Crystal Nights

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from Interzone 215

1

"More caviar?" Daniel Cliff gestured at the serving dish and the cover irised from opaque to transparent. "It's fresh, I promise you. My chef had it flown in from Iran this morning."

"No thank you." Julie Dehghani touched a napkin to her lips then laid it on her plate with a gesture of finality. The dining room overlooked the Golden Gate bridge, and most people Daniel invited here were content to spend an hour or two simply enjoying the view, but he could see that she was growing impatient with his small talk.

Daniel said, "I'd like to show you something." He led her into the adjoining conference room. On the table was a wireless keyboard; the wall screen showed a Linux command line interface. "Take a seat," he suggested.

Julie complied. "If this is some kind of audition, you might have warned me," she said.

"Not at all," Daniel replied. "I'm not going to ask you to jump through any hoops. I'd just like you to tell me what you think of this machine's performance."

She frowned slightly, but she was willing to play along. She ran some standard benchmarks. Daniel saw her squinting at the screen, one hand almost reaching up to where a desktop display would be, so she could double-check the number of digits in the FLOPS rating by counting them

off with one finger. There were a lot more than she'd been expecting, but she wasn't seeing double.

"That's extraordinary," she said. "Is this whole building packed with networked processors, with only the penthouse for humans?"

Daniel said, "You tell me. Is it a cluster?"

"Hmm." So much for not making her jump through hoops, but it wasn't really much of a challenge. She ran some different benchmarks, based on algorithms that were provably impossible to parallelise; however smart the compiler was, the steps these programs required would have to be carried out strictly in sequence.

The FLOPS rating was unchanged.

Julie said, "All right, it's a single processor. Now you've got my attention. Where is it?"

"Turn the keyboard over."

There was a charcoal-grey module, five centimetres square and five millimetres thick, plugged into an inset docking bay. Julie examined it, but it bore no manufacturer's logo or other identifying marks.

"This connects to the processor?" she asked.

"No. It *is* the processor."

"You're joking." She tugged it free of the dock, and the wall screen went blank. She held it up and turned it around, though Daniel wasn't sure what she was looking for. Somewhere to slip in a screwdriver and take the thing apart, probably. He said, "If you break it, you own it, so I hope you've got a few hundred spare."

"A few hundred grand? Hardly."

“A few hundred million.”

Her face flushed. “Of course. If it was two hundred grand, everyone would have one.” She put it down on the table, then as an afterthought slid it a little further from the edge. “As I said, you’ve got my attention.”

Daniel smiled. “I’m sorry about the theatrics.”

“No, this deserved the build-up. What is it, exactly?”

“A single, three-dimensional photonic crystal. No electronics to slow it down; every last component is optical. The architecture was nanofabricated with a method that I’d prefer not to describe in detail.”

“Fair enough.” She thought for a while. “I take it you don’t expect me to buy one. My research budget for the next thousand years would barely cover it.”

“In your present position. But you’re not joined to the university at the hip.”

“So this is a job interview?”

Daniel nodded.

Julie couldn’t help herself; she picked up the crystal and examined it again, as if there might yet be some feature that a human eye could discern. “Can you give me a job description?”

“Midwife.”

She laughed. “To what?”

“History,” Daniel said.

Her smile faded slowly.

“I believe you’re the best AI researcher of your generation,” he said. “I want you to work for me.” He reached over and took the crystal from her. “With this as your platform, imagine what you could do.”

Julie said, “What exactly would you want me to do?”

“For the last fifteen years,” Daniel said, “you’ve stated that the ultimate goal of your research is to create conscious, human-level, artificial intelligence.”

“That’s right.”

“Then we want the same thing. What I want is for you to succeed.”

She ran a hand over her face; whatever else she was thinking, there was no denying that she was tempted. “It’s gratifying that you have so much confidence in my abilities,” she said. “But we need to be clear about some things. This prototype is amazing, and if you ever get the production costs down I’m sure it will have some extraordinary applications. It would eat up climate forecasting, lattice QCD, astrophysical modelling, proteomics…”

“Of course.” Actually, Daniel had no intention of marketing the device. He’d bought out the inventor of the fabrication process with his own private funds; there were no other shareholders or directors to dictate his use of the technology.

“But AI,” Julie said, “is different. We’re in a maze, not a highway; there’s nowhere that speed alone can take us. However many exaflops I have to play with, they won’t spontaneously combust into consciousness. I’m not being held back by the university’s computers; I have access to SHARCNET anytime I need it. I’m being held back by my own lack of insight into the problems I’m addressing.”

Daniel said, “A maze is not a dead end. When I was twelve, I wrote a program for solving mazes.”

“And I’m sure it worked well,” Julie replied, “for small, two-dimensional ones. But you know how those kind of algorithms scale. Put your old program on this crystal, and I could still design a maze in half a day that would bring it to its knees.”

“Of course,” Daniel conceded. “Which is precisely why I’m interested in hiring you. You know a great deal more about the maze of AI than I do; any strategy you developed would be vastly superior to a blind search.”

“I’m not saying that I’m merely groping in the dark,” she said. “If it was that bleak, I’d be working on a different problem entirely. But I don’t see what difference this processor would make.”

“What created the only example of consciousness we know of?” Daniel asked.

“Evolution.”

“Exactly. But I don’t want to wait three billion years, so I need to make the selection process a great deal more refined, and the sources of variation more targeted.”

Julie digested this. “You want to try to *evolve* true AI? Conscious, human-level AI?”

“Yes.” Daniel saw her mouth tightening, saw her struggling to measure her words before speaking.

“With respect, I don’t think you’ve thought that through.”

“On the contrary,” Daniel assured her. “I’ve been planning this for twenty years.”

“Evolution,” she said, “is about failure and death. Do you have any idea how many sentient creatures lived and died along the way to *Homo sapiens*? How much suffering was involved?”

“Part of your job would be to minimise the suffering.”

“*Minimise it?*” She seemed genuinely shocked, as if this proposal was even worse than blithely assuming that the process would raise no ethical concerns. “What right do we have to inflict it at all?”

Daniel said, “You’re grateful to exist, aren’t you? Notwithstanding the tribulations of your ancestors.”

“I’m grateful to exist,” she agreed, “but in the human case the suffering wasn’t deliberately inflicted by anyone, and nor was there any alternative way we could have come into existence. If there really *had* been a just creator, I don’t doubt that he would have followed Genesis literally; he sure as hell would not have used evolution.”

“Just, *and omnipotent,*” Daniel suggested. “Sadly, that second trait’s even rarer than the first.”

“I don’t think it’s going to take omnipotence to create something in our own image,” she said. “Just a little more patience and self-knowledge.”

“This won’t be like natural selection,” Daniel insisted. “Not that blind, not that cruel, not that wasteful. You’d be free to intervene as much as you wished, to take whatever palliative measures you felt appropriate.”

“*Palliative measures?*” Julie met his gaze, and he saw her expression flicker from disbelief to something darker. She stood up and glanced at her wristphone. “I don’t have any signal here. Would you mind calling me a taxi?”

Daniel said, “Please, hear me out. Give me ten more minutes, then the helicopter will take you to the airport.”

“I’d prefer to make my own way home.” She gave Daniel a look that made it clear that this was not negotiable.

He called her a taxi, and they walked to the elevator.

“I know you find this morally challenging,” he said, “and I respect that. I wouldn’t dream of hiring someone who thought these were trivial issues. But if I don’t do this, someone else will. Someone with far worse intentions than mine.”

“Really?” Her tone was openly sarcastic now. “So how, exactly, does the mere existence of your project stop this hypothetical bin Laden of AI from carrying out his own?”

Daniel was disappointed; he’d expected her at least to understand what was at stake. He said, “This is a race to decide between Godhood and enslavement. Whoever succeeds first will be unstoppable. I’m not going to be anyone’s slave.”

Julie stepped into the elevator; he followed her.

She said, “You know what they say the modern version of Pascal’s Wager is? Sucking up to as many Transhumanists as possible, just in case one of them turns into God. Perhaps your motto should be ‘Treat every chatterbot kindly, it might turn out to be the deity’s uncle’.”

“We will be as kind as possible,” Daniel said. “And don’t forget, we can determine the nature of these beings. They will be happy to be alive, and grateful to their creator. We can select for those traits.”

Julie said, “So you’re aiming for *übermenschen* that wag their tails when you scratch them behind the ears? You might find there’s a bit of a trade-off there.”

The elevator reached the lobby. Daniel said, “Think about this, don’t rush to a decision. You can call me any time.” There was no commercial flight back to Toronto tonight; she’d be stuck in

a hotel, paying money she could ill-afford, thinking about the kind of salary she could demand from him now that she'd played hard to get. If she mentally recast all this obstinate moralising as a deliberate bargaining strategy, she'd have no trouble swallowing her pride.

Julie offered her hand, and he shook it. She said, "Thank you for dinner."

The taxi was waiting. He walked with her across the lobby. "If you want to see AI in your lifetime," he said, "this is the only way it's going to happen."

She turned to face him. "Maybe that's true. We'll see. But better to spend a thousand years and get it right, than a decade and succeed by your methods."

As Daniel watched the taxi drive away into the fog, he forced himself to accept the reality: she was never going to change her mind. Julie Dehghani had been his first choice, his ideal collaborator. He couldn't pretend that this wasn't a setback.

Still, no one was irreplaceable. However much it would have delighted him to have won her over, there were many more names on his list.

2

Daniel's wrist tingled as the message came through. He glanced down and saw the word PROGRESS! hovering in front of his watch face.

The board meeting was almost over; he disciplined himself and kept his attention focused for ten more minutes. WiddulHands.com had made him his first billion, and it was still the pre-eminent social networking site for the 0–3 age group. It had been fifteen years since he'd founded the company, and he had since diversified in many directions, but he had no intention of taking his hands off the levers.

When the meeting finished he blanked the wall screen and paced the empty conference room for half a minute, rolling his neck and stretching his shoulders. Then he said, “Lucien”.

Lucien Crace appeared on the screen. “Significant progress?” Daniel enquired.

“Absolutely.” Lucien was trying to maintain polite eye contact with Daniel, but something kept drawing his gaze away. Without waiting for an explanation, Daniel gestured at the screen and had it show him exactly what Lucien was seeing.

A barren, rocky landscape stretched to the horizon. Scattered across the rocks were dozens of crab-like creatures – some deep blue, some coral pink, though these weren’t colours the locals would see, just species markers added to the view to make it easier to interpret. As Daniel watched, fat droplets of corrosive rain drizzled down from a passing cloud. This had to be the bleakest environment in all of Sapphire.

Lucien was still visible in an inset. “See the blue ones over by the crater lake?” he said. He sketched a circle on the image to guide Daniel’s attention.

“Yeah.” Five blues were clustered around a lone pink; Daniel gestured and the view zoomed in on them. The blues had opened up their prisoner’s body, but it wasn’t dead; Daniel was sure of that, because the pinks had recently acquired a trait that turned their bodies to mush the instant they expired.

“They’ve found a way to study it,” Lucien said. “To keep it alive and study it.”

From the very start of the project, he and Daniel had decided to grant the Phites the power to observe and manipulate their own bodies as much as possible. In the DNA world, the inner workings of anatomy and heredity had only become accessible once highly sophisticated technology had been invented. In Sapphire, the barriers were designed to be far lower. The basic

units of biology here were ‘beads’, small spheres that possessed a handful of simple properties but no complex internal biochemistry. Beads were larger than the cells of the DNA world, and Sapphire’s diffractionless optics rendered them visible to the right kind of naked eye. Animals acquired beads from their diet, while in plants they replicated in the presence of sunlight, but unlike cells they did not themselves mutate. The beads in a Phite’s body could be rearranged with a minimum of fuss, enabling a kind of self-modification that no human surgeon or prosthetics engineer could rival – and this skill was actually essential for at least one stage in every Phite’s life: reproduction involved two Phites pooling their spare beads and then collaborating to ‘sculpt’ them into an infant, in part by directly copying each other’s current body plans.

Of course these crabs knew nothing of the abstract principles of engineering and design, but the benefits of trial and error, of self-experimentation and cross-species plagiarism, had led them into an escalating war of innovation. The pinks had been the first to stop their corpses from being plundered for secrets, by stumbling on a way to make them literally fall apart *in extremis*; now it seemed the blues had found a way around that, and were indulging in a spot of vivisection-as-industrial-espionage.

Daniel felt a visceral twinge of sympathy for the struggling pink, but he brushed it aside. Not only did he doubt that the Phites were any more conscious than ordinary crabs, they certainly had a radically different relationship to bodily integrity. The pink was resisting because its dissectors were of a different species; if they had been its cousins it might not have put up any fight at all. When something happened in spite of your wishes, that was unpleasant by definition, but it would be absurd to imagine that the pink was in the kind of agony that an antelope being flayed

by jackals would feel – let alone experiencing the existential terrors of a human trapped and mutilated by a hostile tribe.

"This is going to give them a tremendous advantage," Lucien enthused.

"The blues?"

Lucien shook his head. "Not blues over pinks; Phites over tradlife. Bacteria can swap genes, but this kind of active mimetics is unprecedented without cultural support. Da Vinci might have watched the birds in flight and sketched his gliders, but no lemur ever dissected the body of an eagle and then stole its tricks. They're going to have *innate* skills as powerful as whole strands of human technology. All this before they even have language."

"Hmm." Daniel wanted to be optimistic too, but he was growing wary of Lucien's hype. Lucien had a doctorate in genetic programming, but he'd made his name with FoodExcuses.com, a web service that trawled the medical literature to cobble together quasi-scientific justifications for indulging in your favourite culinary vice. He had the kind of technobabble that could bleed money out of venture capitalists down pat, and though Daniel admired that skill in its proper place, he expected a higher insight-to-bullshit ratio now that Lucien was on his payroll.

The blues were backing away from their captive. As Daniel watched, the pink sealed up its wounds and scuttled off towards a group of its own kind. The blues had now seen the detailed anatomy of the respiratory system that had been giving the pinks an advantage in the thin air of this high plateau. A few of the blues would try it out, and if it worked for them, the whole tribe would copy it.

"So what do you think?" Lucien asked.

"Select them," Daniel said.

“Just the blues?”

“No, both of them.” The blues alone might have diverged into competing subspecies eventually, but bringing their old rivals along for the ride would help to keep them sharp.

“Done,” Lucien replied. In an instant, ten million Phites were erased, leaving the few thousand blues and pinks from these badlands to inherit the planet. Daniel felt no compunction; the extinction events he decreed were surely the most painless in history.

Now that the world no longer required human scrutiny, Lucien unthrottled the crystal and let the simulation race ahead; automated tools would let them know when the next interesting development arose. Daniel watched the population figures rising as his chosen species spread out and recolonised Sapphire.

Would their distant descendants rage against him, for this act of ‘genocide’ that had made room for them to flourish and prosper? That seemed unlikely. In any case, what choice did he have? He couldn’t start manufacturing new crystals for every useless side-branch of the evolutionary tree. Nobody was wealthy enough to indulge in an exponentially growing number of virtual animal shelters, at half a billion dollars apiece.

He was a just creator, but he was not omnipotent. His careful pruning was the only way.

3

In the months that followed, progress came in fits and starts. Several times, Daniel found himself rewinding history, reversing his decisions and trying a new path. Keeping every Phite variant alive was impractical, but he did retain enough information to resurrect lost species at will.

The maze of AI was still a maze, but the speed of the crystal served them well. Barely eighteen months after the start of Project Sapphire, the Phites were exhibiting a basic theory of mind: their actions showed that they could deduce what others knew about the world, as distinct from what they knew themselves. Other AI researchers had spliced this kind of thing into their programs by hand, but Daniel was convinced that his version was better integrated, more robust. Human-crafted software was brittle and inflexible; his Phites had been forged in the heat of change.

Daniel kept a close watch on his competitors, but nothing he saw gave him reason to doubt his approach. Sunil Gupta was raking in the cash from a search engine that could 'understand' all forms of text, audio and video, making use of fuzzy logic techniques that were at least forty years old. Daniel respected Gupta's business acumen, but in the unlikely event that his software ever became conscious, the sheer cruelty of having forced it to wade through the endless tides of blogorrhoea would surely see it turn on its creator and exact a revenge that made *The Terminator* look like a picnic. Angela Lindstrom was having some success with her cheesy AfterLife, in which dying clients gave heart-to-heart interviews to software that then constructed avatars able to converse with surviving relatives. And Julie Dehghani was still frittering away her talent, writing software for robots that played with coloured blocks side-by-side with human infants, and learnt languages from adult volunteers by imitating the interactions of baby talk. Her prophesy of taking a thousand years to 'get it right' seemed to be on target.

As the second year of the project drew to a close, Lucien was contacting Daniel once or twice a month to announce a new breakthrough. By constructing environments that imposed suitable selection pressures, Lucien had generated a succession of new species that used simple tools,

crafted crude shelters, and even domesticated plants. They were still shaped more or less like crabs, but they were at least as intelligent as chimpanzees.

The Phites worked together by observation and imitation, guiding and reprimanding each other with a limited repertoire of gestures and cries, but as yet they lacked anything that could truly be called a language. Daniel grew impatient; to move beyond a handful of specialised skills, his creatures needed the power to map any object, any action, any prospect they might encounter in the world into their speech, and into their thoughts.

Daniel summoned Lucien and they sought a way forward. It was easy to tweak the Phites' anatomy to grant them the ability to generate more subtle vocalisations, but that alone was no more useful than handing a chimp a conductor's baton. What was needed was a way to make sophisticated planning and communications skills a matter of survival.

Eventually, he and Lucien settled on a series of environmental modifications, providing opportunities for the creatures to rise to the occasion. Most of these scenarios began with famine. Lucien blighted the main food crops, then offered a palpable reward for progress by dangling some tempting new fruit from a branch that was just out of reach. Sometimes that metaphor could almost be taken literally: he'd introduce a plant with a complex life cycle that required tricky processing to render it edible, or a new prey animal that was clever and vicious, but nutritionally well worth hunting in the end.

Time and again, the Phites failed the test, with localised species dwindling to extinction. Daniel watched in dismay; he had not grown sentimental, but he'd always boasted to himself that he'd set his standards higher than the extravagant cruelties of nature. He contemplated tweaking the creatures' physiology so that starvation brought a swifter, more merciful demise, but Lucien

pointed out that he'd be slashing his chances of success if he curtailed this period of intense motivation. Each time a group died out, a fresh batch of mutated cousins rose from the dust to take their place; without that intervention, Sapphire would have been a wilderness within a few real-time days.

Daniel closed his eyes to the carnage, and put his trust in sheer time, sheer numbers. In the end, that was what the crystal had bought him: when all else failed, he could give up any pretence of knowing how to achieve his aims and simply test one random mutation after another.

Months went by, sending hundreds of millions of tribes starving into their graves. But what choice did he have? If he fed these creatures milk and honey, they'd remain fat and stupid until the day he died. Their hunger agitated them, it drove them to search and strive, and while any human onlooker was tempted to colour such behaviour with their own emotional palette, Daniel told himself that the Phites' suffering was a shallow thing, little more than the instinct that jerked his own hand back from a flame before he'd even registered discomfort.

They were not the equal of humans. Not yet.

And if he lost his nerve, they never would be.

Daniel dreamt that he was inside Sapphire, but there were no Phites in sight. In front of him stood a sleek black monolith; a thin stream of pus wept from a crack in its smooth, obsidian surface. Someone was holding him by the wrist, trying to force his hand into a reeking pit in the ground. The pit, he knew, was piled high with things he did not want to see, let alone touch.

He thrashed around until he woke, but the sense of pressure on his wrist remained. It was coming from his watch. As he focused on the one-word message he'd received, his stomach tightened. Lucien would not have dared to wake him at this hour for some run-of-the-mill result.

Daniel rose, dressed, then sat in his office sipping coffee. He did not know why he was so reluctant to make the call. He had been waiting for this moment for more than twenty years, but it would not be the pinnacle of his life. After this, there would be a thousand more peaks, each one twice as magnificent as the last.

He finished the coffee then sat a while longer, massaging his temples, making sure his head was clear. He would not greet this new era bleary-eyed, half-awake. He recorded all his calls, but this was one he would retain for posterity.

"Lucien," he said. The man's image appeared, smiling. "Success?"

"They're talking to each other," Lucien replied.

"About what?"

"Food, weather, sex, death. The past, the future. You name it. They won't shut up."

Lucien sent transcripts on the data channel, and Daniel perused them. The linguistics software didn't just observe the Phites' behaviour and correlate it with the sounds they made; it peered right into their virtual brains and tracked the flow of information. Its task was far from trivial, and there was no guarantee that its translations were perfect, but Daniel did not believe it could hallucinate an entire language and fabricate these rich, detailed conversations out of thin air.

He flicked between statistical summaries, technical overviews of linguistic structure, and snippets from the millions of conversations the software had logged. *Food, weather, sex, death.* As human dialogue the translations would have seemed utterly banal, but in context they were

riveting. These were not chatterbots blindly following Markov chains, designed to impress the judges in a Turing test. The Phites were discussing matters by which they genuinely lived and died.

When Daniel brought up a page of conversational topics in alphabetical order, his eyes were caught by the single entry under the letter G. *Grief.* He tapped the link, and spent a few minutes reading through samples, illustrating the appearance of the concept following the death of a child, a parent, a friend.

He kneaded his eyelids. It was three in the morning; there was a sickening clarity to everything, the kind that only night could bring. He turned to Lucien.

"No more death."

"Boss?" Lucien was startled.

"I want to make them immortal. Let them evolve culturally; let their ideas live and die. Let them modify their own brains, once they're smart enough; they can already tweak the rest of their anatomy."

"Where will you put them all?" Lucien demanded.

"I can afford another crystal. Maybe two more."

"That won't get you far. At the present birth rate – "

"We'll have to cut their fertility drastically, tapering it down to zero. After that, if they want to start reproducing again they'll really have to innovate." They would need to learn about the outside world, and comprehend its alien physics well enough to design new hardware into which they could migrate.

Lucien scowled. “How will we control them? How will we shape them? If we can’t select the ones we want – ”

Daniel said quietly, “This is not up for discussion.” Whatever Julie Dehghani had thought of him, he was not a monster; if he believed that these creatures were as conscious as he was, he was not going to slaughter them like cattle – or stand by and let them die ‘naturally’, when the rules of this world were his to rewrite at will.

“We’ll shape them through their memes,” he said. “We’ll kill off the bad memes, and help spread the ones we want to succeed.” He would need to keep an iron grip on the Phites and their culture, though, or he would never be able to trust them. If he wasn’t going to literally *breed them* for loyalty and gratitude, he would have to do the same with their ideas.

Lucien said, “We’re not prepared for any of this. We’re going to need new software, new analysis and intervention tools.”

Daniel understood. “Freeze time in Sapphire. Then tell the team they’ve got eighteen months.”

4

Daniel sold his shares in WiddulHands, and had two more crystals built. One was to support a higher population in Sapphire, so there was as large a pool of diversity among the immortal Phites as possible; the other was to run the software – which Lucien had dubbed the Thought Police – needed to keep tabs on what they were doing. If human overseers had had to monitor and shape the evolving culture every step of the way, that would have slowed things down to a glacial pace. Still, automating the process completely was tricky, and Daniel preferred to err on

the side of caution, with the Thought Police freezing Sapphire and notifying him whenever the situation became too delicate.

If the end of death was greeted by the Phites with a mixture of puzzlement and rejoicing, the end of birth was not so easy to accept. When all attempts by mating couples to sculpt their excess beads into offspring became as ineffectual as shaping dolls out of clay, it led to a mixture of persistence and distress that was painful to witness. Humans were accustomed to failing to conceive, but this was more like still birth after still birth. Even when Daniel intervened to modify the Phites' basic drives, some kind of cultural or emotional inertia kept many of them going through the motions. Though their new instincts urged them merely to pool their spare beads and then stop, sated, they would continue with the old version of the act regardless, forlorn and confused, trying to shape the useless puddle into something that lived and breathed.

Move on, Daniel thought. *Get over it.* There was only so much sympathy he could muster for immortal beings who would fill the galaxy with their children, if they ever got their act together.

The Phites didn't yet have writing, but they'd developed a strong oral tradition, and some put their mourning for the old ways into elegiac words. The Thought Police identified those memes, and ensured that they didn't spread far. Some Phites chose to kill themselves rather than live in the barren new world. Daniel felt he had no right to stop them, but mysterious obstacles blocked the paths of anyone who tried, irresponsibly, to romanticise or encourage such acts.

The Phites could only die by their own volition, but those who retained the will to live were not free to doze the centuries away. Daniel decreed no more terrible famines, but he hadn't abolished hunger itself, and he kept enough pressure on the food supply and other resources to force the Phites to keep innovating, refining agriculture, developing trade.

The Thought Police identified and nurtured the seeds of writing, mathematics, and natural science. The physics of Sapphire was a simplified, game-world model, not so arbitrary as to be incoherent, but not so deep and complex that you needed particle physics to get to the bottom of it. As crystal time sped forward and the immortals sought solace in understanding their world, Sapphire soon had its Euclid and Archimedes, its Galileo and its Newton; their ideas spread with supernatural efficiency, bringing forth a torrent of mathematicians and astronomers.

Sapphire's stars were just a planetarium-like backdrop, present only to help the Phites get their notions of heliocentricity and inertia right, but its moon was as real as the world itself. The technology needed to reach it was going to take a while, but that was all right; Daniel didn't want them getting ahead of themselves. There was a surprise waiting for them there, and his preference was for a flourishing of biotech and computing before they faced that revelation.

Between the absence of fossils, Sapphire's limited biodiversity, and all the clunky external meddling that needed to be covered up, it was hard for the Phites to reach a grand Darwinian view of biology, but their innate skill with beads gave them a head start in the practical arts. With a little nudging, they began tinkering with their bodies, correcting some inconvenient anatomical quirks that they'd missed in their pre-conscious phase.

As they refined their knowledge and techniques, Daniel let them imagine that they were working towards restoring fertility; after all, that was perfectly true, even if their goal was a few conceptual revolutions further away than they realised. Humans had had their naive notions of a Philosopher's Stone dashed, but they'd still achieved nuclear transmutation in the end.

The Phites, he hoped, would transmute *themselves*: inspect their own brains, make sense of them, and begin to improve them. It was a staggering task to expect of anyone; even Lucien and

his team, with their God's-eye view of the creatures, couldn't come close. But when the crystal was running at full speed, the Phites could think millions of times faster than their creators. If Daniel could keep them from straying off course, everything that humanity might once have conceived of as the fruits of millennia of progress was now just a matter of months away.

5

Lucien said, "We're losing track of the language."

Daniel was in his Houston office; he'd come to Texas for a series of face-to-face meetings, to see if he could raise some much-needed cash by licensing the crystal fabrication process. He would have preferred to keep the technology to himself, but he was almost certain that he was too far ahead of his rivals now for any of them to stand a chance of catching up with him.

"What do you mean, losing track?" Daniel demanded. Lucien had briefed him just three hours before, and given no warning of an impending crisis.

The Thought Police, Lucien explained, had done their job well: they had pushed the neural self-modification meme for all it was worth, and now a successful form of 'brain boosting' was spreading across Sapphire. It required a detailed 'recipe' but no technological aids; the same innate skills for observing and manipulating beads that the Phites had used to copy themselves during reproduction were enough.

All of this was much as Daniel had hoped it would be, but there was an alarming downside. The boosted Phites were adopting a dense and complex new language, and the analysis software couldn't make sense of it.

"Slow them down further," Daniel suggested. "Give the linguistics more time to run."

"I've already frozen Sapphire," Lucien replied. "The linguistics have been running for an hour, with the full resources of an entire crystal."

Daniel said irritably, "We can see exactly what they've done to their brains. How can we not understand the effects on the language?"

"In the general case," Lucien said, "deducing a language from nothing but neural anatomy is computationally intractable. With the old language, we were lucky; it had a simple structure, and it was highly correlated with obvious behavioural elements. The new language is much more abstract and conceptual. We might not even have our own correlates for half the concepts."

Daniel had no intention of letting events in Sapphire slip out of his control. It was one thing to hope that the Phites would, eventually, be juggling real-world physics that was temporarily beyond his comprehension, but any bright ten-year-old could grasp the laws of their present universe, and their technology was still far from rocket science.

He said, "Keep Sapphire frozen, and study your records of the Phites who first performed this boost. If they understood what they were doing, we can work it out too."

At the end of the week, Daniel signed the licensing deal and flew back to San Francisco. Lucien briefed him daily, and at Daniel's urging hired a dozen new computational linguists to help with the problem.

After six months, it was clear that they were getting nowhere. The Phites who'd invented the boost had had one big advantage as they'd tinkered with each other's brains: it had not been a purely theoretical exercise for them. They hadn't gazed at anatomical diagrams and then reasoned their way to a better design. They had *experienced* the effects of thousands of small experimental changes, and the results had shaped their intuition for the process. Very little of that

intuition had been spoken aloud, let alone written down and formalised. And the process of decoding those insights from a purely structural view of their brains was every bit as difficult as decoding the language itself.

Daniel couldn't wait any longer. With the crystal heading for the market, and other comparable technologies approaching fruition, he couldn't allow his lead to melt away.

"We need the Phites themselves to act as translators," he told Lucien. "We need to contrive a situation where there's a large enough pool who choose not to be boosted that the old language continues to be used."

"So we need maybe twenty-five per cent refusing the boost?" Lucien suggested. "And we need the boosted Phites to want to keep them informed of what's happening, in terms that we can all understand."

Daniel said, "Exactly."

"I think we can slow down the uptake of boosting," Lucien mused, "while we encourage a traditionalist meme that says it's better to span the two cultures and languages than replace the old entirely with the new."

Lucien's team set to work, tweaking the Thought Police for the new task, then restarting Sapphire itself.

Their efforts seemed to yield the desired result: the Phites were corralled into valuing the notion of maintaining a link to their past, and while the boosted Phites surged ahead, they also worked hard to keep the unboosted in the loop.

It was a messy compromise, though, and Daniel wasn't happy with the prospect of making do with a watered-down, Sapphire-for-Dummies version of the Phites' intellectual achievements.

What he really wanted was someone on the inside reporting to him directly, like a Phite version of Lucien.

It was time to start thinking about job interviews.

Lucien was running Sapphire more slowly than usual – to give the Thought Police a computational advantage now that they'd lost so much raw surveillance data – but even at the reduced rate, it took just six real-time days for the boosted Phites to invent computers, first as a mathematical formalism and, shortly afterwards, as a succession of practical machines.

Daniel had already asked Lucien to notify him if any Phite guessed the true nature of their world. In the past, a few had come up with vague metaphysical speculations that weren't too wide of the mark, but now that they had a firm grasp of the idea of universal computation, they were finally in a position to understand the crystal as more than an idle fantasy.

The message came just after midnight, as Daniel was preparing for bed. He went into his office and activated the intervention tool that Lucien had written for him, specifying a serial number for the Phite in question.

The tool prompted Daniel to provide a human-style name for his interlocutor, to facilitate communication. Daniel's mind went blank, but after waiting twenty seconds the software offered its own suggestion: Primo.

Primo was boosted, and he had recently built a computer of his own. Shortly afterwards, the Thought Police had heard him telling a couple of unboosted friends about an amusing possibility that had occurred to him.

Sapphire was slowed to a human pace, then Daniel took control of a Phite avatar and the tool contrived a meeting, arranging for the two of them to be alone in the shelter that Primo had built for himself. In accordance with the current architectural style the wooden building was actually still alive, self-repairing and anchored to the ground by roots.

Primo said, “Good morning. I don’t believe we’ve met.”

It was no great breach of protocol for a stranger to enter one’s shelter uninvited, but Primo was understating his surprise; in this world of immortals, but no passenger jets, bumping into strangers anywhere was rare.

“I’m Daniel.” The tool would invent a Phite name for Primo to hear. “I heard you talking to your friends last night about your new computer. Wondering what these machines might do in the future. Wondering if they could ever grow powerful enough to contain a whole world.”

“I didn’t see you there,” Primo replied.

“I wasn’t there,” Daniel explained. “I live outside this world. I built the computer that contains this world.”

Primo made a gesture that the tool annotated as amusement, then he spoke a few words in the boosted language. *Insults? A jest? A test of Daniel’s omniscience?* Daniel decided to bluff his way through, and act as if the words were irrelevant.

He said, “Let the rain start.” Rain began pounding on the roof of the shelter. “Let the rain stop.” Daniel gestured with one claw at a large cooking pot in a corner of the room. “Sand. Flower. Fire. Water jug.” The pot obliged him, taking on each form in turn.

Primo said, “Very well. I believe you, Daniel.” Daniel had had some experience reading the Phites’ body language directly, and to him Primo seemed reasonably calm. Perhaps when you

were as old as he was, and had witnessed so much change, such a revelation was far less of a shock than it would have been to a human at the dawn of the computer age.

"You created this world?" Primo asked him.

"Yes."

"You shaped our history?"

"In part," Daniel said. "Many things have been down to chance, or to your own choices."

"Did you stop us having children?" Primo demanded.

"Yes," Daniel admitted.

"*Why?*"

"There is no room left in the computer. It was either that, or many more deaths."

Primo pondered this. "So you could have stopped the death of my parents, had you wished?"

"I could bring them back to life, if you want that." This wasn't a lie; Daniel had stored detailed snapshots of all the last mortal Phites. "But not yet; only when there's a bigger computer. When there's room for them."

"Could you bring back *their* parents? And their parents' parents? Back to the beginning of time?"

"No. That information is lost."

Primo said, "What is this talk of waiting for a bigger computer? You could easily stop time from passing for us, and only start it again when your new computer is built."

"No," Daniel said, "I can't. Because *I need you to build the computer.* I'm not like you: I'm not immortal, and my brain can't be boosted. I've done my best, now I need you to do better. The

only way that can happen is if you learn the science of my world, and come up with a way to make this new machine."

Primo walked over to the water jug that Daniel had magicked into being. "It seems to me that you were ill-prepared for the task you set yourself. If you'd waited for the machine you really needed, our lives would not have been so hard. And if such a machine could not be built in your lifetime, what was to stop your grandchildren from taking on that task?"

"I had no choice," Daniel insisted. "I couldn't leave your creation to my descendants. There is a war coming between my people. I needed your help. I needed strong allies."

"You have no friends in your own world?"

"Your time runs faster than mine. I needed the kind of allies that only your people can become, in time."

Primo said, "What exactly do you want of us?"

"To build the new computer you need," Daniel replied. "To grow in numbers, to grow in strength. Then to raise me up, to make me greater than I was, as I've done for you. When the war is won, there will be peace forever. Side by side, we will rule a thousand worlds."

"And what do you want of *me*?" Primo asked. "Why are you speaking to me, and not to all of us?"

"Most people," Daniel said, "aren't ready to hear this. It's better that they don't learn the truth yet. But I need one person who can work for me directly. I can see and hear everything in your world, but I need you to make sense of it. I need you to understand things for me."

Primo was silent.

Daniel said, "I gave you life. How can you refuse me?"

6

Daniel pushed his way through the small crowd of protesters gathered at the entrance to his San Francisco tower. He could have come and gone by helicopter instead, but his security consultants had assessed these people as posing no significant threat. A small amount of bad PR didn't bother him; he was no longer selling anything that the public could boycott directly, and none of the businesses he dealt with seemed worried about being tainted by association. He'd broken no laws, and confirmed no rumours. A few feral cyberphiles waving placards reading SOFTWARE IS NOT YOUR SLAVE! meant nothing.

Still, if he ever found out which one of his employees had leaked details of the project, he'd break their legs.

Daniel was in the elevator when Lucien messaged him: moon very soon! He halted the elevator's ascent, and redirected it to the basement.

All three crystals were housed in the basement now, just centimetres away from the Play Pen: a vacuum chamber containing an atomic force microscope with fifty thousand independently movable tips, arrays of solid-state lasers and photodetectors, and thousands of micro-wells stocked with samples of all the stable chemical elements. The time lag between Sapphire and this machine had to be as short as possible, in order for the Phites to be able to conduct experiments in real-world physics while their own world was running at full speed.

Daniel pulled up a stool and sat beside the Play Pen. If he wasn't going to slow Sapphire down, it was pointless aspiring to watch developments as they unfolded. He'd probably view a

replay of the lunar landing when he went up to his office, but by the time he screened it, it would be ancient history.

‘One giant leap’ would be an understatement; wherever the Phites landed on the moon, they would find a strange black monolith waiting for them. Inside would be the means to operate the Play Pen; it would not take them long to learn the controls, or to understand what this signified. If they were really slow in grasping what they’d found, Daniel had instructed Primo to explain it to them.

The physics of the real world was far more complex than the kind the Phites were used to, but then, no human had ever been on intimate terms with quantum field theory either, and the Thought Police had already encouraged the Phites to develop most of the mathematics they’d need to get started. In any case, it didn’t matter if the Phites took longer than humans to discover twentieth-century scientific principles, and move beyond them. Seen from the outside, it would happen within hours, days, weeks at the most.

A row of indicator lights blinked on; the Play Pen was active. Daniel’s throat went dry. The Phites were finally reaching out of their own world into his.

A panel above the machine displayed histograms classifying the experiments the Phites had performed so far. By the time Daniel was paying attention, they had already discovered the kinds of bonds that could be formed between various atoms, and constructed thousands of different small molecules. As he watched, they carried out spectroscopic analyses, built simple nanomachines, and manufactured devices that were, unmistakably, memory elements and logic gates.

The Phites wanted children, and they understood now that this was the only way. They would soon be building a world in which they were not just more numerous, but faster and smarter than they were inside the crystal. And that would only be the first of a thousand iterations. They were working their way towards Godhood, and they would lift up their own creator as they ascended.

Daniel left the basement and headed for his office. When he arrived, he called Lucien.

"They've built an atomic-scale computer," Lucien announced. "And they've fed some fairly complex software into it. It doesn't seem to be an upload, though. Certainly not a direct copy on the level of beads." He sounded flustered; Daniel had forbidden him to risk screwing up the experiments by slowing down Sapphire, so even with Primo's briefings to help him it was difficult for him to keep abreast of everything.

"Can you model their computer, and then model what the software is doing?" Daniel suggested.

Lucien said, "We only have six atomic physicists on the team; the Phites already outnumber us on that score by about a thousand to one. By the time we have any hope of making sense of this, they'll be doing something different."

"What does Primo say?" The Thought Police hadn't been able to get Primo included in any of the lunar expeditions, but Lucien had given him the power to make himself invisible and teleport to any part of Sapphire or the lunar base. Wherever the action was, he was free to eavesdrop.

"Primo has trouble understanding a lot of what he hears; even the boosted aren't universal polymaths and instant experts in every kind of jargon. The gist of it is that the Lunar Project people have made a very fast computer in the Outer World, and it's going to help with the fertility problem…somehow." Lucien laughed. "Hey, maybe the Phites will do exactly what we

did: see if they can evolve something smart enough to give them a hand. How cool would that be?"

Daniel was not amused. Somebody had to do some real work eventually; if the Phites just passed the buck, the whole enterprise would collapse like a pyramid scheme.

Daniel had some business meetings he couldn't put off. By the time he'd swept all the bullshit aside, it was early afternoon. The Phites had now built some kind of tiny solid-state accelerator, and were probing the internal structure of protons and neutrons by pounding them with high-speed electrons. An atomic computer wired up to various detectors was doing the data analysis, processing the results faster than any in-world computer could. The Phites had already figured out the standard quark model. Maybe they were going to skip uploading into nanocomputers, and head straight for some kind of femtomachine?

Digests of Primo's briefings made no mention of using the strong force for computing, though. They were still just satisfying their curiosity about the fundamental laws. Daniel reminded himself of their history. They had burrowed down to what seemed like the foundations of physics before, only to discover that those simple rules were nothing to do with the ultimate reality. It made sense that they would try to dig as deeply as they could into the mysteries of the Outer World before daring to found a colony, let alone emigrate *en masse*.

By sunset the Phites were probing the surroundings of the Play Pen with various kinds of radiation. The levels were extremely low – certainly too low to risk damaging the crystals – so Daniel saw no need to intervene. The Play Pen itself did not have a massive power supply, it contained no radioisotopes, and the Thought Police would ring alarm bells and bring in human

experts if some kind of tabletop fusion experiment got underway, so Daniel was reasonably confident that the Phites couldn't do anything stupid and blow the whole thing up.

Primo's briefings made it clear that they thought they were engaged in a kind of 'astronomy'. Daniel wondered if he should give them access to instruments for doing serious observations – the kind that would allow them to understand relativistic gravity and cosmology. Even if he bought time on a large telescope, though, just pointing it would take an eternity for the Phites. He wasn't going to slow Sapphire down and then grow old while they explored the sky; next thing they'd be launching space probes on thirty-year missions. Maybe it was time to ramp up the level of collaboration, and just hand them some astronomy texts and star maps? Human culture had its own hard-won achievements that the Phites couldn't easily match.

As the evening wore on, the Phites shifted their focus back to the subatomic world. A new kind of accelerator began smashing single gold ions together at extraordinary energies – though the total power being expended was still minuscule. Primo soon announced that they'd mapped all three generations of quarks and leptons. The Phites' knowledge of particle physics was drawing level with humanity's; Daniel couldn't follow the technical details any more, but the experts were giving it all the thumbs up. Daniel felt a surge of pride; of course his children knew what they were doing, and if they'd reached the point where they could momentarily bamboozle him, soon he'd ask them to catch their breath and bring him up to speed. Before he permitted them to emigrate, he'd slow the crystals down and introduce himself to everyone. In fact, that might be the perfect time to set them their next task: to understand human biology, well enough to upload him. To make him immortal, to repay their debt.

He sat watching images of the Phites' latest computers, reconstructions based on data flowing to and from the AFM tips. Vast lattices of shimmering atoms stretched off into the distance, the electron clouds that joined them quivering like beads of mercury in some surreal liquid abacus. As he watched, an inset window told him that the ion accelerators had been re-designed, and fired up again.

Daniel grew restless. He walked to the elevator. There was nothing he could see in the basement that he couldn't see from his office, but he wanted to stand beside the Play Pen, put his hand on the casing, press his nose against the glass. The era of Sapphire as a virtual world with no consequences in his own was coming to an end; he wanted to stand beside the thing itself and be reminded that it was as solid as he was.

The elevator descended, passing the tenth floor, the ninth, the eighth. Without warning, Lucien's voice burst from Daniel's watch, priority audio crashing through every barrier of privacy and protocol. "Boss, there's radiation. Net power gain. Get to the helicopter, *now*."

Daniel hesitated, contemplating an argument. If this was fusion, why hadn't it been detected and curtailed? He jabbed the stop button and felt the brakes engage. Then the world dissolved into brightness and pain.

7

When Daniel emerged from the opiate haze, a doctor informed him that he had burns to sixty per cent of his body. More from heat than from radiation. He was not going to die.

There was a net terminal by the bed. Daniel called Lucien and learnt what the physicists on the team had tentatively concluded, having studied the last of the Play Pen data that had made it off-site.

It seemed the Phites had discovered the Higgs field, and engineered a burst of something akin to cosmic inflation. What they'd done wasn't as simple as merely inflating a tiny patch of vacuum into a new universe, though. Not only had they managed to create a 'cool Big Bang', they had pulled a large chunk of ordinary matter into the pocket universe they'd made, after which the wormhole leading to it had shrunk to subatomic size and fallen through the Earth.

They had taken the crystals with them, of course. If they'd tried to upload themselves into the pocket universe through the lunar data link, the Thought Police would have stopped them. So they'd emigrated by another route entirely. They had snatched their whole substrate, and ran.

Opinions were divided over exactly what else the new universe would contain. The crystals and the Play Pen floating in a void, with no power source, would leave the Phites effectively dead, but some of the team believed there could be a thin plasma of protons and electrons too, created by a form of Higgs decay that bypassed the unendurable quark-gluon fireball of a hot Big Bang. If they'd built the right nanomachines, there was a chance that they could convert the Play Pen into a structure that would keep the crystals safe, while the Phites slept through the long wait for the first starlight.

The tiny skin samples the doctors had taken finally grew into sheets large enough to graft. Daniel bounced between dark waves of pain and medicated euphoria, but one idea stayed with him throughout the turbulent journey, like a guiding star: *Primo had betrayed him.* He had given the

fucker life, entrusted him with power, granted him privileged knowledge, showered him with the favours of the Gods. And how had he been repaid? He was back to zero. He'd spoken to his lawyers; having heard rumours of an 'illegal radiation source', the insurance company was not going to pay out on the crystals without a fight.

Lucien came to the hospital, in person. Daniel was moved; they hadn't met face-to-face since the job interview. He shook the man's hand.

"You didn't betray me."

Lucien looked embarrassed. "I'm resigning, boss."

Daniel was stung, but he forced himself to accept the news stoically. "I understand; you have no choice. Gupta will have a crystal of his own by now. You have to be on the winning side, in the war of the Gods."

Lucien put his resignation letter on the bedside table. "What war? Are you still clinging to that fantasy where überdorks battle to turn the moon into computronium?"

Daniel blinked. "Fantasy? If you didn't believe it, why were you working with me?"

"You paid me. Extremely well."

"So how much will Gupta be paying you? I'll double it."

Lucien shook his head, amused. "I'm not going to work for Gupta. I'm moving into particle physics. The Phites weren't all that far ahead of us when they escaped; maybe forty or fifty years. Once we catch up, I guess a private universe will cost about as much as a private island; maybe less in the long run. But no one's going to be battling for control of this one, throwing grey goo around like monkeys flinging turds while they draw up their plans for Matrioshka brains."

Daniel said, “If you take any data from the Play Pen logs – ”

“I’ll honour all the confidentiality clauses in my contract.” Lucien smiled. “But anyone can take an interest in the Higgs field; that’s public domain.”

After he left, Daniel bribed the nurse to crank up his medication, until even the sting of betrayal and disappointment began to fade.

A universe, he thought happily. *Soon I’ll have a universe of my own.*

But I’m going to need some workers in there, some allies, some companions. I can’t do it all alone; someone has to carry the load.

ENDS