Journal
World Cultures eJournal, 18(1)

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Publication Date
2011-02-22

Peer reviewed

Biocultural Prerequisites for the Development of Advanced Technology[1]

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In 1961, astronomer Frank Drake developed an equation to permit the estimation of the number of extraterrestrial civilizations in our galaxy via the quantification of what he felt to be relevant factors. Drake's equation contains two terms, f_i and f_c, that refer, respectively, to the fraction of planets that harbor intelligent life and the fraction of those with intelligent life that develops a technology that would allow communication with other worlds. These are two of the most difficult terms in the equation to estimate and, not surprisingly, a relatively wide range of values has been offered for each. Estimates of the values of the terms depend on a number of conjectures and assumptions. These include aspects of embodiment, such as sensory modalities and faculties to manipulate the environment, and aspects of culture that seem to be crucial for the development of advanced technology. However, the only data on technological development that we have available is from Earth. Several terrestrial species use technologies, although all of these are very simple with the exception of those created by humans. Similarly, a variety of species are now also claimed to have culture, depending on how it is defined. The purpose of this paper is to examine how embodiment, culture, and their interaction, based on their Earthly manifestations, might affect the values of f_i and f_c.

Keywords: Technology, SETI, cultural evolution.

1. INTRODUCTION

In 1961, Frank Drake attempted to quantify the number of civilizations capable of interstellar in the Milky Way galaxy. To do so, he proposed the following equation,

$$N = R^{*} \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

where:

N is the number of civilizations in our galaxy capable of interstellar communication.

R* is the rate of star formation per year in the galaxy

$\mathbf{f_p}$ is the fraction of stars with planets

$\mathbf{n_e}$ is average number of habitable planets per star with planets

$\mathbf{f_l}$ is the fraction of habitable planets that develop life

$\mathbf{f_i}$ is the fraction of planets with life that develop intelligent life

$\mathbf{f_c}$ is the fraction intelligent civilizations able (and willing) to communicate

L is the expected lifetime of such civilizations

There are several excellent on-line calculators for the Drake Equation but the one from the NOVA "Origins" series (PBS 2004) is especially attractive and user-friendly. These calculators permit the interested to plug in their own estimates for the parameter values described above. This is good, clean fun but it also suggests a problem. The problem is this: are the parameter values in the Drake Equation any more than just guesses? Are they even "informed guesses?" In an address at the California Institute of Technology in 2003, science fiction author Michael Crichton claimed, with regard to the Drake Equation, that

> This serious-looking equation gave SETI a serious footing as a legitimate intellectual inquiry. The problem, of course, is that none of the terms can be known, and most cannot even be estimated. The only way to work the equation is to fill in with guesses. And guesses–just so we're clear–are merely expressions of prejudice. Nor can there be "informed guesses." If you need to state how many planets with life choose to communicate, there is simply no way to make an informed guess. It is simply prejudice.

Crichton went on to claim that, since the Drake Equation cannot be tested, SETI is therefore not science but based on faith. Therefore, for Crichton, SETI is religion, not science. One of my goals here is to demonstrate that it is possible to bring some relevant data to bear on the issue of extraterrestrial intelligence. For better or worse, there seems always to be some element of faith (in assumptions, in methods, etc.) in science but, given certain assumptions (i.e., the Principles of Mediocrity and of the Uniformity of Nature), SETI can be grounded in science, as well.

2. DRAKE PARAMETER ESTIMATES

Equation parameters have been estimated numerous times using a variety of methods from pure guessing to various sorts of statistical analyses. The initial estimates by Drake and his colleagues at for the equation parameters were:

- $R^* = 10$/year
- $fp = 0.5$
- $n_e = 2$
- $f_l = 1$
- $f_i = 0.01$
- $f_c = 0.01$
- $L = 10$ years

These estimates result in a value of 0.01 for N.

Sagan (1980), using his redefined variables, provided the following estimates:

- $R^* = 4 \times 10^{11}$
- $fp = 0.33$
- $n_e = 2$
- $f_l = 0.33$
- $f_i = 0.1$
- $f_c = 0.1$
- $fl = .01$

These estimates result in a value of approximately 1.3×10^7 for N, one rather wildly different from the early estimate by Drake and his colleagues. Drake's current estimates, according to the PBS NOVA Origins series (2004), are:

- $R^* = 5$
- $fp = 0.5$
- $n_e = 2$
- $f_l = 1.0$
- $f_i = 0.2$
- $f_c = 1.0$
- $fl = 10{,}000$

These values give an N of 10,000 communicating civilizations in the Milky Way galaxy.

The difficulty with these estimates is precisely that they are estimates. Are there any empirical ways in which these can be enhanced? The purpose of this paper is to examine some things that we know in order to narrow estimates of two of the most intractable terms in the equation, f_i and f_c. First, I will look at how other terms have been estimated.

The equation has been presented in different forms over the last 50 years and a host of interpretations and estimates for its parameters have been proposed. For example, R* is generally defined as the rate of star formation per year in the galaxy. However, it is also defined as the rate of formation of *suitable* stars, meaning sun-like stars rather than red giants, for example. Estimates range, therefore, from about 20 stars of all sorts to 1 sun-like star per year. Carl Sagan (1980:299) defined R* as "the number of stars in the Milky Way Galaxy," rather than as their rate of formation. Obviously, there is a huge difference between the rate of star formation and the number of stars in the galaxy, a discrepancy that would profoundly influence the results of the equation.

When R* is defined as the rate of star formation per year in the galaxy or the rate of suitable star formation in the galaxy, we do know something about its approximate value and most estimates have converged on values between about 5 and 20. We are much less certain about the other parameters. As for f_p, the first confirmed exoplanet, with approximately 1.5 times the mass of Jupiter, was found orbiting the star 51 Pegasi in October 1995. Since then some 526 extra solar planets have been confirmed as of February 4, 2011 (The Extrasolar Planets Encyclopedia 2011). NASA's Kepler mission team located the first confirmed rocky planet orbiting a star other than the sun. Named Kepler-10b, it was found based on data gathered by the Kepler space telescope between May 2009 and January 2010 and is approximately 1.4 times the size of Earth (NASA 2011a). Kepler-10b's orbit takes less than a day, indicating it is more than 20 times closer to its star than Mercury is to the sun and, therefore, blazing hot and uninhabitable. On February 1, 2011, NASA's Kepler team reported finding an additional 1,235 possible planets orbiting stars other than the sun. Of these, 68 are 1.25 times the size of Earth or smaller and 54 are within the "habitable zone," where temperatures are such that liquid water could exist on the surface of a planet. Five of those are "near Earth-sized" (NASA 2011b). While it will take years to confirm the status of these candidates, statistical tests suggest that 80 to 95 percent are likely to be planets rather than due to measurement error.

While no verified Earth-like planets have been found so far, a system that has at least some solar characteristics has been identified. In June 2002, Geoffrey Marcy of the University of California at Berkeley and Paul Butler of the Carnegie Institution in Washington announced that the star 55 Cancri has a planet approximately 3.5 to 5 times as massive as Jupiter orbiting at a distance of about 500 million miles, just over the average distance of Jupiter to the sun (483,630,000 miles). The 55 Cancri system has four additional planets, the innermost being slightly smaller than Jupiter and orbiting about 10 million miles from the star while the second is about .25 the mass of Jupiter and orbits about 23 million miles from the star (Fischer et al. 2008). This is important because Jupiter almost certainly plays a key role in the development of life on Earth as its enormous gravity likely guards the inner planets from cosmic debris, such as comets. On the other hand, Jupiter may have also disrupted an asteroid from the asteroid belt, sending it on a collision course with Earth that ended the reign of the dinosaurs 65 million years ago. The demise of the dinosaurs, but not small mammals, may mean that intelligent life (us) developed here that might not have otherwise.

The sun is often referred to as an "average star" in the popular press. However, this is somewhat misleading. The sun is classified on the Hertzsprung-Russell (H-R) Diagram as a type G2V star. The H-R Diagram is a plot of star color (an indicator of surface temperature) versus luminosity (indicating intrinsic brightness). The resulting graph shows star color, temperature, luminosity, spectral type, and evolutionary stage (but does not indicate the frequency of the types). A G2V star, like the sun, is a main sequence yellow dwarf and is relatively uncommon as up to 90% of the approximately 200-400 billion stars in the Milky Way are (Type M) red dwarfs (Turnbull 2004) while Sun-like, or G stars, comprise only about 5%. Red dwarfs, both smaller and cooler than the sun, emit large bursts of X-Rays but not much ultraviolet radiation. The former is not favorable for life as we know it while the latter may well be essential.

Nearly 10 years ago, Lineweaver and Grether (2003) suggested that at least 20% of sun-like stars have planets. The number of planets found in the interim implies that the percentage may be higher. Henry (2005) proposed that more attention be paid to M type stars because, while their habitable zones are very narrow, there are so many more of them than G type stars that the odds of M type stars having planets in the habitable zone are fairly high.

While the definition of f_p, is relatively undisputed, Weisstein (2005) replaces n_e with n_{lz} and defines it as the number of planets per star in the habitable zone for 4 billion years, giving such planets approximately the amount of time that earth has had to evolve intelligent life. Definitions of the other terms are relatively agreed-upon although Sagan (1980:299) replaced L with f_l and defined it as "the fraction of a planetary lifetime graced by a technological civilization." Again, this change would have a major effect on the outcome of the equation.

The value of f_l, the fraction of hospitable planets that actually develop life, has generally thought to be very high, usually 1. Given that life developed on Earth relatively soon after it cooled enough to permit liquid water and that life on Earth inhabits a very wide range of ecologies, this estimate seems very reasonable. The estimates of f_i and f_c, however, are even more uncertain than those for any of the previous terms in the equation.

3. ESTIMATING f_i

The Principle of Mediocrity holds that the Earth, the solar system, our location in the Milky Way, the Milky Way Galaxy, and its location in the universe are not special in any sense (in contrast to the anthropic principle, the idea that everything must be exactly as it is for our existence and, since we exist, it is that way) (Darling 2005a). Hence, the Earth is representative of other earth-like planets in other sun-like solar systems, and so on. So, while any data we can bring to bear on f_i is based on a sample size of only one, it is nevertheless valid and reliable. But what evidence do we actually have, based on Earth's circumstances? How many "intelligent" species are there, and have there been, on Earth?

Intelligence

What is intelligence? Like many, if not most, constructs in the social and behavioral sciences, the nature of intelligence has been under scrutiny for a century or more and no single, universally agreed-upon, definition presently exists. In a general sense, however, two definitions seem to cover the territory. The American Psychological Association offered the first in 1995:

> Individuals differ from one another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought. Although these individual differences can be substantial, they are never entirely consistent: a given person's intellectual performance will vary on different occasions, in different domains, as judged by different criteria. Concepts of "intelligence" are attempts to clarify and organize this complex set of phenomena.

A second definition, in a statement signed by 52 scholars with expertise in intelligence and related fields, was first published in Tuesday, December 13, 1994, issue of *The Wall Street Journal* in response to exchanges over Herrnstein & Murray's book, *The Bell Curve* (1994):

> Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings—"catching on", "making sense" of things, or "figuring out" what to do (Mainstream Science on Intelligence 2005).

Additionally, intelligence is very commonly addressed from a psychometric perspective; that is, intelligence is effectively what is measured on intelligence tests such as the Sanford-Binet, the Weschler Adult Intelligence Test, and so on. Scores on such tests, which translate to measures such as *IQ* (Intelligence Quotient) or *g* (General Intelligence), tend to be highly reliable but their validity has often been questioned. That is, do they measure the range of what should be thought of as intelligence? Largely in response to this issue, psychologists, such as Howard Gardiner (1983) and Robert J. Sternberg (1985) have proposed theories of multiple intelligences, each of which individuals may have in greater or lesser quantities (or qualities?). Sternberg (1985) proposed a triarchic theory of intelligence wherein intelligence involves the degree to which individuals adapt to environmental changes throughout their lifespan. The three aspects of intelligence in his theory are analytic, creative, and practical. Of these, only the analytic aspects of intelligence are regularly addressed by intelligence tests. A simple distinction between analytic and practical questions is that the former typically have one "right" answer while the latter may have several adequate responses. In his theory of multiple intelligences, Gardiner included verbal-linguistic and mathematical-logical intelligence, similar to what traditional intelligence tests measure. In addition, he included visual-spatial, body-kinesthetic, auditory-musical, inter- and intra-personal communication for a total of seven "intelligences" (sometimes "naturalism" is included as an eighth). Gardiner argues that psychometric tests ignore aspects of intelligence beyond the verbal, logical, and some aspects of spatial both because of the questions addressed in the test and how they are administered (i.e., pencil & paper or by computer).

There is an enormous literature on the nature of intelligence and its measurement. The question here, however, is what sort of intelligence do we have in mind when we talk of extraterrestrial intelligence? While Gardiner's theory of multiple intelligences lacks wide support (some of what he calls "intelligences" [e.g., body-kinesthetic, auditory-musical] are called "skills" by others), Sternberg and others feel that intelligence cannot be reduced to a single number such as *IQ* or *g*. If they are correct, what sort of intelligence would extraterrestrials require in order to develop a technological civilization capable of interstellar communication?

Which Earthly Animals are Intelligent?

Given the two general definitions of intelligence above and the possibility of various sorts of multiple intelligences, which animals do we regard as the most intelligent? Normally, we tend to be very anthropomorphic about this and regard the most intelligent animals to be those that are most like us. This means that we consider great apes (chimpanzees, bonobos, gorillas, orangutans) to be quite intelligent. Since, as will be shown below, we regard tool use as a sign of intelligence, and each of these species has been seen to use tools (the gorilla being most recently observed using tools in the wild), they are pretty smart in our book. Cetaceans (dolphins, whales, porpoises) are generally regarded to be very bright, as well, although tool use in nature among these species (in the bottlenose dolphin) has been observed only recently. All mammals appear to engage in at least some to relatively extensive pre-adult learning from parents and others. Some birds, such as the crow or parrot, appear to be precocious. The African grey parrot, for example, seems to be remarkably adept at both (human) linguistic and cognitive activities. Cephalopods (octopus, squid, cuttlefish, nautilus) are the most intelligent of non-vertebrates. Indeed, researchers claim to have observed play behavior, a strong correlate of cortical development (Chick 2002), in the octopus (Service 1998, see Burghardt 2005 for possible examples of play among various other animal classes).

Given their close genetic relatedness to us, we can reasonably assume that the nature of chimpanzee and gorilla intelligence, for example, is similar to our own. But what of dolphin intelligence or octopus intelligence? Does the notion of a dolphin *IQ* or *g* in an octopus make any sense? If we apply Gardiner's theory of multiple intelligences to dolphins or octopi, we might make a case for both having very high body-kinesthetic and visual-spatial intelligence. Dolphins may also rate highly in terms of intra- and inter-personal communication and, certainly, auditory-musical intelligence. They may also do reasonably well in terms of mathematical-logical intelligence. Since we have been unable to decipher their "languages" of whistles, clicks, and so on, it is difficult to assess their verbal-linguistic intelligence, if it even makes any sense to consider it.

What Good is Intelligence?

Another not insignificant problem is that we are unsure of both why and how we ended up being as intelligent as we are. Although the exact course of human evolution is open to debate, one clear feature of the earliest to present hominids is increasing brain size and complexity. Why that happened is far less clear although theories abound. It is obvious that intelligence is not required for evolutionary success if measured either in terms of the number of individual organisms or in biomass. The biomass of Antarctic krill (*Euphausia superba*), for example, is estimated to exceed that of humans by about a factor of 2 (500 vs. 250 million metric tons) and in sheer number by a factor of perhaps 2,300 to 1 (Wikipedia 2011). According to the U.S Census Bureau, the total population of the Earth is projected to be 6,896,856,946 on January 30, 2011, at 5:24 EST. In comparison, one estimate puts the number of arctic krill at 150 million million (Low Life 2005). Oceanic bacteria comprise perhaps 150 times the biomass of humans and, given their size, many orders of magnitude greater in number. Neither krill nor bacteria are especially intelligent, however.

Nevertheless, intelligence has undoubtedly helped our evolutionary ancestors in the struggle to survive given that humans are not naturally particularly well armed. Indeed, there is now only one human species despite evidence that two or more may have existed simultaneously at one or more times in the past. Moreover, over the past few decades, we have all but exterminated our less well-endowed hominoid relatives (as well as numerous other species). Nevertheless, the primary human-like adaptation after the ancestors of both humans and chimpanzees diverged seems to have been an upright stance, not intelligence. Indeed, some estimates place an upright stance some 2 million years prior to encephalization (e.g., White, Suwa, and Asfawa 1994) and half a million years prior to tool manufacture and use (Semaw et al. 2003). The key here, by the way, is *manufacture* and use as all other extant hominoids use tools but do not necessarily manufacture them.

Flinn, Geary, and Ward (2005) provide an excellent review of theories of why hominids developed high intelligence and find little evidence for the majority of them. Environmentally based theories, for example, fail to explain why other animals that faced ecological problems similar to those likely confronting early humans did not evolve similar cognitive abilities. Intelligence as a social tool explanations ran into similar problems. Social group size and brain size correlate across many taxa (Kudo and Dunbar 2001; van Schaik and Deaner 2003) and hominid group size was probably about the same as that of other extant hominoids (Flinn et al. 2005). So why did other social species not develop high intelligence? Flinn et al. (2005) suggest that Alexander's (1989, 1990) ecological dominance-social competition hypothesis offers a solution. Briefly, Alexander theorized that hominids became the "ecologically dominant" species, meaning that selection pressure on them gradually shifted from external (e.g., predators, climate, resources) to internal; that is, interactions with members of their own species. Animals such as lions, elephants, dolphins and orcas seem to be ecologically dominant and their reproductive success appears to be influenced heavily by interactions with conspecifics (Flinn et al. 2005). Flinn et al. (2005) present a range of evidence in support of the ecological dominance hypothesis and indicate "significant increases of ecological dominance roughly coincided with the appearance of *H. erectus* (2005:22). They do not, however, indicate how pre *Homo* human ancestors began the establishment of ecological dominance while other animals did not.

Intelligence and the Ability to Manipulate the Environment

Cetaceans and cephalopods have still another problem. Even if they are intelligent in terms of one or more of Gardiner's criteria, they fail in terms of several requirements for the emergence of intelligence offered by Casti (1989). Specifically, Casti (1989:357-359) points out that interstellar communication requires tool making and indicates what he believes to be necessary for such a communication technology to come into being: (1) Development of an atmosphere containing free oxygen; (2) Movement of life from the sea to land; (3) Emergence of hands and eyes; 94) Use of tools; (5) Appearance of social structures (Casti 1989:357).

Leaving aside the development of an oxygen-rich atmosphere, what about the other criteria? First, if movement from sea to land is truly required, the cetaceans seemingly have it backwards as their ancestors were land-dwellers while cephalopods are helpless out of water. Tentacles appear to be quite handy in the water but all but useless out of it (although the elephant's trunk might be a good land-based analog of tentacles). Second, some sort of grasping and manipulative appendage or appendages are essential for tool making although hands, per se, may not be the only answer. Various creatures have claws (e.g., crabs, lobsters, scorpions, praying mantises), some use their bodies (e.g., snakes), and many others use their mouths (e.g., dogs), mouth parts (e.g., ants), or beaks (e.g., birds) to grasp and manipulate food or objects. None of these solutions seems to be as effective as hands, however. Lastly, Casti reasonably claims that the use of tools is a prerequisite for interstellar communication. Tool use has been observed in numerous non-human animals, including all of the great apes and many other mammals (e.g., sea otters), some birds, and, most recently, the bottlenose dolphin (holding a sponge in their mouths, apparently to protect their tender snout, as they forage on the sea bottom), as mentioned earlier. However, none of these applications, as observed in the wild, seem to be headed to more advanced tool use.

Eyes are another matter. Many animals have eyes or some type of light sensing organ or organs and eyes come in many designs. Whether eyes evolved independently in insects, vertebrates, and mollusks, for example, or whether the same genetic material underlies all eyes is currently disputed (see, e.g., Tomarev et al. 1997). Moreover, some species (e.g., cave fish, cave insects) whose ancestors had eyes have lost them while others augment eyes with other sensory (or signaling) apparatus such as echolocation (e.g., bats, cetaceans), electric fields (e.g., electric eels) or light producing organs (e.g., fireflies, many species of deep-sea animals). Still, complex eyes dominate. Tomarev et al. (1997) note that while only 6 of 30 animal phyla have complex eyes, these 6 are the dominant animals on the planet. They estimate that 95% of all animal species have complex eyes based on about a dozen different designs.

Putting It All Together

So, what does all of this mean for f_i? If Casti (1989) is right, aquatic species are doomed to never develop substantial technologies. So we can eliminate cephalopods and cetaceans, however "intelligent" they might be, from our Earthly list of potential communicators via technology and, hence, any similar species that might exist on extra-solar planets. Somewhere between 1.5 and 2 million living species have been cataloged on Earth and estimates for the true number of species run much higher (generally between 2 and 50 million but some up to 100 million). Of these, there are about 800 living species of cephalopods (Wood 2011) and about 80 living species of cetaceans. Hence, cetaceans comprise less than 0.05% (.0005) of extant species even when using only 2 million as an estimate for the number of living species. There are currently approximately 18 or 20 species in the superfamily Hominoidea (apes and humans). These include 12 species divided among 4 genera of the family Hylobatidae (the gibbons; Gibbon Conservation Center, 2005) and 6, or possibly 7, species in the family Hominidae, which includes humans, gorillas (1 or 2 species; AnimalInfo.org 2005), chimpanzees (2 species; Myers et al. 2005), and orangutans (2 species; Orangutan Foundation International 2005). With a generous inclusion of about 20 species of hominoids among a (probably low) total of 2 million extant species, primates comprise only .00001 (0.001%) of the living species on Earth. Moreover, only 1 of these 20 species has developed a technology capable of interstellar communication. In sum, the development of high intelligence on Earth has been extremely rare and there is little evidence to support the idea that its development is inevitable. Moreover, even if some forms of intelligence do evolve, there is no good reason to believe that at least one of them must be human-like and technologically-oriented. Hence, high estimates of f_i seem to be both extremely anthropocentric and highly optimistic.

Additionally, we have at least three significant unanswered questions: (1) why is high intelligence worth having, (2) why, if it is worth having, did it develop only once in more than 3.5 billion years of biological evolution, and (3) how did it evolve at all? The answers to these questions will allow much more precise estimates of f_i than we are presently capable of producing.

4. ESTIMATING f_c

Drake defined f_c as the fraction of intelligent civilizations both able and willing to communicate. This effectively eliminates the possibility that intelligence could appear in forms other than collectives of organisms. So, Fred Hoyle's (1959) fictional *Black Cloud*, an intelligent entity composed of a network of various molecules that arrives at our solar system, discovers intelligent life on Earth, and proceeds to communicate, is ruled out. Hive intelligence, exhibited by social animals such as ants, termites, and many bees and portrayed (universally negatively) in science fiction (in movies such as *Invasion of the Body Snatchers* (1956), on TV with *Star Trek's* Borg, and in novels such as Arthur C. Clarke's *Childhood's End* (1953), also appears to be out. So, what must a group of intelligent, individual, organisms have in order to develop a means of interstellar communication, if they so desire. Minimally, they must be able to share information and to cooperate. That means that they must have a culture and some sort of social organization, or society.

Definitions of culture abound; in their 1952 book, Kroeber and Kluckhohn identified more than 160 and many others have been added since then. Edward Burnett Tylor offered the first definition of culture from an anthropological perspective in 1871: “that complex whole which includes knowledge, belief, art, law, morals, custom, and any other capabilities and habits acquired by man as a member of society” (1871:1). While Tylor’s definition is still useful, since we are addressing intelligence and information, a cognitively oriented definition may be have more value (for a categorization of types of definitions of culture, see Chick 1997). Ward Goodenough’s (1957:167) highly influential definition of culture is a step in the right direction:

> A society’s culture consists of whatever it is one has to know or believe in order to operate in a manner acceptable to its members. Culture is not a material phenomenon; it does not consist of things, behavior, or emotions. It is rather an organization of these things. It is the form of things that people have in mind, their models for perceiving, relating, and otherwise interpreting them.

So, Goodenough (1957) holds culture to be information. John M. Roberts developed a related definition of culture in 1964 that augments Goodenough’s: “It is possible to regard all culture as information and to view any single culture as an “information economy” in which information is received or created, retrieved, transmitted, utilized, and even lost” (Roberts 1964:438)

The “information economy” of which the developed world is a part dates to antiquity. While much information attributable to ancient civilizations such as the Egyptians (e.g., how they constructed the pyramids) or the Aztecs (e.g., the rules for the famed Mesoamerican ballgame), for example, has been lost, cultural knowledge stored in the heads of members of extinct or vanishing indigenous peoples may represent an even greater loss. Nonetheless, diffusion of cultural information has surely occurred over the millennia. The question, of course, is *how much* of our present cultural information—what we need to know to operate in a way acceptable to our fellows—can be traced to antiquity. Since we lack a means to measure culture content as well as adequate knowledge of that content between then and now, determining this is not presently possible.

Many estimates of f_c also are in the 1 in 10 (.1) range. Is this reasonable, given the data we have available from Earth? Indeed, what data are relevant to the issue? Since, again, Earth provides the only available data and the Principle of Mediocrity seems appropriate, as well, we can ask, “what percent of known societies/cultures achieved, or would have achieved, the technological sophistication to make interstellar contact possible?” The problem, obviously, is that there is no database that covers all known societies/cultures from the beginning of such groups until now. Moreover—and related to the last parameter in the equation, *L*—how does one determine where one society/culture ends and another begins? The Roman Empire, for example, never developed the means for interstellar communication while we (i.e., Euro-American society) did so in the 20th century. But we certainly retain cultural knowledge developed during the Roman Empire while they retained cultural knowledge developed by the ancient Greeks (and many others) even earlier. In statistics, the issue here is independence of cases; in cross-cultural research, it is known as Galton's Problem. So, while the political entity known now as the Roman Empire fell, much of the culture associated with it did not.

So, how can knowledge of human societies be used to estimate f_c? One way would be to choose a sample of historical "civilizations" from around the world, such as ancient Egypt, Harappa-Mohenjodaro, the Inca, the Natchez, the Greeks, and so on, and speculate on their potential for becoming technologically sophisticated enough to develop the means an desire to engage in interstellar communication had they not fallen. Jared Diamond, in his Pulitzer Prize-winning book, *Guns, Germs, and Steel* (1997) offered environmental reasons why some societies progressed technologically while others did not. Basically, the West had access to the raw materials (including plant and animal species that can be domesticated) needed to support technical culture while others did not as well as lines of communication and migration that did not cross inhospitable territory. In his next book, *Collapse* (2004), Diamond provided several case studies of societies that, in fact, collapsed due to a combination of factors, including environmental degradation, climate change, hostile neighbors, friendly trading partners, and responses by societies to environmental problems. While his data and methods have been criticized, Diamond has raised important issues and provided answers that may have some validity. It may be, therefore, that the Inca and the Aztecs, for example, if left on their own, would never have developed advanced technology because they lacked the raw materials in their respective environments that would have enabled them to do so. Moreover, culture is important. The ancient Chinese were extremely inventive and great engineers but many of their inventions (e.g., gunpowder, moveable type) never had the impact in China that they later imparted in European society. Moreover, simply cherry picking a sample of civilizations and then speculating about their possible technological advances had they not collapsed or been conquered seems to violate proper sampling techniques and to involve speculation better reserved for science fiction (e.g., an episode of *Star Trek* (Episode 43, 1966) where the Roman Empire on an Earth-like planet never fell).

An alternative is to take a sample of societies from the recent anthropological record and then see what percentage of them ultimately developed advanced technology. For this task, I have chosen the Standard Cross-Cultural Sample (SCCS), developed by Murdock and White in 1969. The SCCS is composed of 186 societies chosen, not randomly, but to represent cultures and languages distributed across world areas and to avoid Galton's Problem. It is widely used in cross-cultural comparative research and codes for approximately 2000 variables are currently available for it, including "cultural complexity." In 1973, Murdock and Provost coded the SCCS for cultural complexity based on "ten groups of comparable traits, each ordered according to a five-point scale of relative complexity." These were (1) Writing and Records, (2) Fixity of Residence, (3) Agriculture, (4) Urbanization, (5) Technological Specialization, (6) Land Transport, (7) Money, (8) Density of Population, (9) Level of Political Integration, and (10) Social Stratification. Murdock and Provost summed the ten individual scales in order to provide a single, composite scale. The major weakness of the SCCS is that it lacks any modern, industrial societies. For my purpose here, however, that may actually be a good thing.

Murdock and Provost (1973) assumed that their index is unidimensional, demonstrated by the fact that they added the ten individual scales to provide a single, overall index of cultural complexity. However, a principal components analysis (with varimax rotation, factors extracted where the eigenvalue is equal to or greater than 1) of the 10 individual scales shows that the scale has two factors, not one as assumed by Murdock and Provost. Factor 1 appears to be related to social and technological complexity while Factor 2 contains variables related to the complexity of the human ecology of societies (Chick 1997). These are shown in Table 1.

Table 1. Principal Components Analysis of the SCCS Index of Cultural Complexity

Complexity Scales	Factor 1	Factor 2	Communality
Writing and Records	**0.848**	0.150	.741
Land Transport	**0.846**	0.047	.719
Social Stratification	**0.716**	0.402	.675
Level of Political Integration	**0.669**	0.466	.665
Technological Specialization	**0.606**	0.442	.563
Money	**0.578**	0.401	.495
Fixity of Residence	0.068	**0.918**	.847
Agriculture	0.213	**0.849**	.766
Density of Population	0.284	**0.824**	.759
Urbanization	0.454	**0.542**	.500
Percent of Total Variance Explained by Unrotated Factors	52.77	14.53	

N of Cases = 186

Whether or not this index is an appropriate measure of cultural complexity is debatable, depending on how both culture and complexity are defined (see Chick 1997, for a discussion of these topics). Nevertheless, it is the most widely used measure of the construct and may be of some value for estimating f_c.

How many of the societies in the SCCS either did, or would have been likely to, go on to develop technology that would permit interstellar contact? Of the 186 societies in the sample, 7 have the maximum possible score of 30 when the 6 variables making up the social and technological complexity factor are summed while 7 more have a score of 29. These 14 therefore comprise about 7.5% of the SCCS. Only 1 society has a score of 28 while 3 score 27 and 2 score 26. So, 29 is something of a natural break point. These 14 societies, and the year at which their culture was pinpointed, are:

Burmese	1965
Koreans	1947
Babylonians	1750 BC
Romans	110
Balinese	1958
Irish	1932
Basques	1934
Javanese	1954
Uttar Pradesh	1945
Siamese	1955
Chinese	1936
Japanese	1950
Turks	1950
Russians	1955

Would any, or all, of these, left to their own devices, have developed the means for interstellar communication? A problem is obvious: despite Murdock and White's efforts to insure the independence of the societies in the SCCS, it is clear that this is not true for these 14. Babylonian culture surely had some influence on the Romans and some knowledge of it passed through the Romans to us. All of the other societies had at least some contact with each other and contact with European culture (and therefore Roman culture) by the dates that they were studied. Hence, is it more appropriate to regard these societies as having only 1 technical tradition, 14 different ones, or something in between?

The reports used in the SCCS for 12 of the 14 societies were written after Karl Jansky discovered radio waves emanating from the Milky Way in 1932 and 3 more were completed before Grote Reber constructed the first dish radio telescope at his home in Wheaton, Illinois, in 1937. So, human society has now had the capability of receiving extraterrestrial signals for about 70 years while sending them (from commercial radio stations, at least) for about a dozen years longer. Of the 14 societies, major radio telescopes are presently located in 5 (Korea, India, China, Japan, and Russia [Gallery of Radio Telescopes 2005]). These were not developed independently but, for the sake of argument, let's say that they were. Optimistically, then, 5 out of a sample of 186 (2.7%) human cultures might have developed the means to communicate with extraterrestrials.

Less optimistically, since there is really only one cultural tradition of radio telescope development and use—a tradition passing though the Roman Empire—only 0.5% of human civilizations would have gone on to develop the means to communicate with extraterrestrials, based on this method[2]. Hence, one "finding" from this exercise is that the value for f_c might lie between 0.005 and 0.027.

One Culture or Many?

A more important result may be that looking at a sample of human cultures studied pretty much across a slice of time and then attempting to extrapolate shows that the method is highly questionable because of the problem of cultural diffusion. Indeed, in the early history of anthropology, members of several schools of thought claimed that humans were basically uninventive and that important technological advances had occurred only once and thereafter moved to other areas of the world either through cultural diffusion or migration. These include the German *Kulturkreis* school, which held that that inventions spread via migration, the American "cultural area" school, which emphasized diffusion, and the most extreme, the idea that all cultural advances, especially modern inventions, came from Egypt (the pan-Egyptian or heliolithic theory), a perspective championed by G. Eliot Smith and, later, his student William James Perry (for reviews of these perspectives, see, e.g., Hays 1958, de Waal Malefijt 1974, Harris 1968). These schools were born, in part, as a reaction to early cultural evolutionism that emphasized relatively fixed stages through which all cultures must develop. So, while these schools of thought are largely gone, they still influence American anthropology, in particular, through attention to individual culture histories and through lingering notions of culture areas as manifested in the sampling for the SCCS, for example.

While there is little evidence to suggest that the Aztec or Inca civilizations, for example, were influenced by Egyptian, Chinese, or Roman civilization (despite various theories about the lost tribes of Israel), the question remains whether we can reasonably trace modern radio astronomy back to the rise of ancient Greek civilization or perhaps even to earlier civilizations of the Middle East? Does SETI result from one cultural tradition or many?

Political scientist David Wilkinson (1987) argued that an economic and military integration of Egypt and Mesopotamia around 3500 BP resulted in what he termed the "Central Civilization." According to Wilkinson, this civilization expanded over the next several millennia to include the entire Middle East and Europe. Finally, via European expansion, Central Civilization came to include the Americas, much of Africa, China and Japan. Hence, our advanced technology, including that used in SETI, developed in this polycultural Central Civilization rather than in specific cultures, societies, or empires.

5. SUMMARY AND CONCLUSIONS

Estimating any of the values for the Drake equation involves a lot of guesswork although our knowledge of R* and, especially, f_p has increased dramatically in recent years. We may soon be able to estimate n_e on a more empirical and less hopeful basis. There is general agreement that the fraction of habitable planets that develop life should be very high. However, the fraction of planets that develop intelligent life and the fraction of those that develop both the means and the will to communicate across space are unlikely to reach any sort of consensus soon. The one thing that we can do in the meantime, however, is determine exactly what we are talking about and looking for. That is, just as the question of "what is life" has been extensively discussed (see, e.g., Darling 2001), what do we mean by "intelligence?" While numerous authors (e.g., Casti 1989; Darling 2001, 2005b; Shklovskii and Sagan 1966) have discussed this issue, the general mode of thinking when considering extraterrestrial intelligence is one of anthropomorphism—they will be like us. Additionally, the evolution of intelligence is often seen as inevitable or, at least, the end point of progressive evolution. That is, once multicellular life evolves, intelligence is on its way. Discussion of intelligent dinosaurs, who might still be here except for a fortuitous (although not for them) asteroid or comet hit on Earth some 65 million years ago, reflect this progressive notion of evolution. As Byrne (2001:147-148) points out, "the assumption that our descent was linear and progressive," that "when we studied a lemur or monkey we were seeing in a direct way what our ancestors were like," "is just plain wrong." Moreover, all other "modern animals have evolved for exactly as long as we have" (Byrne 2001:148) yet, after all this evolution, only one species has developed the sort of intelligence that has led to the technology and the interest to seek communications with other like species in the universe. This does not lend much support to the idea that the development of this kind of intelligence is inevitable, let alone common, once life appears.

As for f_c, the fraction of intelligent civilizations able and willing to communicate, the exercise reported above using a sample of human societies culled from the anthropological record also does not support high estimates. As Dunbar (2001) indicates, there is a relatively strong relationship between the neocortex ratio (defined as the volume of the neocortex divided by that of the remainder of the brain) and group size in primates. A regression equation, using group size to neocortex ratio permits the estimation of group size for species for which we know only the latter. In the case of humans, the estimate is about 150 (Dunbar 2001, p. 181). As Dunbar points out, group size refers to the network of individuals who know each other and have relatively strong affiliative relationships, who interact with one another frequently, and who maintain some type of spatial coherence over time. The ethnographic record supports group sizes of 125 – 200 in recent and contemporary human societies. Finally, Dunbar notes that there are two main determinants of group size. First, there are benefits to living in groups, primarily in terms of defense against predators but also in terms of resource defense. This benefit acts in opposition to the costs of group living. These include the need for greater food resources, sometimes involving energetically costly travel (and possible predation resulting from defensive problems during such travel) and the need to devote more time and energy to social interaction in the prevention of group conflicts. Models of maximum group size based on only three variables (mean annual temperature, mean annual rainfall, and rainfall seasonality) among chimpanzees, geladas, and baboons are "surprisingly robust" (Dunbar 2001:186). Dunbar (2001) notes that "mean group size is, of course, a rough measure of social complexity" (2001:179) and, as it turns out, an excellent way to measure cultural complexity in human societies is simply to use the size of the largest settlement in the society[3], rather than to scale societies in terms of several parameters, such as in the Murdock and Provost (1973) index (e.g., Bowden 1972, Naroll and Divale 1976, Chick 1997).

So, even if intelligent and technologically capable life develops, environmental parameters will constrain the likelihood that societies comprised of such beings will develop complex societies that will support advanced technologies. We do not presently know if other Earth-like planets exist or, if they do, what sort of limiting environmental conditions exist on them. If we apply the Principle of Mediocrity, analyses such as those by Diamond (1997), suggest that such societies will develop relatively rarely. It can be argued that such a culture developed on Earth only once.

6. NOTES

1. Presented at the session on Historical Perspectives on Anthropology and the Search for Extraterrestrial Intelligence [SETI]. American Anthropological Association December 3, 2005.

2. A similar search of the eHRAF (electronic Human Relations Area Files), an online database of 158 (as of October 21, 2005) societies yielded results similar to those with the SCCS. None of the societies in the eHRAF had independently developed radio astronomy and radio telescopes were associated with only three of the societies in the sample.

3. To be precise, the base-10 logarithm of the size of the largest settlement is used rather than the population number itself. This serves to reduce excessive variance caused by curvilinearity, thus increasing correlations with other linear variables.

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