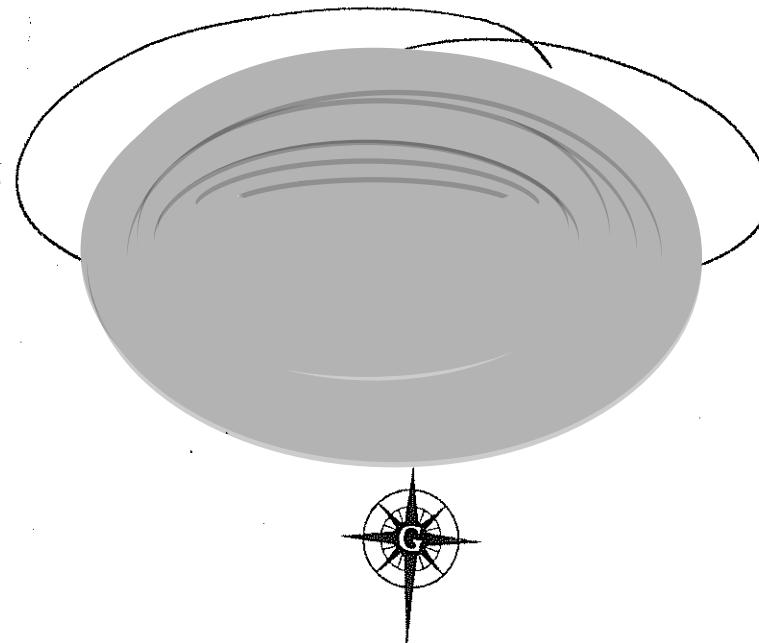


Wang's Carpets

from

diASPORA

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they hear that we've found life, they'll feel more like collaborators in the discovery because of it.'

Paolo felt a stirring of unease. *Emigration and suicides? Was that why Orlando had been so gloomy? After the disaster of the Forge, and then another three hundred years of waiting, how high had expectations become?*

A buzz of excitement crossed the floor, a sudden shift in the tone of the conversation. Hermann whispered, mock-reverentially, 'First microprobe has surfaced. And the data is coming in now.'

The non-sentient Heart was intelligent enough to guess its patrons' wishes. Although everyone could tap the library for results, privately, the music cut out and a giant public image of the summary data appeared, high in the chamber. Paolo had to crane his neck to view it, a novel experience.

The microprobe had mapped one of the carpets in high resolution. The image showed the expected rough oblong, some hundred metres wide – but the two- or three-metre-thick slab of the neutrino tomographs was revealed now as a delicate, convoluted surface – fine as a single layer of skin, but folded into an elaborate space-filling curve. Paolo checked the full data: the topology was strictly planar, despite the pathological appearance. No holes, no joins – just a surface which meandered wildly enough to look ten thousand times thicker from a distance than it really was.

An inset showed the microstructure, at a point which started at the rim of the carpet and then – slowly – moved towards the centre. Paolo stared at the flowing molecular diagram for several tau before he grasped what it meant.

The carpet was not a colony of single-celled creatures. Nor was it a multicellular organism. It was a *single molecule*, a two-dimensional polymer weighing twenty-five thousand tonnes. A giant sheet of folded polysaccharide, a complex

mesh of interlinked pentose and hexose sugars hung with alkyl and amide side chains. A bit like a plant cell wall, except that this polymer was far stronger than cellulose, and the surface area was twenty orders of magnitude greater.

Karpal said, 'I hope those entry capsules were perfectly sterile. Earth bacteria would gorge themselves on this. One big floating carbohydrate dinner, with no defences.'

Hermann thought it over. 'Maybe if they had enzymes capable of breaking off a piece – which I doubt. No chance we'll find out, though: even if there'd been bacterial spores lingering in the asteroid belt from early flesher expeditions, every ship in the Diaspora was double-checked for contamination *en route*. We haven't brought smallpox to the Americas.'

Paolo was still dazed. 'But how does it assemble? How does it . . . grow?' Hermann consulted the library and replied, before Paolo could do the same.

'The edge of the carpet catalyses its own growth. The polymer is irregular, aperiodic – there's no single component which simply repeats. But there seem to be about twenty thousand basic structural units, twenty thousand different polysaccharide building blocks.' Paolo saw them: long bundles of cross-linked chains running the whole two-hundred-micron thickness of the carpet, each with a roughly square cross-section, bonded at several thousand points to the four neighbouring units. 'Even at this depth, the ocean's full of UV-generated radicals which filter down from the surface. Any structural unit exposed to the water converts those radicals into more polysaccharide – and builds another structural unit.'

Paolo glanced at the library again, for a simulation of the process. Catalytic sites strewn along the sides of each unit trapped the radicals in place, long enough for new bonds to

form between them. Some simple sugars were incorporated straight into the polymer as they were created; others were set free to drift in solution for a microsecond or two, until they were needed. At that level, there were only a few basic chemical tricks being used . . . but molecular evolution must have worked its way up from a few small autocatalytic fragments, first formed by chance, to this elaborate system of twenty thousand mutually self-replicating structures. If the 'structural units' had floated free in the ocean as independent molecules, the 'life form' they comprised would have been virtually invisible. By bonding together, though, they became twenty thousand colours in a giant mosaic.

It was astonishing. Paolo hoped Elena was tapping the library, wherever she was. A colony of algae would have been more 'advanced' – but this incredible primordial creature revealed infinitely more about the possibilities for the genesis of life. Carbohydrate, here, played every biochemical role: information carrier, enzyme, energy source, structural material. Nothing like it could have survived on Earth, once there were organisms capable of feeding on it – and if there were ever intelligent Orpheans, they'd be unlikely to find a trace of this bizarre ancestor.

Karpal wore a secretive smile.

Paolo said, 'What?'

'Wang tiles. The carpets are made out of Wang tiles.'

Hermann beat him to the library, again. 'Wang as in the twentieth-century mathematician, Hao Wang. Tiles as in any set of shapes which can cover the plane. Wang tiles are squares with various-shaped edges, which have to fit complementary shapes on adjacent squares. You can cover the plane with a set of Wang tiles, as long as you choose the right one every step of the way. Or in the case of the carpets, grow the right one.'

Karpal said, 'We should call them Wang's Carpets, in honour of Hao Wang. After twenty-three hundred years, his mathematics has come to life.'

Paolo liked the idea, but he was doubtful. 'We may have trouble getting a two-thirds majority on that. It's a bit obscure.'

Hermann laughed. 'Who needs a two-thirds majority? If we want to call them Wang's Carpets, we can call them Wang's Carpets. There are ninety-seven languages in current use in C-Z – half of them invented since the polis was founded. I don't think we'll be exiled for coining one private name.'

Paolo concurred, slightly embarrassed. The truth was, he'd completely forgotten that Hermann and Karpal weren't actually speaking Modern Roman.

The three of them instructed their exoselves to consider the name adopted: henceforth, they'd hear 'carpet' as 'Wang's Carpet' – but if they used the term with anyone else, the reverse translation would apply.

Orlando's celebration of the microprobe discoveries was very much a *carnevale*-refugee affair. The scape was an endless sunlit garden strewn with tables covered in *food*, and the invitation had politely suggested attendance in strict ancestral form. Paolo politely faked it, simulating most of the physiology but running the body as a puppet, leaving his mind unshackled.

He drifted from table to table, sampling the food to keep up appearances, wishing Elena had come. There was little conversation about the biology of Wang's Carpets; most of the people here were simply celebrating their win against the opponents of the microprobes – and the humiliation that faction would suffer, now that it was clearer than ever

that the 'invasive' observations could have done no harm. Liesl's fears had proved unfounded; there was no other life in the ocean, just Wang's Carpets of various sizes. Paolo, feeling perversely even-handed after the fact, kept wanting to remind these smug movers and shakers: *There might have been anything down there. Strange creatures, delicate and vulnerable in ways we could never have anticipated. We were lucky, that's all.*

He ended up alone with Orlando almost by chance; they were both fleeing different groups of appalling guests when their paths crossed on the lawn.

Paolo asked, 'How do you think they'll take this, back home?'

'It's first life, isn't it? Primitive or not. It should at least maintain interest in the Diaspora, until the next alien biosphere is discovered.' Orlando seemed subdued; perhaps he was finally coming to terms with the gulf between their modest discovery and Earth's longing for world-shaking results. 'And at least the chemistry is novel. If it had turned out to be based on DNA and protein, I think half of Earth C-Z would have died of boredom on the spot. Let's face it, the possibilities of DNA have been simulated to death.'

Paolo smiled at the heresy. 'You think if nature hadn't managed a little originality, it would have dented people's faith in the charter? If the solipsist polises had begun to look more inventive than the universe itself...'

'Exactly.'

They walked on in silence, then Orlando halted, and turned to face him. 'There's something I've been meaning to tell you. My Earth-self is dead.'

'What?'

'Please, don't make a fuss.'

'But... why? Why would he?' *Dead* meant suicide; there was no other cause.

'I don't know why. Whether it was a vote of confidence in the Diaspora' – Orlando had chosen to wake only in the presence of alien life – 'or whether he despaired of us sending back good news, and couldn't face the waiting, and the risk of disappointment. He didn't give a reason. He just had his exoself send a message, stating what he'd done.'

Paolo was shaken. 'When did this happen?'

'About fifty years after the launch.'

'My Earth-self said nothing.'

'It was up to me to tell you, not him.'

'I wouldn't have seen it that way.'

'Apparently, you would have.'

Paolo fell silent, confused. How was he supposed to mourn a distant version of Orlando, in the presence of the one he thought of as real? Death of one clone was a strange half-death, a hard thing to come to terms with. His Earth-self had lost a father; his father had lost an Earth-self. What exactly did that mean to *him*?

What Orlando seemed most concerned about was the culture of Earth C-Z. Paolo said carefully, 'Hermann told me there'd been a rise in emigration and suicide. But morale has improved a lot since the spectroscope picked up signs of Orphean water, and when they hear that it's more than just water –'

Orlando cut him off sharply. 'You don't have to talk things up for me. I'm in no danger of repeating the act.'

They stood on the lawn, facing each other. Paolo composed a dozen different combinations of mood to communicate, but none of them felt right. He could have granted his father perfect knowledge of everything he was feeling – but what exactly would that knowledge have

conveyed? In the end, there was fusion, or separateness. There was nothing in between.

Orlando said, 'Kill myself – and leave the fate of the Coalition in your hands? You must be out of your fucking mind.'

They walked on together, laughing.

Karpal seemed barely able to gather his thoughts enough to speak. Paolo would have offered him a mind graft promoting tranquillity and concentration – distilled from his own most focused moments – but he was sure that Karpal would never have accepted it. He said, 'Why don't you just start wherever you want to? I'll stop you if you're not making sense.'

Karpal looked around the white dodecahedron with an expression of disbelief. 'You live here?'

'Some of the time.'

'But this is your homescape? No trees? No sky? No furniture?'

Paolo refrained from repeating any of Hermann's naïve-robot jokes. 'I add them when I want them. You know, like ... music. Look, don't let my taste in décor distract you –'

Karpal made a chair and sat down heavily.

He said, 'Hao Wang proved a powerful theorem, twenty-three hundred years ago. Think of a row of Wang tiles as being like the data tape of a Turing Machine.' Paolo had the library grant him knowledge of the term; it was the original conceptual form of a generalised computing device, an imaginary machine which moved back and forth along a limitless one-dimensional data tape, reading and writing symbols according to a given set of rules.

'With the right set of tiles, to force the right pattern, the

next row of the tiling will look like the data tape after the Turing Machine has performed one step of its computation. And the row after that will be the data tape after two steps, and so on. For any given Turing Machine there's a set of Wang tiles that can imitate it.'

Paolo nodded amiably. He hadn't heard of this particular quaint result, but it was hardly surprising. 'The carpets must be carrying out billions of acts of computation every second ... but then, so are the water molecules around them. There are no physical processes that don't perform arithmetic of some kind.'

'True. But with the carpets, it's not quite the same as random molecular motion.'

'Maybe not.'

Karpal smiled, but said nothing.

'What? You've found a pattern? Don't tell me: our set of twenty thousand polysaccharide Wang tiles just happens to form the Turing Machine for calculating pi.'

'No. What they form is a universal Turing Machine. They can calculate anything at all – depending on the data they start with. Every daughter fragment is like a program being fed to a chemical computer. Growth executes the program.'

'Ah.' Paolo's curiosity was roused – but he was having some trouble picturing where the hypothetical Turing Machine put its read/write head. 'Are you telling me only one tile changes between any two rows, where the "machine" leaves its mark on the "data tape" ... ?' The mosaics he'd seen were a riot of complexity, with no two rows remotely the same.

Karpal said, 'No, no. Wang's original example worked exactly like a standard Turing Machine, to simplify the argument ... but the carpets are more like an arbitrary number of different computers with overlapping data, all

working in parallel. This is biology, not a designed machine – it's as messy and wild as, say, a mammalian genome. In fact, there are mathematical similarities with gene regulation: I've identified Kauffman networks at every level, from the tiling rules up; the whole system's poised on the hyperadaptive edge between frozen and chaotic behaviour.'

Paolo absorbed that, with the library's help. Like Earth life, the carpets seemed to have evolved a combination of robustness and flexibility which would have maximised their power to take advantage of natural selection. Thousands of different autocatalytic chemical networks must have arisen soon after the formation of Orpheus, but as the ocean chemistry and the climate changed in the Vegan system's early traumatic millennia, the ability to respond to selection pressure had itself been selected for, and the carpets were the result. Their complexity seemed redundant, now, after a hundred million years of relative stability – and no predators or competition in sight – but the legacy remained.

'So if the carpets have ended up as universal computers ... with no real need any more to respond to their surroundings ... what are they *doing* with all that computing power?'

Karpal said solemnly, 'I'll show you.'

Paolo followed him into a scape where they drifted above a schematic of a carpet, an abstract landscape stretching far into the distance, elaborately wrinkled like the real thing, but otherwise heavily stylised, with each of the polysaccharide building blocks portrayed as a square tile with four different-coloured edges. The adjoining edges of neighbouring tiles bore complementary colours – to represent the complementary, interlocking shapes of the borders of the building blocks.

'One group of microprobes finally managed to sequence an entire daughter fragment,' Karpal explained, 'although the exact edges it started life with are largely guesswork, since the thing was growing while they were trying to map it.' He gestured impatiently, and all the wrinkles and folds were smoothed away, an irrelevant distraction. They moved to one border of the ragged-edged carpet, and Karpal started the simulation running...

Paolo watched the mosaic extending itself, following the tiling rules perfectly – an orderly mathematical process, here: no chance collisions of radicals with catalytic sites, no mismatched borders between two new-grown neighbouring 'tiles' triggering the disintegration of both. Just the distillation of the higher-level consequences of all that random motion.

Karpal led Paolo up to a height where he could see subtle patterns being woven, overlapping multiplexed periodicities drifting across the growing edge, meeting and sometimes interacting, sometimes passing right through each other. Mobile pseudo-attractors, quasi-stable waveforms in a one-dimensional universe. The carpet's second dimension was more like time than space, a permanent record of the history of the edge.

Karpal seemed to read his mind. 'One-dimensional. Worse than flatland. No connectivity, no complexity. What can possibly happen in a system like that? Nothing of interest, right?'

He clapped his hands and the scape exploded around Paolo. Trails of colour streaked across his sensorium, entwining, then disintegrating into luminous smoke.

'Wrong. Everything goes on in a multi-dimensional frequency space. I've Fourier-transformed the edge into over a thousand components, and there's independent informa-

tion in all of them. We're only in a narrow cross-section here, a sixteen-dimensional slice – but it's oriented to show the principal components, the maximum detail.'

Paolo spun in a blur of meaningless colour, utterly lost, his surroundings beyond comprehension. 'You're a *gleisner robot*, Karpal! Only sixteen dimensions! How can you have done this?'

Karpal sounded hurt, wherever he was. 'Why do you think I came to C-Z? I thought you people were flexible!'

'What you're doing is . . . ' *What?* Heresy? There was no such thing. Officially. 'Have you shown this to anyone else?'

'Of course not. Who did you have in mind? Lies? *Hermann?*'

'Good. I know how to keep my mouth shut.' Paolo jumped back to the dodecahedron; Karpal followed. 'How can I put this? The physical universe has three spatial dimensions, plus time. Citizens of Carter-Zimmerman inhabit the physical universe. The false promises of Kozuch Theory kept us from the stars for a thousand years. Higher-dimensional mind games are strictly for the solipsists.' Even as he said it, he realised how pompous he sounded.

Karpal replied, more bemused than offended, 'It's the only way to see what's going on. The only sensible way to apprehend it. Don't you want to know what the carpets are *actually like?*'

Paolo felt himself being tempted. *Inhabit a sixteen-dimensional slice of a thousand-dimensional frequency space?* But it was in the service of understanding a real physical system – not a novel experience for its own sake.

And nobody had to find out.

He ran a quick self-predictive model. There was a ninety-three per cent chance that he'd give in, after a kilotau spent

agonising over the decision. It hardly seemed fair to keep Karpal waiting that long.

He said, 'You'll have to loan me your mind-shaping algorithm. My exoself wouldn't know where to begin.'

When it was done, he steeled himself, and jumped back into Karpal's scape. For a moment, there was nothing but the same meaningless blur as before.

Then everything suddenly crystallised.

Creatures swam around them, elaborately branched tubes like mobile coral, vividly coloured in all the hues of Paolo's mental palette – Karpal's attempt to cram in some of the information that a mere sixteen dimensions couldn't show? Paolo glanced down at his own body; nothing was missing, but he could see *around it* in all the thirteen dimensions in which it was nothing but a pinprick. He quickly looked away. The 'coral' seemed far more natural to his altered sensory map, occupying 16-space in all directions, and shaded with hints that it occupied much more. Paolo had no doubt that it was 'alive'; it looked more organic than the carpets themselves, by far.

Karpal said, 'Every point in this space encodes some kind of quasi-periodic pattern in the tiles. Each dimension represents a different characteristic size – like a wavelength, although the analogy's not precise. The position in each dimension represents other attributes of the pattern, relating to the particular tiles it employs. So the localised systems you see around you are clusters of a few billion patterns, all with broadly similar attributes at similar wavelengths.'

They moved away from the swimming coral, into a swarm of something like jellyfish: floppy hyperspheres waving wispy tendrils (each one of them more substantial than Paolo). Tiny jewel-like creatures darted among them. Paolo was just beginning to notice that nothing moved here like a

solid object drifting through normal space; motion seemed to entail a shimmering deformation at the leading hypersurface, a visible process of disassembly and reconstruction.

Karpal led him on through the secret ocean. There were helical worms, coiled together in groups of indeterminate number – each single creature breaking up into a dozen or more wriggling slivers, and then recombining . . . although not always from the same parts. There were dazzling multicoloured stemless flowers, intricate hypercones of 'gossamer-thin' fifteen-dimensional petals – each one a hypnotic fractal labyrinth of crevices and capillaries. There were clawed monstrosities, writhing knots of sharp insectile parts like an orgy of decapitated scorpions.

Paolo said, uncertainly, 'You could give people a glimpse of this in just three dimensions. Enough to make it clear that there's . . . *life* in here. This is going to shake them up badly, though.' Life – embedded in the accidental computations of Wang's Carpets, with no possibility of ever relating to the world outside. This was an affront to Carter-Zimmerman's whole philosophy: if nature had evolved 'organisms' as divorced from reality as the inhabitants of the most inward-looking polis, where was the privileged status of the physical universe, the clear distinction between reality and illusion? And after three hundred years of waiting for good news from the Diaspora, how would they respond to this back on Earth?

Karpal said, 'There's one more thing I have to show you.'

He'd named the creatures 'squid', for obvious reasons. They were prodding each other with their tentacles in a way that looked thoroughly carnal. Karpal explained, 'There's no analogue of light here. We're viewing all this according to *ad hoc* rules which have nothing to do with the native physics. All the creatures here gather information about

each other by contact alone – which is actually quite a rich means of exchanging data, with so many dimensions. What you're seeing is communication by touch.'

'Communication about what?'

'Just gossip, I expect. Social relationships.'

Paolo stared at the writhing mass of tentacles.

'You think they're *conscious*?'

Karpal, point-like, grinned broadly. 'They have a central control structure, with more connectivity than a citizen's brain, which correlates data gathered from the skin. I've mapped that organ, and I've started to analyse its function.'

He led Paolo into another scape, a representation of the data structures in the 'brain' of one of the squid. It was – mercifully – three-dimensional, and highly stylised, with translucent coloured blocks to represent mental symbols, linked by broad lines indicating the major connections between them. Paolo had seen similar diagrams of citizens' minds; this was far less elaborate, but eerily familiar nonetheless.

Karpal said, 'Here's the sensory map of its surroundings. Full of other squid's bodies, and vague data on the last known positions of a few smaller creatures. But you'll see that the symbols activated by the physical presence of the other squid are linked to *these*' – he traced the connection with one finger – 'representations. Which are crude miniatures of *this whole structure* here.'

'This whole structure' was an assembly labelled with gestalt tags for memory retrieval, simple tropisms, short-term goals. The general business of being and doing.

'The squid has maps, not just of other squid's bodies, but their minds as well. Right or wrong, it certainly tries to know what the others are thinking about. And' – he pointed out another set of links, leading to another, less crude,

miniature squid mind – 'it thinks about its own thoughts as well. I'd call that *consciousness*, wouldn't you?'

Paolo said weakly, 'You've kept all this to yourself? You came this far, without saying a word – ?'

Karpal was chastened. 'I know it was selfish, but once I'd decoded the interactions of the tile patterns, I couldn't tear myself away long enough to start explaining it to anyone else. And I came to you first because I wanted your advice on the best way to break the news.'

Paolo laughed bitterly. 'The best way to break the news that *first alien consciousness* is hidden deep inside a biological computer? That everything the Diaspora was meant to prove to the rest of the Coalition has been turned on its head? The best way to explain to the citizens of Carter-Zimmerman that after a three-hundred-year journey, they might as well have stayed on Earth running simulations with as little resemblance to the physical universe as possible?'

Karpal took the outburst in good humour. 'I was thinking more along the lines of the best way to point out that if we hadn't travelled to Orpheus and studied Wang's Carpets, we'd never have had the chance to tell the solipsists of Ashton-Laval that all their elaborate invented life forms and exotic imaginary universes pale into insignificance compared to what's really out here – and which only the Carter-Zimmerman Diaspora could have found.'

Paolo and Elena stood together on the edge of Satellite Pinatubo, watching one of the scout probes aim its maser at a distant point in space. Paolo thought he saw a faint scatter of microwaves from the beam as it made its way out through Vega's halo of iron-rich dust. *Elena's mind being diffracted all over the cosmos?* Best not to think about that.

He said, 'When you meet the other versions of me who haven't experienced Orpheus, I hope you'll offer them mind grafts so they won't be jealous.'

She frowned. 'Ah. Will I or won't I? You should have asked me before I cloned myself. No need for your clones to be jealous, though. There'll be worlds far stranger than Orpheus.'

'I doubt it. You really think so?'

'I wouldn't be doing this if I didn't believe that.' Elena had no power to change the fate of the frozen clones of her previous self. But everyone had the right to emigrate.

Paolo took her hand. The beam had been aimed almost at Regulus, UV-hot and bright, but as he looked away, the cool yellow light of the sun caught his eye.

Vega C-Z was taking the news of the squid surprisingly well, so far. Karpal's way of putting it had cushioned the blow: it was only by travelling all this distance across the real, physical universe that they could have made such a discovery – and it was amazing how pragmatic even the most doctrinaire citizens had turned out to be. Before the launch, 'alien solipsists' would have been the most unpalatable idea imaginable, the most abhorrent thing the Diaspora could have stumbled upon – but now that they were here, and stuck with the fact of it, people were finding ways to view it in a better light. Orlando had even proclaimed, 'This will be the perfect hook for the marginal polises. "Travel through real space to witness a truly alien virtual reality." We can sell it as a synthesis of the two world views.'

Paolo still feared for Earth, though, where his Earth-self and others were waiting in hope of guidance. Would they take the message of Wang's Carpets to heart, and retreat into their own hermetic worlds, oblivious to physical

reality? Lacerta could be survived, anything could be survived: all you had to do was bury yourself deep enough.

He said plaintively, 'Where are the aliens, Elena? The ones we can meet? The ones we can talk to? The ones we can learn from?'

'I don't know.' She laughed suddenly.

'What?'

'It just occurred to me. Maybe the squid are asking themselves exactly the same question.'

part five