How Common is Intelligence?

We will now explore some of the details that come in to the factor f_i in the Drake equation: if life has developed, how common is it that intelligent life will follow? As part of our answer we will need to determine what intelligence is. This is not an easy question, and there has been vigorous disagreement about it over the years, but after giving some possible answers we will discuss current animals on Earth other than humans that might qualify. We will then offer up some likely biological prerequisites for intelligence, talk about the development of intelligence in humans with its advantages and costs, and think about how competition and cooperation have played their roles.

What is intelligence?

This is a question that has occupied and divided researchers in psychology and neuroscience for well over a century. We will begin with some of the relatively uncontroversial aspects of intelligence, then address the unresolved issue of whether there is some monolithic and general "intelligence" or whether it must always be broken up into specializations.

Any creature with a claim to intelligence must certainly have some measure of:

- Adaptability to changes or a new environment. This was the weakness of computers always used by Captain Kirk on "Star Trek": when faced with an apparently all-powerful computer he would demand that it calculate the last digit of pi or give it a logical paradox and the hapless thing would go up in smoke.
- Capacity for knowledge, reason, and abstractions. Indeed, the capability for passing on knowledge (verbally, in writing, or in other ways) has meant that human society has evolved in a Lamarckian way. That is, if the previous generation has found out how to do something, yours can learn how to do it as well without waiting for genetic change. That's what has allowed us to progress to quickly. However, a capacity for abstractions and for finding patterns can also be a weakness. For example, many people are fooled by pseudosciences such as astrology because they remember when a horoscope appeared accurate and forget when it was inaccurate or just vague.
- Capacity for original thought. Here we have to be careful, because this can be a matter of degree rather than kind. Most people would agree that current-day computers do *not* have the ability to think original thoughts. They are programmed, and do what they are told without breaking the bonds of their programming. However, there are games such as chess in which computers are far better than the best humans, and can make the correct decisions in positions they have never encountered before. Is this original thought?

So far, so good. But can these be lumped into one general category of "intelligence"? One school of psychology, led by Charles Spearman and his heir Sir Cyril Burt in the early to mid 1900s, said yes. They gave intelligence tests to endless people and decided that although a given question on the test might rely on specific knowledge or particular experiences, the results of the test as a whole really did measure a single monolithic quantity. Another school, led by their contemporary L. L. Thurstone, suggested that intelligence is actually broken up into distinct categories. You could imagine a mathematical intelligence, a musical intelligence, a mechanical intelligence, and even something like an emotional intelligence that serves you well in social situations.

But why does it matter? From our standpoint in this course, it is of some interest because the tasks at which we in technological society need to excel are rather different from those required of our ancestors 100,000 years ago. Special aptitude in mathematics or music would have been irrelevant to individuals trying to find their next meal or avoid becoming something else's!

As always, the truth is undoubtedly between the extremes. It is clear that some people are better at abstract thought than at building things, or at language than at mathematics. Therefore, it is not as if intelligence is a single unbreakable quantity. On the other hand, our ability as a species to do so many different things indicates that our brains have not been hard-wired for a limited set of tasks. A question that we cannot answer is how typical this is of life elsewhere. We can, however, explore the abilities of other animals to see what they can offer.

Intelligence of other animals

Handing a non-human animal a test and a pen is rarely useful. People have therefore devised various other tests in order to rank intelligence among animals. For example, you can place a fence through which the animal can see food, and make it clear that the fence ends. A cow will stand there stupidly looking at the food, unwilling to move away from the food to get to it. Smarter animals such as pigs, however, will solve this problem easily.

Going beyond this, it used to be thought that an ability unique to humans was that of making tools. From flint chips to bows and arrows to computers, we have made profound use of this ability to extend our reach in every possible way. In fact, however, a variety of animals has this capacity as well. A surprising example is that of crows, which along with its relatives are arguably the smartest of birds. In the wild, and in controlled tests in labs, crows have solved problems by making and using tools. As an example, a small bucket of food with a wire handle was placed deep enough in a container that the crow could not reach it. A variety of items were around in the lab, including some straight wire. The crow considered the situation, then made a small hook at the end of the wire and used it to bring the bucket out.

Pretty impressive! Would you consider this proof that crows are intelligent in the sense that with the right evolutionary niche they could build a communicative civilization? I think the odds are not good; the brains of crows are small enough that they have to specialize their abilities, and after all we don't see crow civilizations on Earth. It is not, however, easy to put our fingers on where they fall short.

Other clearly intelligent animals are chimps and bonobos (our two closest relatives) and dolphins. Neither of these have as high a ratio of brain mass to body mass as we do, but they are creative and have remarkable learning capacity. Dolphins do, however, suffer from not having significant manipulative capacity. Therefore, they cannot modify their environment significantly. Chimps, bonobos, and other primates do not have this limitation. They also have opposable thumbs, and if humans were to vanish it is possible that they would eventually occupy our niche. That they are not currently writing poetry and launching rockets may be caused by our competition rather than their intrinsic limitations. More on that later.

The final category of animals we should consider are those that live in collectives, like bees and termites. Each individual is highly restricted in its activities, but the whole colony has complex interactions. For example, in a termite colony there are multiple queens, kings that mate with the queens, and workers that sometimes grow and turn into soldiers. Science fiction authors have extended this concept to intelligent hive entities, and perhaps it happens that way somewhere in the universe.

Biological prerequisites for intelligence

I am confident in saying that intelligent life must be multicellular! Getting to that point, however, took a really long time on Earth. Life itself popped up rapidly; within 100–200 million years since the last major sterilizing impact during early bombardment. It could have been 10 million years, or 1 million; the very first life would have been so primitive it would be difficult to detect its traces now. However, multicellular life took a good three billion years from that point.

Why was that? Our single-example limitations make this tough to say, but one could imagine that successful cooperation between different cells, or incorporation as in endosymbiosis, was an extremely improbable activity that required profound luck. If so, it might be that we got lucky much more rapidly than average, and thus that intelligent life is very rare in the universe. One could also imagine that there are metabolic costs associated with multicellular life that require a strong energy source, and that atmospheric oxygen was needed. If this is the case, the gradual rise of oxygen as a photosynthetic waste product might make multicellular life seem inevitable (although since photosynthesis already existed it is not clear to me why multicellular plants couldn't have emerged earlier).

From the cellular standpoint, the cell-within-a-cell aspect of organelles such as mito-

chondria and cell nuclei might have been the critical step. Another candidate is stem cells, which have been in the news over the last several years because embryonic stem cells have the potential to become any type of cell and are thus thought promising for future treatments of many diseases. The key to these cells is that they all start the same way, but in a fashion apparently controlled by chemical signals they can become more than 200 different types of cell. Therefore, rather than having to start off with hundreds of different cells, an organism can begin as one and differentiate with time.

There are other developments that appear helpful in our case, but it is not clear how widespread they must be. Sexual reproduction has a significant metabolic cost, but has the advantage that because the offspring are not clones of the parents, there is greater diversity and thus greater resistance to diseases. However, all animals are multicellular, yet almost none would qualify as having significant intelligence. Indeed, by far the most intelligent organisms on Earth are all mammals. It is not obvious why, for instance, reptiles could not be just as intelligent.

The development of human intelligence

Human brains are not the largest in the animal kingdom. Elephants and whales outdo us by significant factors. However, our brain to body weight ratio is unmatched. Whether or not this is a unique indicator of intelligence, we clearly have a lobe up on all other animals.

Looking at the skull capacities of our ancestors, we see that among the human family of Hominidae our capacity has roughly tripled in the last three million years, of which the last million have seen the most developments. The reasons for this are likely various. Primates in general have good vision, which requires a lot of processing power. We also are extremely dexterous. More recent developments include facility with complex language and social interactions. Incidentally, we should not at all think that our biological evolution has stopped; it's just that the entire $\sim 6,000$ years of human history is a blink of an eye to evolution, so essentially our biology has been frozen while our society has surged forward.

Our intelligence is so advantageous to us that it is easy to overlook the huge cost of a big brain. Our brains consume about 20% of our daily calories, but have only around 2% of our body mass. That's a huge price. In addition, big heads make birth much more dangerous for the mother and human babies are about as helpless as they come. We are therefore faced with related paradoxes: how were we able to fight through these disadvantages, and why aren't many other animals comparably intelligent if intelligence is such a big deal?

In terms of how we did it, the answer is likely to be that evolutionary advantages can be obtained in many ways: by speed, strength, claws, poison, and so on, and intelligence is one of those factors. It just happens that our ancestors benefited from better visual processing, more finessed hand control, and improved practical problem-solving. It has also

been suggested that the relatively rapid surge in brain size over the last million years could have been in part due to sexual selection; individuals found big heads sexy!

In terms of why there aren't other animals around with similar capabilities, a likely answer is that it is partially our fault. Fossil evidence suggests that Neanderthals existed with us up to about 30,000 years ago. Their brains were actually *larger* than ours. This doesn't guarantee that they were more intelligent, but it does suggest that other factors entered, and some of them are not so pleasant. For example, we could have been much more aggressive and either beaten them to food sources or beaten them, period. Whatever the story, Neanderthals were not the stupid subhumans often depicted in cartoons. For example, they used many tools and had death rituals such as burials. It is a pity that they went extinct, but those are the breaks of the evolutionary game.

The roles of competition and cooperation

Competition is critical to the development of species. Without it, there is no adaptation. It has also been essential in the development of human society. As an example of this we can take the classic question: why did the scientific revolution take place in Europe after the reformation, rather than in, say, China, which was in most ways more advanced at the beginning of that period? This is far from a settled question, but a thought-provoking answer I once heard is that at the time Europe was a collection of many small countries without a dominant nation such as the Roman Empire or a dominant religious entity such as the Catholic church, which had organized the area in centuries past. In contrast, China had for much of its history been ruled by at most a small number of large nations. The argument is that in a fragmented society such as post-Reformation Europe, any little advantage was important, and that this fostered competition and a willingness to think differently. Intriguing.

On the other hand, we are well aware of some of the negatives of competition. Battling ideologies, nations, and races have produced untold misery through the years, and as our destructive power grows it becomes increasingly possible that it could set us back a long way. In smaller but important senses it also causes problems. For example, if everyone on Earth agreed to use less energy and work for alternative fuels, it could be argued that we would all benefit greatly. But in the near term, if everyone *else* sacrifices themselves, it is to our benefit to keep using easy fuels.

This brings us to the issue of cooperation. Why would you bother helping an old lady across the street? Why would a police officer risk her life to save someone she doesn't know? This is an interesting question, but we should realize that such behavior also occurs for non-humans. Different types of animals will sacrifice themselves to save the group; consider, for example, soldier bees that die in defense of the hive. Basically, what benefits the group benefits each individual.

Such cooperative behavior has played a major role in the development and use of human intelligence. It is also critical to our continued strides out to the stars. No matter how intelligent an individual is, she cannot get there alone. Cooperation is critical, and means that even an intelligent alien species will not get far if it is too solitary.