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SLANTED TRUTHS OF LYNN MARGULIS

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The name of Lynn Margulis (1938-2011), a famous American naturalist, is one of the most recognizable in biological science. She was an iconoclast who E.O.Wilson called “one of the most successful synthetic thinkers of modern biology.” It is hard to tell which areas of natural science were not influenced by Margulis’s scientific and educational activity: from phycology to genomics, from medical biology to biogeochemistry. At the same time, hundreds of biologists across the world who knew Margulis called her simply Lynn.

She was an unusual person: at 14, enrolled in University of Chicago; at 19, married Carl Sagan, later a famed astronomer. All her life Lynn studied algae and other protists (in her terminology, protoctists). With her son Dorion Sagan, she wrote a number of popular books. Her major achievement in the 1960s was her celebrated theory of serial endosymbiogenesis – the origin of eukaryotic cells, or the abovementioned protoctists – through symbiosis of prokaryotes (bacteria). Her first, now classic, paper “On the origin of mitosing cells” (1967) was rejected by 15 journals; it grew later into a fundamental book, *Symbiosis in Cell Evolution* (Russian translation 1983).

Lynn’s sharply polemical papers such as her 1990s “Words as battle cries: Symbiogenesis and the new field of endocytobiology” awakened imagination. One of her latest books with Dorion Sagan, *Acquiring Genomes*: *A Theory of the Origins of Species* (2002) states that the main mechanism of evolution and speciation is not a slow accumulation of small mutations but genome exchange (horizontal transfer). As always in Margulis’s works, a reader finds in this book a “royal road” to the microcosm of bacteria and protoctists.

The latest work of Lynn and her collaborators, *Chimeras and Consciousness* (MIT Press, 2011), covers evolution of signals and interactions from viruses and bacteria to the Earth’s planetary biosphere. The biospheric, ecosystem level of symbiogenesis (Gaia, or Vernadsky’s biosphere) was another field in which Margulis worked for decades as one of the prominent scholars.

It was Lynn who organized the first full English translation of Vernadsky’s *Biosphere* book, published only in 1998. Earlier, in 1992, she encouraged a translation of another Russian monograph, by L. N. Khakhina, on the history of symbiogenetic studies in Russia. Such attention of Lynn to history of science and foreign studies (published not only in Russian, but also in German, Spanish etc.) was important and unusual. Since English became the lingua franca of modern biology, the Anglophone researchers usually do not know other languages.

I knew Lynn only for a few years but she made an indelible print in my life, which is true for any person she knew. Sadly, people of such temperament and energy level often burn fast.

I was privileged not only to meet Lynn several times, but also to work with her (largely by correspondence) in 2005-2010, on translation and publication of a book, *A new principle of biology: An outline of a theory of symbiogenesis* (1924). This is a classic and forgotten work of a Russian botanist Boris Mikhaylovich Kozo-Polyansky (1890-1957), published during NEP by a short-lived, private "Puchina" publishers, whose production mostly included science fiction. A copy that was once owned by A.S. Serebrovsky was found in the library of Institute of Cytology and Genetics in Novosibirsk. Translation took a couple of years. Lynn directly participated in the process of translation as a co-editor, meticulously helping to verify terminology and names, often obscure. She carefully watched and directed my adopted English to reflect old-fashioned academic narrative of Kozo-Polyansky but at the same time to be precise and understandable to a modern reader. The translation was published by Harvard University Press in 2010 under a title *Symbiogenesis: A New Principle of Evolution*.

This 2010 publication of *Symbiogenesis* was a special joy for Lynn. Her time was scheduled a year in advance. We agreed that when Kozo-Polyansky's book is published, she will visit our university to present it. Her visit in the end of September 2010 to West Virginia, to our Huntington (population 50,000) became an unforgettable feast of scientific thought. For many hours over two days, Lynn talked with our professors and students. She presented three talks, of which one was followed by videos of her other presentations, including Oxford debates with the famous ultra-Darwinist Richard Dawkins. This footage lasted for another two hours, and finally only a few best students and other curious local intellectuals. Some of them have been my students in Genetics and Evolution classes. In my 16 years of work at Marshall University this was, without a doubt, the most important visit by a scientific luminary.

The book was presented on 24 September 2010 in the university theatre, where not less than 400 people present—which is a lot for a biology event in a small American town. The university bookstore ordered 100 copies of *Symbiogenesis*, and after Lynn's presentation a line formed next to the stage for book signing. Lynn told me later that she never has had such a ceremonial event, as she never carried boxes of her books with her as "real writers" do.

During the presentation, I was sitting in the second row and did not expect that Lynn will call me to the stage. As she reached a slide with a 16-line Russian summary of Kozo-Polyansky's presentation on symbiogenesis at the Petrograd Congress of Botanists in 1921, Lynn unexpectedly asked me to come and translate these lines, which I did. The audience probably did not believe that this improvisation has not been staged in advance. In recent years, Lynn constantly quoted this summary: she liked how Boris Mikhaylovich, who favored "Hegelian" generalization, put forward his statement that two different things united in a system (hydrogen plus oxygen equals water) gives this system new properties, and therefore "missing links" often are absent. *Natura facit saltum* (Nature makes jumps), rephrased Kozo-Polyansky in 1921 an old saying "Nature does not make jumps (*Natura non facit saltum*). This was also a credo of Lynn Margulis herself, who was so glad when L. N. Khakhina found for us a copy of that 1921 page that could not be found in American libraries.

In his Introduction to our translation of *Symbiogenesis*, the great American botanist Peter Raven wrote: "Certainly the lack of appreciation of Kozo-Polyansky's concepts in Western Europe and North America stems partly from its extreme originality. But it also comes from the

inaccessibility we Anglophones have to foreign languages. In particular, we generally lack knowledge of Russian biological literature. Much credit is also due Lynn Margulis, who has devoted a lifetime to exploring the symbiotic nature of the complex cells". Raven further recalls: "In 1975 at the International Congress of Botany in Leningrad, a well-attended panel session about the origins of chloroplasts was arranged by Dr. Takhtajan—at the time the Director of the fabulous, extensive Leningrad Botanical Garden— to which I was invited. I had just written a paper arguing the multiple origins of plastids of the different colored algal lineages. I encouraged Lynn Margulis, then an assistant professor of the Boston University Department of Biology, to attend and present her ideas of symbiogenesis and plastid evolution. ... The final program was assembled by Dr. A. Takhtajan, the proper chairman, who became acutely aware that his Western guests (P.R. & L.M.) were profoundly ignorant of the symbiogenesis literature of the Russian botanists, especially one whom no one had even heard about, his mentor Boris Kozo-Polyansky…

Dr. A. Takhtajan scolded us: "You Anglophones believe you originated everything in botany and evolutionary science". He admonished me, "Here, read this." He thrust his minimal translation at me. And Dr. Takhtajan was correct! How arrogant of us to believe, especially at mid-twentieth century, when German science had dominated the nineteenth, that because we could read it, all important science was only in the professional literature of the English language! Now, 35 years later, finally we are able to respond to his admonishment!"

Another, still ongoing story, also Russia-related, has developed at the same time as the book translation project, in 2006-2008. Lynn asked me to serve as a liaison with Moscow microbiologists who discovered a special kind of bacteria in sulfuric mud of Staraya Russa (pictured as Skotoprigonyevsk in *Brothers Karamazov*). I helped to establish an "intercultural" connection with the Moscow group of G.A. Dubinina, translated their letters and presentations at a conference in Berlin in 2008. An article describing the new bacterium, a free-living spirochete, was finally published in 2010. According to Lynn's theory, such bacteria are similar to our faraway ancestors who formed eukaryotic cells via symbiogenesis. It therefore could be possible to discover, in our cells and genes, the traces of times long gone, the components that remain parts of us. This story is still unfinished, and the spirochete's genome study could confirm (or reject) the far-reaching, as always, ideas of Lynn Margulis.

Occasionally, Lynn even found time to answer good questions on Internet. In 2007, on one of the evolution blogs she was asked how common symbiotic relationships beyond the world of microorganisms are. She replied: "By no means are these ideas only in the microcosm. What is a cow (or a bison) unable to eat grass? A starved cow. What is a subterranean termite unable to eat and digest wood? A dead termite. Both these types of animals owe their existence to great communities of highly specific symbionts that digest their foodstuffs, make them change their bodies (over time, of course). The rumen, the hindgut. The literature is vast and so detailed that in 1924 Kozo-Polyansky wrote a book explaining this. He united Darwin's "natural selection (which only *eliminates* life forms, does not create them) with *symbiogenesis* that does create new species in the same genus. Other modes of species change include: polyploidy in plants, hybridization in marine larvae, karyotypic fissioning in mammals ... All are far more significant for the generation of new species than "random mutation". Of course random mutations hone and refine the bigger hereditary processes but there is no evidence I know of that proves that random mutation *generates* evolutionary novelty, i.e. new species."

In 2007, in their letter to "Nature", Lynn and her colleague Michael Dolan noted that "many have lost sight of the organismic biology forest for the molecular biology trees." Lynn herself preferred to be called a "naturalist" rather than a "biologist." Recall that when A.P. Chekhov and V.A. Wagner first planned to publish their *Priroda* journal they wanted to call it *Naturalist*.

One wonderful feature of the American academic system is that even famous scientists are not necessarily locked in their ivory towers but are welcomed to teach introductory college classes, and often, as in Lynn's case, consider it their duty. Her classes were attended by brilliant students, not only biologists but also chemists, geologists and astronomers.

Another field where Lynn contributed her time and energy was preservation of old instructional films on biology of algae and other protists, and transfer of this footage to digital format. Lynn created a special section for storage of such films in the US Library of Congress. In 1950s-1960s, there still were many experts on these groups in USA and elsewhere, and they helped to film life habits and behavior of various creatures. Today, with transition to computers, these films are not used anymore, and there are no projectors to show them. This wonderful evidence of microcosm's life could disappear. Russian universities, I suspect, also store hundreds of meters of such instructional films with commentaries of top experts.

In September 2009, Lynn was invited to speak at a Darwin conference in St. Petersburg, which celebrated at the same time Darwin's 200th birthday and 150th anniversary of his "Origin of Species". Lynn's plenary lecture was titled "Symbiogenesis, A New Principle of Evolution: Rediscovery of Boris Mikhaylovich Kozo-Polyansky (1890–1957)"; its text was published in 2010, in English, in *Istoriko-biologicheskie issledovaniya* [*Studies in Historical Biology*], St. Petersburg). Carefully recorded on video by her colleague James McAllister and reproduced from this recording, the lecture retains Lynn's direct speech, which one wants to translate in verse.

"I want to show you now the power of symbiogenesis. We begin with amber.... Here is a fossil termite, *Mastotermes electrodominicus*, that preserved so well that in the amber fossil record David Grimaldi (American Museum of Natural History, New York City) saw fossil muscle tissue at the light microscopic level! …So, Grimaldi said to us, since we see details of muscle tissue, why can we not also seek the termite's intestinal protists? And we did! We not only see protist fossils in *Mastotermes*, but we found the oldest spirochetes!

…Now I show you a video of *Mixotricha paradoxa*, a unique termite protist that lives only inside *Mastotermes darwiniensis*. We take a trip to Kakadu Park in northern Australia, near Darwin. Inside those termites, in 1956, Professor L.R. Cleveland photographed the organism you see here on 16-mm. black and white film… He had read that this *Mixotricha paradoxa* "protozoan" bears both cilia and flagella on its same cell. He did not believe that. …And we are now sure that these beating "hairs" are not cilia. They are spirochetes. The tiny surface spirochetes of *Mixotricha* are morphologically indistinguishable from *Treponema pallidum*, spirochetes of syphilis… This, in other words, is a motility symbiosis.

Five different kinds of spirochetes comprise the cell (Wenzel et al., 2003). In the posterior ingestive area are another set of endosymbiotic bacteria. Termites can eat wood, but they cannot digest it. Therefore the one *Mixotricha* cell equals approximately a total of nine different kinds of prokaryotic microbes comprising a single protist. One *M. paradoxa* cell is comprised of half a million individuals. Without the symbiotic associates, no termite digests wood. Here you see the large spirochete *Canaleparolina*, the treponema spirochetes, the protist with a large piece of

wood inside. When we say here is “one individual,” you Neo-Darwinists, where is your head?? I assume you are not laughing, because you don’t understand me? …The termite insect starves within about two weeks if we remove its bacteria and protists. …What, then, is the "individual" here? It is a community. Of course “group selection” occurs!

…New species in eukaryotes evolve primarily because ancestral ones acquire entire new genomes that, by many steps, integrate over geological periods of time. …The best contemporary work on this now is by microbiologists and agriculturally-oriented entomologists.

Perhaps you know the older book of Professor Soren Sonea *Une nouvelle bacteriologie*. His new book is called *Prokaryotology*. He’s a Romanian who has lived in Canada, in Quebec, for his entire professional life. He and his colleagues show that the bacterial genetic system is worldwide. When a bacterium is cultured in the laboratory, one deals with the “terminals” of the worldwide system of bacteria—the “terminals”, not the “computer” itself. In Sonea's metaphor the computer is outside, the "mainframe computer" dwells in nature.

Bacteria have access to huge numbers of bacterial genes. Indeed they may access any gene of another bacterium by means of transforming-principle DNA extruded into the environment, transduction by phage, conjugation, plasmid transfer and other “small replicon” or “genophore” unidirectional bacterial gene transfer. So we either have one worldwide species of bacteria or no bacterial species at all.”

Lynn saw a kindred soul in a great American poet Emily Dickinson (1830-1866). By chance or not, they were neighbors: Lynn’s house in Amherst, Massachusetts, is just next to Dickinson’s where a poet’s museum is now. A profound iconoclast and debater, Lynn used to quote Emily Dickinson’s lines:

> Tell all the truth but tell it slant,
> Success in circuit lies,
> Too bright for our infirm delight
> The truth's superb surprise;
>
> As lightning to the children eased
> With explanation kind,
> The truth must dazzle gradually
> Or every man be blind.

Two books of Lynn Margulis and Dorion Sagan have titles taken from this poem, *Slanted Truths* and *Dazzle Gradually*.

The *New Principle* of Kozo-Polyansky ends with emotional words combining Darwin’s quote with an apocryphal “Eppur si muove” of Galileo:

“Even today, for many, of course, the theory of symbiogenesis would seem paradoxical, moreover – improbable. But “when it was first said that the sun stood still and world turned round, the common sense of mankind declared the doctrine false.”

And yet it does move!”

Lynn Margulis, decades later, could repeat the same words.