# INTRODUCTION

## The Encounter

Between 1967 and 1970, NASA funded four annual conferences, organized through the New York Academy of Sciences, on the Origins of Life. Their format was conversational, reflecting the eminence of the central attendees, including Frank Fremont-Smith, Norman Horowitz, William McElroy, Philip Abelson, Sidney W. Fox, Leslie Orgel, and Stanley Miller.[1] A number of those present were already professional mentors or colleagues of Lynn Margulis, or would soon become so – Cyril Ponnamperuma, Elso Barghoorn, J. William Schopf, Joan Oró, and Philip Morrison. Margulis participated in all four meetings and was tasked to edit their transcripts into volumes (published between 1970 and 1973). The co-chair of these gatherings, Norman Horowitz, also happened to be Lovelock's colleague as the director of the biology section at NASA's Jet Propulsion Laboratory (JPL). This relationship likely had some role in Lovelock's invitation to the second Origins of Life meeting in May 1968. His attendance brought about his first encounter with Margulis: "Margulis, as the youngest member present, had the job of rapporteur. . . . Perhaps the task of reporting everything we said was onerous and she had no time or opportunity to think about it. Certainly, I had no contact or discussion with her at the meeting. My fruitful collaboration with Lynn was not to begin until some time later" (Lovelock 2000: 254).

Margulis at that moment was rapidly gaining professional momentum in her scientific career. She had always been precocious, entering the undergraduate program at the University of Chicago at the age of 15 and marrying Carl Sagan at 19, soon after receiving her baccalaureate degree in 1957. She gave birth to two sons while earning a master's degree in zoology and genetics from the University of Wisconsin in 1960 and a doctorate in genetics from the University of California, Berkeley in 1965. Margulis divorced Sagan that same year but maintained a professional relationship with him within the close milieu of NASA science. As it happened, Carl

[1] Biographical entries on professional colleagues will be footnoted or placed in the glossary of names.

Sagan was also an occasional attendee of the Origins of Life meetings as well as an occasional colleague of Lovelock's at JPL. Around 1970, Margulis had conceived research questions of her own regarding biological contributions to the planetary atmosphere. She asked Sagan whom to contact for expert opinion about the composition of the atmosphere, and he suggested Lovelock. Thus, when she wrote to Lovelock, initiating their correspondence in the summer of 1970, both parties had already had an opportunity to observe the other in professional action.

## Careers and Personae

### Lovelock

Lovelock often describes himself as both an "inventor" and an "independent scientist" (Lovelock 1979b, 2000). An inventor and engineer he certainly was. When his collaboration with Margulis began, Lovelock was a seasoned 52-year-old investigator, married to Helen Lovelock and the father of four grown children. Trained as an analytical chemist, he worked for 20 years (between 1941 and 1961) at the National Institute for Medical Research, an institute of the Medical Research Council, based in Mill Hill, North London, on various technical and scientific problems. One was the effects of heat and cold on living tissues and blood coagulation: his pioneer works in cryobiology – freezing hamsters and trying to resuscitate them – are still cited today. He studied the aerial transmission of cold infections and carried out various investigations into the biochemistry and biophysics of cells. While at Mill Hill, he invented numerous devices, from a pen able to write on cold and wet glassy surfaces to a sensitive anemometer for measuring the velocity of gases, leading to his utmost specialty, instruments for analytical chemistry – gas chromatography more specifically – that were able to detect and measure minute traces of chemical compounds. His most famous invention remains the electron capture detector (ECD), invented in 1957, which enabled the sensitivity of chemical measurements previously possible to increase by several orders of magnitude. This invention and his unique expertise in gas chromatography earned him an international reputation. Lovelock's taste for invention and engineering shows through the correspondence, for instance, when he begs to differ with "the comment 'you can't make a wristwatch to run on steam.' Want to bet? This is the sort of challenge that diverts me from other work" (Letter 99). On the strength of these accomplishments, in

1961 he left a comfortable salaried position at Mill Hill to establish himself as an "independent scientist."

An early instance of Lovelock's self-presentation as such can be found in Margulis's edition of the transcript from the 1968 Origins of Life meeting:

> I am not any sort of specialist. I guess I am a scientific general practitioner. This, of course, means that you cannot work in any institution anywhere, because there is no general practice in science. So I operate a one-man laboratory about 10 miles south of Stonehenge, which is both an observatory and a computer, and what more, really, could one want? (Margulis 1971c: 11).

Lovelock has enjoyed retelling the romantic story of a secluded scientist, retired far from the agitation of the world and "buried" in the countryside of Bowerchalke, where he could think more freely about Gaia, life, and nature. His 1961 invitation from NASA to work at JPL, on gas chromatographs for extraplanetary duty on landing modules, was certainly an important starting point for his professional establishment in this regard. But during this same period, an impressive number of both scientific institutions and private companies – primarily Shell and Hewlett Packard, but others on occasion, such as DuPont – hired Lovelock as a consultant. Over the next 20 years, these included the federal US scientific organizations of NASA, NOAA, and NCAR.[2] He was also employed in the UK by the secret service MI6. Original as it may seem to some, Lovelock's professional status was not that exceptional. As the historian Steven Shapin neatly documented, the status of "scientist entrepreneur . . . people with one foot in the making of knowledge and the other in the making of artifacts, services, and, ultimately, money" (Shapin 2008: 210) was literally booming right at that time, the paradigmatic example being the biotech startups in Silicon Valley. In many ways Lovelock fits neatly into this category (Briday and Dutreuil 2019, Dutreuil 2017). Other examples could be found within Lovelock's close circle, for instance, Archer Martin – Nobel prize winner, father of partition chromatography, with whom Lovelock worked at Mill Hill – who tried Lovelock's path of scientific independence for a while from the late 1950s onward (Lovelock 2004a), but with less success, and James Lodge, a chemist and colleague of Lovelock's at NCAR, who sought

[2] These acronyms and other instances of technical nomenclature are spelled out in the glossary of terms.

Lovelock's advice on establishing professional autonomy in the early 1970s (Dutreuil 2016).

For Lovelock, the label "independent" is important in two ways. On the one hand, it evokes his ideal of scientific activity, modeled on the nineteenth-century image of a solitary genius, a savant and inventor doing "small science," for instance, with equipment compact enough to carry into the field and transport around the world on one's own. What he despised was its obverse, the "big science" of the twentieth century, reduced to routine by collectives of functionaries in large civil institutions. On the other hand, without a doubt Lovelock was advertising his independent status in order to counteract the numerous accusations in the 1970s that targeted him with conflicts of interest. This line of defense would be especially important when Lovelock – who, thanks to his ECD, became the first scientist to measure atmospheric CFCs (chlorofluorocarbons) – started saying publicly, including in testimony on behalf of DuPont before a committee of the US Congress, contrary to alarms raised in other quarters, that the human release of CFCs was not imminently harmful to the ozone layer. In his own defense, Lovelock argued that the very diversity of his clients preserved his independence. He hired himself out too broadly to be accused of any singular conflict of interest, and he could drop any client or employer if he did not feel morally at ease with what was asked of him.

Nevertheless, just as it would be misleading to see Lovelock as a romantic thinker, retired in the countryside, so it would also be incorrect to see him as one of Shapin's "scientist entrepreneurs" whose ethos was "having fun, making money." Lovelock's goal has never been self-enrichment. He is as genuinely fascinated by and devoted to the natural world as the nineteenth-century naturalists. The passages in his autobiography describing how, with a guidebook in one hand and his chromatograph in the other, he would measure the chemical substances emitted by algae around his Irish cottage, are certainly revealing. But more telling than an autobiography – in which one consciously presents oneself to the public – is the private correspondence of this volume, as when he informs Margulis: "Helen and I also go to the beach and gather sea water and algae looking for sources of new and even stranger compounds coming from the sea; this I do not regard as work" (Letter 58).

For what matters in the context of this volume, it suffices to recall that Lovelock was neither outside the production of scientific knowledge, as some critical accounts that discounted the science of Gaia might suggest, nor outside the political, institutional, and academic world, as his narrative of independence might imply. During the heyday of his collaboration with Margulis, Lovelock was *the* international expert in gas chromatography. He had an intensely active scientific life with a strong empirical and engineering bent – measuring chemical compounds on oceanographic vessels crossing the Atlantic, in military planes sampling the stratosphere, and in the air of the English and Irish countryside; writing papers for *Nature* about these measurements; advising Shell in Thornton (UK) and HP in Avondale (USA) on engineering issues; writing on climate change, both internal reports for Shell and academic papers, and participating in major conferences on the topic; advising the British secret service how to detect explosives or track an individual through chemical marks; and keeping the accounts of his companies, Ionics Research and Brazzos Limited. Numerous letters document Lovelock's demanding travelling schedule. Margulis comments: "You love the remote countryside because you travel so much your life is too hectic otherwise" (Letter 61).[3]

**Margulis**

At the outset of her collaboration with Lovelock in 1972, Margulis was 33 years old, now married to crystallographer Nick Margulis, and the mother of four children from a toddler to a teenager. Five years earlier, after 15 rejections, she had published what would later be recognized as a landmark article, "On the origin of mitosing cells" (Sagan 1967). Within her dedicated biological specialization of microbial evolution, she had already published a book-length version of that article's thesis, *Origin of Eukaryotic Cells* (Margulis 1970a). This work is a remarkably monumental accomplishment for a debut volume in any discipline, documenting a steady command in the exposition of highly specialized content combined with the courage to synthesize and speculate. It develops what soon came to be called "serial endosymbiosis theory," an innovative account of the evolutionary assembly of the eukaryotic or nucleated cell from the merger of prokaryotic precursors. Margulis would become mindful how far out on another speculative limb Lovelock was taking her on what in 1973 he called "this Gaia adventure" (Letter 52). However, regarding serial endosymbiosis theory, as historian of biology Jan Sapp has summarized the matter, "the field of molecular evolution . . . closed the debate over the symbiotic origin of chloroplasts and mitochondria in the early 1980s" (Sapp 2015: 118) by cementing the key

[3] See also Letters 82 and 87.

components of Margulis's theory with evidence drawn from matching the genetic sequences of these eukaryotic organelles with their prokaryotic origins. While the evidence for other aspects of her entire theory – in particular, for the spirochetal origin of the mitotic apparatus – had not yet arrived, Margulis never gave up that search. At the end of an interview with Dick Teresi, published in *Discover* a few months before her death, he asked, "Do you ever get tired of being called controversial?" Margulis replied, "I don't consider my ideas controversial. I consider them right" (Teresi 2011).

The Gaia adventure Margulis embarked upon with Lovelock in 1972 became a lifelong side project flanking her dedicated research on the theme captured in the title of a co-edited essay collection, *Symbiosis as a Source of Evolutionary Innovation* (Margulis and Fester 1991). Her Gaia research was largely unfunded, save for occasions when she succeeded in bootlegging it into funded projects in "planetary biology" and "environmental evolution." For Margulis, too, Gaia was a staunch pursuit carried out alongside a range of teaching duties, regular research commitments, and professional initiatives in a hyperactive academic calling. For most of her university career, Margulis shouldered relentless teaching responsibilities and directed a research laboratory while mentoring scores of graduate students; her letters to Lovelock detail on occasion the exhausting schedule she maintained. She also arranged yearly field excursions to locations such as Laguna Figueroa in Baja California; chaired numerous professional, executive, and advisory committees; sat on the editorial boards of multiple academic journals; managed the creation and production of teaching materials such as booklets, audiotapes, and CD-ROMs; organized frequent professional symposia; and co-directed a legendary NASA-sponsored summer research and internship program, while also publishing a constant stream of professional articles and books and meeting increasing requests for her appearance on the domestic and international scientific lecture circuit. Her devotion of energies on behalf of Gaia is threaded through these many other activities and obligations.

The 1980s saw the publication of her first volumes co-authored with her son Dorion Sagan – their first book-length foray into popular science writing, *Microcosmos* (Margulis and Sagan 1986a), and a provocative co-authored offshoot of her research on early evolution, *Origins of Sex* (Margulis and Sagan 1986b). In 1993, she published the second edition of *Symbiosis in Cell Evolution* (Margulis 1993a). In her last two decades, Margulis continued to produce prolifically on multiple fronts, including Gaia. If we review, for instance, just a selection of her books and edited collections over this final period, her output is remarkable: *What is Life?* with Dorion Sagan (Margulis and Sagan 1995); *Slanted Truths: Essays on Gaia, Symbiosis and Evolution* with Dorion Sagan (Margulis and Sagan 1997); her memoir, *Symbiotic Planet* (Margulis 1998); second editions of *Diversity of Life: An Illustrated Guide to the Five Kingdoms* with Karleen Schwartz and Michael Dolan (Margulis, Schwartz, and Dolan 1999), *Environmental Evolution: Effects of the Origin and Evolution of Life on Planet Earth* with Clifford Matthews and Aaron Haselton (Margulis, Matthews, and Haselton 2000), and *Early Life: Evolution on the Precambrian Earth* with Michael Dolan (Margulis and Dolan 2002); *Acquiring Genomes: A Theory of the Origins of Species* with Dorion Sagan (Margulis and Sagan 2002); her second essay collection co-authored with Dorion Sagan, *Dazzle Gradually* (Margulis and Sagan 2007), her venture into literary fiction, *Luminous Fish: Tales of Science and Love* (Margulis 2007); and her last publication before the mortal stroke in 2011, *Chimeras and Consciousness: Evolution of the Sensory Self* with Celeste Asikainen and Wolfgang Krumbein (Margulis, Asikainen, and Krumbein 2011).

It's revealing to put all that alongside a message she sent in 1995 – capped with a postscript to Jim and Sandy Lovelock – to her partner, microbiologist Ricardo Guerrero, who was then hosting the Lovelocks in Barcelona. This epistolary occasion, meant primarily to bring Guerrero up to speed on her doings, provides a rare but telling view of her in-house academic tribulations as well as her own dedicated research in microbial evolution and eukaryotic microbes (protoctists) at that moment: "Both the National Academy and Lounsbery turned down (rejected) my request for funds. I am going to have terrible money problems for the next two years" (Letter 243). Nevertheless, her work needed to go on. She had to "do properly the chimeric model of the eukaryotic nucleocytoplasm: archaebacteria (*Thermoplasma*) + (eubacteria) *Spirochaeta* in detail since the data is coming in very quickly now. It is important to make people understand that protoctist symbionts aren't lichens." She wittily transformed the political slogan "power to the people" into "power to the protoctists," a shout-out to the most neglected and disrespected biological kingdom (with which, one imagines, she particularly identified): "Between the protein/nucleic acid sequence data and the fossil materials power can be delivered to the protoctists (both live and fossil) but no one can do this work for me" (Letter 243).

With regard to their respective careers, then, we think that it is worth recalling the impressive accomplishments Lovelock and Margulis had both already achieved when their collaboration began. Their actual professional standing contrasts with a typical account that puts Gaia outside the realm of scientific institutions (e.g., Postgate 1988). As Lovelock asserted to Margulis early on, "Gaia is no half-baked notion of a pair of amateurs to be demolished by the first glance of criticism" (Letter 50). However, we can note another aspect of the personae common to both Lovelock and Margulis: they both presented themselves as professional contrarians standing out from the usual fray. With respect to scientific institutions, Lovelock emphatically branded his "independent" status, to the extent that Margulis had to remind him that "the independent scientist" as a generic species was, like the unicorn, "an utterly mythical beast" with an "example of one: you" (Letter 156). Lovelock also assumed a contrarian stance toward those he called "the greens," in spite of his having entertained close ties with leaders of these heterogeneous movements, such as Jonathon Porritt, Edward (Teddy) Goldsmith, Satish Kumar, and Stewart Brand. And Margulis was able to position her combative character both as a woman holding her own in rooms full of men and as a scientist with strong views often at odds with mainstream positions within evolutionary biology and environmentalist circles.

## On the Materiality and Sociality of Collaborations

Studying the private correspondence between scientists enables historians to shed light on the material aspects of their collaboration: how often did they meet? What kind of documents and information did they exchange? Through which mediums? Most of the items transcribed in this volume originate from the last period in contemporary history when physical letters rather than emails record the exchanges between collaborating scientists. For instance, in both Lovelock's archives and Margulis's papers the gradual appearance of printed emails indicates their progressive replacement of letters and even faxes. The historical span of this correspondence from 1970 to 2007 allows one to question the significance of the medium conveying the content of the exchanges. Our impression, however, is that for these correspondents, the more recent emails do not differ in any crucial way from the earlier holograph and typewritten letters. In whatever medium, some are long and written with care to discuss scientific issues or technical and practical matters (bearing on measuring instruments or recent advances in computers, etc.); others are short and bear on the organization of collaborative activities, obtaining specific pieces of information, or sharing personal doings between friends. Occasionally the letters accompany the exchange of materials such as manuscripts, tables and diagrams, and 35-mm slides, the coin of the pedagogical realm before digital projection. The earliest years are marked by intensely active exchanges, with immediately following replies often crossing in the mail. Later periods experience occasional lulls. Sometimes the phone was preferred over letters, although as the correspondence shows, Lovelock developed a telephone phobia that hindered Margulis's prodigious dialing habit.

The correspondence reveals certain matters one would expect from any other candid scientific correspondence, things that go on "behind the scenes," common practices of working scientists, known to historians and sociologists of science but often concealed by idealist and naïve depictions of science in action. For instance, the letters show the strategies Lovelock and Margulis occasionally used to navigate around, and sometimes bypass, the perils of peer review.[4] The various materials of their correspondence also offer glimpses into the frequency and manner of their social encounters, enabling an appreciation of their differences in style. Margulis was continually around other people. She ran a lab with a constant complement of graduate students. She also delighted in gathering teams of colleagues to bring on elaborate trips to the field, usually to go microbe hunting. So, on the occasion of Lovelock's visits to the States, where he would combine appointments at HP, JPL, or NCAR with sundry meetings and conferences at other companies and universities, she would invite him to visit her lab or to come along on her excursions.

While Lovelock's own lab was truly a one-man operation, he did possess a "tribe" (as he would say) of close professional friends and colleagues, dispersed in universities on multiple continents and in the companies for which he worked. When it came to Gaia, Lovelock's manner was indeed tribal. He made strong demarcations between Gaia-friendly associates and those not so friendly, between critics of Gaia with whom it was acceptable to discuss the topic and others to be avoided. Lovelock would often invite persons from both receptive and wary camps to his place for the weekend, or longer for close friends. Margulis was herself a frequent guest, as much as her schedule allowed. Most of the scientific discussions would take place during walks (Merchant 2010). Besides the specific case of Margulis, to meet with people personally, and even more so at his own home, was a way for Lovelock to ease tensions and criticisms. As he confessed in an

4 A good example is Letter 42. On this score, see also further details provided by Betsey Dyer's article in this volume.

interview with one of us, when it comes to one's critics, it's easier to write nasty things about other people's ideas when you are not facing them (Lovelock, personal communication, during an interview with Dutreuil in 2016).

As Lovelock recalls in the interview with Merchant, "Gaia was very much a part-time job." As we have noted, so it was for Margulis as well: "During the 1970s and until 1982, when I fell ill, Lynn Margulis and I spent as much of our time developing Gaia as we could. Neither of us received support for our work, and both of us were busy with other work. Lynn had her teaching and other duties at Boston University, and I had my customers" (Lovelock 2000: 260–261). And in the mid-1970s, as we will go on to detail, Lovelock found himself distracted from Gaian matters by his immersion in the "Ozone War." This is not to say that Gaia was of secondary importance for Lovelock: notwithstanding his "hectic" life, he considered Gaia of the utmost importance, as the correspondence testifies: "It would be lovely to be able to concentrate on a good book on Gaia and not be pressured by a lot of bread and butter tasks to pay the way" (Letter 161). Thus, we can think of their Gaia collaboration not as a primary, unique, and central preoccupation, but rather, as something that became essential to pursue even while it also had to be fitted in among many other commitments and preoccupations. For example, for most of the 1980s, Lovelock also had to deal with the progression of his wife Helen's multiple sclerosis, ending with her death in February 1989.

Lovelock's subsequent marriage to Sandy Orchard shortly thereafter coincided with his oft-expressed desire to withdraw somewhat from the usual professional fray and with his concern to insulate himself from the growing clamor of media interest: "We have changed our unlisted number repeatedly, but always it reaches the pests, the intrusive media people and other nuisances that we both know" (Letter 190). Finding herself behind the same barriers, Margulis complained to Lovelock that she felt personally cut off. He replied: "Dear Lynn, please don't assume that my desperate attempts at a quiet life are meant to exclude you" (Letter 190). Lovelock's excuses appear to have appeased Margulis at that moment: "Stay well and avoid the vultures" (Letter 191). But such difficulties eventually became endemic. Her later letters expressed unrealized hopes to recover opportunities for the fertile exchange of ideas that marked their collaboration in the 1970s. Margulis continued to struggle with these new circumstances in Lovelock's affairs, but the social conditions of their working relationship were now irrevocably changed.