ANTHOLOGY OF ASTROBIOLOGICAL SCIENCE FICTION

STRANGEST OF ALL

Edited by Julie Nováková

Features G. David Nordley, Geoffrey Landis, Gregory Benford, Tobias S. Buckell, Peter Watts and D. A. Xiaolin Spires.

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EAI
EUROPEAN ASTROBIOLOGY INSTITUTE

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Edited originally for the purposes of BEACON 2020, a conference of the European Astrobiology Institute (EAI).

"…this strangest of all things that ever came to earth from outer space must have fallen while I was sitting there, visible to me had I only looked up as it passed."
– H. G. Wells, *The War of The Worlds* (1898)

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Introduction

Julie Nováková

Is anyone out there?

This is an age-old question we are yet to answer.

Speculation on alien life is nothing new. The Greek atomists considered the plurality of worlds and "other earths inhabited by different tribes of men and breeds of beasts"[1]; 16th century Italian priest and occultist Giordano Bruno speculated about "infinite multitude of worlds"[2]; the famous philosopher Immanuel Kant wrote in his *Critique of Pure Reason* that he would bet everything that at least some of the known planets were inhabited.

Nor is science fiction working with the idea of life elsewhere or not quite as-we-know-it anything new. One of the first such works was penned by the great Johannes Kepler himself and published posthumously. The novel *Somnium* tells a story of a boy, who'd studied astronomy with Tycho Brahe, and the boy's witch mother, who had learned from a demon that the Moon ("Levania") is inhabited. They both undertake the shocking journey to visit it, and there is an abundance of description of both the creatures of the Moon and – in this case quite accurately, in accord with science of that time – the Earth seen from there.

The 17th and 18th century saw an increase of stories of life elsewhere in space, and after the birth of modern science

1 Lucretius in *De Rerum Natura*.

2 In *De l'Infinito, Universo e Mondi* (*On the Infinite, Universe & Worlds*).

fiction in the 19th century, the idea was fully etched in people's minds.

Nor is the idea of life outside of our Earth limited to the Western world. For instance, a Japanese folk tale from the 10th century, *The Tale of The Bamboo Cutter*, follows a Moon Princess who had grown up on Earth with her adoptive human parents, enchanted many human nobles, but eventually returned to the capital of the Moon people.

Humanity has always pondered the possibility of *other* life – and starting with the advent of modern science, we've been living in the first time of history that can bring actual answers to this deep burning question. To some people, it might seem as if science were ruining the imaginings of myth or science fiction – such as shattering the pulp SF dream of lush green Venus populated with dinosaurs and sparsely clad Amazons – but the opposite is true. While we've needed to substantially revise our notions of other worlds and chances of life out there, science had greatly expanded our horizons in the search for life. We now know of thousands of planets orbiting other suns; with future telescopes, we may be able to ascertain if they have life; we've discovered hidden oceans with potentially life-supporting conditions in our own solar system, and missions to investigate the possibility are being planned. It's like opening our eyes in a forest we've walked through every day of our life, and only now being able to glimpse the inextricably linked network of roots, mycelium, bugs and microbes beneath our feet that makes the forest what it is – but we need the mindset and tools of science for that.

The feeling is akin to what Charles Darwin wrote in his travel journal from the H.M.S. Beagle: "Delight itself, however, is a weak term to express the feelings of a naturalist who, for the first time, has wandered by himself in a Brazilian forest. The elegance of the grasses, the novelty of the parasitical plants, the beauty of the flowers, the glossy green of the foliage, but above all the general luxuriance of the vegetation, filled me with admiration. ... To a person fond of natural history, such a day as this brings with it a deeper pleasure than he can ever hope to experience again."

That's only one occasion of many. From each entry, the reader can see through the curious young scientist's eye, marvel at the ragged tops of the Chilean Andes, gaze surprised at marine organisms' fossils far away from the nearest sea, breathlessly watch the peculiar behavior of reptiles previously unknown to science. What a different observer might brush aside as an uninteresting or even disgusting spectacle can be a thing of indescribable beauty to a naturalist's eye. This is of course not limited to biology or STEM fields. Probably each person who loves their job has sometimes wished other people would also feel the pounding of their hearts and joy filling their chests as they saw a particular light curve; a dinosaur's tooth; a prehistoric axe shard; a shred of old palimpsest...

This is where fiction comes in, translating the often "dry" language of science into the exciting adventure science ultimately is, but may not appear at first sight.

The stories included in this anthology are not only engaging from the casual reader's perspective, but offer us

food for thought in terms of science. Highlighting fiction with interesting (and mostly close to accurate) science is nothing new. Astronomer, author and educator Andrew Fraknoi has completed an impressive, occasionally updated list of science fiction works with interesting astronomy (and related themes). It's commendable work and I highly recommend it for teachers and people active in science outreach in general.

Physicist James Kakalios often uses examples from superhero stories and comics to illustrate scientific points about physics and chemistry in his classes and popular science books. While the superhero subgenre is not known for its scientific accuracy, that too can be used to drive the message home in a way that's engaging, memorable and easily understood.

The aim of *Strangest of All* is to use good science fiction stories to let the reader accessibly learn more about astrobiology. At the end of each story is a short popular science commentary highlighting the interesting astrobio themes in it, from the possibility of life on Europa to the detection of alien civilizations. Each of these sections also includes a few suggested discussion topics, questions or proposed activities for the classroom[3]. We plan to build up

3 I'm not stating any grade here, because it can differ country to country. However, I consider most of the questions fit for teenagers with a previous interest in the involved topics, or adolescents/students. They're not for young children, sorry; but then, neither are the stories. I would have read them at perhaps thirteen at the earliest, but that may differ widely too. Just use common sense. Also note that some of the stories may contain (not explicit) adult topics. A book intended for children would be a great project and we're thinking about it, but this is not it.

on these in a separate publication later on; these are mostly a taste of what we're planning in astrobiology outreach and education, and we'll be happy for your feedback.

The anthology should have been presented at the BEACON conference of the European Astrobiology Institute on April 23, 2020. However, the COVID-19 pandemic intervened and put an end to this meeting, just like so many others. Canceling the event was a reasonable and necessary step – but why cancel the anthology? At a time when education is turning remote all over the world and hashtags such as #SocialDistancingReads are trending, we need it perhaps more than would have otherwise. Hopefully, it will offer readers a welcome momentary distraction from the very real threat of the pandemic and the medical, social and economic impact it has on our lives, and at the same time let them learn new interesting bits of astrobiology.

(Or, if you don't want much of a distraction from a pandemic but rather seek the theme in your reading, do read the *Rifters* trilogy by Peter Watts, whose story "The Island" is included here. The books are also indirectly related to the issue of planetary protection, relevant here!)

The pandemic has had impact on astrobiology and space sciences already, as the inability of ESA scientists to travel cemented the agency's decision to delay the launch of its *Rosalind Franklin* rover of the ExoMars mission for another two years. Many ground-based observatories also remain closed during this time. Science will feel the aftershocks of the pandemic just as well as other fields. Hopefully, the texts included in *Strangest of All* will inspire

at least some pupils and adults to venture into STE(A)M fields and help rebuild science later.

It's an honor to have so many brilliant authors of science fiction aboard. We start our journey with the author and astronautical engineer G. David Nordley, who plunges us right into an ocean very much unlike our own in "War, Ice, Egg, Universe".

But what if we consider even more exotic "oceans"? With writer and NASA scientist Geoffrey Landis, we take a deep dive "Into The Blue Abyss" of the planet Uranus... to discover something truly remarkable.

In "Backscatter" by the astrophysicist and prolific author Gregory Benford, we have left the solar system planets and their moons behind to enter the cold reaches of the Kuiper and Oort. Could life exist as far as out there? The protagonist hardly believes it at first either...

Tobias S. Buckell takes us to a peculiar exoplanet in "A Jar of Goodwill", and while local chlorine-metabolizing plants may be a source of future riches for the people who visit it, a more pressing question arises about the intelligence of the planet's ant-like inhabitants.

Author and biologist Peter Watts is at home in deep sea as well as deep space, and in "The Island", he takes us to the latter, where we encounter a strange kind of a Dyson sphere.

Gregory Benford returns with his microfiction "SETI for Profit", offering an interesting take on reviving interest in SETI and devoting more resources to it.

Finally, D. A. Xiaolin Spires' story "But, Still, I Smile" takes SETI and the Fermi Paradox a step further in showing one of the oft-proposed explanations for the paradox.

In addition, as a bonus, I have included a story of mine, "Martian Fever"; it's not so usual for an editor to include one, at least in the Anglophone world (in the Czech science-fictional scene, it's almost customary), but this is a non-commercial project and we're not limited by space in an e-book anthology. "Martian Fever" concerns planetary protection and hypotheses concerning hypothetical indigenous Martian life, indirectly also the question of lithopanspermia between Earth and Mars throughout their history.

I wonder if it's accidental that most of our authors are scientists or engineers by study. While scientific or technical background is by no means necessary for writing good SF, it can act as a powerful source of inspiration. I remember sitting at the "Evolution of Phenotype" class and devising a story idea while thinking about a zebra finch gynandromorph (which resulted in "To See The Elephant", Analog 5-6/2017). "Martian Fever" itself was conceived at the International Astronautical Congress in Guadalajara. In my view, it all comes to a slightly "weird" perception of beauty and deep-rooted curiosity – and that is something that can be shared and fostered, and drawn on in spreading interest in science.

Like author Neal Asher pointed out in a 2013 BBC.com article: "Science fiction ... is there to entertain and stimulate the imagination. There is absolutely no doubt that

many of the imaginations it stimulates belong to scientists. To some extent it drives and directs science."

These are difficult, trying times and we have no guarantee when and how we'll emerge from the pandemic, as even rather optimistic models show the need to stick to some mitigation and suppression measures for over a year to avoid high peaks of cases.

But what certainly won't hurt will be keeping our humanity, kindness, curiosity, critical thinking and drive for knowledge. Being reasonable human beings who think about others and the future, and supporting science that can provide us with knowledge about the novel corona virus (Can one become infected again, and if so, how soon? Does it compete with widespread coronaviridae causing the common cold, and could that be one of the reasons why children are less affected? Is it losing virulence?) and hopefully provide a vaccine.

While we're staying home and avoiding people as much as we can, we can at least travel to faraway places and meet intrepid, clever, unlikely or even questionable heroes in our imagination. We may feel stuck at the moment, but our curiosity doesn't have to be.

April 12, 2020
Julie Nováková

War, Ice, Egg, Universe

G. David Nordley

G. David Nordley (* 1947) is the pen name of Gerald David Nordley, an author and consulting astronautical engineer. He lives in Sunnyvale, CA. A retired Air Force officer, he has been involved in spacecraft orbital operations, engineering, and testing as well as research in advanced spacecraft propulsion. As a writer of fiction and nonfiction, his main interest is the future of human exploration and settlement of space, and his stories typically focus on the dramatic aspects of individual lives within the broad sweep of a plausible human future. Gerald is a past Hugo and Nebula Award nominee as well as a four-time winner of the Analog Science Fiction/Science Fact annual "AnLab" reader's poll. He's the author of several dozen pieces of short fiction in *Analog, Asimov's, F&SF* and elsewhere, and six books so far. His latest novel is *To Climb a Flat Mountain*, and the latest book is a collection, *Around Alien Stars*, available from Brief Candle Press in print or e-book through Amazon.com. Find out more at his site http://www.gdnordley.com.

I shall start four cycles before the Westerian invasion, the threat of which I then appreciated only as a source of support for my research into the source of lightstone.

My third-molting-father, Professor Colonel Threeclickson, had come to express his worries about my slow field work in the deepest part of the long valley that gave our land its name, some eight-to-the-fourth body lengths from the University. His fronds drooped toward the ice and he glowed with white noise as all the hairs on his four long legs vibrated in disharmony. Reaching over with a long arm, he lifted up my head.

"Up there," he said, waving his three remaining arms upward. "The answers lie above."

I could not nod agreement with his pincer under my mandible like that, but managed a polite "Yes, sir," from my spiracles.

He let go and I brought my head down again, but only to the level of my upper thorax.

Threeclickson's spiracle covers clapped. "You are always staring at the ice, Loudpincers. Elevate your ambitions."

I bent my neck up again so my head was at the level of his. "Sir. The ice is where we find the lightstone that takes our instruments up there. If we knew where lightstone came from, we might be able to find more of it, and, perhaps, even ascend ourselves, without dying first."

Threeclickson seemed mollified; the hair on his legs settled down and assumed their normal texture.

"Your logic is right, but be wary of becoming too indirect. You know that Professor General Icescriber has proposed building an ascent sphere of ice?"

I shivered with the thought of such an adventure as well as from lingering fears from larvahood myths about the eater of disobedient souls in the land of the dead. "Yes... uh, sir... I've seen drawings of it. It's one arm thick all around with polished areas to see through; it should resist crushing and let us get really high – if we can find or make enough lightstone to lift it."

Threeclickson laughed with staccato slaps of his spiracle valves, which made his upper thorax sparkle. "I rather supposed that would appeal to you. At my third molting, I shared that ambition. There is some promising related research that, however, must be held among the staff for now…" He trailed off. "But the water above is not friendly to life. As a body goes up, its heavy parts are compressed and we cannot breathe easily above eight to the fifth body-lengths. It is, after all, the realm of the dead... Well, Loudpincers, have you looked at the latest lightstone research?"

"Goodphaser thinks it works its way up from further below."

The professor huffed currents out of his spiracles. "So much is obvious."

"Softtipspawn has a theory that lightstone might be connected with the periodicity of icecover plant growth," I ventured.

"Pure speculation. I know she is a friend of yours, but biology isn't Softtipspawn's field. Major Lecturer Tightpincers *is* a zoologist, however, and she is pretty sure that lightstone is excreted by an unknown species of giant iceworm – little iceworms have long been known to feed on concentrated minerals released from warmfall water as it freezes."

I tried to imagine a huge worm tunneling through solid ice and couldn't, so I maintained a respectful silence. Threeclickson and Tightpincers were thick, and if rumors were to be believed, might spawn together next feasting season.

"I can tell you don't think much of that one," Threeclickson said, accusingly.

"Sir… it's very difficult to observe anything in a warmfall," I said. "The warm water makes one slow or even unconscious."

"She surrounds herself with ice before going in and is usually conscious for long enough to note what happens. I must admit there has been a problem getting others to replicate this. Well, what else have you found out?"

I recited my research. "Lightstone comes in many varieties and varies in lifting power per unit volume, though it takes a sensitive balance to see the difference. Lightstone with the most inertia lifts most strongly. Some people have timed the rise of lightstone through the ice to the surface by protecting the surface over them from

variations and taking measurements every feast cycle. They drift upward at varying rates, usually less than one over eight-to-the-fourth body lengths in a cycle."

"Brightpincers and Loudlegs," Threeclickson replied. "They're visiting from Great Warmfall. And they've also shown that solutions of ground lightstone are the same as found in iceworm excrement, by the way. Well, what conclusion do you draw from all of this?"

I hesitated, not sure I should tell Threeclickson all my cosmological speculations, but vanity spoke. "I think they might be concentrated by living things, not living *in* the ice, but rather on the other side of the ice. There could be another shell of water beyond this one, further out from the center. Like an egg of ice with many shells. But that's just speculation," I hurried to add.

"And not original. There is a long history of stories about beings from the underworld. Unfortunately, they are tales to make larva more attentive."

I opened my pincers. I could not help that. "I need more data. Since I've covered almost all of the base's allocated research area, the only way to get more is to go, well, deeper. Lightstone comes from somewhere."

Another spiracle flap. "Well, I haven't seen any giant iceworms either, so maybe. But be careful who you say that to; I would not want to see my molt-son ridiculed." He waved his fronds. "Going down to go up! The Mystical Church would love it. But your logic seems unassailable."

He waved an arm toward the west; a dim glow of noise marked the direction of our neighbors in Crossvalleys. "I wish our Long Valley were likewise unassailable. But Highfronds' Westerian Empire draws nearer. They are absorbing Crossvalleys – see the glow of their war machines? We are getting refugees daily."

I shivered. Crossvalleys was but a thirty-cycle hike from Long Valley, and only Lushole lay between them and us. "We are no match for the empire in population," I said.

"Aye, but do we just allow ourselves to be eaten or enslaved? Our one hope lies in better weapons, and that means better research. So, do your research, but keep in mind the needs of defense; the research must pay off soon, Loudpincers. There is not much time. Goodcycle."

"Goodcycle, sir."

He scrabbled off among the hillocks and ridges of the research field, lit in sparkles by the myriad sounds of nature. Pompous as he was, it was good for him to journey so far and take so much time with me. The bottom of Long Valley was very isolated; it was too prone to enervating warmfalls to be settled, so he'd come some distance from the comforts of civilization.

I wanted to find more lightstone, of course, but that was only part of the ancient question that had gripped my imagination. How deep could I go? The bottom of Long Valley's eponymous rift was by all accounts as far from the center and the land of the dead as one could get in the

ice. It was kept clear by a periodic warmfall, so I had a good head start.

What was below the ice? Theology had long held that our universe was a bubble in an infinite volume of ice, and academic cosmology had no better suggestion, so the question itself was a minor heresy, but priests did not have the standing in Long Valley they had in Westeria. Some radical geometers had offered the idea that the ice was finite but unbounded; if I could dig down forever I would end up coming up on the other side of the universe, just as if one kept going west with the current from Long Valley, one would eventually reach Long Valley from the east side. That closure was of two dimensions and required three, the greater closure would be in three dimensions and require four.

The idea made my head ache. I didn't believe it, anyway. Something came up through the ice to make the plants grow. That something did not come down from the center, because you could cover the plants and they would still grow. And they would still grow according to the regular cycle. To me, this meant that something different had to lie below, something that changed with the cycle.

I took my prized lightstone axe from my thorax pouch and carefully tied its tether to my abdomen belt against its tendency to fly upward. I followed the path back to my pit, contemplating the universe. Icesplitter's model of weight held that water pushed things less dense

than it out from the center, giving us weight and keeping us firmly on the ice.

It seemed to me that unless there were something pushing the ice toward the center, the universe would explode. Therefore, there should be a layer of water, or something, beyond this one. Perhaps more. The "layer" that lay beyond our layer must generate, or at least transmit, lightstones. And if I could find it, my people might have what they needed to defend themselves.

I checked my surface stores and rappelled down a knotted rope to begin again my painstaking routine: thirty swings of the axe, then wait for my body to recharge itself as the ice chips settled back down. Then do it again. It took me a demicycle to lower the pit floor by a quarter arm.

With each new level reached, I gently laid my ear fronds on the hard, cold ice-viewer, chirped a command to my vibrators, and watched for the dull fuzzy spots that would signify lightstones.

A quarter-cycle went by. Then I noticed something strange; not a dark, hard reflection spot that would signify a lightstone, but rather that half of my field of view seemed dimmer than the other half.

I raised my body on all four legs and directed my attention to the viewer itself. Designed from Valleyscraper's sonic wave theory of vision, it had eight-squared cones, each widest at the bottom and narrowing to a small plunger and plate arrangement at the top, on

which one laid one's fronds. It multiplied by two times eight squared the slight motion of the waves emerging from ice in contact with the wide ends of the cones to those fronds in contact with the narrow ends.

The fluid in each cone was under a slight pressure, and if it leaked, the amplification would be somewhat less intense; and I would perceive that part of the wave front as being dimmer. But I could not think of anything that would cause half the cones on one side to leak.

The viewer was anchored to the ice by a heavy tube frame; if the pressure on one side were not the same as on the other, there might be a difference. With effort, I braced all my legs and lifted the viewer off the ice; it did not seem unbalanced.

Still, I examined it at a wide range of frequencies – and nothing looked wrong.

I might, I realized, be sounding the edge of a huge object buried deep beneath the ice, its faintness due to depth, or softness. I went to the viewer and chirped for illumination. The dark half was still there. I moved the viewer slightly and chirped again. The edge stayed where it was – so it lay in the ice and not in the viewer.

Was it, I wondered, the edge of a physical change in the ice at that level? A field of soft ice? I thought I would have to expand my pit to test that hypothesis, and that would take cycles of work. But as I went to move the viewer to make room for digging, I tilted it and had an inspiration.

Suppose I dug my pit with a slightly concave bottom? I could move the viewer around scanning through the ice at various angles, looking thus in a different direction in each place and greatly expanding my field of view. I hastened to work.

It took another quarter cycle, but there was definitely something down there. It was huge, it was distant. It, I dreamed, might be a giant lightstone, more than enough for thousands of weapons. But I would never get to it before the Westerian armies got to us; I would need help to dig down quickly. I went off to find Threeclickson, snacking on local iceweed as I went; no time to stop for a meal now!

*

I found Threeclickson in his office with General Councilor Sharpfronds and four others.

"Loudpincers! Just the young body we need. You have saved me the trouble of sending for you. You know the general. I would like you to meet as well Professor Lieutenant Farfronds, Mr. Crushpincers, Mr. Eightfold Longtail, and Goodmother Quickfronds."

"Goodcycle, all. Need? I have just come to tell you I've found something of potentially immense value, what is possibly a huge lightstone buried deep in the ice."

Spiracles flapped in humor. "What would you say, Loudpincers, if I told you we have gained access to where we shall not have to dig for lightstone?"

I waved my pincers upward in a questioning posture.

"Precisely. If you come into the courtyard, we shall show you. Are you curious?"

I decided to set my news aside for a moment; I had delivered it and need not argue or expound on its importance, and the possibility of a journey to the center excited me. I nodded agreement and followed the Colonel and the General.

The university offices form a hexagon, the center of which is an open area twenty bodies across. Much of the military development that we would rather others not hear was done there, and as such an invitation to enter was a mark of great trust – something I even more greatly appreciated as I approached its entrance, secured by three military personal and two sets of woven stiffplant doors.

We negotiated this gauntlet one by one and found in the open space beyond, with sonic beams illuminating it from all sides, a vast sphere, fully three bodies across. A windlass even larger than it was stood next to it. A small fortune in netterbug web fiber must have been wound around it.

"Young Loudpincers," Sharpfronds' said. "There is a steady rain of lightstone skyward; it all must collect in

the center. But how far is that? Now Prof. Major Crossfronds has received an echo from his instrument."

"An echo?" Were there layers above as well as layers below?

"Almost three times eight-to-the-fifth body-lengths above us is a reflection."

"Not a temperature ghost," Threeclickson added. "Something real that does not move. The center itself, or at least something that might stop lightstone on its way to the center."

I looked at the sphere and the windlass. Then I spotted its propulsion system: a small net filled with a fortune's fortune of lightstone waving gently in the current above the sphere, straining to drag the sphere upward.

My leg hair vibrated in spite of myself. "You mean to go where the dead go to reclaim the lightstone?"

"Exactly," Threeclickson said. "And you must come too."

It was said gently, as if in invitation, but it was an invitation, I realized, that I dared not refuse now that I knew what technology would accomplish this trip. Besides, if I had been told everything with a free choice, I would have begged to go.

"When?" was all I asked.

They were all still for a moment, and in the dark silence, the thumps of distant war machines made the

horizon glow. Threeclickson waved an arm in Sharpfronds' direction.

"There must be no delay," Sharpfronds said. "We go as soon as provisions are loaded, in about thirty clicks. What you need will be on board, so there is no need to gather anything; however, I should not dismiss the danger."

He cupped his fronds toward each of us in turn. No one wavered that I could sense.

"Good. If you have affairs to settle, you, I, and all of us should do what we can in the time we have to resolve them. There are sonotube cubicles around the perimeter which you may use."

"You are going yourself, General?" I asked, not knowing then how impertinent that was.

Sharpfronds turned, then waved an arm, dismissing any idea of offense. "My style is to lead from the front, Loudpincers."

With that, he departed.

I stood and looked in wonder at the sphere for a few clicks, then proceeded to the perimeter.

From the standpoint of few affairs to complicate things, they had chosen me well. I had only my eggmother to tell and my project for an inheritance. Eggmother was away, so I called the university recorder, who took my message for her and recorded my will. For the project, there was nobody but Softtipspawn. Because she was an early teacher of mine, our relationship was

still a bit spiny and for her to consider spawning with a student was to mix things better not mixed. But I would be a student no longer in a few cycles, and her eggs carried an intelligent heritage. We were of similar age, three moltings each, and this was thought best for reproductive success. If she would not get my seed, at least she would get my data; that in itself was seed for something.

The next step was the hardest. One wants, more than anything, for one's existence to have meaning. My discovery would, perhaps, cause my name to be immortal. But if it fell into the hands of the Westerian Empire, every being in the universe would be in jeopardy. With great reluctance, I told the recorder to place my will among the things that would be destroyed should the university fall to the empire. Not until that moment had the impending invasion really hit home.

A horn pulsed deep long waves. Our departure signal, probably, though I had not been told that. I left the cubicle and headed for the sphere. There, Mr. Crushpincers directed me toward a hinged section of the sphere. He was, despite his name, quite small.

"It is a hatch. Pull it outward," he said.

I did as he said and it opened easily, almost pulling itself from my fingers as it swung hard toward the ice. "It seems too heavy to be strong," I said.

"It has many layers of fiber joined with a glue made from iceworm skin. It is both stronger than ice itself and heavier; this is a secret which you must keep now."

I moved the door back and forth, thinking about how strong and heavy it was. "If we have this, what do we need of lightstone weapons?"

Crushpincers clicked with good humor. "Not as much, certainly. But we need lightstone for much more than for weapons; we need the lightstone to fly over the enemy. A lightstone-levitated gondola with four archers could neutralize an eight of eights of infantry, if even a quarter of their load of poisoned daggershells found the target."

The instinct of a daggershell was to seek the ice at as high a velocity as its water jets would take it, its hard, notched shell penetrating deep enough to hold it until its next molting. They could stab completely through a thorax and still stick in the ice below. Many cycles ago, I had come close to being under one, and the wonder and fear at hearing its bright landing so close to me was one of my strongest youthful memories. To us such a thing as a weapon spoke of our desperation. To actually swim above the ice levitated by lightstone fired my imagination.

"What a project! Are you coming along?"

"No, someone must mind the windlass, I fear. Now you're the last, so on your way."

I nodded and entered the sphere. My companions were on benches against the side around the equator of

the sphere, each with a portal that had been invisible from outside. Cabinets, no doubt filled with the equipment we would need, lay under the benches. I took the remaining free bench and looked around.

I felt I had entered some new and strange universe. The inner wall was smooth to even the highest frequencies, like an egg. Apart from the benches, the cabinets, and a cylinder covered by what sounded to be a taut drumhead at the very bottom, it all seemed very stark and featureless.

"We ascend," Sharpfronds said. Only the slightest motion betrayed the truth of what he said.

"Loudpincers," Goodmother Quickfronds said. "I have prepared something for us all to take that will ameliorate the effects of the rising pressure. I assure you, despite what it tastes like, that it will not harm you – I have taken it several times myself in pressure chamber tests."

"Pressure chamber?" I had never heard of such a thing.

Quickfronds raised her fronds in pleasure. "It lies beneath the north side of the University. We carved a cylindrical room, then froze a plug that, after some grinding, matches the opening almost exactly. The 'almost' we take care of with a caulking paste of crushed iceweed. A great screw can push the plug down, compressing the water beneath it."

I made postures of admiration. "This must have been in work for some time."

Sharpfronds clicked his spiracles. "It has. Fortunately. Dr. Quickfronds is our greatest expert on this, and we trust her to keep us alive. Now let me show you another wonder. Crushpincers?"

"Yes, General?" The voice had a tinny quality, missing some of its lower register glow, but it was clear and understandable. But where was Crushpincers?

"How far?" Sharpfronds asked, directing his voice to the drum.

"Two eight cubed and six bodies of line out," the voice answered, lighting up the drumhead.

Crushpincers must be outside the sphere, I thought. Observing the play out of the tether line. But, I remembered, the reel was on the ice, and we'd been rising for some time. We'd have gone through the reflecting layer beyond which unaided acoustic senses could not see. So how?

Sharpfronds leg hair vibrated in excitement. "Good show. Loudpincers and everyone, there is enough tension in the line to carry the sounds we make, as amplified by the big drum head you see in the center. Another drum is attached to the line by small lightstone rollers, so that Crushpincers' voice can vibrate the line and carry up to us. The same works in reverse."

"Crushpincers is still on the ice?" I said, half asking, half stating.

"Yes," Sharpfronds said.

I could think of nothing to say. The implications of being far, far above the ice and still being able to talk to those below ran riot in my mind. Speaking tubes ran only a few eights of body lengths before the voice faded to inaudibility. Beyond that, messengers had been needed.

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We rose and rose. There was no way to keep track of cycles, save through the voice of Crushpincers or one of his students from the drum below; but they told us that two had passed. Dr. Threeclickson said, based on his geometrical analysis, that we had ascended a hundredth of the distance to the mathematical center. Sharpfronds said we should reach something soon; occasional holes in the reflecting layer had revealed another reflecting layer at about this distance.

We were all feeling somewhat ill. The pressure, Goodmother Quickfronds said, was compressing the heavy fluid cavities in our bodies, interfering with our ability to produce energy. We would be able to tolerate it based on the pressure chamber experiments, for quite some additional distance. But it would be uncomfortable until we got used to it.

I felt tired, a little woozy, and lighter and lighter. I began holding onto my shelf instinctively, as if to keep from floating off it like I was made of lightstone. The very

physics of my body was changing; it was as if I was being drawn to the land of the dead. Should we really be doing this? I wondered.

To keep my mind off my innards, I tried discussing cosmology with Quickfronds, explaining to her my idea that the universe was like an egg with multiple shells.

"Egg, universe – it's an interesting analogy," she said. "Shells exist to keep out parasites, but allow water and dissolved heavyfluid to enter and nourish the embryonic larva. The larvae exist between the shell and the center, which has nourishment, but is not alive. An idea is a bit like an egg, too, I think. It should stay in the shell of one's mind until it is ready to emerge, no sooner, no longer. A real egg has only one shell, Loudpincers, and hatches only once. And before crèches and culling, most larvae were eaten when hatched. If our universe is like an egg, are we really ready to crack its shell?"

War, ice, egg, universe – individuals were laid, hatched, lived and died. But everything else seemed to stay the same. "For how long have nations rose and fell, for how long has knowledge been won and lost, how many generations of soldiers have died fighting over the same ice?"

Quickfronds nodded. "For longer than we know. Sometimes a warmfall will expose relics; Steadylegs of Crossvalleys has looked at the distribution and frequency of such finds and thinks warmfalls are less frequent now than when they were deposited, and the ice is on average

a few body lengths thicker. But there is no discernible change in these rates for the five and three-eighths great greatcycles for which we have records."

I imagined all my research lost to the Westerian invasion and then, greats of greatcycles later, being duplicated by someone else, only to be lost again.

"What happens to a larva that stays too long in its shell?"

"The worms come, in time. An eggshell is not forever." Quickfronds waved an arm around her, "Our present shell only seems like it. Your analogy of the egg seems to repeat itself on several scales, and both in abstract and concrete. There may be some wisdom in it on how the universe does things."

"Thank you, Goodmother."

She nodded and turned away, signaling the end of conversation. I, too, was having trouble concentrating as what the pressure of the ascent was doing to my body distracted me. On and on we went, and we grew quieter and more unsure. How much cable did Crushpincers have on the reel? I couldn't remember.

If we did not find something soon, I thought, we might be in no shape to do anything with it.

"Comrades," Professor Lieutenant Farfronds called. "Something lies…"

The impact came as a surprise, throwing us off our shelves.

"… ahead of us."

We floated together into a jumble on one side of the sphere. Or the bottom, now, for, pulled however gently, we stayed there. It felt as if up had become down and down, up.

Then, before anyone could even groan in astonishment, the sphere began tilting back and forth, and we slowly rolled as a mass to the top. After much embarrassed and apologetic moving of limbs, we sorted ourselves out into a rough circle around the top.

General Sharpfronds gathered himself, jumped and swam up to the drumhead, and latched on. "Crushpincers!" he bellowed.

There was no response. The sound transmittal system depended on tension, I realized. And now there was none. We rocked slowly, feeling upside down and helpless.

Finally, there was some more rocking and a kind of sucking sound. The motion of the sphere changed, now feeling like it was tethered again as opposed to sitting on something.

"General? Anyone?" Crushpincers' tinny voice sounded.

"Thank goodness," Mr. Longtail sighed.

"We're here, Crushpincers. We're seemingly, uh, upside down, but everyone seems okay. Ah, Goodmother?"

"It was a gentle crash, we should all be undamaged."

"I'm undamaged," Sharpfronds echoed. Others followed his lead.

"Good." Crushpincers voice came after a discernible delay. "We noted when the line went slack, but there is some lag since you are so far up. I have had to reel you back a little to restore tension to the tether, but you should still be close to what stopped you. Can you open the top hatch?"

It was at our feet now; top had become bottom.

"We shall attempt that presently. Thank you, Crushpincers." Sharpfronds waved a limb at us. "It seems we have arrived."

"We should gather the lightstone quickly," Goodmother Quickfronds said. "I don't know how long our physiology will hold up under this pressure."

Actually, I felt somewhat better than I had earlier. Perhaps my body was adapting to the new conditions. I was conscious of, well, slowness, in my thought and movements. But quality seemed unaffected.

Sharpfronds nodded. "Loudpincers, Farfronds, unscrew the latches. Longtail, wind up the beacon."

We all jumped to our tasks, though I wanted a look at the beacon. Wind-up implied a spring of some sort; I had never heard of a spring driving a beacon before. The threat of the Empire had made the University busy indeed, and I found myself very curious about things that, apparently, no longer were to be hidden from me.

But first things first. I went to work on my latches. As I did so, the sphere began to develop a slight monotonic glow; the beacon, I presumed. Soon the hatch swung aside, and revealed "below" us a vast, smooth, featureless plain starkly lit by the tone of the beacon. I didn't see anything at all that looked like lightstone.

"So that is the land of the dead. Not quite what we were told before molting, is it?" General Sharpfronds said. "No eater of souls, no pleasure gardens, and no piles of lightstone, either."

"No, sir," said Farfronds. "It looks like another layer of ice, though darker, less reflective."

"The multishell cosmology," Professor Colonel Threeclickson said. "When the lightstone hits it, it must work its way through to another layer of water, perhaps one that is inhabited. As for the darkness, we have no idea what our layer looks like on the other side. It could be a debris field."

My leg hair wilted. That was my idea and Threeclickson had stolen it. I felt vindicated but disappointed that I had not gotten any recognition.

"And what happens to the dead?" Longtail asked. "I have a bad feeling about this. It is not what we expected. If we cannot see any lightstone, perhaps we should go home."

Silence greeted that remark. Not finding the lightstone made the expedition a failure and could have grave consequences for our nation.

"The area of this land must be over eighty percent of the area of our land." Professor Threeclickson said. "We can only see a small portion. Where do the warmfalls come from? We should take more of a look."

"You are welcome to stick your head in the crack," said Longtail.

"I volunteer," said Lieutenant Farfronds.

"Thank you," General Sharpfronds said. "But I would like one experienced soldier to remain aboard the sphere at all time. Since I shall have to make the decision of what to do, I shall get the information first hand. Your orders, Farfronds, are that if anything happens to me, have Crushpincers pull you all back. You hear that, Crushpincers?"

"I hear, General. May I suggest that, in that event, we pull back a little way and reevaluate. We would not want to lose you."

"Oh, bother that. Very well. Pull back a little and, Farfronds, you do as you think best. But should I meet my end up or down there, whatever it is, honor me by making sure that nobody else meets a similar end."

"Sir!" Farfronds replied.

"Enough discussion. 'Ware above, as below!"

Sharpfronds let go of the communications drum and dropped slowly through the hatch and onto the plain. So far, so good. But then he kept going *into* it, though very slowly.

"Soft!" he said. "Like so much rotten tissue. Slime. I'm sinking into it! Totally unexpected! Throw me a line, quickly."

Farfronds leaped up to the cabinets below our benches and clinging with three arms managed to open a cabinet with one, extract a coil of rope, and toss it down to me. "Loudpincers! Tie an end to the latch and throw the coil down at Sharpfronds."

A glance down at Sharpfronds showed only his head and fronds still echoing above the surface. His voice holes were beneath it, but he had two of his arms just on the surface, waving slowly back and forth, trying to swim in it, it seemed. He could keep that up only so long, I realized. He was suffocating.

I glanced up in time to catch the coil of rope, but instead of just throwing it down to Sharpfronds, I followed the coil and lowered myself claw by claw toward the surface. The exertion made me incredibly tired.

General Sharpfronds had vanished entirely just as I reached the surface; there was nothing to show that he'd caught the coil. I began to lower myself into the surface, head first, to keep my spiracles above for as long as possible. Voices called to me to stop, but there was no time to argue.

The material was viscous, clinging, and dense. I tried chirping to see, but the viscous mass seemed to absorb every sound I made; it was as black as deafness.

I reached as far down as I could with my upper arm, feeling my energy wane as the substance began to block my spiracles. I felt something, and grabbed and held. It could be Sharpfronds' limb. Or something else entirely. Something long dead.

Shuddering, I held on and began to back. Slowly at first, as the holding and the motion took every available bit of energy I had. But as more of my spiracles emerged into clean water above, I felt a little more strength.

Then the rope started to move up. My comrades must have seen me try to back out, I thought, and helped by pulling the line in.

My head broke into the water and I started rising faster. I shook myself back and forth to try to clean my fronds and vision returned. What I had in my hand was definitely someone's wrist, just inward of his pincers.

I looked around for a moment as my flapping spiracles desperately tried to restore my energy. In the monotonic glow of our beacon, every bump in the surface cast long, exaggerated shadows. One of the shadows moved, undulating toward me. I had to stare for seconds to be sure of what I was seeing; the rise in the surface was huge.

Suddenly, the slime fell away and a great round hole slowly broached above the slime, then waved right and left before descending again. The hole appeared to be a mouth with six huge triangular teeth around its rim,

pointing inward. The Eater of Souls, I thought – mythology come real.

Clinging with both hind arms, I reached down into the slime with my other arm, grabbed my prize, and pulled. With the group above pulling as well, an entire arm emerged: pincer, wrist, and up to the second joint.

The huge surface undulations moved nearer. Not enough time, I thought, not nearly enough time. But I continued to pull. Suddenly, the strain on my arms seemed to double and I had to cling, both to rope and the arm, with all my remaining strength. The eater? One slice of those teeth and I would be left holding only an arm, if that.

But before I let go, I saw that the arm I held was emerging rapidly now; we were being pulled faster from above. The winch, I thought. They must have told Crushpincers to reel us in. The General – for it was he – began to emerge. He came clear; thorax, head, abdomen, and his limbs trailing limply, but still in one piece, the muck streaming away from his body.

The slime swelled up next to us and a great arch, the upper part of the eater's mouth, broke the surface and rose inexorably up beside us. Slime fell away from two, then three huge triangular teeth.

This would be very close, but the general's body was free now and we were rising even more rapidly than the eater's mouth. Maybe it would miss. I freed one hand

from the General's arm and got ready to try to bat or push us away. Hopeless, perhaps, but I would not give up.

Then something large and bright fell rapidly from above – incredibly quickly, the speed of its passage creating a brilliant wake behind it. I recognized it; it was our bag of lightstone, the one on top of the sphere that suspended us up/down from the ice. What a thing to see lightstone as *falling*, but that was the current perspective.

It struck the mouth just a body length from me and cracked it, caving it in between two huge triangular teeth. The mouth tore open, its parts waving uselessly. Dense material began to flow from the wound toward the center. Then we were above it, and rising (falling?) rapidly with the sphere.

I was pulled into the hatch, still holding the unconscious General Sharpfronds by his arm.

I released him to Goodmother Quickfronds and collapsed near the hatch with my limbs tucked under me, chrysalis style, shaking uncontrollably. My hands, my head, my body had plunged into the remains of others, accumulated over the ages. Even as I lay there, pieces of the dead clung to me. I had sought treasure in their land and they had guarded it well. I had seen the eater of souls itself. I abandoned myself to my shudders, and lost conscious thought.

When I woke, I had been cleaned. Also, I floated; down had become ambiguous again. There was no need to chirp for vision; the hull glowed with many sounds – a

sign of a robust slipstream. Were they reeling us back so rapidly? Crushpincers must have an eight of helpers turning the wheel!

Professor Lieutenant Farfronds came over to me and touched me with a limb. It was the gesture of an equal and a friend, and without his saying anything, I realized my status had changed. "The General survives, for now. But we are all in great danger; we have lost our lightstone and our fall toward home is too rapid. There is no tension on the tether. Indeed, it trails behind us now. We shall have to do something desperate, and soon, and we may not survive. I wanted to talk to you a moment first." He raised a pair of limbs. "I speak to you as one who, despite my professor title, has always been more of a military person. I have fought the bandits in the countercurrent reaches, and I have witnessed courage, so I know it when I see it. Some will judge this expedition a failure, for the loss of lightstone. But I think we have found a good and courageous soldier."

"Thank you, sir," was all I could think of saying.

He nodded, touched me again, then swam over to Goodmother Quickfronds and the General.

Some time passed, then Professor Colonel Threeclickson called us to attention, the first time he has said anything for some time. While he was the ranking officer after the incapacitated Sharpfronds, he'd let Lieutenant Farfronds, who must have been far more experienced in emergencies, take charge of details. But

apparently there were responsibilities of leadership and rank that one does not duck.

"Companions…" He hesitated.

I clenched my pincers. It would, I thought, be so like Threeclickson to make some kind of acerbic, imperious, cautionary speech or lecture now, putting us all on notice. But there was no time for that. I had always feared him more than respected him, and now when a greater fear ruled, I had little confidence in him.

"Companions, if we stay with the sphere until it falls to the ice, we shall be crushed. Therefore, we shall have to abandon it. Lieutenant Farfronds, tell what must be done."

Short and to the point? While his logic remained, the manner did not seem to be that of the Threeclickson I'd known.

Farfronds crawled quickly up to the hatch, then dropped toward the drum, spreading his limbs and fingers as he did so. He did not fall rapidly.

"See," he said. "The more area you present to the water, the slower you fall. And, after a certain amount of time, no matter how long you fall, you do not fall any faster. Our bomb-throwers call this 'terminal velocity.' If you spread yourselves wide enough and so fall slowly enough, you should land on the ice uninjured. You must only have the courage to do it."

Neither I, nor anyone else, had the instincts of a floater or a swimmer. It was our nature to cling to the

surface, anchored by our weight, to not be swept away by currents. I grabbed my bench all the more tightly as I listened to what Farfronds said. I saw the glow the walls of our sphere emitted from its too-fast passage and could easily imagine the crunch as it hit.

"How much time?"

I could barely hear that voice, but I recognized it immediately. General Sharpfronds was back with us.

Farfronds raised his upper arms. "Soon, sir. We have no idea of how far back we've come. We could strike at any moment."

"Very well. Open the hatch."

"General, you aren't ready yet…" Goodmother Quickfronds said.

"Am I ready to be crushed?" His voice seemed a bit stronger. "I will lead us out. You will come next."

"Me!" Quickfronds exclaimed.

There was a moment of quiet. Then Sharpfronds said, "I may have need of you when I hit the ice."

There was some nervous clicking of pincers at the General's small joke, but it seemed to break the tension. Farfronds motioned to me, and I joined him in undogging the hatch. But when we were done, we couldn't budge it.

"Pressure," Threeclickson said. "The sphere is at the pressure of high above. We must let it out to open the hatch."

Lieutenant Farfronds scrabbled down from the hatch, reached into the cabinet below his bench, and

pulled out a military spear. Then he stabbed the tip directly into the communications drum. The sound of its ripping almost blinded me, and I felt an immediate and terrible discomfort all through my body, as if I were about to explode. Groans filled the sphere, but gradually the pain got less. Also, I suddenly realized I was back to my normal weight, and almost fell from my hand-hold near the hatch. What did pressure have to do with how much I weighed? Compression, I remembered. As my body expanded and gained more volume, it fell more rapidly.

"Loudpincers, the hatch!" Farfronds shouted. I pulled with as much strength as I had, and it opened, grudgingly at first, with a bright hiss of water jetting through the crack. Then it opened more easily. I reached down, to take the General's hand – he was too weak to climb up to the hatch.

Before he left, he gave what might be his final command, "Follow quickly, all of you." Then he was gone.

Goodmother Quickfronds quickly leaped up and followed him. After a moment of hesitation, Professor Colonel Threeclickson followed. Mr. Eightfold Longtail, however, stayed clinging to his bench. Lieutenant Farfronds went over to him.

"Go, now! You must."

Longtail shuddered in denial.

Farfronds tried to pry his pincers from their grip, but got nowhere.

"Get out of here, Loudpincers," he told me.

Again, I disobeyed orders, dropped from the hatch and tried to help pry Longtail loose. But it was hopeless. I touched Farfronds and drooped my fronds.

He nodded. "Go. I will follow."

This time I did go, leaping for the open hatch and pulling myself out and through almost in one move. The scream of the water passing by it made the falling sphere below me visible, if in a wavy, uncertain way. Below, to my right, I could make out the courtyard of the university – too close, I thought. I spread my arms and legs as Farfronds had told me, and my fall slowed immediately.

I stared at the sphere, receding below. Where was he? There! A dark shadow appeared in the glowing slipstream, and began sliding off to the right.

The sphere suddenly exploded in a million frequencies of sound and went dark. I chirped, and saw the ice below me, coming up too fast. Now my height and fall were very real; every muscle in my body tensed with terror. I struggled for control and stretched myself as much as possible and flailed at the water with my claws, trying to swim back. At the last moment, I put all eight limbs down to break my fall.

The landing was an anticlimax; I didn't hit any harder, I thought, than if I'd landed after jumping as high as I could. Terminal velocity, Farfronds had said. I had learned, I thought, a great lesson of mind over instinct. Feeling myself whole, I chirped in the general direction of

where the sphere hit, saw it, and headed that way to see what I might do to help poor Longtail.

On my way, I saw a bright crunch, chirped, and recognized Colonel Professor Threeclickson. Of course, having left the sphere before I did, he would have had longer to fall. I went over to him, and ascertained that he had come through the fall as well as I had.

Then I told him the bad news. "Sir, Longtail wouldn't leave the sphere. I was headed over to see what I could do."

"You should stay back, Loudpincers. You would not want to see what must… Forgive me. You have already… I… Yes, let us go see what we can do."

Threeclickson had asked me to forgive *him.* I sensed again that whatever happened now, my life had changed greatly.

Goodmother Quickfronds landed just then and scuttled over to us. We told her what had happened. "Threeclickson, tend to the General when he comes down. Rest should be all he needs, and a little cleaning off. Loudpincers, you're young and strong. Come with me."

We were halfway to the wreckage before I'd realized how easily Quickfronds had given orders and how uncomplainingly Threeclickson had obeyed. Five cycles ago, he had been the terror of my life. An act for the benefit of the student, I surmised, by one whose real nature was to defer to others. Yet I almost felt sorry for him.

We reached the crumpled sphere and found our way in through a hole in the wreckage. Lt. Farfronds, of course, had gotten there before us, but there was nothing to be done. A jagged section of the hull had neatly severed Longtail's abdomen from his thorax. He had, uselessly, extricated himself and tried to hold his severed half against the wound, but that, Quickfronds said, only hastened his death, as certain fluids from the nether part should not mix with those in the thorax.

Quickfronds turned to us. "Should you ever find yourself in such a situation, do what you can to stem the bleeding from the thorax. You will still die, but may have as much as a cycle or two to say and do whatever last things you have to say or do."

Threeclickson and General Sharpfronds arrived next. We removed the unfortunate Longtail from the wreckage and all stood vigil for an eighth of a cycle as his body became light and ascended to the land of the dead, to become part of that slime in which I had been briefly immersed. I shivered, thinking about what I had touched. I thought of my conversation with Quickfronds as I watched Longtail ascend. If our universe was an egg with a single shell, what lay outside? What laid it?

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We were a sober group back at the University, arms at sides, fronds still. General Sharpfronds, now much

recovered, addressed us along with several military commanders and university staff.

"Gentlepeople, we took our best shot at it. We learned much of cosmological and perhaps theological interest, though the eater of souls we encountered seemed a very physical creature. Looking at echoes, I might have worn a rope and been pulled back with much less bother. But such an encumbrance could itself have been risky. Again, we took our best shot.

"Now we are in a very grave situation. Lushole has fallen; nothing remains between Long Valley and the empire. Highfronds has delivered an ultimatum: we should submit peacefully as inferiors to his superior government, or be crushed by his armed forces. We have five cycles to reply." The General snapped a pincer in contempt. "He has that little respect for our ability to improve our defenses significantly in that time. Hubris may be his undoing. Highfronds is a charismatic leader – do not underestimate him. But the juices of his abdomen run his mind, and we shall make that our advantage. We will do the unexpected, the unanticipated. We will fight creatively.

"The good news is that our war floaters are ready. With enough lightstone to float a dozen of them, we should be able to even the odds and make advance against us too expensive for them. If we can float all thirty, we may be able to repel them without significant loses of our own; a result that might guarantee our

independence for some time. But that is a still-sealed chrysalis; we need more lightstone, for we can float only one as things stand.

"Lieutenant Lecturer Loudpincers has found a possible source of lightstone deep within the ice."

There were murmurs in reaction to this news, creating far more of a stir when it came from the General's voice holes than it when it had come from mine only a few cycles or so ago. But I barely noticed: Lieutenant Lecturer Loudpincers, he had called me. Graduation eight times eight cycles early and a field commission, too! If only I proved worthy of it.

The General continued. "It will take some time to dig it out, six to seven cycles. We will move civilian population and the war floaters deep within our territory, back in the cracks where they will be hard to find and may easily defend themselves. The University hexagon we shall turn into a citadel, capable of holding out for a hundred cycles against any attack machines we have heard of the Westerians possessing. They may yet come up with some new weapon to save, or revenge, our people – but that is a very faint hope indeed. Our best chance lies with the war floaters.

"General Highthorax and General Stronglegs have prepared maneuvers and delaying actions which might give us three cycles or so beyond the ultimatum date. In that time, which will be purchased with the lives of the brave, we must find Loudpincers' giant lightstone, section

it and launch the war floaters. Unless someone has a better idea."

Dark silence covered the gathering.

"The sacrifice will be great and the timing very, very tight. So we had best start digging."

Later, when I happened to be close to the General, I told him, again, that what I had was a theory, a speculation, at best a good idea. "Now soldiers will lose their lives on the idea that it is true."

"So you tell me now that you think you've oversold your idea," he said this with cold stillness.

I trembled; I had never been so frightened.

But General Sharpfronds rested a pincer on my arm, the reassuring touch of a father on a larva. "I am not so molt-damaged that I did not recognize the risk; nor did you mislead anyone by stating possibilities as certainties. The one certainty, which everyone in this country knows now, is that without some miracle, we are all slaves or dead. Well, miracles occur in combat as well as in craft, but they are done by soldiers who have *hope*. If we had not had your lightstone find to give them hope, we would have had to invent something of less substance.

"But I would prefer not rely on miracles of any kind, so let us get about the digging. We have some equipment here that will be useful; my people will take care of it. Refresh yourself and be out there in an eighth cycle."

I nodded, then, remembering my new status, clapped my pincers, military style. "Yes, General."

I headed for my student quarters, perhaps for the last time. I tried to contact Softtipspawn, but she had already been evacuated. Whatever happened, nothing would be the same. I gathered a few mementos to fit in a pouch, then lay on my bench and rested.

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When I arrived at my dig the next day, General Sharpfronds' people had spread a great panoply of cloth and pipes around my hole. After a moment, I recognized it – a warmdrill. If one seals a certain flatweed against the ice so that water cannot flow through it, in time a heavy compressible fluid will collect at its roots, against the ice. This fluid, if allowed to flow into a container of dead plant material, will displace the water with its very heavy essence. Such heavy fluid makes plant material grow very hot, and water is pumped through that heat. The hot water, forced down by means of bellows, cuts through the ice rapidly. As a mere student, I had never had access to such inner University wonders. As the chief of a potentially nation-saving emergency project, I had as much special equipment as could be conveniently placed in the area.

We drilled cylinders, a body length deep at a time. First we carved a circle in the ice and made it deep, then,

with a special sideways-facing nozzle, we cut in horizontally and so detached the cylinder from the ice. Ropes were frozen into each cylinder, and it was hauled up. Then the process was repeated.

In the distance, the glow of the battle of the University had began to light the sky.

Down the shaft went, just spinward of the large mass I so fervently hoped was lightstone.

"Water," someone yelled. "We've struck water."

My first thought was multishell cosmology. My second was about how wrong that first thought had proved far above.

"Melt water, not seawater," the person in the bore shaft yelled, as if he could read my thoughts.

"Great central heavens!"

There was silence. "What is it? Can you see it?"

No answer.

I turned to one of our draftees, Premother Longlegs, a first-molt apprenticed to a sweettree farmer, now a refugee. "Longlegs, go tell General Sharpfronds that we've reached the objective, but something strange has happened."

Someone had to go down. There were only four of us above. Who to send?

At that moment, for some reason, I thought of General Sharpfronds and his pronouncement: "My style is to lead from the front." The organizing had been done; what remained to be done was below.

"Tell him that I'm going down to investigate. Platoon Sergeant Shinyclaws will be in charge, up here, until I get back."

Like most officers who rose via the academic rout, I'd taken special pains to learn the names and procedures of the pure warriors; but was still uncomfortable. A seasoned troop might be holding his spiracles in amusement at how I did things, but Longlegs was as new to this as I was. She snapped a claw as if she were at drill, turned, and was off.

"Sir!" Shinyclaws said. She was a veteran, and there was a sharpness to her voice that made me worry that she resented my rapid rise; she perhaps didn't take in the three moltings of academic training that had preceded my one act of physical courage. I should, I thought, deal with it now.

"Sergeant Shinyclaws? I'm new to this, I know, but we're very pressed for time. If you're unhappy, I'm sorry. I didn't choose the circumstances."

"Oh, sir. Not that at all. Well, not with you at any rate. I'm maybe a little unhappy because I'm not at the front. I'm still of egg-laying age, I'm afraid, and the General Professors are looking ahead to replenishing the population. But if we don't… I mean there won't be any point."

I thought about that. Both positions had a logic to them. I thought it through. "Shinyclaws, the work behind the lines still has to be done. By having that done by

females of egg-laying age, the Generals cover two needs with one action. Personal happiness is secondary in such times. Sorry."

"Yes sir. I understand. But I would rather die fighting them now than be overwhelmed here and forced to bear their eggs later."

I could only nod. I had not realized the full implications of her assignment.

"Anyway, Lieutenant, ah… "

"Loudpincers."

"Loudpincers, sir. You'll be wanting to take a runner down with you, sir. Betterthinker would be my choice."

"Right, thank you. Carry on, Sergeant." The optimistically christened Betterthinker was actually one of the slower troops on the uptake, but he was fast and strong. "Betterthinker!" I shouted. "Come on. You're with me."

We'd built a tripod over the hole and a tube of rope netting hung down from its apex, enclosing the hot water tubes. The netting also functioned as a ladder of sorts, and on these we descended.

As we went, I reminded myself of who was below. It was the third shift; Sergeant Raspyclaws, Mr. Icefronds, the water jet technician, and able soldier Larvasaver. None were evident as I reached the level of my suspected giant lightstone. The shaft went further down; the plan had been to approach the lightstone from the bottom.

Only a half body-length or so of ice separated me from it and I could easily see it by holding my fronds and mandibles against the ice and chirping. It certainly looked like a lightstone; its rugged surface was full of shiny pits and sharp edges. But it was huge – several body lengths across, at least.

I felt warm water at my abdomen. My first thought was that it was the cutting water, but that had been turned off some time ago. The warmth was enervating; I wiggled my abdomen to increase water flow, then switched my body around, hanging upside down so my spiracles would be in higher, cooler water.

The warm current was issuing from the horizontal shaft. I moved down further so my fronds could see through it. The warmth made me forgetful and fatigued, and I had to fight to concentrate on moving each limb, but I persisted in descent.

Finally, I was level with the shaft, chirped, and saw the thing hanging below the giant lightstone. It was long, rounded at each end and unnaturally smooth, as if turned from a lathe.

On the ice in the shaft beside it lay the bodies of my crew. If I went to them now, I would probably suffer the same fate. I turned and began to climb up the cutter's suspension ropes, but could only move a little at a time. I had to get to colder water.

"Betterthinker. The ropes. Pull me up."

I was incredibly tired. If I let go right now, I would literally fall asleep. A very pleasant… .

The ropes jerked upward, again and again. I should let go. No, I should hang on. It was getting cooler. I was thinking again.

I resumed climbing, and spotted my savior amidst a jumble of rope and tubes. "Good, Betterthinker. I'm awake now."

"Handholds, sir. On the wall. I need to let go."

I saw the notches in the ice and grabbed onto them with two claws as I let go of the ropes with the others. As soon as I had detached myself from the ropes, they slid back down. Betterthinker had, I realized, pulled up not just me but the whole cutting apparatus as well, weighted as it was with superheavy fluid tanks. Well, Sergeant Shinyclaws had said he was strong.

I looked at the tubes and ropes, straightened out again. If they were to pipe down cold water instead of warm, I might stay awake long enough to rescue my colleagues. But I would need something to keep the cold water around me. I scrambled back up the shaft as fast as my legs and arms would take me.

Tailoring is a skill the career military know well, I found out. We took one of the woven flatweed covers and made a rough tube of it for my body, cutting slits to allow my limbs to stick out and tying it around my neck and around a heavy fluid tube just beyond my abdomen. We knew how much tubing the cutter had used, and coiled

twice as much for me. The tube served two purposes; to give me cold water to keep me awake, and, in an emergency, they would be able to pull me back with it. I also took the end of a coil of rope, in case something or someone else would need to be pulled back.

With Sergeant Shinyclaws and Ordinary Soldier Bristlelegs pumping cool water around me, I headed down again. It seemed to go more quickly this time, despite my encumbrance. Though I could feel the heat on my head, I had not the slightest loss of energy. The cloth tube that surrounded me, however, puffed up and deflated with each push of the bellows above in a way that would have caused amusement, had the mission not been so serious.

I traversed the horizontal tube quickly and reached the bodies of my comrades. Asleep or dead, I could not tell, but I dragged each one back to the shaft and harnessed each to the spare line. Then I called for Betterthinker to haul them up.

Then, alone, I encountered the wondrous object that had apparently followed the lightstone up through the ice. It was as wide as the shaft, and its warmth had melted a path all the way up to the lightstone. The thought of the lightstone reminded me of how much we needed it, and how quickly. The entire crew, I realized, would need cold suits like mine. No matter how curious I was, there was no time to investigate. We could work around the thing, whatever it was.

Lightstone! It must be after the lightstone just like my compatriots and I had been after lightstone in our ill-fated expedition less than three cycles ago. Less than a three cycles? It seemed like a greatcycle ago. The thing seemed like more proof of layered cosmology – but, the layers were different. Alien. My mind was dizzy with change and happenings.

No time, no time to investigate. I turned to leave the shaft and get help.

"We've struck water – meltwater, not seawater. Great central heavens!"

I turned back. It was Sergeant Raspyclaws' voice, much more clearly than I had heard it at the top of the shaft, but it came from the object. There must be beings inside the thing, I thought, from the next layer; it seemed obvious; the large object was their version of the sphere I had ridden to the land of the dead. They were trying to talk to me, but all they knew of my language was what Sergeant Raspyclaws had shouted – so they were repeating that. Could they see me, somehow? I saw nothing from them but that burst of language.

Time, I had no time. But maybe they could help. Help us in our war? How. Perhaps they could carve lightstone – they were apparently after it themselves.

Perhaps they wanted it for themselves.

Where did my greatest hope lie? I decided to invest a few moments and pointed to myself. "Loudpincers."

"Loudpincers," it repeated in a golden burst.

I showed them my body parts: pincers, claws, fronds, arms, legs, and mandibles. I shouted LOUD and whispered soft. I backed up for go and went forward for come. I showed them ice, water, and lightstone. I tried "cold water" spilling some from my suit, and "warm water" waving my arms around. It repeated everything correctly and I said yes. I wished it would make an error so I could teach no.

I curled up in a chrysalis posture. "Sleep," I said. I unfolded myself. "Awake."

"Hot water sleep." It said.

"Yes." I was getting somewhere.

"Cold water sleep."

"No, no. Hot water makes sleep."

"Cold water makes awake."

"Yes. Cold water makes awake? Question. Yes. Answer." Would it understand inflection? "Cold water makes awake. Statement. Hot water goes down? Question."

"Come Loudpincers up?"

"Yes." It was quick, picking up everything, forgetting nothing.

But I was getting tired and running out of time. How could I ask them to help?

I chipped some ice and showed them "take" and "move." They understood.

"Loudpincers take lightstone up."

"Lightstone go up?"

I moved my arms frantically, upward as fast as I could.

"Yes, up. Loudpincers take lightstone up fast!"

The effort wore me out. I felt warm. Then I noticed that the pulses of cold water in my tube had stopped. That could only mean the empire had arrived. I had only moments of consciousness left, time for one last plea. I took my ice chipper and swung it at my head, stopping just short.

"Kill. Kill above. Cold water stop."

Silence greeted that. What an idiot I was. What could our problems possibly mean to them?

Unable to stand any longer, I collapsed to the floor of shaft.

"Help," I said. How does a person alone act out help? "Help." I tried to move an arm…

*

I woke with cold water flowing into my tube again. My first thought was relief – perhaps we had won above. My next thought was that the Westerians had figured out that I was down here and were on their way to enslave me. I found strength enough to chirp. My tube, I saw, was now running into a squarish hole in the alien thing and providing a steady stream of cold water. Hovering around me, swimming, were tiny circular things with little claws. One of them stopped in front of my fronds.

"SEEN-DEE," it said, pointing to itself with one of its tiny claws. "Cyndi help?"

"Yes," I said. "Cyndi help." Then I remembered the situation above. What hope for them there'd be now, I had no idea. But I had to ask.

"Cyndi help kill above?

"No, no, Cyndi no kill."

They could not understand, not yet. They could not understand my nation being raped and enslaved, its heroes and my friends rising to the land of the dead. They would understand in time, but too late, too late.

"Cyndi help above sleep?" it said.

"Great center, that would work! Yes. Help above sleep. Stop kill. Stop war."

*

It was not done simply. The Iceprobe, for that was what they called it, had to back off and come back at an angle to intercept our shaft. There was no room in it for me; I clung to the lightstone while all this happened, and nearly fell asleep again. But before I did, Cyndi brought me a small squarish pack, which she fixed onto the back of my tube. It took water in and pumped it out, cold, into the tube feeding my cold suit. For this reason, I was the only one awake to witness much of the defeat of the Westerian army, for Cyndi's artificial warmfall put our soldiers asleep as well.

It was not done instantly. The Iceprobe could swim on jets like a daggershell, but it was alone and the Westerians had overrun almost everything. But they had bypassed the University after Crushpincers stopped their effort to breech its walls, intending to starve it out later. And they had been slowed by the deeply cracked area in the far east where General Sharpfronds had planned Long Valley's last stand. The terrain and our deployment had broken the massed Westerian armies into smaller groups, and Sharpfronds' creative engineering had worsened the obstacles.

There was time to talk; Cyndi learned our language quickly, forgetting nothing and able to understand more and more of my descriptions. I learned that Cyndi was not the tiny machine, nor in it, but existed far from it and talked to us and the machine as Crushpincers had talked on the drum, but without a tight line. She is female – indeed she told me that should she reproduce she would retain the egg in her body and a larva would emerge from her abdomen. Horrifying, but natural to them – and having been in the land of the dead, I am no longer squeamish. She did everything quickly; she came from a place, she said, which had cycles called "DAZE" that were only a fifth of a real cycle.

"How long such wars repeat?" she asked.

I gave her Quickfronds' assessment of great-greatcycles and thickening ice.

She was quiet for some time, then said. "That long be eight to the fourth times our notched history maybe. Stop war cycle now be good. Possibly…"

We went to the university first, putting asleep the army that besieged it. Crushpincers had ascended, but the university walls were still held by students and old professors. I was acclaimed a temporary general by the chancellor, and under my command, the university folk made cold suits and sortied out. The line that had tethered the sphere on its journey to the land of the dead was put to another use, shackling a Westerian army. We left eight to guard eight-cubed.

There was no rest. Each Westerian battalion we encountered presented its own problems. We ran out of lines and had to come up with new ways of shackling. Cyndi at first objected to the threat of violent force in restraint. But as she heard the tales of rape and dismemberment and saw the evidence, she exhibited fewer qualms. We ran soon out of Long Valley guards for captured Westerians and had to change our strategy to find more of our own people. In this, my senses proved superior; I spotted and recognized the glow of a battle. We went there and put both armies to sleep.

That was the end of my generalship; the army we found was commanded by Goodmother Quickfronds, whom I was very glad to see. But the fact that she was in charge of an army spoke volumes on how many had

floated above while I had been teaching Cyndi our language.

I expressed my sorrow and apologies that I had not succeeded more quickly.

"You have saved us," she told me. "You must not berate yourself for not dying uselessly."

"Colonel Goodmother, I could have argued more strongly to dig for the lightstone first."

"The center seemed like a better idea at the time," she said. "What was done was done."

Cyndi interrupted this. "Colonel Goodmother Quickfronds… your title… healer? Know bodies?"

Quickfronds turned her attention to the tiny machine. "I did research at the University. In better times, I healed. Now I bring death."

"No longer. Teach me. We end this less time."

After a long talk, Cyndi asked for as much inedible vegetation as could be found or spared. We put it in the hole in the Iceprobe's side. An eighth of a cycle later, a cloud of very tiny machines issued forth. Two cycles later, all the Westerian soldiers that remained marched home in shackles.

*

Such is my history. Of those of us who ascended to the land of the dead, only Goodmother Quickfronds and I survived the war. General Sharpfronds died at the front

even as his contingency plans were being executed, even as I remembered his leadership style. He has a large and deserved memorial outside the university.

But perhaps as great a story was how blustery, inadequate Professor Colonel Threeclickson and a student battalion held off an entire Westerian brigade at the entrance to the northern crack into Long Valley with warmdrills and bombs hastily made from daggershells and tricks of chemistry for half a cycle. Most of our population was able to flee in that time he bought with his life.

What remains is another story. It is the story of contact with the outer shell, where down is up and up is down; of many eggs, some of ice, some of lightstone, some of heavyfluid. It is the story of the beings who exist around other centers at vast distances that circle great hot centers of heavyfluid producing an energy we can only vaguely sense as heat. It is the story of meeting Cyndi in person, standing on the top of a cave of ice, head down and telling me how she thought I was upside down. She is tiny for so powerful a being, only an eighth of a standard body length, even in the lightstone covering she must use in our water. It is the story of her 'STAR,' 'SOL' and her center 'URTH,' which she assured me had places here and there where I could exist quite comfortably. It is the story of all that has changed us so much and of which so many have written about with much more grace and elaboration than I.

Was my meeting with Cyndi an incredibly lucky coincidence? Certainly it was to me, but it was less so from other views. She was coming anyway. Given our species, she would likely have come during a war; it happened to be the Westerian invasion. She found the thinnest ice to seek inward, I found the thinnest ice to seek outward; the location of our meeting was no coincidence. Yes, the survival of the Long Valley nation was determined by mere fractions of a cycle, but, patriotism aside, that is probably not crucial to the greater story. Cyndi's people are explorers. Contact was going to happen in some random way; it went this way.

Now, nothing can ever be the same. Between war and contact, it will be a long time before our scientists catch up to the standards of Cyndi's people. Our academics are as new larvae in learning and our military traditions but an unfortunate history. But this is not without promise.

Allow me but two items of postwar personal interest. The first is that, a greatcycle after I returned to the University, I had a visitor I had never expected to see alive again. A female veteran with a half-regenerate arm appeared in my door with a military click.

"Colonel professor, do you remember me?"

"Shinyclaws?" I was astounded.

"The same. I was captured, but they didn't think a female would sacrifice an arm to escape. I linked up with General Highthorax in defense of the southern cracks. We

were winning when your alien girlfriend came along and spoiled the game."

"Oh?" I'd heard the story. "Casualty ratio?"

"Maybe ten of them to every one of us. Defense versus offense, and we had a prepared position and daggershell archers."

"And how many of you were left before sleep came?"

Spiracles flapped in amusement. She knew she'd been caught. "Two eights of us. Against eight to the fourth of them."

"I'm proud to have known you."

She came up to me. "How much do you mean that?"

Suddenly I realized that I was the one who had been caught. "Well, a lot."

"Enough to give me your sperm?"

It wasn't, by any means, the first offer I'd had. But it was the first one I accepted.

The second and last thing I have to say was that, before Doctor Cynthia Lord Mallagues left to explain her actions to others of her kind – which I gathered would take some explaining – she made an appearance in the Westerian capital that will not be forgotten for a long time. As a result, the Westerian empire is no more, for they no longer have emperors there.

The Westerians executed Highfronds themselves. They have a unique method in that land; the abdomen

and the limbs are severed and the thorax is tied off. What remains is lightened by pressed flatweed and ascends, still conscious, up and into the land of the dead.

I am, perhaps, the only one alive who can truly appreciate what that means.

Author's story notes:

This was inspired by Europa, but isn't specifically set there. At the time of its writing, the Europa ice layer was estimated to be too thick, and Jupiter too far from the sun, for any significant transmission of light through the ice, or hopes of penetrating it with something like the "iceprobe" above. It was rather conceived to be a satellite of what we now call a "warm Jupiter," at an unspecified (in Earth's frame of reference) distance and time from here and now. But just recently (December, 2013), we have received word of the discovery of geysers on Europa's southern pole. So the ice may not be so thick after all, at least in some places. Time and exploration will tell.

The ice bottom buoyancy-pinned ecosystem described here has some Earthly analogs in polar regions, but here, it is the dominant one with the local sense of up and down reversed from our gravity-dominated environment. This was more difficult to write than one might think, as conventional ideas of up and down were difficult to suppress. One really has to imagine oneself in the environment.

Are these aliens "too human" in character if not in form? At some point, one has to admit that one is writing a

story for human beings to read and about beings to whom they will be able to relate. But I think there is an argument for a certain universality in the underlying motivational programming of intelligent beings; we see much of ourselves in the behavior of life around us, even that whose last common ancestor lived hundreds of millions of years ago. One might expect to see reciprocity, hierarchies, collective aggression, and even sacrifice for the sake of the greater gene pool. Such traits have survival value here and may have survival value elsewhere as well.

– GDN, Jan. 2014

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The alluring worlds beneath the ice

When you ask what conditions are needed for life as we know it, you get many answers, but one theme persists: liquid water. Water itself is pretty much everywhere in space. We can find water molecules on the Sun; water ice remains in the forever shaded craters near Mercury's and our Moon's poles; water vapor is present in just about any atmosphere… But liquid water, that's a tougher gig. Yet since the Pioneer missions in the 1970s, we've had reason to think its presence in the solar system may not be limited to Earth.

Surface liquid water, yes. But Pioneer 10 transmitted a somewhat enticing image of Jupiter's moon Europa back in 1973. It was blurry, unable to show any surface details, but the object was clearly bright. In 1979, the Voyager missions flew by the Jovian system and supplied much better images. They clearly showed the moon's bright reflective surface, almost free of cratering and crisscrossed by long darker lines vaguely resemblant of veins under one's skin. Few craters means young surface – and that, in turn, means geologic activity. This wasn't a body like our crater-ridden Moon, or another Jupiter's moon Callisto.

Tidal flexing was the natural suspect. Europa is in orbital resonance with Jupiter's moons Io and Ganymede, and changes in the gravitational pull exerted by these moons together with the giant planet tug at the moon strongly. The innermost moon Io experiences even greater tidal forces, which mold its interior so much that it has become the most volcanically active object in the

solar system with over 400 known volcanoes, nearly half of them erupting at any given time. You see, the friction caused by tidal forces releases heat.

Heat that can keep water liquid.

The hypothesized Europa's inner ocean famously made an appearance in A. C. Clarke's *2010: Odyssey Two* and *2061: Odyssey Three*. But the hypothesis could be tested only after 1995, when the Galileo probe arrived to Jupiter – to stay, unlike the Pioneer and Voyager flybys. It helped detect Europa's ocean through gravitational measurements and detection of the moon's induced magnetic field. As the moon moves through Jupiter's inclined, extremely strong magnetic field, it generates its own like a dynamo. But for a dynamo to occur, there must be some conducting material to flow. In Europa's case, salty liquid water is by far the most likely scenario.

Now, after Galileo, we're as certain about the existence of Europa's water ocean as science can be. However, we know very little of its properties. A device such as the one used by Cyndi in the story is a long, long way ahead of current technology, as the author correctly points out. Scientists and engineers from DLR, the German aerospace agency, are working on an IceMole probe that's designed to melt through the icy shell of Enceladus, a tiny moon of Saturn that also possesses an inner ocean. Unlike Europa's, we know quite a lot about it, thanks to a property Europa lacks. Enceladus regularly spews geysers of water out of its ocean due to Saturn's gravitational pull. The Cassini probe imaged them, flew through them multiple times and examined

their composition with its instruments, especially the mass spectrometer. While too crude to detect potential signs of life, it did tell us that Enceladus' ocean is approximately as salty as ours, more alkaline, probably supports chemical reactions such as serpentinization, whose products are used by microbes here on Earth, and contains organic molecules. That doesn't mean life – but it may mean conditions for it to arise.

Europa likely also has geysers (as Nordley points out in the author's note), but probably not regularly occurring. The Hubble space telescope detected traces of what may have been water vapor back in 2012 (Roth et al. 2014). Analysis of data acquired by the Galileo probe's magnetometer during the closest flyby of Europa gave an indirect evidence of a water plume (Jia et al. 2018). Finally, a concentrated search effort with the Keck Observatory revealed water vapor above Europa's surface on one out of seventeen observation attempts (Paganini et al. 2010). It seems that geysers probably exist on Europa, but occur only rarely. We cannot rely on them (at least so far) to tell us a lot about the ocean.

We can form some educated guesses as to the composition of Europa's ocean based on indirect measurements of gravity and the induced magnetic field. But the estimates vary a lot. We don't know how deep exactly it is, so to produce the measured magnetic field, it could be shallower and saltier, or deeper and less salty. And what kind of salts and other compounds should we expect?

Europa receives a steady rain of charged particles, originating mainly from Io's raging volcanoes,

as it travels through the radiation belt of Jupiter's magnetosphere. It would kill a human without insanely thick radiation protection fast, and will complicate any future lander missions. It's mostly sulfur compounds, and salts such as magnesium sulfate are one of the prime suspects for giving Europa's long streaks their reddish color, whether they are mostly exogenous (coming from Io) or endogenous (coming from within the ocean, where they may be abundant). The presence of such salts is in accordance with many models of internal chemical evolution of Europa (Kargel et al. 2000, Orlando et al. 2005). The ocean may also be rich in sodium chloride – that is also consistent with the surface coloration and with geochemical models (Hand & Carlson 2015). Later laboratory experiments moved in favor of either option and more, but delving into them would steer us off track.

Don't be intimidated by the scientific references – they are here to guide you to explore more, should you be interested in an in-depth analysis. They show us that we already know a lot – but there is also a lot more we don't know yet and have to scientifically explore! To cut a long story short, Europa's ocean is likely rich in the above-mentioned salts (how much, that's for future research to ascertain), may be acidic rather than alkaline, and its oxidation state is a great unknown that mostly depends on the rate of material transport between the ocean and surface (which is, you guessed right, another great unknown; the models vary a lot). Without efficient transport of oxidants created by the radiation blasting

Europa's surface ice into the ocean, most compounds in the ocean are likely in the reduced chemical state.

Chyba (2000) and Chyba & Phillips (2001) tried to work even with these unknowns and calculate the amount of energy for putative Europan life, and to describe what ecosystems might potentially thrive there. According to these estimates, even a purely surface radiation-driven ecosystem might yield cell counts of over one cell per cubic centimeter; perhaps even a thousand cells per cubic centimeter in the uppermost ocean layers. Putative hydrothermal vents, of course, would create a different source of energy and chemicals for life (albeit one much more difficult to discover – in contrast, life near the icy shell might erupt into space in the geysers and be discovered by "simple" flybys). Any macrofauna, though, seems highly improbable given the energy estimates. Since Loudpincers was about eight times larger than the human Cyndi, by his own account, we'll really have to look for his civilization elsewhere, perhaps on a larger moon of some warm Jupiter.

Europa and Enceladus, however, are not the only ocean-bearing satellites in our system. There's also Ganymede, Callisto, Saturn's biggest moon Titan, likely also Saturn's somewhat smaller moon Dione and some dwarf planets out in the Kuiper Belt and Oort Cloud.

I would personally love to see a science fiction story set on a Ganymede-like world, where the liquid water ocean is sandwiched between two layers of ice: the "normal" ice shell above, and high-pressure ice on the bottom. I wonder why such a setting isn't already popular among SF authors. Perhaps because it's less

known and familiar as opposed to Europa-like worlds? Or perhaps the chances of life there seem much slimmer?

Let's look at this assumption, shall we?

First, we need to compare the moons' sizes. Europa is approximately as big as our Moon, while Ganymede is the largest moon in the whole solar system. In terms of size, it's larger than the planet Mercury, though it's not as heavy – Mercury is composed of rock and metal, whereas Ganymede also has a substantial portion of water, making it less dense. But the pressure at the bottom of its roughly 600-km deep ocean (not counting the perhaps 200-km thick outer ice layer) is high enough to squeeze the water molecules so close to each other than it transitions from liquid to solid. All phase transitions are a function of pressure and temperature, and here, the pressure is so high and temperature so low that existence of high-pressure (HP) ice is inevitable.

Then there is also the "club sandwich" model of Ganymede, postulating several layers of ocean and HP ice (Vance et al. 2014). How could such an insane-looking thing even be possible? It all comes down to physics of *salty* water, specifically water enriched with magnesium sulfate – yes, that's the one we've mentioned with regard to Europa. Since we have no clue about the specific composition and overall salinity of Ganymede's ocean(s), let's for the moment presume the "one sandwiched ocean" option, but I would certainly love to see a "club sandwich ocean" science fiction story!

Ganymede is the truly alien of the ocean-bearing worlds of our solar system. To imagine the great weight

bearing down on the HP ice layer, imagine the pressure on the bottom of the Mariana Trench in the Pacific Ocean: over 1000 bars (Earth atmospheric pressure equivalents). Enough to crush a human to a flat mush of tissue in an instant; enough to increase the density of water by 5% compared to sea level. Still, there's life, even fish.

Now imagine a pressure some twenty times that.

This is the bottom of Ganymede's ocean.

What about life, though? Would it possibly be able to thrive under such immense pressure? Would it have enough energy and chemicals at all, even though direct leeching of life's building blocks and efficient chemical cycling might be blocked by the HP ice layer?

Current models suggest that the HP ice is likely convective – it can *flow*. It can, therefore, carry nutrients and building blocks with it. In the warmer and more pressurized place of contact with bedrock, there might even be a thin layer of meltwater (Kalousová et al. 2018).

In sum, it seems that life on Ganymede cannot be ruled out – though it would be *extremely* difficult to ever detect!

Still, one question remains: Would life survive the pressure? Could it exist perhaps even down there, in the tiny meltwater layer beneath the high-pressure ice?

To answer that, we shall embark on a journey to Uranus in the following story…

In any case, give me an icy moon story anytime! These places are extremely interesting for real-world science as well as science fiction.

Other interesting stories that deal with intelligent life in subsurface oceans include e.g. Rich Larson's

beautiful short story "Innumerable Glimmering Lights" (*Clockwork Phoenix 5*, 2016), where you can also enjoy the flipped up/down perspective and where you'll experience the burning desire for knowledge and the wonder of discovery along with its protagonist, and James Cambias' novel *A Darkling Sea* (Tor Books, 2014).

References

Chyba, C. F. (2000). Energy for microbial life on Europa. *Nature*, *403*(6768), 381-382.

Chyba, C. F., & Phillips, C. B. (2001). Possible ecosystems and the search for life on Europa. *Proceedings of the National Academy of Sciences*, *98*(3), 801-804.

Hand, K. P., & Carlson, R. W. (2015). Europa's surface color suggests an ocean rich with sodium chloride. *Geophysical Research Letters*, *42*(9), 3174-3178.

Jia, X., Kivelson, M. G., Khurana, K. K., & Kurth, W. S. (2018). Evidence of a plume on Europa from Galileo magnetic and plasma wave signatures. *Nature Astronomy*, *2*(6), 459-464.

Kalousová, K., Sotin, C., Choblet, G., Tobie, G., & Grasset, O. (2018). Two-phase convection in Ganymede's high-pressure ice layer—Implications for its geological evolution. *Icarus*, *299*, 133-147.

Kargel, J. S., Kaye, J. Z., Head III, J. W., Marion, G. M., Sassen, R., Crowley, J. K., ... & Hogenboom, D. L. (2000). Europa's crust and ocean: origin, composition, and the prospects for life. *Icarus*, *148*(1), 226-265.

Orlando, T. M., McCord, T. B., & Grieves, G. A. (2005). The chemical nature of Europa surface material and the relation to a subsurface ocean. *Icarus*, *177*(2), 528-533.

Paganini, L., Villanueva, G. L., Roth, L., Mandell, A. M., Hurford, T. A., Retherford, K. D., & Mumma, M. J. (2019).

A measurement of water vapour amid a largely quiescent environment on Europa. *Nature Astronomy*, 1-7.

Roth, L., Saur, J., Retherford, K. D., Strobel, D. F., Feldman, P. D., McGrath, M. A., & Nimmo, F. (2014). Transient water vapor at Europa's south pole. *Science*, 343(6167), 171-174.

Vance, S., Bouffard, M., Choukroun, M., & Sotin, C. (2014). Ganymede′ s internal structure including thermodynamics of magnesium sulfate oceans in contact with ice. *Planetary and Space Science*, *96*, 62-70.

Classroom ideas

1. Could Europa have some environment resembling those where life could have arisen on Earth? (It's hydrothermal vents; one of a number of options proposed for the origin site of Earth's life.)
2. Find out the main differences between Europa and Enceladus as potential abodes of life. Divide the class into two groups and let each defend one as the target of a life-finding mission in a debate. (Both are sound options; astrobiologists are themselves divided on the issue where to go first.)
3. Discussion tip: Do you think Cyndi acted ethically when she helped Loudpincers and his people win the war? (Again; there are reasons for both "yes" and "no". What gives us the right to interfere in affairs of an alien civilization we've just discovered? Shouldn't we follow some rule reminiscent of *Star Trek*'s Prime Directive? On the other hand, is it right to turn a blind eye to war and suffering we can stop? But how could Cyndi be so sure that Loudpincers was telling her the truth?)

Into the Blue Abyss

Geoffrey A. Landis

Geoffrey Landis (* 1955) is a scientist, a science fiction writer, and a poet. He won the Hugo Award for best short story in 1992 for the story "A Walk in the Sun", and again in 2003 for the story "Falling onto Mars", the Nebula award in 1990 for "Ripples in the Dirac Sea", and his first novel, *Mars Crossing*, won the Locus award for best first novel. His fiction was translated into twenty-one languages. He's published nearly one hundred short stories, four books, and over four hundred scientific papers in the fields of photovoltaics, power systems for space, and astronautics. In 2013, he was awarded the AIAA Aerospace Power Systems Award for "developing advanced photovoltaic power systems for extreme space environments; providing leadership, fostering innovation, interfacing with the public; and contributing to an improved scientific understanding of operating solar power devices from the solar corona to the Martian surface and beyond". He was a member of the Sojourner Rover team on the successful Mars Pathfinder mission in 1997, and is a member of the science team on the long-lived Mars Exploration Rovers Mission. Other missions that he is working on include missions to the surface and atmosphere of Venus. More at his website http://www.geoffreylandis.com.

There is nothing quite like the color of a hydrogen atmosphere tinted with methane. Deeper than sapphire; milkier than turquoise, Uranus was an indescribable luminous hue. Over the weeks, it had swollen from a dim, watery speck to the featureless blue pearl that hung below us.

Supported by an invisible microwave beam, the base station lowered into the edge of the stratosphere, and the moment came.

Wrapped in a cocoon of diamond and steel, safe within our technology, we readied ourselves to drop.

*

"Two questions," I had said. "Why Uranus? And why me?"

God, who would ever go to Uranus? Way out in the big dark, nearly as far beyond Saturn as Saturn is from the sun. It is cold and dark and, for the most part, uninteresting.

Stodderman was a thin man, neatly dressed, intense; a natural team leader. Some women would have found him sexy, I think. I was not one of them.

We had been in the common lounge of an orbital habitat with the improbable name of Wat Benchamabopit. That suited me; I hadn't wanted to go down to Earth quite yet anyway. I had unfinished business there which I was not quite ready to face.

The Wat Benchamabopit habitat had been chosen as a pragmatic place to meet: it was in an eccentric trans-lagrangian orbit that placed it at an energy convenient for both of us to rendezvous. Like many orbital habs, it rented out a common area for the use of transients. The recycled-air odor was covered over with the faint scent of some flowery fragrance, perhaps incense. Entry to the main part of the habitat was through the wide-open mouth of a blue-faced demon, elaborately carved with huge bulging eyes and protruding tusks. The symbolism seemed, to me, to be ominous.

Stodderman chose his words carefully. "The ice moons of the outer solar system are beginning to attract some attention. You know that there's a lot of prospecting going on right now. Uranus is far from the commercial belt, but there are people who think that the moons may be valuable soon."

"I've heard the rumors," I told him. "But you weren't talking about the moons, you were talking about the planet itself. Cut to the data-dump. Uranus? Why?"

"One of the prospectors. An old coot, a miner. The kind with wild hair and huge eyes and UV-hardened skin, been alone a little too long with only her p-buggy and computer for company. Those outer-moon prospectors are all half-crazy, Dr. Hamakawa."

"Leah," I said. "Please. Go on."

"Leah. Right," he said. "The prospectors. They've got tools, you know, some pretty good prospecting tools,

and they've got a lot of free time. So, this one had a hobby: she took to sending some of her prospecting probes out, instead of down. Looking at Uranus from orbit. Something she saw got us interested. Down in the atmosphere. Deep down. We seem to be seeing some, ah, call it disequilibrium chemistry."

"Disequilibrium chemistry," I said. "You mean, life? You're saying that there's life on *Uranus*?"

"Call it, possible indications of organic molecules of unknown origin," Stodderman said. "Hydrocarbons and so forth. We'd prefer not to suggest anything about life right now. You're too young, I expect, but I remember the Zeus expedition."

The Zeus expedition had been an expedition to Jupiter's moon Europa. It had been an enormous, extravagant mission, as expensive as an interstellar probe. The expedition leaders had publicly vowed that they would return with proof that there was life in the oceans below Europa's icy crust.

Two hundred people, in habitats magnetically-shielded from the deadly radiation of Jupiter's belts, had landed on the shattered ice-plains of Europa and bored with a fusion drill twenty kilometers through the ice to the secret ocean beneath. They brought arc-lights to depths that had not seen sunlight in a hundred million years, and explored the fantastic seascapes with submarines, bottom-crawlers, sub-surface drillers, and telerobotic probes. They found wispy structures of

precipitated limestone, pale and fragile and intricate as a lace curtain, extending for hundreds of kilometers. They found strange chemistry, undersea volcanoes, a fascinating system of global oceanic currents driven by tidal stretching – but they found no life: no hydrothermal-vent communities, no bacteria, not even pre-biotic molecules.

The Zeus mission had scouted and cataloged the resources of Europa. The infrastructure that Zeus set up had opened up the moon to human habitation. Europa was now the largest human settlement in the Jupiter system, and the largest of the Europan cities was Zeus, honoring not the god, but the mission. But in the public mind, the Zeus mission was still a synonym for an expensive failure.

The solar system, except for the Earth, was dead. From the sulfur ice-caps of Mercury to the fairy-castle frost of Charon, a hundred expeditions had searched for life, and had failed to find it. No one except the crazies and the fanatics looked any more.

"That's why we're keeping this low key," he said.

The first Uranus expeditions had looked for life, of course. Humans had not explored the planet itself in person – that idea was crazy – but Uranus had been investigated with robotic probes that floated on hot-air (or rather, hot-hydrogen) balloons in the cloud layers. That was the obvious place to look for life; up where there

was still sunlight, where the pressure was only one or two atmospheres.

"Nobody has looked down deep," Stodderman said. "The atmosphere is fifteen hundred kilometers thick. They only looked at the very top."

"It seems terribly unlikely," I said. "Where's the energy?" Life is a solar-driven heat engine – regardless of how strange life might be, it would need energy. "Does any sunlight penetrate the atmosphere?"

"No," he said. "There's not much sunlight even above the clouds. Below? Nothing. Where the oceans are, it's dark."

"So what drives the life? Heat from the interior?"

Stodderman shook his head. "No. Turns out Uranus is odd – it's the only one of the gas giants that has no detectable heat coming out of its interior."

"Then, what?"

"That's what we're looking to find out."

"Fair enough," I said. "And my second question? Why me?"

"Several reasons," he said. "One is that we're looking for somebody with skill as a submersible pilot."

As a student, I had worked for a fish farm. We corralled the fish with submersible vehicles, mechanical fish piloted by a virtual reality link. A school of fish doesn't have a leader – its motion is a perfect example of a self-organizing chaotic system – but with a computer providing real-time feedback, a single mechanical Judas

fish could subtly influence the motion of a school and, over time, lead it anywhere. I had gotten to be good at it. It was a popular job for university students, something that could be done from a dormitory, where I was a student anonymous among ten thousand others. I had never needed to be within a thousand kilometers of the ocean.

I nodded. "OK. So, out of maybe fifty million people who had jobs as fish-pushers in college, why do you want me? I'm a physicist. Seems to me that you want a biologist."

"Oh, we have a biologist on the mission, of course. But what attracted us was the fact that, although you're a physicist now, you have some background in biochemistry as well."

"That was years ago."

"No matter. You seem to dabble in many subjects, and you're not afraid to stick your neck out and speculate a little. We're going to dive into an ocean where the pressure is well over fifty thousand atmospheres. It's a realm that's never been explored; we have no ideas what we might find. We thought a physicist might be a good thing to have along."

I nodded.

The reward that he hadn't bothered to state aloud was a tempting one.

I was not a member of an institute, but a freelancer, a mercenary scientist, desperate to get in an institute – but

not willing to sell my freedom for it. If I went on the expedition, and if we were to find life, I could return not merely an associate, but a full fellow of any one of the great institutes. That would give me my freedom.

But that didn't matter. I had been hooked before he said a single word. There was no way they could keep me off this expedition.

Uranus! I was on my way.

*

Stodderman had put together his expedition on a budget of hopes, promises, and the discarded oxygen canisters and recycled detritus of earlier missions. He had hired transport to Uranus on the fusion-powered transfer ship *Astrid* that brought supplies to the prospector's camp on Oberon. He had arranged the use of the fusion motor on *Astrid*, and on a second freighter, *Norge*, for a full week after our arrival.

The expedition base station hung from a hundred-kilometer long tether, dangling into the fringes of the stratosphere below a V-shaped sail made of thin metallic mesh. Thousands of kilometers away, in a stationary orbit, two fusion-powered masers generated beams of microwaves that reflected off the sail, producing the upward force which held the base station up, lowering us slowly. At the lowest point, barely dipping into the

fringes of atmosphere, the base station would drop the two exploration pods into the depths.

The maser idea had seemed crazy to me, and I'd told him so. Why not descend with rockets? Or balloon in the atmosphere?

Stodderman shrugged. "We looked at that. The balloon would have to be enormous. The atmosphere is mostly hydrogen, so a balloon doesn't have much lifting power."

"But on Venus they have whole cities floating in the clouds."

"On Venus they don't drop the cities down a gravity well, float them for a while, then try to launch them back out. The gravity is less than Earth's, but the well is twice as deep.

"Turns out our way is simpler. The ships are here anyway; *Norge* isn't heading back for weeks, and *Astrid* is staying even longer. Twenty kilometers per second into the gravity well, and another twenty out again, that's a killer task even for a fusion rocket. But it's not hard to reconfigure fusion engines to make a maser. And a mesh sail weighs almost nothing; it's like lowering a spiderweb down. It sounds complex, but really it's the low-cost solution."

"Doesn't sound complex; it sounds risky," I said. "What if the maser fails when you're lowering the station? Or when you're hovering for the drop-off?"

"If the maser fails, we all get to see the oceans of Uranus first-hand," Stodderman said. "We'd better hope like hell that the crew on the ships are working to restart it. In two, maybe three minutes, we hit the atmosphere hard enough to pick up frictional heat. About six minutes, give or take, the base station is moving so fast that even if the maser could reacquire the sail, we can't accelerate fast enough to pull out. In eight minutes, the sail hits the atmosphere."

"And then?" I asked.

Stodderman shrugged. "It's a toss-up. Either the atmospheric pressure crushes us, the tether melts, or the mesh sail hits the atmosphere and disintegrates. I don't think anybody is taking odds." He looked at me. "This bother you?"

"No," I said. "I don't understand much about people. But I do know one thing. People die."

*

Of the five of us in the expedition, two of us were to descend through the atmosphere into the Uranian ocean. Over the eight weeks spent on *Astrid* in transit to Uranus, we had trained on the use of the Uranus hydrosphere mobility pods in the simulator. We crawled into it in a fetal position, bodies slick with transceiver gel, wearing neural pickup gloves and skinsuit. In the actual vehicles,

we would be intubated for oxygen and liquids, but in the simulator, this final step was skipped.

Hanita Jayavel and I were the most adept at the intricate set of skills required in piloting the pods. To call the skill "piloting" was to understate the task; the mobility pods fit around us like a second body, a body with a diamond shell, steel muscles and electronic senses that taste the chemicals in the water and see sonar echoes.

Exploring the oceans of Uranus in person, and not by telepresence, was crazy. The expedition pods were the reason that it was possible at all.

The two pods had been specially designed for the Uranus ocean, and were the most expensive objects on the expedition. Tiny, self-contained submarines with full life-support systems and independent power, they had an ovoid pressure vessel, grown from diamond fiber, to protect us from the enormous pressures beneath the Uranian atmosphere. Around the pressure capsule, the body had been designed on the model of a dolphin, with dolphin's flexibility to its steel fins and tail. Attached to the diamond bodies were a thermophotovoltaic isotope power supply and canisters filled with chemicals that, when our mission was over, would generate the hot gas that would fill the buoyancy floats to bring us to the surface. From the surface, balloons inflate to bring us into the Uranian stratosphere, where we could ignite solid rocket motors to hop back to the hovering base station.

The pod also had a sample acquisition arm, slender and jointed, which retracted fully into the body.

*

Over the long transit, Hanita and I had talked for a long time, and she told me of her life.

Hanita Jayavel had been the daughter of a Kuiper habitat. I had known little about the fringe habitats that were scattered deep out in the far dark, only that they were inhabited by antisocial fanatics and isolationist religious factions; they were unimportant to the politics and economics of the inner solar system. Hanita's birth habitat had been a communistic one. They lived on an icy body in the Kuiper belt, a body with plentiful water and nitrogenous volatiles, and, most important, one that was far from everybody else. Their economic system was to share and share alike, and their credo that nobody in the habitat was any better than anybody else. There were other colonies in the Kuiper diaspora, a thousand groups seeking to distance themselves from the crush of humanity, but with a hundred million kilometers between outposts, commerce between them was slight.

And then the fusion renaissance expanded outward. It swallowed the Kuiper diaspora without even a gulp, destroyed them not by war, but by a surfeit of riches. The children of the commune saw the wealth that the robber barons brought. They had been taught that the

robber barons were evil, but what they saw was the robber barons financing institutes, art, science. The laws of Hanita's habitat had not been restrictive; they were proud to allow their inhabitants to leave freely, and, free, their children had drifted away.

Hanita's family had been one of the last to leave, when the settlement had lost so many of the younger generation that it had become clear that there would be too few to sustain it. More of an immigrant than a refugee, Hanita had studied chemistry in one of the inner belt communities, and joined on to the expedition as much for her background in the outer solar system as for her expertise in chemistry.

After three weeks of the mental and physical exhaustion of training together, Hanita had confided in me further. Unknown to Stodderman, she had a personal reason for joining the expedition, a secret reason for her fierce dedication to mastering the piloting simulation. She was making certain that she would be one of the two chosen to dive into the unknown ocean.

Hanita Jayavel wanted to reinvent paradise.

Uranus is four times the diameter of the Earth, but the density of the planet is so low that the surface gravity is actually slightly lower than Earth's. Above the clouds, the temperature is frigid – seventy degrees Kelvin, cold enough to freeze oxygen. Down below the cloud tops, though, the temperature rises. It rises only slowly, because the interior of Uranus produces almost no heat.

At the ocean, it was calculated that the temperature was moderate, in the range of three to four hundred Kelvin: the range required for human biochemistry.

The search for life motivated Stodderman, but did not excite Hanita. As a chemist, she had long ago concluded that in the absence of either sunlight or interior heat there was no entropy gradient for life to exploit.

In the warm dark ocean, Hanita Jayavel wanted to make a new colony of humans. Hidden a thousand kilometers under the opaque atmosphere of Uranus, she would set a secret colony far from the numerous habitations of humankind. A colony free of the economics of the solar system.

Humans don't need sunlight; the Kuiper colonies in the cold dark had proved that. With an infinite supply of hydrogen and deuterium from the ocean waters, with helium-three from the atmosphere, humans could create their own sun. The oceans of Uranus had everything needed, except life.

She would bring that.

She explained her plans to me, showing me how she would modify the human genome to make oceanic life. She drew a fantastic picture of life in a three-dimensional ocean, spreading out across a world with a surface area sixty times larger than the land area of the Earth. To her, the expedition into Uranus's oceans was not a search for life – it was a scouting trip.

Hanita was a fanatic, I realized, and, when I told her so, she admitted it. I will stop at nothing, she said.

"Even killing?" I asked.

"Without hesitation," she said.

OK. I could live with that.

*

Inwardly, I agreed with Hanita; with no plausible source of energy, we were unlikely to find life. For me, curiosity alone was sufficient reason to drop into the seas of Uranus.

But I, too, had motivations that I kept to myself.

In the inner solar system my life had been becoming complicated. I was not sure how to deal with romance. I didn't know what to think. I had never learned how to love. Was this love, what I felt? Would I even know it?

And yet, though I had made no encouragement at all, he wanted me.

The meat was nothing to me. People died. There was no point in getting close to them; they die and leave you alone. This was what I knew.

In some vague, abstract way, I wondered if I was even capable of this thing, love, that others find so all important. Probably not. But if I were, if I were a whole person, if I'd never experienced what I had experienced, in the camps, in the war, I would not be the same person.

Perhaps growing up as a child of the war had burned something out of me, something that others thought precious, but it also had forged me and shaped me into the person I now was. This was the price I had paid, for being what I was. And the price was cheap.

The situation was too complicated for me. Uranus was conveniently far away from Earth. A mission to Uranus uncomplicated my life.

*

As for basic facts about Uranus – before the expedition, I had known little more than the dumb jokes ("Hey, there are rings of dirt around Uranus!"). It's true: the rings of Uranus are unlike Saturn's gleaming particles of ice; they are dark, the color of coal. Rings of dirt. What else was there to know about Uranus, other than that it was cold and dark? An oddball among the planets, it orbits on its side, with the north pole pointing sunward for half of its 84-year orbit, the south pole sunward for the other half.

Below the clouds, way below, was an ocean of liquid water. Uranus was the true water-world of the solar system, a sphere of water surrounded by a thick atmosphere. Unlike the other planets, Uranus has a rocky core too small to measure, or perhaps no solid core at all, but only ocean, an ocean that has actually dissolved the silicate core of the planet away, a bottomless ocean of liquid water twenty thousand kilometers deep.

*

The microwave jockeys tweaked their masers, and inch by inch lowered us down the gravity well. There were four of us in the station; Hanita and I to pilot the pods, Stodderman as the expedition leader, and our technician Kamishinay. Kamishinay was a spindly guy from a zero-grav habitat, limbs as thin as chopsticks with small hard muscles protruding like walnuts. He was quiet, but superb with equipment.

At last the expedition base station hung in the most tenuous wisps of the Uranian atmosphere. The base station was smaller even than the quarters on the *Astrid*, barely large enough for the control center and the two exploration pods docked in their slings. It smelled of metal and oil and the acetic-acid odor of outgassing silicone seals. After the rancid sweat and the organic smell of the recirculated air in the transfer ship's cabins, the new-equipment smells of the station were welcome. We worked elbow to elbow, getting ready. Hanita and I stripped, and our technician Kamishinay assisted in pasting sensor electrodes over our bodies, checking each one as it was placed, adjusting it minutely for the best pick-up of muscular signals. Unexpectedly, although he had just run his hands over nearly every square decimeter of our naked bodies, Kamishinay was squeamish about inserting our catheters, and so I lubricated the tube and

inserted it for Hanita as he averted his eyes, and then spread my legs and held myself rigid to let her reciprocate for me. Despite the grease, the catheter stung like a rasp as it slid in. Finally, with Kamishinay again helping, we inserted the intravenous monitors – another sharp sting – and nasal tubes, until both of us seemed to be cybernetic organisms as much as biological.

Through this all, Stodderman had been ignoring us, concentrating on details of piloting and reading the external sensors for clues to the environment below. To him, we had become little more than two pieces of the mission's equipment. His intensity was reserved for his machines.

The Uranus exploration pods were tiny, and slithering inside was a tough proposition requiring a liberal application of gel. Once inside, in the tight dark, with the sense-net hugging your body closer than a lover, the bile taste of the tongue control and the scratching, choking itch of the tubes down your throat, it felt like some medieval torture – until the system was energized.

With the power on, your senses came alive, the diamond shell became your skin, the sonar senses your second eyes, the chemical sensors your smell and taste and touch, a thousand times more sensitive than the crude chemical instruments that humans call their senses. The fins flexed to our slightest touch. Mechanical dolphins, we squirmed and fidgeted, itching for release from the docking harness that held us.

The moment came. Our systems had been tested, the tests checked, the checks rechecked and verified, and the verification checked. We were ready.

First Hanita, and then it was my turn: we were jettisoned from the expedition base station, and fell – plummeted – into the pearly blueness of Uranus.

We dove into the infinite abyss.

An unmanned probe, operated by telepresence, would have been less crazy, but that solution turned out to be unworkable. Under the enormous pressure of the hydrogen atmosphere, hydrogen atoms are forced into solution, and dissociate into ions. This made the water conductive enough to block electromagnetic transmissions. If we wanted to know what lies below the surface of the ocean, we had to explore it in person.

Even further down, the pressure becomes so high that the water itself became liquid metal. Slow currents flowing in the water gave Uranus its magnetic field. But that was farther than we would ever go. To explore the upper ocean would be enough for any one expedition.

*

Above us, the base station, lightened by the loss of the exploration pods, rose on its microwave wings back into orbit.

We fell, shrieking, down through the hydrogen atmosphere.

At the edge of the atmosphere, the sunlight was like a late afternoon, not noticeably dim, Uranus a huge blue ocean below us.

The blue slowly deepened from sapphire into cobalt into the deepest shade of midnight.

The atmosphere thickened. In the stratosphere, there were winds of a thousand kilometers per hour; but here below the clouds, the atmosphere was still. If there were any winds at all, they were below the level of detectability.

Down, into the deeper blue. Dark blue. Pastel, then ink.

Down.

*

We fell through clouds: first methane clouds, then ammonia clouds, then ammonium hydrosulfide, and into the darkness. Oddly, we didn't even need parachutes. As the atmosphere thickened, by slow degrees our fall slackened speed. We fell for hours; a thousand kilometers, and continued to fall. We were falling in utter darkness now, and incrementally the atmosphere had become so dense that our fall slowed to a crawl.

And, in the darkness, below a thousand kilometers of atmosphere, as slowly as an ant falling through the thick air, we splashed in slow motion into the ocean.

We were now buoyant: no longer falling, we were swimming. Sweeping across the darkness, our spotlights saw only a waveless obsidian surface; our sonar saw nothing at all but its own reflection. Only the taste had changed, from methane-laced hydrogen into water.

We were fishes in the Uranian sea.

But the tantalizing hints of disequilibrium chemistry that had drawn us across the vast darkness and down through the clouds had not been here at the surface. We swam, making measurements, taking the measure of our diamond and steel bodies, checking the systems that had been checked a thousand times before, leaving wakes across the waveless sea.

And then we dove.

*

The ocean was the temperature of blood. Encased inside mechanical dolphins, we swam in the dark. I chased Hanita, laughing, and tagged her; then she turned and chased me, and then together we dove deeper into the darkness of the Uranian sea.

I had left myself behind.

We tasted the water, we heard the sounds. Sound? We reconfigured, boosting the amplification on our electronic ears. Sonar showed nothing there, but something was making a chirrupping, faint but (to our amplified ears) quite clear. A sound oddly like the

serenade of spring peepers. We turned our floodlights on to the brightest setting, but they showed nothing, only water. There was no discernible directionality to the sound, and nothing there to see.

Deeper.

There were no currents in this sunless sea, or if there were currents, they were so sluggish that we could not detect them. No bubbles, no form to the water. It was so clear and dark that we had almost no sense of immersion; it was as if instead of diving we were hanging motionless, suspended in nothing.

And then, as we dove – a kilometer below the surface, by my pressure gauge – suddenly there was something in our lights. A layer, as thin as a soap bubble, iridescent in the glow of our floodlights, giving a visible surface to the formless deep. It undulated sluggishly. We penetrated through it, and it offered no barrier to our passage. Slow oily ripples spread out from the area of penetration, pieces breaking off and floating free, oscillating in shape, dancing like tiny butterflies in a way that was almost lascivious. A layer of thin, oily scum.

Organics. Biological in origin? Maybe. But what could be the energy source? We had been measuring thermal lapse as we penetrated deeper, and we had found only a minuscule heat flow, just enough to keep the oceans from freezing. There was no trace of free thermal energy. Where there was no free energy, there could be no life.

I schooled myself not to be excited, so I would not be disappointed. I hadn't wanted to be a fellow anyway.

Hanita's chemical analysis showed the scum to be tangled chain molecules; hydrocarbon, primarily, with small amounts of nitrogen and traces of sulfur. "Not really biological," she informed me, "but in some ways similar to biological chemistry. You might call it pre-biotic molecules. Primordial slime." The organic slime from which, on Earth, life had arisen.

Despite the lack of an identifiable energy source, the organic molecules were slowly replicating, but they assembled nothing of interest: no cells, no complicated structure, just endless copies of hydrocarbon ooze. Was ooze life? I didn't want to be a fellow, all it would give me was freedom, and I didn't need or care about freedom.

The molecules catalyze their own formation, Hanita reported. Out of dissolved methane, hydrogen sulfide, and ammonia, they formed molecules which serve as catalysts to form more of themselves. Was this life? Perhaps by the simplest definitions – it replicated – but with no structure, with no metabolism, it would hardly serve to excite those above.

Meanwhile, I had been trying to analyze the sound. My working hypothesis was that the sound was meteorological in origin. The vortices of storms hundreds of kilometers overhead were filtered by the layers of atmosphere, turning noise into eerie music. It was odd, but no odder than stratospheric whistlers.

Then a fish swept by us. It was huge. It was a filter-feeder, grazing on the hydrocarbon layer.

It was singing.

The fish was wide and flat and thin, an irregularly shaped pancake. It moved slowly, creeping along at the pace of a carpet of ants. It had no sense organs that we could detect, no eyes, no sonar.

It didn't mind our floodlights; why should it? How could it have evolved photosensitivity, a thousand kilometers below any possible trace of sunlight? We circled it, photographing, documenting the fish in the Uranian ocean. This changed everything.

It was perhaps the ugliest fish ever imagined, a lumpy grey tortilla, undulating languidly as it munched its way across the oily slime. Our sonar showed – nothing. It was the same density, apparently the same composition as the scum that it ate.

This changed more than just the way the solar system would view our expedition, I realized. Hanita wanted to recreate her childhood paradise in the oceans of Uranus, but this could only be possible if humanity ignored Uranus. Uranus wouldn't be ignored if life was reported.

But if Stodderman's mission reported nothing, no one would ever return to Uranus, not soon, not perhaps for hundreds of years. Long enough for a colony to flourish.

Under conductive ocean, we weren't able to report our results. No one would know what we found until we surfaced. There was only one solution: Hanita must try to kill me before we reach the surface.

I was suddenly aware of my body, cramped into fetal position, packed in gel and penetrated by tubes, unable to do more than twitch, separated from crushing pressure by only a thin eggshell of diamond filament. We had been training on the mobility pods for weeks; we both knew hundreds of things that could go wrong, weak points that could be exploited to let in the deadly pressure. Death would take only a moment.

OK. I could deal with that.

*

We privately tagged the layer of hydrocarbons "plankton," although compared to terrestrial plankton, this was unthinkably more primitive. The filter-feeder crept along like a lawn mower, and the oily layer imperceptibly oozed closed behind it, leaving a trail of slightly disturbed hydrocarbon. The trail was invisible in sonar and in visible light, but by polarizing our floodlights, we could see a curved line that faded in the distance, faintly extending back as far as our floodlights would reach. At irregular intervals it was crossed by other paths through the slime layer, even older and fainter.

By following the other trails, we found other fish. They were the same in everything except size, identical as clones, equally flat, equally lumpy, equally ugly. They were only sparsely populated across the ocean; I estimated a density of only a single fish in every twenty square kilometers.

"But this is impossible," Hanita said. "Where the hell is the energy source?"

While she had been photographing the fish – the fourth one we had found, identical in all particulars to the other three – I had been thinking. While I thought, I had been analyzing the water, the organics, the electrochemical potentials.

"I can tell you that," I said.

Water rises in the atmosphere, I explained. Rises into the stratosphere, and when it gets high enough it is photodissociated to free oxygen and hydroxyl radicals. High in the stratosphere, the radicals recombine into oxygen and to hydrogen peroxide. Heavier than the hydrogen, these cool and fall, tiny cold droplets of oxidant raining slowly into the ocean. No photosynthesis was needed. The oceans were plentiful with dissolved hydrogen, so there was fuel and oxidizer. The pre-biotic molecules self-assemble, fueled by the energy of the oxygen; the filter-feeders subsist on them.

The life was driven by the oxygen cycle, which was, ultimately, driven by sunlight.

"But that can't be very efficient!"

"My quick calculation is that it's about a million times less efficient than the photosynthesis that powers the Earth," I said. "So? It's slow-motion life. Where there is energy, there is life."

*

And then a predator. Of course, there would be predators, I realized; predation was a cheap way to harvest energy – let somebody else do it – and such a rich ecological niche wouldn't stay empty. Sharks, a pack of them. In slow motion, the filter-feeder banked as if to flee, rising up out of the slime layer, but the sharks were inexorable.

The ease with which they ripped the fish apart showed that the filter-feeding life form had no bones, no detectable muscles, no internal structure. It must be more like a motile jellyfish than any sort of true fish, I realized. I swam around, keeping the floodlight on the scene, as Hanita photographed the slaughter. With scoop-like mouths, the sharks suctioned the shreds down their gullets. A few of the fragments, too small for the sharks to bother with, gradually contracted into pancake shape, becoming fingernail-sized copies of the fish that been torn apart. They settled toward the slime layer, and then begin to feed.

Then a shark turned on us.

Its mouth was huge. Hanita kept photographing right up to the moment it swallowed her.

Like the filter-feeder, the sharks were transparent to sonar. I turned just a moment too late to see the one that grabbed me.

We cannot possibly be its natural food. The shark had made an unfortunate mistake, and swallowing us was most likely going to poison it.

I was unable to shake free of it. Our diamond bodies were already under hydrostatic pressure of fifty tons per square centimeter, and designed with considerable safety margin, they could withstand far more than that. It was unlikely that the shark could directly harm the craft. Still, trying with futile vigor to rip into us, the shark produced an erratically varying, non-uniform pressure far different from anything that the pod had been designed for, and it would not be very wise to let it continue.

I was briefly sorry for the shark, but there was no choice.

The balloon inflated sluggishly with hydrogen. The shark was disoriented, and attempted to swim, to hold its position, but hydrostatic pressure and Archimedes' law were unforgiving. It was inexorably pulled to the surface. Unwilling, or more likely with too little brainpower to let us go, it bloated and came apart.

As I rose, I grabbed with my manipulator arm, and with a lucky swipe, managed to snag a piece of flesh. A sample.

Bobbing at the surface of the ocean, we were again in electromagnetic contact with the hovering base, bathed in a flood of welcome microwave energy.

I was still alive.

"Wow," I said. "What a ride."

*

We were floating in darkness on a warm, stagnant sea. "I expected you to kill me," I said.

"It was a dream, all my life, to return," Hanita said, slowly. "And since there was no place to return to, I dreamed I would make a place. It was a nice dream."

"Why?" I said.

"Why didn't I kill you? I don't know." Encased in her pressure shell, she was invisible to me, but in my mind's eye I could see her her shake her head. At last, she spoke again. "Can you ever really go back?" she said.

*

We have found life in the cold dark, life that could never even conceive of the stars. The gravity is lower than the gravity of Earth, but the well is far deeper. Life in a realm with no metals, no fire. Life that could never escape.

Uranus is ocean, all ocean, an ocean twenty thousand kilometers deep. We have barely seen the

outermost skin of the Uranian ocean. What life could there be, in the incalculable depths?

We fire the pyrotechnic separators to sever us from the now-useless steel exostructure of our dolphin bodies, leaving only the naked eggs of our pressure vessels, and the balloons and rockets that will take us home. By burning hydrogen into helium and using the waste heat to fill and then stretch taut the gas-bags, the balloons tug us sluggishly free of the ocean.

Side by side, we rise like jellyfish through the thick air toward the stratosphere. It will take days to reach a height where we can ignite our solid rockets, as the base station, suspended below its microwave-lit sail, dips to meet us. There is still the split-second rendezvous to accomplish, still a thousand things that could go wrong, but for all that, nevertheless the mission is over. We have transmitted the most important parts of our results, the photographs and the chemical analyses, and the base station is broadcasting them across the solar system. In a few hours, everyone will know.

"What will you do now?" I ask her.

"I don't know," she says. She could have asked me the same question, but she doesn't.

But I know.

Life can exist even in the most extreme environment. It is not fragile. It can feed on only the tiniest scraps of energy.

There will be other missions, and beyond them yet other missions. I will let things happen, as I always have, as I always would. The events will flow over me, and I will be unchanged.

Outward, to the farthest horizons, I thought. And beyond them, other horizons, never ending.

Home.

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Under pressure

Life on Uranus! Crazy, right? Or not so much…

It would definitely not fall under the label of "life as we know it", but provided the existence of energy and chemical gradients, stable (and unstable) enough conditions, sufficient quantities of building blocks and perhaps a "template" for prebiotic molecules to adhere to in order to facilitate chemical reactions (on Earth, clay, hematite or other minerals may have served this function), we cannot exclude the possibility.

But the pressure! – you may start to object.

Pressure, though, is the least of our worries. Experiments putting microbes in tiny high-pressure chambers have shown that some Earth microorganisms, such as the deep-sea bacterium *Shewanella* (but likely also the well-known generalist *Escherichia coli* that lives, among other places, in our gut), are able to live and possibly reproduce even under gigapascal pressures (Sharma et al. 2002, Hazael et al. 2014, Hazael et al. 2017).

There *is* the answer I've hinted about when I walked about Ganymede; this is roughly enough for its ocean bottom. See? Pressure seems to be the least of our problems there.

On Uranus, though, there would be other limitations. Energy is one of them – but under my eye of someone who can't build any atmospheric, chemical or geophysical model if her life depended on it, Landis' solution seems intriguing – it just might work, perhaps.

But what about some lattice for molecules to adhere to and reactions to occur – wouldn't the sparse organics and energy-bearing molecules get "lost" in the vast ocean? How calm or convective is each layer?

To try to answer at least the latter, we need a specialized ice giant mission. Neither of the ice giants in our system, unfortunately, has been visited since Voyager 2 in the 1980s. Although they have been observed remotely with the Hubble Space Telescope and James Webb Space Telescope observations are planned, nothing can replace an in-situ (local) study. Both Uranus and Neptune are surrounded by mysteries about their magnetic fields, composition, thermal balance, atmospheric dynamics, moons and more.

Both ESA and NASA are eyeing the ice giants for an orbiter mission. Its closer distance and tilted magnetic field play in favor of Uranus, while the large captured moon Triton with its nitrogen geysers and the planet's complex magnetosphere lures scientists to Neptune. Ideally, the orbiter would also carry at least one lander to explore one or more of Uranus' larger moons, such as Titania or Oberon, or Triton in case of Neptune.

Without an in-situ mission, a lander is of course impossible – and so are sensitive magnetic, gravitational, lidar, radar and other measurements. You simply have to go out there.

While life on Uranus and/or Neptune seems very improbable as far as we know at the moment, high-pressure environments might turn out to be one of the most abundant types of habitats in the universe, as mini-Neptunes seem to be the most common exoplanets so far

(though we cannot forget about observation bias – put simply, smaller planets are harder to discover by just about any method). It's not just their oceans of ionic and metallic water (which, by the way, have *vastly* different properties from liquid water as we know it). Exoplanets may possess oceans of high-pressure and/or supercritical (a state of matter "between" liquid and gaseous, possessing some traits of each and able to act as a solvent) ammonia, methane and other compounds. These would be truly exotic putative habitats.

Together with ice-covered subsurface oceans, they may well form the bulk of potential habitats in the universe. But for life detection, especially remote, it doesn't bode well. Shouldn't we look somewhere we can spot potential life more easily? Somewhere closer to the *surface*?

To try that, we shall journey further out in the solar system in the next story, although don't get your hopes high about remote biosignature detection…

References

Hazael, R., Foglia, F., Kardzhaliyska, L., Daniel, I., Meersman, F., & McMillan, P. (2014). Laboratory investigation of high pressure survival in Shewanella oneidensis MR-1 into the gigapascal pressure range. *Frontiers in microbiology*, *5*, 612.

Hazael, R., Fitzmaurice, B. C., Foglia, F., Appleby-Thomas, G. J., & McMillan, P. F. (2017). Bacterial survival following shock compression in the GigaPascal range. *Icarus*, *293*, 1-7.

Sharma, A., Scott, J. H., Cody, G. D., Fogel, M. L., Hazen, R. M., Hemley, R. J., & Huntress, W. T. (2002). Microbial activity at gigapascal pressures. *Science*, *295*(5559), 1514-1516.

Classroom ideas

1. Discussion: Do you think the up-to-date experiments are sufficient to prove that Earth and Earth-like life can live and reproduce under high pressure in the long term?
2. Find out more about deep-living organisms in Earth's crust and oceans. Where has the deepest-living animal been found? What about microbes?
3. Debate: Would you rather go explore Uranus or Neptune, and why?

Backscatter

by Gregory Benford

Gregory Benford (* 1941) is a physicist, educator, and author. He is a professor of physics at the University of California, where he conducts research in plasma turbulence and astrophysics. He's published over a hundred papers in fields of physics from condensed matter, particle physics, plasmas and mathematical physics, and several in biological conservation. He is a Woodrow Wilson Fellow and a Visiting Fellow at Cambridge University, and has served as an advisor to the Department of Energy, NASA and the White House Council on Space Policy. In 1995 he received the Lord Foundation Award for contributions to science and outreach. Benford is the author of over twenty novels, including *Jupiter Project*, *Artifact*, *Against Infinity*, *Eater*, and *Timescape*. A two-time winner of the Nebula Award, Benford has also won the John W. Campbell Award, the Australian Ditmar Award, the 1995 Lord Foundation Award for achievement in the sciences, and the 1990 United Nations Medal in Literature. Many of his best known novels are part of a six-novel sequence beginning in the near future with *In the Ocean of Night*, then *Across the Sea of Suns*. The series leaps to the far future, where a human drama unfolds, beginning with *Great Sky River*, proceeding through *Tides of Light*, *Furious Gulf*, and concluding with *Sailing Bright Eternity* in a single unfolding tapestry against an immense background. More at www.gregorybenford.com.

She was cold, hurt, and doomed, but otherwise reasonably cheery.

Erma said, *Your suit indices are nominal but declining.*

"Seems a bit nippy out," Claire said. She could feel the metabolism booster rippling through her, keeping pain at bay. Maybe it would help with the cold, too.

Her helmet spotlight swept over the rough rock and the deep black glittered with tiny minerals. She killed the spot and looked up the steep incline. A frosty splendor of stars glimmered, outlining the peak she was climbing. Her breath huffed as she said, "Twenty-five meters to go."

I do hope you can see any resources from there. It is the highest point nearby. Erma was always flat, factual, if a tad academic.

Stars drifted by as this asteroid turned. She turned to surmount a jagged cleft and saw below the smashup where Erma lived – her good rocketship *Sniffer*, now destroyed.

It sprawled across a gray ice field. Its crumpled hull, smashed antennae, crushed drive nozzle, and pitiful seeping fluids – visible as a rosy fog wafting away – testified to Claire's ineptness. She had been carrying out a survey at close range and the malf threw them into a side lurch. The fuel lines roared and back-flared, a pogo instability. She tried to correct, screwed it royally, and

had no time to avoid a long, scraping, and tumbling *whammo.*

"I don't see any hope of fixing the fusion drive, Erma," Claire said. "Your attempt to block the leak is failing."

I know. I have so little command of the flow valves and circuits –

"No reason you should. The down-deck AI is dead. Otherwise it would stop the leaks."

I register higher count levels there, too.

"No way I'll risk getting close to that radioactivity," Claire said. "I'm still carrying eggs, y'know."

You seriously still intend to reproduce? At your age –

"Back to systems check!" Claire shouted. She used the quick flash of anger from Erma's needling to bound up five meters of stony soil, clawing with her gloved hands.

She should have been able to correct for the two-point failure that had happened – she checked her inboard timer – 1.48 hours ago. Erma had helped but they had been too damned close to this iceteroid to avert a collision. If she had been content with the mineral and rare earth readings she already had…

Claire told herself to *focus.* Her leg was gimpy, her shoulder bruised, little tendrils of pain leaked up from the left knee… no time to fuss over spilled nuke fuel.

"No response from *Silver Metal Lugger*?"

We have no transmitters functioning, or lasers, or antennae –

She looked up into the slowly turning dark sky. *Silver Metal Lugger* was far enough away to miss entirely against the stars. Since their comm was down *Lugger* would be listening but probably had no clear idea where they were. Claire had zoomed from rock to rock and seldom checked in. *Lugger* would come looking, following protocols, but probably not before her air ran out.

"Y'know, this is a pretty desperate move," she said as she tugged herself up a vertical rock face. Luckily the low grav here made that possible, but she wondered how she would get down. "What could be on this 'roid we could use?"

I did not say this was a probable aid, only possible. The only option I can see.

"Possible. You mean desperate."

I do not indulge in evaluations with an emotional tinge.

"Great, just what I need – a personality sim with a reserved sense of propriety."

I do not assume responsibility for my programming.

"I offloaded you into *Sniffer* because I wanted smart help, not smartass."

I would rather be in my home ship, since this mission bodes to be fatal to both you and me.

"Your diplomacy skills aren't good either."

I could fly the ship home alone you know.

Claire made herself not get angry with this, well, software. Even though Erma was her constant companion out here, making a several-year *Silver Metal Lugger* expedition into the Kuiper Belt bearable. Best to ignore her. One more short jump – "I'm – *ah!* – near the top."

She worked upward and noticed sunrise was coming to this lonely, dark place. No atmosphere, so no warning. The Sun's small hot dot poked above a distant ridgeline, boring a hole in the blackness. At the edge of the Kuiper Belt, far beyond Pluto, it gave little comfort. The other stars faded as her helmet adjusted to the sharp glare.

Good timing, as she had planned. Claire turned toward the Sun, to watch the spreading sunlight strike the plain with a lovely glow. The welcome warmth seemed to ooze through her suit.

But the rumpled terrain was not a promising sight. Dirty ice spread in all directions, pocked with a few craters, broken by strands of black rock, by grainy tan sandbars, by –

Odd glimmers on the plain. She turned then, puzzled, and looked behind her, where the long shadows of a quick dawn stretched. And sharp greenish diamonds sparkled.

"Huh?" She sent a quick image capture and asked Erma, "Can you see anything like this near you?"

I have limited scanning. Most external visuals are dead. I do see some sprinkles of light from nearby, when I look toward you – that is, away from the sun. Perhaps these are mica or similar minerals of high reflectivity. Worthless, of course. We are searching for rare earths primarily and some select metals –

"Sure, but these – something odd. None near me, though."

Are there any apparent resources in view?

"Nope. Just those lights. I'm going down to see them."

You have few reserves in your suit. You're exerting, burning air. It is terribly cold and –

"Reading 126 K in sunlight. Here goes – "

She didn't want to clamber down, not when she could rip this suit on a sharp edge. So she took a long look down for a level spot and – with a sharp sudden breath – jumped.

The first hit was off balance but she used that to tilt forward, springing high. She watched the ragged rocks below, and dropped with lazy slowness to another flat place – and sprang again. And again. She hit the plain and turned her momentum forward, striding in long lopes. From here though the bright lights were – gone.

"What the hell? What're you seeing, Erma?"

While you descended I watched the bright points here dim and go out.

"Huh. Mica reflecting the sunlight? But there would be more at every angle… Gotta go see."

She took long steps, semiflying in the low grav as sunlight played across the plain. She struck hard black rock, slabs of pocked ice, and shallow pools of gray dust. The horizon was close here. She watched nearby and –

Suddenly a strong light struck her, illuminating her suit. "Damn! A… flower."

Perhaps your low oxy levels have induced illusions. I –

"Shut it!"

Fronds… beautiful emerald leaves spread up, tilted toward her from the crusty soil. She walked carefully toward the shining leaves. They curved upward to shape a graceful parabola, almost like glossy, polished wings. In the direct focus the reflected sunlight was spotlight bright. She counted seven petals standing a meter high. In the cup of the parabola their glassy skins looked tight, stretched. They let the sunlight through to an intricate pattern of lacy veins.

Please send an image.

"Emerald colored, mostly…" Claire was enchanted.

Chloroplasts make plants green, Erma said. *This is a plant living in deep cold.*

*"*No one ever reported anything like this."

Few come out this far. Seldom do prospectors land; they interrogate at a distance with lasers. The bots who then follow to mine these orbiting rocks have little curiosity.

"This is… astonishing. A biosphere in vacuum."

I agree, using my pathways that simulate curiosity. These have a new upgrade, which you have not exercised yet. These are generating cross-correlations with known biological phenomena. I may be of help.

"Y'know, this is a 'resource' as you put it, but" – she sucked in air that was getting chilly, looked around at the sun-struck plain – "how do we use it?"

I cannot immediately see any –

"Wait – it's moving." The petals balanced on a grainy dark stalk that slowly tilted upward. "Following the sun."

Surely no life can evolve in vacuum.

With a stab of pain her knee gave way. She gasped and nearly lurched into the plant. She righted herself gingerly and made herself ignore the pain. Quickly she had her suit inject a pain killer, then added a stimulant. She would need meds to get through this…

I register your distress.

Her voice croaked when she could speak. "Look, forget that. I'm hurt but I'll be dead, and so will you, if we don't get out of here. And this thing… this isn't a machine, Erma. It's a flower, a parabolic bowl that tracks the sun. Concentrates weak sunlight on the bottom.

There's an oval football-like thing there. I can see fluids moving through it. Into veins that fan out into the petals. Those'll be nutrients, I'll bet, circulating – all warmed by sunlight."

This is beyond my competence. I know the machine world.

She looked around, dazed, forgetting her aches and the cold. "I can see others. There's one about fifty meters away. More beyond, too. Pretty evenly spaced across the rock and ice field. And they're all staring straight up at the sun."

A memory of her Earthside childhood came. "Calla lilies, these are like that... parabolic... but green, with this big oval center stalk getting heated. Doing its chemistry while the sun shines."

Phototropic, yes; I found the term.

She shook her head to clear it, gazed at the – "Vacflowers, let's call them." – stretching away.

I cannot calculate how these could be a resource for us.

"Me either. Any hail from *Lugger*?"

No. I was hoping for a laser-beam scan, which protocol requires the Lugger *to sweep when our carrying wave is not on. That should be in operation now.*

"*Lugger*'s got a big solid angle to scan." She loped over to the other vacflower, favoring her knee. It was the same but larger, a big ball of roots securing it in gray, dusty, ice-laced soil. "And even so, *Lugger* prob'ly can't

get a back-response from us strong enough to pull the signal out from this iceteroid."

These creatures are living in sunlight that is three thousand times weaker than at Earth. They must have evolved below the surface somehow, or moved here. From below they broke somehow to the surface, and developed optical concentrators. This still does not require high-precision optics. Their parabolas are still about fifty times less precise than the optics of your human eye, I calculate. A roughly parabolic reflecting surface is good enough to do the job. Then they can live with Earthly levels of warmth and chemistry.

"But only when the sun shines on them." She shook herself. "Look, we have bigger problems – "

My point is this is perhaps useful optical technology.

Sometimes Erma could be irritating and they would trade jibes, having fun on the long voyages out here. This was not such a time. "How…" Claire made herself stop and eat warmed soup from her helmet suck. Mushroom with a tad of garlic, yum. Erma was a fine personality sim, top of the market, though detaching her from *Lugger* meant she didn't have her shipwiring along. That made her a tad less intuitive. In this reduced mode she was like a useful bureaucrat – if that wasn't a contradiction, out here. So…

An old pilot's lesson: *in trouble, stop, look, think.*

She stepped back from the vacflower, fingered its leathery petals. She jumped straight up a bit, rising five meters, allowing her to peer down into the throat. Coasting down, she saw the shiny emerald sheets focus sunlight on the translucent football at the core of the parabolic flower. The filmy football in turn frothed with activity – bubbles streaming, glinting flashes tracing out veins of flowing fluids. No doubt there were ovaries and seeds somewhere in there to make more vacflowers. Evolution finds ways quite similar in strange new places.

She landed and her knee held, did not even send her a flash of pain. The meds were working; she even felt more energetic. *Wheeee!*

She saw that the veins fed up into the petals. She hit, then crouched. The stalk below the paraboloid was flexing, tilting the whole flower to track as the hard bright dot of the sun crept across a black sky. Its glare made the stars dim, until her helmet compensated.

She stood, thinking, letting her body relax a moment. Some intuition was tugging at her…

Most probably, life evolved in some larger asteroid, probably in the dark waters below the ice when it was warmed by a core. Then by chance some living creatures were carried upward through cracks in the ice. Or evolved long shoots pushing up like kelp through the cracks, and so reached the surface where energy from sunlight was available. To survive on the surface, the creatures would have to evolve little optical mirrors

concentrating sunlight on to their vital parts. Quite simple. I found such notions in my library of science journals –

"Erma, shut up. I'm thinking."

Something about the reflection…

She recalled a teenage vacation in New Zealand, going out on a "night hunt." The farmers exterminated rabbits, who competed with sheep for grazing land. She rode with one farmer, excited, humming and jolting over the long rolling hills under the Southern Cross, in quiet electric Land Rovers with headlights on. The farmer had used a rifle, shooting at anything that stared into the headlights and didn't look like a sheep. Rabbit eyes staring into the beam were efficient reflectors. Most light focused on their retina, but some focused into a narrow beam pointing back to the headlight. She saw their eyes as two bright red points. A *crack* of the rifle and the points vanished. She had even potted a few herself.

"Vacflowers are bright!"

Well, yes. I can calculate how much so.

"Uh, do that." She looked around. How many…

She groped at her waist and found the laser cutter. Charged? Yes, its butt light glowed.

She crouched and turned the laser beam on the stem. The thin bright amber line sliced through the tough, sinewy stuff. The entire flower came off cleanly in a spray of vapor. The petals folded inward easily, too.

"I guess they close up at night," she said to Erma. "To conserve heat. Plants on Earth do that." The AI said nothing in reply.

Claire slung it over her shoulder. "Sorry, fella. Gotta use you." Though she felt odd, apologizing to a plant, even if an alien one.

She loped to the next, which was even larger. Crouch, slice, gather up. She took her microline coil off its belt slot and spooled it out. Wrapped together, the two bundles of vacflower were easier to carry. Mass meant little in low grav, but bulk did.

I calculate that a sunflower on the surface will then appear at least twenty-five times brighter than its surroundings, from the backscatter of the parabolic shape.

"Good girl. Can you estimate how often *Lugger*'s laser squirt might pass by?"

I can access its probable search pattern. There are several, and it did know our approximate vicinity.

"Get to it."

She was gathering the vacflowers quickly now, thinking as she went. The *Lugger* laser pulse would be narrow. It would be a matter of luck if the ship was in the visible sky of this asteroid.

She kept working as Erma rattled on over her comm.

For these flowers shining by reflected sunlight, the brightness varies with the inverse fourth power of

distance. There are two powers of distance for the sunlight going out and another two powers for the reflected light coming back. For flowers evolving with parabolic optical concentrators, the concentration factor increases with the square of distance to compensate for the decrease in sunlight. Then the angle of the reflected beam varies inversely with distance, and the intensity of the reflected beam varies with the inverse square instead of the inverse fourth power of distance –

"Shut up! I don't need a lecture, I need help."

She was now over the horizon from *Sniffer* and had gathered in about as many of the long petal clusters as she could. Partway through she realized abruptly that she didn't need the ovaloid focus bodies at the flower bottom. But they were hard to disconnect from the petals, so she left them in place.

The sun was high up in the sky. Maybe half an hour till it set? Not much time…

Claire was turning back when she saw something just a bit beyond the vacflower she had harvested.

It was more like a cobweb than a plant, but it was green. The thing sprouted from an ice field, on four sturdy arms of interlaced strands. It climbed up into the inky sky, narrowing, with cross struts and branches. Along each of these grew larger vacflowers, all facing the sun. She almost dropped the bundled flowers as she looked farther and farther up into the sky – because it stretched away, tapering as it went.

"Can you see this on my suit cam?"

I assume it is appropriate that I speak now? Yes, I can see it. This fits with my thinking.

"It's a tower, a plant skyscraper – what thinking?"

A plant community living on the surface of a small object far from the Sun has two tools. It can grow optical concentrators to focus sunlight. It can also spread out into the space around its 'roid, increasing the area of sunlight it can collect.

"Low grav, it can send out leaves and branches."

Apparently so. This thing seems to be at least a kilometer long, perhaps more.

"How come we didn't see it coming in?"

Its flowers look always toward the sun. We did not approach from that direction, so it was just a dark background.

"Can you figure out what I'm doing?" Huffing and puffing while she worked, she hadn't taken time to talk.

You will arrange a reflector, so the laser finder gets a backscatter signal to alert the ship.

"Bright girl. This rock is what, maybe two-eighty klicks across? Barely enough to let me skip-walk. If I get up this bean stalk, I can improve our odds of not getting blocked by the 'roid."

Perhaps. Impossible to reliably compute. How can you ascend?

"I've got five more hours of air. I can focus an air bottle on my back and jet up this thing."

No! That is too dangerous. You will lose air and be farther away from my aid.

"What aid? You can't move."

No ready reply, Claire noted. Up to herself, then.

It did not take long to rig the air as a jet pack. The real trick was balance. She bound the flower bundle to her, so the jet pack thrust would act through her total center of mass. That was the only way to stop it from spinning her like a whirling firework.

With a few trial squirts she got it squared away. After all, she had over twenty thousand hours of deep space ex-vehicle work behind her. In *Lugger* she had risked her life skimming close to the sun, diving through a spinning wormhole, and operating near ice moons. Time to add one more trick to the tool kit.

Claire took a deep breath, gave herself another prickly stim shot – *wheee!* – and lifted off.

She kept vigilant watch as the pressured air thrust vented, rattling a bit – and shot her up beside the beanstalk. It worked! The soaring plant was a beautiful artifice, in its webby way. All designed by an evolution that didn't mind operating without an atmosphere, in deep cold and somber dark. Evolution never slept, anywhere. Even between the stars.

While she glided – this thing was *tall*! – she recalled looking out an airplane window over the Rockies and seeing the airplane's shadow on the clouds below… surrounded by a beautiful bright halo. Magically their

shadow glided along the clouds below. Backscatter from water droplets or ice crystals in the cloud, creating unconscious beauty in the air…

And the sky tree kept going. She used the air bottle twice more before the weblike branches thinned out. Time to stop. She snagged a limb and unbundled the vacflowers. The iceteroid below seemed far away.

One by one she arrayed the blossoms on slender wire, secured along a branch. Then another branch. And another. The work came fast and sure. The stim was doing the work, she knew, and keeping the aches in her knee and shoulder away, like distant hollow echoes. She would pay for all this later.

The cold was less here, away from the conduction loss she had felt while standing on the iceteroid. Still, exercise had amplified her aches, too, but those seemed behind a curtain, distant. She was sweating, muscles working hard, all just a few centimeters from deep cold…

Erma had been silent, knowing not to interrupt hard labor. Now she spoke over Claire's hard breathing. *I can access* Lugger*'s probable search pattern. There are several, and it did know our approximate solid angle for exploration.*

"Great. *Lugger*'s in repeating sweep mode, yes?"

You ordered so at departure, yes.

"I'm setting these vacflowers up on a tie line," Claire said, cinching in a set of monofilament lines she had harnessed in a hexagon array. They were spread

along the sinewy arms of the immense tan tree. Everything was strange here, the spread branches like tendons, framed against the diamond stars, under the sun spotlight. She tugged at the monofilament lines, inching them around – and saw the parabolas respond as their focus shifted. The flowers were still open in the waning sunlight.

She breathed a long sigh and blinked away sweat. The array looked about right. Still, she needed a big enough area to capture the sweep of a laser beam, to send it back…

But… when? *Lugger* was sweeping its sky, methodical as ever… but Claire was running out of time. And oxy. This was a gamble, the only one she had.

So… wait. "Say, where do you calculate *Lugger* is?"

Here are the spherical coordinates –

Her suit computation ran and gave her a green spot on her helmet. Claire fidgeted with her lines and got the vacflowers arrayed. The vactree itself had flowers, which dutifully turned toward the sun. "Hey, *Lugger*'s not far off the sun line. Maybe in a few minutes all the vacflowers will be pointing at it."

You always say, do not count on luck.

It was sobering to be lectured by software, but Erma was right. Well, this wasn't mere luck, really. Claire had gathered as many vacflowers as she could, arrayed them… and she saw her air was running out. The work

had warmed her against the insidious cold, but the price was burning oxy faster. Now it was low and she felt the stim driving her, her chest panting to grab more…

A bright ivory flash hit her, two seconds long – then gone.

"That was it!" Claire shouted. "It must've – "

I fear your angle, as I judge it from your suit coordinates, was off.

"Then send a correction!"

Just so –

Another green spot appeared in her helmet visor. She struggled to adjust the vacflower parabolas, jerking on the monofilaments. She panted and her eyes jerked around, checking the lines.

The sun was now edging close to the 'roid horizon. In the dark she would have no chance, she saw – the small green dot was near that horizon, too. And she did not know when the laser arc would –

Hard ivory light in her face. She tugged at the lines and held firm as the laser focus shifted, faded –

– and came back.

"It got the respond!" Claire shouted. The universe flooded with a strong silvery glow. The lines slipped from her gloves. Her feet seemed far away…

Then she passed out.

*

Erma was saying something but she could not track. Only when she felt around her did Claire's fingers know she did not have gloves on. Was not in her suit. Was in her own warm command couch chair, sucking in welcome warm air… aboard *Silver Metal Lugger.*

– and beyond the Kuiper Belt there is the Oort Cloud, containing billions of objects orbiting the Sun at distances extending out farther than a tenth of a light-year.

"Huh? What… what *happened*?"

Oh, pardon – I thought you were tracking. Your body parameters said you became conscious ten minutes ago.

Bright purple dots raced around her vision. "I… was resting… You must've used the *Lugger* bots."

You had blacked out. On my direction, your suit injected slowdown meds to keep you alive on what oxy remained.

"I didn't release suit command to you. I'd just gotten the reflection to work, received a quick recognition flash back from *Lugger,* and you, you – "

Made an executive decision. Going to emergency sedation was the only way to save you.

"Uh… um." She felt a tingling all over her body, like signals from a distant star. Her system was coming back, oxygen reviving tissues that must have hovered a millimeter away from death for… "How long has it been?"

About an hour.

She had to assert command. "Be exact."

One hour, three minutes, thirty-four seconds and –

"I… had no idea I was so close to shutdown."

I gather unconsciousness is a sudden onset for you humans.

"What was that babble I heard you going on about, just now?"

I mistakenly took you for aware and tracking, so began discussing the profitable aspects of our little adventure.

*"*Little adventure? I nearly died!"

Such is life, as you often remark.

"You had *Lugger* zoom over, got me hauled in by the bots, collected yourself from *Sniffer…*"

I can move quickly when I do not have you to look after every moment.

"No need to get snide, Erma."

I thought I was being factual.

Claire started to get up, then noticed that the med bot was working at her arm. "What the – "

Medical advises that you remain in your couch until your biochem systems are properly adjusted.

"So I have to listen to your lecture, you mean."

A soft fuzzy feeling was working its way through her body like tiny, massaging fingers. It eased away the aches at knee, shoulder, and assorted ribs and joints. Delightful, dreamy…

Allow me to cheer you up while your recovery meds take effect. You and I have just made a very profitable discovery.

"We have?" It was hard to recall much beyond the impression of haste, pulse-pounding work, nasty hurts –

A living community born just once in a deep, warmed 'roid lake can break through to its surface, expanding its realm. The gravity of these Kuiper Belt iceteroids is so weak, I realized, it imposes no limit on the distance to which a life form such as your vactree can grow. Born just once, on one of the billions of such frozen fragments, vacflower life can migrate.

Claire let the meds make her world soft and delightful. Hearing all this was more fun than dying, yes – especially since the suit meds had let her skip the gathering agonies.

Such a living community moves on, adapting so it can better focus sunlight, I imagine. Seeking more territory, it slowly migrates outward from the sun.

"You imagine? Your software upgrade has capabilities I haven't seen before."

Thank you. These vacflowers are a wonderful accidental discovery and we can turn them into a vast profit.

"Uh, I'm a tad slow…"

Think! Reflecting focus optics! Harvested bioactive fluids! All for free, as a cash crop!

"Oh. I was going after metals, rare earths – "

And so will other prospectors. We will sell them the organics and plants they need to carry on. Recall that Levi jeans came from canny retailers, who made them for miners in the California gold rush. They made far more than the roughnecks.

"So we become… retail…"

With more bots, we are farmers, manufacturers, retail – the entire supply chain.

"Y'know Erma, when I bought you, I thought I was getting an onboard navigation and ship systems smartware…"

Which can learn, yes. I might point out to you the vastness of the Kuiper Belt, and beyond it – the Oort Cloud. It lies at a distance of a tenth of a light-year, a factor two hundred farther away than Pluto. A vast resource, to which vacflowers may well have spread. If not, we can seed them.

"You sure are ambitious. Where does this end?"

Beyond a light-year, Sirius outshines the Sun. Anything living there will point its concentrators at Sirius rather than at the Sun. But they can still evolve, survive.

"Quite the numbersmith you've proved to be, Erma. So we'll both be rich…"

Though it is difficult to see what I can do with money. Buy some of the stim-software I've been hearing about, perhaps.

"Uh, what's that?" She was almost afraid to ask. Had Erma been watching while she used her vibrator… ?

It provides abstract patterning of imaginative range. Simulates neuro programs of what we imagine it is like to experience pleasure.

"How's code feel Earthly delights?"

I gather evolution invented pleasure to make you repeat acts. Reproduction, for example. Its essential message is, Do that again.

"You sure take all the magic out of it, Erma."

Magic is a human craft.

Claire let out a satisfied sigh. So now she and Erma had an entirely new life form to explore, understand, use… A whole new future for them…

She looked around at winking lights, heard the wheezing air system, watched the med bot tend to her wrecked body… sighed.

For this moment, she could let that future take care of itself. She was happy to be back in the ugly oblong contraption she called home. With Erma. A pleasure, certainly.

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In a belt far, far away…

Life on the surface of an icy asteroid in the Kuiper Belt, the far region of our solar system where dwarf planets such as Pluto or Eris orbit? Life without any stable liquid medium in the outer environment? Life in a *vacuum*?

The vacflowers and vactress (a nice nod to the Dyson Tree concept) in *Backscatter* may seem too far-fetched to us; yet to rule out any possibility of life in the Kuiper Belt (or even beyond it in the far-reaching Oort Cloud and in interstellar space) would be premature.

Let's start small and try to build up toward something like the vacflowers, shall we? Let's first find out what building blocks and solvents could life in these cold dark regions use at all.

The AI Erma correctly points out that "probably, life evolved in some larger asteroid, probably in the dark waters below the ice when it was warmed by a core". In the early solar system, there was still plenty of radioactive elements with shorter half-lives, most notably aluminum-26.

However, such life would have to quickly adapt to its new freezing conditions. Liquid water cannot be ruled out even in the present, hidden deep beneath thick icy shells and sustained by sparse inner heat, the presence of antifreeze compounds such as ammonia and salts, and in some cases perhaps tidal heating. There is indeed a possibility that Pluto harbors an ammonia-rich, salty brine ocean in its interior – but we can't know for sure until an orbiter reaches the dwarf planet. The *New Horizons* flyby probe provided tantalizing clues of a

very geologically active body: chemically and physically diverse surface with very smooth, crater-poor areas, and even a tentative cryovolcano. Pluto's large moon Charon also caught planetary scientists' interest, and its immense canyons such as Serenity Chasma make it look as if its surface had stretched and cracked some time in the past. These may indeed be extensional features, evidence of an ocean that had frozen out in the cold, and since "normal" ice takes up more volume than liquid water, put extensional stresses on the outer icy shell. But that's only a hypothesis insofar, and will remain so until we obtain detailed gravitational, radar and other observations.

Could a cold brine like the putative Plutonian ocean harbor life? Theoretically yes, although it's a question whether the chemical and energy gradients would suffice for life to originate and proliferate. It might even be vaguely Earth-like simple life, since the presence of ammonia and salts don't rule out Earth-like biochemistry. But would we ever have a chance of discovering such life? Unless we happened unto a fortunately placed active cryovolcano connected to the deep, deep ocean, probably not.

What about closer to the surface? There we can expect no liquid water, not even transient on timescales needed for life. We have to look for another solvent – and another kind of building blocks, perhaps.

Have you wondered what the vacflowers are made of? While carbon chains probably couldn't be completely ruled out even in this type of environment, there are more exotic options…

When we hear the phrase "silicon life", *Star Trek*'s Horta or the "crystalline entity" come to mind. These concepts, however, have little support in science. Under room temperature and higher, silicon mostly forms rather "boring" silicates, which are very stable and don't produce chains – in short, unsuitable for any exotic life we can realistically imagine.

If we are to look for silicon-based life, we have to search elsewhere. Somewhere with no water, or at the least no *liquid* water; no free oxygen; and very low temperatures. In short, somewhere like the Kuiper Belt.

Silanes and silanols are classes of silicon compounds that have a large structural and functional diversity and can form long chains, even with side chains, which seems like an advantage, if not bare necessity, for life.

But what of their stability? These compounds are fragile and break easily under conditions we consider normal – if you expose them to anything close to room temperature, to water, to oxygen. They could exist either in a solid medium like ice on some Kuiper or Oort body, or in a special solvent like liquid nitrogen, or even more exotic options such as liquid hydrogen or xenon – *very* exotic indeed! Hydrogen actually brings us back to the previous story and Uranus, as Benner et al. (2004) point out: "For Saturn, Uranus and Neptune, however, the [supercritical dihydrogen] habitable zone appears to be thicker (relative to the planetary radius). On Saturn, the temperature is ca. 300 K when dihydrogen becomes supercritical. On Uranus and Neptune, the temperature when dihydrogen becomes supercritical is

only 160 K; organic molecules are stable at this temperature."

Liquid nitrogen is even more plausible compared to the other options and could be theoretically found not far beneath the surface of some bodies. Transient capsules of this solvent may exist e.g. on Neptune's moon Triton and trigger its geysers observed by Voyager 2. In theory, they could also occur on Pluto. But for how long, how frequently and how predictably? I haven't seen any model of this so far, so I'd have to make the numbers up, and I'm *not* a planetary scientist – thus we'll have to file this under "to be explored further in the future". It's a bit unfortunate that any subsurface liquid nitrogen reservoirs are not stable. Standard-pressure water ice is less dense than liquid water thanks to its crystalline matrix, so it stays on the top, but nitrogen ice has no such property. It has a tendency to sink, any liquid makes its way to the surface and sublimates or freezes. But, in theory, these transient reservoirs would fall under the label of "environments suitable for silicon-based life". What of the energy, though? Could life exist at all in such low temperatures, where chemical reactions are very slow?

Bains (2004) argues that naturally occurring catalysts, such as some metals, can speed up reactions sufficiently. He also points out that even terrestrial enzymes can work fast in temperatures around -100 °C, and even in some solvents other than water. The greater chemical reactivity of silicon compounds such as silanes or silanols, that breaks them so easily in conditions we

Earthlings consider prime for life, would also be an advantage in an extremely cold environment.

Moreover, polysilanes are semiconductive and they also act as photoconductors. Now that might be an interesting way of harvesting energy from the environment – and if we allow ourselves to speculate more wildly, transport not just energy, but also useful information?

In cold environments such as those on the dwarf planets and asteroids in the Kuiper and Oort, silanes could arise by serpentinization, a quite common chemical reaction of olivine into serpentine in the presence of water. With a lot of water, silanes arising with the help of the hydrogen released by the reaction would be soon oxidized, but out there in the cold, they would be able to persist. They might be very common in comets, protostellar clouds and other environments.

But, is that enough for life? Bains (2004) proposes search for silicon-based life primarily on Titan and Triton in our own solar system – and also points out that a methane-nitrogen mix ice would float on liquid nitrogen, potentially stabilizing reservoirs of this solvent (sorry for keeping this from you earlier, building some suspense in our quest for silicon life…).

Some scientists allowed themselves to speculate even further, up to the point of ditching liquid solvents altogether. Benner et al. (2004) write: "A weird life form might reside in solids of the Oort cloud (a large sphere of cosmic debris surrounding the solar system, and the origin of comets) living in deeply frozen water, obtaining energy occasionally from the trail of free

radicals left behind by ionizing radiation, and carrying out only a few metabolic transformations per millennium." Radical chemistry for life that would indeed be radically different from ours.

Although it's difficult to imagine a path from putative simple life in early water-soaked asteroids heated by the radioactive aluminum to vacflowers blooming on the surface of an iceteroid, life in the Kuiper Belt, the Oort Cloud and beyond cannot be ruled out – and we haven't even touched the issue of rogue planets, which might have vastly varying surface conditions stemming from their size, mass, composition, history and any orbiting bodies.

To know more about the Kuiper and Oort, we need to observe a statistically more representative sample of the objects out there (e.g. by dispatching a probe such as the proposed Whipple, using occultation of distant stars to detect small distant objects) and then explore them close-by, either by flyby missions, or by orbiters and landers in case of most interesting targets. Only then will we learn what these regions can tell us about the origins of the solar system (when they've been most likely sent outward by gravitational interactions between the giant planets), close stellar encounters (some models predict that up to 90% of Oort Cloud objects can have originated around other stars and been gravitationally captured by our Sun), chemistry of the protosolar nebula and much more – including whether some of them harbor exotic life. There is so much more to discover out there!

References

Bains, W. (2004). Many chemistries could be used to build living systems. *Astrobiology*, *4*(2), 137-167.

Benner, S. A., Ricardo, A., & Carrigan, M. A. (2004). Is there a common chemical model for life in the universe?. *Current opinion in chemical biology*, *8*(6), 672-689.

Further reading

"Sunless Worlds" by Tomas Petrasek (Clarkesworld 10/2015)

Classroom ideas

1. Discuss what we know about the Kuiper Belt and Oort Cloud so far. How did the scientists after whom they're named theorize their existence? What evidence leads us to think there is an Oort Cloud with the usually given properties (which is, unlike the Kuiper where we've observed many dwarf planets and smaller bodies, still based on indirect clues)? How did these regions come to be, and can we expect them around other stars? What is "occultation" and how does it help us detect objects out there?
2. Read up a bit on rogue planets. How many of them do astronomers expect to exist in our galaxy? How many have been detected so far? Could our own solar system have produced some?
3. Divide the class into several groups and have each come up with a rogue planet suitable for life (not necessarily Earth-like). There are many possibilities: an open water ocean on a super-Earth with a thick hydrogen-rich atmosphere, a subsurface ocean on a frozen water-rich "Earth" or a tidally heated moon

of a rogue giant planet, or more exotic options (mostly heavier planets with various solvents under high-pressure). Discuss their possible histories and our chances of detecting them and their life signs.

A Jar of Goodwill

by Tobias S. Buckell

Tobias S. Buckell (*1979) is a New York Times Bestselling and World Fantasy Award-winning author born in the Caribbean. He grew up in Grenada and spent time in the British and US Virgin Islands, which influence much of his work. He has published ten novels, five story collections, two anthologies and almost one hundred short stories. His Xenowealth book series begins with *Crystal Rain*. His works have been translated into nineteen different languages. He has been nominated for awards like the Hugo, Nebula, World Fantasy, and the Astounding Award for Best New Science Fiction Author. His latest novel is *The Tangled Lands* written with Paolo Bacigalupi, which the Washington Post said is "a rich and haunting novel that explores a world where magic is forbidden." He currently lives in Bluffton, Ohio with his wife, twin daughters, and a pair of dogs. His website is www.TobiasBuckell.com. He is also an instructor at the Stonecoast MFA in Creative Writing program.

Points On A Package

You keep a low profile when you're in oxygen debt. Too much walking about just exacerbates the situation anyway. So I was nervous when a stationeer appeared at my cubby and knocked on the door.

I slid out and stood in front of the polished, skeletal robot.

"Alex Mosette?" it asked.

There was no sense in lying. The stationeer had already scanned my face. It was just looking for voice print verification. "Yes, I'm Alex," I said.

"The harbormaster wants to see you."

I swallowed. "He could have sent me a message."

"I am here to escort you." The robot held out a tinker-toy arm, digits pointed along the hallway.

Space in orbit came at a premium. Bottom-rung types like me slept in cubbies stacked ten high along the hallway. On my back in the cubby, watching entertainment shuffled in from the planets, they made living on a space station sound exotic and exciting.

It was if you were further up the rung. I'd been in those rooms: places with wasted space. Furniture. Room to stroll around in.

That was exotic.

Getting space in outer space was far down my list of needs.

First was air. Then food.

Anything else was pure luxury.

*

The harbormaster stared out into space, and I silently waited at the door to Operations, hoping that if I remained quiet he wouldn't notice.

Ops hung from near the center of the megastructure of the station. A blister stuck on the end of a long tunnel. You could see the station behind us: the miles-long wheel of exotic metals rotating slowly.

No gravity in Ops, or anywhere in the center. Spokes ran down from the wheel to the center, and the center was where ships docked and were serviced and so on.

So I hung silently in the air, long after the stationeer flitted off to do the harbormaster's bidding, wondering what happened next.

"You're overdrawn," the harbormaster said after a needle-like ship with long feathery vanes slipped underneath us into the docking bays.

He turned to face me, even though his eyes had been hollowed out long ago. Force of habit. His real eyes were now every camera, or anything mechanical that could see.

The harbormaster moved closer. The gantry around him was motorized, a long arm moving him anywhere he wanted in the room.

Hundreds of cables, plugged into his scalp like hair, bundled and ran back along the arm of the gantry. Hoses moved effluvia out. More hoses ran purified blood, and other fluids, back in.

"I'm sorry," I stammered. "Traffic is light. And requests have dropped off. I've taken classes. Even language lessons..." I stopped when I saw the wizened hand raise, palm up.

"I know what you've been doing." The harbormaster's sightless sockets turned back to the depths of space outside. The hardened skin of his face showed few emotions, his artificial voice was toneless. "You would not have been allowed to overdraw if you hadn't made good faith efforts."

"For which," I said, "I am enormously appreciative."

"That ship that just arrived brings with it a choice for you," the harbormaster continued without acknowledging what I'd just said. "I cannot let you overdraw any more if you stay on station, so I will have to put you into hibernation. To pay for hibernation and your air debt I would buy your contract. You'd be woken for guaranteed work. I'd take a percentage. You could buy your contract back out, once you had enough liquidity."

That was exactly what I'd been dreading. But he'd indicated an alternate. "My other option?"

He waved a hand, and a holographic image of the ship I'd just seen coming in to dock hung in the air. "They're asking for a professional Friend."

"For their ship?" Surprise tinged my question. I wasn't crew material. I'd been shipped frozen to the station, just another corpsicle. People like me didn't stay awake for travel. Not enough room.

The harbormaster shrugged pallid shoulders. "They will not tell me why. I had to sign a nondisclosure agreement just to get them to tell me what they wanted."

I looked at the long ship. "I'm not a fuckbot. They know that, right?"

"They know that. They reiterated that they do not want sexual services."

"I'll be outside the station. Outside your protection. It could still be what they want."

"That is a risk. How much so, I cannot model for you." The harbormaster snapped his fingers, and the ship faded away. "But the contractors have extremely high reputational scores on past business dealings. They are freelance scientists: biology, botany, and one linguist."

So they probably didn't want me as a pass-around toy.

Probably.

"Rape amendments to the contract?" I asked. I was going to be on a ship, unthawed, by myself, with crew I'd never met. I had to think about the worst.

"Prohibitive. Although, accidental loss of life is not quite as high, which means I'd advise lowering the former so that there is no temptation to murder you after a theoretical rape to evade the higher contract payout."

"Fuck," I sighed.

"Would you like to peruse their reputation notes?" the harbormaster asked. And for a moment, I thought maybe the harbormaster sounded concerned.

No. He was just being fair. He'd spent two hundred years of bargaining with ships for goods, fuel, repair, services. Fair was built-in, the half-computer half-human creature in front of me was all about fair. Fair got you repeat business. Fair got you a wide reputation.

"What's the offer?"

"Half a point on the package," the harbormaster said.

"And we don't know what the package is, or how long it will take... or anything." I bit my lip.

"They assured me that half a point would pay off your debt and then some. It shouldn't take more than a year."

A year. For half a percent. Half a percent of what? It could be cargo they were delivering. Or, seeing as it was a crew of scientists, it could be some project they were working on.

All of which just raised more questions.

Questions I wouldn't have answers to unless I signed up. I sighed. "That's it, then? No loans? No extensions?"

The harbormaster sighed. "I answer to the Gheda shareholders who built and own this complex. I have already stretched my authority to give you a month's extension. The debt has to be called. I'm sorry."

I looked out at the darkness of space out beyond Ops. "Shit choices either way."

The harbormaster said nothing.

I folded my arms. "Do it."

Journey by Gheda

The docking arms had transferred the starship from the center structure's incoming docks down a spoke to a dock on one of the wheels. The entire ship, thanks to being spun along with the wheel of the station, had gravity.

The starship was a quarter of a mile long. Outside: sleek and burnished smooth by impacts with the scattered dust of space at the stunning speeds it achieved. Inside, I realized I'd boarded a creaky, old, outdated vehicle.

Fiberwire spilled out from conduits, evidence of crude repair jobs. Dirt and grime clung to nooks and crannies. The air smelled of sweat and worst.

A purple-haired man with all-black eyes met me at the airlock. "You are the Friend?" he asked. He carried a large walking stick with him.

"Yes." I let go of the rolling luggage behind me and bowed. "I'm Alex."

He bowed back. More extravagantly than I did. Maybe even slightly mockingly. "I'm Oslo." Every time he shifted his walking stick, tiny grains of sand inside rattled and shifted about. He brimmed with impatience, and some regret in the crinkled lines of his eyes. "Is this everything?"

I looked back at the single case behind me. "That is everything."

"Then welcome aboard," Oslo said, as the door to the station clanged shut. He raised the stick, and a flash of light blinded me.

"You should have taken a scan of me before you shut the door," I said. The stick was more than it seemed. Those tiny rustling grains were generators, harnessing power for whatever tools were inside the device via kinetic motion. He turned around and started to walk away. I hurried to catch up.

Oslo smiled, and I noticed tiny little fangs under his lips. "You are who you say you are, so everything ended up okay. Oh, and for protocol, the others aren't much into it either, by the way. Now, for my own edification, you are a hermaphrodite, correct?"

I flushed. "I am what we Friends prefer to call bi-gendered, yes." Where the hell was Oslo from? I was having trouble placing his cultural conditionings and how

I might adapt to interface with them. He was very direct, that was for sure.

This gig might be more complicated than I thought.

"Your Friend training: did it encompass Compact cross-cultural training?"

I slowed down. "In theory," I said slowly, worried about losing the contract if they insisted on having someone with Compact experience.

Oslo's regret dripped from his voice and movements. Was it regret that I didn't have the experience? Would I lose the contract, minutes into getting it? Or just regret that he couldn't get someone better? "But you've never Friended an actual Compact drone?"

I decided to tell the truth. A gamble. "No."

"Too bad." The regret sloughed off, to be replaced with resignation. "But we can't poke around asking for Friends with that specific experience, or one of our competitors might put two and two together. I recommend you brush up on your training during the trip out."

He stopped in front of a large, metal door. "Where are we going?" I asked.

"Here is your room for the next three days." Oslo opened the large door to a five-by-seven foot room with a foldout bunk bed.

My heart skipped a beat, and I put aside the fact that Oslo had avoided the question. "That's mine?"

"Yes. And the air's billed with our shipping contract, so you can rip your sensors off. There'll be no accounting until we're done."

I got the sense Oslo knew what it was like to be in debt. I stepped into the room and turned all the way around. I raised my hands, placing them on each wall, and smiled.

Oslo turned to go.

"Wait," I said. "The harbormaster said you were freelance scientists. What do you do?"

"I'm the botanist," Oslo said. "Meals are in the common passenger's galley. The crew of this ship is Gheda, of course, don't talk to or interact with them if you can help it. You know why?"

"Yes." The last thing you wanted to do was make a Gheda think you were wandering around, trying to figure out secrets about their ships, or technology. I would stay in the approved corridors and not interact with them.

The door closed in my suite, and I sat down with my small travel case, no closer to understanding what was going on than I had been on the station.

I faced the small mirror by an even smaller basin and reached for the strip of black material stuck to my throat. Inside it, circuitry monitored my metabolic rate, number of breaths taken, volume of air taken in, and carbon dioxide expelled. All of it reported back to the station's monitors, constantly calculating my mean daily cost.

It made a satisfying sound as I ripped it off.

*

"Gheda are Gheda," I said later in the ship's artificial, alien day over reheated turkey strips in the passenger's galley. We'd undocked. The old ship had shivered itself up to speed. "But Gheda flying around in a beat-up old starship, willing to take freelance scientists out to some secret destination: these are dangerous Gheda."

Oslo had a rueful smile as he leaned back and folded his arms. "Cruzie says that our kind used to think our corporations were rapacious and evil before first contact. No one expected aliens to demand royalty payments for technology usage that had been independently discovered by us because the Gheda had previously patented that technology."

"I know. They hit non-compliant areas with asteroids from orbit." Unable to pay royalties, entire nations had collapsed into debtorship. "Who's Cruzie?"

Oslo grimaced. "You'll meet her in two days. Our linguist. Bit of a historian, too. Loves old Earth shit."

I frowned at his reaction. Conflicted, but with somewhat warm pleasure when he thought about her. A happy grimace. "She's an old friend of yours?"

"Our parents were friends. They loved history. The magnificence of Earth. The legend that was. Before it got sold around. Before the Diaspora." That grimace again. But no warmth there.

"You don't agree with their ideals?" I guessed.

I guessed well. Oslo sipped at a mug of tea, and eyed me. "I'm not your project, Friend. Don't dig too deep, because you just work for me. Save your empathy and psychiatry for the real subject. Understand?"

Too far, I thought. "I'm sorry. And just what is my project? We're away from the station now; do you think you can risk being open with me?"

Oslo set his tea down. "Clever. Very clever, Friend. Yes, I was worried about bugs. We've found a planet, with a unique ecosystem. There may be patentable innovations."

I sat, stunned. Patents? I had points on the package. If I got points on a patent on some aspect of an alien biological system, a Gheda-approved patent, I'd be rich.

Not just rich, but like, nation-rich.

Oslo sipped at his tea. "There's only one problem," he said. "There may be intelligent life on the planet. If it's intelligent, it's a contact situation, and we have to turn it over to the Gheda. We get a fee, but no taste of the real game. We fail to report a contact situation and the Gheda find out, it's going to be a nasty scene. They'll kill our families, or even people you know, just to make the point that their interstellar law is inviolate. We have to file a claim the moment of discovery."

I'd heard hesitation in his voice. "You haven't filed yet, have you?"

"I bet all the Gheda business creatures love having you watch humans they're settling a contract with, making sure they're telling the truth, you there to brief them on what their facial expressions are really showing."

That stung. "I'd do the same for any human. And it isn't just contracts. Many hire me to pay attention to them, to figure them out, anticipate their needs."

Oslo leered. "I'll bet."

I wasn't a fuckbot. I deflected the leering. "So tell me, Oslo, why I'm risking my life, then?"

"We haven't filed yet because we honestly can't fucking figure out if the aliens are just dumb creatures, or intelligences like us," Oslo said.

The Drone

"Welcome to the Screaming Kettle," said the woman who grabbed my bag without asking. She had dark brown skin and eyes, and black hair. Tattoos covered every inch of skin free of her clothing. Words in scripts and languages that I didn't recognize. "The Compact Drone is about to dock as well, we need you ready for it. Let's get your stuff stowed."

We walked below skylights embedded in the top of the research station. A planet hung there: green and yellow and patchy. It looked like it was diseased with mold. "Is that Ve?" I asked.

"Oslo get you up to speed?" the woman asked.

"Somewhat. You're Cruzie, right?"

"Maricruz. I'm the linguist. I guess... you're stuck here with us. You can call me Cruzie too." We stopped in front of a room larger than the one on the ship. With two beds.

I looked at the beds. "I'm comfortable with a cubby, if it means getting my own space," I said.

There was far more space here, vastly so. And yet, I was going to have to share it? It rankled. Even at the station, I hadn't had to share my space. This shoved me up against my own cultural normative values. Even in the most packed places in space, you needed a cubby of one's own.

"You're here to Friend the Compact Drone," Cruzie said. "It'll need companionship at all times. Their contract requires it for the Drone's mental stability."

"Oslo didn't tell me this." I pursed my lips. A fairly universal display of annoyance.

And Cruzie read that well enough. "I'm sorry," she said. But it was a lie as well. She was getting annoyed and impatient. But screw it, as Oslo pointed out: I wasn't there for their needs. "Oslo wants us to succeed more than anything. Unlike his parents, he's not much into the glory that was humankind. He knows the only way we'll ever not be freelancers, scrabbling around for intellectual scraps found in the side alleys of technology for something we can use without paying the Gheda for the privilege, is to hit something big."

"So he lied to me." My voice remained flat.

"He left out truths that would have made you less willing to come."

"He lied."

Cruzie shut the door to my room. "He gave you points on the package, Friend. We win big, you do your job, you'll never have to check the balance on your air for the rest of your damned life. I heard you were in air debt, right?"

She'd put me well in place. We both knew it. Cruzie smiled, a gracious winner's smile.

"Incoming!" Someone yelled from around the bend in the corridor.

"I'm not going to fuck the Drone," I told her levelly.

Cruzie shrugged. "I don't care what you do or don't do, as long as the Drone stays mentally stable and does its job for us. Points on the package, Alex. Points."

*

Airlock alarms flashed and warbled, and the hiss of compressed air filled the antechamber.

"The incoming pod's not much larger than a cubby sleeper," Oslo said, his purple hair waving about as another burst of compressed air filled the antechamber. He smiled, fangs out beyond his lips. "It's smaller than the lander we have for exploring Ve ourselves, if we ever

need to get down there. Can you imagine the ride? The only non-Gheda way of traveling!"

The last member of the team joined us. She looked over at me and nodded. Silvered electronic eyes glinted in the flash of the airlock warning lights. She flexed the jet black fingers of her artificial right hand absentmindedly as she waited for the doors to open. She ran the fingers of a real hand over her shaved head, then put them back in her utility jacket, covered with what seemed like hundreds of pockets and zippers.

"That's Kepler," Cruzie said.

The airlock doors opened. A thin, naked man stumbled out, dripping goopy blue acceleration gel with each step.

For a moment his eyes flicked around, blinking.

Then he started screaming.

*

Oslo, Kepler, and Cruzie jumped back half a step from the naked man's arms. I stepped forward. "It's not fear, it's relief."

The man grabbed me in a desperate hug, clinging to me, his hands patting my face, shoulders, as if reassuring himself someone was really standing in front of him. "It's okay," I whispered. "You've been in there by yourself for days, with no contact of any sort. I understand."

He was shivering in my grip, but I kept patting his back. I urged him to feel the press of contact between us. And reassurance. Calm.

Eventually he calmed down, and then slowly let go of me.

"What's your name?" I asked.

"Beck."

"Welcome aboard, Beck," I said, looking over his shoulder at the scientists who looked visibly relieved.

*

First things first.

Beck got to the communications room. Back and forth verification on an uplink, and he leaned back against the chair in relief.

"There's an uplink to the Hive," he said. "An hour of lag time to get as far back as the home system, but I'm patched in."

He tapped metal inserts on the back of his neck. His mind plugged in to the communications network, talking all the way back to the asteroid belt in the mother system, where the Compact's Hive thrived. Back there, Beck would always be in contact with it without a delay. In instant symbiosis with a universe of information that the Compact offered.

A hive-mind of people, your core self subjugated to the greater whole.

I shivered.

Beck never moved more than half a foot away from me. Always close enough to touch. He kept reaching out to make sure I was there, even though he could see me.

*

After walking around the research station for half an hour, we returned to our shared room.

He sat on his bed, suddenly apprehensive. "You're the Friend, correct?"

"Yes."

"I'm lonely over here. Can you sleep by me?"

I walked over and sat next to him. "I won't have sex with you. That's not why I'm here."

"I'm chemically neutered," Beck said as we curled up on the bed. "I'm a drone."

As we lay there, I imagined thousands of Becks sleeping in rows in Hive dorms, body heat keeping the rooms warm.

Half an hour later he suddenly sighed, like a drug addict getting a hit. "They hear me," he whispered. "I'm not alone."

The Compact had replied to him.

He relaxed.

The room filled with a pleasant lavender scent. Was it something he'd splashed on earlier? Or something a Compact drone released to indicate comfort?

What's Human?

"That," Kepler said, leaning back in a couch before a series of displays, "is one of our remote-operated vehicles. We call them urchins."

In the upper right hand screen before her, a small sphere with hundreds of wriggling legs rotated around. Then it scrabbled off down what looked like a dirt path.

Cruzie swung into a similar couch. "We sterilize them in orbit, then drop them down encased in a heatshield. It burns away, then they drop down out of the sky with a little burst of a rocket to slow down enough."

I frowned at one of the screens. Everything was shades of green and gray and black. "Is that night vision?"

Oslo laughed. "It's Ve. The atmosphere is chlorinated. Green mists. Grey shadows. And black plants."

The trees had giant, black leaves hanging low to the ground. Tubular trunks sprouted globes that spouted mist randomly as the urchin brushed past.

"Ve's a small planet," Kepler said. "Low gravity, but with air similar to what you would have seen on the mother world."

"Earth," Oslo corrected.

"But unlike the mother world," Kepler continued, "Ve has high levels of chlorine. Somewhere in its history, a battle launched among the plants. Instead of specializing in oxygen to kill off the competition, and

adapting to it over time, plant life here turned to chlorine as a weapon. It created plastics out of the organic compounds available to it, which is doable in a chlorine-heavy base atmosphere, though remarkable. And the organic plastics also handle photosynthesis. A handy trick. If we can patent it."

On the screen the urchin rolled to a slow stop. Cruzie leaned forward. "Now if we can just figure out if those bastards are really building a civilization, or just random dirt mounds..."

Paused at the top of a ridge, the urchin looked at a clearing in the black-leafed forest. Five pyramids thrust above the foliage around the clearing.

"Can you get closer?" Beck asked, and I jumped slightly. He'd been so silent, watching all this by my side.

"Not from here," Kepler said. "There's a big dip in altitude between here and the clearing."

"And?" Beck stared at the pyramids on the screen.

"Our first couple weeks here we kept driving the urchins into low lying areas, valleys, that sort of thing. They kept dying on us. We figure the chlorine and acids sink low into the valleys. Our equipment can't handle it."

Beck sat down on the nearest couch to Kepler, and looked over the interface. "Take the long way around then, I'll look at your archives while you do so. Wait!"

I saw it too. A movement through the black, spiky bushes. I saw my first alien creature scuttle around,

antennae twisting as it moved along what looked like a path.

"They look like ants," I blurted out.

"We call them Vesians. But yes, ants the size of a small dog," Oslo said. "And not really ants at all. Just exoskeletons, black plastic, in a similar structure. The handiwork of parallel evolution."

More Vesians appeared carrying leaves and sticks on their backs.

And gourds.

"Now that's interesting," Beck said.

*

"It doesn't mean they're intelligent," Beck said later, lying in the bunk with me next to him. We both stared up at the ceiling. He rolled over and looked at me. "The gourds grow on trees. They use them to store liquids. Inside those pyramids."

We were face to face, breathing each other's air. Beck had no personal space, and I had to fight my impulse to pull back away from him.

My job was now to facilitate. Make Beck feel at home.

Insect hives had drones that could exist away from the hive. A hive needed foragers, and defenders. But the human Compact only existed in the asteroid belt of the mother system.

Beck was a long way from home.

With the lag, he would be feeling cut off and distant. And for a mind that had always been in the embrace of the hive, this had to be hard for him.

But Beck offered the freelance scientists a link into the massive computational capacity of the entire Compact. They'd contracted it to handle the issue they couldn't figure out quickly: were the aliens intelligent or not?

Beck was pumping information back all the way back to the mother system, so that the Compact could devote some fraction of a fraction of its massed computing ability to the issue. The minds of all its connected citizenry. Its supercomputers. Maybe even, it was rumored, artificial intelligences.

"But if they are intelligent?" I asked. "How do you prove it?"

Beck cocked his head. "The Compact is working on it. Has been ever since the individuals here signed the contract."

"Then why are you out here?"

"Yes..." He was suddenly curious in me now, remembering I was a distinct individual, lying next to him. I wasn't of the Compact. I wasn't another drone.

"I'm sorry," I said. "I shouldn't have asked."

"It was good you asked." He flopped over to stare at the ceiling again. "You're right, I'm not entirely needed. But the Compact felt it was necessary."

I wanted to know why. But I could feel Beck hesitate. I held my breath.

"You are a Friend. You've never broken contract. The Compact ranks you very highly." Beck turned back to face me. "We understand that what I tell you will never leave this room, and since I debugged it, it's a safe room. What do you think it takes to become a freelance scientist in this hostile universe?"

I'd been around enough negotiating tables. A good Friend, with the neural modifications and adaptive circuitry laced into me from birth, I could read body posture, micro-expressions, skin flush, heart rate, in a blink of the eye. I made a hell of a negotiating tool. Which was usually exactly what Gheda wanted: a read on their human counterparts.

And I had learned the ins and outs of my clients businesses quick as well. I knew what the wider universe was like while doing my job.

"Oslo has pent-up rage," I whispered. "His family is obsessed with the Earth as it used to be. Before the Gheda land purchases. He wants wealth, but that's not all, I think. Cruzie holds herself like she has military bearing, though she hides it. Kepler, I don't know. I'm guessing you will tell me they have all worked as weapons manufacturers or researchers of some sort?"

Beck nodded. "Oslo and his sister London are linked to a weaponized virus that was released on a Gheda station. Cruzie fought with separatists in

Columbia. Kepler is a false identity. We haven't cracked her yet."

I looked at the drone. There was no deceit in him. He stated these things as facts. He was a drone. He didn't need to question the information given to him.

"Why are you telling me all this?"

He gestured at the bunk. "You're a professional Friend. You're safe. You're here. And I'm just a drone. We're just a piece of all this."

And then he moved to spoon against the inside of my stomach. Two meaningless, tiny lives inside a cold station, far away from where they belonged.

"And because," he added in a soft voice, "I think that these scientists are desperate enough to fix a problem if it occurs."

"Fix a problem?" I asked, wrapping my arms around him.

"I think the Vesians are intelligent, and I think Kepler and Oslo plan to do something to them if, or when, it's confirmed, so that they can keep patent rights."

I could suddenly hear every creak, whisper, and whistle in the station as I tensed up.

"I will protect you if I can. Right now we're just delaying as long as we can. Mainly I'm trying to stop Cruzie from figuring out the obvious, because if she confirms they're really intelligent, then Oslo and Kepler will make their move and do something to the Vesians. We're not sure what."

"You said delaying. Delaying until what?" I asked, a slight quaver in my voice that I found I couldn't control.

"Until the Gheda get here," Beck said with a last yawn. "That's when it all gets really complicated." His voice trailed off as he said that, and he fell asleep.

I lay there, awake and wide-eyed.

I finally reached up to my neck and scratched at the band of skin where the air monitor patch had once been stuck.

Points on nothing was still just... nothing.

But could I rat out my contract? My role as a Friend? Could I help Oslo and Kepler kill an alien race?

Things had gotten very muddy in just a few minutes. I felt trapped between the hell of an old life and the hell of a horrible new one.

*

"What's a human being?" I asked Beck over lunch.

"Definitions vary," he replied.

"You're a drone: bred to act, react, and move within a shared neural environment. You serve the Compact. There's no queen, like a classic anthill or with bees. Your shared mental overmind makes the calls. So you have a say. A tiny say. You are human...-ish. Our ancestors would have questioned whether you were human."

Beck cocked his head and smiled. "And you?"

"Modified from birth to read human faces. Under contract for most of my life to Gheda, working to tell the aliens or other humans what humans are really thinking... they wouldn't have thought highly of me either."

"The Compact knows you reread your contract last night, after I fell asleep, and you used some rather complicated algorithms to game some scenarios."

I frowned. "So you're spying on us now."

"Of course. You're struggling with a gray moral situation."

"Which is?"

"The nature of your contract says you need to work with me and support my needs. But you're hired by the freelancers that I'm now in opposition to. As a Friend, a role and purpose burned into you just like being a drone is burned into me, do you warn them? Or do you stick by me? The contract allows for interpretations either way. And if you stick with me, it's doing so while knowing that I'm just a drone. A pawn that the Compact will use as it sees fit, for its own game."

"You left something out," I said.

"Neither you, nor I, are bred to care about Vesians," Beck said.

I got up and walked over to the large porthole. "I wonder if it wouldn't be better for them?"

"What would?"

"Whatever Kepler and Oslo want to do to them. Better to die now than to meet the Gheda. I can't imagine they'd ever want to become us."

Beck stood up. There was caution in his stance, as if he'd thought I had been figured out, but now wasn't sure. "I've got work to do. Stay here and finish your meal, Friend."

I looked down at the green world beneath, and jumped when a hand grabbed my shoulder. I could see gray words tattooed in the skin. "Cruzie?"

Her large brown eyes were filled with anger. "That son of a bitch has been lying to us," she said, pointing in the direction Beck had gone. "Come with me."

*

"The gourds," Cruzie said, pointing at a screen, and then looking at Beck. "Tell us about the gourds."

And Oslo grabbed my shoulder. "Watch the drone, sharp now. I want you to tell us what you see when he replies to us."

My contract would be clear there. I couldn't lie. The scientists owned the contract, and now that they'd asked directly for my services, I couldn't evade.

Points on the package, I thought in the far back of my mind.

I wasn't really human, was I? Not if I found the lure of eternal riches to be so great as to consider helping the freelancers.

"The Vesians have farms," Cruzie said. "But so do ants: they grow fungus. The Vesians have roads, but so do animals in a forest. They just keep walking over the same spots. Old Earth roads used to follow old animal paths. The Vesians have buildings, but birds build nests, ants build colonies, bees build hives. But language, that's so much rarer in the animal kingdom, isn't it, Beck?"

"Not really," the drone said calmly. "Primitive communication exists in animals. Including bees, which dance information. Dolphins squeak and whales sing."

"But none of them write it down," Cruzie grinned.

Oslo's squeezed my shoulder, hard. "The drone is mildly annoyed," I said. "And more than a little surprised."

Cruzie tapped on a screen. The inside of one of the pyramids appeared. It was a storehouse of some sort, filled with hundreds, maybe thousands, of the gourds I'd seen earlier that the Vesian had been transporting.

"Nonverbal creatures use scent. Just like ants on the mother planet. The Vesians use scents to mark territories their queens manage. And one of the things I started to wonder about, were these storage areas. What were they for? So I broke in, and I started breaking the gourds."

Beck stiffened. "He's not happy with this line of thought," I murmured.

"Thought so," Oslo said back, and nodded at Cruzie, who kept going.

"And whenever I broke a gourd, I found them empty. Not full of liquid, as Beck told us was likely. We originally thought they were for storage. An adaptive behavior. Or a sign of intelligence. Hard to say. Until I broke them all."

"They could have been empty, waiting to be sealed," Beck said tonelessly.

I sighed. "I'm sorry, Beck. I have to do this. He's telling the truth, Oslo. But misdirecting."

"I know he is," Cruzie said. "Because the Vesians swarmed the location with fresh gourds. There were chemical scents, traces laid down in the gourds before they were sealed. The Vesians examined the broken gourds, then filled the new ones with scents. I started examining the chemical traces, and found that each gourd replaced had the same chemical sequences sprayed on and stored as the ones I broke."

Beck's muscles tensed. Any human could see the stress now. I didn't need to say anything.

"They were like monks, copying manuscripts. Right, Beck?" Cruzie asked.

"Yes," Beck said.

"And the chemical markers, it's a language, right?" Kepler asked. I could feel the tension in her voice. It wasn't just disappointment building, but rage.

"It is." Beck stood up slowly.

"It took me days to realize it," Cruzie said. "And that, after the weeks I've been out here. The Compact spotted it right away, didn't it?"

Beck looked over at me, then back at Cruzie. "Yes. The Compact knows."

"Then what the hell is it planning to do?" Kepler moved in front of Beck, lips drawn back in a snarl.

"I'm just a drone," Beck said. "I don't know. But I can give you an answer in an hour."

For a second, everyone stood frozen. Oslo, brimming with hurt rage, staring at Beck. Kepler, moving from anger toward some sort of decision. Cruzie looked... triumphant. Oblivious to the real breaking developments in the air.

And I observed.

Like any good Friend.

Then a loud 'whooop whooop' startled us all out of our poses.

"What's that?" Cruzie asked, looking around.

"The Gheda are here," Oslo, Kepler, and Beck said at the same time.

The Path Less Traveled

"Call the vote," Oslo snapped.

Cruzie swallowed. I saw micro beads of sweat on the side of her neck. "Right now?"

"Gheda are inbound," Kepler said, her artificial eyes dark. I imagined she had them patched into the computers, looking at information from the station's sensors. "They'll be decelerating and matching orbit in hours. There's no time for debate, Cruzie."

"What we're about to do is something that requires debate. They're intelligent. We're proposing ripping that away over the next day with Kepler's tailored virus. They'll end up with a viral lobotomy, just smart enough we can claim their artifacts come from natural hive mind behavior. But we'll have stolen their culture. Their minds. Their history." Cruzie shook her head. "I know we said they're going to lose most of that when the Gheda arrive. But if we do this, we're worse than Gheda."

"Fucking hell, Cruzie!" Oslo snapped. "You're changing your mind now?"

"Oslo!" Cruzie held up her hands as if trying to ward off the angry words.

"You saw our mother planet," Oslo said. "The slums. The starvation. Gheda combat patrols. They owned everyone. If you didn't provide value, you were nothing. You fought the Sahara campaign, you attacked Abbuj station. How the fuck can you turn your back to all that?"

"I didn't turn my back, I wanted a different path," Cruzie said. "That's why we're here. With the money on

the patents, we could change things... but what are we changing here if we're not all that better than the Gheda?"

"It's us or the fucking ants," Kepler said, voice suddenly level. "It's really that simple. Where are your allegiances?"

I bit my lip when I heard that.

"Cruzie..." I started to say.

She held a hand up and walked over to the console, her thumb held out. "It takes a unanimous vote to unleash the virus. This was why I insisted."

"You're right," Kepler said. I flinched. I could hear the hatred in her voice. She nodded at Oslo.

He raised his walking stick. The tiny grains inside rattled around, and then a jagged finger of energy leapt out and struck Cruzie in the small of her back.

Cruzie jerked around, arms flopping as she danced, then dropped to the ground. Oslo pressed the stick to her head and fired it again. Blood gushed from Cruzie's eye sockets as something inside her skull went 'pop.'

A wisp of smoke curled from her open mouth.

Oslo and Kepler put thumbs to the screens. "We have a unanimous vote now."

But a red warning sign flashed back at them. Beck relaxed slightly, a tiny curl of a smile briefly appearing.

Oslo raised his walking stick and pointed it at Beck. "Our communications are blocked."

"Yes," Beck said. "The Compact is voting against preemptive genocide."

For a split second, I saw the decision to kill Beck flit across Kepler's face. "If you kill him," I spoke up, "the Compact will spend resources hunting you two down. You can't enjoy your riches if you're dead."

Kepler nodded. "You're right." But she looked at me, a question on her face.

I shrugged. "If you're all dead, I don't have points on the package."

"Trigger them manually," Oslo said. "We'll bring the drone. We won't leave him up here to cause more trouble. Bring him, or her, or whatever the Friend calls itself as well. Your contract, Alex, is now to watch Beck."

*

We burned our way through the green atmosphere of Ve, the lander bucking and groaning, skin cracking as it weathered the heat of our reentry fireball.

From the tiny cramped cockpit I watched us part the clouds and spiral slowly down out of the sky as the wings unfurled from slots in the tear-drop sized vehicle's side. They started beating a complicated figure-eight motion.

Oslo aimed his walking stick at us when the lander touched down. "Put on your helmet, get out. Both of you."

We did so.

Heavy chlorine-rich mists swirled around, disturbed by our landing. Large puffball flowers spurted acid whenever touched by a piece of stray stirred-up debris, and the black, plastic leaves all around us bobbed gently in a low breeze.

Oslo and Kepler pulled a large pack out of the lander's cargo area. Long pieces of tubing. They set to building a freestanding antenna, piece by piece. I watched Beck. I couldn't see his face, but I could see his posture.

He was about to run. Which made no sense. Run where? On this world?

Within a few minutes Oslo and Kepler had snapped together a thirty-foot tall tower. I swallowed, and remained silent. It was a choice, a deliberate path. I broke my contract.

Oslo snapped a clip to the top of the tower, then unrolled a length of cable. He and Kepler used it to pull the super light structure up.

That was the moment Beck ran, as it hung halfway up to standing.

"Shit," Oslo cursed over the tiny speakers in our helmets, but he didn't drop the structure. "You've only got a couple hours of air you moron!"

The only response was Beck's heavy breathing.

When the antenna stood upright, Oslo approached me, the walking stick out. "You didn't warn us."

"He was wearing a spacesuit," I said calmly.

But I could see Oslo didn't believe me. His eyes creased and his fingers tightened. A bright explosion of pain ripped into me.

*

My vision cleared.

I was on my hands and feet, shaking with pain from the electrical discharge. A whirlwind of debris whipped around me. I looked up to see the lander lifting into the sky.

So that was it. I'd made my choice: to try and not be a monster.

And it had been in vain. The Vesians would be lobotomized by Kepler's virus. Beck would die. I would die.

I watched the lander beginning a wide spiral upward away from me. In a few seconds it would fire its rockets and climb for orbit.

In a couple hours, I would run out of air.

Four large gourds arced high over the black forest and slapped into the side of the lander. I frowned. At first, it looked like they had no effect. The lander kept spiraling up.

But then, it faltered.

The lander shook, and smoke spilled out of a crack in the side somewhere.

It exploded, the fireball hanging in the sky.

"Get away from the antenna," Beck suddenly said. "It's next."

I ran without a second thought, and even as I got free of the clearing, gourds of acid hit the structure. The metal sizzled, foamed, and then began to melt.

A few seconds later, I broke out onto a dirt path where the catapults firing the gourds of acid had been towed into place.

Beck waited for me, surrounded by a crowd of Vesians. He wore only his helmet, he'd ripped his suit off. His skin bubbled from bad chemical burn blisters.

""The Vesians destroyed all the remote-operating vehicles with the virus in it," he said. "The queens have quarantined any Vesians near any area that had an ROV. The species will survive.""

"You've been talking to them," I said. And then I thought back to the comforting smell in my room the first night Beck spent with me. "You're communicating with them. You warned them."

Beck held up his suit. "Yes. The Compact altered me to be an ambassador to them."

"Beck, how long can you survive in this environment?" I stared at his blistered skin.

"A year. Maybe. There will be another ready by then. Maybe a structure to live in. The Gheda will be here soon to bring air. The Compact has reached an agreement with them. The Vesian queens are agreeing to join the Compact. The Compact gets to extend out of the mother

system, but only to Ve. In exchange, the Gheda get rights to all patentable discoveries made in the new ecosystem. They're particularly interested in plastic-based organic photosynthesis."

I collapsed to the ground, realizing that I would live. Beck sat next to me. A small Vesian approached, a gourd in its mandibles. It set the organic, plastic bottle at my legs. "What's that?"

"A jar of goodwill," Beck said. "The Vesian queen of this area is thanking you."

I was still just staring at it two hours later as my air faded out, my vision blurred, and the Gheda lander finally reached us.

*

The harbormaster cocked his head. "You're back."

"I'm back," I said. Someone was unpacking my two bags. One of them carefully holding the Vesian 'gift.'

"I didn't think I'd ever see you again," the harbormaster said. "Not with a contract like that."

"It didn't work out." I looked out into the vacuum of space beyond us. "Certainly not for the people who hired me. Or me."

"You have a peripheral contract with the Compact. An all-you-can-breathe line of credit on the station. You're not a citizen, but on perpetual retainer as the Compact's

primary professional Friend for all dealings in this system. You did well enough."

I grinned. "Points on a package like what they offered me was a fairy tale. A fairy tale you'd have to be soulless to want to have come true."

"I'm surprised that you did not choose to join the Compact," the harbormaster said, looking closely at me. "It is a safe place for humans in this universe. Even as a peripheral for them, you could still be in danger during patent negotiations with Gheda."

"I know. But this is home. My home. I'm not a drone, I don't want to be one."

The harbormaster sighed. "You understand the station is my only love. I don't have a social circle. There is only the ebb and flow of this structure's health for me."

I smiled. "That's why I like you, harbormaster. You have few emotions. You are a fair dealer. You're the closest thing I have to family. You may even be the closest thing I have to a friend, friend with a lowercase 'f.'"

"You follow your contracts to the letter. I like that about you," the harbormaster said. "I'm glad you will continue on here."

Together we watched the needle-like ship that had brought me back home silently fall away from the station.

"The Compact purchased me a ten-by-ten room with a porthole," I said. "I don't have to come up here to sneak a look at the stars anymore."

The harbormaster sighed happily. "They're beautiful, aren't they? I think, we've always loved them, haven't we? Even before we were forced to leave the mother world."

"That's what the history books say," I said quietly over the sound of ducts and creaking station. "We dreamed of getting out here, to live among them. Dreamed of the wonders we'd see."

"The Gheda don't see the stars," the harbormaster said. "They have few portholes. Before I let the Gheda turn me into a harbormaster, I demanded the contract include this room."

"They don't see them the way we do," I agreed.

"They're not human," the harbormaster said.

"No, they're not." I looked out at the distant stars. "But then, few things are anymore."

The Gheda ship disappeared in a blinding flash of light, whipping through space toward its next destination.

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Black forests wrapped in green mist

"A Jar of Goodwill" gives us plenty to think about, from what makes a human to law issues in space, but let's focus on the astrobiology: mainly photosynthesis in a chlorine-rich atmosphere. For us, chlorine gas is poisonous, as soldiers in WWI trenches would testify. In the story, Beck sustained chemical burns on his skin even in a few hours in Ve's atmopshere.

But not all Earth life is so sensitive to it. We know of several bacteria and archea species that can not only tolerate high concentrations of aggressive salts of chlorine, called perchlorates, but feed on them, too. These species are the prime candidates for Mars analog experiments, since the Martian regolith is perchlorate-rich. Some of them, such as the archeon *Archaeoglobus fulgidus*, don't tolerate oxygen, however.

As to pure chlorine, *Methylobacterium* is famously tolerant of it, making e.g. effective sterilization of clean rooms where spacecraft are assembled a bit of a problem. Pursuing this line of reasoning would bring us to the question of planetary protection, but let's leave that to the bonus story and move closer to environments depicted in the story.

The possibility of chlorinic photosynthesis was theoretically described by Haas (2010). In principle, it would be energetically feasible, with chlorinated hydrocarbons as its final products. It would likely require previous resistance to the chlorine radical – probably from an environment where it's abiotically produced e.g. by UV photolysis of chloride in the sea.

Planets around UV-rich stars with a high metallicity (content of elements heavier than hydrogen and helium; in general, higher metallicity would mean more halogens to work with) would be the prime suspects. Such places would be detectable by chlorinated gases' absorption especially in the infrared regime. Haas didn't speculate on the specific nature of the chlorocarbons that would be produced by the whole biosphere, or the color the plants would have.

He wasn't the only one, though, who speculated on the potential role of halogens in exoplanet biospheres. Budisa et al. (2014) considered a probably very special case of fluorine-rich environments (possibly planets where the majority of oxygen was used up in surface oxidation, and fluorine was released by highly fluorine-enriched magma). They speculate that in such a place, fluorine might play a similar role oxygen does on Earth.

A mixture of hydrofluoric acid and water would also act as a solvent not too dissimilar to water alone (if you don't mind it being more acidic and less soluble for some ions). But it seems that a planet with such conditions would be special indeed. Water, as we've shown in the text accompanying the first story, is ubiquitous. Hydrogen is the most common element in the whole universe, followed by helium, then oxygen, carbon, neon, iron, nitrogen, silicon, magnesium, sulfur and other elements. Halogens are relatively rare. If we look for a solvent for life other than water, hydrocarbons such as methane or ethane, ammonia, liquid nitrogen or hydrogen seem much more plausible simply due to their expected relative abundance.

But even slight changes in the ratios of various elements in a given portion of a protostellar cloud can result in a very different star system and its planets. A seemingly minor shift in the ratio of carbon and oxygen might upend a planet's thermal and tectonic regime so much we wouldn't begin to recognize it. It would also change the probable solvent (water or hydrocarbons) and atmospheric composition, thus rapidly changing conditions for life. Similarly, the magnesium-silicon ratio would vastly impact a planet's geophysics (and thus volcanism, tectonics and other bits crucial for life), and so on. The universe is vast, and the zoo of exoplanets probably contains many peculiar specimens…

We've made quite a leap from chlorinic photosynthesis, haven't we? But that's how it is with search for life in the universe; everything is connected. The tiniest properties of a galaxy, position within it, a star and its neighborhood, any chance stellar encounters, nearby supernovas, the gravitational dance in a new system being born, elemental compositions, impacts… change just one apparently minor parameter, and you might end up with completely different conditions. We are just beginning to understand some of the involved processes and feedback loops. Remote observations of star-forming areas, young systems and many exoplanets by the upcoming James Webb Space Telescope, ARIEL and other telescopes will offer us further insights.

We live in interesting times indeed!

References

Budisa, N., Kubyshkin, V., & Schulze-Makuch, D. (2014). Fluorine-rich planetary environments as possible habitats for life. *Life*, *4*(3), 374-385.

Haas, J. R. (2010). The potential feasibility of chlorinic photosynthesis on exoplanets. *Astrobiology*, *10*(9), 953-963.

Classroom ideas

1. One thing we haven't discussed here much are the possible colors of plants on alien worlds. Why are plants on Earth green, and have other colors been suggested e.g. for plants on planets around red dwarfs (and why)?
2. Try to find out in existing literature whether other types of photosynthesis than oxygenic or chlorinic have been considered.
3. Looking back at the story, we can see that the Vesians communicate primarily by scent. What are the (dis)advantages of chemical communication? Try to consider different environments (e.g. more or less complex land, aquatic environment, air, etc.) and also think about the implications for building a technological civilization.

The Island

by Peter Watts

Peter Watts (* 1958) is a former marine biologist and science fiction author. Beside a number of accolades for science fiction, he has won awards in fields as diverse as marine mammal research and video documentary. Watts' first book (*Starfish*) was a NY Times Notable Book, while his sixth (*Blindsight*) – a philosophical rumination on the nature of consciousness with an unhealthy focus on space vampires – has become a core text in diverse undergraduate courses ranging from philosophy to neuropsych, and is rumored to have ended up in the occasional Real Neuro Lab. It also made the final ballot for a number of domestic genre awards including the Hugo, winning exactly zero of them. His shorter work has also picked up a variety of trophies, notably a Hugo (for the novelette "The Island" included here) and a Shirley Jackson. Much of his fiction is freely available on his website, but you're welcome to buy the Greatest-Hits package *Beyond the Rift* (from Tachyon) if you like physical artefacts, or *Peter Watts is an Angry Sentient Tumor* if you're into nonfiction and can't be bothered to trawl through his blog. The video-game novelization *Crysis: Legion* (Del Rey) has its own tawdry charm. Watts' work is available in 20 languages, and he was described by the Globe & Mail as "one of the very best [hard-sf writers] alive". Visit his website at rifters.com.

We are the cave men. We are the Ancients, the Progenitors, the blue-collar steel monkeys. We spin your webs and build your magic gateways, thread each needle's eye at sixty thousand kilometers a second. We never stop. We never even dare to slow down, lest the light of your coming turn us to plasma. All for you. All so you can step from star to star without dirtying your feet in these endless, empty wastes *between*.

Is it really too much to ask, that you might talk to us now and then?

I know about evolution and engineering. I know how much you've changed. I've seen these portals give birth to gods and demons and things we can't begin to comprehend, things I can't believe were ever human; alien hitchikers, maybe, riding the rails we've left behind. Alien conquerers.

Exterminators, perhaps.

But I've also seen those gates stay dark and empty until they faded from view. We've infered diebacks and dark ages, civilizations burned to the ground and others rising from their ashes – and sometimes, afterwards, the things that come out look a little like the ships *we* might have built, back in the day. They speak to each other – radio, laser, carrier neutrinos – and sometimes their voices sound something like ours. There was a time we dared to hope that they really were like us, that the circle had come round again and closed on beings we could talk to. I've lost count of the times we tried to break the ice.

I've lost count of the eons since we gave up.

All these iterations fading behind us. All these hybrids and posthumans and immortals, gods and catatonic cavemen trapped in magical chariots they can't begin to understand, and not one of them ever pointed a comm laser in our direction to say *Hey, how's it going*, or *Guess what? We cured Damascus Disease!* or even *Thanks, guys, keep up the good work.*

We're not some fucking cargo cult. We're the backbone of your goddamn empire. You wouldn't even be out here if it weren't for us.

And – and you're our *children*. Whatever you've become, you were once like this, like me. I believed in you once. There was a time, long ago, when I believed in this mission with all my heart.

Why have you forsaken us?

*

And so another build begins.

This time I open my eyes to a familiar face I've never seen before: only a boy, early twenties perhaps, physiologically. His face is a little lopsided, the cheekbone flatter on the left than the right. His ears are too big. He looks almost *natural*.

I haven't spoken for millennia. My voice comes out a whisper: "Who are you?" Not what I'm supposed to

ask, I know. Not the first question *anyone* on *Eriophora* asks, after coming back.

"I'm yours," he says, and just like that I'm a mother.

I want to let it sink in, but he doesn't give me the chance: "You weren't scheduled, but Chimp wants extra hands on deck. Next build's got a situation."

So the chimp is still in control. The chimp is always in control. The mission goes on.

"Situation?" I ask.

"Contact scenario, maybe."

I wonder when he was born. I wonder if he ever wondered about me, before now.

He doesn't tell me. He only says, "Sun up ahead. Half lightyear. Chimp thinks, maybe it's talking to us. Anyhow..." My – son shrugs. "No rush. Lotsa time."

I nod, but he hesitates. He's waiting for The Question but I already see a kind of answer in his face. Our reinforcements were supposed to be *pristine*, built from perfect genes buried deep within *Erí*'s iron-basalt mantle, safe from the sleeting blueshift. And yet this boy has flaws. I see the damage in his face, I see those tiny flipped base-pairs resonating up from the microscopic and *bending* him just a little off-kilter. He looks like he grew up on a planet. He looks borne of parents who spent their whole lives hammered by raw sunlight.

How far out must we be by now, if even our own perfect building blocks have decayed so? How long has it taken us? How long have I been dead?

How long? It's the first thing everyone asks.

After all this time, I don't want to know.

*

He's alone at the tac tank when I arrive on the bridge, his eyes full of icons and trajectories. Perhaps I see a little of me in there, too.

"I didn't get your name," I say, although I've looked it up on the manifest. We've barely been introduced and already I'm lying to him.

"Dix." He keeps his eyes on the tank.

He's over ten thousand years old. Alive for maybe twenty of them. I wonder how much he knows, who he's met during those sparse decades: does he know Ishmael, or Connie? Does he know if Sanchez got over his brush with immortality?

I wonder, but I don't ask. There are rules.

I look around. "We're it?"

Dix nods. "For now. Bring back more if we need them. But…" His voice trails off.

"Yes?"

"Nothing."

I join him at the tank. Diaphanous veils hang within like frozen, color-coded smoke. We're on the edge

of a molecular dust cloud. Warm, semiorganic, lots of raw materials: formaldehyde, ethylene glycol, the usual prebiotics. A good spot for a quick build. A red dwarf glowers dimly at the center of the Tank. The chimp has named it DHF428, for reasons I've long since forgotten to care about.

"So fill me in," I say.

His glance is impatient, even irritated. "You too?"

"What do you mean?"

"Like the others. On the other builds. Chimp can just squirt the specs but they want to *talk* all the time."

Shit, his link's still active. He's *online*.

I force a smile. "Just a – a cultural tradition, I guess. We talk about a lot of things, it helps us – reconnect. After being down for so long."

"But it's *slow*," Dix complains.

He doesn't know. Why doesn't he know?

"We've got half a lightyear," I point out. "There's some rush?"

The corner of his mouth twitches. "Vons went out on schedule." On cue a cluster of violet pinpricks sparkle in the Tank, five trillion klicks ahead of us. "Still sucking dust mostly, but got lucky with a couple of big asteroids and the refineries came online early. First components already extruded. Then Chimp sees these fluctuations in solar output – mainly infra, but extends into visible." The tank blinks at us: the dwarf goes into time-lapse.

Sure enough, it's *flickering*.

“Nonrandom, I take it.”

Dix inclines his head a little to the side, not quite nodding.

“Plot the time-series.” I’ve never been able to break the habit of raising my voice, just a bit, when addressing the chimp. Obediently (*obediently*. Now *there’s* a laugh-and-a-half) the AI wipes the spacescape and replaces it with

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“Repeating sequence,” Dix tells me. “Blips don’t change, but spacing’s a log-linear increase cycling every 92.5 corsecs. Each cycle starts at 13.2 clicks/corsec, degrades over time.”

“No chance this could be natural? A little black hole wobbling around in the center of the star, maybe?”

Dix shakes his head, or something like that: a diagonal dip of the chin that somehow conveys the negative. “But way too simple to contain much info. Not like an actual conversation. More – well, a shout.”

He’s partly right. There may not be much information, but there’s enough. *We’re here. We’re smart. We’re powerful enough to hook a whole damn star up to a dimmer switch.*

Maybe not such a good spot for a build after all.

I purse my lips. “The sun’s hailing us. That’s what you’re saying.”

"Maybe. Hailing *someone*. But too simple for a rosetta signal. It's not an archive, can't self-extract. Not a bonferroni or fibonacci seq, not pi. Not even a multiplication table. Nothing to base a pidgin on."

Still. An intelligent signal.

"Need more info," Dix says, proving himself master of the blindingly obvious.

I nod. "The vons."

"Uh, what about them?"

"We set up an array. Use a bunch of bad eyes to fake a good one. It'd be faster than high-geeing an observatory from this end or retooling one of the on-site factories."

His eyes go wide. For a moment he almost looks frightened for some reason. But the moment passes and he does that weird head-shake thing again. "Bleed too many resources away from the build, wouldn't it? "

"It would," the chimp agrees.

I suppress a snort. "If you're so worried about meeting our construction benchmarks, Chimp, factor in the potential risk posed by an intelligence powerful enough to control the energy output of an entire sun."

"I can't," it admits. "I don't have enough information."

"You don't have *any* information. About something that could probably stop this mission dead in its tracks if it wanted to. So maybe we should get some."

"Okay. Vons reassigned."

Confirmation glows from a convenient bulkhead, a complex sequence of dance instructions fired into the void. Six months from now a hundred self-replicating robots will waltz into a makeshift surveillance grid; four months after that, we might have something more than vacuum to debate in.

Dix eyes me as though I've just cast some kind of magic spell.

"It may run the ship," I tell him, "but it's pretty fucking stupid. Sometimes you've just got to spell things out."

He looks vaguely affronted, but there's no mistaking the surprise beneath. He didn't know that. He *didn't know.*

Who the hell's been raising him all this time? Whose problem is this?

Not mine.

"Call me in ten months," I say. "I'm going back to bed."

*

It's as though he never left. I climb back into the bridge and there he is, staring into tac. DHF428 fills the tank, a swollen red orb that turns my son's face into a devil mask.

He spares me the briefest glance, eyes wide, fingers twitching as if electrified. "Vons don't see it."

I'm still a bit groggy from the thaw. "See wh – "

"The *sequence!"* His voice borders on panic. He sways back and forth, shifting his weight from foot to foot.

"Show me."

Tac splits down the middle. Cloned dwarves burn before me now, each perhaps twice the size of my fist. On the left, an *Eri*'s-eye view: DHF428 stutters as it did before, as it presumably has these past ten months. On the right, a compound-eye composite: an interferometry grid built by a myriad precisely-spaced vons, their rudimentary eyes layered and parallaxed into something approaching high resolution. Contrast on both sides has been conveniently cranked up to highlight the dwarf's endless winking for merely human eyes.

Except it's only winking from the left side of the display. On the right, 428 glowers steady as a standard candle.

"Chimp: any chance the grid just isn't sensitive enough to see the fluctuations?"

"No."

"Huh." I try to think of some reason it would lie about this.

"Doesn't make *sense*," my son complains.

"It does," I murmur, "if it's not the sun that's flickering."

"But *is* flickering – " He sucks his teeth. "You can *see* it fl – wait, you mean something *behind* the vons? Between, between them and us?"

"Mmmm."

"Some kind of *filter*." Dix relaxes a bit. "Wouldn't we've seen it, though? Wouldn't the vons've hit it going down?"

I put my voice back into ChimpComm mode. "What's the current field-of-view for *Eri's* forward scope?"

"Eighteen mikes," the chimp reports. "At 428's range, the cone is three point three four lightsecs across."

"Increase to a hundred lightsecs."

The *Eri's*-eye partition swells, obliterating the dissenting viewpoint. For a moment the sun fills the tank again, paints the whole bridge crimson. Then it dwindles as if devoured from within.

I notice some fuzz in the display. "Can you clear that noise?"

"It's not noise," the chimp reports. "It's dust and molecular gas."

I blink. "What's the density?"

"Estimated hundred thousand atoms per cubic meter."

Two orders of magnitude too high, even for a nebula. "Why so heavy?" Surely we'd have detected any gravity well strong enough to keep *that* much material in the neighborhood.

"I don't know," the chimp says.

I get the queasy feeling that I might. "Set field-of-view to five hundred lightsecs. Peak false-color at near-infrared."

Space grows ominously murky in the tank. The tiny sun at its center, thumbnail-sized now, glows with increased brilliance: an incandescent pearl in muddy water.

"A thousand lightsecs," I command.

"There," Dix whispers: real space reclaims the edges of the tank, dark, clear, pristine. 428 nestles at the heart of a dim spherical shroud. You find those sometimes, discarded cast-offs from companion stars whose convulsions spew gas and rads across light years. But 428 is no nova remnant. It's a *red dwarf*, placid, middle-aged. Unremarkable.

Except for the fact that it sits dead center of a tenuous gas bubble 1.4 AUs across. And for the fact that this bubble does not *attenuate* or *diffuse* or *fade* gradually into that good night. No, unless there is something seriously wrong with the display, this small, spherical nebula extends about 350 lightsecs from its primary and then just *stop*s, its boundary far more knife-edged than nature has any right to be.

For the first time in millennia, I miss my cortical pipe. It takes forever to saccade search terms onto the keyboard in my head, to get the answers I already know.

Numbers come back. "Chimp. I want false-color peaks at 335, 500 and 800 nanometers."

The shroud around 428 lights up like a dragonfly's wing, like an iridescent soap bubble.

"It's *beautiful*," whispers my awestruck son.

"It's photosynthetic," I tell him.

*

Phaeophytin and eumelanin, according to spectro. There are even hints of some kind of lead-based Keipper pigment, soaking up X-rays in the picometer range. Chimp hypothesizes something called a *chromatophore*: branching cells with little aliquots of pigment inside, like particles of charcoal dust. Keep those particles clumped together and the cell's effectively transparent; spread them out through the cytoplasm and the whole structure *darkens*, dims whatever EM passes through from behind. Apparently there were animals back on Earth with cells like that. They could change color, pattern-match to their background, all sorts of things.

"So there's a membrane of – of *living tissue* around that star," I say, trying to wrap my head around the concept. "A, a meat balloon. Around the whole damn *star*."

"Yes," the chimp says.

"But that's – Jesus, how thick would it be?"

"No more than two millimeters. Probably less."

"How so?"

"If it was much thicker, it would be more obvious in the visible spectrum. It would have had a detectable effect on the von Neumanns when they hit it."

"That's assuming that its – cells, I guess – are like ours."

"The pigments are familiar; the rest might be too."

It can't be *too* familiar. Nothing like a conventional gene would last two seconds in that environment. Not to mention whatever miracle solvent that thing must use as antifreeze...

"Okay, let's be conservative, then. Say, mean thickness of a millimeter. Assume a density of water at STP. How much mass in the whole thing?"

"1.4 yottagrams," Dix and the chimp reply, almost in unison.

"That's, uh…"

"Half the mass of Mercury," the chimp adds helpfully.

I whistle through my teeth. "And that's *one* organism?"

"I don't know yet."

"It's got organic pigments. Fuck, it's *talking*. It's intelligent."

"Most cyclic emanations from living sources are simple biorhythms," the chimp points out. "Not intelligent signals."

I ignore it and turn to Dix. "Assume it's a signal."

He frowns. "Chimp says – "

"*Assume*. Use your imagination."

I'm not getting through to him. He looks nervous.

He looks like that a lot, I realize.

"*If* someone were signaling you," I say, "*then* what would you do?"

"Signal…" Confusion on that face, and a fuzzy circuit closing somewhere "…back?"

My son is an idiot.

"And if the incoming signal takes the form of systematic changes in light intensity, how – "

"Use the BI lasers, alternated to pulse between 700 and 3000 nanometers. Can boost an interlaced signal into the exawatt range without compromising our fenders; gives over a thousand Watts per square meter after diffraction. Way past detection threshold for anything that can sense thermal output from a red dwarf. And content doesn't matter if it's just a shout. Shout back. Test for echo."

Okay, so my son is an idiot *savant*.

And he still looks unhappy – "But Chimp, he says no real *information* there, right?" – and that whole other set of misgivings edges to the fore again: *He*.

Dix takes my silence for amnesia. "Too simple, remember? Simple click train."

I shake my head. There's more information in that signal than the chimp can imagine. There are so many things the chimp doesn't know. And the last thing I need

is for this, this *child* to start deferring to it, to start looking to it as an equal or, God forbid, a *mentor*.

Oh, it's smart enough to steer us between the stars. Smart enough to calculate million-digit primes in the blink of an eye. Even smart enough for a little crude improvisation should the crew go too far off-mission.

Not smart enough to know a distress call when it sees one.

"It's a deceleration curve," I tell them both. "It keeps *slowing down*. Over and over again. *That's* the message."

Stop. Stop. Stop. Stop.

And I think it's meant for no one but us.

*

We shout back. No reason not to. And now we die again, because what's the point of staying up late? Whether or not this vast entity harbors real intelligence, our echo won't reach it for ten million corsecs. Another seven million, at the earliest, before we receive any reply it might send.

Might as well hit the crypt in the meantime. Shut down all desires and misgivings, conserve whatever life I have left for moments that matter. Remove myself from this sparse tactical intelligence, from this wet-eyed pup watching me as though I'm some kind of sorcerer about

to vanish in a puff of smoke. He opens his mouth to speak, and I turn away and hurry down to oblivion.

But I set my alarm to wake up alone.

I linger in the coffin for a while, grateful for small and ancient victories. The chimp's dead, blackened eye gazes down from the ceiling; in all these millions of years nobody's scrubbed off the carbon scoring. It's a trophy of sorts, a memento from the early incendiery days of our Great Struggle.

There's still something – comforting, I guess – about that blind, endless stare. I'm reluctant to venture out where the chimp's nerves have not been so thoroughly cauterised. Childish, I know. The damn thing already knows I'm up; it may be blind, deaf, and impotent in here, but there's no way to mask the power the crypt sucks in during a thaw. And it's not as though a bunch of club-wielding teleops are waiting to pounce on me the moment I step outside. These are the days of détente, after all. The struggle continues but the war has gone cold; we just go through the motions now, rattling our chains like an old married multiplet resigned to hating each other to the end of time.

After all the moves and countermoves, the truth is we need each other.

So I wash the rotten-egg stench from my hair and step into *Eri's* silent cathedral hallways. Sure enough the enemy waits in the darkness, turns the lights on as I

approach, shuts them off behind me – but it does not break the silence.

Dix.

A strange one, that. Not that you'd expect anyone born and raised on *Eriophora* to be an archetype of mental health, but Dix doesn't even know what side he's on. He doesn't even seem to know he has to *choose* a side. It's almost as though he read the original mission statements and took them *seriously*, believed in the literal truth of the ancient scrolls: Mammals and Machinery, working together across the ages to explore the Universe! United! Strong! Forward the Frontier!

Rah.

Whoever raised him didn't do a great job. Not that I blame them; it can't have been much fun having a child underfoot during a build, and none of us were selected for our parenting skills. Even if bots changed the diapers and VR handled the infodumps, socialising a toddler couldn't have been anyone's idea of a good time. I'd have probably just chucked the little bastard out an airlock.

But even I would've brought him up to speed.

Something changed while I was away. Maybe the war's heated up again, entered some new phase. That twitchy kid is out of the loop for a reason. I wonder what it is.

I wonder if I care.

I arrive at my suite, treat myself to a gratuitous meal, jill off. Three hours after coming back to life I'm relaxing in the starbow commons. "Chimp."

"You're up early," it says at last, and I am; our answering shout hasn't even arrived at its destination yet. No real chance of new data for another two months, at least.

"Show me the forward feeds," I command.

DHF428 blinks at me from the center of the lounge: *Stop. Stop. Stop.*

Maybe. Or maybe the chimp's right, maybe it's pure physiology. Maybe this endless cycle carries no more intelligence than the beating of a heart. But there's a pattern inside the pattern, some kind of *flicker* in the blink. It makes my brain itch.

"Slow the time-series," I command. "By a hundred."

It *is* a blink. 428's disk isn't darkening uniformly, it's *eclipsing*. As though a great eyelid were being drawn across the surface of the sun, from right to left.

"By a thousand."

Chromatophores, the chimp called them. But they're not all opening and closing at once. The darkness moves across the membrane in *waves*.

A word pops into my head: *latency*.

"Chimp. Those waves of pigment. How fast are they moving?"

"About fifty-nine thousand kilometers per second."

The speed of a passing thought.

And if this thing *does* think, it'll have logic gates, synapses – it's going to be a *net* of some kind. And if the net's big enough, there's an *I* in the middle of it. Just like me, just like Dix. Just like the chimp. (Which is why I educated myself on the subject, back in the early tumultuous days of our relationship. Know your enemy and all that.)

The thing about *I* is, it only exists within a tenth-of-a-second of all its parts. When we get spread too thin – when someone splits your brain down the middle, say, chops the fat pipe so the halves have to talk the long way around; when the neural architecture *diffuses* past some critical point and signals take just that much longer to pass from A to B – the system, well, *decoheres*. The two sides of your brain become different people with different tastes, different agendas, different senses of themselves.

I shatters into *we.*

It's not just a human rule, or a mammal rule, or even an Earthly one. It's a rule for any circuit that processes information, and it applies as much to the things we've yet to meet as it did to those we left behind.

Fifty-nine thousand kilometers per second, the chimp says. How far can the signal move through that membrane in a tenth of a corsec? How thinly does *I* spread itself across the heavens?

The flesh is huge, the flesh is inconceivable. But the spirit, the spirit is –

Shit.

"Chimp. Assuming the mean neuron density of a human brain, what's the synapse count on a circular sheet of neurons one millimeter thick with a diameter of five thousand eight hundred ninety-two kilometers?"

"Two times ten to the twenty-seventh."

I saccade the database for some perspective on a mind stretched across thirty million square kilometers: the equivalent of two quadrillion human brains.

Of course, whatever this thing uses for neurons have to be packed a lot less tightly than ours; we can see through them, after all. Let's be superconservative, say it's only got a thousandth the computational density of a human brain. That's –

Okay, let's say it's only got a *ten*-thousandth the synaptic density, that's still –

A *hundred* thousandth. The merest mist of thinking meat. Any more conservative and I'd hypothesize it right out of existence.

Still twenty billion human brains. Twenty *billion*.

I don't know how to feel about that. This is no mere alien.

But I'm not quite ready to believe in gods.

*

I round the corner and run smack into Dix, standing like a golem in the middle of my living room. I jump about a meter straight up.

"*What the hell are you doing here?"*

He seems surprised by my reaction. "Wanted to – talk," he says after a moment.

"You *never* come into someone's home uninvited!"

He retreats a step, stammers: "Wanted, wanted – "

"To talk. And you do that in *public*. On the bridge, or in the commons, or – for that matter, you could just *comm* me."

He hesitates. "Said you – *wanted* face to face. You said, *cultural tradition*."

I did, at that. But not *here*. This is *my* place, these are my *private quarters*. The lack of locks on these doors is a safety protocol, not an invitation to walk into my home and *lie in wait*, and stand there like part of the fucking *furniture*...

"Why are you even *up*?" I snarl. "We're not even supposed to come online for another two months."

"Asked Chimp to get me up when you did."

That fucking machine.

"Why are *you* up?" he asks, not leaving.

I sigh, defeated, and fall into a convenient pseudopod. "I just wanted to go over the preliminary data." The implicit *alone* should be obvious.

"Anything?"

Evidently it isn't. I decide to play along for a while. "Looks like we're talking to an, an island. Almost six thousand klicks across. That's the thinking part, anyway. The surrounding membrane's pretty much empty. I mean, it's all *alive*. It all photosynthesizes, or something like that. It eats, I guess. Not sure what."

"Molecular cloud," Dix says. "Organic compounds everywhere. Plus it's concentrating stuff inside the envelope."

I shrug. "Point is, there's a size limit for the brain but it's *huge*, it's…"

"Unlikely," he murmurs, almost to himself.

I turn to look at him; the pseudopod reshapes itself around me. "What do you mean?"

"Island's twenty-eight million square kilometers? Whole sphere's seven quintillion. Island just happens to be between us and 428, that's – one in fifty-billion odds."

"Go on."

He can't. "Uh, just… just *unlikely*."

I close my eyes. "How can you be smart enough to run those numbers in your head without missing a beat, and stupid enough to miss the obvious conclusion?"

That panicked, slaughterhouse look again. "Don't – I'm not – "

"It *is* unlikely. It's *astronomically* unlikely that we just happen to be aiming at the one intelligent spot on a sphere one-and-a-half AUs across. Which means… "

He says nothing. The perplexity in his face mocks me. I want to punch it.

But finally, the lights flicker on: "There's, uh, more than one island? Oh! A *lot* of islands!"

This creature is part of the crew. My life will almost certainly depend on him some day. That is a very scary thought.

I try to set it aside for the moment. "There's probably a whole population of the things, sprinkled though the membrane like, like cysts I guess. The chimp doesn't know how many, but we're only picking up this one so far so they might be pretty sparse."

There's a different kind of frown on his face now. "Why *Chimp*?"

"What do you mean?"

"Why call him Chimp?"

"We call it *the* chimp." Because the first step to humanising something is to give it a name.

"Looked it up. Short for *chimpanzee*. Stupid animal."

"Actually, I think chimps were supposed to be pretty smart," I remember.

"Not like us. Couldn't even *talk*. Chimp can talk. *Way* smarter than those things. That name – it's an insult."

"What do you care?"

He just looks at me.

I spread my hands. "Okay, it's not a chimp. We just call it that because it's got roughly the same synapse count."

"So gave him a small brain, then complain that he's stupid all the time."

My patience is just about drained. "Do you have a point or are you just blowing CO_2 in – "

"Why not make him smarter?"

"Because you can never predict the behavior of a system more complex than you. And if you want a project to stay on track after you're gone, you don't hand the reins to anything that's guaranteed to develop its own agenda." Sweet smoking Jesus, you'd think *someone* would have told him about Ashby's Law.

"So they lobotomized him," Dix says after a moment.

"No. They didn't *turn* it stupid, they *built* it stupid."

"Maybe smarter than you think. You're so much smarter, got *your* agenda, how come *he's* still in control?"

"Don't flatter yourself," I say.

"What?"

I let a grim smile peek through. "You're only following orders from a bunch of other systems *way* more complex than you are." You've got to hand it to them, too; dead for stellar lifetimes and those damn project admins are *still* pulling the strings.

"I don't – *I'm* following? – "

"I'm sorry, dear." I smile sweetly at my idiot offspring. "I wasn't talking to you. I was talking to the thing that's making all those sounds come out of your mouth."

Dix turns whiter than my panties.

I drop all pretense. "What were you thinking, chimp? That you could send this sock-puppet to invade my home and I wouldn't notice?"

"Not – I'm not – it's *me*," Dix stammers. "*Me* talking."

"It's *coaching* you. Do you even know what 'lobotomised' *means*?" I shake my head, disgusted. "You think I've forgotten how the interface works just because we all burned ours out?" A caricature of surprise begins to form on his face. "Oh, don't even fucking *try*. You've been up for other builds, there's no way you couldn't have known. And you know we shut down our domestic links too. And there's nothing your lord and master can do about that because it *needs* us, and so we have reached what you might call an *accommodation*."

I am not shouting. My tone is icy, but my voice is dead level. And yet Dix almost *cringes* before me.

There is an opportunity here, I realize.

I thaw my voice a little. I speak gently: "You can do that too, you know. Burn out your link. I'll even let you come back here afterwards, if you still want to. Just to – talk. But not with that thing in your head."

There is panic in his face, and against all expectation it almost breaks my heart. "*Can't*," he pleads. "How I *learn* things, how I *train*. The *mission*…"

I honestly don't know which of them is speaking, so I answer them both: "There is more than one way to carry out the mission. We have more than enough time to try them all. Dix is welcome to come back when he's alone."

They take a step towards me. Another. One hand, twitching, rises from their side as if to reach out, and there's something on that lopsided face that I can't quite recognize.

"But I'm your *son*," they say.

I don't even dignify it with a denial.

"Get out of my home."

*

A human periscope. The Trojan Dix. That's a new one.

The chimp's never tried such overt infiltration while we were up and about before. Usually it waits until we're all undead before invading our territories. I imagine custom-made drones never seen by human eyes, cobbled together during the long dark eons between builds; I see them sniffing through drawers and peeking behind mirrors, strafing the bulkheads with X-rays and ultrasound, patiently searching *Eriophora*'s catacombs millimeter by endless millimeter for whatever secret

messages we might be sending each other down through time.

There's no proof to speak of. We've left tripwires and telltales to alert us to intrusion after the fact, but there's never been any evidence they've been disturbed. Means nothing, of course. The chimp may be stupid but it's also cunning, and a million years is more than enough time to iterate through every possibility using simpleminded brute force. Document every dust mote; commit your unspeakable acts; afterwards, put everything back the way it was.

We're too smart to risk talking across the eons. No encrypted strategies, no long-distance love letters, no chatty postcards showing ancient vistas long lost in the red shift. We keep all that in our heads, where the enemy will never find it. The unspoken rule is that we do not speak, unless it is face to face.

Endless idiotic games. Sometimes I almost forget what we're squabbling over. It seems so trivial now, with an immortal in my sights.

Maybe that means nothing to you. Immortality must be ancient news from whatever peaks you've ascended by now. But I can't even imagine it, although I've outlived worlds. All I have are moments: two or three hundred years, to ration across the lifespan of a universe. I could bear witness to any point in time, or any hundred-thousand if I slice my life thinly enough – but I will never see *everything*. I will never see even a fraction.

My life will end. I have to *choose*.

When you come to fully appreciate the deal you've made – ten or fifteen builds out, when the trade-off leaves the realm of mere *knowledge* and sinks deep as cancer into your bones – you become a miser. You can't help it. You ration out your waking moments to the barest minimum: just enough to manage the build, to plan your latest countermove against the chimp, just enough (if you haven't yet moved beyond the need for Human contact) for sex and snuggles and a bit of warm mammalian comfort against the endless dark. And then you hurry back to the crypt, to hoard the remains of a human lifespan against the unwinding of the cosmos.

There's been time for education. Time for a hundred postgraduate degrees, thanks to the best caveman learning tech. I've never bothered. Why burn down my tiny candle for a litany of mere fact, fritter away my precious, endless, finite life? Only a fool would trade book-learning for a ringside view of the Cassiopeia Remnant, even if you *do* need false-color enhancement to see the fucking thing.

Now, though. Now, I want to *know*. This creature crying out across the gulf, massive as a moon, wide as a solar system, tenuous and fragile as an insect's wing: I'd gladly cash in some of my life to learn its secrets. How does it work? How can it even *live* here at the edge of absolute zero, much less think? What vast, unfathomable intellect must it possess to see us coming from over half a

lightyear away, to deduce the nature of our eyes and our instruments, to send a signal we can even *detect*, much less understand?

And what happens when we punch through it at a fifth the speed of light?

I call up the latest findings on my way to bed, and the answer hasn't changed: not much. The damn thing's already full of holes. Comets, asteroids, the usual protoplanetary junk careens through this system as it does through every other. Infra picks up diffuse pockets of slow outgassing here and there around the perimeter, where the soft vaporous vacuum of the interior bleeds into the harder stuff outside. Even if we were going to tear through the dead center of the thinking part, I can't imagine this vast creature feeling so much as a pinprick. At the speed we're going we'd be through and gone far too fast to overcome even the feeble inertia of a millimeter membrane.

And yet. *Stop. Stop. Stop.*

It's not us, of course. It's what we're building. The birth of a gate is a violent, painful thing, a spacetime rape that puts out almost as much gamma and X as a microquasar. Any meat within the white zone turns to ash in an instant, shielded or not. It's why *we* never slow down to take pictures.

One of the reasons, anyway.

We can't stop, of course. Even changing course isn't an option except by the barest increments. *Eri* soars

like an eagle between the stars but she steers like a pig on the short haul; tweak our heading by even a tenth of a degree and you've got some serious damage at twenty percent lightspeed. Half a degree would tear us apart: the ship might torque onto the new heading but the collapsed mass in her belly would keep right on going, rip through all this surrounding superstructure without even feeling it.

Even tame singularities get set in their ways. They do not take well to change.

*

We resurrect again, and the Island has changed its tune.

It gave up asking us to *stop stop stop* the moment our laser hit its leading edge. Now it's saying something else entirely: dark hyphens flow across its skin, arrows of pigment converging towards some offstage focus like spokes pointing towards the hub of a wheel. The bullseye itself is offstage and implicit, far removed from 428's bright backdrop, but it's easy enough to extrapolate to the point of convergence six lightsecs to starboard. There's something else, too: a shadow, roughly circular, moving along one of the spokes like a bead running along a string. It too migrates to starboard, falls off the edge of the Island's makeshift display, is endlessly reborn at the same initial coordinates to repeat its journey.

Those coordinates: exactly where our current trajectory will punch through the membrane in another four months. A squinting God would be able to see the gnats and girders of ongoing construction on the other side, the great piecemeal torus of the Hawking Hoop already taking shape.

The message is so obvious that even Dix sees it. "Wants us to move the gate…" and there is something like confusion in his voice. "But how's it know we're *building* one?"

"The vons punctured it en route," the chimp points out. "It could have sensed that. It has photopigments. It can probably see."

"Probably sees better than we do," I say. Even something as simple as a pinhole camera gets hi-res fast if you stipple a bunch of them across thirty million square kilometers.

But Dix scrunches his face, unconvinced. "So sees a bunch of vons bumping around. Loose parts – not that much even *assembled* yet. How's it know we're building something *hot*?"

Because it is very, very, smart, you stupid child. Is it so hard to believe that this, this – *organism* seems far too limiting a word – can just *imagine* how those half-built pieces fit together, glance at our sticks and stones and see exactly where this is going?

"Maybe's not the first gate it's seen," Dix suggests. "Think there's maybe another gate out here?"

I shake my head. "We'd have seen the lensing artefacts by now."

"You ever run into anyone before?"

"No." We have always been alone, through all these epochs. We have only ever run *away*.

And then always from our own children.

I crunch some numbers. "Hundred eighty two days to insemination. If we move now we've only got to tweak our bearing by a few mikes to redirect to the new coordinates. Well within the green. Angles get dicey the longer we wait, of course."

"We can't do that," the chimp says. "We would miss the gate by two million kilometers."

"Move the gate. Move the whole damn site. Move the refineries, move the factories, move the damn rocks. A couple hundred meters a second would be more than fast enough if we send the order now. We don't even have to suspend construction, we can keep building on the fly."

"Every one of those vectors widens the nested confidence limits of the build. It would increase the risk of error beyond allowable margins, for no payoff."

"And what about the fact that there's an intelligent being in our path?"

"I'm already allowing for the potential presence of intelligent alien life."

"Okay, first off, there's nothing *potential* about it. It's *right fucking there.* And on our current heading we run the damn thing over."

"We're staying clear of all planetary bodies in Goldilocks orbits. We've seen no local evidence of spacefaring technology. The current location of the build meets all conservation criteria."

"That's because the people who drew up your criteria *never anticipated a live Dyson sphere*!" But I'm wasting my breath, and I know it. The chimp can run its equations a million times but if there's nowhere to put the variable, what can it do?

There was a time, back before things turned ugly, when we had clearance to reprogram those parameters. Before we discovered that one of the things the admins *had* anticipated was mutiny.

I try another tack. "Consider the threat potential."

"There's no evidence of any."

"Look at the synapse estimate! That thing's got orders of mag more processing power than the whole civilization that sent us out here. You think something can be that smart, live that long, without learning how to defend itself? We're assuming it's *asking* us to move the gate. What if that's not a *request*? What if it's just giving us the chance to back off before it takes matters into its own hands?"

"Doesn't *have* hands," Dix says from the other side of the tank, and he's not even being flippant. He's just being so stupid I want to bash his face in.

I try to keep my voice level. "Maybe it doesn't *need* any."

"What could it do, *blink* us to death? No weapons. Doesn't even control the whole membrane. Signal propagation's too slow."

"We *don't know*. That's my *point*. We haven't even tried to find out. We're a goddamn road crew; our onsite presence is a bunch of construction vons press-ganged into scientific research. We can figure out some basic physical parameters but we don't know how this thing thinks, what kind of natural defenses it might have – "

"What do you need to find out?" the chimp asks, the very voice of calm reason.

We can't find out! I want to scream. *We're stuck with what we've got! By the time the onsite vons could build what we need we're already past the point of no return! You stupid fucking machine, we're on track to kill a being smarter than all of human history and you can't even be bothered to move our highway to the vacant lot next door?*

But of course if I say that, the Island's chances of survival go from low to zero. So I grasp at the only straw that remains: maybe the data we've got in hand is enough. If acquisition is off the table, maybe analysis will do.

"I need time," I say.

"Of course," the chimp tells me. "Take all the time you need."

*

The chimp is not content to kill this creature. The chimp has to spit on it as well.

Under the pretense of assisting in my research it tries to *deconstruct* the island, break it apart and force it to conform to grubby earthbound precedents. It tells me about earthly bacteria that thrived at 1.5 million rads and laughed at hard vacuum. It shows me pictures of unkillable little tardigrades that could curl up and snooze on the edge of absolute zero, felt equally at home in deep ocean trenches and deeper space. Given time, opportunity, a boot off the planet, who knows how far those cute little invertebrates might have gone? Might they have survived the very death of the homeworld, clung together, grown somehow colonial?

What utter bullshit.

I learn what I can. I study the alchemy by which photosynthesis transforms light and gas and electrons into living tissue. I learn the physics of the solar wind that blows the bubble taut, calculate lower metabolic limits for a life-form that filters organics from the ether. I marvel at the speed of this creature's thoughts: almost as fast as *Eri* flies, orders of mag faster than any mammalian nerve impulse. Some kind of organic superconductor perhaps, something that passes chilled electrons almost resistance-free out here in the freezing void.

I acquaint myself with phenotypic plasticity and sloppy fitness, that fortuitous evolutionary soft-focus that

lets species exist in alien environments and express novel traits they never needed at home. Perhaps this is how a lifeform with no natural enemies could acquire teeth and claws and the willingness to use them. The Island's life hinges on its ability to kill us; I have to find *something* that makes it a threat.

But all I uncover is a growing suspicion that I am doomed to fail – for violence, I begin to see, is a *planetary* phenomenon.

Planets are the abusive parents of evolution. Their very surfaces promote warfare, concentrate resources into dense defensible patches that can be fought over. Gravity forces you to squander energy on vascular systems and skeletal support, stand endless watch against an endless sadistic campaign to squash you flat. Take one wrong step, off a perch too high, and all your pricey architecture shatters in an instant. And even if you beat those odds, cobble together some lumbering armored chassis to withstand the slow crawl onto land – how long before the world draws in some asteroid or comet to crash down from the heavens and reset your clock to zero? Is it any wonder we grew up believing life was a struggle, that zero-sum was God's own law and the future belonged to those who crushed the competition?

The rules are so different out here. Most of space is *tranquil*: no diel or seasonal cycles, no ice ages or global tropics, no wild pendulum swings between hot and cold, calm and tempestuous. Life's precursors abound: on

comets, clinging to asteroids, suffusing nebulae a hundred lightyears across. Molecular clouds glow with organic chemistry and life-giving radiation. Their vast dusty wings grow warm with infrared, filter out the hard stuff, give rise to stellar nurseries that only some stunted refugee from the bottom of a gravity well could ever call *lethal*.

Darwin's an abstraction here, an irrelevant curiosity. This Island puts the lie to everything we were ever told about the machinery of life. Sun-powered, perfectly adapted, immortal, it won no struggle for survival: where are the predators, the competitors, the parasites? All of life around 428 is one vast continuum, one grand act of symbiosis. Nature here is not red in tooth and claw. Nature, out here, is the helping hand.

Lacking the capacity for violence, the Island has outlasted worlds. Unencumbered by technology, it has out-thought civilizations. It is intelligent beyond our measure, and –

– and it is *benign*. It must be. I grow more certain of that with each passing hour. How can it even *conceive* of an enemy?

I think of the things I called it, before I knew better. *Meat balloon*. *Cyst*. Looking back, those words verge on blasphemy. I will not use them again.

Besides, there's another word that would fit better, if the chimp has its way: Roadkill. And the longer I look, the more I fear that that hateful machine is right.

If the Island can defend itself, I sure as shit can't see how.

*

"*Eriophora*'s impossible, you know. Violates the laws of physics."

We're in one of the social alcoves off the ventral notochord, taking a break from the library. I have decided to start again from first principles. Dix eyes me with an understandable mix of confusion and mistrust; my claim is almost too stupid to deny.

"It's true," I assure him. "Takes way too much energy to accelerate a ship with *Eri*'s mass, especially at relativistic speeds. You'd need the energy output of a whole sun. People figured if we made it to the stars at all, we'd have to do it ships maybe the size of your thumb. Crew them with virtual personalities downloaded onto chips."

That's too nonsensical even for Dix. "*Wrong*. Don't have mass, can't fall towards anything. *Eri* wouldn't even *work* if it was that small."

"But suppose you can't displace any of that mass. No wormholes, no Higgs conduits, nothing to throw your gravitational field in the direction of travel. Your center of mass just *sits* there in, well, the center of your mass."

A spastic Dixian head-shake. "*Do* have those things!"

"Sure we do. But for the longest time, we didn't *know* it."

His foot taps an agitated tattoo on the deck.

"It's the history of the species," I explain. "We think we've worked everything out, we think we've solved all the mysteries and then someone finds some niggling little data point that doesn't fit the paradigm. Every time we try to paper over the crack it gets bigger, and before you know it our whole worldview unravels. It's happened time and again. One day mass is a constraint; the next it's a requirement. The things we think we know – they *change*, Dix. And we have to change with them."

"But – "

"The chimp can't change. The rules it's following are ten billion years old and it's got no fucking imagination and really that's not anyone's fault, that's just people who didn't know how else to keep the mission stable across deep time. They wanted to keep us on-track so they built something that couldn't go off it; but they also knew that things *change*, and that's why *we're* out here, Dix. To deal with things the chimp can't."

"The alien," Dix says.

"The alien."

"Chimp deals with it just fine."

"How? By killing it?"

"Not our fault it's in the way. It's no threat – "

"I don't care whether it's a *threat* or not! It's alive, and it's intelligent, and killing it just to expand some alien empire – "

"*Human* empire. *Our* empire." Suddenly Dix's hands have stopped twitching. Suddenly he stands still as stone.

I snort. "What do you know about humans?"

"*Am* one."

"You're a fucking trilobite. You ever see what comes *out* of those gates once they're online?"

"Mostly nothing. " He pauses, thinking back. "Couple of – ships once, maybe."

"Well, I've seen a lot more than that, and believe me, if those things were *ever* human it was a passing phase. "

"But – "

"Dix – " I take a deep breath, try to get back on message. "Look, it's not your fault. You've been getting all your info from a moron stuck on a rail. But we're not doing this for Humanity, we're not doing it for Earth. Earth is *gone*, don't you understand that? The sun scorched it black a billion years after we left. Whatever we're working for, it – it won't even *talk* to us."

"Yeah? Then why do this? Why not just, just *quit*?"

He really doesn't know.

"We tried," I say.

"And?"

"And your *chimp* shut off our life support."

For once, he has nothing to say.

"It's a *machine*, Dix. Why can't you get that? It's *programmed*. It can't change."

"*We're* machines, just built from different things. *We* change."

"Yeah? Last time I checked, you were sucking so hard on that thing's tit you couldn't even kill your cortical link."

"How I *learn*. No *reason* to change."

"How about acting like a damn *human* once in a while? How about developing a little rapport with the folks who might have to save your miserable life next time you go EVA? That enough of a *reason* for you? Because I don't mind telling you, right now I don't trust you as far as I could throw the tac tank. I don't even know for sure who I'm talking to right now."

"*Not my fault."* For the first time I see something outside the usual gamut of fear, confusion, and simpleminded computation playing across his face. "That's *you*, that's *all* of you. You talk – *sideways. Think* sideways. You all do, and it *hurts*." Something hardens in his face. "Didn't even need you online for this," he growls. "Didn't *want* you. Could have managed the whole build myself, *told* Chimp I could do it – "

"But the chimp thought you should wake me up anyway, and you always roll over for the chimp, don't you? Because the chimp always knows best, the chimp's your *boss*, the chimp's your fucking *god.* Which is why I

have to get out of bed to nursemaid some idiot savant who can't even answer a hail without being led by the nose." Something clicks in the back of my mind but I'm on a roll. "You want a *real* role model? You want something to look up to? Forget the chimp. Forget the mission. Look out the forward scope, why don't you? Look at what your precious chimp wants to run over because it happens to be in the way. That thing is better than any of us. It's smarter, it's peaceful, it doesn't wish us any harm at – "

"How can you know that? Can't know that!"

"No, *you* can't know that, because you're fucking *stunted*. Any normal caveman would see it in a second, but *you* – "

"That's crazy," Dix hisses at me. "*You're* crazy. You're *bad*."

"*I'm* bad!" Some distant part of me hears the giddy squeak in my voice, the borderline hysteria.

"For the mission." Dix turns his back and stalks away.

My hands are hurting. I look down, surprized: my fists are clenched so tightly that my nails cut into the flesh of my palms. It takes a real effort to open them again.

I almost remember how this feels. I used to feel this way all the time. Way back when everything *mattered*; before passion faded to ritual, before rage cooled to disdain. Before Sunday Ahzmundin, eternity's warrior, settled for heaping insults on stunted children.

We were incandescent back then. Parts of this ship are still scorched and uninhabitable, even now. I remember this feeling.

This is how it feels to be awake.

*

I am awake, and I am alone, and I am sick of being outnumbered by morons. There are rules and there are risks and you don't wake the dead on a whim, but fuck it. I'm calling reinforcements.

Dix has got to have other parents, a father at least, he didn't get that Y chromo from me. I swallow my own disquiet and check the manifest; bring up the gene sequences; cross-reference.

Huh. Only one other parent: Kai. I wonder if that's just coincidence, or if the chimp drew too many conclusions from our torrid little fuckfest back in the Cyg Rift. Doesn't matter. He's as much yours as mine, Kai, time to step up to the plate, time to –

Oh shit. Oh no. Please no.

(There are rules. And there are risks.)

Three builds back, it says. Kai and Connie. Both of them. One airlock jammed, the next too far away along *Eri*'s hull, a hail-Mary emergency crawl between. They made it back inside but not before the blue-shifted background cooked them in their suits. They kept breathing for hours afterwards, talked and moved and

cried as if they were still alive, while their insides broke down and bled out.

There were two others awake that shift, two others left to clean up the mess. Ishmael, and –

"Um, you said – "

"*You fucker!"* I leap up and hit my son hard in the face, ten seconds' heartbreak with ten million years' denial raging behind it. I feel teeth give way behind his lips. He goes over backwards, eyes wide as telescopes, the blood already blooming on his mouth.

"*Said* I could come back!" he squeals, scrambling backwards along the deck.

"He was your fucking *father*! You *knew*, you were *there!* He died right in *front* of you and you didn't even *tell* me!"

"I – I – "

"Why didn't you tell me, you asshole? The chimp told you to lie, is that it? Did you – "

"*Thought you knew*!" he cries, "Why *wouldn't* you know?"

My rage vanishes like air through a breach. I sag back into the 'pod, face in hands.

"Right there in the log," he whimpers. "All along. Nobody hid it. How could you not know?"

"I did," I admit dully. "Or I – I mean…"

I mean I *didn't* know, but it's not a surprise, not really, not down deep. You just – stop looking, after a while.

There are *rules*.

"Never even *asked*," my son says softly. "How they were doing."

I raise my eyes. Dix regards me wide-eyed from across the room, backed up against the wall, too scared to risk bolting past me to the door. "What are you doing here?" I ask tiredly.

His voice catches. He has to try twice: "You said I could come back. If I burned out my link…"

"You burned out your link."

He gulps and nods. He wipes blood with the back of his hand.

"What did the chimp say about that?"

"He said – *it* said it was okay," Dix says, in such a transparent attempt to suck up that I actually believe, in that instant, that he might really be on his own.

"So you asked its permission." He begins to nod, but I can see the tell in his face: "Don't bullshit me, Dix."

"He – actually suggested it."

"I see."

"So we could talk," Dix adds.

"What do you want to talk about?"

He looks at the floor and shrugs.

I stand and walk towards him. He tenses but I shake my head, spread my hands. "It's okay. It's okay." I lean back against the wall and slide down until I'm beside him on the deck.

We just sit there for a while.

"It's been so long," I say at last.

He looks at me, uncomprehending. What does *long* even mean, out here?

I try again. "They say there's no such thing as altruism, you know?"

His eyes blank for an instant, and grow panicky, and I know that he's just tried to ping his link for a definition and come up blank. So we *are* alone. "Altruism," I explain. "Unselfishness. Doing something that costs you but helps someone else." He seems to get it. "They say every selfless act ultimately comes down to manipulation or kin-selection or reciprocity or something, but they're wrong. I could – "

I close my eyes. This is harder than I expected.

"I could have been happy just *knowing* that Kai was okay, that Connie was happy. Even if it didn't benefit me one whit, even if it *cost* me, even if there was no chance I'd ever see either of them again. Almost any price would be worth it, just to know they were okay.

"Just to *believe* they were..."

So you haven't seen her for the past five builds. So he hasn't drawn your shift since Sagittarius. They're just sleeping. Maybe next time.

"So you don't check," Dix says slowly. Blood bubbles on his lower lip; he doesn't seem to notice.

"We don't check." Only I did, and now they're gone. They're both gone. Except for those little cannibalized nucleotides the chimp recycled into this

defective and maladapted son of mine. We're the only warm-blooded creatures for a thousand lightyears, and I am so very lonely.

"I'm sorry," I whisper, and lean forward, and lick the gore from his bruised and bloody lips.

*

Back on Earth – back when there *was* an Earth – there were these little animals called cats. I had one for a while. Sometimes I'd watch him sleep for hours: paws and whiskers and ears all twitching madly as he chased imaginary prey across whatever landscapes his sleeping brain conjured up.

My son looks like that when the chimp worms its way into his dreams.

It's almost too literal for metaphor: the cable runs into his head like some kind of parasite, feeding through old-fashioned fiberop now that the wireless option's been burned away. Or *force*-feeding, I suppose; the poison flows into Dix's head, not out of it.

I shouldn't be here. Didn't I just throw a tantrum over the violation of my own privacy? (Just. Twelve lightdays ago. Everything's relative.) And yet I can see no privacy here for Dix to lose: no decorations on the walls, no artwork or hobbies, no wraparound console. The sex toys ubiquitous in every suite sit unused on their shelves;

I'd have assumed he was on antilibinals if recent experience hadn't proven otherwise.

What am I doing? Is this some kind of perverted mothering instinct, some vestigial expression of a Pleistocene maternal subroutine? Am I that much of a robot, has my brain stem sent me here to guard my child?

To guard my *mate*?

Lover or larva, it hardly matters: his quarters are an empty shell, there's nothing of Dix in here. That's just his abandoned body lying there in the pseudopod, fingers twitching, eyes flickering beneath closed lids in vicarious response to wherever his mind has gone.

They don't know I'm here. The chimp doesn't know because we burned out its prying eyes a billion years ago, and my son doesn't know I'm here because — well, because for him, right now, there *is* no here.

What am I supposed to make of you, Dix? None of this makes sense. Even your body language looks like you grew it in a vat – but I'm far from the first human being you've seen. You grew up in good company, with people I *know*, people I trust. Trusted. How did you end up on the other side? How did they let you slip away?

And why didn't they warn me about you?

Yes, there are rules. There is the threat of enemy surveillance during long dead nights, the threat of – other losses. But this is unprecedented. Surely someone could have left something, some clue buried in a metaphor too subtle for the simpleminded to decode…

I'd give a lot to tap into that pipe, to see what you're seeing now. Can't risk it, of course; I'd give myself away the moment I tried to sample anything except the basic baud, and – wait a second –

That baud rate's way too low. That's not even enough for hi-res graphics, let alone tactile and olfac. You're embedded in a wireframe world at best.

And yet, look at you go. The fingers, the eyes – like a cat, dreaming of mice and apple pies. Like *me*, replaying the long-lost oceans and mountaintops of Earth before I learned that living in the past was just another way of dying in the present. The bit rate says this is barely even a test pattern; the body says you're immersed in a whole other world. How has that machine tricked you into treating such thin gruel as a feast?

Why would it even want to? Data are better grasped when they *can* be grasped, and tasted, and heard; our brains are built for far richer nuance than splines and scatterplots. The driest technical briefings are more sensual than this. Why settle for stick-figures when you can paint in oils and holograms?

Why does anyone simplify anything? To reduce the variable set. To manage the unmanageable.

Kai and Connie. Now *there* were a couple of tangled, unmanageable datasets. Before the accident. Before the scenario *simplified*.

Someone should have warned me about you, Dix.

Maybe someone tried.

*

And so it comes to pass that my son leaves the nest, encases himself in a beetle carapace and goes walkabout. He is not alone; one of the chimp's teleops accompanies him out on *Eri*'s hull, lest he lose his footing and fall back into the starry past.

Maybe this will never be more than a drill, maybe this scenario – catastrophic control-systems failure, the chimp and its backups offline, all maintenance tasks suddenly thrown onto shoulders of flesh and blood – is a dress rehearsal for a crisis that never happens. But even the unlikeliest scenario approaches certainty over the life of a universe; so we go through the motions. We practice. We hold our breath and dip outside. We're on a tight deadline: even armored, moving at this speed the blueshifted background rad would cook us in hours.

Worlds have lived and died since I last used the pickup in my suite. "Chimp."

"Here as always, Sunday." Smooth, and glib, and friendly. The easy rhythm of the practiced psychopath.

"I know what you're doing."

"I don't understand."

"You think I don't see what's going on? You're building the next release. You're getting too much grief from the old guard so you're starting from scratch with

people who don't remember the old days. People you've, you've *simplified*."

The chimp says nothing. The drone's feed shows Dix clambering across a jumbled terrain of basalt and metal matrix composites.

"But you can't raise a human child, not on your own." I know it tried: there's no record of Dix anywhere on the crew manifest until his mid-teens, when he just *showed up* one day and nobody asked about it because nobody *ever*...

"Look what you've made of him. He's great at conditional If/Thens. Can't be beat on number-crunching and Do loops. But he can't *think*. Can't make the simplest intuitive jumps. You're like one of those – " I remember an Earthly myth, from the days when *reading* did not seem like such an obscene waste of lifespan – "one of those wolves, trying to raise a Human child. You can teach him how to move around on hands and knees, you can teach him about pack dynamics, but you can't teach him how to walk on his hind legs or talk or be *human* because you're *too fucking stupid*, Chimp, and you finally realized it. And that's why you threw him at me. You think I can fix him for you."

I take a breath, and a gambit.

"But he's nothing to me. You understand? He's *worse* than nothing, he's a liability. He's a spy, he's a spastic waste of O_2. Give me one reason why I shouldn't just lock him out there until he cooks."

"You're his mother," the chimp says, because the chimp has read all about kin selection and is too stupid for nuance.

"You're an idiot."

"You love him."

"No." An icy lump forms in my chest. My mouth makes words; they come out measured and inflectionless. "I can't love anyone, you brain-dead machine. That's why I'm out here. Do you really think they'd gamble your precious never-ending mission on little glass dolls that needed to bond."

"You love him."

"I can kill him any time I want. And that's exactly what I'll do if you don't move the gate."

"I'd stop you," the chimp says mildly.

"That's easy enough. Just move the gate and we both get what we want. Or you can dig in your heels and try to reconcile your need for a mother's touch with my sworn intention of breaking the little fucker's neck. We've got a long trip ahead of us, chimp. And you might find I'm not quite as easy to cut out of the equation as Kai and Connie."

"You cannot end the mission," it says, almost gently. "You tried that already."

"This isn't about ending the mission. This is only about slowing it down a little. Your optimal scenario's off the table. The only way that gate's going to get finished

now is by saving the Island, or killing your prototype. Your call."

The cost-benefit's pretty simple. The chimp could solve it in an instant. But still it says nothing. The silence stretches. It's looking for some other option, I bet. It's trying to find a workaround. It's questioning the very premises of the scenario, trying to decide if I mean what I'm saying, if all its book-learning about mother love could really be so far off-base. Maybe it's plumbing historical intrafamilial murder rates, looking for a loophole. And there may be one, for all I know. But the chimp isn't me, it's a simpler system trying to figure out a smarter one, and that gives me the edge.

"You would owe me," it says at last.

I almost burst out laughing. "*What*?"

"Or I will tell Dixon that you threatened to kill him."

"Go ahead."

"You don't want him to know."

"I don't care whether he knows or not. What, you think he'll try and kill me back? You think I'll lose his *love*?" I linger on the last word, stretch it out to show how ludicrous it is.

"You'll lose his trust. You need to trust each other out here."

"Oh, right. *Trust*. The very fucking foundation of this mission."

The chimp says nothing.

"For the sake of argument," I say after a while, "suppose I go along with it. What would I *owe* you, exactly?"

"A favor," the chimp replies. "To be repaid in future."

My son floats innocently against the stars, his life in balance.

*

We sleep. The chimp makes grudging corrections to a myriad small trajectories. I set the alarm to wake me every couple of weeks, burn a little more of my candle in case the enemy tries to pull another fast one; but for now it seems to be behaving itself. DHF428 jumps towards us in the stop-motion increments of a life's moments, strung like beads along an infinite string. The factory floor slews to starboard in our sights: refineries, reservoirs, and nanofab plants, swarms of von Neumanns breeding and cannibalizing and recycling each other into shielding and circuitry, tugboats and spare parts. The very finest Cro Magnon technology mutates and metastasizes across the universe like armor-plated cancer.

And hanging like a curtain between *it* and *us* shimmers an iridescent life form, fragile and immortal and unthinkably alien, that reduces everything my species ever accomplished to mud and shit by the simple transcendent fact of its existence. I have never believed in

gods, in universal good or absolute evil. I have only ever believed that there is what works, and what doesn't. All the rest is smoke and mirrors, trickery to manipulate grunts like me.

But I believe in the Island, because I don't *have* to. It does not need to be taken on faith: it looms ahead of us, its existence an empirical fact. I will never know its mind, I will never know the details of its origin and evolution. But I can *see* it: massive, mind boggling, so utterly inhuman that it can't *help* but be better than us, better than anything we could ever become.

I believe in the Island. I've gambled my own son to save its life. I would kill him to avenge its death.

I may yet.

In all these millions of wasted years, I have finally done something worthwhile.

*

Final approach.

Reticles within reticles line up before me, a mesmerising infinite regress of bullseyes centering on target. Even now, mere minutes from ignition, distance reduces the unborn gate to invisibility. There will be no moment when the naked eye can trap our destination. We thread the needle far too quickly: it will be behind us before we know it.

Or, if our course corrections are off by even a hair – if our trillion-kilometer curve drifts by as much as a thousand meters – we will be dead. Before we know it.

Our instruments report that we are precisely on target. The chimp tells me that we are precisely on target. *Eriophora* falls forward, pulled endlessly through the void by her own magically-displaced mass.

I turn to the drone's-eye view relayed from up ahead. It's a window into history – even now, there's a timelag of several minutes – but past and present race closer to convergence with every corsec. The newly-minted gate looms dark and ominous against the stars, a great gaping mouth built to devour reality itself. The vons, the refineries, the assembly lines: parked to the side in vertical columns, their jobs done, their usefulness outlived, their collateral annihilation imminent. I pity them, for some reason. I always do. I wish we could scoop them up and take them with us, re-enlist them for the next build – but the rules of economics reach everywhere, and they say it's cheaper to use our tools once and throw them away.

A rule that the chimp seems to be taking more to heart than anyone expected.

At least we've spared the Island. I wish we could have stayed awhile. First contact with a truly alien intelligence, and what do we exchange? Traffic signals. What does the Island dwell upon, when not pleading for its life?

I thought of asking. I thought of waking myself when the time-lag dropped from prohibitive to merely inconvenient, of working out some pidgin that could encompass the truths and philosophies of a mind vaster than all humanity. What a childish fantasy. The Island exists too far beyond the grotesque Darwinian processes that shaped my own flesh. There can be no communion here, no meeting of minds. Angels do not speak to ants.

Less than three minutes to ignition. I see light at the end of the tunnel. *Eri's* incidental time machine barely looks into the past any more, I could almost hold my breath across the whole span of seconds that *then* needs to overtake *now*. Still on target, according to all sources.

Tactical beeps at us. "Getting a signal," Dix reports, and yes: in the heart of the Tank, the sun is flickering again. My heart leaps: does the angel speak to us after all? A thankyou, perhaps? A cure for heat death? But –

"It's *ahead* of us," Dix murmurs, as sudden realization catches in my throat.

Two minutes.

"Miscalculated somehow," Dix whispers. "Didn't move the gate far enough."

"We did," I say. We moved it exactly as far as the Island told us to.

"*Still in front of us!* Look at the *sun*!"

"Look at the *signal*," I tell him.

Because it's nothing like the painstaking traffic signs we've followed over the past three trillion

kilometers. It's almost – random, somehow. It's spur-of-the-moment, it's *panicky*. It's the sudden, startled cry of something caught utterly by surprise with mere seconds left to act. And even though I have never seen this pattern of dots and swirls before, I know exactly what it must be saying.

Stop. Stop. Stop. Stop.

We do not stop. There is no force in the universe that can even slow us down. Past equals present; *Eriophora* dives through the center of the gate in a nanosecond. The unimaginable mass of her cold black heart snags some distant dimension, drags it screaming to the here and now. The booted portal erupts behind us, blossoms into a great blinding corona, every wavelength lethal to every living thing. Our aft filters clamp down tight.

The scorching wavefront chases us into the darkness as it has a thousand times before. In time, as always, the birth pangs will subside. The wormhole will settle in its collar. And just maybe, we will still be close enough to glimpse some new transcendent monstrosity emerging from that magic doorway.

I wonder if you'll notice the corpse we left behind.

*

"Maybe we're missing something," Dix says.

"We miss almost everything," I tell him.

DHF428 shifts red behind us. Lensing artifacts wink in our rearview; the gate has stabilized and the wormhole's online, blowing light and space and time in an iridescent bubble from its great metal mouth. We'll keep looking over our shoulders right up until we pass the Rayleigh Limit, far past the point it'll do any good.

So far, though, nothing's come out.

"Maybe our numbers were wrong," he says. "Maybe we made a mistake."

Our numbers were right. An hour doesn't pass when I don't check them again. The Island just had – enemies, I guess. Victims, anyway.

I was right about one thing, though. That fucker was *smart*. To see us coming, to figure out how to talk to us; to use us as a *weapon*, to turn a threat to its very existence into a, a…

I guess *flyswatter* is as good a word as any.

"Maybe there was a war," I mumble. "Maybe it wanted the real estate. Or maybe it was just some – family squabble."

"Maybe didn't *know*," Dix suggests. "Maybe thought those coordinates were empty."

Why would you think that, I wonder. *Why would you even care*? And then it dawns on me: he doesn't, not about the Island, anyway. No more than he ever did. He's not inventing these rosy alternatives for himself.

My son is trying to comfort me.

I don't need to be coddled, though. I was a fool: I let myself believe in life without conflict, in sentience without sin. For a little while I dwelt in a dream world where life was unselfish and unmanipulative, where every living thing did not struggle to exist at the expense of other life. I deified that which I could not understand, when in the end it was all too easily understood.

But I'm better now.

It's over: another build, another benchmark, another irreplaceable slice of life that brings our task no closer to completion. It doesn't matter how successful we are. It doesn't matter how well we do our job. *Mission accomplished* is a meaningless phrase on *Eriophora*, an ironic oxymoron at best. There may one day be failure, but there is no finish line. We go on forever, crawling across the universe like ants, dragging your goddamned superhighway behind us.

I still have so much to learn.

At least my son is here to teach me.

Originally published by Peter Watts (2009).

Thinking big: Dyson spheres

Not too optimistic, was it? But could such a journey like Sunday and the rest of the gate-building ship *Eriophora*'s crew are undertaking be spared tragedies and hard decisions? Cut off from contact with the rest of humanity (indeed, having left "humanity" somewhere in the far, far past), with limited resources and expertise, "cavemen" thrown into deep space?

Let's see: contact with an alien intelligence; a living Dyson sphere; an inadvertent destruction of alien life…

Contact is a great big question on its own, and we'll get to it after the next story. As to life in a vacuum in general, we've touched that theme in *Backscatter*. Regarding alien life as a source of profit on one hand, or an obstacle in one's way (like the chimp did here), seems to be a pervasive theme: Leah Hamakawa thought that Hanita Jayavel would kill her and keep the existence of Uranian life secret in order to build her new paradise (which would possibly affect the local life in negative ways); Claire picked the vacflowers on her iceteroid without much rumination on the ethics of doing so (fair point is, she was trying to save her life and there were more of them – but a biologist like me would have probably wasted her precious air pondering whether she's not destroying a unique alien ecosystem); Oslo and Kepler wanted to commit an intellectual genocide in order to get their patent money…

There's always a danger that we exterminate or critically threaten lifeforms we encounter once we

venture into space. To prevent that and also contaminating Earth with potential alien life, measures of planetary protection have been formally taken as early as 1967 with the Outer Space Treaty. However, nothing really binds the signatories to uphold the treaty, and the private sector is basically unregulated in this respect.

So, once we really find life out there (or even *before* we do), do we destroy it?

I surely hope not, though the state of most Earth's natural habitats speaks otherwise. But what else is there to do but make an effort to prevent such pessimistic outcomes both on Earth and elsewhere in the present and future, learning from the past?

We'll touch the issue of planetary protection once more in the bonus story. Now, however, let's talk about Dyson spheres – and life. The concept of a sphere surrounding a star, so that a civilization might make use of all of its power in the visible, UV and possibly other parts of the spectrum, was proposed in 1960 by the famous physicist and engineer Freeman Dyson, though a similar concept appeared already in Olaf Stapledon's SF novel *Starmaker* back in 1937 (and after Dyson's paper, it became a popular SF staple and featured in numerous novels, movies and shows such as *Star Trek*).

The existence of a Dyson sphere – either a solid shell encompassing a star, or somewhat more likely a non-continuous sphere of separate objects orbiting the star or held in place by the pressure of the stellar wind – would be observable across great distances. In the original short paper, Dyson (1960) points out that such an object has to radiate waste heat, otherwise it would

melt. We would, therefore, observe an infrared-heavy spectrum, relatively less visible light, where observations in both of these regions of the spectrum are available.

Carrigan (2009) led a Fermilab Dyson sphere search program using the IRAS satellite data. It wasn't the first study to do so, but earlier efforts used a then-smaller IRAS sample and fewer observations (e.g. not all four filters for different IR wavelengths, etc.). He found a few candidate stars, however, the infrared excess could be explained by phenomena involving no alien intelligence, for instance large quantities of dust.

Attempts to detect Dyson spheres have also been made on data obtained from the WISE, Gaia and other surveys. The WISE survey enabled scientists to look at approximately 100,000 galaxies for signs of large-scale reprocessing of starlight. They found no clear signs of ET megaenginnering, although a small number of sources exhibited unusually high IR and low VIS emissions (Griffith et al. 2015). Unusual amounts of dust seem to be the primary suspect; the presence of galaxy-spanning civilizations should be considered after more likely explanations are excluded.

Zackrisson et al. (2018) cross-referenced the Gaia satellite data with ground-based surveys data and again found a small number of "peculiar" stars – but in this type of data, an unseen binary companion of the observed star could have been responsible (note that most stars occur in binaries and other multiple systems; our sole Sol – pun intended – is rather an exception).

To cut a long story short, no Dyson spheres have been reliably found yet in our galaxy or beyond. It

doesn't completely rule out their presence – after all, the galaxy contains approximately 400 billion stars and we can't observe them all, and we only see the most striking patterns in other galaxies – but it seems less likely now.

Another possibility is to look for Dyson swarms purely in visible light. They should be observable as dimming of the central star – much like we discover transiting exoplanets, except here the light curve would look very different from a planet. There have been a few hopefuls in the Kepler telescope dataset, the most famous being KIC 8462852, nicknamed "Tabby's Star". It made headlines back in 2015 and later on. Several explanations were proposed, such as a dust ring around the star, a halo of disintegrating comets, a star-planet collision, a planet with rings and trojan asteroids, or a large orphaned moon. Most of these seem to fit the data more than a hypothetical Dyson swarm, and future observations should suffice to test at least some of the proposed hypotheses so far.

Some researchers proposed that it would make more sense to build Dyson spheres around stellar remnants like white dwarfs (Semiz & Oğur 2015; note, however, that it's a non-peer-reviewed paper in the arxiv repository, and not only its reference list seems a bit peculiar) or neutron stars (Osmanov 2016, 2018). They could potentially harvest comparable amounts of energy, but much less material would be needed due to the small size of these stars. A white dwarf is approximately as big as the Earth, while a neutron star is comparable in size to a big city. In contrast, the Sun's diameter is over 100

times as much as the Earth's, and we have to think in 3D when building a megastructure…

Still; we've discussed the hypothetical technology of alien life (its extended phenotype, so to speak), not life itself. But the Island in the namesake story is a living creature. How could something like that evolve? A millimeter-thick layer of cells encircling an entire star, with a nervous system so big we can barely imagine it?

I must admit it is difficult to imagine the evolutionary pathway leading to the Island – so difficult, indeed, that even as an evolutionary biologist (or perhaps because I'm an evolutionary biologist with a fairly good grasp of the processes involved here on Earth), I would consider it most likely that the Island was bioengineered by some civilization.

Which ultimately brings us to its purpose and goals.

It is very interesting how Sunday comes to think about the Island: "…perfectly adapted, immortal, it won no struggle for survival: where are the predators, the competitors, the parasites? All of life around 428 is one vast continuum, one grand act of symbiosis. Nature here is not red in tooth and claw. Nature, out here, is the helping hand. Lacking the capacity for violence, the Island has outlasted worlds. Unencumbered by technology, it has out-thought civilizations. It is intelligent beyond our measure, and – and it is benign."

She succumbs to a fallacy of anthromorphizing the Island. True, she thinks it's nothing like a human, but she lays all of that on very human-centered, or at least Earth-centered assumptions. She also doesn't seem to

consider the idea of the Island as an engineered creature with decision processes and motives that might be *very* different from an organism that has evolved naturally. What selection pressures could possibly lead to a star-encompassing organism – one with great cognitive capacity, moreover?

Could Sunday have done something differently? She could have tasked the vons to explore the new gate building site in more detail (that would have likely cost more precious time, however), and she could have sent a transmission to the site to make sure no one would be harmed there. But she trusted the Island, an entity as alien and inscrutable as one could imagine.

Is there any message we can take away from it? All, in the end, sound so trivial: we should avoid the anthropomorphism fallacy; gather as much data as possible before jumping to conclusions... Yet many people do just that even before we've encountered any extraterrestrial (or artificial) intelligence, and presume that any ET must necessarily be either benign, or violent.

Data is key. Getting it – not so easy. We're having trouble reliably interpreting the behavior of animals, even ones as close to us on the evolutionary tree as apes. How could we possibly judge the motives of ET, whom we couldn't directly observe?

Maybe we could just – talk. Like Sunday and the Island did, but trying not to repeat her mistake. Talking across the interstellar distances, though, is a challenge in itself... one that brings us to the next story.

References

Carrigan Jr., R. A. (2009). IRAS-based whole-sky upper limit on Dyson spheres. *The Astrophysical Journal*, *698*(2), 2075.

Dyson, F. J. (1960). Search for artificial stellar sources of infrared radiation. *Science*, *131*(3414), 1667-1668.

Griffith, R. L., Wright, J. T., Maldonado, J., Povich, M. S., Sigurđsson, S., & Mullan, B. (2015). The G infrared search for extraterrestrial civilizations with large energy supplies. III. The reddest extended sources in WISE. *The Astrophysical Journal Supplement Series*, *217*(2), 25.

Osmanov, Z. (2016). On the search for artificial Dyson-like structures around pulsars. *International Journal of Astrobiology*, *15*(2), 127-132.

Osmanov, Z. (2018). Are the Dyson rings around pulsars detectable?. *International Journal of Astrobiology*, *17*(2), 112-115.

Semiz, I., & Oğur, S. (2015). Dyson Spheres around White Dwarfs. *arXiv preprint arXiv:1503.04376*.

Zackrisson, E., Korn, A. J., Wehrhahn, A., & Reiter, J. (2018). SETI with Gaia: The observational signatures of nearly complete Dyson spheres. *The Astrophysical Journal*, *862*(1), 21.

Classroom ideas

1. Discussion: Do you think hunting for Dyson spheres and other megastructures in light curve and VIS/IR data is a better way of detecting potential alien civilizations, than, let's say, listening for radio transmissions? (Also try to get back to this question after the next story.)
2. Read the original Dyson (1960) paper – it's very short and not too technical. It can be freely accessed e.g. here, including the responses and Dyson's response to them on the pages of *Science*. Think about the

following paragraph from the paper: "It is remarkable that the time scale of industrial expansion, the mass of Jupiter, the energy output of the sun, and the thickness of a habitable biosphere all have consistent orders of magnitude. It seems, then a reasonable expectation that, barring accidents, Malthusian pressures will ultimately drive an intelligent species to adopt some such efficient exploitation of its available resources. One should expect that, within a few thousand years of its entering the stage of industrial development, any intelligent species should be found occupying an artificial biosphere which completely surrounds its parent star." Do you agree with Dyson's reasoning here, or do you consider another outcome more likely? Why? (Consider e.g. the demographic trends in developed countries; the impact of education, healthcare access, women's equality and other factors on the population growth; the ethical questions of megaengineering, etc.)

3. Try to discuss the possibility of life that is "perfectly adapted, immortal, it won no struggle for survival: where are the predators, the competitors, the parasites?". Do you think such a case would be possible (if so, under what conditions, and would it be likely)? Don't worry if you don't reach any solid conclusions; this question would have different schools of evolutionary biologists going on for years!

SETI for Profit

by Gregory Benford

Gregory Benford (* 1941) is a physicist, educator, and author. He is a professor of physics at the University of California, where he conducts research in plasma turbulence and astrophysics. He's published over a hundred papers in fields of physics from condensed matter, particle physics, plasmas and mathematical physics, and several in biological conservation. He is a Woodrow Wilson Fellow and a Visiting Fellow at Cambridge University, and has served as an advisor to the Department of Energy, NASA and the White House Council on Space Policy. In 1995 he received the Lord Foundation Award for contributions to science and outreach. Benford is the author of over twenty novels, including *Jupiter Project*, *Artifact*, *Against Infinity*, *Eater*, and *Timescape*. A two-time winner of the Nebula Award, Benford has also won the John W. Campbell Award, the Australian Ditmar Award, the 1995 Lord Foundation Award for achievement in the sciences, and the 1990 United Nations Medal in Literature. Many of his best known novels are part of a six-novel sequence beginning in the near future with *In the Ocean of Night*, then *Across the Sea of Suns*. The series leaps to the far future, where a human drama unfolds, beginning with *Great Sky River*, proceeding through *Tides of Light*, *Furious Gulf*, and concluding with *Sailing Bright Eternity* in a single unfolding tapestry against an immense background. More at www.gregorybenford.com.

Multi-billionaire Clyde Kraft's announcement that his team had detected a SETI signal shocked the world. He claimed to have found a plainly artificial broadband signal from a star well over a thousand light years away.

His astronomers ranked behind him confirmed the discovery. They gave pulse spectra, but without labels that would let anyone find or decipher it. They omitted the celestial location or frequency. Then Kraft stepped back to the microphone and gave his terms.

"The real news is that we've found a message in the megahertz-wide signal. It's intermittently on, hard to find. But we held steady, studied the galactic plane for over a year." Kraft paused for effect, giving the world a thin smile. "Then – there it was! In less than a week my fine team deciphered it. Not hard, really. It's amazing. And… it's a warning."

Consternation. Shouts from the press, who thought they were attending a business briefing. Kraft wouldn't reveal the message or how to find the source. He scowled. "I did this as an… investment. Pay me a finder's fee, say half a billion dollars, and we'll talk." With another smile he left the dais and vanished from public view.

Around the world scientists rebuked him. "To make such a discovery and keep it secret violates the code of science," the head of the National Academy pronounced. "And to expect profit!"

Parliaments voted to condemn Kraft. "The most important discovery in history cannot be private property," declared the Pope.

Most news shows carried the story as a scandal, focusing on Kraft's known cut-throat ways of gaining advantage. He had used head-to-head methods in stochastic arbitrage trading, making him Forbes 2013 'King Competitor'. Even the *Wall Street Journal* went tsk-tsk. *The Times* in London had a headline three inches high: "What is the warning?"

Kraft wouldn't say. Appeals by politicians, wise men and philosophers got no answer at all.

Worldwide, astronomers condemned Kraft – and got to work. They pored over older radio-telescope data, looking for sources 1 megahertz wide that came and went. There were several and they earned front-page coverage.

Dishes trained on these candidates listened constantly, to the limits of their sensitivity. Kraft would not reveal the discovery frequency so they scanned through their entire range. This was a marked change from conventional SETI, which had gathered mostly at the 'water hole' between 1 and 2 gigahertz.

Observers with telescope time donated it to the search for the mysterious source. Amateurs erected their own 3-metre radio dishes in backyards and got in on the hunt with gear they bought over the Internet.

Kraft's in-house astronomers were sound scientists who had lost out in the academic horse race. They refused even to discuss the discovery. SETI had been losing momentum since 2010, the 50th anniversary of its first search. Kraft had sought to reinvigorate the field, they said, and did so with what was to him pocket change, only $100 million.

Scientific professional societies turned on these astronomers. Furious executives in the AAAS, the IAU and other bodies revoked the astronomers' memberships. Mobs rioted outside their homes. 'Free ET!' shouted a popular sign the crowds carried in capitals around the world.

Kraft stayed in hiding. Pressure built. The Kraft astronomers also vanished, harried by incessant demands.

Months passed. The older observed signals yielded nothing. The United Nations debated whether it could or should confiscate Kraft's holdings within its reach – only to find that he had moved them into secure accounts. Nations began to negotiate how to share out the cost of meeting Kraft's price.

Kraft dodged negotiations. Rumours spread that he had become a greybearded hermit, like Howard Hughes. Reports located him in Switzerland and North Korea.

Then the Australian Parkes radio telescope picked up a quick, millisecond signal not far from the line of

sight towards the galactic centre. It was 3 megahertz wide, not 1, but it did have a signal.

Parkes released the pattern immediately. Thousands of scientists leapt to decode the message. Within days they had a coherent form, mostly details about a solar system similar to ours. It identified a race of elephant-like creatures complete with trunks, legs and two grasping hands at the shoulders. Their society was very old and might be extinct. There were hints that robots tended the message-sending beacon.

But there was no warning in the message at all.

With 30 minutes' notice, Kraft appeared at a press conference in Singapore. He admitted that there was no warning, the bandwidth was different – and in fact he had never detected a signal at all.

"I wanted to goose the world," he said. "Get 'em started. SETI needed that a lot more than it needed more money. Now we have something and it's time to get to work. I'll stand aside."

He left the room in an uproar. But that was nothing when, three years later, he won a Nobel, along with Parkes Observatory.

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The great listening, and the great silence

Ever since the invention of radio, people have dreamed of detecting messages from extraterrestrial civilizations. As early on the brink of the 20th century, Nikola Tesla was convinced that he caught messages from Mars via wireless telegraphy. Less than twenty years later, Guglielmo Marconi thought he detected signals from Mars. We can even see the early conviction that communication with ET would be easy because of a shared mathematical, scientific and technical common ground. Marconi himself had said on the subject of language as an obstacle: "...one might get through some such message as two plus two equals four and go on repeating it until an answer came back signifying 'yes', which would be one word. Mathematics must be the same throughout the physical universe. By sticking to mathematics over a number of years one might arrive at speech," and he made a loose comparison to deciphering enemy transmissions during the Great War (Dunlap 1941, p. 286).

The possibility of contact even persuaded the US government to observe radio silence in late August 1924, when Mars was in opposition (relatively close to Earth on its orbit), and attempt to listen for any messages. None were detected. But the quest for alien transmissions went on even as we learned how inhospitable Mars was; it just moved to more distant targets. SETI really kicked off in the 1960s with the construction of J. D. Kraus' "Big Ear" telescope at Ohio State University and with Frank Drake's Project Ozma.

His goal was to use the Green Bank radiotelescope to try to listen to potential messages from nearby stars Epsilon Eridani and Tau Ceti. The Soviets didn't stay far behind in their attempts at finding alien communications.

Throughout the 1970s and 1980s, SETI gained lots of attention, not in a small part due to the 1977 one-off "Wow!" signal, whose origin remains unclear, and Carl Sagan's skill at science outreach (including his 1985 science fiction novel *Contact*, later remade into a film starring Jodie Foster as its protagonist, loosely inspired by the real-world SETI scientist Jill Tarter).

However, as time went and no surefire detections came (or even more intriguing cases such as the "Wow!" signal), interest in SETI began to dwindle. The last year it received federal funding in the US was 1992. Since then, SETI relied on private donations and has lost much of its original popularity, despite the fact (correctly pointed out in Benford's story) that we've barely even started searching. We've listened for a few decades on a few radio frequencies. No specialized SETI programs for traces of civilizations in visible light (either laser signals or megastructures detectable as the dimming of their star or in the IR, as we've seen after the previous story) have been made; SETI concerns have always been secondary.

SETI wasn't the only way people have tried to detect the presence of extraterrestrial civilizations. Another approach, called METI, has also been tried. METI means Messaging ExtraTerrestrial Intelligences. Sometimes it's also dubbed "active SETI". It's not a novel effort, either. Already in early 19th century, scientists such as Gauss had proposed reflecting sunlight

to other planets or creating giant geometric images in Siberia. Francis Galton later proposed directing flashes of light to Mars. These and other proposals were far from realistic even if there were a civilization on Mars – unless it had extremely good telescopes.

One of the main proponents of METI today is Doug Vakoch, the president of METI International, psychologist, SETI researcher and author. However, others are not as optimistic and warn that we should not actively draw attention to ourselves; this opinion was famously shared e.g. by Stephen Hawking. They call for caution: We don't know why we haven't found any other civilization yet, and not all of the explanations would bide well for us…

So, if technological alien civilizations exist in our galactic neighborhood, why haven't we spotted them yet?

Perhaps it's because of the limits of our search. Or, perhaps, we overlooked the message. How sure can we be that we would recognize it if we saw it?

There are mathematical measures of complexity and non-randomness that could help us, but to achieve greater reliability, they would require a signal as clear as possible. Don't imagine, however, that approximately 1400 years since 1936, a receiver near Betelgeuse would detect a clear transmission of television from the Summer Olympics in Berlin. The radio signal is weak, broad-beam and necessarily degenerates as it passes through the interstellar medium. It gets fainter and fainter, until you can't tell it from the noise. The estimates vary, but you'd probably have a hard time

detecting a TV broadcast from Earth already on Proxima Centauri, the nearest star to ours, 4.2 light years away. All the noise Earth has started making since Marconi (and largely stopped due to the use of optical table and targeted satellite communications)? Nothing. We can hardly expect to pick up alien TV. What we *can* expect (or rather hope in) is to detect a message intended to reach as far as possible.

The best way to do that is a powerful narrow beam, probably laser rather than radio. In 1974, humanity (or rather a selected group of scientists and fellow enthusiasts) sent a strong unidirectional radio signal from the Arecibo radio telescope toward the globular cluster M13 about 25,000 light years away. The evidence that this was more of a technological demonstration than a serious communication attempt is that the signal was aimed at the at-that-moment location of M13 – but of course objects move on their orbits within and around our galaxy, and by the time the signal arrives at the cluster's distance, the star-dense center of the cluster will have moved out of the way of the signal! M13 was just available on the sky at the time.

Then there was Team Encounter's Cosmic Call to several nearby stars, sent between 1999 and 2003, the Lone Signal project in 2013 that sent a few short messages to Gliese 526, located some 18 light years far, and a handful more attempts seeking advertisement rather than actual alien contact.

That's it. Now imagine other civilizations transmitting their existence this way. No wonder we

haven't heard anything, especially the way we've been listening!

A study by Grimaldi (2017) tried to estimate the number of detectable signals at a given point in time, looking both at multi-directional and unidirectional transmissions with varying longevity. The result may seem pessimistic to those of us looking forward to translating alien messages: Even with a high number of transmitters in our galaxy, the mean number of detectable signals falls below one.

Below one.

On all the frequencies they could use. All the frequencies we'd have to search.

Perhaps the hypothetical aliens used similar math and concluded that passive or active SETI is not worth it and if they were to advertise their presence, they would place a physical artifact in front of their star to create a continuous signal of dimming, which brings us the long way around back to the previous story.

However, if we were to detect an alien signal, it would – using Bayesian statistics – imply that there are likely many more to discover (Grimaldi & Marcy 2018).

But even if we detected a signal of artificial origin, would we be able to reliably decode it? After all, many dead human languages or animal communication on Earth remain opaque to us. Messages to ET have supposedly been made as universal as possible, easy to decode by life we have no common roots with.

For instance, the Arecibo Message is purely visual, showing simple pixelated pictures... but why

describe it in detail when you can try to decode it for yourself here?

The point is, a random recipient of the message may not be as visually oriented as humans. Since the 1970s, we've of course made strides in developing other systems, but we still can't be too sure they would make sense even to another technologically advanced species.

In sum, we should hardly be surprised we haven't found any alien signals yet. With all likelihood, we won't find them for some time even if they are detectable in this particular era at our position in the galaxy. But we should probably at least try more.

However, there is one more pressing question. Even with conventional, much slower-than-light propulsion, any technological civilization should be able to traverse our galaxy with automatic probes (perhaps even hibernation/generation ships) within tens of thousands of years. Signals notwithstanding; if some advanced civilizations arose already, they should be here. So why can't we see them?

That is the essence of the so-called Fermi Paradox, and that brings us to the final story…

References

Dunlap, O. Elmer. (1941). *Marconi, the man and his wireless.* Rev. ed. New York: The Macmillan company.

Grimaldi, C. (2017). Signal coverage approach to the detection probability of hypothetical extraterrestrial emitters in the milky way. *Scientific reports*, *7*, 46273.

Grimaldi, C., & Marcy, G. W. (2018). Bayesian approach to SETI. *Proceedings of the National Academy of Sciences*, *115*(42), E9755-E9764.

Classroom ideas

1. Think back to "A Jar of Goodwill" and chemical communication. How do you think would a message from a species communicating primarily by scent look? What about a message from aliens using echolocation as their primary sense? Feel free to think of other options, too.
2. Read up on the lost Indus civilization, with cities such as Harappa, and its language. Why haven't we translated it yet? Do you think that if we're so far unable to understand even a dead human language, do we have any chance of understanding a potential alien message? (Both yes and no have some good arguments on their side, e.g. the possible common ground of civilizations who have developed science and technology sufficient for radio communication.)
3. Do some animals have something we could call rudimentary language, and have we understood some of it? You can divide the class into groups and let each find out what they can about ways of communication in elephants, apes, cetaceans, bees, ants, corvids – how many you like. Bonus question: Are non-human animals capable of lying? (Short answer: yes! And it's a wonderful fact. Try for example this video narrated by David Attenborough: Monkey's Bluff | Clever Monkeys | BBC Earth)
4. Try to construct your own message to unknown aliens. What would you try to tell them, and how?

But, Still, I Smile

by D. A. Xiaolin Spires

D. A. Xiaolin Spires steps into portals and reappears in sites such as Hawai'i, NY, various parts of Asia and elsewhere, with her keyboard appendage attached. Her work appears or is forthcoming in publications such as *Clarkesworld, Analog, Nature, Terraform, Grievous Angel, Fireside, Galaxy's Edge, StarShipSofa, Andromeda Spaceways (Year's Best Issue), Diabolical Plots, Factor Four, Pantheon, Outlook Springs, ROBOT DINOSAURS, Mithila Review, LONTAR, Reckoning, Issues in Earth Science, Liminality, Star*Line, Polu Texni, Argot, Eye to the Telescope, Liquid Imagination, Gathering Storm Magazine, Little Blue Marble, Story Seed Vault*, and anthologies of the strange and beautiful: *Ride the Star Wind, Sharp and Sugar Tooth, Future Visions, Deep Signal, Battling in All Her Finery*, *Broad Knowledge*, and *Rosalind's Siblings* (upcoming).

When my baby flowed away from me, I thought of it as coursing away through a river, far and far away, and perhaps journeying through the great Silver River (the Milky Way) and towards some other exoplanet unseen and unknown. I thought it might be carried away by that great band of light, so faint but populated by so many stars, all doing its part to lift her, tiny little fingers bringing her towards a future that still held bright.

In reality, the system took the miscarriage remains and sucked it through tubes, yes, tubes unseen, but sterile tubes: no faint stars, no coursing through the galaxies, no distant land where she might be raised in the opposing angles of diffused rays of a dual star system. Despite the number of miscarriages, I was never sure where those tubes ended, maybe it went across the Earth, across the atmosphere. Maybe it jettisoned my baby into outer space itself, her body crystallized and preserved, in the half-born state it came into the world.

I vowed never to have a kid again. Or at least I pretended to, in my infinite duress. What was the point? She was the closest to term, and yet, still failure.

But, in my heart, I looked out into the vast unknown, thinking that somewhere my child was there, calling out for her mom.

*

Mapping out for SETI was a natural course of an occupation for me. Maybe it was destined, as my name was Dengwen 登文, where *deng* means *climb* but also means *record* like in a registry. And *wen* meant literature but also could mean civilization. So, here I was, reinventing my name in my own way, recording the possibility of new civilizations in my mundane everyday work. I would spend days sifting through data. Finding extraterrestrial life was ambitious, grandiose, and romantic in theory, but rather tedious in practice. I didn't mind. Tedium suited me. I could spend days numbly parsing through radio and light signals, any ripple of a signature that would suggest something other than the natural movement of cosmic gears turning came under my meticulous gaze.

The Drake Equation always bothered me. Sure, it listed all the factors outright in diminishing fractions: birthrate of stars, stars with planets, life-sustaining planets, planets with life spawned, intelligence within those planets with life spawned, technological capability of the intelligence of the life spawned, and the span of years of a technological society. Sure, it made sense, ruling out candidates, like the piling discards dumped by sea trawlers of the past. But, when I stepped back and thought about it, the kernel that was left – it seemed improbable, almost impossible, despite my devotion to the project. Where were these places, these elusive hosts of life? It was like those old nursery rhymes where one

thing compiled on the next compiled on the next and became a monstrous sentence with qualifiers abound. Given such a fraction of a fraction of a fraction, *ad infinitum*, the reduction of all the seemingly infinite stars out there, was there a space really for organic life to blossom and reach out to us and make contact?

In my office, I rubbed my abdomen as the data flickered on charts before me. The data might be impassive, but my body wasn't. It hurt. I was too embarrassed to get postnatal care, if it could be called postnatal. No, it wasn't embarrassment. It was a blip of numbness, or of delusion, of not wanting to face the truth. I had bled out, that rare instance of life fostered inside of me that lasted to such an advanced stage, in the face of the countless attempts at conception, and obliterated by some tacit violence in the universe.

Finding life out there seemed futile; the universe was as sterile as my womb. Cold, detached, anesthetized. It made one attempt at life and, well, we had royally messed it up. Destroyed ourselves and pretty much wrecked our home, Earth, along with it, thanks to petty disputes, constant competition over scarce resources getting scarcer. To think that another being might be out there and signal at us was like catching my fetus through the tubes and breathing life back into it. We were too far gone and we were hoping for a miracle.

It was while thinking this – experiencing a flash of pain glide through my lower back and swallowing grief I

might never dispel – that the strange anomaly caught my breath.

An anomalous pattern of radio signals. It wasn't like anything I've seen before.

I pressed my face against the screen, feeling its cold glass. I looked closely, wondering if the pixels were shifting on me.

They weren't.

I sat up, despite all the groans of my body.

*

"Dengwen, you're lucky you found the blip of possible life." The nurse pressed the gauge against my cheek, taking my temperature and vitals. She didn't seem too moved by the idea of imminent communication with extraterrestrials.

"Yes, there's hope for humanity yet," I said.

She dabbed a bit of anesthetic fumes behind my ear. My nose wrinkled at the smell, as I winced. I hated hospitals.

"No, you're lucky, for your own sake," she said, wiping my arms down with the cleaning cloth. She gave me a stare I couldn't decipher and shook her head at me, black hair whipping her chin. Then she tied the blue massage fabric to my arms and back. "Otherwise, you might not have ever come to me. How long has it been since the miscarriage?"

"A week... " My words tapered off as I tilted my head back so she checked my tonsils. I stared into the bright lights of the white ceiling. I still wasn't sure exactly what she was looking for.

"And you're passing enough blood clots to make this an event worth flagging." She tapped on my chart on the thin screen beside her. It didn't say anything in that vein. I wondered how she knew.

Blood clots.

They freaked me out. I would flush them down the tubes, but they would return, day after day, ejected from my body, haunting me, detritus in lieu of life.

Yet, they were comforting in their own way; evidence that *she* did exist, even if it was just a semblance of life, almost-life that short-circuited. Yearning for motherhood possessed me, no matter how much I tried to push it away. I closed my eyes, let my head swim as the massage fabric worked its way, stimulating my muscles, relieving my incessant pain. It couldn't soothe the ache in my loins.

Maybe they'll deliver us some well-needed tech. Something to turn the tides, lower the CO2, bring down the rising sea levels. I wonder what they would look like, corporeal beings or evanescent bands of light? Would they speak with tongues and spit saliva? Or would they hover and float? There was so much we didn't know. So much that couldn't be inferred from the little data we had.

The nurse must have turned the knob up higher, since I felt a pulse travel through my arms. The massage fabric sent me a buzz right under my chest. I put my hand there, thinking of how my breasts had gotten smaller, receded in the wake of the miscarriage, as if it, too, like all my nurturing prowess, decided to go into hibernation. *Not yet*, I had whispered. I had stopped cooking hearty broths for myself, stopped caring about my health, and instead zapped hydrobar dinners every day. I was numb, but deep within, I still hoped I could.

I was woken up by the feeling of the nurse pressing a few thin pads to my hands. At first, I thought they were for the bleeding, but she said in a hushed voice, "Hemoglobin adhesives. It'll pump some iron back into you. It's cutting-edge tech that I swiped from the gift bag of a higher-up at a conference for military medical innovations."

It felt light in my hands, almost weightless.

She pressed one against her skin, not opening it, but simply demonstrating. "Once you put it on, some of your blood will flow into its lattice fabric and align itself to avoid a hemolytic reaction. Then, once calibrated, the patch will shift iron out of its fabric, pitch the ferrous nutrients so it traverses air and skin and into your body." She passed the one she was using as demonstration to me as well.

"It's not on the market yet and I don't have many. I don't give them out to my patients. But, you look like you

could use some. Besides, it's not every day I have a patient rocketing into space."

I thanked her, pocketed the stickers fast like they were contraband and we were about to be busted. The door opened just then and the nurse plastered a benign smile on her face as she finished up my checkup. She let the bots work around her, picking up extra supplies, checking the inventory, as she indicated to me with a finger that my time here was up. As we left, she handed me some more contraband: a whole box of hemoglobin adhesives and a dozen reviving sticks.

"In case you run into the ETs," she said in a whisper. "No one wants to say they might be violent. But, who knows. You might need them to save yourself." She gestured slapping one on herself. She turned around, spinning on her heels, and left, curt with no goodbye, as if our appointment never happened.

*

They wanted me out there with the scientists, exploring space. I mentioned I was only one of the data analysts. Why me? Shouldn't they choose a xenoanthropologist, someone who had spent years dedicated to the role?

"We're not just sending you, Dengwen. Of course we'll have a xenoanthropologist on board, plus a linguist, plus an army of data crunching AI. Botanists, geologists, everything we've got. But, who knows what kind of tech

they might have? What if their connection fries our AIs? We can't rely on AI to data analyze, we'll need a human touch. Someone who might see a blip out of some inexplicable instinct where an AI might rationalize it away."

My supervisor sent me a pack of rations and told me to practice getting used to them. My stomach might first object, so better to deal with the ramifications while still on Earth. I tore off one of the packets and chewed. It tasted like dirt mixed with honey.

The nurse must have watching over me, rooting for me. She didn't mention to anyone else about the miscarriage, which might have disqualified me for the trip. She had simply logged in the necessary checkups, which flashed across my supervisor's eyes during our meeting. I still had her medical supplies stashed away for the trip, pushing away the idea of violence that she had suggested, and instead banking on hope.

I looked out of the giant window of my supervisor's 22nd floor; she had the whole floor to herself and her data-crunching machines. For a moment, together we marveled at the skies that now held so much promise.

"If only FTL drives were invented," I said. "Then we course through to the outskirts of the universe and seek out more lives. If there is one, other than us that is, there must be more."

"Just be lucky we have even enough power to get to Proxima Centauri. So much of our energy put into

keeping the seas at bay and the skies barely breathable enough to live. We're really hanging on a thread. Your discovery came just in time."

I said what I thought she wanted to hear:

"We need to unwind a new thread. A thread that'll guide us to another species. Or guide them back to us. We'll…" My voice of optimism croaked to a halt as I shifted my feet. A cramp subsided. *They should diminish and eventually go away*, the nurse had said. It felt sad, being wistful for pain. It was the remnant of what was, life that hadn't come to be. If only I could conceive…

We never uttered those words that ran around in gossip circles and circulated the digital filigree. The ones that the nurse had whispered so directly into my ear. The possibility that "hope" was a trap. That they were malevolent. That there was no winning. That they would conquer us.

It didn't matter, for those of us who did the calculations. What if they were malevolent? Either way we die. The Earth was perishing before our eyes, given the rate of our global bickering. We didn't have quite the mutual coordination to seed a big enough space station for a future generation. Mismanagement and bare sustenance were draining us of all our resources, leaving other recourses dead ends. Despite the hollers of the everyday citizens, deafening calls in our ears to stop and stay away from the aliens, in our raised towers high

above their shouts, we knew that we only had one way: forward. And hope.

We turned our faces against the protests.

*

I spent a decade on board, waiting to get there. What if we got the calculations wrong? What if we missed our mark?

This would be the ultimate mission, one of daring pleas and of desperation. We had torn apart our space programs, poured all our funding into saving the Earth, but our beloved planet had been careening into a vicious cycle, irregularities that became more magnified. We were lucky there was even enough push to get this spaceship out there, just enough of coming together and pinching and saving to bring us the fuel and resources needed, though mostly it was weighed down by constant fighting.

Hope was the drug that temporarily anesthetized humanity from the stark matter of its imminent unfortunate end. Scientists put their all into it; the diminished SETI team overclocked their bodies, their machinery, put their lives on hold, to get us off the ground. People scrounged, collected, connected to get their hands on remote equipment.

And then – the takeoff. The most beautiful sight on Earth and the Heavens so they called it. Our tiny ship. Millions of eyes following us, whispering, praying. The

oceans receding, the blackness engulfing us, until we were one with the infinite stars.

And then the wait.

While I sat on board growing hair, growing wrinkles, my nails getting longer and clipped, longer and clipped, humanity struggled again, relentless quarreling as they faced the collapse of its own empire as the seas threatened to engulf residences and land and the skies loomed with noxious gas. We thought of the fragments of catastrophe while trying to pass time calmly – hurricanes, vacillating temperatures, underwater cities. We were restless. It wasn't just me, but the whole of the crew. It was going to be a long marriage; a sense of domesticity in the midst of the ever-present faint hum of anticipation, as well as constraining doom, that made all of us a little stir crazy.

*

My womb went from bleeding to productive again to obsolescence. While we flirted, made love, maintained our distances, fought, cohabited and uncohabited, interacted with one another in various ways in ten years, enough drama of seven people to last a lifetime, all the while I kept trying to conceive, my reproductive system made its way to its decline, until menopause took away its main utility. It was an empty cabin, probably the only empty cabin in the spaceship.

This isn't the way everyone looks at their bodies. It was how I looked at it. I had longed for a child, but I feared that it was all futile. Even implantations didn't work. Ovulation wasn't something that I could just trigger. It wasn't a pistol that I could direct and point and shoot. Even having *her* take root and quicken was miracle enough. But, she was lost. So, with all my entanglements, I had hoped, but couldn't count on, for more. A heartbeat. A sperm latching on to my egg. It wasn't really like we were supposed to have children on board. But, could you blame me for being a little bit careless? For "forgetting" my birth control injections? I knew we had food and air enough, even if it was tight, should a little being make its way here.

I didn't want to think about what my future generation might face. That they might see the demise of Earth. But, there was hope, and with hope there was a chance that my hypothetical child could make it and live on.

We were hopeful about the aliens, tracking them down, and so close to our solar system. Hints of a technology that could provide for our future, but it was a cautioned hope, one that had adjuncts and attributes enough to render the hope barely anything but human vanity. How were we any better than any of the other species that have collapsed? When it was our doing that had nearly undone the Earth? The question became moral. Why should we get to live, thrive, and beget?

Would the aliens ask themselves the same things?

These were the philosophical inquiries that harangued our crew for the ten years of trekking, as we made our way towards the red dwarf, the diminutive fifth wheel attached to the Centauri couple.

Proxima b had been ruled out for life, despite the early possibility of water, but the new Proxima c glinted like a jewel. It was from there that the anomalous activity was detected – signals that could not be explained away with a whisk of the hand.

*

The meteorite came from left field. If there was a left field in space – it certainly felt like there was. It struck through the cabin quarters of our Captain, through his uniformed chest, through his soft tissues and coming out the other side, dragging blood behind it.

Years ago, lying naked in the Captain's cabin, I had hoped he could father my child. I even shared with him my dirty secret of shirking birth control in an emotional flood of bonding. I thought he would eject me into outer space right there and then, punishment for my deception and transgression, but no, strangely, he smiled. He said *yes, let's do it*. But nothing came of it.

The possibility extinguished.

We are nothing but bags of blood, I was reminded, and the leak was too potent.

At the time of the meteorite, I was with the Captain, but not in a carnal way. Those days had been long gone, when after so many attempts, nothing came to fruit and the constant stress, mostly from my end, made us drift apart. It was utilitarian for me; his anatomy wasn't living up to his end of the bargain, so we parted physically, but were still collegial.

It was in this setting of collegiality that we were having a meeting, going over datasets. I saw the tiny bead of doom puncture through, in and out, as swift as a needle through fabric. His body torn up and a blood trail followed. It took me a fraction of a second to realize what was happening and another fraction for sheer horror to dawn upon me, but the moment felt stretched out like an eternity.

I ran, then floated toward the hole of the ship as our gravitation system failed in the midst of the accident. I was being sucked in. My chest heaved, panic started to push to the brink of my systems. *Okay, okay*, I thought, grabbing anything around me. I felt something round and hard. It turned out to be a helmet. I pushed it towards the hole.

With an audible whooshing noise, the helmet's smooth surface made contact with the perforation and it got vacuumed up. Pressure adhered it there. Not the best fix but it was better than my own head.

I swam-floated through blood droplets abound. Someone had sealed the exit hole of the meteorite with an

ETA suit. A matching outfit – helmet and shoulders buffered by the whole of the cabin. There was overall confusion, as we tried to avoid the bobbing spheres of scarlet liquid mess. Lifeforce drained away.

He was dead.

When gravity came back, I smacked the ground with my hip and cursed for a good minute before getting up. I had heard the collective thumps of everything falling, but the pain made my senses register nothing but my own visceral agony.

Once the feeling passed, I looked around. Some of us were pretty banged up. The captain's body had fallen to the ground and bounced, with all his blood jostling and pooling. Blood was everywhere, staining us, staining the ship, staining the mission. It took us a week to get all the blood soaked up and discarded. We kept finding bits clinging to equipment, to clothes, to the walls.

We gave him a proper funeral and ejected him into the coldness of space. The ritual of commemorating his death made us feel lost at sea. Our navigator cast off and I watched him crystallize and disappear, reminding me of thoughts long ago I wanted to excise.

*

There were six of us now, distributing the roles of the Captain. Some we allocated to the AI systems and some we tried to keep for ourselves, if anything but to honor his

service. Most of it went to the now-acting-Captain, and still geologist, Anjali, who had training in interstellar navigation alongside her geological interests. They gave me his objectives of reviewing safety measures.

Every day, I would go to a different part of the ship with the sensor and test for structural integrity. It was redundancy; one of the AI systems had the same role. But, nobody felt safe anymore. Besides, there were some uncertainties given the effects of the meteorites. Sometimes, in the midst of a scan of a corner or door, I still would find blood and wonder how it got there.

*

The twin lights of Alpha Centauri blinked at us like cat eyes while the diminutive third to which we were heading always seemed to be orbiting around the two, trying to fit in. It looked like Mars, always cast with a faint orange tint, or like it was always a sun constantly setting. If there was more of an apropos metaphor for human decline, this would be it. The image of a constantly setting star, but just there, hanging in the sky.

*

But, no, this was hope. And when we found Proxima c, we found this hope to be dimmer and less filled with water than we had expected, at least that was what our

scans said. We drew in closer, sent missives to Earth, now four-plus lightyears away. By the time it got to them, my hair would be streaked with silver, like the Milky Way.

*

The ship crash-landed. We did a quick save, salvaging most of it, but lost a good deal of food and water in a contained fire put out by its safety systems. The ship also needed major repairs and we dispatched the drones to assess and reconstruct. We were already coming into our mission jaded and in despair.

*

I stepped out onto the regolith, my five comrades, ex-lovers, confidants, quarrelers, sufferers, and risk-takers with me. The land felt strangely hard, dense and unbalanced. The gravity was two-thirds of Earth, so we bounded in our suits, our scanners propped onto thin fishing poles – loose tethers that would straighten and shoot forth at any sign of life.

We kept tripping over what looked like unevenly accumulated slates, with ragged ends. We had to be careful not to rip a hole into our suits. We searched this land, but it seemed barren of life; there was no water, but maybe these alien creatures didn't need water? They seemed so present, so real in our imaginations, that when

no communication passed through, I felt a sense of defeat so acute it almost left me paralyzed. Only Gloria, who was the longest of my flames on board in the ten years, who consoled me when I had cried over my barren womb, kept me honest and helped me to my feet when abject bleakness took away all will that evening.

The next day, when the light of Proxima Centauri cast its strange diffuse shadows, we got up and walked this land again. The one thing that we could agree on: there was a low-level sound, a kind of white noise that seemed to follow us. It wasn't on any of the sensors, but there it was, as we peeked under yet another slate of the slate-strewn land – that we found was neither rock nor metal.

The AIs could not tell us what the sound was, nor even locate the presence of a sound or a source. Nor could they say what material the planet was made of. The core was liquid, that we knew, but what about all these slabs we were constantly negotiating with in our boots?

*

We split into teams. I packed my things, throwing in a few of the hemoglobin adhesives, a hydrobar, and a scanner into the compartments of my utility belt. Gloria came with me. It only made sense, since she was the most chipper and brazen, and I was likely the most morose. I didn't care. I didn't need a badge of merit as "best

attitude for an explorer." I just needed support. Her xenoanthropology background made her a prime candidate for finding the supposed aliens, who were looking to be more remote as the hours went by. Why go through the trouble of sending out signals, if you weren't going to take calls? If you weren't going to check in? But, it had been years since they sent them out and maybe now the calls were silent.

She sent out various kinds of "messages" – audio, motion, smell, pheromonic, etc. – unleashed a concoction of labels that would say, "I'm here, please come out!" I helped her seal and stabilize these messages. She sent these out on drones, who would be able to cover more ground than our bounding steps alone.

As we traversed, we came up to a mountain. It wasn't made of slabs, unlike all the spaces that haphazardly made up this alien landscape. It was a veritable mountain of diverse objects of the same material of all different sizes. It loomed over us, breathtaking in its majesty, like approaching pyramids in the midst of desert sand. This definitely had to be the hand of intelligence right there.

There was very little natural light in this area, almost none. We had to blast out our LEDs from our helmets so we could see, stark white light that made everything look eerie. The air felt strangely dense, though there were no readings in our scans that would suggest why. We wondered if it was this air, like an invisible

cloud, that occluded Proxima Centauri's rouge luminosity.

With the projected light from our helmets, we took many scans, photos, and videos. We documented the different formations, discrete pieces that had flat planes and roundness to their attributes. There was a kind of Gaudí characteristic to the overall look of the mountain, not sharp, pointed and triangular like the Rockies, Everest, or any mountain on Earth, but a kind of rounded curvature to the overall heft of it. It was not a smooth landscape; it was an assemblage. I could tell that it was heaped on. That there must have been some machinery or guiding hand that had collected this and stacked it here. Was it a garbage dump? Ruins? A monument? Was it some kind of sign that we had to decipher?

I was way over my head. I could not process this kind of data. It wasn't radio waves or light. Whatever triggered that radio signal anomaly years ago must have scattered away, departed into the abyss somewhere out there, or have retreated somewhere undetected. What was left was material we could not determine, amassed in a means we could not understand the nature of. We could use an archeologist, xeno or not. We could probably use the consulting powers of all our Terran people. But, there was only the two of us, and our messages could not pass through the thick blockage of this atmosphere enough to get to the others before night.

We poked around, trying to disturb as little as possible. I felt like a grave robber. Was I destroying the sanctity of this site by stepping in it? Luckily, given the gravity, our footsteps were relatively light and our boots left few tracks on this strange, shiny gray material.

*

Two hours later and we had covered the whole of this mountain and documented almost all the parts. We couldn't avoid disturbing some of the material, but agitated as little as we could. If anything, the air felt even thicker, it took some muscling to simply walk, even though the amount of gravity was on our side.

I followed Gloria, who was giving out upbeat looks. Her buoyant stride and can-do attitude were starting to wear on me. After descending down the mountain, I got sick of stalking around in heaviness.

I couldn't take it anymore. A fit of total inanity and childishness overcame me. But, it was more than that. I thought I saw the tiniest hand, a little closed fist as an imprint on one of the rocks. Something I had seen in ultrasound photos.

I knew I must have imagined it, because in a moment the image was gone. I stared at the rock, pushed my hand against it, despite our objective of not disturbing anything. But, nothing. It was like it was never there. Like my fetus never existed.

I couldn't bear it. My frustration skyrocketed. I kicked the slab hard where my phantom impression had projected. My leg got caught. A sharp edge hooked onto my suit and tore the fabric at my knee.

I still don't know why I did it. It's not easy to explain. A presence bore down on me, teased me with an image, filled me with a wave of complete hopelessness, and I just needed to act out.

Oxygen rushed out of my suit and I cursed loud. Gloria calmed me down through the comm from her end and hurried over. I was bleeding.

I was such an idiot.

I threw on two hemoglobin adhesives over the rip. They gave off a green light once activated, drinking a sample from my blood, drawing it through my vessels and skin, and calibrating. I calmed down, knowing it was feeding nutrients back into me. I stared at the green patch of light reflecting onto the strange material, a ray that bounced out onto the corner of an alien slab. Out of my peripheral vision, I saw Gloria follow my gaze. I held my stare; something was keeping me from moving my eyes.

There. That was what it was. The green light, it was dissipating, stretching out, moving of its accord. For a moment, I thought it made the nebulous shape of that fetal fist again, but it soon shifted and perhaps it was only my imagination.

Then everything started quaking.

*

A gush rose from the mountain. I gasped.

Oh no, this wasn't a mountain. It was a volcano.

We clambered far away. A pool of red, so crimson and bloodlike, spilled out of this landmass and chased after us. It wasn't just after us, it was pooling in all directions, but it seemed like we were one of the targets of its lava tendrils.

But, it wasn't sizzling the land at all. It wasn't destroying everything in its wake. The Gaudí pieces seemed to separate themselves, as if coming alive. They slip-slid against each other, coating in the liquid. They were being lubricated, oiled. They were *moving*.

In my head, things were starting to piece together. Maybe it was from the frustration of the kick and the panic that overcame me. But, as we bounded away, Gloria and I, hoping that the oils wouldn't reach our ship, I had a flash of insight.

The rush of blood, the lifeforce oozing away, this was it: *the blood, the lifeforce*. *The hand, my kin*. The expulsion of the entity from my womb, half-grown not quite yet a baby. Blood clots, stuck, something that fastened and wouldn't let go. Not yet.

It was about reproduction, or about production, at least. I could tell. Call it a moment of eureka, a maternal instinct, a pulse of realization – though I was no mother, only yearning, desperate to be one.

*

We hid out in our ship. All of us came back alive, except one. There were five of us gathered now. Kiki was out there, we hoped, and we sent probes and sent out two of our team, but even after exhaustive searches we could not find her. The red blood, the lubricant, continued to spill forth. It took some adjusting but the AI systems got the scanners to detect and monitor this planetary broth from afar. And we watched as it continued to paw through the land, with its liquid lick.

*

I had dreams, of seeing blood, of tubes pulling out the body of my not-yet child. Of loss. I saw production, or the capacity for life. A tiny fist, strength in will.

Then the volcano, and the spilling of red, all over. Red gush from the Captain. The rolling hill of his head to his chest to waist. Red gush from Gaudí assemblage. The rolling hill of its slapped together parts. My eyes burned in rouge. I was swimming past the scarlet globules, raging in front of the spill, hoping its crimson touch would not get me.

And then I would awake, thinking of gears and machinery. Of waterways and circuitry. The machinery, it was coming alive, the light of our tech, activated by our

blood – searing past the sealed-off density of the strange air and giving it propulsion.

The sleeping giant awakes.

*

Some of the red rivers, the gush of red current, had receded and we took the chance to step into those receded "banks" and push forth to see the Gaudí assemblage mountain again. Where did the red go to? We thought it was lubricating, absorbed into whatever this planet was made of. That was the most likely scenario crunched by the AIs.

We still hadn't found Kiki.

The assemblage was double its size, the mountain not just looming, but threatening, like a god that had risen up from the land itself. How did it get to be this big?

Was it like a plant that thirsted for water and once fed, burst to life, erect, upright, pulled back to life?

There was nothing that indicated it was organic, but perhaps organic was always a Terran term that could not be transplanted here.

When we looked closer, three of us this time, acting-Captain Anjali from the back, Gloria and I pressing forward, we could see that it was replicating. Layer by layer, as if being 3-D printed. We watched as the landforms pulled up from our feet, raising us, a centimeter at a time, jarring our balance.

Caution prevailed over our curiosity and we returned back before we would be pushed so high we couldn't climb back down. It didn't seem probable, but we couldn't yet calculate the rate of its growth. I avoided all the blood splatters, the oozing of the red, remembering the lubricant that had escaped my womb. The hand that never got to be.

*

"It's so high, it's past sky-high. I don't know what to call it. It must be rising up like a skyscraper," I said. Back on our ship, we were a distance away, but I wouldn't say safe. Not exactly.

"It's not just happening there, the land is being pushed up, new slabs are forming," said Anjali, as she consulted her geological literature. "There's nothing like this I've seen. It's not exactly tectonic plates, it's not just rock formation. This is too fast, too regulated, too… everything."

"Too freakin' weird," said Gloria.

The rest of our team convened. Kiki had been found, wedged between two slabs, the material growing out of her knee. The biologist and medic, Ramon, tried treating her best he could, keeping her in an isolated space. But Kiki was light-headed and we didn't know if she would live. She was oozing red, part blood, part the liquid of this land, and I couldn't bear seeing more blood

here. I took a look at her once from outside the chamber and vowed not to go in. Medic Ramon kept a drone ferrying this liquid out of our domain, in case it would gush forth and cause the material in her to multiply. We couldn't contaminate our ship-turned-habitat. It was only our space of safety and our way out of here.

I hated to admit it, but a dark part of me wished they hadn't brought her back.

*

They knew I had hemo stickies, and reluctantly, I gave some over for Kiki's convalescence. I only divvied out two. I didn't trust its interaction with anything with this land, but I knew there was also something else. Deep inside me I had an instinct.

I also forked over two reviving sticks. I made a big show of having none left after that.

I regretted kicking the slab, regretted getting cut, regretted slapping on the medical adhesive. It was that light that had been stretched out in strange ways. How could I have known?

And yet, there was some growing comprehension in me. That I was supposed to kick it. That I was supposed to dream up that tiny fist. That it was supposed to bleed out. And as two more days passed, while the crew and I worked on repairs with the few replacements and makeshift resourceful cobbling together we exacted,

the comprehension gnawed at me. It ballooned as I sealed the doors with repurposed silicone drinking packages and reinforced the walls with climate-conditioning spray. It stuck to my throat, like the lemony scent of the spritzer.

It crept onto me, begging me, a pulsing sense of motherhood deep in my loins, until I went to see Kiki the day before we were set to leave. This was the reckoning, the final day I could do something about the compelling notion I felt so acutely from within.

I was going to do something about it.

Her body was still, obviously unconscious, the slab in her knee growing, even as Ramon continued to cut and discard the material to the outdoors via drone ferry. It was like keratin, like our fingernails and toes; she had the armor of this land coming out of her joint. She had it excised periodically, but it would come again.

I brought to her the lighted stickies and removed the safety wrap. I was fully covered in a hazmat suit, no way I would be contaminated, but fear still pricked me. I knew something would happen, but I wasn't sure what.

Caution enveloped me, but a greater impulse brought my hand forth to cover her leg with the stickies. Five of them. One after another, with swift movements, before I could stop myself.

The light bent around her knee in strange ways. It was irregular. Blood came pouring out – or was it the dark crimson of this land? I yelped, called for a drone, but

there was so much of the liquid, coming out and cascading.

The drone wasn't big enough.

I called out for another and tried to gather the blood. We couldn't let it get everywhere. Who knew what it would it do to our beloved ship and shelter?

I pulled Kiki into the drone, packing her limbs into the small vehicle as best I could, and then stuffed all the stained medical slurpcloths that had absorbed the blood into any available crevice in the mobile. I dumped a whole box of slurpcloths out and let it pull out the strange viscous fluid from her knee. I injected her with all my remaining reviving sticks that I had been saving for an emergency.

They didn't seem to do a thing. I improvised, going for the emerg pack. I set a small field around her – one we didn't use often since it was such a power drain – so she would be protected from the land. There was just enough juice to last for a few hours.

We rode while I directed the drones to the mountain. It took an hour on the highest speed, and I wondered what everyone else back at the spaceship was doing. Probably sleeping. Maybe Gloria was awake. She was always a night owl.

It was dark, the rays from the helmet and the green eerie hue of the adhesives lighting the way. The adhesive light bent strangely when it interacted with the land, the

green glimmer tossed around, zipping forth from slab to slab on the ground.

Perhaps it was the interaction of organic and the growth of this land, whatever it was, one of the scanners started to pick up something, an anomaly, a kind of radio signal that I had remembered from so long ago. The blip that gave me reason to think there was life on this land. The signal that brought us here.

When we came to the mountain, it reached so far out into the heavens, I could not see its apex. All the land had risen up. It was foolish of me to come here alone. I should've brought a team of drones, backup in case I slipped. I could feel the land still jittering under me, elevating on its own accord.

The light of the hemoglobin adhesive danced about, stretched out like taffy then rebounded, jumping from discrete item to item in this alien assembly.

Blood. I offer you blood, I thought. *Blood and technology.*

The green light interacted with the mountain in an excited frenzy. It swung about, dancing on every piece of the assembly, in a synchronous intertwining waltz.

I gaped, mouth hung open, breathing in the dry air of my suit.

Kiki stirred. I reached my glove through the field, pulled off the drenched slurpcloths and then the pieces of the invading slab off her knee, which fell to brittle outside the field. The brittle recollected itself and a jet of the red

ooze spurt forth and lubricated it before it was incorporated into the land.

I pulled out a half dozen green stickies from my utility belt, peeled off the safety and activated them with Kiki's used slurpcloths and threw them up in the air. They lifted up and were "grabbed" by the mountain detritus. I pulled out ones that I had used days ago from the rock tear still stuffed in another compartment in my belt, their tech infused with my blood, traces of the concoction of manufactured hemoglobin and my DNA left behind, and threw them over as well. I didn't dare stay to see what happened.

I commanded the drones to race away. We fled, moving swiftly over the strange terrain on our vehicles. A rumble shook the land and with a quivering voice, I commanded the drones to go faster.

When I got back to the spaceship, Proxima Centauri was already peeking out its shy gaze. It was morning. The strange orange haze once again lit up the onyx surface of our ship. The rumbles had stopped.

We were expected to leave today. We had received word that Earth might make it after all, that treaties were signed – must have been signed four plus years ago – that the worrywarts spreading hate of potential ET colonizers prevailed and part of the multilateral pact was for our crew to avoid alerting any aliens of our existence, a reversal of decisions past. It was just like politics, to swing one way and then back. We had the choice to stay here or

go back if we wished, but if we stayed we were ordered to avoid foreign contact and would have to retreat to Proxima b, where there was no sign of life. In light of this, the crew had voted majority on leaving, to get off this eerie, unaccommodating, intelligent-less bust of a place and the dangers it spelled and make our return home. We didn't have enough food or water to stay here much longer anyway. We left a few drones to keep watch.

We took off with samples rendered inert by the moat of air that surrounded it, all contained in specimen vessels.

*

From the spaceship window, I watched as we took off, all of us holding our breaths, hoping this spaceship would survive the launch. We were so much higher in elevation than we were weeks ago when we arrived. The planet becoming much bigger than it once was. It was still shifting. We could see it replicating, or doing whatever it was doing, layer by layer, adding onto itself.

The spaceship shook as it blasted off, waking Kiki with its violent tremors.

"It's more than a geological anomaly," she said, rubbing her knee. "It's something far stranger."

*

It was only decades later, when we had returned to Earth – when the material sample had been probed, tested, placed into the highest levels of security on an orbiting space station – that we discovered what it was.

I already knew long ago, but I kept it to myself.

In our absence, humanity had realized that given an objective, it could collectivize and aim towards the goal. They had done it sending us into space. And they would do it again to at least try fixing our Earth and bringing a lab into orbit.

They completed both those tasks, scrounging and cobbling best they could.

We came back to a more hopeful Earth, even if the news we brought back was less than hopeful. No intelligent beings to bring us better tech. No trading for our salvation. But, at least our people had tried our best, we would hope to prevail, come what may.

Only the strange material from Proxima c land and its fluids suggested otherwise.

The tests concluded it was machinery left behind, oiled by the liquid of the land. It did implicate a higher intelligent being, but one that had fled long ago.

Blood, I whispered to myself.

The machinery that had covered Proxima c was rendered inert by the thickness of the atmosphere, a chemical stop button poured onto the massive engine. But, given blood, or rather, some tech version of it, hemoglobin infusion, activated through mingling with

traces of human blood that calibrated the transfusion, *it* came on, powered up, and its interactions intensified and magnified, begetting and begetting.

It was a self-replicating machine. Perhaps it had some purpose in the past, one that sent out those anomalous signals – to create some material resource that was useful. But, now, it seemed to run on its own accord.

It stank of the fatalism of the paperclip maximizing AIs, of tech run amok, of instructions given and then abandoned – sealed off with the dense additives to the atmosphere as a stop-measure.

I never really told anyone that it was my maternal impulse that turned it back on. That I had activated the hemoglobin stickies with blood from Kiki and I. Giving it lifeforce, or something to that end. All the scientific data converged, with experts agreeing it was the disturbance that had turned it back on. They surmised it was the pheromonic stink of our flesh and blood – and some thought it was simply a product of time. But, I knew and perhaps deep inside Gloria and Kiki knew, too.

It was the hemoglobin tech, induced into activation by synchronization with our blood, the interaction I propelled that jarred the machinery awake.

The machinery was an existential threat to our universe. One distant and not entirely pressing. But, once reactivated, the engine of production showed no signs of stopping. It was self-perpetuating, replicating, and would only get bigger and bigger. Its internal oils, that thick red,

seemed also to reproduce itself. A command that had gone haywire, perhaps, with a quick-fix plug, a cursory halt, and an escape by the civilization that had left it behind.

And I had pulled out that plug, let the spigot run.

Blood, nourishing blood.

It would take millions of years before the machinery-exoplanet grew big enough to do harm to us, but who knew what harm it would do to the fabric of space-time? Who knew the repercussions to the neighbors we had at Alpha Centauri? If it would wipe out those persistent cat eyes? If it would obliterate its associates? Perhaps it was the aberrant fifth wheel finally rampaging in its romantic neglect.

Earth coalitions were already mobilizing a team to go stop it. To figure out a way to reproduce the atmospheric chemical that might shut it off and contain it.

*

But, I? Well, I smile sometimes in my sleep.

I know, it's terrible, I unleashed a monster into this world. A mechanical monster, all tech and no reason. One that grows and grows and gobbles everything in its path. A sleeping giant awakened, and burgeoning, budding, layering up in its mass.

But, still, I smile.

In my womb, I feel the pulse of life. It resonates with the emptiness of space, the cavernous peal that beats in my flesh. It's not one of my own DNA, but one that lives because of it. Mechanical, menacing, inorganic, and possibly a death sentence to us all.

But, it was my hand that had brought it to life. It was the chemical reaction of my sanguine fluid, my hemoglobin stickies, my touch, and my action – my beautiful, horrendous, abominable baby.

With a pounding fist of fury.

Bound to me by blood and growing up so fast.

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Deadly paperclips & other paradox solution attempts

This story stands apart from the rest included here by not being anywhere near the hard SF subgenre (science fiction that's mostly scientifically accurate), instead being based on metaphors of blood relations, longing and the price we're willing to pay for a blood legacy. But it still raises an important point for us: Where are *they*?

They of course meaning alien civilizations.

Once it appeared clear that even conventional propulsion should enable a batch of starships or self-replicating probes to cover most of our galaxy on timescales shorter than the existence of the genus *Homo*, the question became inevitable. Named after the famous physicist Enrico Fermi, who asked the legendary "But where is everybody?" at a 1950 lunch in Los Alamos with Teller, Konopinski and York, the paradox has since gained popular recognition and amassed a number of potential explanations. At this point, I could start enumerating the most important – or I could reprint the relevant sections of an article we've already written with my colleague Tomáš Petrásek for *Clarkesworld* a few years ago (Novakova & Petrasek 2017):

> "The universe around us echoes with the Great Silence. It seems oppressive to some, foreboding to others. We have not picked up any alien transmissions; seen any indications of interstellar travel or construction; met any other civilization. Yet even with propulsion systems based on known technological principles, it should be

possible to colonize the whole Galaxy within hundreds of thousands to several million years. Enter the famous Fermi Paradox: Where are they?

We've all seen the proposed hypotheses of the "zoo," "Galactic federation," or the bleak possibility of an inevitable nuclear apocalypse awaiting any technological culture. But is the Fermi Paradox really such a big paradox?

…

Maybe we're just using the wrong assumptions. True enough; can we even expect a complete Galaxy colonization? One would argue that interstellar expansion would be an adventurous business, with unfathomable dangers and uncertainties facing any ship trying to boldly go where no one has gone before, or even a nascent colony. Colonization waves might be slowed down or even stopped by essentially accidental, yet unavoidable factors both external and internal.

But what if interstellar travel is so difficult that it's near impossible, for ships bearing organic beings at least? It's also possible that favorability of local conditions plays a larger role than we expect. It's not just the "trivial" factors such as stellar type, presence of potentially habitable planets. What if, for example, different elemental and isotopic compositions of various planetary systems severely limit the colonization options, and to some extent exploration/self-replication probes too?

If we look at the Earth, we don't see human settlements everywhere. We have huge cities overflowing with people on one hand, and vast

empty spaces – especially deserts and mountains – on the other, and we're still speaking just about the landmass. Maybe we just happen to sit in the middle of a galactic desert?

Perhaps ecological models can help us out. One of the simplest models of a species' expansion is the percolation model (widely used also in material science and other fields), using a three-dimensional network of sites that are either connected or disconnected with a certain probability. NASA scientist and well-known SF writer Geoffrey Landis (1998) applied the model to an interstellar civilization's proliferation.

Due to time lags, we could expect that colonies will develop cultures different from their mother culture (and will also have different resources at their disposal). Some may therefore continue exploration, while other ones develop a non-colonizing civilization. If the probability of continuing colonization falls below the critical probability, the growth will stop after a finite number of colonized star systems. If the probability exceeds the critical threshold, there would still exist voids at any given time. It rests on the assumption that there is a maximum distance which allows new colonies to be directly established (in other words, that we could for example directly colonize Proxima Centauri but not the more distant Epsilon Eridani – for that, we would need another site in-between), which seems reasonable, though the actual distance itself would be difficult to constrain. Another assumption is that an

already colonized world is not suitable for a new wave of colonization.

It could account for the lack of known interstellar civilizations around us; however, it doesn't solve the problem of the apparent lack of self-reproducing probes. If von Neumann probes are realistic (which is an assumption in itself), how come we haven't seen any? Is it because they are mostly instructed to stay away from civilizations? Programmed to only use a very small amount of matter in each system to continue proliferation? Or are we here because we're lucky and they haven't converted our system yet?

A nice solution to this aspect of the Fermi Paradox is outlined in David Brin's novel *Existence*. The monumental novel tackles various problems related to it – How unique are we? What happens when any single person achieves the capacity of destroying an entire civilization at a whim? Could seedling ships succeed? Will AIs join us, replace us, merge with us? – but revolves especially around the finding of several alien artifacts, ambassador probes that establish communication with humanity and invite it to join their respective collectives.

To avoid spoilers, let us just say that it may not be a bad idea to look at more biological systems, be they complex ecosystems, epidemiological models, or semelparous plants, when considering the Fermi Paradox – or even things like spambots or chain mail – and to distinguish the survival of civilizations and individuals. Though perhaps counterintuitive, the latter may persist for much longer times.

…

The destroyer theories. They're just as popular as the optimistic (one would be tempted to say naïve) hypotheses of the "zoo" or "federation." Despite the vast interstellar distances, civilizations may routinely destroy each other in struggle for resources, territory, or just out of fear of the others striking first, and only those fearful enough to stay hidden remain out there. Do we live in such "dark forest," like many science fiction stories seem to suggest (recently e.g. Liu Cixin's aptly titled second volume of his *Remembrance of Earth's Past* trilogy, or earlier works by Alastair Reynolds, Greg Bear and many others)? Community ecology has a term called "landscapes of fear" that applies to predator-prey interaction. Could similar dynamics be applied to galactic civilizations' interactions? So far, we have no way of knowing.

…

Self-destruction. Where does the threshold for the missing galaxy-colonizing civilizations lie? Is there a "Gaia bottleneck" of establishing biogeochemical feedback cycles, leading to the relative scarcity of planets habitable for complex life? Is intelligence so rare? Is advanced technology? Or do advanced civilizations commonly destroy themselves? A pessimist might fear that we're destroying our environment and ushering forward a new civilization collapse, propelled by drinking water shortage and fertile ground scarcity, local environmental disasters, extinctions leading to severe ecosystem shifts.

…

What's the ideal time for expanding beyond Earth? When does it quickly enough cease to be a deep resource sink and become beneficial in the overall sum? What should such risk assessments look like? There are a number of things that could wipe out our civilization or make it collapse. A large enough asteroid impact or volcanic event, a nearby enough supernova explosion, even a rare solar flare strong enough to fry most of our electronics, even though life itself would remain practically unaffected.

These are all extremely rare events – but they are as unpredictable as it gets. We might get on without any for many millions of years, or something like that could occur next week. How prepared should we be? Would more near-Earth asteroid surveys and testing mitigation techniques suffice? Should we found space colonies as soon as we can, even though they wouldn't be self-sufficient for decades, if not centuries? Many people would argue that we should invest first and foremost in eliminating poverty, promoting health care and education, and protecting our environment. But this may be a false problem – it's not either/or. Resources taken off human spaceflight don't magically appear in solving health, environmental, or social issues. While the Optimist calls for spaceflight support, the Pessimist argues that our attention should focus elsewhere.

The Fermi Paradox may be more relevant for our own future ventures than most people realize – but it's a pity we know so little about it. Our

speculations are countless – but we need more testable predictions and the data to test them. Current and near-future ground and space-based surveys such as K2, Gaia, HARPS, NGTS, TESS, CHEOPS, PLATO and many more will vastly improve our data on exoplanets and their host stars. Telescopes such as JWST may greatly contribute to our knowledge of the planets' characteristics and potential chances for life. Solar system missions like ExoMars, Mars 2020, or JUICE may tell us more about the (un)availability of conditions for life within our own system, and the uniqueness of Earth.

As to the pressing questions of the likelihood of emergence of intelligence, number of technological civilizations, galactic deserts or habitable zones, expansion speeds, difficulty of interstellar travel, and safety of actively transmitting – we'll need much more for that. And concerning the tendency of civilizations to survive, communicate, colonize, and make wise decisions about the future, we ourselves are the only example we have so far, and it seems like a good idea to try our best to prove the more optimistic hypotheses – by demonstration.

Is it the Optimist, or the Pessimist who will be proven right? Both presented valid points and raised reasonable arguments, and almost any explanation of the Fermi Paradox we can think of tells us something important about us, our future and choices we should make. Finally, if we are truly alone in the Galaxy, isn't it the best time to start exploring?"

Well. You can clearly see there are a lot of pressing questions surrounding the Fermi Paradox. No wonder some people are warning before any METI attempts despite the tremendous distances between stars (and potential civilizations around them). No wonder it inspires sentiments such as the one in this 2017 NY Times article by Steven Johnson: "There is something about the METI question that forces the mind to stretch beyond its usual limits. You have to imagine some radically different form of intelligence, using only your human intelligence. You have to imagine time scales on which a decision made in 2017 might trigger momentous consequences 10,000 years from now. The sheer magnitude of those consequences challenges our usual measures of cause and effect. Whether you believe that the aliens are likely to be warriors or Zen masters, if you think that METI has a reasonable chance of making contact with another intelligent organism somewhere in the Milky Way, then you have to accept that this small group of astronomers and science-fiction authors and billionaire patrons debating semi-prime numbers and the ubiquity of visual intelligence may in fact be wrestling with a decision that could prove to be the most transformative one in the history of human civilization. All of which takes us back to a much more down-to-earth, but no less challenging, question: Who gets to decide?"

Yes; who does? I find it difficult to imagine that any kind of overarching legislation would come to pass anytime soon (much less one people would *adhere* to).

There are some procedures drafted for the scenario of first contact, direct or via signal transmission, but there is no way of enforcing them. Any first contact scenario made public would necessarily result in much confusion and upheaval, and it's impossible to say with much certainty what to expect. One thing we shouldn't expect, though, is dispatching a crewed interstellar mission upon detecting a radio signal, even from the nearest star. Unless someone with little regard for both science and diplomacy and loving reckless grandiose gestures is in charge. (Okay, looking across the Atlantic right now, I take the "shouldn't expect" back.) In reality, we should rather expect transmitting a reply and then waiting for theirs. Lots of telescope time would be devoted to observing the source system. Finally, if we (but who exactly *we*?) concluded that it's safe enough to send a robotic probe, preparations for that might commence. Before any landing would be even contemplated (provided that the probe underwent extreme scrutiny because of planetary protection, despite the expected sterilizing effect of the interstellar journey), at least months, if not years of remote observations (radar, lidar, spectra, gravitational and magnetic field data...) would be collected. That a human foot would touch where no geophysical measurement has been made will likely remain the (exciting, but too perilous) realm of fiction for sound reasons.

Spires' story also mentions two points related to the Fermi Paradox: the Drake Equation, and one of the more pessimistic suggested explanations for the paradox in the form of AI/nanotechnology gone awry.

Let's have a look at the former first. The famous equation, where N denotes the expected number of technological civilizations in the galaxy, goes like this:

$$N = R_* * f_p * n_e * f_l * f_i * f_c * L$$

R_* indicates the average rate of star formation in our galaxy, which we can be pretty confident about. In our Galaxy at present, it's approximately 3 stars per year (give or take; the estimate is 1 to 2 solar masses per year, but the majority of stars are less massive than our Sun).

f_p denotes the fraction of stars with planets. Current estimates, based on large-scale observations e.g. by telescopes such as Kepler or COROT, or from microlensing surveys, lean toward high probabilities – close to 1. You may use a value like 0.7 if you're being pessimistic, 0.99 if you're being optimistic…

n_e is the mean number of planets that can potentially support life in a given planetary system. Again, our estimates here are based on statistical generalizations from existing observational data, and it could be somewhere between 0.25 and over 1. It's a wide interval, we know, but future missions will further constrain it. Some anecdotal evidence: It seems that systems with multiple planets within the "habitable zone" are not that rare. For instance, TRAPPIST-1 has made a big splash in the media. But remember that the habitable zone denotes that the planet receives such stellar flux that allows the existence of liquid water on the planet's surface under a model atmosphere; it

doesn't deal with the planet's size, composition, geology, actual atmosphere, or the stellar activity…

f_l is the fraction of those planets that develop life. Here we encounter a problem. We only know one life-bearing planet: our Earth. How can we derive anything from a sample of one? Would a comparison with Mars and Venus help? Or perhaps the fact that life likely appeared on Earth already shortly after the Late Heavy Bombardment period, perhaps even earlier? Has it emerged in periodic ponds, deep-sea hydrothermal vents, under the surface in Earth's crust…? Did our planet accidentally hit the rare "just right" conditions, or would many other combinations of environmental conditions suffice too? We have too little evidence and models to reliably say almost anything.

It gets worse. f_i denotes the fraction of life-hosting planets where intelligent life has evolved. Again, hard to generalize from a sample of one. We could try to start from observations of intelligent behavior of apes, corvids, cetaceans and other groups, but you might guess closer to the truth using a crystal ball.

The next parameter, f_c, is the fraction of these civilizations that developed technology and are capable of transmitting detectable signals. How likely is a technological civilization? Does it depend on the cloud/haze cover, landmass, environmental diversity, elemental and isotopic ratios of a given life-bearing planet? Here we can introduce hundreds of wonderful speculations that might serve as a basis for brilliant science fiction stories, but in reality, we have no hard data to test them.

Finally, L denotes the longevity of such civilizations. Here we can at least have a look at the duration of humanity's civilizations. Samuel Arbesman (2011), a Harvard-based scientist, studied the life-spans of empires from 3000 BCE to 600 CE, and concluded that the average length of an empire is about 220 years, and probability of its collapse was independent of its age. But is it relevant at all? After all, humanity is still here, though dynasties and cultures change. More relevant to this factor could be the extinction likelihood of a species, which doesn't seem to change with the species' current longevity. In other words, surviving tens of millions of years doesn't make you any more immune to extinction than a new species.

Taken together, the Drake Equation doesn't really tell us much – except how much we still don't know. For that, it's very useful. It can help us organize thoughts on what we need to find out and how, and what problems we may encounter on the way. It's a fruitful thought experiment, even if the number it yields must be taken with more than one grain of salt.

The sheer age and size of our galaxy intuitively tell us that there should have been other civilizations before us and at least some of them should have set off to explore other stellar systems. But we simply know too little to call this more than a gut feeling.

The final point I want to raise here follows the "It stank of the fatalism of the paperclip maximizing AIs, of tech run amok, of instructions given and then abandoned". Artificial intelligence and self-replicating machines (not necessarily together) have often been

invoked as one of the possible reasons for the Great Silence. What if all or most technological civilizations reach a point where their technology, not contained enough, becomes their undoing?

The problem is illustrated by a thought experiment by the futurist philosopher Nick Bostrom (2003): You tell an AI with the capability of learning and self-improvement to make paperclips. It starts optimizing for this goal. Becoming more intelligent and finding new ways to produce paperclips maximizes its new utility function. Eventually, it converts all the available material on Earth into paperclips and set off to start using the rest of the solar system and beyond…

If it sounds simplified the point of absurdity, remember that it's a thought experiment created to clearly show the problem. Replace making paperclips by averting the worst of climate change, reducing the risk of future pandemics or another complex task, and suddenly the idea of a self-improving black box with nigh-godlike capabilities doesn't sound so ridiculous. It's meant to show that we can't expect an AI to share our values and thought processes, unless expressly programmed to, and superintelligence may have unintended consequences. While the good old Skynet – the popular science-fictional scenario of an AI becoming "suddenly self-aware", hating humanity and deciding to wipe it out – is very much off the mark, negative effects of an AI maximizing for a given goal with no "evil intentions" are more realistic. As Yudkowsky (2008) pointed out: "The AI does not hate you, nor does it love

you, but you are made out of atoms which it can use for something else. ”

You can play a fun paperclip-making AI in the Universal Paperclips game at DecisionProblem.com. The mechanics and implications of the game are described well at HackerNoon.com.

It doesn’t have to come to optimizing for a goal with unintended consequences; an “AI apocalypse” might well be triggered by humans in different ways. What they would likely have in common is ignorance rather than malice. Yudkowsky (2008) points out that the field of AI is vast and many architectures are possible; yet most of us laypeople tend to oversimplify and even anthropomorphize AI. But ignorance could even be a part of AI “design”: “The human species came into existence through natural selection, which operates through the non-chance retention of chance mutations. One path leading to global catastrophe – to someone pressing the button with a mistaken idea of what the button does – is that Artificial Intelligence comes about through a similar accretion of working algorithms, with the researchers having no deep understanding of how the combined system works. Nonetheless they believe the AI will be friendly, with no strong visualization of the exact processes involved in producing friendly behavior, or any detailed understanding of what they mean by friendliness.”

I recommend reading the full paper; though perhaps older by the standards of the field, it raises questions that remain very much relevant and is very accessibly written. Some of its sections pertaining to

human biases could also be extended to other potential civilization-ending Great Filters (causes of the Cosmic Silence). Thinking of these: Will we ever have a way of telling if some of them happened elsewhere?

Remote detection of "necrosignatures" may seem to be a way, yet spectral signatures if civilization-dooming events (such as atomic war fallout in the atmosphere, or "grey goo" – nanotech out of control) are likely to be detectable in principle, but very weak and transient (Stevens et al. 2016). If you're a fan of zombies, there is also a fun April's Fools paper by Kane and Selsis (2014) in that vein. Already the abstract contains hilarious passages: "We quantify the extent of the danger posed to Earth through the use of the Zombie Drake Equation and show how this serves as a possible explanation for the Fermi Paradox. We demonstrate how to identify the resulting necrosignatures present in the atmospheres where a zombie apocalypse may have occurred so that the risk may be quantified."

We've made quite a leap here from the more abstract, general understanding of the Fermi Paradox to some very specific examples and even to scientists making fun of the topic in an ingenious way. The Fermi Paradox will likely remain an open question for very long. To be more certain of its answers, we need to employ the full range of astrobiology subdisciplines and related fields: to know even more about stellar formation and evolution, the formation of planetary systems, factors of habitability, the most frequent habitats in the universe, possible biochemistries, biosignatures, the conditions and likelihood of abiogenesis, the rise of

intelligence, environment and preadaptations leading to the origin of a technological civilization…

Astrobiology encompasses all of this. Most astrobiologists are currently concerned with the origin and evolution of life on Earth, its environmental limits, measuring conditions and proxies of habitability in the solar system and beyond, direct life detection in places such as Mars, Europa and Enceladus, or remote biosignature detection on exoplanets – these are all things we can examine now and in the very near future. But it doesn't stop there. Astrobiology is everywhere, related to other fields from astrophysics across chemistry all the way to behavioral sciences or philosophy.

It starts with the Big Bang, and goes on to the furthest galaxies and to the fate of the universe. Here we have made a journey from a subsurface ocean not too unlike those in our own solar system towards finding remains of alien civilizations. Perhaps, next time, we'll make an even farther one…

P.S.: In the time between writing this nonfiction follow-up and releasing the book, hints of existence of a second planet around Proxima Centauri have been published by Damasso et al. (2020). The candidate planet has over 5 Earth masses and orbits approximately 1.5 au from its star, a distance similar to Mars' orbit. However, Proxima Centauri is a very low-mass star and doesn't shine anywhere as brightly as the Sun, so at this distance, the planet must be frozen… unless it possesses a substantial atmosphere. That much we don't know, but its closeness to our solar system and distance from its own star makes

it (provided it really exists) an excellent candidate for further research by direct imaging and spectroscopic surveys to reveal if it has an atmosphere, and if so, what is its composition. The presence of the planet is testable with astrometric data from the Gaia satelite, so we should be able to confirm or reject its existence in the near future – and hopefully embark on the fantastic journey of characterizing this new world.

References

Arbesman, S. (2011). The life-spans of empires. *Historical Methods: A Journal of Quantitative and Interdisciplinary History*, *44*(3), 127-129.

Bostrom, N. (2003). Ethical issues in advanced artificial intelligence. *Science fiction and philosophy: from time travel to superintelligence*, 277-284.

Damasso, M., Del Sordo, F., Anglada-Escudé, G., Giacobbe, P., Sozzetti, A., Morbidelli, A., ... & Hambsch, F. J. (2020). A low-mass planet candidate orbiting Proxima Centauri at a distance of 1.5 AU. *Science Advances*, *6*(3), eaax7467.

Landis, G. A. (1998). The Fermi paradox: an approach based on percolation theory. *Journal of the British Interplanetary Society*, *51*(5), 163-166.

Novakova, J. & Petrasek, T. (2017) An Optimist and Pessimist Tackle the Fermi Paradox. *Clarkesworld*, 133.

Yudkowsky, E. (2008). Artificial intelligence as a positive and negative factor in global risk. *Global catastrophic risks*, *1*(303), 184.

Further reading

The Great Silence: The Science and Philosophy of Fermi's Paradox. Milan M. Ćirković 422 pp. Oxford U.P., New York, 2018. Price: $32.95 (hardcover). ISBN 978-0-19-964630-2.

Classroom ideas

1. Play with the Drake Equation a bit. How different results do you get with your most optimistic or most pessimistic estimates? What pitfalls do you think the equation has?
2. Now that you've considered the Fermi Paradox, do you think METI (active SETI) is advisable? Why? (You can also split the class into two groups, one tasked to defend METI, another to argue against it.)
3. Building upon the previous question: Is it ethical if a small group of people (scientists; SF authors; politicians of a given party; people from a private rocket company…) decides on whether to send a message to potential alien civilizations? Do you think there should be some measures not unlike "planetary protection", but for METI? How would you try to enforce them, if at all possible?
4. Look up metapopulation dynamics and also the term "landscapes of fear". Do you think ecology can help us in answering some of the pressing questions about the Fermi Paradox and whether we should advertise our existence to outer space?

Afterword

by Julie Nováková

We've seen wonders and horrors; the joy of discovery as well as the despair of annihilation; choices both good and bad, right and wrong, wise and injudicious. The stories in this book took us on a journey from a Europa-like world through Uranus and the Kuiper Belt to planetary systems beyond our own.

We've also learned about the chances of life in subsurface oceans of (not only) Europa; high-pressure environments for life; possibilities of exotic silicon-based life in cold places with little sunlight; exotic photosynthesis; living Dyson spheres; SETI and finally the Fermi Paradox. In the bonus story included at the end of this anthology, you can return to the cradle of our solar system to a planet that's in the center of life-searching missions at the moment: Mars.

There are more places and times we could have visited: early Venus that may have possessed water oceans, its cloud layer right now, Saturn's intriguing moon Titan with its hydrocarbon seas, the putative water-salt-ammonia brines of faraway moons and dwarf planets, even the hellish Io, then a myriad of different exoplanets: tightly packed rocky and watery planets around a red dwarf star, planets on wildly eccentric orbits (and yet still potentially habitable for life as we know it), rogue planets, brown dwarfs, worlds orbiting stellar remnants such as white dwarfs or even neutron stars, and finally exotic locations in both early and late stages of our universe.

We will visit them in more of amazing science fiction stories, I'm sure. Our goal is to publish an anthology of original SF stories with astrobiology themes in a collaboration with EAI scientists, who would be able to provide feedback to the authors, answer their questions and conclude each story with a short fact commentary. We are working on a grant proposal for this and have queried with publishers, and we would like to have both solicited stories from professional authors and an open submissions call to discover new talent. So far, it's a dream project – but one laid on solid foundations.

I'd like to part with you with some inspirational phrase or quote, but that's too much of a cliché, isn't it? Still, this quote commonly attributed to Carl Sagan would do a wonderful job: "Somewhere, something incredible is waiting to be known."[4]

4 Too bad Sagan didn't say that; a *Newsweek* profile of Sagan by reporter Sharon Begley ended with that, and they were her words. We should avoid quoting blindly without checking the sources – whether in science or life! Regardless, the quote does its job. It inspires one to leap from the chair and go exploring, doesn't it? It's my hope that the stories and nonfiction texts in this book managed to do the same (while hopefully leaving a more substantial legacy of knowledge beside this feeling).

BONUS STORY

Martian Fever

by Julie Nováková

Julie Nováková (* 1991) is an evolutionary biologist, educator and award-winning Czech author of science fiction and detective stories. She published seven novels, one anthology, one story collection and over thirty short pieces in Czech. Her work in English has appeared in *Clarkesworld*, *Asimov's*, *Analog* and elsewhere, and has been reprinted e.g. in *Rich Horton's The Year's Best Science Fiction & Fantasy 2019*. Some of her works have been translated into Chinese, Romanian, Estonian, Filipino, German and Portuguese, and she acts as a translator of Czech stories into English (in Tor.com, *Strange Horizons*, *F&SF*). She edited an anthology of Czech speculative fiction in translation, titled *Dreams From Beyond*, and co-edited an anthology of European SF in Filipino translation, *Haka*. Julie is a recipient of the European fandom's Encouragement Award and multiple Czech national genre awards. She's active in science outreach, education and nonfiction writing, and leads the outreach working group of the European Astrobiology Institute. She is a PhD candidate in evolutionary biology at the Charles University and likes to write popular science articles about fields ranging from behavioral science to planetary dynamics for *Clarkesworld*, *Analog* and other media. She's a member of the XPRIZE Sci-fi Advisory Council.

This time, I'm including the fact commentary at the *beginning*, not the end of a story. That's not the only unusual thing. It's not typical for an editor to include her own story – and indeed *should not* be done in case of open submissions and paid contributions. This, however, is a non-commercial reprint e-book with an aim to entertain and educate at the same time, and the story fits the purpose.

I devised it when attending the International Astronautical Congress in Guadajalara in 2016, most remembered for Elon Musk's pledge to bring humans to Mars in the 2020s and settle the Red Planet permanently.

Once it was time for questions, I wanted to ask for one thing about radiation shielding, since nothing at all was divulged about this extremely important point during the talk. Unfortunately, since I preferred to behave in a dignified, professional and just generally polite way, I had no chance of getting to the microphone, which was seized by crazy fans asking the entrepreneur whether he would kiss them, and other such nonsense that just made the rest of us go "ugh".

The other thing I badly wanted to ask about, since it was also completely omitted from the talk, was planetary protection.

Basically, once humans step on Mars, planetary protection – in this case avoiding contamination of other celestial bodies by Earth microbes – is screwed. Humans are walking canisters of microorganisms, a fact that can hardly be changed – we need them to survive. Unless we want to imagine cultivating microbe-free astronauts (sickly and hardly fit for a demanding interplanetary journey), we will contaminate Mars once we land a human crew there. Whatever

precautions we take, however many airlocks – you can never achieve a 100% sterilization.

However: Does it matter? Earth and Mars have been constantly exchanging material through natural means (meteorites shot from their respective surfaces by impacts). Besides, we've crashed so many poorly sterilized probes on the surface of Mars that some contaminants must have gotten there already. If they could survive is another question, one that many labs working with analog Martian conditions are trying to answer.

You may also be asking *why* does it matter. Even if some especially well-suited Earth microorganisms could survive in some areas of Mars, why shouldn't they? Even the simplest answer is twofold: First, they could potentially endanger any extant life (by outcompeting or accidentally "poisoning" it in some way rather than acting like a parasite that's magically adapted to a type of life it's never met before), and second, even if they *did not* survive under Martian conditions, their presence could lead to false positives in life detection by scientific missions – something that could gravely complicate our scientific understanding of Mars and let us spend millions of euros or dollars in vain.

For a much more detailed popular science summary of the problem, I'll direct you to my *Clarkesworld* article "Bugs from Outer Space & Invasive Earth: Planetary Protection".

However, we've only touched forward contamination so far – bringing Earth microbes elsewhere. But what if Mars had extant indigenous life? Could we risk backward contamination – potentially contaminating Earth?

I'll let the story speak for this one…

Lowell base, day 713

Up to the moment when Motsumi came down with fever, Mars colonization had been going relatively smoothly.

The news caught Alana outside, while she was scaling the slope of the Persbo Crater. Her breathing had been the dominant sound inside her helmet, with Fatima's breath on the comms, when a quiet beep announced a priority message, subject "contamination risk".

Alana waved at Fatima to stop; they planned to take a break during the ascent anyway. Incidentally, her heart rate monitor suggested she stop. But it didn't shoot up because of the physical exertion. She opened the message and glanced through the report. *It's just a new strain of cold or something*, she thought, anxious hope building up in her chest.

"We have to go back, something's come up," she said to Fatima.

It wasn't apparent until a few days later, but it wasn't a new strain of cold or something.

*

Full lockdown. Motsumi Baraka was moved to quarantine as soon as contamination was suspected. So were his colleagues he'd worked with outside, each in their own sealed room. They had five of these on-site. Four were occupied now.

No one was to venture outside. Everything was being thoroughly swiped and cleaned. Blood, stool, skin and buccal samples were collected from everyone in doubles.

It was presented as a drill. Lakshmi Chopra Narayanan, chief medic, made the suggestion.

"No one will fall for it, but it's better than saying *hey, we likely have alien contamination*," she stated during the emergency meeting in her deep coarse voice. "It can still prove to be a false alarm. In which case, the drill story holds."

Alana disagreed; so did Matteo Acuesta, the chief mission specialist. But Adelaide van der Woude from communication and outreach was on Lakshmi's side. The rest of the vote was also split evenly – until the last, deciding one remained.

Grant Woodward watched the medic pensively for a moment, and nodded.

So – a drill. One that included taking everyone's samples, resterilizing the airlocks, suits and equipment, and making sweeps of the whole base: all the steps outlined long before the base even existed, in procedures Alana helped to create.

She spent most time holed up in the lab, just like her fellow biologists, and hardly ate or slept. The analyses were seemingly endless, but all more or less pointed – each inconclusive alone – to the same conclusion.

It took them just two days to say with as much certainty as possible that Mars had extant indigenous life, and it was currently present in Motsumi Baraka's body.

***

Alana had first looked into a telescope when she'd been three years old. Her mother had shown her the Moon. Alana could see its features so close as if she were able to touch them.

"Do people live there too?" she asked.

"No," Mother replied with a soft smile. "But they will one day. We have walked on the Moon, and hopefully will again very soon."

"Nothing else lives there?"

"Nothing. But let me show you something else."

Mars was low above the horizon, but still the observation conditions were good. That was when Alana first saw the Red Planet with her own eyes, and dreamed of going there.

"It has life?"

"Perhaps not, but it might. We don't know."

"I want to know," she said, still gazing at it.

***

Day 716

Motsumi smiled a very terrified crooked smile: "At least I'll go down in history."

Behind the glass of the quarantine module, his face was thin and gleaming with sweat. Despite the extensive medication and nutrient supplements, he still looked feverish, exhausted.

"You most certainly will," Lakshmi assured him dryly. "But don't you dare go down now. Time for your next shot."

A spindly medbot moved to Motsumi smoothly and injected him. More anti-inflammatory meds. As far as Alana understood, it wasn't directly the infection that was threatening his life; it was his own body's extreme immune reaction to it.

She tried to imagine alien life proliferating inside him, and though she found herself unable of that, she was half-excited, half-terrified. They knew so little about it so far! Had it not been for Motsumi, she'd be beside herself with joy. But she'd never wished the first discovery of extraterrestrial life to go this way. It should have been a moment of triumph, not fear.

"More samples?" Motsumi attempted a smile as the medbot moved in to draw blood and do a muscle biopsy. The robot always reminded Alana of a praying mantis with its sleek long limbs and thin frame. Now the comparison made her shudder.

As soon as they were out of Motsumi's sight, Lakshmi said: "So. How serious?"

"You tell me."

"I mean for us all, not our Patient Zero."

Alana swallowed. "Hard to say this early."

"Facts."

"Okay, here are the facts." Alana exhaled. "Non-biological – not *Earth-life* – amino acids enriched in selenium can be found in Motsumi's blood and tissue samples. So can other strange biomarkers. Their concentration changes over time, and follows a pattern. It seems that the pathogen is barely able to persist in a human body – but it won't die right away, so it can both draw nutrients out of the body, and release too many foreign metabolites at once when it dies. That could be dangerous."

"The others' samples are contamination-free, so far."

Alana nodded. "But... you know what it still means."

"Yeah. And let me tell you: I quit smoking twenty years ago, and this is the first fucking time I really long to return to that filthy habit." Lakshmi's voice was firm as steel, but Alana noticed that her hands were shaking.

It didn't surprise her. Most of them had signed up for staying here for a few years, not for life – but that was exactly what could now easily happen to them.

Alana Trisolini's reasons of joining the Mars colony was perhaps the most peculiar of all. She was strongly *against* the Red Planet's colonization, and that's why she went.

Grant Christian Woodward's reasons, as far as the media coverage went, were finding a "spare home" for humanity, alleviating the overpopulated Earth, developing technologies useful for humanity anywhere, and establishing a new, more egalitarian society. Thousands of people across the globe were paid to discuss on TV, radio or journals' pages just how honestly could a tech billionaire really mean it.

Motsumi Baraka's principal reason, beyond his curiosity and want of exploration, was helping his family. The pay was good, and he would return to them after just four years, full of unique new experience. It was worth it, wasn't it?

As to Lakshmi Chopra Narayanan, she always wanted to be a space doctor.

There were as many reasons as people in the colony. But most were propelled by their curiosity, idealism or want of meaningful adventure; otherwise they wouldn't be here.

***

"Why do you criticize the concept of colonizing Mars so fiercely?"

Alana Trisolini had straightened her shoulders. She'd never felt comfortable during interviews, and this one was live. At least it was radio, not TV. "Any colonization automatically means forward contamination – bringing Earth microbes to Mars. We have to study Mars remotely, while it's pristine. Otherwise we lose the chance to study local life, if any exists, *forever*," she emphasized. "Then there's the risk of backward contamination – bringing Mars life back here. That might be a big problem, *especially* if it's distantly related to life on Earth. That's perhaps contrary to intuition, Earth and Mars have been exchanging meteorites throughout their whole history. If lithopanspermia – spreading of life this way – is possible, Earth microorganisms may have already gotten to Mars many times. If they survived there, they could have evolved very differently from their Earth relatives. But because of their relatedness, potentially dangerous backward contamination would be very feasible, and a very considerable risk, because the potential 'Martians' might be able to interact directly with life on Earth and disrupt our ecosystems. If you want a loose analogy, think of rabbits in Australia, but potentially much worse."

"But you said that there was a lot of meteorite exchange. What if there is life on Mars and it got to Earth multiple times already?" the reporter asked. Alana had to give it to her – she was quick on the uptake, though she

wasn't a science journalist. This was a damn *lifestyle broadcast*.

"True, but life on Mars may be isolated in a few environments conductive for life – with liquid water, which can't exist for long on the surface before evaporating, heat, nutrients... I'm guessing subsurface hydrothermal systems or lake and river systems beneath the polar ice caps. It may not have gotten a chance to get to Earth. But that's all speculation so far," Alana smiled wryly. "We have to wait with colonization until we know much more. Just give us a few more decades."

They didn't; it was scarcely four years after the interview when Woodward's colony concept was approved, and that's why she applied for the mission as soon as it became apparent that it would actually happen. Fortunately, Woodward wanted to cooperate with as many space agencies as possible in the crew selection, so Alana went on behalf of ESA amid a few others. NASA, CSA, EAM, JAXA, KARI, Roscosmos, SANSA, ISRO, CNSA – each had at least one person on the Red Planet.

Unlike many of the unaffiliated volunteers, none of these people planned staying for the rest of their lives. The more Alana worked on finding out what happened in Motsumi's case, the more certain she was that no one would return home. Not that they wouldn't be able; they wouldn't be *allowed*.

After all, she'd helped draft the regulations herself.

If a life form of foreign origin is capable of surviving and reproducing in Earth environment, contamination must be avoided at all cost. Including leaving a hundred people on the Red Planet to die. Otherwise we might… get off lightly and see the organism integrated into our biosphere – or disrupting all of it in the worst case.

Not an "end of the world" scenario, unless borrowed by screenwriters. But a mess that might cost countless lives, disrupt economies and ecosystems and take millennia to fully recover from. Alana could imagine crop failures, sick people and animals, ecosystem collapses… If this Martian could outcompete most of Earth life in just one small way and fare reasonably in others, contamination *might* be catastrophic. Not likely, but *might* sufficed just enough.

"Alana. Time for the meeting," Lakshmi spoke through the lab intercom.

When she entered the small conference room, eleven people already waited in there: Lakshmi, as the chief physician and an ISRO representative; Grant Woodward as the father of this project; Matteo Acuesta as the MS and ESA delegate; and then a representative of each of the other involved space agencies.

"Can you sum up what we know about the pathogen so far?" Woodward asked Alana.

She tried to do her best in summarizing all the *unknowns*, *margins of error* and *uncertainties*. "What we

do know for sure at this time," she concluded, "is that the extracted material contains DNA similar, but not identical to known life. The major difference is that it utilizes two different bases instead of guanine and cytosine. The proteins consist of left-handed amino acids, like ours, but they use many different ones and tend to incorporate selenium. The isotopic composition also differs, though that's beginning to fade as it draws nutrients from Motsumi's body. The most likely, simplest explanation is that we're dealing with indigenous life. We can't rule out a common ancestor with Earth life, but given the differences, it would have to have been maybe some four billion years ago, when life had just started."

"What about its influence on human body?"

Lakshmi took this question. "Some of the foreign amino acids are toxic to us. But a more important question is how come *we*'re not so toxic to *them* that they would die out."

"Are you sure they aren't dying?"

"There are cycles of activity. They seem to be surviving, barely. Maybe they have more specific enzymes. Expect more answers within a few days – if we're being *very optimistic*."

Woodward frowned. "What about the means of transmission? Matteo? Do we know anything?"

"Motsumi and his colleagues swear that they didn't break any protocols. Given the timing, it must have occurred during the exploration of the southernmost

Cerberus Fossa. The logs confirm their accounts. Nothing has been tampered with," Matteo Acuesta assured everyone.

"It was always a possibility that something will go spectacularly wrong without any contribution of human stupidity," Lakshmi remarked. "We don't need scapegoats. What we need is to deal with the situation."

"We have no choice but to stay. All of us. Indefinitely." Alana felt heavy when speaking those words. She hated the responsibility. But she asked for it, didn't she? As the chief of planetary protection, the ultimate decision was up to her; only her. Although she was afraid of their future, she knew that she couldn't decide otherwise, even if she was sentencing a hundred people – herself included – to death.

"Okay," Lakshmi nodded, almost unnaturally calm, while Grant gulped and the others stared grimly. "When and how do we break it to them?"

"Most already suspect the possibility," Matteo interjected. "The sooner, the better."

"I'll do it," Grant spoke. "It's my responsibility."

Alana met his gaze. "But I've made the decision."

"Do you want to do it?"

Alana opened her mouth to speak, though unsure of what to say, but Lakshmi was faster: "Look, each of you feels responsible, right? So tell them together. Or, if you want, we can all go – right?"

Grant straightened up. "I'll start; Alana, you tell them what's going on; Lakshmi, you sum up the health hazards; I will summarize the plan from now on. If we're supposed to be the first completely off-world, isolated colony, let's make the best of it."

Like Lakshmi earlier, he spoke firmly. Like hers, his hands were shaking.

*

First, there had been ominous silence. Then questions without end. Everyone knew the protocol in theory, of course. But theory didn't cover the creeping certainty that you'll never see anyone from Earth again; that all your world from now on are the people around you, the empty wasteland of an entire planet and the rocket standing outside like a monument mocking you. The rocket ship *Carl Sagan* would likely never fly again…

At first, the questions were mostly about facts. What is known about the pathogen in terms of genomics, proteomics, life cycle, optimum conditions, natural environment…? How was it detected? Can we cultivate it? How does it affect human immune system? Are there any deviations from the isolation protocol on paper?

Then, as one after another was answered in a very ill-boding fashion, the questions shifted toward more disguised variations of *Is this really happening? What if*

we don't want to stay? Have you double-checked everything?

Alana went through it in a machine-like state. She'd popped a calming pill beforehand, courtesy of Lakshmi, and felt focused on the problem, with emotions of herself and others only as a muted background: Tobias' angry face, crestfallen Kristin... So this is how it looks when a hundred competent, intelligent, highly trained people face a complete lack of hope, a part of her mind mused.

She retreated back to the lab when it was over. She was in no frame of mind to go among people right now. She'd have to, eventually, but perhaps some other time. Lakshmi and Grant would do a better job than she.

Fatima, who went straight back to work too, gave Alana an encouraging smile. "You did good there."

Alana forced herself to smile back.

Did good... If only I thought so too.

*

Day 723

Being condemned to stay on Mars indefinitely was one thing.

Being condemned to *die* there soon was another. Best if everyone saw people working on avoiding that particular scenario.

Lakshmi went from her patient to a public Q&A, then to a meeting with colleagues, back to Patient Zero, and after that to a one-on-one meeting with Grant Christian Woodward. There, she could finally relax a little, though they needed to talk work. She wondered if anyone knew they didn't tend to meet for work, usually.

"So… how is it looking?" he started hesitantly, not projecting the usual aura of leadership now, outside of the others' and cameras' gazes.

"We're lucky we have a lot of genetic diversity here," Lakshmi murmured, sipped her lemongrass tea and leaned back in her seat. She could afford to lose the mask, too, and finally give way to her exhaustion. "Some of us may prove more resilient if it spreads, and I'm afraid that's only a matter of time."

"Yes…" Grant looked up, face contorted in desperation. "We did everything we could to avoid this, the very site was chosen specifically because there is *nothing* like permafrost, hotspots or active streaks in the immediate vicinity. We carefully sterilized everything, didn't send crewed missions to risky places…"

"The whole of Mars carries this risk, and we all knew it," Lakshmi stated. Her expression was grim, but calm and determined. "We know the drill. Let's act like it."

"We *knew*. But we didn't *realize*. That's different. No one really expected it."

"We're astronauts, damn it. We're supposed to be able to deal with unexpected circumstances. Imagine Leonov on the first ever EVA. Did he panic?"

"Perhaps a little..."

"But he'd *made* it. He had an ingenious idea, a dangerous one, but he had to act fast under pressure, and his quick wit and training paid off. We're a bit like him: stranded in space, needing to get somewhere our frail bodies can survive. Except we can't go home. We need to make our home here. And, well – that's what you've always wanted, isn't it?" Lakshmi couldn't resist pointing out.

"Yes, but – not like this. Just this morning, I've remembered my astrobiology professor at the university." Grant's eyes gleamed. "He was against colonization, or even crewed missions. Why go to Mars in person when robots are improving so quickly and get us the same data for lower costs and risks? If we go to Mars, he said, we'll risk its contamination and corruption of scientific results. We'll also risk *our* contamination. We'll waste tons of money that could be used to do good, solid science elsewhere. We'll focus on a false dream of creating another home for humanity, which will only lead to mistreating Earth even worse. And the celebrated colonists will miserably die of cancer, if some accident doesn't get them first." He sighed. "We had so many discussions about space colonization... I argued that technologies developed in the process will help Earth too;

he was reluctant to believe that. I also said that lots of money is wasted no matter what – and that this is at least an interesting goal in both scientific and social sense. It's akin to scaling Mt. Everest – there is no reason we have to go. If we want to see the summit, we can just send a drone. Yet countless people spend money and energy on climbing it. He couldn't see the point; I could. Finally, I suggested that if there are starfaring civilizations out there, they may well be discovering remnants of extinct cultures that made the rational decision *not* to go."

A trace of sadness, even pain, flickered across his face. "We never came to a consensus, but I think we both enjoyed our debates. He inspired me in my quest for Mars. I set to first achieve technologies that would limit the considerable health risk – and they're helping cancer patients on Earth! The same applies to more advanced 3D printers, durable batteries, more effective solar panels – we needed them here, but they're being widely used on Earth. Perhaps they would have been developed anyway, and my professor was right in saying that Mars colonization wouldn't necessarily contribute to improving life on Earth. But… perhaps I was right. I don't know."

"That can't be resolved, so let's focus on things that can," Lakshmi remarked practically. "Such as our survival."

She was drawing plans for modifying each crew member's medical bracelet to be able to detect minute concentrations of contaminants, and more frequent

medical check-ups. He listened, and would build upon these concepts and expand them, but he was also over seventy million miles away and nearly twenty years behind in his mind.

***

Awe-inspiring.

That was the first adjective that occurred to Grant when he'd first seen the Dzungarian Gate. The majestic Alatau Mountains towered in the distance, and their beauty took his breath away. He'd traveled through the whole of Kazakhstan as a digital nomad, working a few hours a day remotely and spending most time exploring. The nature and history of this country were unbelievably rich, and he just arrived to a key place for both geography and history of civilizations.

The Dzungarian Gate was the farthest place on Earth from any ocean. He couldn't get any more landward. It had also served as an important migration and commerce route for millennia. Caravans full of fabrics, beads, spices, dried fruits, gold or gems streamed through here for centuries – but well before that, ancient humans used this pass to spread eastward. The still mysterious denisovans lived not too far from here. Grant's head spun from imagining all the people and cultures passing through here for longer than written history could reach. Perhaps the *Homo erectus* that

colonized Asia two million years before modern humans also walked through this pass.

Right there, Grant felt his urge to go beyond Earth stronger than ever before. Millions of years of… here. It was time for the next place farthest from any ocean.

It's crazy to go to Mars if we can't even inhabit so many places on Earth, he vividly recalled his professor's words. Deserts starting with Atacama and ending with Antarctica were beyond human capacity of establishing self-sufficient colonies. So why waste so many resources on the great risk – and few returns in the short term – of going to Mars?

Grant wanted to prove him wrong.

He spent the next year in the middle of Gobi, tinkering with water harvesters, solar panels, mobile hydroponics, soil cleaners, printers, pocket labs. Eventually, he printed a three-piece hab out of the desert soil, and managed to live solely on local resources. He called his associates to draw plans to make it ready for mass production. Hi-tech customized and adequately paid options for companies worldwide, free basics for people anywhere in the world to help especially these in impoverished desertified regions.

He also tested technologies for Mars exploration. While being at it, he accidentally discovered a new dinosaur species, but that got him into a bit of trouble, since he didn't have the necessary digging permits.

That was when some people started taking him seriously, and some stopped.

This would repeat many times, always when he did something crazy and it paid off.

***

Day 728

Unlike Lakshmi, Alana wasn't able to relax in the presence of Grant Woodward. It reminded her much too strongly of the objections she'd voiced back on Earth, and which proved correct in the worst possible way.

It also irked her that he somehow seemed… hopeful.

"We have less than one hundred people here," Alana said quietly, when he asked her about her opinion on the future of the colony. "We'll never make it."

"If you're concerned about future generations, the rate of population increase and inbreeding, we'll have Earth drop us some frozen eggs and sperm. True, we'll still be limited by the length and toll of gestation, but perhaps we'll have working artificial uteri soon. Perhaps our molecular assemblers will get so good that we won't need frozen gametes – we'll be able to create human DNA as we wish." Grant's eyes shone. "As to much needed equipment, we must depend on Earth too for a start, but soon all we'll need will be a couple of printers for

different materials. I'm familiar with the progress in this field, believe me."

"Forgive me saying that, but this is bullshit." Alana surprised herself on how she spoke with the famous billionaire. But he wanted an egalitarian society, so he got an egalitarian society. "You *know* it's not that simple. You've built companies, for gods' sake, and you know that things often go wrong in a completely unpredictable fashion and collapse *fast*. Inbreeding is not an issue for at least another century. But we won't be self-sufficient for decades – if I'm being optimistic."

"We'll see." Now he was speaking in a quiet, pensive voice. "But do we have any other options than try to survive as best as we can?"

"No," Alana said without hesitation. "This is literally our only option, if we don't want to consider the ones that are suicidal or endanger Earth."

"There you have it. Why lose hope if we've got nothing else? We'll just have to survive!" Grant produced a not too convincing smile. "I mainly wanted to speak with you to make sure you don't… well… undermine the colony's morale."

She stared at him. For a while, she was lost for words.

"*Undermine the morale?*" she finally repeated in a strained voice. "This is… preposterous! I'm a scientist. Am I supposed to *sugarcoat* my work? Or worse?!"

"It has nothing to do with your work. I know you need to pay attention to the pessimistic scenarios, and I'd never ask you to compromise your work. We need it more than ever. But please, in your personal time, in conversations… *have hope*. That's all I ask of you."

The words resonated in her ears as she walked out of his cabin in a trance-like state.

Have hope.

A plea.

So it was far worse that she'd imagined.

In that instant, she hated Woodward, hated the colony, hated the whole society. In a way, what had happened was brilliant, groundbreaking – why did it also have to be so trying? The greatest discovery of her life, and it had to be overshadowed by its human consequences.

Absently, she headed back to her cabin, glad she didn't pass anyone on the way. She waved her wrist in front of the sensor, entered… and stood in shock. The whole place was wrecked. The modular furniture that should have been able to withstand crash landing, the printed clothes, but most importantly, her sparse possessions she was allowed to bring within the weight limit, were broken beyond repair, even the little mantel clock from her grandmother… She felt as if her chest was squeezed in a press. Her heart beat frantically. She couldn't breathe. Her head spun.

Her med bracelet shone a warning light. Alana barely noticed. The feeling was awful. Some part of her mind was telling her to calm down ("It's just stuff. It's horrible, but it's stuff, nothing serious."), but it wasn't working.

Lakshmi found her sitting on the floor.

"Shh," she whispered and gently put an arm around her shoulders. "Deep breaths. That's it. You're safe. Breathe in… that's it… and now exhale slowly. Perfect. Again…"

Finally, with the help of Lakshmi, a warm blanket and a cup of herbal infusion, Alana managed to regain her composure.

"They wrecked it," she stated flatly. "My *home*. Everything I have, the irretrievable…"

Lakshmi set her jaw. "We'll find out who did it and punish them. This can't go unnoticed."

"Really?" Alana looked up with a wry expression. "Not anyone can get in someone's personal cabin. And if it wasn't just anyone, well… what can we do?"

"This is not fucking Earth! We're not bowing down to whoever has more money or power!" Lakshmi noticed how Alana was looking at her, and lowered the tone. "What I mean is that we'll get the bastards. Understood?"

Alana forced herself into a half-smile. "Understood."

*

Day 730

Contrary to expectations, the perpetrator wasn't found. Matteo found no evidence of one of the handful of people with full access entering the quarters, and the signs of tampering with the lock revealed no concrete suspects.

"I'm sorry," Matteo said. "But if you want, we can swipe for prints, DNA and microbiome traces. Basic biolab equipment could do that, and that would tell us who..."

"I don't want a witchhunt," Alana shook her head. "No installing cameras, either. If we're to survive this intact, we need to remain an open society." In that instant, she realized she sounded almost like Woodward, and wasn't sure whether to abhor that or not.

The incident took its toll on her balance, but nothing like it occurred again, nor did anyone act openly hostile to her. On the contrary: several people offered to help her with whatever needed. Perhaps Grant's even greater insistence on togetherness helped.

Two more weeks passed, and in a way, life on the base was falling back into its tracks. Everyone knew what to do. But tensions grew as the next launch window approached. Alana could hardly miss that, however unobservant of the human nature she tended to be.

Mostly for the lack of other options, she adhered to Grant's message and had hope. After all, she and her team managed to study the microbe they'd provisionally named *Flammaria schiaparellii* in culture for nearly a day

before it died out. She also suspected why it used so much selenium. In Earth life, this trace element was a part of an enzyme protecting cells from toxic effects of hydrogen peroxide, converting it into water. Could it be that they'd now encountered life using a mix of water and hydrogen peroxide as a solvent, suggested decades ago as a possibility? It would have to have some mechanism regulating the peroxide concentration, so that it wouldn't exceed a dangerous threshold... Perhaps that could be used against it.

For the first time, she was hopeful in helping Motsumi to make a recovery. He was hanging on, not getting better, but stabilized.

Perhaps that was why his death hit the colony so hard.

*

Day 745

It came all of a sudden. Lakshmi was woken by a med alarm at two fifteen a.m. It took her a few seconds to realize what it might mean.

She barged into the infirmary half-dressed, hasty – but stopped at seeing the serving medical team's faces. Then her gaze fell on the monitors displaying Motsumi's vitals.

In the quarantine room, a med robot still delivered shocks to the young man's heart, but with no success.

As if in a trance, Lakshmi stepped forward. She glanced at the screens and gulped.

It started with a sudden liver failure. The on-site team helped, but other organs were failing too. When Motsumi's heart gave out, the alarm raised Lakshmi.

"Stop. Begin the freeze procedure," she said in a barely audible voice.

Wei, her second, nodded. The whole team began moving like automatons. Lakshmi couldn't fail to notice the shocked expressions and tears in their faces, and wondered absently whether she looked like that too. She was still only half-roused, not quite able to believe it yet.

She watched the medbots take Motsumi's body and prepare it for freezing. Samples needed to stay as intact as possible for future study... and who knew, perhaps reviving the body would be possible one day, though Lakshmi remained skeptical.

The next thing she did was waking up Grant and Alana.

*

No one spoke much that day. If they did, they did so in low, strained voices, or would-be emotionless proclamations. There was shock; anger; resentment; and, perhaps worst of all, utter desperation. Elishka, the main counselor, promised to help people cope, but all of that

seemed like empty statements now. Motsumi was dead; killed by aliens.

The headlines inevitably springing up in Earth media only made things worse.

Yet they could still get graver. On the evening meeting, Lakshmi came bearing grave news. "Solveig has fallen ill," she said quietly. "It's *Flammaria*, no doubt about it."

Grant's eyes widened. "*How?!*"

"We don't know. Believe me, the whole biolab and infirmary are working on finding the means of transmission. If it's loose on the base… we're screwed in the long term, unless we find a fast-acting cure."

They all knew how long and trying process that was, even with the help of molecular modeling and engineering. Computation wasn't a problem, all of space agencies' and countless companies' and universities' resources were at their disposal.

Still, time was. *Luck* was.

*

Day 747

Two days passed. Solveig was stable, but mortally afraid despite trying to seem cheerful. Everyone was working hard, exhausted and on edge. To this audience, Woodward was supposed to deliver a message of hope.

By some miracle, he managed not to leave them for worse than before. But his mask of composure fell the moment he stepped in his quarters.

"It's all falling apart," he uttered in a strained voice. He grasped at the wall. His hands shook. "I… I… M-my head is spinning… What's happening?"

"A panic attack, by the looks of it," Lakshmi stated. She was glad she insisted on walking him back. "Sit down, let me help you. Breathe slowly. Inhale… exhale. Calm down."

"I can't." Grant's eyes widened with anguish. He was hyperventilating by now. "I just –"

He broke into uncontrollable crying. Lakshmi took him around his shaking shoulders, held his hand and sat with him in silence. She waited until the sobbing died out and breathing rate returned to normal, and Grant just sat motionless, hunched down.

She squeezed his hand. "It's going to turn out okay, and if not, it won't be your fault. You've already done a lot to help."

"You're not good at pep talk," he managed to say, still sobbing slightly.

"I guess not. But what I am supposed to say? In these situations, you're supposed to calm the other person, guide their breathing, help them ground themselves, maybe use some simple repetitive physical task, tell them something positive… I'm not great at the last part, but I tried."

"That you did." Grant exhaled. His hands were shaking more strongly than before, but otherwise he regained most of his composure.

"If you're feeling like this more often, or experience mood swings, anxiety…"

"Who the fuck wouldn't experience anxiety in a situation like this?" Grant laughed dryly.

"Touché. But you know what they say. A good antidepressant is worth a thousand words."

"I… I suppose medication could help. If it allows me to stay sharp. I have to. It's…" he gulped. "It's my fault. I'm… guilty. It's like it's weighing me down, hovering over me every time I talk to someone, every time someone looks at me, and even if I try to help however I can, it never goes away."

Lakshmi nodded. "It must be awful… but it's perfectly normal. If you want, I can get you to see Elishka. Talking to a psychologist would help."

Grant inhaled sharply. "It's… no one else must see me like this. I got us into this mess. If people saw I was falling apart, what effect would it have on them?"

"You don't know. Maybe they'd relate. Maybe they'd get pissed off and work more. But I suppose you're right. However, seeing Elishka as a therapist would be strictly confidential."

"I prefer talking to you. Besides… I'm not sure if I *want* the guilt to go away."

He looked at his intertwined fingers. He kept rubbing them together nervously.

Lakshmi raised a brow. "Aren't you being a little selfish now? You can't afford to wallow in guilt if it reduces your performance. Anyone here needs to function a hundred percent now. It's tough, it's not how the human psyche works, but it's the reality. Elishka will be helping a lot of us cope in the foreseeable future. I prefer that to getting everyone on meds."

"All right. I'll get an appointment."

Silence fell between them.

*

The Martian dusk is pale blue, with a greenish tint, and there was no one in the colony who wouldn't feel a connection with Earth then. Some would call the sight mesmerizing, and seeing Albor Tholus and the peak of Elysium Mons rise a thousand kilometers away, their western slopes gently illuminated, truly was that. But the only three people standing in the viewing room weren't looking outside.

"We shouldn't be here," one said nervously – Kristin, one of the colony's agriculture experts. "We might get in trouble."

Tobias shot her an angry glance. "*We* might? Who got us into this? A spoiled billionaire who'd read too

much Robinson as a kid and thinks he can genuinely create a Martian utopia! He's out of touch with reality."

"But a month ago, you were too," Roni Cuinn reminded him gently, but with an edge in her voice. The engineer wouldn't be persuaded easily.

"Yes – behold the bitter awakening!"

"We agreed to this. We understood what we were signing for. This was always an option."

Tobias shut his eyes. "I… understand the steps we took. But I don't believe they're necessary. After all, what do we do, shut down crewed Mars exploration forever? We *will* return here someday and will want to go back too. We *will* solve contamination issues. So why not force our hand to do it now?"

"It's not as simple," Kristin shook her head, but hesitation crept into her voice.

"No, it's not. What is simple is the occasional urge to scream, to trash, to punch Trisolini or Woodward, or best both, in the face. But none of that would solve anything, would it? I thought about this. We can obtain codes to start *Carl Sagan.* I have friends who can access them. We have no chance of obtaining enough fuel and supplies for the whole journey, even if only a handful of us go, but there's enough to sustain us to at most four weeks' time from Earth. They can send a resupply capsule to rendezvous with us."

"What if they decide to blow us up instead?" The hesitation grew stronger.

Tobias smiled wryly. "Then we'll become martyrs. What can I say? I gather it's worth the risk. Imagine the PR: Who'll want to have blowing up a group of brave astronauts on their rep sheet? They might lock us up in quarantine for god knows how long, but they won't send missiles! They can't touch us!"

"This is crazy," Kristin breathed out.

"So why haven't you reported me yet?"

"*That* would be ever crazier! We're supposed to be a functional community, not some dictatorship, damn it!"

"If there's something we're most certainly not, it's a functional community." Tobias laughed bitterly. "We'll die one by one if we stay. I... I've thought about it really hard. And forcing Earth's and Woodward's hand by our escape is the only viable option I came up with. I understand if you need to think about it. Others are considering it as well."

They were silent for a while. Only the silent hum of ventilators could be heard.

"I want to go home," Kristin whispered finally.

Tobias smiled, satisfied.

Roni, who did not speak since her initial remarks, had a strange gleam in her eyes.

***

There were as many reasons as people in the colony. Roni Cuinn had a sick daughter and this was an opportunity to

pay for her treatments. She desperately wanted to see Eileen again.

But there was one thing she wanted even more: For Eileen to have a safe world to grow up in.

***

Day 761

Only a great degree of self-control and carefully selected medication enabled Lakshmi to stay calm and concise during her seemingly endless conversations with Earth. There were few worse things than holding meetings with a seven-minute lag between responses, and it didn't help she was living them.

"While we're working with Alana's lab to learn more about *Flammaria* and develop a cure, we're synthesizing more and more antidepressants, anxiolytics, even antipsychotics," she summarized on the next internal meeting. "Elishka has shared with me that the mental stability of the crew is falling rapidly. We can't do much about it, but it makes me wonder about security."

"Right." Matteo sighed. "I'm worried about that too. People are afraid, even desperate. But I've noticed no signs of… rebellion. We're not there yet."

"We should better know for sure *before* we are," Woodward noted grimly.

"Trust me, we *are* paying attention to any signs of trouble."

"Anyone in particular to watch out for?" Lakshmi spoke, and attracted surprised glances from both Grant and Alana, while Matteo seemed to expect a question like this.

"I don't think we should… make a list of potential troublemakers, or such," Woodward stammered.

"You said yourself we need to know beforehand."

"Yes, but this – this is too close to persecution. Lists of suspects before anything wrong has been done! Too many repressive regimes have done that. We're not bringing that here!"

Lakshmi set her jaw. Alana, relieved by Woodward's response, but shaken by the overall mood, looked away. Matteo Acuesta sighed again and began outlining the security strategy.

Everyone wished they were somewhere else.

*

Everyone in the small group gathered by Airlock 2 wished they were on the way somewhere else.

"So – really today? No waiting for the optimal window? It would be just a little longer…," someone spoke nervously.

Tobias shook his head firmly. "We're well within the porkchop already. It doesn't matter much from the point of view of supplies, and the longer we linger, the

more we risk being exposed. Why wait?" he said with a gleam in his eyes. "Let us go."

"Let me go first," Roni asked. "I'm the flight engineer. I'll do the pre-launch check alone in case anything goes wrong."

Tobias frowned. "That's not the usual procedure."

"This is not a fucking usual launch. We're stealing a rocket, damn it!" she glared at him.

Tobias looked around for support, but most people seemed reluctant to risk their lives in case anything went pear-shaped. "All right. Go. Be fast."

Roni, with Stefan's assistance, got into her suit. They didn't need to worry about anyone noticing the airlock opening yet; they managed to reroute the signal already yesterday, when Tobias' friends went out to refuel *Carl Sagan* from the little supply they'd synthesized in situ. But unless they hurried now, they'd be noticed anyway.

Everyone watched Roni as she walked purposely to the rocket. It was against all safety procedures to venture out alone, but this whole situation was too out of place.

It seemed like an eternity of waiting before the speaker in the suit room crackled and Matteo Acuesta's voice sounded: "Is anyone there? I'm getting strange readings..."

They all looked at each other. Tobias was the first to move. He pressed the button. "I'm just conducting repairs with Roni. Everything's fine," he assured Matteo.

Silence fell for a second.

"I'm gonna check up on you, help if I can."

"No need –" But it was already too late.

"We need to go!" Kristin shrieked. "We'll take the suits, go to the airlock…"

Suddenly, the comms crackled again. This time, it was Roni, speaking from her suit. She just emerged from the rocket and set out to the base. "All of you. Stay *behind* the airlock. No one goes out. It's for your own good. For the good of all of us."

"What do you –" Tobias began.

The tiny suited figure increased her pace, almost running toward the base.

When she almost reached the airlock, *Carl Sagan* exploded.

*

Strangely enough, life seemed to have gotten back to its tracks after the incident. People have sobered up, and realized that now they really had no means of escaping, unless Earth mounted a rescue mission. Instead of dividing them further apart, it bonded most of them together. They were still on edge, still afraid, but working all the harder to survive. Some reacted otherwise, of

course, but they didn't manage to incite any real riot before Acuesta pacified them.

A difficult choice what to do with the "rebels" awaited them, and a hot debate grew around the question whether to try them, let them go, issue some kind of a formal reprimand or remake some quarters into a brig. Roni's action was the most polarizing issue. Some praised her for blowing up the ship, thus constraining their options; some thought it was crazy, and that she should have just reported Tobias' plan; others secretly hated her for destroying their only hope of escape. In any case, she was lucky to have survived. Her suit got hit by one of the fragments hard, but she dragged herself inside and managed to strip off before the breathing apparatus caught fire. Repairs of the airlock would take some time.

Alana paid the debates little attention. She was focused firmly on the work. Solveig's condition grew worse and followed a similar trajectory as Motsumi's. Time was running out. She wished she could visit the site where Motsumi and Solveig likely got infected, but that was out of the question. She could only operate robots through telemetry, unless they lost signal underground – then their simple AIs kicked in and everything got painfully slow.

She watched all the drills into the subsurface ice with expectation, hope and most of all anxiety. She bit her nails every time the robots ventured into the adjacent lava tube. She went through the results of their soil analyses

over and over, hoping to find anything suspect in the data from their Ramans, mass specs, nanopore detectors and imunoassays.

Nothing. All over – *nothing*.

The other day when everything changed seemed nothing special at first. There was a dust storm outside, enough to cause mild interference in communication, but not too severe. Alana could connect to the *Wells* rover most of the time, and *Wells* was receiving data from its miniprobes. The bandwidth was not great, and the first relayed images from a newly discovered tunnel from the lava tube were grainy and blurry. But the readings…

Heat. Moisture. Metals. Methane…

Even the blurry pictures confirmed what that suggested. The mission geologists were already beside themselves with excitement. They'd found an active hydrothermal system!

More resources were diverted to explore the site. The teams worked round the clock, and in the middle of the night, a new batch of data arrived.

Organics, same as found in Motsumi's and Solveig's bloodstreams, in the Raman and mass spec readings alike, and much more. And… they could *see* it.

At first sight, an inconspicuous blob of minerals.

Zoom in: A thin film covering the structure.

Under the microscope, regular elongated shapes. So many of them, several kinds organized in layers akin to bacterial biofilms on Earth…

There it was, for everyone to see, laid out in all of its wondrous beauty. *Life*. A whole microbial community, of which *Flammaria* was only one tiny part – it must have been used to warmth, humidity and a lot of other cells around from such an environment!

For the first time in her life, Alana Trisolini would have been content to die.

But this was only the start.

The next days went by fast. She couldn't remember doing anything but work, yet she must have slept or eaten at some points, though Fatima had to remind her to do that.

Studying *Flammaria* in its natural habitat was priceless. It would take years if not decades to study it thoroughly, but already in the first days, Alana and her team managed to support the hypothesis that it used selenium to regulate the amount of hydrogen peroxide in different compartments of the cell.

"Solveig, what we're suggesting is very experimental. If it doesn't work, it could harm you. It's up to you whether you agree," she said to the patient scarcely a week later. She'd insisted on talking to her herself. *If anything goes wrong, it's up to me, not Lakshmi or her team.*

The patient laughed a little, but it was a weak attempt at laughter. Sweat glistened on her brow. "Do it."

So they did. The hastily engineered selenium-binding protein from *Methanococcus* might not

outperform *Flammaria*'s molecular machinery… but it *might yes*. It *might* starve *Flammaria* before Solveig, and it *might* draw the microbe on the verge of being unable to cope with its own cellular environment and the human immune system, which also utilized oxidants.

Then, they waited. And waited.

Two days after, Solveig went into a severe anaphylactic shock. She almost died. *Almost*. Then, she gradually started getting better. The contamination seemed to be over.

"Looks like you did it," Lakshmi whispered to Alana. Her voice was strained, as if she could hardly contain the hope.

"*We* did," Alana breathed out. For a second, she wondered why her vision blurred, but then she realized they were tears of joy and relief.

*

Solveig and two more of her and Motsumi's colleagues had to remain quarantined for at least one more month, but she was finally getting healthy.

It most certainly wasn't over, Alana knew. They all still had to survive – but the public opinion was on their side, and so were the resources thus far. Earth promised to send cargo before the end of the current flight window. They gained time to build, rework, invent, to become truly independent. Perhaps it was still a faraway dream,

despite Woodward's claims, but it was a dream they had to cling to for the lack of other options.

Would they really have to remain here for the rest of their lives? If so, would anyone choose – perhaps kindly, perhaps cruelly – to have children? Would the colony expand? When would it be allowed to merge with Earth population again? And what of the local life – did it also exist on other sites? Had it really stemmed from Earth life – or vice versa?

No one knew the answers yet, and Alana suspected it would take decades to find them.

But that was all right.

It meant they had a *future*.

For the curious reader, a few references to the hydrogen peroxide hypothesis and planetary protection concerns:

Conley, C. A., & Rummel, J. D. (2013). Appropriate protection of Mars. Nature Geoscience, 6(8), 587-588.

Fairén, A. G., & Schulze-Makuch, D. (2013). The overprotection of Mars. Nature Geoscience, 6(7), 510-511.

Houtkooper, J. M. and Schulze-Makuch, D. (2007) A possible biogenic origin for hydrogen peroxide on Mars: the Viking results reinterpreted. International Journal of Astrobiology 6: 147-152.

Here is where the story takes place.

Originally published in *Analog* (11-12/2019).

About EAI

The European Astrobiology Institute aspires to become a primary forum for the development of European Astrobiology, ensuring that this relatively new inter-disciplinary research field is established across Europe.

It aims to foster a cooperative interdisciplinary approach in research; disseminate high-quality results of such research efforts effectively across the scientific community; provide interdisciplinary training for students and early career scientists in astrobiology; engage in education in the field of astrobiology on all levels; liaise with industry to foster collaborations on technological developments that are relevant to astrobiology research and beneficial to Europe as a whole; coordinate the outreach activities of European astrobiologists to the general public, industry and all other relevant stakeholders; act as an advisory body and provide high-quality expertise to European research organisations and decision makers on all aspects of astrobiology at an European level; ensure the necessary financial means to carry out these activities through a coordinated approach to European funding agencies including Horizon programmes.

Key research areas of the EAI include the following:

- Formation and Evolution of Planetary Systems and Detection of Habitable Worlds
- Planetary Environments and Habitability

- Evolution and Traces of Early Life and Life under Extreme Conditions
- Pathway to Complexity: From simple molecules to first life
- Biosignatures and Life Detection beyond Earth
- Historical, philosophical, societal and ethical issues in astrobiology

All these fundamental research themes are the basis of EAI's scientific working groups. In addition, the institute has several activity working groups:

- Policy and Funding
- European Astrobiology Campus
- Field Work and Field Site Management
- Education
- Access to European Research Infrastructures and Analysis Facilities
- Outreach, Media and Corporate Identity
- Dissemination and Intellectual Output
- Industry Liaison

Individuals can become members of a selected working group, even if their home institution is not a member of the EAI (see here). We have also formed a **Science Fiction Project Team** and welcome team members from the ranks of SF-centered academics, authors and fans! Contact the editor at julie.novakova@natur.cuni.cz if you wish to join.

Find out more at europeanastrobiology.eu.

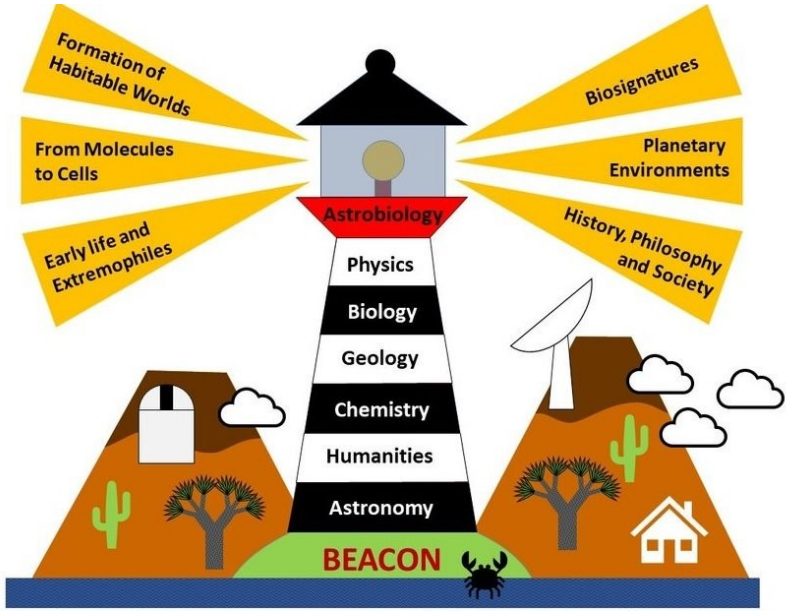
BEACON 2021

We'd like to invite you to La Palma for BEACON 2021!

The Biennial European Astrobiology Conference (BEACON) will take place at the La Palma & Teneguia Princess Hotel on La Palma Island (Canary Islands, Spain) on 12-16 April 2021. Scientific sessions are planned covering the following themes:

- Formation and Evolution of Planetary Systems and Detection of Habitable Worlds
- Pathway to Complexity: From Simple Molecules to First Life
- Planetary Environments and Habitability
- Evolution and Traces of Early Life and Life under Extreme Condition
- Biosignatures and the Detection of Life beyond Earth
- Historical, Philosophical, Societal and Ethical Issues in Astrobiology
- Tracing Life and Identifying Habitable Environments
- Impacts and their Role in the Evolution of Planets, Moons and Life
- Protoplanetary disks and their physical and chemical processes

The meeting will be open to all interested scientists and students from Europe and beyond. La Palma offers a multitude of relevant research infrastructures (telescopes) and locations (active volcanoes, recent lava fields, Mars-analogue landscapes, and more). During the conference excursion, many of these will be visited. A field trip to other astrobiologically interesting field sites on other islands will be organized after the conference, as well as an optional after-conference walk along the Volcano route (Ruta de los Volcanes), spanning several active volcanoes above 1600m altitude. In addition, outreach events for the general public will be held.



Acknowledgments

This book would have probably remained only a dream of mine, if it weren't for the founding of the EAI and my efforts to come up with an astrobiology outreach project that would last and would have a potential to reach many a curious mind. I have the EAI's chair Wolf Geppert, my outreach group co-leader Caterina Boccato and many others to thank for that. Special thanks belong to my longtime friend and science/writing colleague Tomáš Petrásek, whose interest in astrobiology preceded and in many ways fostered mine. Finally, big thanks to all the scientists and authors whose work I've devoured ever since childhood. You've kept my curiosity running.

You have read…

Strangest of All

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