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On the Plausibility of Intelligent Life on Other Worlds

A Cognitive-Semiotic Assessment of $f_i \cdot f_c \cdot L$

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Abstract The apprehension of the last three factors of the Drake equation, $f_i \cdot f_c \cdot L$, is misguided or at least not very well examined. This article scrutinizes the underlying suppositions involved in the search for extraterrestrial intelligence (SETI) research. What is meant by "intelligence," "technology," and "civilization"? What makes them possible, and how do they evolve? The present examination aims to arrive at a more well-founded search for extraterrestrial intelligence that takes into account current research within cognitive science, the history of technology, and the history of socialization. What we need is a cognitive-semiotic approach to the extent, distribution, and evolution of extraterrestrial intelligence. The three variables $f_i \cdot f_c \cdot L$ concern how an extraterrestrial biosphere evolves cognitively flexible organisms that, through a biocultural coevolution, acquire an increasing capability to manipulate the surrounding environment for the purpose of transferring shared mental states. In addition, this has to last for a period of time long enough to coincide with the relatively brief existence of *Homo sapiens sapiens*.

Keywords civilization, cognition, communication, Drake equation, evolution, intelligence, sociability, technology

Introduction

The Drake Equation

The idea that there might be intelligent life in outer space can be traced back to our earliest times.[1] The possible existence of extraterrestrial intelligence has stretched our imagination and our conceptions of what it is to be a thinking, self-conscious, living being. Scientific discoveries and explanations since the sixteenth century have given support to the idea that life can exist beyond Earth; think of the heliocentric worldview

1. Dick, *Plurality of Worlds*; Dick, *Biological Universe*; Guthke, *Mythos der Neuzeit*; Crowe, *Extraterrestrial Life Debate 1750–1900*; Crowe, *Extraterrestrial Life Debate, Antiquity to 1915*; Dunér et al., *History and Philosophy of Astrobiology*; Vakoch, *Astrobiology, History, and Society*; Dunér, Malaterre, and Geppert, "History and Philosophy of the Origin of Life."

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and early modern telescopic observations, and more recently, the studies of extremophiles on Earth and the discovery of thousands of exoplanets. An active search for artificial signals in space that might be proof of an intelligent alien civilization has been performed since the early 1960s. The departure point of this search is that electromagnetic waves, particularly extraterrestrial artificial radio emissions, would be possible to detect, as it was explained by Giuseppe Cocconi and Philip Morrison in a 1959 *Nature* article.[2] The American astronomer Frank Drake soon thereafter launched the Ozma project, which began the quest for artificial extraterrestrial radio waves. To capture the fundamental factors involved in the possibility and extent of alien technological civilizations in the universe, Drake formulated in 1961 his so-called Drake equation.[3] The equation provides a probabilistic model to estimate the number of actively communicating extraterrestrial civilizations in our galaxy, in a reductionist attempt to break it into smaller parts (or variables). It is commonly formulated as:

$$N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

N is the number of civilizations that release detectable signals in our galaxy. The first four factors are all within the natural sciences: (R^*) is the rate of formation of stars suitable for the development of intelligent life; (f_p) the fraction of stars with planetary systems; (n_e) the number of planets, per solar system, with an environment suitable for life; and (f_l) the fraction of suitable planets on which life actually appears. It is not impossible to give rough estimations for the values of these respective factors, perhaps except for f_l. For the purposes of this article, however, I exclusively focus on the last three factors: (f_i) the fraction of life-bearing planets on which intelligent life emerges; (f_c) the fraction of civilizations that develop a technology that releases detectable signs of their existence into space; and (*L*) the length of time such civilizations release detectable signals into space. These factors we know very little about, due to, of course, the fact that we only know of one example of a technological civilization: our own. And what complicates things further is the fact that the Drake equation is not just about possible intelligent life forms out there but also about ourselves and our ability to perceive and interpret our surrounding world or, in phenomenological terms, our Lifeworld. As we go further to the right in the equation, the variables become more local, complex, and uncertain. The complexity of the last factors follows from their dependence on the particular local environment and its history. An estimation of the factors on the left are to a large extent determined by predictable cycles or events, for example, astronomical, geological, and climatological circumstances. Those on the right, however, relate to stochastic events that are not so much based on geological or biological premises as on cognitive, cultural, and social grounds. All the seven factors are, of course, expressions

2. Cocconi and Morrison, "Searching for Interstellar Communications."

3. Drake, "Search for Extra-terrestrial Intelligence"; Schuch, "Project Ozma"; Vakoch and Dowd, *Drake Equation*.

of and shaped by human cognition, history, and culture. In this article I restrict myself, for the time being, to the last three, which pretend in the same way as the former to be scientifically well-defined, but are actually not.

Agenda

The apprehension of these last three factors of the Drake equation, I contend, is misguided and not very well examined. We need to scrutinize the underlying, often unconsidered suppositions involved. What do we mean by "intelligence," "technology," and "civilization"? And what makes them possible; how do they evolve? As Nathalie Cabrol has argued, we need to broaden our understanding of the evolutionary and systematic components in the search for extraterrestrial intelligence and revaluate concepts that are taken for granted.[4] Here I will go a step further by emphasizing the need for cognitive semiotics and allied research fields. The search for extraterrestrial intelligence is not just a scientific problem. The last three factors, in contrast to the first four, are all within the domain of the humanities and the social sciences, particularly cognitive science, the history of technology, and the history of socialization. If we ever want to solve these problems, I strongly suspect we need to turn our attention to research within the history and philosophy of astrobiology, and take contemporary research in cognitive science, linguistics, semiotics, and history (to name just a few relevant research fields) into account.

So, what are we presupposing when we, human beings, are searching for "extraterrestrial intelligence"? What, exactly, are we searching for? Basically there are four characteristics of possible extraterrestrial life forms that we have in mind and that are presumed in our search. We assume that "they" are "intelligent," "social," "communicative," and have "technology." To some extent we actually search for ourselves, for an intelligent life form similar to us, something to which we can relate and establish a mutual understanding. We assume that they are social beings willing to communicate and intelligent enough to be able to invent advanced technology for interstellar communication. It is also assumed that we, the receivers, can decode these interstellar messages. Search for extraterrestrial intelligence (SETI) research has mostly focused on the detection methods (especially radio and optical searches), rather than seriously addressing the question of who and what extraterrestrial intelligence could be, which in turn would direct us to where and how we should search for it.[5] The question here is: what are intelligence, sociability, communication, and advanced technology in the first place? Why do we have these abilities, and why should they have them? And finally, how have these characteristics of intelligent life evolved? In what follows I address these questions; I thus aim to arrive at a more well-founded search for extraterrestrial intelligence which—and this is crucial—takes current research in cognitive science, the history of technology, and the history of socialization into account.

4. Cabrol, "Alien Mindscapes."
5. Ibid.

The Cognitive Semiotics of Extraterrestrial Intelligence

This article outlines a cognitive-semiotic approach to the extent, distribution, and evolution of extraterrestrial intelligence. By cognitive semiotics, I understand the study of meaning-making structured by the use of different sign vehicles and the properties of meaningful interactions with the surrounding environment, both with the physical and the social environment.[6] Cognitive semiotics is a synthesis of theories of meaning production and approaches to the embodied mind. It incorporates perspectives, theories, and findings from semiotics, cognitive science, phenomenology, evolutionary theory, and other fields. As such, cognitive semiotics rests on the supposition that meaning-making creatures use abilities that have evolved through millions of years of cognitive-semiotic evolution.

A key concept here is that of biocultural coevolution, that is, the idea that meaning-making is a result not just of a natural, biological-genetic evolution but also of a cultural evolution, and of the incessant interaction between the mind and its environment.[7] Cultural evolution could be explained as the transmission of learned behavior and knowledge that is not biologically encoded or, in other words, the ability to transfer information that does not use the genetic code for its transfer but is learned, taught, and transmitted by a multitude of communicative and cultural devices and artifacts, like language, signs, pictures, sounds, objects, and so on, from generation to generation. This biocultural coevolution of cognition is what can explain the emergence of advanced cognitive skills. Central here is the view of the mind as embodied, situated, enactive, and distributed, in other words, the coevolution of cognition and environment. Mind is thus a product of the interaction between the body and the surrounding environment, both the physical and the cultural environment. My hypothesis is that the very specific coevolution of cognition and environment, and the stochastic events it is subdued to, determines the emergence of a particular intelligent species on a particular exoplanet. The random nature of biocultural coevolution would most likely result in very distinct and unique forms of cognition in outer space. The stochastic events in the history of a species will give each intelligent life form its unique fingerprint. If this is correct, the extraterrestrial intelligences we might encounter one day and their respective thought processes would be completely alien to us.

The search for life in the universe has to a great extent highlighted how strongly the evolution of life and environment are intertwined,[8] and that the coevolution of life and environment determines the uniqueness of an extraterrestrial life form.[9] The same could be said of cognition and environment. We should search not only for

6. Sonesson, "New Considerations"; Zlatev, "Cognitive Semiotics: An Emerging Field"; Zlatev, "Cognitive Semiotics"; Dunér and Sonesson, *Human Lifeworlds*.

7. Richerson and Boyd, *Not by Genes Alone*.

8. Golding and Glikson, *Earliest Life on Earth*; Cabrol, "Alien Mindscapes."

9. Watson, "Coevolution of the Earth's Environment and Life"; Kooijman, "On the Co-evolution of Life and Its Environment"; Dietrich, Tice, and Newman, "Co-evolution of Life and Earth"; Irwin and Schulze-Makuch, "Assessing the Plausibility of Life."

environmental habitability but also for "environmental cogitability." Biocultural coevolution, in respect to long-term processes and different environmental pressures, will probably make extraterrestrial cognitive abilities and intelligence very different from ours. Cognition is an adaptation to, and is formed by, the specific environment and its history. SETI research is to a large extent an endeavor to understand how intelligent life interacts with its environment and communicates information about this interaction to the wider world.

My argument rests on the conviction that we need to focus on the cognitive-semiotic foundations of interstellar communication, and that cognition and communication are results of a particular biocultural coevolution that takes place in a specific habitable, extraterrestrial environment. The cognition of an extraterrestrial life form is adapted to a specific environment, and the way this cognitively skilled organism expresses and communicates its thoughts, perspectives, and interpretations of its environment is a result of its specific biocultural coevolution. The mathematical, logical, and technological search for interstellar messages are of limited use if we do not take the cognitive basis of intelligence in space, the emergence and evolution of cognitive capacities, how meaning-making works, and the cognitive, cultural, and societal requisites for a sustainable advanced technology into account.

The Fraction of Life-Bearing Planets on Which Intelligent Life Emerges, f_i

To get a grip on factor f_i, the fraction of life-bearing planets on which intelligent life emerges,[10] we need to scrutinize more closely what "intelligent" life is and also look into the conditions of its "emergence." So the problem is twofold: we need to know, first, what abilities characterize intelligence and, second, what evolutionary scenarios make it possible. In my view, cognitive science can give us valuable indications.

Astrocognition

Elsewhere I have discussed the significance of cognitive science as a tool for understanding the cognitive challenges the human mind faces in space and the cognitive foundations of interstellar communication.[11] In the present article, I emphasize the role of evolutionary cognitive science and cognitive semiotics in apprehending what it means to be "intelligent" and why advanced cognitive skills emerge under particular environmental circumstances. The field of astrocognition, first discussed in 2011,[12] deals with these questions, that is, cognition in extraterrestrial environments and the emergence of cognitive abilities through evolutionary processes in different habitable environments.[13]

10. Crowe, "Fraction of Life-Bearing Planets"; Marino, "Fraction of Life-Bearing Planets."

11. Dunér, "Astrocognition"; Dunér, "Cognitive Foundations of Interstellar Communication"; Dunér, "Introduction"; Dunér, "Extraterrestrial Life and the Human Mind"; Dunér, "Interstellar Intersubjectivity."

12. Dunér, "Astrocognition."

13. See also Osvath, "Astrocognition."

In general terms, the multidisciplinary field of astrocognition could be defined as "the study of the origin, evolution and distribution of cognition in the Universe." While astrobiology searches for the necessary and sufficient conditions for life in the universe, astrocognition goes further and seeks the necessary and sufficient conditions for awareness and self-awareness, or in other terms, cognition. In terms of astrocognition, "cognition" can be described as the ability of processing sensory inputs for action in the environment. In connection to f_i are two specific questions in astrocognition. As mentioned above, what is cognition (or intelligence), and what is needed for higher cognitive skills to evolve? Or, to be a little more specific, what physical, biological, societal, cultural, and other environmental factors shape cognition? In the following, I will give some tentative answers to these questions. My argument starts from a fundamental premise, which I refer to as the evolutionary astrocognitive premise: "Cognition in the universe develops through evolutionary processes of adaption to a specific, but changing, environment and the challenges it presents."

Intelligence

What is intelligence? When we search the skies for extraterrestrial intelligence, we should have at least some ideas of what kind of phenomena we are looking for.[14] Within the SETI community this question has been overlooked. The Drake equation and much SETI research have adopted an operative, pragmatic understanding of "intelligence," and just look for a civilization able to transmit electromagnetic waves. "Intelligence" is, in that narrow sense, "the ability to transmit electromagnetic waves." This is of course not what we mean when we recognize something as "intelligent" in ordinary life. Nor is it sufficient to help us understand the distribution of intelligence in space. If we want to detect content-rich and meaningful signals from an extraterrestrial civilization, it is not enough that the "intelligent" being is able to construct advanced devices; it should also be able and willing to communicate, that is, to share experiences through a medium.

The definition of intelligence has commonly been connected to problem solving.[15] As such, intelligence is understood as the ability to solve problems, to make rational choices, to reason logically, to handle the constraints and limitations of time, space, and materials. However, this is not enough to explain the development of advanced technology. As a broader concept, cognition includes not only the abilities that we call rational, logical, or intelligent. An important part of what it is to be intelligent is having emotional skills, a capacity to emotionally appraise the relevant environment with attraction, disgust, and so on, and to respond to socializing, bounding, coupling, and so

14. Chick, "Biocultural Prerequisites"; Marino, "Landscape of Intelligence"; Ruse, "Klaatu Barada Nikto"; Schneider, "Alien Minds."

15. Sternberg, *Beyond IQ*; Sternberg, "Search for Criteria."

on, in a social group. By this, I mean that intelligence is an efficient strategy for coping with not only the physical but also—importantly—the social environment.

There are two features (among many other possible ones) of an "intelligent" life form that are particularly important. First, it can imagine things not existing, that is, things, events, and so on, not present in time or space right in front of the thinking subject. Second, an intelligent being is also able to engage in intersubjective interactions, understand other minds, imagine and envision what they will do, what they feel, and how they reason. To be intelligent is to have intersubjective skills, to be able to understand and make inferences about other minds. If the extraterrestrial being that we encounter is lacking these two abilities, it would probably not have complex communication and advanced technology, and we would not be able to communicate with it. Without the ability of imagining nonexisting things, it would not be able to construct abstract concepts, anticipate future needs, and invent new technology. Without intersubjective skills it would not be able to collaborate to achieve shared goals.

"Intelligence" could be explained as a kind of cognitive flexibility, an ability to adjust to changes in the physical and sociocultural environment. It is an evolved mental flexibility required to survive and reproduce within a specific environment. This includes the capabilities of representing activities and making inner models of reality and other minds. "Extraterrestrial intelligence" is actually a rather misleading and narrow concept, referring, for the most part, to problem solving and rational reasoning skills, and not to those mental abilities (e.g., intersubjectivity) that are indispensable for a life form to have civilization, culture, and technology. Thus, instead of searching for extraterrestrial intelligence, we should search for extraterrestrial cognitive flexibility. We should search for a certain cognitive flexibility that is a result of a more or less unique adaptation to the specific habitable environment in which it has its origin.

Evolution

We now come to the question of the evolution of cognition. Due to changing environmental pressures on other planets, sometimes similar, sometimes utterly different from those that formed life on Earth, we cannot presume that extraterrestrial life would follow the same path as terrestrial life. Why a life form evolves advanced cognition needs to be explained. Complex cognitive skills are not necessary features of a living creature in order to sustain life. Advanced cognitive processing is costly, energy consuming, and not necessarily the most efficient way of securing the continuing survival of the genes of an organism. However, it is evident that cognitive flexibility has evolutionary benefits and is a good strategy for adapting to a changing environment. Intelligence or cognitive flexibility has thus emerged through an evolutionary process due to its benefits for survival, orientation, and adaptation to a variable environment in a Darwinian struggle for existence. Intelligence is thus the ability to respond to changes in the environment with flexibility and success, and a plasticity of learning, that is, being able to learn from experience, whether your own or that of others.

Thinking has an evolutionary origin,[16] and as such, cognition largely evolves as an adaptation to certain problems that the ancestors of a particular organism had faced during the evolution of the species. That is, first, the cognitive processor of the organism is adapted to the physical and biological environment of their celestial body in order to understand and interpret, interact and deal with, and orient itself in the particular physical and biological environment, in relation to its specific conditions, such as planetary orbit, gravitation, light conditions, atmosphere, radiation, temperature, chemistry, geology, ecology, and biota. Second, the cognition of an organism is also adapted to the mind and culture of its conspecifics in order to understand and interact with other individuals, to understand emotions, thoughts, and motives, and so on, in a psychological and sociological interplay that forms that particular "exoculture."

Cognitive flexibility has emerged through a biocultural coevolution of embodied minds due to its benefits for survival, orientation, and adaptation to their changing physical and sociocultural environment. Extraterrestrial minds, like terrestrial minds, have adapted to their specific environment and the specific social interactions between the minds of their species. If we can come closer to an understanding of the processes behind the rapid brain evolution that began a few million years ago on Earth—the encephalization in the Phanerozoic—we can use this knowledge to formulate astrocognitive theories.[17] The evolution of human intelligence is part of a general process of greater encephalization,[18] or the increase of brain size relative to body size over time. The evolution of cognition is not fully elucidated, but it seems that the orientation in the social environment has played a particularly important role with regard to encephalization. According to the social-brain hypothesis there is a correlation between the size of an animal's social group and the size of its brain, leading to the conclusion that social behavior drives encephalization.[19] The benefits of living in social groups, according to Dunbar, are that they provide defense against predators and enhance the defense of resources.[20] A huge part of brainpower is thus used for handling social relations and mutual interactions within a group.

Sociability

A congregation of a number of individuals, call it a "social group" or a "society," has evolutionary benefits for the individuals as well as for the entire group. The efficiency with which social organisms manage to collaborate—their sociability skills—increases their chances for survival. The complex social structure of the group is probably a very important driver for the emergence of intelligence, greater brain size, and communicative complexity. The brain has increased in capacity in order to tackle different kinds of

16. See, e.g., Gärdenfors, *How Homo Became Sapiens*.
17. Carter, "Hominid Evolution."
18. Bogonovich, "Intelligence's Likelihood."
19. Dunbar, *Grooming, Gossip, and the Evolution of Language*; Dunbar, "Social Brain Hypothesis."
20. Dunbar, "Brains on Two Legs"; Chick, "Biocultural Prerequisites."

social relations. Complex social worlds are like selective environments, driving species toward increased cognitive processing ability that then leads to higher social complexity, and when social complexity increases, it gives rise to a greater selection pressure on individuals for cognitive skills; that feedback in turn produces even more social complexity and so on.[21] In complex social systems "individuals frequently interact in many different contexts with many different individuals, and often repeatedly interact with many of the same individuals over time."[22]

In short, intelligent species are social species. Sociability and the social context enhance the adaption to the physical environment and make the individuals less vulnerable to a hostile environment. These social skills cannot subsist without a cognitive capacity to understand, feel, and share experiences with other minds. Beings, which we would recognize as intelligent in outer space, would be aware of themselves and of other minds, and be able to share experiences, actions, information, and mental content. In other words, an extraterrestrial being technologically capable of transmitting and receiving interstellar messages would have intersubjective skills. In contemporary cognitive science, intersubjectivity has become a key concept for understanding not only empathy and altruism, but also intelligence, sociability, and communication.[23] In its most general definition, intersubjectivity can be explained as the "sharing of experiences about objects and events."[24] To be more precise, Zlatev and colleagues describe intersubjectivity as "the sharing of experiential content (e.g., feelings, perceptions, thoughts, and linguistic meanings) among a plurality of subjects."[25] Intersubjectivity, as I myself have argued, is an indispensable requisite for the evolution of intelligence, sociability, communication, and advanced technology.[26]

An extraterrestrial life form that we could recognize as "intelligent" is in some way or another social, able to handle complex social relations, and would have intersubjective skills to interpret, envision, and share the behavior and mind of others. A cognitively flexible organism is as such multi-adaptable to different physical and social environments.

Communication

Communication can be regarded as a sharing of mental states, while its expression can be seen as information about a mental state.[27] The encoding of a message by the

21. Bogonovich, "Intelligence's Likelihood."

22. Freeberg, Dunbar, and Ord, "Social Complexity as a Proximate," 1785; Freeberg, Ord, and Dunbar, "Social Network and Communicative Complexity."

23. Gillespie, "Intersubjective Nature of Symbols"; Hrdy, *Mothers and Others*; Gillespie and Cornish, "Intersubjectivity"; Tylén et al., "Language as a Tool"; Fusaroli, Demuru, and Borghi, "Intersubjectivity of Embodiment"; Gentilucci et al., "Intersubjectivity and Embodied Communication Systems."

24. Brinck, "Role of Intersubjectivity," 116.

25. Zlatev et al., *Shared Mind*, 1.

26. Dunér, "Interstellar Intersubjectivity."

27. Østergaard, "Imitation, Mirror Neurons."

producer is followed by a decoding by the recipient.[28] As such, communication involves interpretation, where the interpreter endows the message with meaning. Communication is not about "things out there"; it is about our conceptualization of the things "out there," or rather our phenomenological experiences of the Lifeworld. According to the "social complexity hypothesis" for communication, "groups with complex social systems require more complex communicative systems to regulate interactions and relations among group members."[29] Social complexity, in other words, leads to communicative complexity. Elsewhere I have discussed the cognitive foundations of interstellar communication and maintained that communication is based on cognitive abilities embodied in an organism that has developed through an evolutionary and sociocultural process by interacting with its specific environment.[30] One of the most crucial cognitive abilities for language acquisition is intersubjectivity. Communication presupposes shared knowledge, or perhaps better, shared experiences.

In order to develop more complex forms of communication, a social organism needs not just attention, imitation, mimetic skills, and iconic signs; but it also needs to be able to use symbolic signs. Symbols, that is, conventional or arbitrary signs that are detached representations, are dependent on culture and social interaction.[31] If the extraterrestrials are intelligent, they probably have some kind of symbolization abilities and abstract thinking detached from the environment, with which they can reason about things nonexistent, nonpresent, senseless, timeless, and abstract. In other words, to reach a higher degree of communicative complexity, they need signs where the expression is separated from the content. In other words, they need symbols.

To sum up, intelligence could be regarded as a cognitive flexibility that enhances the survival of a Darwinian creature. It has evolved due to an adaptation to a changing environment, both the physical and social environment, through a biocultural coevolution. One of the most important abilities of a cognitively flexible creature is intersubjectivity, the ability to understand other minds. This explains the degree of its social and communicative complexity and these, in turn, are fundamental requisites for the emergence of advanced technology.

The Fraction of Civilizations That Develop a Technology That Releases Detectable Signs of Their Existence into Space, f_c

The next factor in the Drake equation, f_c, the fraction of civilizations that develop a technology that releases detectable signs of their existence into space,[32] gives rise to at least two fundamental questions: first, what is technology? And second, what makes it

28. Saint-Gelais, "Beyond Linear B."

29. Freeberg, Dunbar, and Ord, "Social Complexity as a Proximate," 1785.

30. Dunér, "Cognitive Foundations of Interstellar Communication"; see also Arbib, "Evolving an Extraterrestrial Intelligence"; Holmer, "Greetings Earthlings!"

31. Saussure, *Cours de linguistique générale*.

32. Raulin Cerceau, "Fraction of Civilizations"; Shostak, "Fraction of Civilizations"; Frank and Sullivan, "New Empirical Constraint."

possible for an intelligent being to develop advanced technology? In other words, what cognitive abilities are needed for a living organism to be able to manipulate its environment, that is, to develop technology? Here we gradually move from the biocultural coevolutionary to cultural evolutionary explanations, from evolutionary cognitive science to social cognition and the history of technology. The factor f_c actually concerns the cultural evolution of technical civilizations. Technology, resting on specific cognitive abilities, is to a large extent a social phenomenon, a product of cultural evolution. The cultural aspects of SETI have been extensively discussed by John Traphagan, who has developed an anthropological perspective.[33] Here, I stress the importance of cultural-evolutionary processes and the learning and teaching aspects of culture; I am interested in how experiences, motives, and practices can be transferred from one generation to another.

Technology

Within the SETI community advanced technology has often been understood heuristically as "technology for interstellar communication." Behind the SETI conception of technology is the view of advanced technology as an applied science, as a product of the rational, inventive mind. This is of course a very narrow definition of technology that does not fully explain what technology is, why we have it, and where it comes from. In a more general sense, I would rather describe technology as ways of manipulating the surrounding world, using objects in the environment outside the body in order to enhance given capacities, such as body strength, perception, and cognition. Technology gives the intelligent organism the capability to manipulate the environment in order to make it easier to live in it and to adapt the environment to fit the organism, instead of adapting itself to the environment.

To answer the question of how an advanced technology might evolve, we have to turn to studies in the evolution of cognition, how hominids began using and manipulating their environment, and to studies in the history of technology, how the cultural evolution of *Homo sapiens sapiens* made it possible to achieve higher technology.[34] Culture, the ability to learn from others within a society of high social and communicational complexity, is what made advanced technology possible. The rise of civilization involved closeness, interaction of many individuals, and exchanges of ideas, products, and experiences that paved the way for a technological society.

Advanced Technological Civilizations

Interstellar communication is not just a kind of advanced tool-making exclusively conditioned by physical or biological factors.[35] There are, I maintain, three socio-cognitive

33. Traphagan, *Extraterrestrial Intelligence*; Traphagan, *Science, Culture*.

34. Donald, *Origins of the Modern Mind*; Tomasello, *Cultural Origins*; Steels, "Social and Cultural Learning"; Richerson and Boyd, *Not by Genes Alone*; Dennett, "Evolution of Culture"; Rospars, "Trends in the Evolution of Life."

35. Cf. Casti, *Paradigms Lost*; Chick, "Biocultural Prerequisites."

capacities that characterize advanced complex technology and that are crucial for the development of it: first, a sustainable complex social system, with a regulated system for collaboration, such as ethics; second, complex communication for collaboration and abstract conceptualization; and, third, a high degree of distributed cognition. All these capacities require intersubjective skills.

Cooperation within a complex social system is what makes higher technology possible. This requires some fundamental cognitive and communicative functions. Cooperation involving detached, nonconcrete goals requires, primarily, advanced coordination of individuals' inner worlds, that is, intersubjective skills. In order to achieve advanced technology within a civilization, individuals have to cooperate in joint activities where they are sharing goals and attentions. By coordinating their roles when working toward a specific goal, they achieve a joint intention. To this we can add that they must be able to engage in prospective planning, to anticipate the future, that is, have the capacity to represent future needs; in other words, it requires prospective thinking or "mental time travel."[36]

A complex communicative system is needed in order to handle the social complexity, to facilitate collaboration, and to transfer information between individuals; these are requisites for the innovation, development, and maintenance of complex technology. A communicative system must enable its users to construct abstract concepts and symbols, to generalize, to discuss things and events that are not present in one's immediate environment, that have ceased to exist, and have not yet come into being.

Important for the emergence of advanced technology is also the organisms' degree of distributed cognition, that is, the ability to use external objects and/or other minds to enhance thinking.[37] The mind is extended to the environment, and the environment takes an active role in driving the cognitive processes.[38] The ability to construct external cognitive artifacts is significant in human cognition.[39] These organism-independent artifacts or exograms compensate for the limitations of the biological memory, and could be regarded as an externalization and materialization of memory.[40] Distributed cognition strengthens the organism's inborn sensory equipment and gives it a set of devices for thinking. A cognitively flexible organism uses the environment to think with and distributes its thinking to physical objects, but also to other minds. An advanced technological civilization cannot rest on the cognitive flexibility of a few individuals; as many of its members as possible must share their knowledge, cooperate, and complete different specialized tasks.

36. Suddendorf and Corballis, "Mental Time Travel"; Roberts, "Mental Time Travel."

37. Hutchins, "How a Cockpit Remembers."

38. Clark and Chalmers, "Extended Mind"; Clark, *Supersizing the Mind*.

39. Norman, "Cognitive Artifacts"; Norman, "Cognition in the Head"; Malafouris and Renfrew, *Cognitive Life*; Malafouris, "Linear B."

40. Donald, *Origins of the Modern Mind*; Donald, "View from Cognitive Science"; Donald, "Exographic Revolution."

To conclude, if there were intelligent beings able to communicate with advanced technology, they would probably have a complex social system, complex communication, and a high degree of distributed cognition. A requisite for social and communicative complexity is intersubjectivity. A technologically advanced civilization could then be described as a social and communicative organization that facilitates cooperation, and regulates and prevents conflicts. Thus it achieves specific joint intentions for the manipulation of its environment as an adaption of itself to the prevailing physical conditions or as a way of adapting its environment for its own purposes.

A civilization with advanced technology is a complex social system, which entails a high degree of communicative complexity and a high degree of cognitive flexibility. Such a socially complex extraterrestrial civilization would have many individuals rather than few; a high rather than low density; many different, specialized roles rather than few roles; and an egalitarian structure rather than a hierarchical structure. Many individuals entail greater collective brainpower. A high density entails more frequent and faster interactions between individuals. Many different member roles entail a distributed and specialized cognitive processing. And finally, egalitarian societies have greater diversity of directional relations. These four characteristics of social complexity will enhance the emergence of advanced technology.

The Length of Time Such Civilizations Release Detectable Signals into Space, *L*

Factor *L*, the length of time civilizations release detectable signals into space,[41] has to do with survival, sustainability, and societal organization. It is about how an extraterrestrial intelligent life form can create a sustainable society in equilibrium with the physical and biological environment so that it can survive for a time period long enough to significantly increase the probability of detection. Another way of formulating *L* is as the number of Earth years that a cognitively flexible extraterrestrial life form with advanced capability to manipulate its environment can manage to maintain a social organization that enables it to voluntarily transmit electromagnetic radiation that we can detect. *L* is often regarded as the most difficult factor in the Drake equation to estimate.[42] We know only one global advanced technological civilization—ours—and we have not yet seen the end of it. The difficulty has to do with the fact that not only do we lack empirical data about other technological civilizations, but also we are dealing with very complex questions about how self-conscious beings organize their social structure.

The attempt to estimate *L* is essentially a historical problem that confronts us with sociocultural issues concerning how advanced social systems are organized, what social and cultural factors make them possible, and what factors are involved in their eventual breakdown. By merely using the term *L*, we imply a particular time concept and

41. Chick, "Length of Time"; Dunér, "Length of Time."

42. Shostak, "Value of 'L'"; Dominik and Zarnecki, "Detection of Extra-terrestrial Life"; Penny, "Lifetime of Scientific Civilizations"; Denning, "'L' on Earth"; Dunér, "Length of Time."

understanding of historical change: that time is linear; that it has a beginning and an end; that there was a time before civilization and a time after; that time has a direction; and that civilization is something that evolves and progresses cumulatively. As such, the factor *L*, as it is used in the Drake equation, leans on a long human history of understanding time and historical change. In the prehistory of *L*, thoughts about the rise and fall of civilizations nearly always have included beliefs and statements regarding the meaning of history, and the idea that there is a certain teleology embedded in time. The question is whether our way of understanding *L* is still permeated with a search for meaning, direction, and teleology. Rather, we need to reflect on what make us able to think about *L* in the first place. The answer lies in its prehistory.

L on Earth

The rise and fall of civilizations is a question entirely within the scope of history.[43] By "history" I here understand the cultural change of an organism over time. In the human history of conceptualizing the brief time of humanity's being and its civilization, humans have asked themselves some of the great existential questions: Where do we come from? Who are we? Where are we heading? Searching for extraterrestrial life and intelligence, and the origin of life within the astrobiological endeavor, is a modern expression of this seemingly eternal pondering over the brevity of life and civilization. The factor *L* reflects the human understanding of civilization as something that has a beginning and an end, and a number of fundamental philosophical, conceptual, and ontological-metaphysical questions. What are time, history, culture, and civilization? *L* raises historical questions: when did it all start, and how do advanced societies and empires develop? *L* is also about social issues: how are communities organized, how are they maintained and developed, and how do societies handle crises?[44] My aim here is, of course, not to give an answer to these "eternal" enigmas. Instead I want to emphasize that the comprehension of time that underlies the *L*-factor is very much a product of human understanding and historical discussion in a particular era where this particular hominid species happens to inhabit this particular planet. As historical beings we are trapped in our own history, in the biocultural coevolution of our species. Our time concept is to some extent an adaption to our physical and cultural environment.

This is not the place for recapitulating the prehistory of *L*.[45] I here just wish to highlight some characteristics of human conceptions of the longevity of civilizations. Characteristic of the understanding of history in the Western tradition (to which the Drake equation primarily belongs) is the search for meaning, a purpose, and an assumption that there is a teleological direction to the world. Historical events cannot be a sequence of random coincidences. Western historical understanding of the rise and fall

43. Dunér, "Length of Time."
44. Vakoch and Harrison, *Civilization beyond Earth*.
45. See instead Dunér, "Length of Time."

of civilizations, about the temporality of civilization includes: first, notions of the beginning of time, or the dawn and age of the world; second, the direction of time, ideas about how societies emerge, the rise of civilizations, and the notion of advancement; and, third, notions concerning the end of time, the meaning of history, and how and why civilizations or the whole world collapse, often intimately associated with how its members live and act and how the civilization succeeds in managing physical and social threats. *L* in the Drake equation is in line with the conception of time in the Western, modern culture in which it originates—this time is viewed as linear, progressive, teleologic—not circular, open-ended, with no beginning, no end, no direction.

Longevity of Civilizations

The sustainability and continuous survival of a complex social system depends on the flexibility to adapt itself to changing circumstances. Threats to a civilization, in particular, expose the deficiency and inability to cooperate in order to fend off global crises. Civilizations are challenged by external or internal threats, and are exposed to both exogenic and endogenic risks. Theories of external threats emphasize external forces of nature that are stronger than the technological society, such as volcanic eruptions, earthquakes, asteroids, or the real or imagined external threats from alien civilizations. Internal threats—which have dominated much of human historical understanding—on the other hand, emphasize the actions and behaviors of the members of the civilization; here the downfall is a consequence of a malfunctioning society, for example, a society where ethical standards have broken down. As Arnold J. Toynbee famously declared, after he examined how successfully twenty-six different civilizations responded to physical or social challenges: civilizations do not die by murder, but by suicide.[46]

An extraterrestrial civilization capable of transmitting messages for a long period of time, and which has perhaps more advanced technology than we have, must have survived and been capable of recovering from the various disasters and crises it had to confront during its history. These crises may be similar to those that earthlings face—wars, climate change, pollution, decreasing biodiversity, and so on. A technological civilization is perhaps likely to generate an environmental disequilibrium that reverberates across its biosphere and endangers the habitability of its planet. The mere fact that they have survived would indicate that they have a functioning social structure that can handle and avoid crises (or at least that they are able to recover from them), and that they have a complex social system that regulates risks and destructive behavior. To develop advanced technology for destruction is arguably less cognitively demanding than to come up with a consensus ethics for survival. It is easier to understand the laws of physics and chemistry than to understand and predict self-conscious minds and the complex social and cultural interactions of conscious minds. The question of the *L*-factor, the life span of advanced technological civilizations, deals with this

46. Toynbee, *Study of History*.

bottleneck.[47] Longevity, sustainability, and technological growth as well as regulatory systems for behavior (ethics) are linked together.[48] Civilizations develop technology for destruction before they develop a sustainable ethics. If a civilization has advanced technology, which needs cooperation between large numbers of individuals, they have to be able to trust each other; some sort of ethical consent needs to have been established. *L* reflects the idea that civilizations come to an end unless members develop a social system that enhances their ability to cooperate for survival.

The longevity and the rise and fall of specific cultures on Earth will—for obvious reasons—not give us the answer. They are too dependent on human and earthly conditions that are unique to the thinking species that inhabit Earth and certain stochastic events during its history. Civilizations, cultures, and empires in the plural sense are something other than civilization as a singular. But there are certain general phenomena involved in the longevity of civilizations that might give us some clues. The factor *L* can be regarded as a measure of the civilizing or socialization process, and the variables that underlie it, that is, the biocultural coevolution and the interaction between the evolution of cognition and socialization.

The lifetime of an advanced technological civilization seems to be connected to how cognitively flexible creatures are able to control the power of their technology, find equilibrium with their environmental resources, and organize their society in such a way that its breakdown is prevented. In order to deal with destructive behavior within a society, an advanced technological civilization must have advanced intersubjective skills to understand other subjects; must have a high degree of communicative complexity to sustain and strengthen the intersubjective interactions between its members, including long experience of communicating with a diversity of groups and species; and must have arrived at some sort of reliable regulation system for behavior, or what can be called "ethics." *L* is, in other words, about how a congregation of cognitively flexible Darwinian organisms successfully manages the discrepancy between its capacity for manipulating its environment and its regulatory system for collaboration: *L* is a measure of this ratio.

Conclusion

To conclude, the variables $f_i \cdot f_c \cdot L$ are about how an extraterrestrial biosphere evolves cognitively flexible organisms that through biocultural coevolution obtain an increasing capability to manipulate the surrounding environment for the purpose of transferring shared mental states that last for a period of time long enough so it will coincide with the brief existence of the terrestrial species *Homo sapiens sapiens*. Deliberately, I have not attempted to give any qualified estimations of these factors. One of the arguments

47. Sagan, *Communication with Extraterrestrial Intelligence*; Shostak, "Value of 'L'"; Denning, "'L' on Earth."

48. Cf. Traphagan, "Equating Culture."

of this article has instead been to emphasize the crucial role of cognitive semiotics and allied research fields. We need further research in astrocognition, regarding f_i, about the evolution of cognition and its dependence on the specific environment to which the organism has adapted. We need further research, regarding f_c, on what cognitive abilities, what cultural, social, and communicative requisites are crucial for advanced technology to appear. And finally, concerning *L*, we need to know more about what cognitive abilities, what cultural, social, and communicative requisites are crucial to maintain a sustainable civilization.

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