now let me turn to Lynn as the person I knew, a friend with whom I had the opportunity to talk at length on numerous occasions through the years. Thinking about Lynn is not a simple matter. She was probably the most unusual person I have known, and she presented puzzling contradictions. For example, consider her understanding of science. On the one hand, she made a monumental contribution to biology, while on the other hand she championed views that were unjustifiable by the evidence, e.g., that AIDS is caused by a spirochete. How can achievements of gleaming clarity coexist in one brain with ideas that seem inexplicable to most? *¿Que pasa?*

I wish I knew. Lynn left us with only hints, elusive inklings. One trait that does stand out was the impassioned intensity of her convictions. Talking with her meant *listening* to her. One contradicted at one's peril. On the rare occasions when I did, my comments elicited an avalanche of arguments and scientific facts, often peppered by pointed remarks about those who held views contrary to hers. It was not that she was uncaring or disrespectful. Rather, she was visibly carried away by the force of her argument. What deeper meaning can we read in her intensity? Perhaps, because her brain was so focused on developing and then defending her own primary insight that other ideas escaped close scrutiny.

Lynn's enchantment with the poet Emily Dickinson has been commented on by many. I believe that Lynn was a poet at heart. In contrast to the character in Molière's *Le Bourgeois Gentilhomme* who realized that he had been speaking in prose all his life, Lynn may have known that she spoke in a poetic language. Her writings are handsome in a poetic sense, sometimes lyrical, sometimes dramatic. But, beyond that, her writing was imbued with candor and utter integrity. As in the words of Cervantes, the honesty of her writing gave proof to her inner honesty.

I thank Merry Youle for her skillful and insightful editing of this contribution. ❀

IN SEARCH OF TRUTH

Ricardo Guerrero

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“The story of science, a continuous joint narrative, is never the personal tale of any scientist”, writes Lynn Margulis at the end of the prologue to her only fiction book, *Luminous Fish. Tales of Science and Love* (Chelsea Green Pub. Co., White River Junction, VT, 2007; originally published in Spanish in 2002 by Tusquets Ed., Barcelona). Since her death on November 22, 2011, several tributes have been paid in honor of Lynn’s work and surely there will be many more such events in the future. The contributions here aim to put into words the recognition and admiration of a few of her Spanish colleagues and friends, who consider themselves fortunate to have been part of the Spanish experience of this incredible woman. Certainly, Lynn was neither a perfect scientist nor a perfect woman, but she is a role model for all of us. Perfection does not exist and surely she would not have wanted to be perfect. She was tenacious in defending her ideas, provocative in the way she did so, and unorthodox in almost every aspect of her life. In my twenty-eight years of “coexistence” with her, both in professional and personal matters, what I certainly can add to this description is the integrity, the scientific convictions, and the overwhelming personality of this unique woman, housewife, mother, writer, teacher,... who was Lynn Petra Alexander (Chicago, IL, 1938; Amherst, MA, 2011).

In the history and development of science, there are milestones linked to one or more scientists. Besides being the product of the

wit and personal work of someone, they also incorporate ideas and discoveries that others have previously achieved. Science is a cooperative task (“a continuous joint narrative”) that builds and modifies ideas, and leaves doors open to other new ideas to move forward. Lynn followed that way and left us a huge scientific production, her ideas and her commitment to what she believed and defended.

The short texts collected here by Carmen Chica are contributions by colleagues and friends, many of them leading biology researchers, particularly in the field of microbiology, and to a lesser extent in other disciplines. All of them met Lynn and have tried to highlight the mark she left in all of them. So, there are occasionally repetitions in the texts because while authors (either senior or young) recount their work in a particular field of science, they also dive into their first meeting with Lynn. For the youngest, getting to know her was also a way to look towards a future devoted to science and to consider what that commitment meant.

In this regard, Lynn highlighted the influence that some of her own teachers had had in her training. With them, the students worked, commented on articles of researchers and criticized them directly; it was a way to participate in their own education under the guidance of vocational teachers. So, the task of good teachers will never be overemphasized. A good teacher, the one that we will always remember, is the one that infected us with the contagious virus of curiosity.

In the individual contributions of this book, there are also coincidences. This is because all authors had the opportunity to experience with Lynn the best of her: her communication skills; her extreme generosity (her house has been home for almost all of them); her perseverance to go forward despite the difficulties; her tireless way to

work (until exhaustion of herself and their collaborators); her sense of humor (using amusing puns both in English and in Spanish), her laboriousness (it was impossible to get bored with her). Although briefly, because this is not a scientific book, other frequent topics are the origin of the eukaryotic cell by serial endosymbiosis, the Gaia theory developed by James E. Lovelock, the origin and evolution of life. And more. Either reading her writings or listening from her lips, the long and arduous process that eventually led to the establishment of these theories was a unique experience.

Lynn expressed the difficulty of the scientific community to accept changes; she expressed this feeling in a book in which she developed the idea of symbiosis leading to the evolution of nucleated cells and then to other organisms (fungi, plant, animals) when she wrote “many circumstances conspire to extinguish scientific discoveries, especially those that cause discomfort about our culture’s norms.” (*The Symbiotic Planet. A New Look at Evolution*, Weindenfeld & Nicolson, London, 1998). In the same sense are Thomas S. Kuhn’s words: “Concerned with scientific development, the historian then appears to have two main tasks. On the one hand, he must determine by what man and at what point in time each contemporary scientific fact, law, and theory was discovered or invented. On the other hand, he must describe and explain the congeries of error, myth, and superstition that have inhibited the more rapid accumulation of the constituents of the modern science.” (*The Structure of Scientific Revolutions*, The University of Chicago Press, Chicago, 1962). Apart from some explanation about the problem with changes in science, surely neither Lynn nor any other modern scientist (either woman or man) would consider politically correct to attribute discoveries and inventions only to men. But this has been a predominant idea for a long

time, and it does not detract from the great value of a book that in depth analyses science and its philosophical and historical foundations. In another part of Khun's book we can read: "Normal science, for example, often suppresses fundamental novelties because they are necessarily subversive of its basic commitments. Nevertheless, so long as those commitments research ensures that novelty shall not be suppressed for very long."

Lynn never hesitated to mention the scepticism shown towards the theory of endosymbiosis by recognized scientists, including Niles Eldredge and Stephen Jay Gould (1941-2002), both of them good friends of hers. Perhaps she thought that the main problem with those and other relevant scientists was their misconception of seeing microorganisms mainly as pathogenic agents. For this reason, she admired and loved Lewis Thomas (1913-1993), the North American physician, essayist, educator, policy advisor, and researcher. In fact, Thomas, despite being a physician, with a real implication in clinical research, was willing to recognize the existence and the role of many non-pathogenic microorganisms. In his delightful book (which can be considered his autobiography) *The Youngest Science. Notes of a Medicine-Watcher* (The Viking Press, New York, 1983), Thomas stated (referring to some criticism he received on several articles): "Some of the evolutionary biologists criticize the suggestion, running through many of the essays, that the earth's body represents a kind of organism, displaying so many instances of interdependency and connectedness as to resemble an enormous embryo still in the process of developing. This notion has seemed reasonable enough to me, considering the plain paleontological fact that the life on the earth was, for nearly 75 per cent of its existence made up entirely of separate, prokaryote, microbial cells, themselves the progeny of what may have

been, long ago, the single first cell [...] The Gaia hypothesis, proposed by Lovelock and supported by Margulis, goes a step further to postulate that the conjoined life of the planet not only comprises a sort of organism but succeeds in regulating itself.”

An intrinsic property of any scientific assertion is that it can be invalidated by the discovery of new facts or the change in some ideas. Carl Sagan wrote: “In science it often happens that scientists say, ‘You know that’s a really good argument; my position is mistaken,’ and then they would actually change their minds and you never hear that old view from them again. They really do it. It doesn’t happen as often as it should, because scientists are human and change is sometimes painful. But it happens every day. I cannot recall the last time something like that happened in politics or religion.”

Turning again to *Symbiotic Planet*, we find Lynn comments on what being a woman firmly convinced to follow a scientific career implies. In 1957, when she was 19, she married astrophysicist Carl Sagan and she mothered with him two children (Dorion, born in 1959, and Jeremy, born in 1960). They got divorced and she later married chemist Thomas Margulis, with whom she had two more children (Zachary, born in 1967, and Jennifer, born in 1969). Nevertheless, in no way was she willing to adopt the only role of a housewife and to attend social activities consisting of playing cards, being a member of social clubs or participating in contests of apple pies. “I preferred—she wrote—the company of babies, mud, trees, fossils, puppies and microbes, to the normal world of adults.”

In 1958, when she was 20, she published her first scientific article, a short one: “Incorporation of Thymidine in the Cytoplasm of *Amoeba proteus*,” by W. Plaut and L. Alexander Sagan (*J. Biophysic. Biochem. Cytol.*, 1958, 4:843-846). Walter Plaut was an out-

standing scientist that, four years later, in 1962, along with Hans Ris, his close colleague at the Zoology Department of the University of Wisconsin, Madison, reported a major discovery on cell structure. They (Plaut and Ris) found DNA in the chloroplast of *Chlamydomonas*, establishing for the first time that organelles might contain their own genetic information. Lynn had the opportunity to know both of them and surely became contaminated with their passion for science. It was while working in Plaut's lab and earning a master's degree in zoology-genetics that she was intrigued by the curiously independent nature of mitochondria, and later became a proponent of endosymbiosis—a theory first introduced in the 1920s by several Russian scientists—which would have a profound influence on all of her later research. At that time, she stated “I owe my passion for working on Saturday nights to the utter necessity of amoebae feeding and bowl cleaning every day.”

It is well known—in fact she herself used to tell it—that in 1966 several editors of different journals to whom she submitted the manuscript of “The origin of mitosing eukaryotic cells”, noted the novelty of that hypothesis... but rejected it. She later admitted that it had been poorly presented and not correctly written. Finally the work appeared in the *Journal of Theoretical Biology* (14:225-274, 1967), under her name then: Lynn Sagan. Also the publication of an expanded version of her hypothesis as a book suffered uncomfortable situations until it was published, in 1970, by Yale University Press, under the title *Origin of the Eukaryotic Cell*. Here Lynn discusses her early work on the symbiotic origin of cellular organelles, mainly mitochondria and chloroplasts. The preface, written by the worldwide-known ecologist G. Evelyn Hutchinson (1903-1991), contributed indeed to the quick impact of the book.

Lynn loved spirochetes and took them as a matter of study for a long time. As an example, in an interview, she said that her favorite organism was a huge spirochete identified for the first time at the Ebro Delta. She called it her “Catalan spirochete”, referring to *Spirosymplokos deltaeiberi*, that was described in an article published in 1993 in *Archives of Microbiology* (R. Guerrero, J. Ashen, M. Solé and L. Margulis: “*Spirosymplokos deltaeiberi* nov. gen., nov. sp.: variable-diameter composite spirochete from microbial mats.” 160: 461-470). Later on, in 1998, after having acquired more data about this spirochete, the authors were interested in establishing its possible distribution in microbial mats from other locations. The results of that work were published in an article by L. Margulis, A. Navarrete and M. Solé: “Cosmopolitan distribution of the large composite microbial mat spirochete *Spirosymplokos deltaeiberi*” (*Int. Microbiol.* 1: 27-34, 1998). The publication, *International Microbiology*, the official journal of the Spanish Society for Microbiology, was founded by Lynn and myself in that very year, and has nowadays a healthy life of sixteen years.

These unusual spirochetes, previously reported only from the Alfacs Peninsula at the delta of the Ebro River in northeast Spain, contain striking arrays of cytoplasmic granules packed into their protoplasmic cylinders. Both in summer and in winter, the huge spirochetes were found also in mats growing in the Sippewissett salt marsh at Woods Hole, Massachusetts, as well as in microbial mats at North Pond (Laguna Figueroa, Baja California Norte, Mexico). The identity of these spirochetes was confirmed by electron microscopy: number and disposition of flagella, composite structure, measurements of their distinctive cytoplasmic granules. The granules, larger, more conspicuous and present in addition to ribosomes, are hypothesized to contain ATPases. As culture conditions worsen, these spi-

rochetes retract into membrane-bounded round bodies in which they form refractile inclusions. From morphology and behavior, we concluded that the North American spirochetes from both Atlantic and Pacific intertidal microbial mats were indistinguishable from those at the Ebro Delta. We concluded a cosmopolitan distribution for *Spirosymplokos deltaeiberi*. Besides, the observation that spirochetes could resist long periods of desiccation (or other “lethal” conditions) was a clue to a potential explanation of the intermitent life-course and strange behavior of a very well known bacterium, *Treponema pallidum*, the agent of syphilis.

This book contains several friendly opinions on Lynn. In some cases, with Lynn’s own words from talks with friends, interviews, or excerpts of texts. In other cases, with comments on her, her work, her ideas, her personality, and the evolution of her own thoughts in her basic conception of life. In no case, however, we believe this can distort the meaning and significance of her message. Lynn was able to clearly express her thoughts and opinions about many thing in just a few words.

On the many occasions on which she was interviewed for newspapers and magazines, Lynn clearly expressed their ideas and thoughts on microorganisms, evolution and related issues. For instance, she used to explain that evolution came from the recombination of microorganisms that formed a new living being. All living beings are made up of bacteria, included we humans. Ten per cent of our dry weight consists of bacteria. *Homo sapiens* is nothing special. Biologically, not very different from a chimpanzee. Although many people think that bacteria are bugs that we have to fight, there are many and different kinds of bacteria, and very few of them are pathogenic. Even these act only under certain environmental conditions. When

the interviewer tells Lynn that she speaks with more fascination about microorganisms than about humans, she answers: "...I am not at all interested in human biology. We behave like a mammal pest, trying to destroy the environment. Fortunately, nature has proven much more intelligent than us [...] And even though humans are applied to pollution and annihilation, the Earth, which is an ecosystem with its own physiology—a kind of living organism—has sufficient resources to defend itself against these attacks."¹

In another occasion Lynn said: "I refuse to do what people tell me to do. That's always been my problem. The critics say I need proof by molecular biology... but classical biology is perfectly good science, just obscure. To make a contribution to evolution, one has to be broad. People tried to tell me what science to do, and I don't do what they say."²

The Catalan journalist Núria Escur asked her once what was the most beautiful thing she had seen through a microscope, and Lynn's answer was: "Microbes!, but people do not understand this and they make products to kill them. And by doing this, they are killing themselves..."³ In another interview and in relation to the spread of intelligent design (ID) or creationism, Lynn said, "evolution is a fact as proven as gravity. As much as I want to deny it, science is always more powerful than any dogma."⁴

Finally, I remember that, in a lecture at the Institute for Catalan Studies and referring to the "hidden evolution", she said (in Spanish): "Yes, I am a Darwinist, but I am against neo-Darwinism, which is a limited synthesis of the ideas of the Augustinian monk Mendel with the theory of evolution of "daddy" Charles. It is a vision of Dar-

¹ *El Periódico*, March 29, 2001, interviewed by Elena Hevia.

² *The Scientist* vol. 17, No. 13, 2003.

³ *La Vanguardia*, March 19, 2006.

⁴ *El Mundo*, March 20, 2006, interviewed by Pablo Jauregui.

winism that has found its maxim prophet in the idea of the selfish gene. Neo-Darwinism is a reductionist theory because it only considers biological aspects, which are just a small part of the issues that play a role in evolution.”⁵

In the last years of her life, Lynn used to remember the quote by the North American physicist David Bohm (1917–1992): “Science is the search for truth... whether we like it or not.”

Living intensely is laborious and difficult, because it requires a great effort, but also provides great satisfaction. I shared with Lynn a love for science and life. Science that seeks the truth, and life that shares that love, which I find no better way to express than through the words of the Spanish poet Francisco de Quevedo. ♣

⁵ *La Vanguardia*, July 13, 2008, interviewed by Salvador Llopart.

Amor constante más allá de la muerte

*Cerrar podrá mis ojos la postrera
Sombra que me llevare el blanco día,
Y podrá desatar esta alma mía
Hora a su afán ansioso lisonjera;*

*Mas no, de esotra parte, en la ribera,
Dejará la memoria, en donde ardía:
Nadar sabe mi llama el agua fría,
Y perder el respeto a ley severa.*

*Alma a quien todo un dios prisión ha sido,
Venas que humor a tanto fuego han dado,
Medulas que han gloriosamente ardido,*

*Su cuerpo dejará no su cuidado;
Serán ceniza, mas tendrá sentido;
Polvo serán, mas polvo enamorado.*

Love constant beyond death

The last shadow a cloudless day
May cast on me, could close my eyes;
And this, my soul, may be freed by
An hour eager to flatter its ardor:

But on that far shore it will not
Forsake the memory where it burned;
My flame can swim frigid water
And will flaunt so cruel a law.

Soul, long imprisoned by a god,
Veins, fuel you gave to the blaze,
Marrow, gloriously you burned;

It will leave its body, not its cares;
They will be ashes, but still will feel:
Dust they will be, but dust in love.

FRANCISCO DE QUEVEDO (1580-1645)



Lynn and Ricardo in Barcelona,
June 1983. Photo by B. Dyer.



Cuba, October 1983. Photo courtesy of R. Guerrero.



Olga California, Ricardo and Lynn in Amherst (Lynn's home),
December 1990. Photo courtesy of R. Guerrero.



Zach, Lynn, Dany, and Ricardo near Marrakech, January 1993.
Photo courtesy of R. Guerrero.



A picnic with J.F. Crow in Amherst, June 1993.
Photo courtesy of R. Guerrero.



Sampling the microbial mats at the Ebro Delta. December 1997.
Photo courtesy of R. Guerrero.



Brooklin Botanical Garden, at Zach's wedding, August 1997.
Photo courtesy of R. Guerrero.



Pedralbes Monastery, Barcelona, November 2003.
Photo by M. Piqueras.



A windy day at the Giza Pyramids, Cairo, Egypt, January 2004.
Photo by M. Piqueras.



Awaiting the departure, Madrid, September 2009.
Photo courtesy of R. Guerrero.

TEACHING FOR SCIENCE, TEACHING FOR LIFE

Montse Vallmitjana

High school teacher, Barcelona

“For most of the history of life on this planet, the living landscape resembled a time-forgotten seashore. Although inconspicuous, life in the form of bacteria and their diverse communities changed forever the surface and atmosphere of the planet. Although tiny, early life was complex and original. In mudflats, evaporite expanses, fens, and ponds, microbes evolved innovations that we now associate with animals and plants”

LYNN MARGULIS, *Early Life*

A young Lynn Margulis first came to Barcelona in 1973, to attend the Fourth International Conference on the Origin of Life. For her, the conference “had nothing to do with the city,” but “everyone was very nice and it was a lot of fun.” In 1982, she participated, along with other leading scientists, in a conference on Darwinism, organized to commemorate the centenary of Darwin’s death and the opening of the new building housing the Faculty of Biology of the University of Barcelona. But it was at a dinner party held at the home of Joan Senén-Josa and his wife, Catherine, to which Antonio Lazcano, Marta Estrada, Montse Ponsà, Lynn, and I were invited, that I discovered her to be not only a highly intelligent sci-

entist and communicator but also a warm person with a wonderful sense of humor. Getting to know her was a great privilege and the beginning of a long friendship.

During that visit to Barcelona, I interviewed Lynn for *Ciència*, which at the time was the first and only popular science magazine published in Catalan, edited by Joan Senén-Josa. In that interview 30 years ago, Lynn talked about her research, the results of which

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ploides i generacions diploides. Aquest és el regne de les plantes i qualsevol ned de tres anys pot reconèixer el que és una planta i no té res a veure amb un microorganisme. També cal dir que és el regne més jove.

Ara tenim el quart gran regne, que és el dels fongs. Aquests tenen una manera diferent de viure. No tenen mai embrions, ni cilis ni flagels, les cèl·lules no són diploides sinó que són haploides i en el moment en què es troben en la fertilització, es tornen diploides, però immediatament fan una meïosi per esdevenir haploides. És el que s'anomena meïosi cigòtica. És molt fàcil dir el que són els fongs. Vosaltres, a Catalunya en teniu molts, i els mengeu quasi tots! I llegent, quan menja bolets, ho diferència de quan menja plantes o animals. Tenim, doncs, un regne diferent. Des d'

(ciència): — ¿Com queda, en aquest context, la divisió tradicional dels regnes, animal i vegetal, segons defensen?

driem anomenar el dels "cinc regnes" Primer hi ha un regne que inclou tots les cèl·lules procariotes, inclouent-hi les

Lynn Margulis interviewed by Montse Vallmitjana for the magazine *Ciència*. The interview was conducted in 1982 but published in 1983. Photo by G. Serra.

would later be expanded upon and supported: the theory of the origin of the eukaryotic cell by endosymbiosis; the emergence of life; the five kingdoms—four of them defined by cytology, ecology, and life cycle studies, and the fifth, the Protoctista.

Fortunately, in the following years Lynn would often come to Barcelona, to continue her collaboration with the Microbial Ecology Group at the Autonomous University of Barcelona. The group's director, Ricardo Guerrero, always made sure Lynn was aware of the attendance of many high school teachers at her lectures. Afterwards, in her humorous and affectionate way she always asked me "*Cómo está papá Vallmitjana?*" She was asking about my father, Lluís Vallmitjana, professor at the Faculty of Biology of the University of Barcelona. Lynn was quite familiar with his research on mitochondria and other organelles and on protozoa.

Through the powerful arguments laid out in Lynn's books, the scientific community became well acquainted with the undulipodia, Warrawoona, fossil bacterial stromatolites, and especially Protoctista, which we had previously referred to as protists (unicellular eukaryotes). From her we learned about microbial mats, depicted in photos of those formations at Shark Bay, Australia, and later on about the "Catalan spirochete" (*Spirosymplokos deltaiberi*), discovered at the Ebro Delta.

We were captivated by the image that later would provide the cover of *Five Kingdoms*, a hand showing the Earth with a kingdom on each finger. We watched films showing animals in symbiosis with green algae, among them the flatworm *Convoluta roscoffensis*, which contains the alga *Platymonas* in all of its cells. We talked about planets, reducing atmospheres, bacterial photosynthesis, and so much more. Many of her lectures began by asking us to consider the Earth

as seen from the Moon, or to imagine the biosphere, life, and time: three billion years of only bacterial life.

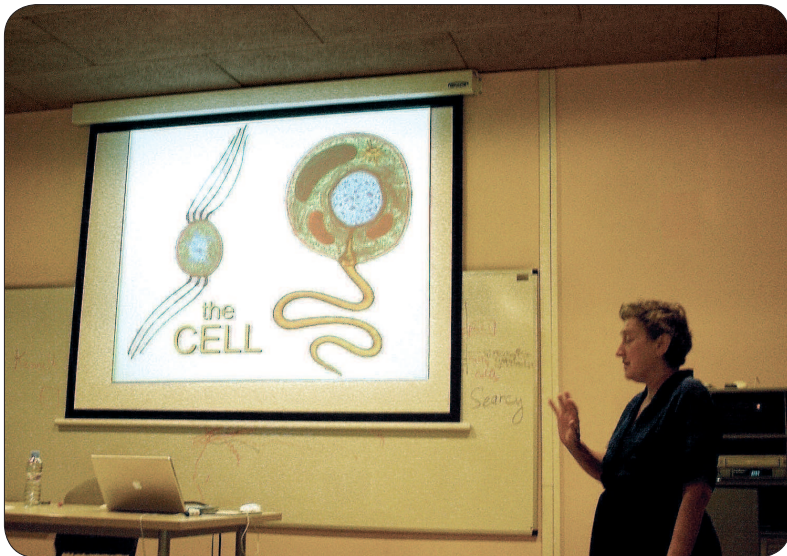
We not so-young high school teachers had been taught that life was about 600 million years old. At university we familiarized ourselves with the many amazing chemical reactions performed by bacteria, a classroom blackboard full of biochemical formulae. But all that information was without any further connection. Little information could be found in books about the many forms of bacteria (cocci, bacilli, vibrios, spirilla) or the diseases they caused. Algae, including the Cyanophyta (blue-green algae) were studied as such; living organisms were classified into three kingdoms (Monera, Plants, and Animals), and we were told that they had appeared and survived on Earth because it was a planet with oxygen in its atmosphere! Now,



Lluís Vallmitjana (center) at the Faculty of Biology of the University of Barcelona, with Lynn and Ricardo Guerrero. Photo courtesy of M. Vallmitjana.

and in large part because of Lynn's work and her advocacy of that of others, we know that the oxygen in the Earth's atmosphere is a byproduct of bacterial metabolism.

Recently, a friend noted that we will always be indebted to Lynn for providing us with an overview of life broad enough to encompass its history, microbial ecology, and endosymbiosis. Life had developed and it proceeded through evolutionary processes. Millions of years of life, allowing the diversification of bacterial metabolism, the appearance of oxygen in the atmosphere, giving rise to the eukaryotic cell and, finally, to multicellular beings. Over the last three decades, Lynn Margulis' ideas on endosymbiosis and the relationship of the biosphere to the environment (later included in the Gaia theory), the classification of living organisms, and the processes of speciation (symbiogenesis) have



Lynn Margulis during a lecture in Barcelona.
Photo by M. Vallmitjana.

become part of the standard high school curriculum.

Within a continuing education program, a group of teachers from the Catalan Society for Biology has been regularly organizing a series of lectures. We had invited Lynn to give a lecture in 2012. Sadly, it was not possible.

I will remember her showing one of her videos, passionately discussing spirochetes, or reciting a poem by Emily Dickinson in her distinct voice. But I imagine her on a remote beach, in the Proterozoic, walking in the sea, barefoot. ♣