



Life at radically different time scales

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Publication note

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Intelligent life might plausibly function at time scales massively longer or incredibly shorter than our own. Could there be meaningful interactions, or would oblivious death and destruction be inevitable?

Typically, when science fiction¹ writers explore the idea of extraterrestrial life there is a general presumption that we humans would be able to recognize new life forms as such when we encounter them. Quite often these stories feature discovered life that is only superficially different from life on earth. Plant-like structures grow in the light from an alien star and support a menagerie of alien creatures that eat the plants-like things and that might, in turn, be eaten by other alien creatures. When humans show up to these worlds, the alien life is just as easily recognizable to them as life in the [Galapagos was to Charles Darwin](#): it's all fascinating and new, but also very familiar.

In these stories, even when there are big, significant differences, life is still recognizable because it does essential things like growing, locomoting, and responding to its environment. Sometimes a story will center on the difficulty of recognizing life that is very different from Earth life, perhaps because it uses different chemistry or has forms radically different from Earth life. In many such stories, the alien life eventually reveals its living, possibly intelligent, nature by how it responds to its environment, particularly to environmental changes created by human interlopers.

What would happen if humans came across some form of life that operates at vastly different *time scales* that are fundamentally incompatible with ours? What if we encounter life forms where their fastest possible response, the alien equivalent of a blink or reflexive flinch, takes over a hundred or even a thousand of our years to happen? Or what about the reverse, where we encounter life forms that can experience a full and complete lifetime in only a few of our milliseconds, and where a single one of our seconds spans the history of several of their generations? Would we be able to recognize life at such radically different time scales? Would we be able to recognize intelligence, and if we did would any meaningful communication between them and us be possible? Is life at these vastly different time scales even possible?

Living at human speed

For humans, one second is a reasonable choice as our basic unit of measuring time because that's about how quickly we react to things. Some things are a bit faster. For example, athletes train to respond more quickly to certain events, or an involuntary blink takes about one-tenth of a second. Other functions in our bodies that we're not consciously aware of, such as neurons firing, happen in the millisecond range. At time scales much smaller than that, it becomes hard to recognize the functions of life in our bodies. With proper equipment, one can observe various electro-chemical reactions happening, but at what we consider incredibly tiny time scales one loses sight of how everything comes together to form a living, reacting being.

From our human perspective, anything that happens in less than a hundredth of a second is perceptually instantaneous. We might be able to make machines that can measure smaller times or record events for slow-motion playback, but there is clearly a limit to the smallest time scale we can naturally perceive.

We also have a limit on the other end, a limit on the largest time scales we can naturally perceive. The observable results of a slow process, such as erosion, might allow us to infer that some slow process is occurring, but a small change that takes place over one hundred years or longer, is imperceptible. We can use technology to measure a change that happens very slowly, or we can compare measurements we take today with measurements made generations ago by our ancestors, but we can't actually observe events at hundred-year or greater time scales directly.

So, returning to the hypothetical encounter, what would happen if humanity encountered an intelligent civilization that was comprised of lifeforms living at a radically different time scale than ours? How could we recognize the encounter as one with a civilization of sentient beings, and if we did what sorts of interactions would be possible between us and them?

Living slow and probably cold

Let's start with the example of much slower lifeforms, where their equivalent of a startled blink happens over one hundred of our years. This wouldn't be life that lives a very long time but otherwise functions at human time scales. For example, the immortal elves from fantasy stories or never-aging human-like androids might live lives spanning millennia, but the time scale at which they experience and react to the world is the same as ours.

We also are not talking about something where the biology operates at the same scale as our biology yet conscious awareness and response to stimuli are very slow. In other words, these slow life forms are not something like intelligent trees or sentient lichen either. This slow life would be based on some biology completely unlike ours, where the processes that lead to life are, from our perspective, incredibly slow.

The most obvious way that such a slow biology could evolve and not be out competed by life based on faster biology would be if some limitation would preclude faster biologies in that environment. An example where faster biology might be precluded would be a cold, low-energy environment out on the edge of a solar system like ours or maybe in a nebula, where there simply is not enough available energy to power faster reactions. With orders of magnitude less radiation and little readily available chemical energy, life would have to take place at a glacial pace or else it would quickly exhaust meager resources. Cognition would also be slow, both because fast thoughts would use energy too quickly, and because any competitive advantage to a lifeform in thinking orders of magnitude faster than it could physically react would probably be outweighed by other evolutionary issues.

If human explorers encountered a civilization comprised of slow life living at low energy levels using unfamiliar biochemistry, it seems quite likely that the humans would not realize what they had found. Structures might be complex but not necessarily recognizable as mechanisms of life. The most basic way of recognizing something as alive, observing its movement and reactions, would not be useful as one would need to wait a hundred or a thousand years to observe even a twitch or blink. An actual conscious reaction to the explorers' presence might take even longer.

The other obvious way to recognize intelligent life would be to recognize complex structures that are either artifacts built by the lifeforms or recognize the complex structures that make up the lifeforms. If we stumbled upon a frozen version of New York City, it seems like it would be trivial to recognize it as a constructed, unnatural complex. However, that recognition relies on the assumption that the frozen city would be comprised of things that look like human buildings with familiar designs and functions. Many natural structures are incredibly complex or feature regular structures that falsely appear unnatural. For example, the hexagonal Iceland basalt columns look like they could have been made with some purpose, but they are in fact natural formations.

If we came across a city built by slow lifeforms using unfamiliar technologies, to satisfy unfamiliar needs, then how could we know that it wasn't just some marvelous, yet natural structure? Or perhaps we might mistake the artificial structures for some natural, unintelligent form of life. Even if we did determine that something was an incredibly slow form of life, or if we mistook artifacts for slow unintelligent life, then how could we possibly determine if it was intelligent? Any interaction that might reveal intelligence would take many human lifetimes.

A very disturbing possibility is that we'd fail to recognize the intelligent beings as alive, or if we did recognize life then we'd still fail to recognize it as intelligent, and we'd then do what humanity has done every other time it's found a valuable natural resource: mine or harvest it. The slow beings would have no chance to resist whatever we ignorantly did to them, even if they were technologically more advanced. From their perspective we would be like some sort of intelligent fire or explosion, destroying and restructuring their world at what they would perceive as an impossibly fast rate. We might wipe out their entire civilization in the blink of one of their eyes.

Or perhaps we'd act as conservationists and refrain from exploiting what might look like unusual natural structures. However, even conservation-minded explorers might still unknowingly wreak havoc on any slow life they encounter because they might not even notice the glacially slow processes they would be unknowingly interfering with. The incredible crystalline formation that some humans might carefully remove and then preserve in a museum could be the equivalent of an alien's decapitated head.

Fast and burning bright

The other possibility to consider is what would happen if we encountered intelligent life that operates at a much faster time scale than we do. One of these beings might be born and live an entire rich life in less than a second. Fast life would require enormous amounts of energy to function. Instead of living out in a cold nebula or, like us, on the outer layer of a ball of rock orbiting a star, these lifeforms might evolve in high-energy environments such as the incredibly vast surface of the star itself, or perhaps near a blackhole or quasar.

It's likely that encountering any sort of fast life would be disastrous to us. Just as we probably would not recognize slow life, fast life might not recognize us as alive or as sentient. Intelligent beings made of plasma, high-energy

fields, or something else hot and destructive, operating machines made of similar materials could appear and overrun our civilization in less time than it would take us to realize what was happening.

Maybe we'd get lucky, and they would preserve us in the same way that we might preserve some natural wonder, but to do us any good they'd have to persist in that conservationist mentality for many, many of their generations. How successful has humanity ever been at actively preserving a natural wonder for more than a few generations? Even their preservation efforts might be incredibly harmful. Luray Caverns in Virginia have been preserved as a natural monument, but walkways were installed to allow visitors to easily access the early parts of the cave system. Imagine if some super-fast, microbe-size, well-meaning aliens set up a nice visitor's center in a person's mouth with little lighted walkways down into their lungs. The choking and dying spasms as the person collapses to the floor would look to them a lot like a building slowly shifting and settling over their centuries.

If a faster lifeform did recognize a slower one as alive and sentient, what sort of communication might be possible? The faster one might be able to create messages that, from their perspective, would take generations to be read. Any response would not arrive until after many further generations had passed. If the slow life had any sort of written or otherwise recorded information, then the fast beings might figure out how to read it and learn from it. This wouldn't really qualify as two-way communication, but it would at least be a mutual exchange of information.

Universal speed limits

In discussing the possibilities of life that is orders of magnitude slower or faster than our own we should also consider what universal constraints might limit how much faster or slower life could be compared to ours. Average available energy density was already alluded to above and a few possible environments mentioned, but would life running at a rate three billion times faster than ours (*i.e.* one of our seconds is like 100 subjective years for them) be sustainable even in those high energy environments? A human body operates at about 100 watts with 20 watts devoted to our brains. So, something with cognitive efficiency similar to a human's but operating three billion times faster would require 60 *gigawatts* just to think, which is just a bit more than the total electric generating capacity of Australia. Is that a plausible number when our sun only emits 60 *megawatts* per square meter of its surface?

What about total available time as a limit on how slow life could be? Would slow life that operates three billion times slower than ours have had time to evolve in a universe that is only 14 billion years old? At the other end of the speed spectrum, would life that operates three billion times faster than ours be impossible because light only travels 300 million meters per second?

These limits, or others, might seem to bias the universe toward evolving life that operates at time scales somewhat close ours, but this apparent bias toward our time scales might just be a bias in how we understand the world. We only know about the carbon/water-based life on our own ball of rock. Other mechanisms of life that we have no inkling of may have ways around those limits. Earth life might be grossly inefficient compared to the sort of life that might evolve on a star's surface, or maybe our sun is too cold for fast life, and we should look to something like a hotter WR-type star that might emit over 60 *terawatts* per square meter.

Slow life might arise from some faster process that jumpstarts evolution, or it might be artificially created by some faster, naturally evolved life. Maybe some faster life is not only faster, but also much smaller so that the light speed limit is not an issue, and its energy requirements are reduced proportionately with its size. Perhaps our understanding of the age of the universe or the speed of light is just wrong. As authors like Vernor Vinge² have imagined, the physical laws of our universe might be dramatically different from what we have assumed based on our very limited observations of our particular, little local neighborhood in the universe.

Even if there are some inescapable limits that would preclude life that operates three billion times faster or slower than ours, those limits might not be an issue for life that is merely a million or a few thousand times faster or slower. At those ratios, the faster life would have a somewhat better chance of recognizing the slower one as alive. Recognizing intelligence might still be difficult, but it seems plausible. The slower life could conceivably interact with the faster life in some meaningful way, particularly if the faster life is willing to make what would be from their perspective a long-term commitment to communicating.

The danger posed by the faster life to the slower one remains significant even with less extreme ratios. Rather than being overrun by an intelligent conflagration, the slower life might instead be confronted by something resembling supersonic ants with advanced technology. That's a situation that would still be dire if the supersonic ants were of an exploitative or hostile disposition, or even if they were peaceful but didn't immediately recognize the slow life as intelligent. Even a benign fast civilization might advance into new areas at an impossibly fast rate, gathering resources from whatever preexisted and converting them into their own structures with ignorant disregard for the slow life being overrun. Perhaps an analogy better than supersonic ants would be a swarm of turbo-termites, building mounds and devouring the slower civilization as if it were trees and brush sitting on the savanna.

Separated by scales of time

The idea of being separated by *distances* in space or time is completely familiar to us. We easily understand that something that happening millions of miles away or thousands of years in the future probably has no significant interactions with here and now.

Separation by spatial scales is also somewhat familiar. I have no idea what the bacteria in the corner of my room are doing and if microscopes hadn't been invented a few hundred years ago I won't even know they existed. One could argue that we would notice giant life around us, but maybe not. A joke I once heard³ goes: An ant scout reports back to the queen, "We are alone here. I searched the entire bathroom floor and didn't find a single pheromone trail." Like those ants, our view of the universe beyond our little world is very limited both in terms of perspective and modality. If two nebulae were having a conversation with each other using gravitational waves, how could we possibly observe that? Of course microbes can make us sick and we can pour pesticide on ants, but impacting a life form, even in a very significant way, is not the same as recognizing or interacting with it.

Like time differences and spatial distances, time scales can also separate life and civilizations in a way that appears to be fundamental, creating what might be an unbridgeable barrier to interaction and communication. At the same time, the potential impact of and danger posed by the faster life to the slower one is immense with no obvious way for the slower to defend itself or otherwise avoid danger. Even with time scales that are less dramatically different from our own than in the previous examples, many of the same issues would arise, although to a lesser, perhaps

manageable, degree.

It would appear that the rate at which humans experience time is determined by our biology and the environment on Earth. In other words, our time rate is appropriate to our context. If humans on Earth had evolved to live at twice the speed we do, then they would probably starve. If humans evolved to live at half the rate we do, then they would probably have been overwhelmed by faster competitors. On some other planet, maybe with a bit more or less sunlight or a different atmosphere, the optimal speed for life might be a few times faster or slower than what it is on Earth. In fact, it would be rather surprising if we encountered extraterrestrial life and found that lived at the same rate that we humans do. (Or at least it would be surprising after we got over the initial shock of finding any extraterrestrial life in the first place!)

Addendum: After publishing this article, a couple readers pointed me to the book Dragon's Egg by

Robert Forward. The book is about intelligent creatures, called “cheela”, that evolved on the surface of a neutron star who live their lives roughly one million times faster than we do. If you compare how Forward imagines a human-cheela encounter to what I wrote above, you’ll see that he’s much more optimistic than I am. In particular, his cheela behave almost exactly like humans, which to me sounds somewhat fanciful, and there are several places where improbable things just work themselves out due to good luck. The serendipity moves the story along, but at the expense of some believability. Regardless of my minor complaint, I liked the book very much and would absolutely recommend reading it.

[1] I often enjoy reading what is sometimes called hard science fiction both for entertaining stories and as a way of exploring implications of actual or hypothetical scientific and technological advances. If you’re not already familiar with the term, the key thing that distinguishes hard science fiction from regular science fiction writing is thorough attention to the mechanisms and plausibility of the futuristic or alien components of the story. It’s not uncommon for hard science fiction books to include entire chapters of (perhaps contrived) conversation where an expert patiently explains in detail to someone else the theoretical science and/or practical engineering behind how a space drive, or some other technology, works. A similar explanation might be used to describe the biology of alien life. This focus on building a speculative yet plausible and reasonable fictional universe allows hard science fiction stories to also be thoughtful explorations of how we might react to some hypothetical future event, and how real technological advances could affect our real world.

[2] Vernor Vinge is well known for his influential 1993 essay, “The Coming Technological Singularity: How to Survive in the Post-Human Era”, that has only become increasingly relevant with the passing of time and recent advances in AI/ML technology. However, his science fiction work also contains many other extremely interesting and thought-provoking ideas. The Zones of Thought trilogy includes an exploration of the idea that the speed of light might not be universally constant, specifically the idea that lightspeed might increase away from the stellar mass concentration of a galaxy. Lightspeed limits the speed of computation, that has big implications for an artificial intelligence. A more earthly book,

, explores a near-future society where a shared AR metaverse is nearly universal. I think it’s required reading for anyone interested in shared AR spaces today.

Rainbow’s End

[3] I have been told that this joke is originally from Neil deGrasse Tyson. Unfortunately, I can't find the source. If you know then please correct me!

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